STONE MASONRY BUILT DURING THE 17TH AND 18TH CENTURIES IN SCOTLAND: MORPHOLOGY AND TECHNIQUES

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DEDICATION

To Filippo Monari, the cornerstone of this castle.

‹‹ Taken as a whole, Scotland's geographical endowment compares unfavourably with that of many other western European countries. Small in size and remote in situation, saddled with a difficult terrain and harsh climate, the country cannot be said to present many natural advantages for the pursuit of architecture.

One favourable circumstance is not lacking, however, namely the ready availability of good building stone, and nearly all Scottish historic buildings of any consequence are constructed of this material. (...) To the observant traveller the dark greywacke of the upper Tweed valley, the sparkling granites of the north east, the grey west highland schist and the smooth regular flagstones of Caithness and Orkney compose a regional pattern no less significant than that delineated by local administrative boundaries. ››

John G. Dunbar 1966
The architecture of Scotland

DECLARATION

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ABSTRACT

The seventeenth and eighteenth centuries were a time of transformation for Scottish architecture (Dunbar 1966; Glendinning et al. 1996, 71-183). This period saw the decline of the long established prevalence of masons in the design and construction of buildings and the emergence of the new role of the architect. The transfer of the Royal Court to England left the initiative of architectural production in the hands of noble families, who placed stately countryside homes at the centre of construction activity. Stone was the prevalent building material because of its good availability in different areas of the territory. Defensive structures, typical of previous centuries, were progressively abandoned in favour of domestic schemes (McKean 1993, 2001; Howard 1995, 50-107). In addition, the extension of ancient family seats became common, resulting in complex structures because of overlaid historical strata. McKean (2003) identified this issue when studying Innes House, and highlighted the need to combine archival research with the direct survey of masonry for adequate interpretation of the heritage.

Despite rich existing literature on the history of Scottish architecture, little is known about the morphology of the stone masonry used for building. In Italy, on the other hand, masonry is considered a valuable primary source of information. In particular, the analysis methodologies developed in the fields of archaeology and conservation overcome esthetical judgements focusing on the identification of features related to construction techniques. Furthermore, a complete understanding of the wider context is considered essential for the adequate interpretation of building complexity.

This research contributes to filling the gap highlighted relating to the study of the morphology of stone masonry identified on the elevations of a group of seventeenth and eighteenth century stately countryside homes in Scotland. The original methodology developed for this purpose learns from the Italian approach and is developed in two parts. The first part focuses on building a base of knowledge of the masonry context. This is achieved by analysing three main aspects: the structure of the territory, the morphology of buildings and the networks of architects and masons active at the time. The results obtained define areas of the territory with homogeneous characteristics, highlight relevant work environments and identify determinant building features for the characteristics of masonry. This provides the criteria necessary for the selection of a group of representative case studies, adequate for proceeding with the analysis of their masonry. The second part of the investigation focuses on the morphological characterisation of masonry, considering four elements of elevation: the solid portion of walls, corners, openings and overall structure. The analysis defined is based on the identification of features related to construction techniques, and include an innovative method for the classification of masonry patterns based on the use of machine learning techniques, which overcomes qualitative approaches. The outcomes obtained yield three different contributions.

The first contribution refers to the history of construction. The investigation highlights characteristic features of Scottish seventeenth and eighteenth century stone masonry architecture, and defines a knowledge base on construction techniques, which, if

expanded, can effectively contribute to conservation purposes. In particular, a progressive evolution of construction techniques is revealed. Clear differences are identified between non-architect and architect related masonry. The former mainly respond to the fulfilment of the stonemason gospel, while the latter include further design ambitions pushing the development of more sophisticated masonry techniques. The first hint of change is found in the quoins built at James Murray's House (first half of the seventeenth century), which highlight uniform heights and counterfeit homogeneous lengths. During the seventeenth century, buildings by Sir William Bruce and James Smith make a novel widespread use of regular masonry, and show special care for its integration within elevation design. Finally, in the eighteenth century, the Adam family further explored the use of highly regular masonry techniques, introducing the use of textured finishing for blurring masonry patterns. Thus, the involvement of architects arguably challenged the work of masons, motivating the development of new construction strategies, seeking design excellence and involving higher elaboration of stone units.

The second contribution concerns the link between masonry and territory. In areas where sandstone is not easily available, the geographical factor is determinant for the morphology of masonry. This demonstrates that the idea of a territory divided into masonry areas set out by Dunbar corresponds to reality, and is a research path worthy of further investigation.

The third contribution refers to the methodology. For the first time in Scotland, the research presented in this thesis into masonry morphology approaches the subject from the understanding of the construction technique. The unique characteristics of the Scottish context lead to an original analysis. In particular, the research provides a unique synthesis of the principles and rules used by masons for the construction of a masonry wall. Further, an innovative objective classification method resolves the risk of misinterpretations resulting from qualitative classifications by successfully defining clusters of patterns with common characteristics. The parameters defined for the classification adequately characterise the masonry built and techniques used, overcoming formal judgements. The outcomes obtained demonstrate the viability and benefits of applying such an approach, highlighting a research path with great potential for future development.

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CHAPTER 7

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ABBREVIATIONS AND ACRONYMS

- **AA**: Parameter defined for the characterisation of the context in chapter 3.
- **ADCRU**: Stands for Architectural Design And Conservation Research Unit. This unit was established in 2013 by Dr. Cristina González-Longo in the department of Architecture at the University of Strathclyde. The project "Building skills for conserving seventeenth and eighteenth century Scottish built heritage" is developing within this research unit, and includes the construction of a database on Scottish architecture built during the 17th and 18th centuries.
- **BGS**: Stands for British Geological Survey.
- **BSDS**: Stands for Building Stone Database for Scotland as referred in BGS (2018) and Gillespie and Tracey (2016, 6).
- **CSD**: Parameter defined for the objective characterisation of masonry patterns in chapter 3.
- **GIS**: Stands for Geographic Information System.
- **HDR**: Stands for “High Dynamic Range”, and refers to a technology able to improve the colour and contrast of digital images.
- **HES**: Stands for Historic Environment Scotland. Charity registered in Scotland No. SC045925.
- **HMN**: Parameter defined for the objective characterisation of masonry patterns in chapter 3.
- **HS**: Stands for Historic Scotland, and predecessor of HES.
- **HSD**: Parameter defined for the objective characterisation of masonry patterns in chapter 3.
- **ICCD**: Stands for Istituto Centrale per il Catalogo e la Documentazione. It is an institute of the Ministry for cultural heritage and activities, which belongs to the Directorate-General for Education and Research, and has scientific and administrative autonomy. It is regulated by the Decreto di organizzazione del 7 ottobre 2008, and the subsequent DM 23 gennaio 2017. The activities carried out by the Institute include three main areas: Cataloging, Photography, and research and training.
- **ICOMOS**: Stands for International Council on Monuments and Sites.
- **ID**: Stands for identification number.
- **ISCUM**: Stands for “Istituto di Storia della Cultura Material”.

- **LIDAR**: Stands for “LIght Detection And Ranging”. It is a technology which allows measuring the distance between two points by means of a laser light.
- **LMT**: Parameter defined for the objective characterisation of masonry patterns in chapter 3.
- **LOR**: Parameter defined for the characterisation of the context in chapter 3.
- **MDT**: Stands for “Minor Destructive Tests”.
- **MQI**: Stands for “Masonry Quality Index”. This index was defined by Donà and De Maria (2011) in order to evaluate the quality of a masonry wall in terms of structural and seismic performance.
- **MS**: Parameter defined for the characterisation of the context in chapter 3.
- **MT**: Parameter defined for the characterisation of the context in chapter 3.
- **NDT**: Stands for “Non Destructive Tests”.
- **NF**: Parameter defined for the characterisation of the context in chapter 3.
- **NV**: Parameter defined for the characterisation of the context in chapter 3.
- **PE**: Parameter defined for the characterisation of the context in chapter 3.
- **PL**: Parameter defined for the characterisation of the context in chapter 3.
- **RC**: Parameter defined for the objective characterisation of masonry patterns in chapter 3.
- **RGB**: Stands for Red Green and Blue.
- **SLCT**: Stands for the Scottish Lime Centre Trust. Charity registered in Scotland No: SCO22692.
- **SP**: Parameter defined for the objective characterisation of masonry patterns in chapter 3.
- **T1**: Parameter defined for the characterisation of the context in chapter 3.
- **T2**: Parameter defined for the characterisation of the context in chapter 3.
- **UA**: Parameter defined for the objective characterisation of masonry patterns in chapter 3.
- **UK**: Stands for United Kingdom.
- **USM**: Stands for “Unita Stratigarphica Muraria”, which literally means “wall stratigraphic unit”. It defines a homogeneous construction action identifiable on a wall (Carandini 1981, 94; Parenti 1988a, 1988b).

GLOSSARY

- **Ashlar masonry**: Term generally referred to masonry characterised by a very regular pattern composed of highly elaborated stone units and very thin joints.
- **Archaeology of architecture:** Approach developed in Italy between the 1970s and 1980s by groups of researchers from the fields of archaeology, architecture and conservation. It focuses on the study of the construction history of buildings from the archaeological perspective, but understanding the building as the result of a production process. Therefore, the characterisation of the building techniques has special relevance (Parenti 2002).
- **Archaeology of buildings**: Term used in Morriss (2000) and referred to a branch of archaeology focused on the study of buildings as archaeological objects.
- **Archaeology of stone**: Term used in Peacock (1998) and referred to a branch of archaeology specifically oriented to the study of stone as an archaeological material
- **Archaeometry**: Term used to define in archaeology the use of science and modern technology to examine and interpret the archaeological remains (*see Collins English Dictionary*).
- **Bond stones**: In a masonry wall, the stones with a length equal to 2/3 of the wall section and used to bond the different layers crossing the wall.
- **Core filling**: In a masonry wall, irregular stones of different sizes used to define the central layer of a wall section.
- **Course of stones**: In a masonry wall, a line of stones built at once.
- **Global archaeology**: The concept of global archaeology is defined in Mannoni, Bandini, and Valeriani (2001) and refers to an approach which aims to study the territory from a wide perspective, understanding it as a museum of the evolution of human culture.
- **Incorporation**: An Incorporation was a body who ruled and governed particular crafts in certain burghs (Knoop and Jones 1939, 64-67). In Edinburgh, masons and wrights were united within the same Incorporation. Such Incorporation met in a building known as the Mary's Chapel (Stevenson 2014, 71). For further information about this topic, see the work published in Allen 2014.
- **Lift of stones**: A portion of masonry wall built at once in the vertical direction, which ideally should have a maximum height of 18-24 inches (40-60cm).

- **Masonry joint**: In a masonry wall, the point of contact between stone units generally filled with binder.
- **Mensiochronology**: Method based on a statistical analysis of the dimensions of synchronous and homogeneous bricks or stones identified in a portion of wall (Mannoni 1984, Mannoni and Milanese 1988, Cantini et al. 2019).
- **Pinnings**: In a masonry wall, stones with a size generally equal or smaller than 5cm, used to fill gaps between facing stones. They reduce the thickness of the mortar joints, which is especially important when the binder is lime mortar because it carbonates most effectively in small thicknesses.
- **Quoin stones**: Each of the stones used to define a corner in a masonry building.
- **Random rubble**: Term generally used in literature, referred to irregular stones.
- **Rubble masonry**: Term generally used in literature, referred to masonry built with irregular stones.
- **Squared masonry**: Term generally used in literature, referred to masonry built with stone units defined by a squared face.
- **Stone unit**: Term used in this thesis, referred to each of the stones composing a masonry wall.
- **Stone bedding**: In a masonry wall, refers to the natural layering of the material. It is related to the material formation process and therefore characteristic of sedimentary rocks
- **Stonemason gospel**: Term used in this thesis to refer to the italian “regola d’arte”. It defines the practical knowledge transmitted from master to apprentice during generations and containing the principles and rules for the construction of durable and stable masonry structures.
- **Through stones**: In a masonry wall, stones with a length equal to the dimension of the wall section and used to bond the different layers crossing the wall from the external face to the internal.
- **Wall core**: Term used to define the central stratum or layer in the section of a masonry wall.
- **Wall face**: In a masonry wall, term used to refer to the external surface of a wall.
- **Wall layer**: Term used to define strata composing the section of a masonry wall.
- **Wedge stones**: In a masonry wall, small stones of various sizes used to block the position of bigger stones and prevent movements.
- **Window lintel**: Horizontal element used to define the upper edge of an opening.
- **Window jamb**: Vertical element used to define the side of an opening.
- **Window sill**: Horizontal element used to define the lower edge of an opening

Chapter 1
INTRODUCTION

1.1 RESEARCH MOTIVATION AND CONTEXT

This research concerns construction history and is part of a wider research project entitled “Building skills for conserving seventeenth and eighteenth century Scottish built heritage” undertaken by the Architectural Design and Conservation Research Unit (ADCRU) at the Department of Architecture at the University of Strathclyde. The investigation had the financial support of the university and a contribution from Historic Environment Scotland.

The seventeenth and eighteenth centuries are a largely overlooked period of Scotland’s history. McKean (2006) ascribed the cause of this research gap to a historical misunderstanding of Scotland’s participation in the Renaissance. The idea of a country that remained anchored to its medieval tradition was a perception accepted for a long time. However, in recent decades, Dunbar (1966), McKean (1993, 2001) and other subsequent authors (e.g. Glendinning et al. (1996), Howard (1995, 2011) and Gonzalez-Longo (2012, 2013, 2020)) have contributed, outlining the relevance of the architecture built during these two centuries and managing to reveal connections between Scotland and the wider European context, presenting this period as a time of transformation.

Dunbar (1966) related the political framework of the time and the transfer of the Royal Court to England to a push in the development of major architectural works led by noble and rich families. In this context, stately countryside houses became the central focus of construction activity (Glendinning et al. 1996). Subsequent researchers (Dunbar 1976; MacKechnie 1993; Colvin 1995; Glendinning et al. 1996; McKean 2001; González-Longo 2012, 2013, 2020; Wemyss 2014) have further extended research in the field of history of architecture, demonstrating the appearance in the seventeenth century of a new figure in the construction industry: the architect. This new role marked the end of the predominance of masons as leading figures in the design and construction of buildings.

The construction industry of the time was based on stone as the prevalent building material, as this was widely available in local quarries. In recent decades, the need for conservation has motivated research into building materials (stone and mortar). Valuable data collected by the British Geological Survey (BGS) and the Scottish Lime Centre Trust (SLCT) has contributed to the development of knowledge that can be summarised in three main areas: (i) identification of historical quarries (McMillan and Gillanders 1997; SLCT 2006); (ii) systematisation of the survey of facades to identify decay and damage processes (Hyslop, Albornoz-Parra, et al. 2006); and (iii) definition of adequate matching stone and mortar when replacements are needed (Hyslop and Albornoz-Parra 2009). The results obtained so far have contributed to raising awareness of the different actors dealing with historic buildings. Technological advances in data collection and data management have opened new opportunities for the creation of relational databases, which can contribute to the conservation of existing heritage (Hyslop et al. 2010). Projects such as the Building Stone Database for Scotland (BGS 2018), intended to create an accessible stone catalogue, or the Properties In Care Asset Management System (PICAMS), which will provide a detailed picture of the condition of historic buildings in the country, assisting with planning effective repair and maintenance programmes, are examples of this (Tracey, Smith, and Lawrie 2016; HES 2018a, 19–20).

Dunbar (1966, 192–97) imagined a map of regional patterns when describing the plenteousness and the variety of stone buildings existing in Scotland. Following best European practice, McKean (2003) raised the importance of correlating the results obtained from the study of historical documents with a detailed analysis of existing fabrics in order to have a complete understanding of the built reality. However, full understanding of the construction knowledge and techniques associated with existing masonry and its historical context still offers wide research possibilities. The literature review developed in this research has not identified a systematic approach focused on this subject in Scotland. The few experiences found that consider the study of masonry in the field of archaeology are isolated and mostly focused on the dating of masonry (Zeune 1992; Potter 2008; Uglow et al. 2012). Furthermore, the works identified in the field of geology (McMillan et al. 2006; Hyslop et al. 2006) include secondary references to the topic. In conservation, the detailed investigation of Davey et al. (1981) into the masonry used in the New Town of Edinburgh is quite unique and does not define a continuous and consolidated research path. However, the situation in other countries is different.

In Italy, the study of masonry has given rise to the development of a rich body of literature. Authors such as Mannoni (1997, 2005) and Parenti (1988, 1994), working from an archaeological perspective, and Giuffré (1991, 2003), Abbaneo et. al (1996) and Donà and De Maria (2011), concerned with the structural performance of masonry structures, agreed to grant significant importance to understandings of construction techniques. The extensive research focused on analysis of existing masonry has contributed to defining types of masonry walls based on the study of building techniques, relating these with specific regions and historical periods. An example of this is the series of works directed by Giovanni Carbonara and developed by Fiorani (1996), Esposito (1996), De Meo (2006) and Chiovelli (2017). Continued research activity has created a structured base of knowledge, which contributed to the definition

of an objective cataloguing system. This organised information enabled links to be made with other types of data in relation to, for example, the structural performance of different masonry solutions, resulting in a valuable contribution to the survey and conservation of existing heritage (ICCD 2013b).

The research presented in this document is framed in this context, assuming that bridging the gap in historic construction knowledge highlighted is a necessary step for the adequate interpretation of the built heritage referred to and, consequently, its future conservation.

1.2 RESEARCH OBJECTIVE

The preceding section depicts the seventeenth and eighteenth centuries as a time of transformation in Scotland. Research developed in recent decades in the history of architecture has highlighted the relevance and distinctive features of buildings constructed during this period in Scotland. In addition, the extensive research developed into the conservation of stone facades from the point of view of material science and geology has contributed to building a valuable base of knowledge on the conservation of damaged and decayed material. However, the study of building techniques related to the construction of such heritage is a field little explored. This investigation aims to fill the gap identified by studying the masonry used to build Scottish countryside stately residences during the seventeenth and eighteenth centuries.

In Italy, the literature on this topic is extensive and was found to be very valuable for the adequate interpretation of existing heritage and consequently also its conservation. For example, Mancinelli and Negri (2017) outline the approaches developed in identification and analysis of masonry techniques in different parts of Italy. The conclusions derived were used to define a survey form (ICCD 2013b) that aimed to record and identify masonry types. In this case, the final objective is to provide an instrument for the acquisition of the data necessary for the later qualification of the structural performance of masonry walls.

The objective of this investigation is therefore the morphological characterisation of masonry based on the study of construction features and techniques. The analysis focuses on elevations and is performed on a group of cases representative of the historical context considered. This enables the conclusions obtained in every case to be related to the wider context already defined, providing new historic construction knowledge.

Such knowledge contributes to the better understanding of the unique and distinctive values of this specific heritage and can be used to underpin future conservation projects. In particular, the identification and adequate interpretation of morphological features related to building techniques is essential to prevent blurring marks and features that reveal the constructive wisdom of masons. This intangible heritage was orally transmitted from masters to apprentices and is rarely found in written documents.

Thus, the existing stone masonry is a valuable historic record, and its correct interpretation is important to prevent inadequate interventions.

1.3 METHODOLOGY OUTLINE

The investigation started with a literature review considering four different areas of knowledge. The first area covered architectural history and focused on identifying the context of the architecture built during the seventeenth and eighteenth centuries in Scotland. This enabled definition of the historical framework and identification of characteristic features of the construction industry and built architecture. The review concluded that the building industry underwent a transformation. The appearance of the architect ended the dominant role of masons, and the stately countryside houses became the focal point of architectural activity. These were mainly built in stone, and designed either by extending ancient family seats or as new planned residences.

The second area concerned construction history and identified state of the art methods for the morphological characterisation of masonry. These were found in two different fields: archaeology and conservation. The literature review developed did not identify a systematic approach focused on this subject in Scotland. The necessary references were therefore sought in another context. During the 1970s, Italy was the scene of intense debate about working methods developing in archaeology and discussions about how to approach the conservation of existing heritage (Tabales Rodriguez 2002, 24–29). The result of this overlap was a sequence of contributions that attributed significant value to the study of existing masonry. The approaches and methodologies developed in this context were extensive and defined a robust base of knowledge, which was integrated into Italian guidelines. These are still being used in the conservation of built heritage (ICCD 2013a, 2013b). Furthermore, the experiences of certain researchers were exported and applied in other countries with successful results, as in the case of Spain, where the archaeology of architecture approach was applied by researchers from different regions, contributing to the preservation of local heritage (Tabales Rodriguez 2002, 59–71).

For the reasons stated, it was considered appropriate to use the contributions developed in the Italian context as references. Specifically, the methodology defined for the attainment of the research objective emerged from the following two points.

- *The definition of types of masonry is not based on the identification of formal features but on the understanding of the construction technique used to build it.* This approach is learned from the work of authors such as Mannoni (1997, 2005) and Parenti (1988, 1994), focused on the archaeological perspective, and Giuffré (1991, 2003), Abbaneo et. al (1996) and Donà and De Maria (2011), concerned more with the structural performance of masonry.

- *It is necessary to build a knowledge base that enables zooming in and out of the context of the object studied and relating the results obtained with a wider framework.* The series of works directed by Giovanni Carbonara and developed by

Fiorani (1996), Esposito (1996), De Meo (2006) and Chiovelli (2017) are examples of this approach.

The third area consequently investigated the practical knowledge of masons in the UK. This served to identify the principles and rules involved in the construction of a wall, to understand the building techniques involved, and to define the base of knowledge necessary to develop masonry analysis.

The last part of the literature review studied methods for capturing and processing data. In this case, the objective was not to undertake an exhaustive investigation into the state of the art, but to provide an overview of the different technologies and approaches available. In particular, machine learning techniques were found to have great potential. The contributions of authors such as Gonzalez Manich et al. (2016) and Valeroet al. (2018) indicated a research path that this investigation further explored with successful results.

The review process highlighted an issue related to the classification of masonry patterns in the UK. In particular, the criteria used for the classification was based on qualitative considerations, which left space for interpretation, leading to results highly dependent on personal sensibility. Solving this issue was important to guarantee adequate interpretation of the results obtained.

The methodology developed defined a sequence of analyses composed of two parts, as illustrated in Figure 1.1. The process began with a study of the historical architectural context. The reviewed literature provided an overview of the context but did not include significant data related to the characteristics of masonry. In order to select a group of meaningful cases for later analysis, it was necessary to make the context significant in terms of masonry. This objective was achieved by individually analysing three different aspects: (1) the structure of the territory, which is directly linked with the sources of building materials, (2) the morphological characteristics of the stately country home built, and (3) the groups of architects and masons working at the time.

First, the study of the territory related to geography and geology and the distribution of buildings on the land. This led to the identification of focal points of building activity and areas rich in good building stone. Second, the most characteristic features of the stately country home were studied by means of a statistical approach, which enabled identification of the features most determinant for the characteristics of their masonry. Finally, a network analysis was adopted for the identification of work environments, which linked prominent architects and masons involved in the design and construction of masonry. The outcomes obtained provided the criteria necessary for the selection of case studies representative of the context investigated, and therefore adequate to include in the analysis of masonry elevations.

The second part of the methodology focused on the morphological characterisation of masonry. The conclusions obtained from the review and study of the practical knowledge of masons enabled definition of meaningful parameters for the characterisation. The analysis process first focused on the elevations and individually studied three main parts of their masonry: (1) the solid portion of walls; (2) the corners, and (3) the openings. Consideration was then given to a more comprehensive vision,

and how the three parts were integrated within the overall system was examined. This sequence of steps was systematically applied to each case study, leading to the identification of common and distinctive features. In addition, in order to overcome issues related to the qualitative classification criteria previously discussed, a novel objective method based on machine learning techniques was developed, providing quantitative indicators. This was used for the characterisation of the solid portion of walls.

The information used for the characterisation was of two types: primary data collected on site and secondary data obtained from existing literature. The first involved the dimensions, arrangement and physical characteristics of the elements inspected. The second included historical data related to the authorship and construction history of the buildings, and materials used. The data obtained was organised in a form designed for this purpose, which eased the separate analysis of the different elements.

The process followed to define the context and to select the cases made possible the interpretation and discussion of the results according to the three aspects initially characterised within the context analysis: the structure of the territory, the stately home and the work environments. The conclusions obtained implied the attainment of the research objective and revealed new knowledge of historic construction, contributing to improved understanding of the unique and distinctive values of this specific heritage. These can therefore be used to underpin future conservation projects. The details of the different analyses are further explained later in this thesis.

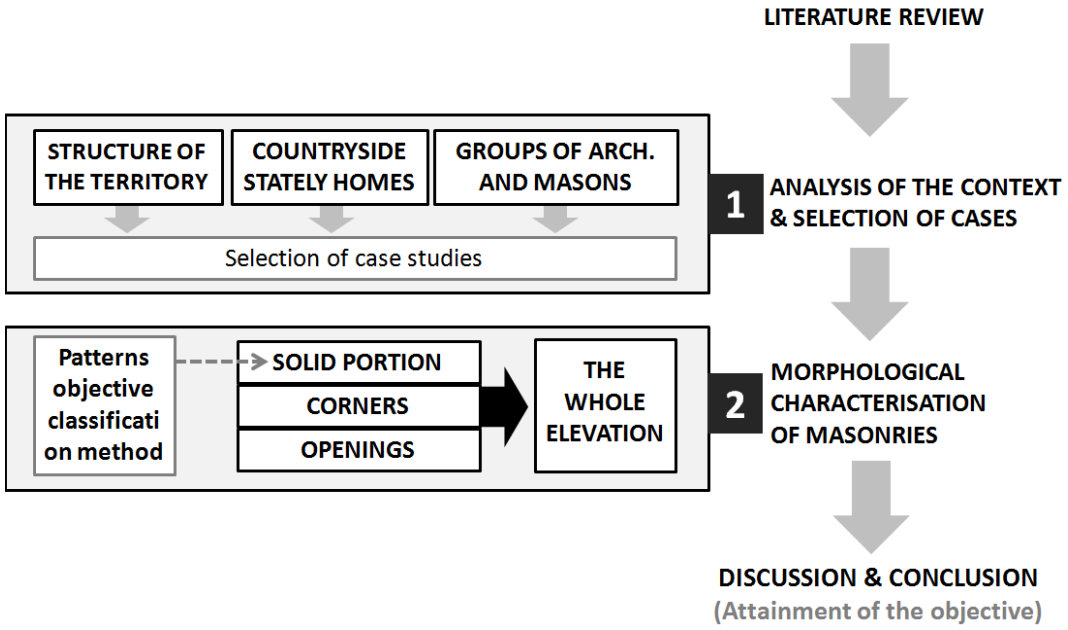


Figure 1.1: Outline of the research methodology.

1.4 RESEARCH BOUNDARIES

The research presented here developed within certain boundaries in relation to the scope of the historical context, the case study approach, the focus of the masonry analysis, the methodology references and the technical means used for analysis.

The investigation focuses on the Scottish context. Renowned authors previously mentioned, such as John G. Dunbar and Charles McKean, have demonstrated the uniqueness and autonomous character of the history of this territory with respect to other areas of the UK. The transfer of the Royal Court to England and the leadership assumed by local wealthy families are signs of the singularity of Scottish history. For this reason, the review of history of architecture focuses only on Scotland, leaving aside analysis of its connection to the wider British context.

Within the Scottish context, the investigation considers the stately countryside home as a type of building at the centre of construction activity during the seventeenth and eighteenth centuries. Other architectural works are left out of the scope. In addition, the approach used is based on case studies. This means that a limited number of buildings were analysed. However, the methodology developed enabled the specific outcomes to be related to the wider context, providing a more comprehensive understanding. Future research applying the methodology proposed to a larger number of cases would bolster the conclusions derived.

Regarding the focus on masonry analysis, the objective is the morphological characterisation of masonry elevations. These are studied from a construction point of view, without consideration of references to material properties, structural performance and other matters. The primary information gathered from the different sites therefore concerns morphology and construction. References to other contextual data related to the chronology or authorship of cases are defined using secondary sources.

The means used to capture data were not sophisticated: a total station Leica builder 209, a conventional camera canon G11, a laser meter, a rigid frame sized 1mx1m, and a 5m long tape. Furthermore, the software Raddrizzamento Digitale Fotogrammetrico (RDF) version 4.0 was used to correct the images captured during the inspection. The literature review chapter includes a section on the evolution of the technical means used for the data capture and processing. Photogrammetry and LIDAR are identified as the two techniques generally used for the acquisition of data, and the use of algorithms for the processing of data is highlighted as a novel research path with significant research opportunities. The resources available in this investigation limited access to the latest data capturing technology. However, the means used were sufficient to provide a dataset adequate for the analysis of masonry, and the use of machine learning techniques enabled the development of a novel method for the classification of patterns.

Finally, the lack of methodologies focused on the study of masonry from the point of view of historical construction in Scotland motivated the search for references in other contexts. The study of the masonry heritage has been considered by research groups working in the fields of archaeology and conservation all over the world, resulting in an

extensive and rich literature. For example, Ucko (1995) presents an overview of the development of archaeology in different countries, evidencing a richness of approaches. However, the experience developed in the Italian environment has a uniqueness that makes it especially relevant for the motivation and focus of this research. This relevance is determined by the overlap that occurred in the 1970s between the debate on the working methods developed in archaeology and the discussions about how to approach the conservation of existing heritage (Tabales Rodriguez 2002, 24–29). This overlap resulted in an approach that grants special relevance to the systematic study of existing masonry. The bases of the approach are solidly established and have been applied in other contexts – such as the Spanish context – with successful results. The extensive research developed has contributed to identification of the characteristics of masonry built in different periods and regions, building up a solid base of knowledge, which has in turn contributed to the fields of history of architecture and conservation. For the reasons noted, the research methodology developed here learns from the references identified in the Italian context, leaving aside experiences developed in other places.

In conclusion, the investigation presented in this document is conducted within the boundaries defined. The aspects neglected because of the limits outlined will become the objects of future research.

1.5 STRUCTURE OF THE THESIS

The thesis is structured in seven chapters. The first three chapters set out the introduction, literature review and methodology of the research. Chapters four, five and six present the results obtained during the analysis, including the discussion in the last section. Finally, a conclusion chapter closes the document. The content of each chapter is outlined as follows:

Chapter 1: Chapter one explains the motivation behind the research, introduces the context in which the research gap is identified, defines the objective, outlines the methodology followed for its attainment, determines the boundaries of the investigation, and, finally, sets out the structure of the document.

Chapter 2: Chapter two outlines the literature reviewed. The state of the art on the topic is defined, highlighting the knowledge gap later addressed, and identifying the references used to underpin the analysis. The review considers different areas of knowledge, which are presented in separate sections. The first gathers contributions studying the historical–architectural context of the seventeenth and eighteenth centuries in Scotland, including references to the building industry and the characteristic features of the stately home. The second focuses on the identification of methodologies developed for the study of masonry. Section three sets out an overview of the technical means for capturing and processing data. Section four synthesises the practical knowledge of masons and related building techniques in the UK. The fifth section highlights an issue related to the classification of patterns. Finally, the chapter closes with a discussion of the key contributions studied and research gaps.

Chapter 3: The third chapter details the methodology developed in the research. As noted, it is composed of two main parts presented separately. The first part defines the process followed to analyse the historical–architectural context considered in order to make it meaningful in terms of masonry. This process includes three different analyses: (1) an analysis of the structure of the territory, which relates built nuclei to stone building resources and the geography of the land; (2) a statistical analysis, which identifies certain aspects of the morphology of buildings determinant for the characteristics of masonry; and (3) a networks analysis, which serves to identify work environments relating people involved in the construction of masonry. The outcomes obtained serve to define criteria for the selection of case studies representative of the context and adequate for the purposes of the research. The second part of the chapter details the sequence followed for the characterisation of masonry. This is divided into two sections. The first section presents the method developed for the objective classification of masonry patterns. The second details the sequence followed for the morphological characterisation of stone masonry.

Chapter 4: Chapter four presents the results obtained from the analysis of the context, organised into separated sections following the sequence defined in the methodology: (1) structure of the territory, (2) morphology of the stately country home, (3) groups of architects and masons. The outcomes obtained are discussed and used to select a group of representative case studies, which is presented in the end of the chapter.

Chapter 5: Chapter five presents the clusters defined in the objective classification of masonry patterns. The analysis sequence followed is hierarchical and includes two levels of classification, which are presented in different sections. The first section presents the main clusters corresponding to the first level of classification, while the second section defines variants of each cluster. Finally, the outcomes are discussed and related to the context initially defined.

Chapter 6: Chapter six includes the results obtained from the morphological characterisation of masonry. This chapter is divided into two parts according to the two main groups of case studies defined. The first gathers the data corresponding to cases not related to the work of an architect, while the second refers to the architect-related case studies. In both parts, the data is systematically presented according to the analysis sequence defined in the methodology. The outcomes obtained are discussed at the end of the chapter.

Chapter 7: Chapter seven concludes the research, summarising the findings of the investigation and highlighting future research paths.

Chapter 2
LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents the state of the art on four different areas of knowledge that define the basis for this research. The first area concerns the history of architecture and considers the context in Scotland during the seventeenth and eighteenth centuries. It overviews the building industry and identifies key characteristics of the architecture built. The second area focuses on construction history and identifies methods used for the morphological characterisation of historic stone masonry. The third area looks in more detail at technological developments in the study of masonry, particularly the capturing and processing of data. The fourth area investigates the principles and rules related to the construction of traditional stone masonry walls in Britain, thus developing understanding of how historic fabrics were produced. The chapter closes with a summary of the main findings of the review. The works referred to in this chapter are those found to be the most relevant for the development of the research. They serve to define the state of the art, identify research gaps and underpin the analysis methodology presented in the subsequent chapter.

2.2 ARCHITECTURE OF THE SEVENTEENTH AND EIGHTEENTH CENTURIES IN SCOTLAND: CONTEXT AND MAIN CHARACTERISTICS

Seventeenth- and eighteenth-century Scottish architecture has not yet been fully studied. As mentioned by McKean (1993, 2006), misunderstandings of Scotland's participation in the Renaissance have prevented the search for other evidence in the past. However, a series of works produced in recent decades has outlined the importance of this period, contributing to the opening of a research path in this area.

One pioneer scholar who highlighted the relevance of the seventeenth and eighteenth centuries in the history of Scottish architecture was John Dunbar (1966). He related the departure of the Court of James VI to Whitehall with a push in the development of major architectural works led by the nobility. Subsequent authors have further developed this thesis, supporting the idea of a period of transformation in which Scotland participated in the European context, at the same time revealing its strong cultural identity (Glendinning et al. 1996; McKean 2001; Howard 1995, 2011). Such transformation can be identified in the changes experienced by the building industry and in the characteristics of the architecture produced.

2.2.1 BUILDING INDUSTRY AND EMERGENCE OF THE ARCHITECT

One of the first studies of the building industry of the period was that of Knoop and Jones (1939). The authors focused on what they defined as “early modern times”, and identified two main systems used to organise the construction process: (i) the direct labour system and (ii) the contract system. As Dunbar (1976, 8–11) has also explained, the direct labour system was applied by employers able to hire officials on a permanent or semi-permanent basis, such as the Royal Works, the Church, or some noblemen. The officials were responsible for all the tasks related to the construction process, including the engagement of the craftsmen, the supply of the material, the organisation of the works, the control of the accounts and, in some cases, maintenance works. In the contract system, on the other hand, the accomplishment of specific work was agreed between two parties: the employer and the tradesman, generally a mason-contractor, or a group of tradesmen. Maintenance works were seldom included in the agreement. The employer usually provided the materials and assumed their transportation, although exceptions existed, and, in some cases, the building contractor also assumed such responsibilities. Dunbar noted that the first system was widespread in medieval times and was used until the seventeenth century, when the second system became commonly utilised. However, he also highlighted that the transition from one to the other is not defined by a straight line, as both systems co-existed in time.

Until the seventeenth century, architectural works were generally designed and built by master masons although, in some cases, wrights also assumed this responsibility (Dunbar 1976, 11; Howard 1995, 211–18). These were educated craftsmen organised in bodies with a defined hierarchy and a specific apprenticeship process. In Scotland, the craft guilds were known as “Incorporations”. These were subordinated to local authorities and regulated the competence of their members, also protecting the interests of the group (Stevenson 2011). In parallel, another type of association was known as Masonic lodges, which did not strictly respond to the practical aspects of masons’ work and had their own secret rituals and doctrines. William Schaw (d.1602) established the basis of modern freemasonry in Scotland in the seventeenth century, which encompassed manual labour with knowledge of geometry (Stevenson 1988a, 1988b).

In their study of building accounts, Knoop and Jones (1939, 26–34) noted diverse classes among stone workers, although boundaries among them were uncertain. In particular, they identified three qualifications: quarriers, masons and cowans. Quarriers seem to have been involved with the winning and dressing of stone, while masons were more directly involved in the construction of masonry. However, the authors found records attributing the winning and dressing of stone to masons. Regarding the term cowans, the authors concluded that this was probably used to identify masons who did not follow a regular apprenticeship, and therefore were not qualified in the trade. The category of master mason is highlighted as a particularly prominent category of mason. The exact duties of this category are not specifically defined in

any record. However, the role is either related to that of a chief technical official involved in direct labour, or a master tradesman in the contract system.

Between the seventeenth and eighteenth centuries, the predominance of masons gradually changed because of the appearance of a new figure to lead the design of buildings: the architect. According to Dunbar (1976, 11), the first architects either came from the tradition of masons, as in the case of Robert Mylne (1733–1811), or were well-travelled gentry such as Sir William Bruce (c.1630–1710). The exact identification of the beginnings of the profession is at the root of a discussion that has generated extensive literature.

Initially, Colvin (1986) noted that the architectural profession was not fully developed until the mid-nineteenth century, when architects achieved economic independence and the social status of gentlemen. However, McKean (1993, 2001) was very critical of approaches not admitting the existence of the architecture profession in the late seventeenth century. McKean highlighted that the distinction between the mason and the architect was not clear at the time, and refers to the first acceptance of non-mason members in Scottish Masonic lodges as a sign of this. For McKean, the buildings produced are the result of the work of skilled and well-educated men, with deep understanding of construction and design, who assumed roles, leading to their identification as architects. Subsequent authors have further demonstrated this.

Colvin himself published the Biographical Dictionary of British Architects, including British architects who worked in England, Scotland and Wales between 1600 and 1840 (Colvin 1995). The term architect is here used in its broader sense and applied to "*anyone, whether amateur, tradesman or professional, who habitually made architectural designs*". However, each entry referred to the specific background and professional qualification of each individual.

Glendinning et al. (1996, 73) highlights that the earliest uses of the term "architect" in Scotland date from 1560 and 1660, when it was applied to two Royal Masters of Work: William Schaw and James Murray (d.1634). MacKechnie (1993) analysed Murray's career and compared it with the definition of the word architect as a "person qualified to design buildings and supervise their erection", concluding that certain correspondence existed between the two. However, architects did not begin to gain wider recognition until the mid-seventeenth century.

Gonzalez-Longo (2012, 2013, 2014, 2020) studied the figure of James Smith (1645–1731) in depth, defining him as the *"first [architect] in a modern sense"*. She notes that the progress of Smith from mason to architect was a combined result of his education in Rome, his skills and his family connections. His impact was recognised by his contemporaries: Colen Campbell (1676–1729), author of *Vitruvius Britannicus*, referred to him as the most experienced architect in Scotland.

Dunbar (1976) applied the term "gentleman-architect" to Sir William Bruce and Alexander Edward. Both lacked the technical expertise of masons but became prominent figures of their time for effectively supplying designs to certain members of the nobility and wealthy classes and indirectly superintending their building works (Lowrey 2020). Glendinning et al. (1996, 73) highlight that Sir William Bruce was acclaimed in 1717 as the "chief introducer of Architecture" in Scotland by his contemporary, Sir John Clerk of Penicuik.

In the late seventeenth century and early eighteenth century, William Adam was identified by his contemporaries as the "universal architect" of Scotland, and his sons Robert and James Adam claimed the appellation of architect themselves in the 1770s (Colvin 1986; Gifford 1990).

Knoop and Jones (1939, 24) declared that they found evidence of the appearance of the architectural profession in the seventeenth century, but also a tendency for the wealthy and noble classes to participate in the design process. Wemyss (2014) enriched this perspective by analysing the role of the client in the design and building process. He notes that the real

challenge for well-known architects such as Sir William Bruce, James Smith and Robert Adam was not to interpret the classical principles but to satisfy the aspirations of clients who followed their work closely. On one hand, the Scottish nobility participated in the intellectual European context, but, at the same time, they valued their historical lineage and aimed to preserve the image of their family tradition. This mindset resulted in residences that externally acknowledged ancient values, but whose interiors were arranged according to the requirements of the educated society of the moment. On the other hand, the "nouveaux riches" aimed to project an image of wealth but were not connected to noble lineages. The country houses designed for them therefore responded to these aspirations. Given the different ambitions of the clients, Wemyss highlights that architects were forced to develop architecture able to integrate their own perspectives with the aspirations of their patrons.

In light of this, it can be concluded that the seventeenth century defines a turning point in architectural production. During this period, the appearance and consolidation of the new role of the architect ended the prevalence of masons as leading figures in the design and construction of architectural works.

2.2.2 MAIN FEATURES OF THE ARCHITECTURE PRODUCED

Dunbar (1966) related the transfer of the Royal Court to England to a push for the development of major architectural works led by noble and rich families. In this context, stately countryside houses became the focal point of construction activity, overshadowing other architectural works (Glendinning et al. 1996). The following sections consider three characteristic features of this type of architecture: (1) the abandonment of defensive schemes, (2) the co-existence of two building strategies, and (3) the predominance of stone as building material.

2.2.2.1 The abandonment of defensive schemes

One of the characteristic features of the architecture produced between the sixteenth and seventeenth centuries is the abandonment of defensive logic in favour of more domestic approaches (Dunbar 1966, 53). The construction of massive tower houses, typical of previous centuries, evolved towards typologies closer to European trends, consisting of different wings and organised around courtyards. This thesis was defended by McKean (1993, 2001), who clearly disproved the castellated conception that can be found, for example, in MacGibbon and Ross (1888). This conception responded to the historiography of a period when Scotland was considered to be disconnected from the European architectural context because of its remote location, and was believed to have continued the construction of medieval defensive seats until the end of the seventeenth century. In contrast, McKean proposed the use of the word "château" to define countryside stately homes, emphasising their link with the European context.

Howard (1995, 50–107) aligned with this idea, and, based on a stylistic approach, identified distinctive features of the architecture produced between 1550 and 1660. One of these characteristics was the free use of symmetry, which was rarely literally applied either in plan or elevation. The prosperity of the time resulted in a gradual increase in the size and scale of these country houses. Changes in lifestyle led to an organisation of spaces that sought to increase privacy and, despite keeping schemes with several floors, tended to develop more horizontally. Nevertheless, skylines were still important and were understood as a sign of economic power. The design of certain elements, such as staircases, roofs and doors, also varied, and conscious use was made of certain stylistic elements to hide messages about the owner's political or religious sympathies. According to Howard, external influences could not therefore eclipse a deeply rooted local building culture, and the combination of these resulted in an architecture that was recognisably Scottish.

Glendinning et al. (1996, 71–183) considered a wider time span, including the late seventeenth and the eighteenth century. According to the authors, between 1660 and 1760, the landed classes focused on the construction of country houses. In this period, the tradition of monumental ashlar facades spread into secular building construction. A stricter application of classical ideals was mixed with local identity and consolidated through the work and interpretation of Sir William Bruce and James Smith. This was later developed with the contributions of William Adam. The end of the eighteenth century was marked by the architecture of Robert and James Adam, which preserved a Scottish identity but at the same time participated in changing trends, which were opening a path towards the innovations of the nineteenth century.

2.2.2.2 The co-existence of two building strategies

The approach used to build country houses between the mid-seventeenth and mid-eighteenth centuries was not homogeneous. Two different trends are identified: (1) the erection of new plan residences, and (2) the extension of historical family seats (Dunbar 1966, 69; McKean 1993, 2001, 17; Wemyss 2014, 317–20). The former was usually driven by “new rich” families in pursuit of residences corresponding to their wealth. The latter was usually adopted by noble families who had lived in their historical seats for generations, considering them a sign of power and an image of their Scottish identity and lineage. These ancient residences usually responded to medieval schemes not always compatible with the life standards of the time. In order to update these to the new requirements and preserve the image of power, the extension and alteration of existing structures became usual.

Especially relevant for the purpose of this investigation is the approach defined by McKean (2001, 16–22). The author left the prevailing descriptive approach for a moment and studied the evolution of two construction strategies (new plant and extension) from a quantitative perspective. To do this, he took the volumes published by Salter (1993, 1994, 1995) as a starting point to build a database. In this database, he recorded the date of construction of the different buildings listed and their geographical locations, classifying each case as a new plant or extension. The result obtained was a graph drawing the evolutionary curve of the construction of new plans and extensions, both chronologically (between 1500 and 1684) and geographically (by councils). The turning point from which extensions became more frequent than new plans happened between 1600 and 1639.

The transformation of existing seats resulted in complex structures composed of superimposed historical strata that are difficult to interpret. As noted by Howard (1995, 104), in most cases, dating is highly uncertain. McKean (2003) faced this issue in the case of Innes House in Moray, where two historical records defined contradictory chronologies. In order to overcome this problem, he decided to perform a detailed study of the fabrics to find evidence clarifying the existing hypotheses. His conclusion was that existing masonry represents a valuable source of primary information. The results allowed him to understand that the house was not built from an empty plot, and the existing building was integrated with a previous structure. Based on this, he highlighted the need to combine documentary research with on-site examination of evidence in future studies, in order to have a better understanding of existing heritage and history. Similarly, González-Longo (2014) managed to distinguish in Drumlanrig Castle the original parts from the later additions based on observation of certain differences in the masonry, such as the size and colour of the ashlars, the thickness of the wall and the morphology of the openings. The idea of studying masonry as a primary source of information is not common in Scotland, but aligns with the approach followed in other European countries, especially in Italy, as we will see later.

2.2.2.3 The predominance of stone as a building material

Stone was the predominant material used to build in Scotland until the twentieth century. Scott-Moncrieff (1938) already referred to this characteristic feature of Scottish architecture in the title of his book: "*The Stones of Scotland*", and defined the pictures included in his publication as a selection to "*present the qualities of Scottish masonry*". This aspect can also be noted by flipping through the Pevsner architectural guides (Walker et al. 2015) and the catalogues of Mike Salter (1993, 1994, 1995). These collections of books include a selection of buildings from different areas of Scotland, and it is easy to verify that the majority are built of stone.

Dunbar related the predominance of stone construction to the plentiful availability of building stone across the country and the late introduction of brick as a common construction material.

> *"To the observant traveller the dark greywacke of the upper Tweed valley, the sparkling granites of the north east, the grey west highland schist and the smooth regular flagstones of Caithness and Orkney compose a regional pattern no less significant than that delineated by local administrative boundaries." Dunbar (1966, 193–97)*

The idea of stone architecture closely related to the territory, and the need to find compatible stone for conservation purposes, motivated studies about the distribution of building stone resources in Scotland, and about the location of historic quarries.

Several authors (McMillan and Gillanders 1997; McMillan et al. 2006) have referred to the complexity and significance of Scottish geology, and divided the region into three rough areas according to geological characteristics and stone resources for building: (i) the Highlands and Islands, composed mainly of metamorphic and igneous rocks, with Aberdeen defined as the "granite city"; (ii) the midland valley or Central Belt, where the major resource was good quality sandstone suitable for building purposes; and (iii) the Borders and Southern Uplands, where sandstones and metamorphic rocks abound.

It has also been highlighted that the extraction of stone from small local quarries was normal practice until well into the nineteenth century (McMillan et al. 2006, 5; McMillan and Gillanders 1997, 10). Indeed, the peak of stone quarrying activity for building in Scotland happened during the nineteenth century, with 700 active quarries. The cost of transporting the material over large distances and the abundance of good quality stone in the territory have been highlighted as factors behind this situation. In the twentieth century, local quarrying activity substantially decreased, resulting in the abandonment of numerous quarries, some unrecognisable today. The BGS map (2001) includes a selection of the larger quarries, which achieved commercial or historic status in Britain. However, its author also mentions that thousands of smaller quarries were producing stone for nearby buildings. The Building Stone Database for Scotland (BSDS) is a project under development, led by the BGS, which aims to compile information about the building stones of Scotland, either historical or current, and the quarries and architectural works associated with them (BGS 2018).

As well as stone, lime is the other material involved in the construction of stone masonry buildings. The SLCT is a non-profit organisation, which has devoted special attention to the study of the use and production of lime mortar. A report (SLCT 2006) presented the results of historic research into the activity developed in the Charlestown lime works. This was an important historical kiln, exporting lime to different areas of Scotland between the eighteenth and nineteenth centuries. The research identified materials produced on the site, mapped the destinations of the different products and the use made of them, and revealed information about

the techniques employed during the production process. In addition, the SLCT has developed an extensive database, which is continuously updated, with information about lime samples obtained from Scottish buildings built in different periods and locations (Schmidt 2017). This database was recently included in a research project expected to contribute to the knowledge on this field in years to come.

2.3 METHODS FOR THE CHARACTERISATION OF HISTORIC MASONRY

The morphological characterisation of historic stone masonry is a subject that has been considered in the fields of archaeology and conservation. The difference between the two fields is clear. The final objective of the former is to disclose the construction history of a site, while the latter is mostly oriented towards preventing decay and damage. However, despite their different focus, the various methodologies developed in both cases include parts specifically oriented to study the construction and morphological features of masonry. For this reason, this section of the chapter reviews literature developed in both fields. The final objective is to identify references that can be used to underpin the development of an analysis methodology adequate for the objective of the investigation.

2.3.1 APPROACHES DEVELOPED WITHIN THE FIELD OF ARCHAEOLOGY

The twentieth century was a period of major developments in the archaeological discipline. The historical, economic and social context boosted research in the field, taking archaeology from its initial humanistic perspective to a more scientific conception. This motivated the development of new methods for the systematic documentation and analysis of historic remains, including masonry walls. The following sections provide an overview of this development, focusing on the approaches most relevant to the purpose of this investigation.

In particular, the review first portrays the push that occurred in the UK during the 1960s. Then considers how the novel approach developed was exported to the Italian territory in the following decade, where it met with discussions about how to approach conservation, resulting in an approach granting special relevance to the systematic study of existing masonry. The extensive research produced in this context, the soundness of the methodologies developed, and the systematic and continuous investigations have resulted in a solid literature. For this reason, the review focuses on this context, leaving aside experiences developed in other environments.

2.3.1.1 The development of the discipline

Until the nineteenth century, the disciplines of history of art and archaeology shared the same objectives and framework. The focus was placed on major architectural works and contributions to knowledge were based mainly on the study of historic records and documents. However, at the beginning of the twentieth century, nationalism dominated the ideological context in Europe, and historical heritage became an element of distinctive value (Tabales Rodriguez 2002, 31–

40). This favoured the development of archaeology in the UK, which progressively abandoned humanist approaches and started applying scientific methodology to the study of prehistoric and ancient age heritage. Names such as the Scottish Mortimer Wheeler (Piggott 1977), who developed a systematic method of excavation based on the use of grids, were key in this process. However, not until the middle of the century did this discipline undergo a definitive transformation.

After the Second World War, cities had deteriorated and required reconstruction. The focus of attention turned towards the architecture making up the inhabited nuclei. The need to record and preserve the standing buildings motivated the development of registers of listed buildings and scheduled monuments based on “The list" developed in 1882 (AMPA 1882). The consolidation of groups oriented towards the conservation of historic buildings, such as the Society for the Protection of Ancient Buildings and the National Trust, contributed to raising awareness of the need to increase knowledge about such heritage in order to guarantee its preservation.

The interest of some researchers turned towards common architecture built in different areas of the country, and direct inspection of existing construction was considered a valuable primary source of information. This was the case for the Vernacular Architecture Group (1952) and the early contributions of the archaeologist Cyril Fox and Lord Raglan's, who pioneered this path with their research about Monmouthshire (Fox and Raglan 1954). Subsequent authors such as Brunskill (1971, 1985), focused on England and Wales, and Naismith (1985), focused on Scotland, delved into the subject aiming to identify regional building traditions based on the development of large, descriptive datasets. In particular, the original purpose of Naismith’s work was the development of a guide to assess the work of architects, planners and builders, encouraging good conservation practices and providing the necessary understanding of the context in order to favour the design of buildings integrated with their surroundings. An extensive survey campaign based on visual inspection led to the collection of data about wall and roofing materials, architectural details, and plan and cross-section proportions. Different types of masonry were mentioned and classified based on a typological approach, which mainly considered the appearance of patterns in elevation. In addition, a brief reference was included to different types of wall corners and possible formations of openings, but this was always considered from a formal point of view. In the end, the method applied led to the identification of “character zones” defined by common features. The focus was on geometry and design criteria. Aspects such as the identification and detailed analysis of different construction techniques, the study of wall sections and the identification of masonry types with specific historical contexts were not within the scope of the publication.

While Fox and Raglan were working on vernacular architecture, the historian W. G. Hoskins focused on the landscape (Hoskins 1953, 1955, 1967). He defended the need for combining analysis of documentary evidence with the study of the existing remains as a primary source of information in order to have a complete understanding of history (Orser 2018). His multi-disciplinary approach to the English historical landscape and the innovative methods used, such as aerial images, were very influential (Gerrard 2009).

The foundation of the Society of Medieval Archaeology in 1957 was pioneering in widening the focus of archaeological research, defining a timeframe from the Roman period to the end of the Middle Ages. The distance between the work of archaeologists and historians has been part of their debate from the beginning, and the need to connect the two disciplines was highlighted in the first editorial of the journal *Medieval Archaeology* (SMA 1957). This was created in London in 1958, providing necessary space for discussion. Such pioneering developments also emerged in other European countries. In France, the magazine *Archéologie médiévale* was founded in 1971 (CRAHM 1971). Two years later, in 1973, the German magazine *Zeitschrift für Archäologie des Mittelalters*, focused on the medieval period, published its first edition (Müller,

Brather, and Steuer 1973). In 1974, the Italian *Archeologia Medievale* was also published for the first time (All'Insegna del Giglio 1974).

The context of the intense archaeological research of the 1960s favoured the development of specific studies on medieval buildings from the archaeological perspective. Examples of this include the work of Hurst (1961) and Jenkins (1965). In the late 1970s, in the context of the English university of Winchester, the archaeologist Edward C. Harris questioned the archaeological methods in use, proposing a method for stratigraphic documentation known as the Harris Matrix (Harris 1979). This method focused on identification of a sequence that relates the different historical strata existing in a specific site. It is based on the individuation of stratigraphic units and the definition of sequential links, which are defined according to the logic of before or after. The contribution of Harris marked a milestone in the development of archaeological methodology, and was adopted by archaeologists from other countries. In Italy and Spain, this became a key tool for the study of historical buildings during the 1980s. Authors such as Brogiolo (1987) and Doglioni (1988) applied the method proposed by Harris to the study of historic masonry.

The intense debate that took place in Britain during the 1960s moved to the Italian stage in the subsequent decades (Tabales Rodriguez 2002, 31–40). In that context, an approach emerged known as "archaeology of architecture". This defined a methodology for the study of historic masonry, between archaeology and conservation, which has continued to develop to the present day. A later section of this chapter details the origins, development and relevance of this approach.

In Britain, the term "archaeology of buildings" was coined a decade later, in 1993, referring to the study of buildings as archaeological objects (Morriss 2000). According to Morriss, the study of buildings should include the study of material culture and should therefore consider three main aspects: fabric, form and function. Despite the similarity of the terms used, the British approach differs from the Italian one. The latter studies in depth aspects related to building techniques, which are not considered with the same relevance in the British context.

Another branch within British archaeology is the archaeology of stone, which is specifically oriented to the study of stone as an archaeological material. This approach focuses on the study of a series of alterations affecting stone, from the original material to current conformations. Such alterations, which can be human or natural, are individuated, leading to reconstruction of the transformation sequence. Peacock (1998) reviews this topic in the British context. As part of a work commissioned by English Heritage, he notes that this approach has a long tradition in the study of pottery, but its application to stone is relatively recent. He clearly differentiates the case of stone artefacts from stones used as building materials, and details the principles and methodology that should be applied for this type of research. In Scotland, one of the few works found within this approach is that of Potter (2008). This work considered the study of early Scottish ecclesiastical buildings. Based on a previous study developed in England, the author examined a large number of Scottish ecclesiastical sites, examining the manner in which stones form arches and wall corners were emplaced with respect to their bedding orientation. The author concluded that, although the results were promising, further work was still needed to define a clear chronology based on bedding orientation.

In Scotland, the influence of the Society of Medieval Archaeology was small, as Scottish medievalists were not engaged with it (Gerrard 2009). However, the literature review developed in this regard highlights two investigations, which approached the study of existing buildings from the perspective of archaeology, both focused on the dating of existing structures.

The first investigation studied Scottish castles built between the fifteenth and seventeenth centuries (Zeune 1992). The author reviewed the dating methods used so far and proposed the

use of a chronotypological approach. He combined the cataloguing of certain elements and features recognised on site with the study of historic records and the identification of chronological marks such as date stones of mason marks. The features considered were varied and include lintels and jambs, heraldic decor stones, shooting point holes, chimneys and plan layouts. The shape and dimensions of each were recorded in a database, leading to a definition of typologies later able to fit within a nationwide chronology. No subsequent works have been identified further developing this path.

The second work was developed by Uglow et al. (2012). This has already been noted in a previous section for its emphasis on the importance of combining the methodologies of architectural history with archaeology in the study of historic buildings. The study focused on two houses by Sir William Bruce. The analysis aimed to unravel the entire history of both buildings in an effort to achieve a complete understanding of their construction phases and alterations. The results led to identification of a correlation between successive alterations of both houses. In the end, the need for further research was highlighted, as well as the importance of ensuring the preservation of elements of historical significance that could make this possible.

From the above outlined, it follows that the archaeological study of masonry is a field little explored in Scotland. The references identified in this specific context do not constitute a continuous body of research. Instead, the approaches developed within archaeology of architecture, archaeology of buildings and archaeology of stone indicate ways to overcome the gap highlighted. The specific focus and consolidated bases of knowledge of archaeology of architecture make this especially interesting for the purposes of this research. The following section reviews in detail the particularities of this approach.

2.3.1.2 Archaeology of architecture: some history

The pioneering archaeological research activity developed in the British context during the 1960s resulted in the appearance of specific studies on medieval buildings, treated for the first time from the perspective of archaeology. During the 1970s, the intensity of the debate on the approach and working methods moved to Italy, where it expanded, incorporating discussions on conservation. The result was the development of an approach known as “archaeology of architecture”. This section presents an overview of the origin, development and main contributions of this approach, but with a focus on aspects related to the characterisation of masonry.

The first works to consider the specific study of existing masonry in Italy happened from the end of the nineteenth to the mid-twentieth centuries. These followed the theory and methods of the classic archaeology that dominated Europe. Durm (1885) is an early example oriented to the identification of masonry types. He was connected to the German school and his studies of Etruscan and Roman architecture therefore follow an approach based on a detailed description of existing remains. His publication includes a chapter about construction techniques in which Durm identifies and describes different masonry patterns, recording the dimensions of stone units and other architectural elements.

The dating of structures was also a central issue for researchers working on the characterisation of masonry. Esther B. Van Deman, educated in North America, developed research focused on the dating of Roman concrete monuments. Van Deman (1912) defined three types of evidence to be used for dating, giving special importance to understanding of the characteristics of materials and the identification of the construction methods used.

The Italian Giuseppe Lugli (1957) also worked on Roman architecture, developing an extensive and systematic classification of different types of masonry and relating these to specific periods of time. However, his approach was criticised by Nino Lamboglia, who considered the method too rigid and based on a stylistic–comparative approach (Della Torre 1996, 7; Quirós Castillo 2005a, 8; Brogiolo and Cagnana 2017, 13). Lamboglia was an archaeologist working at the time in Liguria for the "Soprintendenza", a governmental organ for the protection of cultural heritage. He defended an approach that extended application of the stratigraphic method to architecture. However, this idea was too advanced for the time, and did not find a suitable environment for its development until some decades later.

The ideas defended by Lamboglia had already been proposed by Giacomo Boni (Tabales Rodriguez 2002, 24; D'Angelo and Moretti 2004, 9-12, 31–34), an architect educated in the "Accademia di Belle Arti" in Venice, and involved in the conservation of prominent architectural works such as the Palazzo Ducale and the Bell Tower in the same city. His practical experience led him to develop an innovative view far from the predominant academic framework of archaeology. His interest in medieval heritage led him to discover the British cultural context and the ideas proposed by John Ruskin. In his work, he sought to achieve a complete understanding of the history of buildings, the materials used, the construction techniques involved and even the botanical context of the remains. His scientific approach led him to apply the stratigraphic method of excavation to buildings early, and to develop practical and systematic tools such as the "catastro archeologico-monumentale" mentioned by D'Angelo and Moretti (2004, 32). Such innovations were advanced for the time and did not have great impact. However, they opened a path for later authors such as the aforementioned Lamboglia, and preceded the transformation that occurred in the 1970s.

The archaeological framework that dominated the first half of the twentieth century underwent a deep theoretical and methodological transformation in the 1970s (Quirós Castillo 2005a, 8). The experience of the Society for Medieval Archaeology and its journal *Medieval Archaeology* was imported to Italy by British archaeologists working at different sites such as the Tower of Pavia (Blake 1974). The scientific approach and tools developed during the 1960s in the UK already commented upon in a previous section arrived in Italy in a moment of intense debate about the principles and methods of conservation of historical heritage. The principles defined by Camilo Boito at the end of the nineteenth century (D'Angelo and Moretti 2004, 19–22) were already spread, and the experiences of pioneers such as the already mentioned Boni and Lamboglia were gaining followers. In this scenario, the study of existing buildings took a new impulse towards what was later named "global archaeology" (Mannoni, Bandini, and Valeriani 2001), and the study of existing masonry became a central issue.

The two disciplines met for the first time in the north of Italy. In Lirugia, the "Istituto di Storia della cultura materiale (ISCUM)" directed by Tiziano Mannoni, heir of Lamboglia, was one of the driving forces behind this path. The name of the Institute responded to Mannoni's conceptions about archaeology. He understood it as a science focused on the study of material culture and human know-how (Caballero Zoreda 2010). In the excavations of the Castello di Genova, Mannoni and Poleggi (1974) argued that analysis of archaeologies standing above ground was as important as excavations, and could also contribute to understandings of the historical sequence and techniques employed in the construction. With a focus on aspects related to construction, they proposed an archaeometric analysis of the remaining walls. In order to avoid a purely formal interpretation, they developed a form that gathered information about materials and techniques used for the preparation, sizing and finishing of units. This allowed an objective comparison, overcoming the lack of pre-existing analysis about medieval wall structures in the area. The graphical representation of the results tended to demonstrate the existence of modules identified as potential chronological indicators.

During the second half of the 1970s and in the context of an English university, Harris (1979) developed a method known as archaeological stratigraphy, which questioned the archaeological methods in use so far. This method, already commented upon in a previous section, was adopted by groups working in Liguria, Toscana, Lombardia, Veneto and Lazio. These groups developed their own experiences autonomously at the end of the 1970s and first half of the 1980s.

Carandini (1981) reviewed the contribution of Harris and made the application more adequate for buildings. He redefined the forms used to collect data from the sites by excluding information exclusive to the excavations, including references to the rooms and spaces composing the building, and considering data about specific features of the buildings, such as floor pavements and wall finishing (Tabales Rodriguez 2002, 43–44). Years later, Parenti (1988a) learned from Carandini and further developed the stratigraphic approach. Through the individuation and study of USMs, he managed to identify masonry related to different construction techniques and reconstruct the construction sequence of a building. USM stands for “Unita Stratigraphica Muraria”, and defines a homogeneous construction action identifiable on a wall. In his article, Parenti referred to the work of his colleague Doglioni, and declared his willingness to contribute to his discussion. Doglioni (1988) criticised the harrisian schemes, claiming their conceptual rigidity. His interest was in elaborating a code, which could graphically represent the conclusions obtained from the observation of masonry. Thus, based on his work on Marche, Doglioni defined the “critical survey” (*rilievo critico*). This was an instrument for the study of the evolution and transformation of the materials making up the walls, which used a code specifically defined to graphically identify them and define their links and defects.

The contribution of Brogiolo (1987, 1988) is also relevant in this field. He argued that a building is not only a sequence of construction techniques and structures, meaning that stratigraphic analysis cannot be considered in isolation. According to Brogiolo, each building is influenced by historical context and at the same time responds to specific rules, either contained in historical treaties or derived from orally transmitted tradition. He therefore defined a hierarchy of stratigraphic units, enabling critical collection and organisation of data related to buildings, and reflecting its complexity. Brogiolo’s concern was about the contribution of this approach to the conservation of built heritage. Manacorda (1988) was one of the authors facing this issue. In the conservation of the Crypta Balbi in Rome, he defended the use of the stratigraphic approach as a tool to understand the historical evolution of the monument, but raised the problem of equilibrium between unravelling all historical strata and preserving the exiting..

In parallel to the discussion on the stratigraphic method, Mannoni and his team further developed their research focused on the dating of masonry in Liguria, and in 1984 proposed a new dating method for brick walls, which was known as mensiochronology (Mannoni 1984). This method was based on a statistical analysis of the dimensions of synchronous and homogeneous bricks composing a portion of wall. Years later, this was extended and applied to both brick and stone walls (Mannoni and Milanese 1988). As indicated by Cagnana and Ferrando (1997), the ISCUM also worked on the definition of chronotypologies as an indirect dating instrument. The pioneering unpublished work developed during the 1970s in a rural context was later applied to the area of Alta Fontanabuona, and represented the first attempt to define a chronological classification based on stratigraphic associations (relative chronologies) of masonry techniques, doors, windows and cornices with common dimensions and shapes. Some years later, the work developed in Zignago, considering a larger number of cases and dated references, led to the development of a chronotypology of doors across the centuries.

Parenti was also a key figure in the study of masonry. In the mid-1980s, in the context of the excavation of Montarrenti, he studied the Tower A, developing a first systematic analysis of its masonry (Parenti 1985). He managed to identify and define masonry types, integrating the stratigraphic approach outlined and the contributions of authors such as Mannoni. Years later,

Parenti (1988b) continued learning from the chronological indicators of Mannoni. The focus of his interest was on the study of construction processes. He argued that the analysis of masonry techniques should apply the criteria used in previous decades by archaeologists' for the study of ceramics. This allowed an easy comparison between walls built in different places. He therefore proposed a classification of post-classical masonry techniques based on the study of the exposed faces of walls. In his article, he determined the parameters necessary to characterise a wall: (1) materials used, (2) preparation of material, (3) pattern, (4) dimension of units, (5) finishing, and (6) binder. He affirmed that further extending the research would make possible the codification of a reduced number of masonry techniques and the elaboration of an atlas of walls subdivided by geologically homogeneous areas. This methodology allowed a thorough knowledge of the masonry composing the elevations, becoming a reference for successive authors.

The contributions referred to, together with other similar works developed in the same decades and published in the magazine "Archeologia dell'architettura", resulted in the definition of the theoretical basis of a new approach, which was consolidated during the 1990s as "archaeology of architecture". This approach adopted the instruments of modern archaeological practice: (1) the stratigraphic method, (2) typological comparisons, (3) mensiochronologies, and (4) archaeometric analysis. As a result of its archaeological roots, the focus of archaeology of architecture was the reconstruction of the history of buildings. However, unlike other contemporary approaches, the history of each building was understood as the result of a production process and as part of a broader historical context (Parenti 2002). Research efforts were oriented towards unravelling the keys of their transformation in time, and identifying the techniques and craft involved. Masonry was a valuable primary source of data for this purpose, and the application of an objective method for its analysis based on interdisciplinary work contributed to understandings of construction sequences, construction techniques and production cycles. This provided scientific knowledge that was very useful in the field of conservation and restoration. Consequently, the application of archaeology of architecture to conservation has been a permanent object of study and debate since its origins (Brogiolo and Cagnana 2017).

2.3.1.3 Development and consolidation of archaeology of architecture

The 1990s began a period of development and consolidation of the approach proposed within "archaeology of architecture". This entailed consolidation of the instruments of analysis and the expansion of the databases of knowledge. The experience developed is extensive. The following lines therefore set out a few works developed by relevant authors with the objective of briefly illustrating the consolidation and expansion of the approach. The works selected refer to three aspects related to the study of masonry: (1) the consolidation of the concept of "type of masonry", (2) the study of chronologies, and (3) expansion of databases of knowledge based on the development of extensive survey campaigns.

THE CONCEPT OF "TYPE OF MASONRY"

The outcomes obtained in previous decades from analysis of existing masonry structures in Liguria and Toscana resulted in a definition of the concept of "type of masonry". According to Mannoni (1997b), "type of masonry" is the coincidence of characteristics derived from the need to resolve a specific problem rather than a formal model or inspiration. Parenti further developed his work regarding the definition of objective factors for the identification and classification of masonry types based on patterns in elevation (Parenti 1988b), and included a new parameter in the analysis: the structure of wall sections (Parenti 1994). Years later, the know-how of the

mason was also highlighted as a key factor (Cagnana 1996; Mannoni 1997a, 2005). This led to distinguishing the works developed by a common workforce from those by specialised masons.

Research developed by Bianchi (1996) into the transmission of knowledge and analysis of construction techniques used during medieval times in Tuscany is particularly relevant. According to Bianchi, none of the actions involved in the construction of a masonry structure is a casual choice. Each decision reflects the technical knowledge of the person building it, their cultural–economic environment, and, indirectly, the preferences, requirements and characteristics of the commissioner. Understanding the mental process behind each production chain therefore contribute to the rigorous definition of typologies and knowledge of the historical context.

THE STUDY OF CHRONOLOGIES

The identification of chronological sequences was also a central theme of many investigations. Boato (1996) highlighted the need to combine knowledge from different disciplines to obtain and adequately interpret information contained in built remains. In the context of a systematic study developed in Geneva, she defended the value of research using indirect sources such as building contracts and supply bills, and the use of reference databases as a tool to confirm the hypotheses derived from direct analysis of remains.

Bianchi (1997a) also proposed analysis of stone marks as an additional element to consider within the research. This area has not been researched much in Italy, but, according to Bianchi, analysis of stone marks combined with other material evidence and written records could contribute to understand the construction process, the organisation of works, the know-how of masons, and the socio-economic context of each phase.

Meanwhile, Mannoni (1997c) referred to the classification of masonry as fundamental for the definition of relative chronologies within stratigraphic analysis but not determinative to define absolute chronologies. Boato (1997) also managed to propose a first absolute chronological sequence of the city walls in Geneva based on a combination of different studies, including the chronotypology of doors, the study of masonry techniques, the mensiochronology of stones and analysis of the composition of mortars.

EXPANSION OF DATABASES OF KNOWLEDGE

The development of extensive survey campaigns within the context of a “global archaeology” opened the door to the elaboration of catalogues, which related masonry characteristics to geographical areas, periods and buildings. In the north of Italy, the research programme developed by Cagnana and Ferrando (1997) in Geneva is an example of analysis on an urban scale, which contributed to expanding knowledge about the structure and development of the historical centre of the city. On the same lines, Bianchi (1997b) analysed the residential area in Calatabarbaro (Sicily), applying a methodology of work that allowed the classification of different masonry techniques, types and variants, contributing to understandings of the economic context, the organisation of work, and the know-how of the workers involved. This field also highlights the extensive work led by Ricardo Francovich in Siena (Francovich and Bianchi 2002; Bianchi 2004, 2005). The systematic survey and analysis of specific monuments, abandoned settlements and portions of territory over decades enabled the construction of a database that built a solid base of knowledge about the medieval architecture built in the region and its historical context.

It is also worth noting the guide set out by Cagnana (2000) about materials and construction techniques. Based on a selection of the most common materials used in historical buildings, Cagnana describes their natural characteristics, the history of their use and application in architecture, and their production cycles and building techniques. Consideration is also given the main causes of degradation in order to reinforce its applicability to conservation.

In Lazio, the focus was slightly different. As De Minicis (1997) has noted, the region was studied in its historical context and with consideration given to its physical characteristics (e.g. geology, geography). This led to identification of areas with homogenous characteristics, which were individually investigated. In this context we find a series of works considering the different areas of Lazio and focusing on the study of medieval masonry techniques, but with a focus on the conservation of built remains.

Southern Lazio and Sabina are two areas where calcareous stone is available. Fiorani (1996a, 1996b) and De Meo (2006) studied the medieval architecture built there and succeeded in defining local masonry typologies related to a general chronology. The approach used in both cases started with the study of the context. This considered aspects related to the characteristics of the territory (geomorphology, geology and topography), understandings of the economic–political–historical framework, and identification of the most relevant civil and religious architecture built in the area and its distinctive features. Specific analysis of masonry combined historical research with direct study of existing remains, taking into account different scales of analysis and considering distribution throughout the territory and the vertical stratification of masonry structures considered. This led to the classification of masonry types, considering materials, characteristics of patterns (based on 1sqm of masonry in elevation), structure of wall sections, and aspects related to processing techniques and construction sequences. A combination of historical data and direct surveys enabled definition of a general chronological sequence of types and provided an overview of their development and expansion within the specific context considered.

Esposito (1996) focused on the Roman area. Unlike the work of Fiorani and de Meo, the objective of her research was the study of the evolution and expansion of a specific technique (the “technique a blocchetti”), considering all its aspects (social, economic, technical and historical). Again, the work started from an in-depth study of the context to define the area of influence of the technique considered. Based on previous work developed by Giuseppe Lugli and her own surveys and investigations, Esposito defined the differences between the technique used in Roman time and the variation used in the medieval period. Links between the data obtained from historical documents and the information collected on site allowed the identification of factors behind the evolution of the technique, as well as of sub-types based on changes in dimensions, degree of elaboration of the elements, know-how of the workers and organisation of the construction process.

Chiovelli (2017) resumed the work of Esposito but focused his research on Viterbo. In this specific environment, he managed to define more precise chronologies and follow the evolution of a specific technique based on variations of geometry and dimension, identifying techniques used to process and finish the different elements composing the structure. As Carbonara (2017) has noted, his research incorporated three main areas: (1) archival research, (2) on-site survey and characterisation of masonry, and (3) justification of how and why the technique developed. The detailed study of mensiochronologies and rigorous research of tools and auxiliary means used during the construction process is a reference point and has led to a better understanding of existing remains.

Fiorani (2005) referred to the state of the art on medieval masonry in Italy, highlighting the existence of research gaps in areas such as Marche, Sardinia and Sicily. Putzu (2009) followed the same line and applied to Sardinia the approach used in Lazio by the previous authors.

2.3.1.4 The Spanish contribution

The contributions developed in Italy within archaeology of architecture were closely followed by researchers from neighbouring Spain. An article by Caballero Zoreda (1987), bringing together the main concepts and theoretical framework of the approach, had an important influence in this context. However, the turning point in the dissemination of this discipline in the country happened in 1995, when Caballero Zoreda challenged the established chronology of “visigothic churches” demonstrating an alternative theory resulting from the application of the “Italian approach” (Caballero Zoreda 1995). The consequence was the launching of a research programme focused on surveying an extensive selection of buildings (Caballero Zoreda and Utrero Agudo 2005; Caballero Zoreda 2012). This programme included stratigraphic analysis of existing built remains, identification of masonry types, definition of chronotypologies of architectonic elements, and other related works. Following the same path highlight the contributions of Quirós Castillo (1994) and Tabales Rodríguez (1997a, 1997b). The former studied chronotypologies of doors in the city of Oviedo, while the latter considered chronotypologies of openings in Seville and identified masonry patterns used in the different periods of construction.

Between 1996 and 1998 and within the context of the conservation of the cathedral of Santa Maria in Vitoria, Azkárate went one step further and, following the guidelines of the aforementioned Parenti, proposed the integration of chronotypological and archaeological analysis (Azkarate Garai-Olaum 2010b). Aiming to achieve the most complete knowledge possible about the building, the group defined an analysis sequence, which started with the typological identification of elements and considered two different types of variables: technical–constructive and formal. Technical–constructive variables referred to features such as building materials, types of patterns and techniques used. Formal variables included types of arches, capitals and other similar features. The variables were then georeferenced to define their location in the building system. Then, the data was analysed, leading to the definition of groups of variables or “clusters” with homogeneous construction characteristics. Given that each cluster identified a specific construction phase, the next step involved identification of the boundaries of each cluster and the relationship between priority and posteriority with respect to other clusters. This resulted in the definition of a relative stratigraphic sequence. However, as the objective was to reach an exhaustive level of knowledge, the analysis did not stop at this point. It continued by identifying within each cluster those features that escaped the general chronology but had certain relevance in terms of construction. These were registered and studied as Stratigraphic Units (UE). In parallel to this analysis, an exhaustive archival study emerged of the documentary sources available. The integration of different analyses led to achievement of the research objective and the definition of an absolute chronology, which could be extrapolated in a local context to other cases. This experience was later followed by other authors such as Sánchez Zufiaurre (2007), who applied the approach of clusters to the analysis of early medieval architecture in Alava, and further developed by Azkárate (Azkarate Garai-Olaum et al. 2018).

As well as studying the Spanish context, Quirós also participated in investigations of medieval construction techniques in Italy (Quirós Castillo 2005b). This type of experience and the numerous works published in the Italian magazine “Archeologia dell'Architettura” (Azkarate Garai-Olaum 2010a), and later in the Spanish magazine "Arqueología de la Arquitectura" (Azkarate Garai-Olaum et al. 2002), illustrate the connections between the research developed in both contexts and successful application of the approach outside Italian territory.

2.3.2 APPROACHES FOCUSED ON CONSERVATION

Conservation of masonry heritage requires a deep understanding of built constructions. In some cases, this has motivated the development of approaches aimed at understanding the morphological characteristics of masonry. The following sections first review the state of the art in Scotland, before presenting a series of studies identified in the Italian context which, despite focusing on different aspects of conservation (structural performance, deterioration of materials, etc.), include specific analysis focused on the study of the constructive structure of masonry, which serve as references to underpin the methodology defined in this research.

2.3.2.1 The state of the art in Scotland

In Scotland, the clear predominance of stone as a historic building material has motivated the development of research within the field of geology focused on the conservation of this type of heritage. Despite the focus generally being on identification of historical quarries (McMillan and Gillanders 1997; SLCT 2006), identification of decay and damage processes (Hyslop, Albornoz-Parra, et al. 2006) or definition of adequate matching stone and mortar when replacements are needed (Hyslop and Albornoz-Parra 2009), some publications include references to the characteristics of the masonry used to build historic architectural works. For example, McMillan et al. (2006) related the availability of large stones to the possibility of building wide spanned openings. Hyslop et al. (2006) also associated the country home of “new classicism” with the use of ashlar masonry on principal façades and the relegation of rubble work to rear elevations, the backing of dressed works, and internal walls. However, this type of references are limited and usually collateral to investigations focused on other aspects of the geology of historic architecture, highlighting research paths that have not been systematically studied.

Something similar happens outside the field of geology. From the perspective of structural analysis, Hendry and Khalaf (2001, 70–71) proposed a general overview of masonry construction with the aim of assessing the practical understanding of practitioners. The space devoted to the historic stone masonry wall is reduced. The authors merely noted that a wide variety of constructive solutions can be classified depending on the shape of stones, but do not deepen in the study of their construction features.

In addition, Urquhart and Artis-Young (2008, 43–44) aimed to inform practitioners about the use of natural stone as a building material. However, the main body of the document is devoted to walling systems for modern construction and only a brief reference is included to traditional walls. This shows a section of what is identified as a “typical Scottish traditional stone wall”, defining its usual thickness as 60cm. However, the work of other researchers already mentioned in this chapter points towards a much more complex reality.

Instead, Davey et al. (1981, 59–66) call for its complete analysis and systematic structure. With a clear focus on the conservation of buildings located within the New Town of Edinburgh, this guide was targeted towards anyone responsible for the repair and maintenance of this specific heritage. Adequate conservation action is based on deep understanding of how existing buildings were built and behave. This publication therefore included a detailed description of the different elements forming the structures and masonry used. Rubble and ashlar fabrics were classified in sub-groups and characterised including references to the different types of wall sections, the strategies used to bond the different layers of wall sections, the process followed to build the different wall types, the geometry of the different joints, the characteristics of the mortars and stones employed, and the different stone finishes identified. The result is a comprehensive description of the stone masonry used in the specific context considered.

This section serves to highlight a lack of consolidated and continuous research considering the characteristics and techniques used to build historical masonry in Scotland. Apart from some exceptions, such as the case of Davey et al. (1981), references to this topic are generally secondary. However, this subject has already been successfully researched in other contexts. As previously mentioned, Italy is one of the most relevant references in this regard. The following section explores this context and presents the most relevant research found.

2.3.2.2 Reference contributions oriented to conservation

The review of archaeology of architecture highlighted the relevance of research developed in Italy. Some of the aspects that enriched this approach came from the discussion about conservation. In this field, a sequence of authors interested in the material and structural behaviour of masonry buildings also developed extensive research into masonry morphology. The following section presents an overview of this, defining the framework and approach of the different contributions identified.

The early earthquakes of Friuli (1976) and Irpinia (1980) had an important impact on the existing buildings and aroused interest in the conservation of masonry structures. As Binda, Gambarotta, et al. (1999) have noted, this resulted in the development of several studies that aimed to understand the seismic response and vulnerability of this type of heritage. However, the methodological approach initially used paid limited attention to the specific characteristics of masonry. The use of generic reference models led to the design of heavy retrofitting techniques, which did not necessarily favour conservation of the structures.

This approach evolved during the 1990s, driven by a series of works that recognised the distinctive aspects of each construction solution and allowed the design of effective interventions with minimum impact on existing buildings. The development of these studies started from a detailed study of the characteristics of different masonry, aiming to identify those features influencing the adequate performance of the structure. This specific interest in the characterisation of masonry opened a research path that contributed to better understandings of existing masonry.

One of the authors working in this context was Giuffré (1991), who analysed the mechanical behaviour of masonry structures. He argued that the mechanical characteristics of a wall are related to the way it was built. The mechanical evaluation of a wall is therefore related to the evaluation of the quality of its construction. This quality can be objectively measured by evaluating the fulfilment of what is known as “regola d'arte”.

"Regola d'arte" refers to the group of rules defining the process of adding stones together to create a monolithic wall capable of withstanding the different actions occurring within the structural system. These rules have been defined based on empirical experience accumulated by masons over centuries and transmitted from master to apprentice through generations. However, the “regola d'arte” is an abstraction and its application has in practice resulted in a wide range of solutions, which are influenced by factors such as the availability of material, the economic power of the commissioner, and the skills and craft of the workforce involved. In order to identify the specific techniques used in each case, Giuffré proposed an approach that combined direct observation and analysis of existing masonry with study of the historical context. Giuffré (2003) applied the approach to the case of the historical neighbourhood of Graziella in Siracusa (Ortigia, Italy). The final objective of the work was evaluation of the seismic performance of existing structures. However, to achieve this, Giuffré developed a previous knowledge project based on three consecutive steps: (1) study of the historical context, (2) definition of building typologies, and (3) identification of construction techniques. This led to the

identification of the local “regola d'arte” for the construction of masonry walls and the classification of prevalent types and sub-types of masonry.

Abbaneo, Anzani, and Binda (1996) referred to Giuffré's works, and based on the analysis of 200 stone masonry sections from different Italian regions, concluded that a first evaluation of the mechanical behaviour of these type of walls can be completed based on the visual identification of certain features/parameters related to the “regola d’arte”. These parameters refer to the percentages of stone, mortar and voids that can be identified in a masonry pattern, the dimensions of the stone units and mortar joints, the thickness of the wall and the distribution of voids within the section. According to Abbaneo, given the variety of construction solutions resulting from the application of the “regola d'arte”, a systematic study of these structures should therefore consider identification of homogeneous groups of sections characterised by similar geometries and mechanical behaviour.

The work was further expanded, and, some years later, Binda, Baronio, et al. (1999) presented a methodology for the morphologic and experimental characterisation of stone masonry structures. This methodology involved the systematic classification of samples of masonry from different regions according to the techniques involved in their construction. This resulted in the creation of a database sub-divided by geographic area and enriched by the results of experimental tests and other data related to mechanical behaviour, which was used by subsequent researchers as reference. This was the case of the multi-level approach proposed by Binda, Gambarotta, et al. (1999), which integrated the methodology outlined as part of its approach.

Some years later, the earthquake that affected Molise in 2002 motivated the development of further investigations, expanding this line of research. A procedure for estimating the seismic vulnerability of masonry based on assessment of the quality and efficiency of its construction was developed (Doglioni and Mirabella Roberti 2003; Doglioni, Mirabella Roberti, and Trovò 2004). The quality of masonry referred to the construction characteristics specifically related to the bonding of the section and the elevation. Efficiency referred to deviation from the initial condition of the masonry due to decay, instability or sudden transformations. This procedure considered two groups of parameters: a first group obtained from visual evaluations or geometrical measurements performed at a specific scale, and a second group based on NDT or MDT.

Within the first group, the numerical indicator defined by the LMT highlights the simplicity and effectiveness of application. This indicator determined the bonding of 1sqm of masonry in elevation. A similar approach was used to determine the bonding of the layers making up a wall section. Doglioni and Bondanelli (2006) brought the investigation one step forward, and, based on the LMT, defined a “bonding curve”, which was used to evaluate the tensile strength of 1sqm of masonry.

Cifani, Lemme, and Podestà (2005) and later Curti, Lemme, and Podestà (2008) collected the outcomes of previous research and survey campaigns launched after the earthquake mentioned, and proposed a methodology focused on the development of a massive survey campaign to evaluate the vulnerability of masonry structures during the period of seismic pause. The census of damaged buildings resulted in the creation of a relevant database, which linked the damage modes with the typological and constructive characteristics of masonry built within the Molise area. One of the tools used for the typological classification and constructive characterisation of masonry was the form named “Scheda murature GNDT”, adapted to the local context. This form was based on research developed by Luigia Binda and Tiziano Mannoni and previously outlined. This experience was incorporated in the guidelines and demonstrated that the use of instruments for classification and identification of types enabled a more effective

preliminary diagnosis of the impact of an earthquake, facilitating management of the emergency phase.

Donà and De Maria (2011) continued the same line of investigation and, based on the indicators developed by Doglioni, managed to define the MQI (Masonry Quality Index). This index evaluated the quality of masonry according to the fulfilment of the “regola d'arte” used in the construction of a wall, and could be used to estimate the numerical values of certain mechanical parameters. Borri and De Maria (2015) proposed the incorporation of the MQI in the regulations as part of the process of building knowledge about existing structures, highlighting that it could contribute to defining the category of a wall and the mechanical qualification of those cases not included within the guidelines.

Mancinelli and Negri (2017) refer to a project developed within the ICCD – Institute of the Ministry for Cultural Heritage and Activities in Italy (ICCD 2018). The aim of the project is to develop a form to be used as a unified and flexible guide for the survey and analysis of historical masonry techniques in the country. This form is understood as a preliminary step to the future development of a national atlas of masonry techniques aiming to integrate previous and future experiences developed in the different regions.

The first part of the project reviewed existing contributions to define the state of the art (ICCD 2013a). The authors compared the forms used to characterise of masonry by precedent authors. One aspect noted is that the number of features or parameters mentioned in these forms exceeds 50. However, of these, those able to be determined in a direct inspection of a wall number about 20. These refer to the following aspects: identification of materials; dimensional features of units and joints; characteristics of mortars; morphology of patterns and beds in elevation; arrangement of units and bonding strategies; percentage of different elements composing the masonry (stone, brick, mortar and voids); morphology and thickness of wall sections; identification of the historical period; identification of interventions related to conservation; and understanding of structural performance. In addition, the study of 1m x 1m samples of masonry patterns in elevation is noted as common practice. At the end of the review, the authors highlighted the need for a new form able to synthesise the precedents. They proposed a structure with two levels of approach. The first level would be focused on rapid identification (visual) of existing masonry. The second level would allow for further deepening of knowledge and data analysis.

This idea was further developed in a subsequent publication (ICCD 2013b), where the same authors developed a form for the description and documentation of masonry types. This was conceived as a tool to organise and save the information required by the regulations and necessary to evaluate masonry types according to their characteristics and structural performance. The form was composed of two parts. The objective of the first part focused on building knowledge of the object studied. This included different sections considering data about the context and morphology of the sample considered, the identification and visual characterisation of materials used, the techniques involved in the construction, the identification of interventions and characteristics of the finishing, and identification of special features such as insertions and wedges. Identification of techniques was based on the observation of features related to the application of the “regola d’arte”. These include, on one hand, characteristics of patterns in elevation, such as the arrangement of elements and materials within the system, morphology of courses, thickness of joints, and presence of bonding stones; and, on the other hand, characteristics identifiable on the wall section such as the thickness, structure and morphology of the different layers. The focus of the second part was on qualitative and quantitative evaluation, considering three different points: the vulnerability of the system, archaeometric analysis, and diagnosis. In the end, the form aimed to synthesise the concepts shared in the fields of conservation, history, architecture and archaeology.

The different contributions demonstrate evidence that adequate interpretation of the morphology of masonry provides information about construction features and techniques, which is particularly useful for the structural analysis of buildings. In addition, in order to have a complete understanding of the structure, it is necessary to consider aspects related to its history, context, materials, techniques and people involved in the design, construction and transformation process of the building and its masonry. As mentioned by Fiorani (2005) the engineering vision in isolation can be partial and lead to the loss of context. The complex approach already integrated in the guidelines*, "Linee Guida per la valutazione e riduzione del rischio sismico del patrimonio cultural 2007-2010"* is therefore based on contributions from different fields. According to Brogiolo and Cagnana (2017), the archaeological, architectonical and structural fields are particularly relevant.

2.4 CAPTURING AND PROCESSING MASONRY DATA

One of the challenges faced in research into historic stone masonry involves the development of appropriate methods for the capture, collection and analysis of large amounts of data. This aspect often determines the scope and development of the investigations. Considering the quick evolution of the technological means used for the acquisition and analysis of data in recent decades, it is relevant to dedicate a brief section to this topic. In particular, the aim is not to develop an exhaustive review, but an overview highlighting the potential for future development.

An example illustrating the quick evolution is found in the field of mensiochronology, already presented in previous sections. The initial works of Mannoni and Milanese (1988), based on the manual collection and analysis of data, were streamlined by later investigations such as that of De Minicis (1997). De Minicis moved away from the descriptive approach and decided to apply a statistical method based on one variable. This provided results that could be plotted as quantitative diagrams and therefore are easy to read. He also explored the use of image editing software applied to images of masonry elevations to reveal textures hidden to the naked eye. His aim was to improve the readability of features such as the granulometry of mortars. However, this was just an early attempt at an approach that would develop further in the future. Years later, Esser (2012) applied an approach imported from the field of image analysis. He defined a semi-automatic method, which managed to quickly identify and evaluate the characteristic values of brick patterns from a group of imperial buildings in Rome. His method followed a sequence of steps, which started with the isolation of different bricks identifiable in rectified pictures of brick masonry patterns. He produced a binary image (black and white), which enabled the subsequent automatic evaluation of certain characteristic values. Using a statistical approach, the author was able to analyse the numerical data obtained and calculate the standard values of different features such as the visible area of the units, their degree of deformation, the mean joint thickness and the proportion of brick and mortar in the pattern. This provided precise information, which could be easily plotted and read. More recently, Cantini et al. (2019) applied a similar approach to three buildings from the historic centre of Vimercate (Italy). In this case, the authors analysed brick elevations using high-resolution rectified pictures scaled into vector graphic software for recording the brick sizes. The use of the latest techniques represents a clear advance, as it considerably reduces data acquisition time while providing the accuracy necessary for analysis.

The evolution from two-dimensional to three-dimensional data capturing techniques is also an important aspect to highlight. Two decades ago, Parenti (2002) referred to the qualitative leap that brought about the introduction of photography in stratigraphic studies. Further development

of photogrammetry followed, and, later, the introduction of LIDAR technologies, which overcame two-dimensional graphic representation techniques. Such technologies were rapidly adopted as common tools for surveys and monitoring. An example of this is the contribution of Fiorini and Archetti (2011) who, using photogrammetric technology, studied three different cases: the apse of a church with curved masonry walls, a tower with flat masonry walls and an archaeological site with irregular walls. In all the cases, they first took a series of pictures from different angles, recording for each shot the position of the camera with respect to the target. Then, using photogrammetric software, they were able to produce a cloud of points or coordinates, which enabled the development of a three-dimensional model for each case. Finally, they proceeded to add layers of information to the model, which, in this investigation, referred to the stratigraphy of the masonry.

García-Gómez et al. (2011) evaluated the use of LIDAR technology for the study of the construction history of a building, from the perspective of archaeology of architecture in Spain. In this case, LIDAR is presented as a powerful tool for the acquisition of three-dimensional data. The authors first gave some consideration to practicalities relating to the use of this technology, before describing their experiences of applying it. The objective of the cases referred to was the identification of chronotypologies, based on analysis of an accurate three-dimensional model obtained from the LIDAR scanning. The authors described a method composed of six steps, which was first applied in a study of the Cathedral of Vitoria Gasteiz. The first step consists of the selection of certain elements for analysis (e.g. columns or pilasters). The second step selects the variables for consideration in the analysis (e.g. the horizontal and vertical sections). In the third step, each element is georeferenced to determine its location within the building system. The fourth step involves the identification of groups of elements or clusters with similar characteristics. This provides a map, which allows the definition in the fifth step of USM and their relative construction sequence. Finally, the sixth step focuses on the definition of the absolute chronology.

Also, from the perspective of archaeology of architecture but in the context of a conservation project, Cardaci, Gallina and Versaci (2013) applied LIDAR to the survey of the Santa Croce church in Bergamo (Italy). They argued that the development of a precise three-dimensional measurable model of the masonry made stratigraphic analysis and identification of the techniques used in the construction of the building more flexible. The sequence followed in this case started with planning of the scanning campaign, followed by the acquisition of the data (both metric and material), and ended with processing of the point cloud and production of the three-dimensional model and its later stratigraphic material characterisation. The authors concluded that this method overcomes the limits of two-dimensional representations, provides more accurate data and improves global understanding of the building. However, they also highlight some aspects that needed to improve. The most relevant of these was the difficulty of importing and managing digital models.

Subsequent works have contributed to overcoming such limitations and improving the applicability and use of LIDAR technology in the study and conservation of historic buildings, as in the case of the Scottish Ten Project discussed by Wilson et al. (2013). Located in Scotland, outside the Italian context, this project aimed to digitally document a group of historic sites around the world and focused only on producing a set of information that could later be used by others for the conservation, management and interpretation of sites. The set includes a high-resolution, photo-textured three-dimensional model, which resulted from processing the cloud of points and the addition of the HDR images obtained during the scanning campaign. The processed results are delivered to other agents, who can use them for conservation, management and interpretation of sites. The experience gained has improved both the processes of acquisition and data processing.

In the Scottish context, Bosche, Foster, and Valero (2015) compared the results obtained from the application of three-dimensional capture technologies to surveys of stone masonry walls. They recorded the walls of Craigmillar Castle in Edinburgh using five different techniques: two different types of terrestrial laser scanner and three different photogrammetric systems. The results presented scanning techniques as superior in terms of accuracy, but highlighted the good results obtained from the photogrammetric application of a pool-mounted single camera, which is more economic and therefore accessible. However, the performance of the other two photogrammetric systems was affected by certain practicalities during the survey. This could have affected the results, which require some review. In any case, according to the authors, the use of these three-dimensional data capturing techniques facilitates and accelerates the survey process. However, they also highlight that the process of analysing the data acquired can still improve considerably. For this reason, they also investigated the use of an algorithm to automate the process (Valero, Bosche, and Foster 2018). The case study considered for this purpose involved identification of decayed mortared joints in a flat and curved masonry wall. The authors scanned the two walls to obtain a point cloud. Using the wavelength transform analysis method, they produced a depth map of the wall elevation, plotting in colour the different points of the wall. Using a segmentation algorithm, they then individuated stone units and mortar joints based on identification of what they called “compact coloured regions”. The results obtained from the algorithm were compared with a manual segmentation showing satisfactory results.

Gonzalez Manich et al. (2016) explored a different approach for individuation of the decayed areas identifiable on the surface of a masonry wall from Glasgow Cathedral. Instead of applying LIDAR technology, the authors used a hyperspectral camera to capture images of a portion of flat wall. Instead of the three portions of the electromagnetic spectrum (red, green and blue), which conventional cameras capture, the hyperspectral camera used captured 256 spectral bands. This provided a greater amount of information, which was processed using machine learning techniques. The results obtained on one hand revealed the identification of the mortar joints defining the masonry pattern and, on the other, the classification of different pathologies such as exfoliation, soiling, crust and superficial deposits.

In conclusion, all these contributions belong to a field of research with much potential for future research developments both in the capture and processing of information. The applications are multiple, including dating, recording and surveying damaged or decayed structures. LIDAR and photogrammetry are the technologies generally used for data collection, although the applicability of other alternatives such as hyperspectral cameras is also being explored. The automation of data analysis still offers significant research opportunities. Investigations such as that of Gonzalez Manich et al. (2016) and Valeroet al. (2018) are examples showing the potential for development.

2.5 PRACTICAL KNOWLEDGE OF MASONS IN THE UK AND RELATED BUILDING TECHNIQUES

The review of methods used in the characterisation of stone masonry presented in the previous section highlights the study of construction techniques as essential for any investigation focused on this topic. In the field of archaeology of architecture, authors such as Parenti (1994) and Mannoni (2005) link the concept of masonry type with that of building technique. A similar conception is found outside this approach. Authors such as Giuffré (2003) and Donà and De

Maria(2011), concerned about the performance of historic structures, consider study of the "regola d'arte" essential to understand the logic behind the construction of existing masonry.

As previously mentioned, "regola d'arte" refers to the group of rules or principles that masons follow when building a wall. These are based on empirical experience accumulated by masons over centuries. In this thesis, the English term used to refer to the "regola d'arte" is "Stonemason's Gospel". Such knowledge is practical and was transmitted from master to apprentice through generations. Records on this subject are therefore generally scarce. Donà and De Maria (2011) found part of this practical knowledge contained in historical treatises.

Following their example, the author of this thesis reviewed the British and Scottish historical treatises. However, unlike the Italian case, these sources did not provide relevant data for the purpose of the investigation. The review was then expanded to include manuals and personal records written by masons. Such records represent a valuable source of information, but the way in which the knowledge is presented and organised does not follow a systematic scheme and therefore requires some processing before being used in scientific research. In the following sections, the author of this thesis first presents a review of the different written records, before synthesising the practical knowledge identified. The outcomes presented are used to underpin the research developed afterwards.

2.5.1 REVIEW OF HISTORICAL TREATISES AND OTHER WRITTEN RECORDS

The first publication about architecture in English dates from 1563 and describes the three classical orders of architecture (Shute 1563). However, it was not until the eighteenth century that a new work about architecture appeared in Britain. This was entitled "*Vitruvius Britannicus"* (Campbell 1715). It had the format of a catalogue of architecture and included engravings of buildings designed and built by prominent architects such as Inigo Jones, Sir Christopher Wren and the author himself. Such publications were followed by *Gibbs' Book of Architecture* and later *Vitruvius Scoticus*, which used a similar format (Gibbs 1728; Adam 1812). This series of catalogues was mainly composed of plans, elevations and some detailing of certain ornamental elements. No reference was made to construction processes or techniques.

Some decades later, a series of works self-identified as treaties appeared in the British engineering and architecture context. Peter Nicholson claimed to be the first to publish a practical treatise on the art of stone masonry and stone cutting in English (Nicholson 1835). An architect and the son of a Scottish mason, with a great understanding of mathematics, he described the geometric principles and rules necessary to dominate this art in a way that was simple and accessible to other practitioners. Years later, Hosking, Tredgold and Young (1846) presented a set of treatises, one exclusively devoted to masonry. The main body of this part was focused on detailing "the principles of stability and strength in masonry", using a series of formulas and tables with calculation values. Ashpitel (1867) revised existing treatises, explicitly mentioning the ten books of Vitruvius and Hosking's work, and proposed a new document including his own contributions about architecture "discovered" in Egypt and nearby territories.

The contents of the treatises and catalogues mentioned so far refer to geometric, mathematical and architectural knowledge, leaving out of the scope practical aspects of the mason craft. However, understanding the practical knowledge associated with building techniques is

essential for the purpose of this research. This was found in other types of publications, such as manuals and personal records written by masons.

Purchase (1895) produced the earliest publication of this type. Aiming to initiate beginners into the rules and principles of the craft, he presented the tools and appliances used to work, and explained the geometrical rules that should be known in order to build elements such as arches, vaults, stairs, ramps and windows. However, the reference to stone cutting techniques occupied little space, probably because, as mentioned by later authors, "*apprentices would have been expected to receive most of their training directly from a skilled mason*" (Hill and David 1995, x). Years later, Warland (1929) further developed Purchase's work, including mentions of the latest developments of the period, which mechanised the trade and relegated the traditional mason craft to elaboration of details that could not be produced with machinery. The result was a manual, which is still used as a reference by masons at present. Indeed, Warland's work is referred to as "the stonemason's bible" by Hill and David (1995, x) and O'Connor (2013, 5).

Years later, the masons Ian Cramb and Patrick McAfee also transferred their knowledge into written documents. Cramb (1992) is especially relevant for the research presented in this document, as he is a fifth-generation stonemason, who started his apprenticeship in Dunblane, Scotland. His knowledge of rubble construction inherits a historic tradition, which could easily have its roots in the Scotland of the eighteenth century. In his book, Cramb shared the basic practical rules that masters teach apprentices, and illustrated the different steps involved in construction of a rubble wall. Patrick McAfee, however, comes from the Irish tradition. In his publications (McAfee 1997, 1998), he followed an approach similar to that of Cramb, but included a wider spectrum of masonry techniques, devoting special attention to the case of boundary walls.

In recent times, the industry has evolved towards a scene where the majority of traditional masonry skills are practised in works related to the repair and conservation of historic buildings. In this context, Hill and David (1995) proposed a guide based on Warland's work, but gathering the masonry techniques commonly used in the craft for the repair and conservation of stone buildings. With a similar aim, O'Connor (2013) published his experiences in the field.

Notwithstanding, the most complete compilation of stone masonry construction techniques relates to dry stone boundary walls. These are a very specific type of walls, which differ in morphology and function to the mortared walls generally used to raise buildings. However, both types respond to gravity and therefore share the basic principles of construction. It is therefore useful to add a brief review of publications focused on this topic.

The Dry Stone Walling Association founded in 1968 has been leading the research in this field, contributing to better understanding of the craft and encouraging the repair and maintenance of these structures. The works of Rainsford-Hannay (1857) and Brooks and Adcock (1977) gathered practical knowledge behind this type of construction, producing valuable records. Both publications initially present a brief historical context of the stone walling tradition before, following an order that varies depending on the case, defining the following points: (i) type of stones used and their sources, (ii) a glossary of the parts and elements forming a wall, (iii) identification of working tools, (iv) definition of the construction process and the building techniques involved, and (v) the identification of wall types and variations according to techniques and dimensions of elements. In addition, Rainsford-Hannay also refers to costs, while Brooks includes a valuable collection of drawings, which makes an important contribution to clarifying the aspects noted. Subsequent authors such as Tufnell (1982), Garner (1984), Griffiths (1999) and DSWA (2004), either summarised this knowledge or emphasised certain aspects of the craft. The identification of regional styles in Britain motivated the Millennium Wall Project, which contributed to demonstrating the variety and richness of the technique (DSWA 2002).

2.5.2 SYNTHESIS OF THE PRACTICAL KNOWLEDGE OF MASONS

Masonry is a composite material and the challenge for the mason during the construction process is to produce an element able to behave as a whole – stable and durable. The knowledge necessary to achieve this is contained in what this thesis refers to as "the Stonemason's Gospel". This refers to the set of principles and rules summarising the empirical experience accumulated by masons throughout history. However, fulfilling all the rules simultaneously is difficult, and does not always happens. The "art of the stonemason" relies precisely on knowing how to combine and apply them in every case. Factors such as resources available, building characteristics, the expertise of the masons, local tradition and the influence of other agents involved, including the patron, have always influenced the specific application of these principles, resulting in the development of a wide variety of local techniques.

The following section synthesises a set of these principles and rules related to the construction of stone masonry walls. The summary proposed combines the experience gathered in the publications of Cramb (1992), McAfee (1997, 1998) and Warland (1929), already discussed in a previous section, together with knowledge and understanding of the author's writing. In addition, the reasoning exposed by Mannoni (2005) is considered a reference to organising knowledge.

This section is divided into three parts. The first refers to those aspects related to the size and geometry of the stone units. The second summarises a set of rules that guide the assembly process. The last part gives some consideration to the shape of the units and the construction process. On this occasion, emphasis is on aspects related to the morphology and arrangement of the stone units. The identification and analysis of mortars and stone is not included within the scope of this research.

2.5.2.1 Size and geometry of stone units

Each of the stones making up a masonry wall plays a specific role, which determines its characteristics. Before starting the construction of a wall, the material available is classified according to these different roles. The old masons' saying that *"Every stone has a home"* (Brooks and Adcock 1977, 54) expresses well the mindset of maximum material exploitation that rules the construction process.

- **Facing stones** are stones defining the internal and external layer of the wall. These stones always have at least one flat side, which is used to compose the plain faces of the wall. The dimensions and geometry of the unit vary depending on the case. Figure 2.1 proposes a classification of the different geometries identified, differentiating elevation from plan.

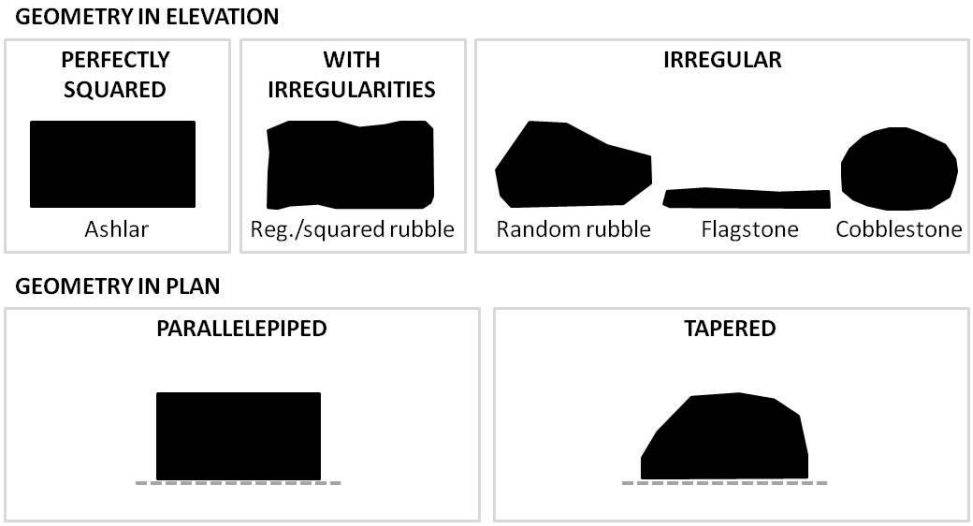


Figure 2.1: Classification of possible geometries of facing stones, differentiating elevation from plan.

- **Wedges, pinnings and filling** are stones with the smallest sizes. The bits produced from the adjustment of bigger stones are usually included in this group.

    - Filling stones make up the core of the wall (when existing). Their shape should be irregular to bind properly. Their size distribution is not homogeneous, and the range of sizes depends on the characteristics of the facing stones. In the case of irregular facing stones, the size of the bigger filling stones tends to increase. In contrast, for perfectly squared facing, filling can be composed of coarse gravel.

    - Pinnings are stones located in the external or internal faces of the wall. They are not usually bigger than 5cm. They are used to reduce the thickness of the mortar joints, filling gaps between facing stones. This is especially important when the binder is lime mortar because it carbonates most effectively in small thicknesses. On occasion, their use can also be ornamental.

    - Wedges are stones used to block the position of bigger stones, preventing movement. Sizes vary depending on the case. The priority is to use the minimum number of wedges possible to reduce the likelihood of displacements.

- **Through and bond stones** are long stones used to tie the layers composing the wall section and equally distribute the loads among them. For this reason, these stones should have at least one of the larger faces flat to enable adequate bedding and avoid flexural efforts. In addition, as in the case of facing stones, the sides making up the face of the wall should also be flat.

    - Through stones traverse the wall section from the internal to the external face and their length is therefore equal to the dimension of the wall section.
    - Bond stones are used when throughs are not available, and their length is equal to two thirds of the wall section.

- **Quoin stones** are stones used to compose corners. Their size is reasonably large and their shape is generally rectangular, with faces at right angles to each other, although on occasion they can also have triangular geometries in elevation (Figure 2.2). Their objective is to tie intersecting walls, meaning that length is important.



Figure 2.2: Classification of possible geometries of quoin stones in elevation

- **Lintel, jamb and sill stones** are stones defining wall openings.

    - Lintels define the upper edge of the window. They can be composed of one long stone or a combination of several stones, forming an arch that can be curved or flat. In the first case, the length of the stones is determined by the span of the opening and the section is related to the bending stress involved. In the second case, the geometry of the units is determined by the geometry of the arch and their specific role within the system: keystone, voussoir or springer.

    - Jambs define the lateral edges of the window. They can be composed of one long stone of considerable size or a combination of several stones tying the different layers of the section. The criteria determining the size of these stones is similar to those for quoins, throughs and bonds.

    - Sills define the lower edges of the window and are usually composed of one flat and one long stone.

- **Other stones:** As well as the stones mentioned, others are also found in the wall system but do not form part of the body of the masonry and are therefore not the central focus of this research.

  This is the case for stones used to compose foundations, which are difficult to inspect. They are usually substantial in size with at least one flat face able to form an adequate base to settle the wall. Stones making up the wall head are also difficult to access because of their location. These usually cover a section of the wall to protect the core from water (coping stones) or to distribute loads from other types of structures, such as the roof. Cornices are also associated with this group. Finally, belt or string course stones can have a double role: making up part of the facade and helping to protect the wall from water. Their height is not necessarily the same as the rest of the courses making up the wall, and the dimensions of the stones vary depending on design.

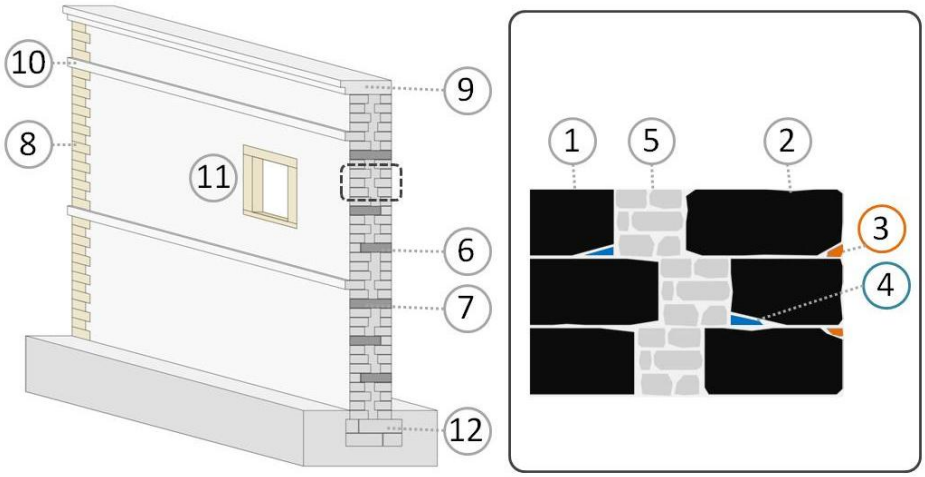


Figure 2.3: Stones in the wall: (1) Outer face stone, (2) Inner face stone, (3) Pinning, (4) Wedge, (5) Filling, (6) Through stone, (7) Bond stone, (8) Quoin, (9) Wall head stones, (10) String or belt course stones, (11) Stones defining wall openings: lintel, jambs and sill, (12) Foundation stones.

2.5.2.2 Assembly process

Construction of a masonry wall has three basic objectives: stability, unity and durability. The process of assembling the different units making up the masonry body is essential to obtain a satisfactory result. According to the mason Vivian (1976, 2), *"There is no such thing as a half-built stone wall. It's either a wall or a stone pile."* Depending on the geometry of the units, strategies can vary. However, the principles are always the same. The following points summarise a set of general rules determining this assembly process.

DISTRIBUTE UNIFORMLY

The actions affecting masonry walls either have an external origin or derive from the weight of the elements composing them. Strategies related to achieving a homogeneous distribution of loads develop at the level of both the individual units and the whole set.

a) Proportion of units

The loading pyramid that forms on a stone when an action is applied is influenced by the ratio between its base and height. Consequently, horizontally oriented stones better distribute loads from above because of the larger dimension of their horizontal faces (Figure 2.4).

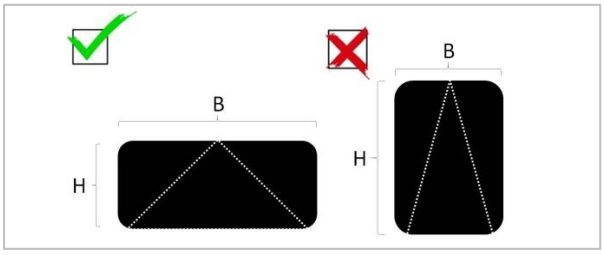


Figure 2.4: Illustration of adequate/inadequate orientation of the stone unit in elevation.

b) Distribution in the wall

The uniform distribution of sizes within the system, both in sections and elevations, contributes to the homogeneous distribution of weights and therefore minimises uneven loading (Figure 2.5).

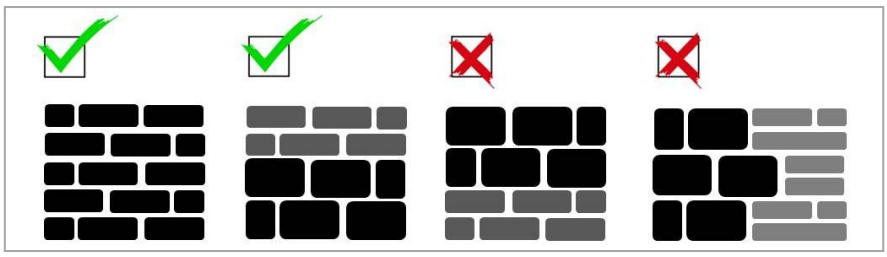


Figure 2.5: Schematic illustration of adequate/inadequate distribution of stones in elevation.

BUILD PERPENDICULAR TO THE LOADS

Masonry performs best under compression. Building perpendicular to the loads helps to minimise the risk of appearance of other types of efforts and their related pathologies. This rule applies to all levels, from the material to the overall wall system.

a) Orientation of the bedding

The bedding of a stone defines the natural layering of the material. This is related to the material formation process and is therefore characteristic of sedimentary rocks. The durability and performance of bedded stone units are affected by the orientation of the bedding with respect to the direction of the loading. Natural bedding, edge bedding and face bedding define three possible orientations for stone units (Figure 2.6).

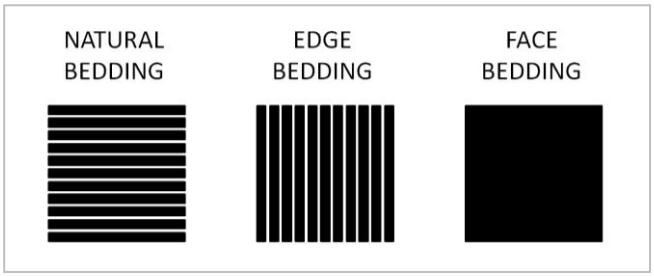


Figure 2.6: Illustration of the three possible bedding orientations that can be identified in a stone unit.

In general, keeping the horizontal orientation of the natural bedding is the most adequate option. Edge bedding is sometimes prioritised for stones used to build steps or cornices to prevent delamination caused by use. Face bedded stones performing a structural role are also affected by delamination and therefore inadvisable. However, the characteristic of presenting a homogeneous surface makes them ideal for certain ornamental purposes.

b) Orientation of units

The levelling of units should seek perpendicular loading lines. This operation has a certain degree of complexity in the case of irregular geometries, where the use of wedges is necessary to achieve adequate alignment (Figure 2.7).

The levelling of through and bond stones is also crucial because of their specific roles related to the distribution of loads through the different layers making up the wall. However, in this case, the use of wedges should be avoided and horizontality should therefore be achieved with the bedding of the lower face of the stone.

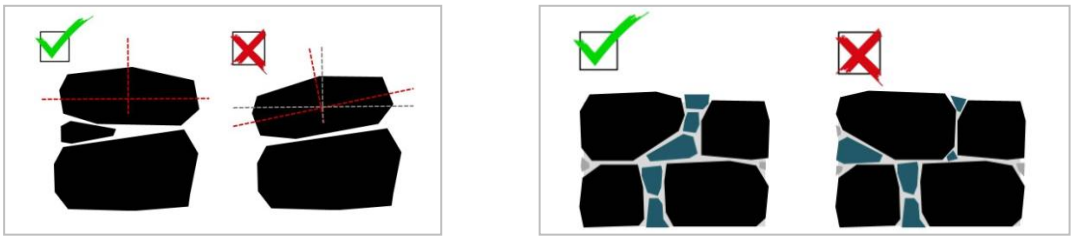


Figure 2.7: Illustration of adequate/inadequate orientation of irregular stones (Left); and adequate/inadequate location of wedges (Right).

c) Layering of the wall

Walls are always built in layers. When each layer corresponds to a line of stones, this is called a course and the wall is therefore described as coursed. Uncoursed walls are those where stones are not aligned defining courses. This is often the case when rubble stone is used as a building material and stones are organised in lifts with, ideally, a maximum height of 18 to 24 inches (40 to 60cm). Each of the courses or lifts should be built perpendicular to the loading line, usually corresponding with the true horizontal. Figure 2.8 illustrates these two cases.



Figure 2.8: Wall composed of courses (left). Wall built in lifts (right)

d) Vertical plumb

Keeping the wall plumbed is important to avoid eccentricities and, at the same time, achieve a flat surface. In walls composed of irregular units, the alignment of stones should be defined according to the most protruding point. The resulting voids are then pinned in order to define a regular face (Figure 2.9).

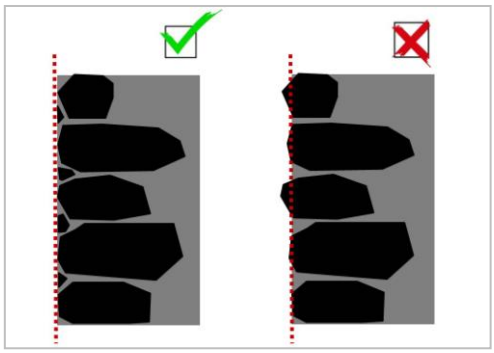


Figure 2.9: Illustration of adequate/inadequate wall plumbing.

BONDING THE WALL

The unitary behaviour of a wall depends in great measure on its bonding, as a result of the bonding of each individual stone unit and of the wall system.

a) Bonding the individual units

In general, bonding between elements is achieved by maximising friction. Considering the individual units, this is achieved by always placing the stone length towards the centre of the wall. Avoiding holes inside the section is also essential to ensure maximum contact. This is achieved by keeping both the face and the core packed in order to fix the position of each single stone.

- **Packing the face:** masonry with packed faces, composed of thin joints, is defined as tight faced, as opposed to slack faced masonry.
- **Packing the core**: The old masons' sayings, *"one stone at a time"* and *"keep the heart up"* refer to the importance of building the wall core at the same time as the facing layers to guarantee adequate packing. When the wall has a central core, packing is achieved by following a sequence of first placing the wedges that fix the facing stones in the internal side of the facing stone then using larger filling stones to block wedges in place, before filling any smaller gap remaining with smaller bits (Figure 2.3).

Making adequate use of the binder also contributes to maximising friction. However, the structural performance of historic mortars is lower than that of stone. For this reason, the binder should never be understood as a substitute for packing.

Sills are an exception in this chapter. Stones playing this role should only have the ends bedded, leaving the central part hollow, only pointed with a weak mortar mix. This prevents cracking when settlements occur.

b) Bonding the wall system

In relation to the wall system, two types of bonding are defined: (1) face bonding, affecting wall faces, and (2) bed bonding, affecting sections. Walls built in lifts have an additional bonding strategy, based on the use of rinsers.

Face bonding

Face bonding refers to the bonding of internal and external wall faces in elevations. The old masons' saying, *"Two on one and one on two"*, which translates to "half on one and one on half" (Brooks and Adcock 1977, 54) summarises the golden rule for face bonding. The objective is to avoid running joints, which would create discontinuities in the system. This rule cannot always be strictly applied. *"Two but not three"* is another complementary saying, which defines the maximum length of continuous vertical joints as two units (Figure 2.10).

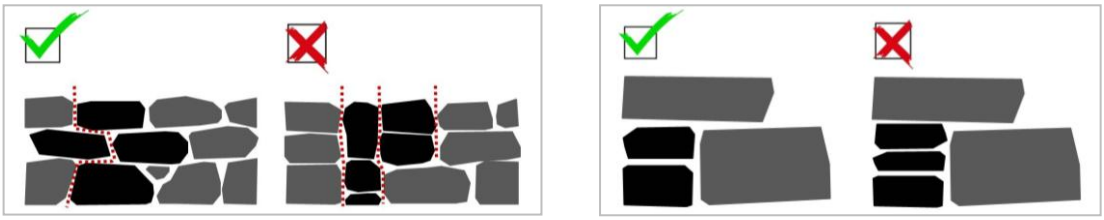


Figure 2.10: Illustration of the "Two on one and one on two" rule (left); Illustration of the "Two but not three" rule (right).

Doglioni and Mirabella Roberti (2003) proposed a method for the evaluation of face bonding based on observation of 1sqm of masonry in elevation. They defined the "LMT", which is the average length of the non-intersecting minimum paths able to be defined, following the masonry joints, between the upper and lower edges of the frame considered. Depending on the resulting value, the face bonding was classified in three categories: (1) respected, (2) partially respected or (3) non-respected.

Bed bonding

Bed bonding refers to the bonding of the wall section. The quality of this type of bonding is difficult to evaluate visually because it runs inside the section and is therefore not visible. An ancient masons' saying, *"God sees everything"*, though, suggests for various reasons it is apparent that, in those walls still standing, this "invisible" work was perfectly executed.

This type of bonding is achieved by using through and bond stones (Figure 2.11a). The ratio of these stones per sqm of elevation varies depending on the type of wall and the mason involved. However, 1sqm is a common reference. In any case, they should always be staggered in elevations and, in the case of bonding stones, a reverse pattern alternating wall face should be in place in every course.

Where there are two intersecting walls, the use of bonding stones is essential to guarantee their continuity. The rule in these cases is to overlap the maximum number of joints possible and bond in the direction of all intersecting walls. Figure 2.11b and 2.11c illustrate examples of two types of intersecting walls (L and T).

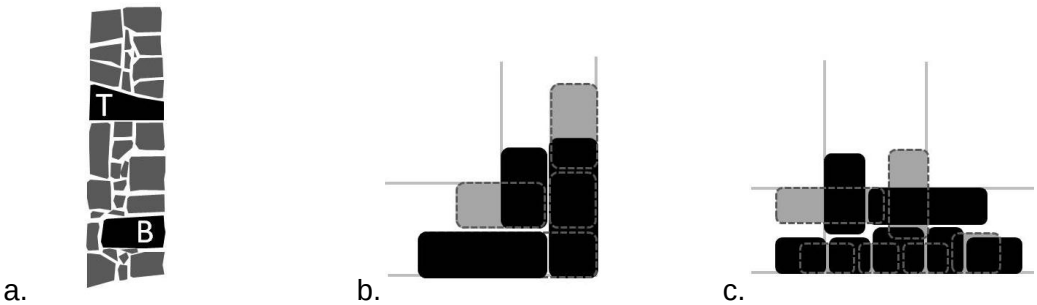


Figure 2.11: Scheme of a wall section in plan, highlighting bonding stones. Left: through (T) and bond (B) stones in a linear wall. Centre and right: example of a corner bonding and a T intersection respectively. See Brooks and Adcock (1977, 93) for further L and T bonds.

Bonding lifts

Walls built in lifts (uncoursed) have additional characteristic bonding derived from the construction processes involved. The definition of lifts generates a horizontal plane, which periodically traverses the wall section, interrupting its continuity. This problem can be solved by leaving risers. A rinser is a facing stone, either internal or external, that exceeds the line defining the end of one lift to connect it with the following one (Figure 2.12).

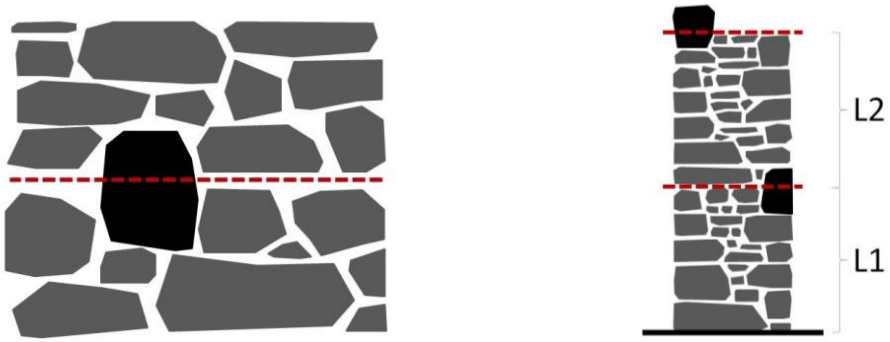


Figure 2.12: Scheme of a rinser in an elevation (left)and a section (right) (Cramb 1992, 27)

KEEP THE WATER OUT

Protecting the masonry from the action of rain is important in wet and cold weathers as found in Scotland. Strategies focused on protection of the wall face from rain can be of two types:

- **Considering the whole wall:** The design of protruding elements such as cornices, string courses, wall coping elements and window sills protects masonry from the direct action of water, contributing to its durability.

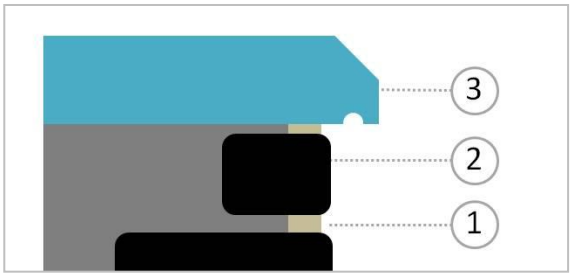


Figure 2.13: Illustration of a stone masonry wall in sections. The numbering corresponds to (1) Pointing, (2) Stone facing, (3) Protruding element (ideally dripped).

- **Considering the masonry:**
  - Joints: Pointing is the part of the mortar joint in contact with the exterior. It is more porous than the stone units and therefore acts as a sacrificial layer, which should be periodically replaced. The finish of the pointing is determined by the shape of the stone edges. For stones with sharp edges, flushed joints are better, while for rounded edges a recessed finishing is more adequate (Figure 2.14).

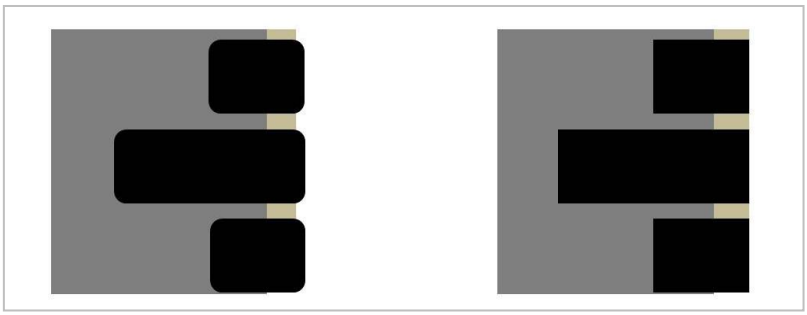


Figure 2.14: Examples of pointing: recessed (left); flush (right).

- Units: Some masons refer to tilting the units making up the external face of the wall as a strategy to foster the drainage of rainwater. However, this point was not identified in the context researched.

2.5.2.3 Units shape and construction process

The geometry of the stone units in the masonry often determines the definition of strategies developed for the application of the principles of the stonemason gospel in specific contexts, and therefore also the derived construction process.

CONSTRUCTION WITH REGULAR STONES

Building with regular stones involves expertise related to dressing stones, which differs from the case for irregular units. Knoop and Jones (1939, 26–28) refer to the tasks developed by quarriers and masons during the sixteenth and seventeenth centuries. According to the documents reviewed, the line dividing the roles is not clear. In some cases, quarriers are involved with the winning and dressing of stones, whilst in others both tasks are defined as part of the work of masons. Mixed situations also arose, with both quarriers and masons winning and dressing the stone in the quarry.

The process of dressing a regular stone from a rough block starts with selection of the “surface of operation”. This surface should be flat to enable the definition of the rest of the faces true squared, and its selection is determined in light of the bedding of the stone. The following step involves successive marking and sharpening of the four straight edges defining the perimeter of the stone face. The resulting lines are known as marginal edges and have a width smaller than 2cm. The superfluous stone enclosed within the edges is then progressively worked parallel to one of the edges to achieve a plain surface. After this, the surface can be reworked to erase the marginal edges and define the finishing desired in every case. With the operational surface completed, the remaining faces of the stone unit can be defined following the same sequence. Figure 2.15 illustrates four cases in which the marginal edges and the operational surfaces are recognisable.

a.  b.  c.  d. 

Figure 2.15: Images of stones with visible marginal edges: (a) Holyrood Palace – sixteenth century, (b) Holyrood Palace – seventeenth century, (c) Newliston House – eighteenth century, (d) Holyrood Palace – nineteenth century.

Stones with this type of geometry (very regular) are easy to organise in horizontal courses because of the parallelism of the faces. The complexity of the process related to the production of the units – assembly on site can vary ostensibly depending on the degree of design of the pattern and its level of integration within the overall design of the building elevations.

Finally, a special case involving construction with regular stones is the reuse of stones from other structures. This material may already be dressed. Consequently, the challenge is to define a unitary pattern able to integrate the stones available within the new project.

CONSTRUCTION WITH IRREGULAR STONES

The construction of masonry composed of irregular stones does not involve expertise in dressing stones. Here, the challenge is in selecting and combining stones during the raising of the wall. The old masons' saying *"Every stone has a home"* is the rule in these cases. However, a certain degree of adjustment is often necessary when setting the stones and some masons recognise that, *"this home might be underneath a well-placed sledgehammer blow"* (Brooks and Adcock 1977, 54).

The geometry of the units hinders the definition of horizontal courses, which are more common than patterns built in layers. Variations on the application in each specific context of the principles contained within the Stonemason's Gospel has resulted in the development of a wide variety of techniques.

2.5.3 KEY ELEMENTS TO CONSIDER IN THIS RESEARCH

The logic behind construction of a stone masonry wall can be deciphered by observing its morphological features. The characteristics and geometry of the stone units determine the strategy followed by the mason in the application of the principles contained within the Stonemason's Gospel. These principles are universal, but the ways in which they are formalised vary, giving rise to different construction techniques.

The summary just presented highlights four different aspects related to the assembly of units, determining the final morphology of a wall: (1) uniform load distribution, (2) orientation of elements with respect to loads, (3) bonding strategies, and (4) protection against water penetration. These are met at all levels, from a scale of detail to the overall wall system.

The pattern defining a wall elevation provides much information about the construction logic applied. Close observation of the wall face reveals the distribution, alignment, face-boding, packing and fit of the units making up the solid portion of the wall. In addition, from a certain distance, detailed inspection of the whole elevation enables understanding of the layering structure defining the overall system. This structure is directly related to the morphology of the quoins that make up the corners. These stones were used as references to define courses or lifts during the construction process. Identification of elements that do not follow the dominant layering scheme opens questions about whether they belong to the original system. Resolution of the unknown always requires deeper analysis.

The structure of the section and its bonding strategy are features difficult to identify as this requires sectioning of the wall. Partially collapsed walls offer a unique opportunity to observe this feature. However, when this is not possible, the thickness of the wall and the strategy applied to define the frame of the openings offer certain clues that, based on the information already outlined, enables to guess the structure of sections.

Four key elements are thus considered as part of the identification of techniques used to build masonry elevations: (1) the solid portion of wall, including the patterns and the section, (2) the corners, (3) the formation of openings, and (4) the overall layering system of the elevation.

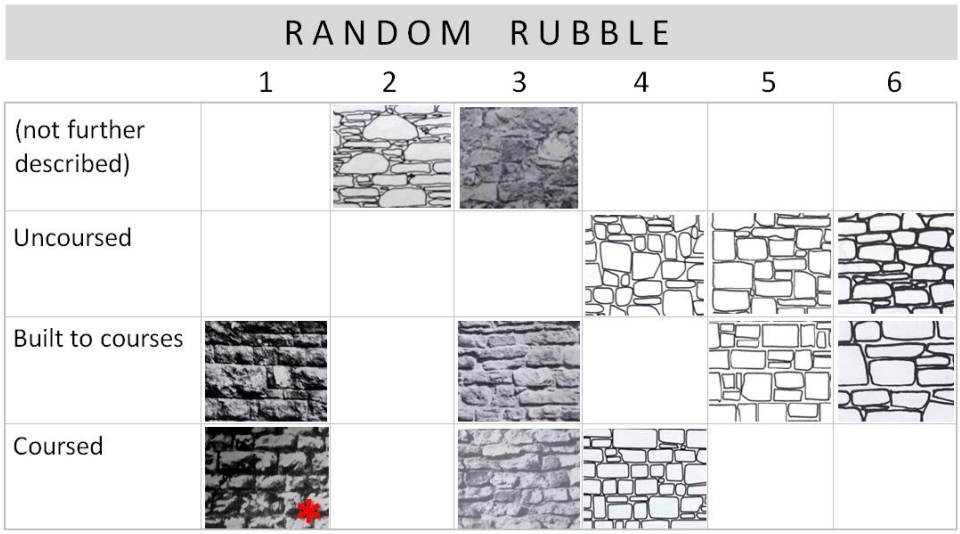
2.6 ISSUES RELATED TO THE CLASSIFICATION OF PATTERNS

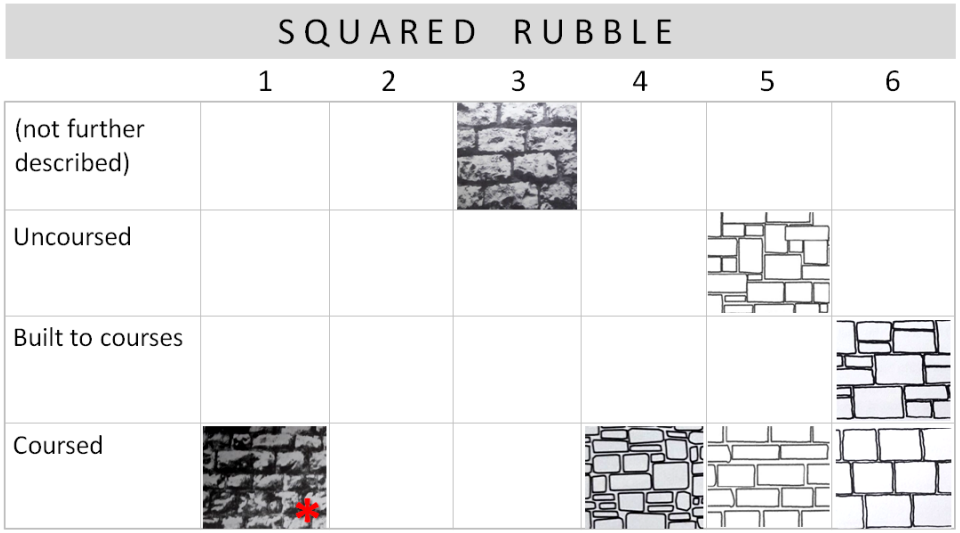
The review of British authors, including references to morphological characteristics of historic stone masonry and related building techniques, has highlighted an issue related to a criterion used to define different masonry. A number of authors classify masonry based on two features identifiable on the patterns in elevation: (1) the shape of the stone units, and (2) their arrangement within the wall system. The former generally includes three main categories: (a) random rubble, referred to as irregular units; (b) squared rubble, referred to as units with a roughly squared shape; and (c) ashlar, referred to as perfectly shaped units. The latter divides masonry into the following: (a) coursed walls, referred to as structures following continuous horizontal beds; (b) uncoursed walls, where courses are not identifiable and therefore appear to follow a random structure; and (c) built to courses – this can be considered an intermediate case between the previous two.

The qualitative character of this classification yields heterogeneous outcomes, dependent on the author's judgement. This is clearly identifiable in Figure 2.16, which juxtaposes images used by six authors to classify masonry types. The similarities between images corresponding to different categories are evident. In particular, the boundaries between random, squared and ashlar masonry are not precise. For example, the polished ashlar of Hendry and Khalaf (2001, 71) looks similar to the coursed squared rubble of Urquhart and Artis-Young (2008, 41–42). The same could be said for the random and squared rubble built to courses, defined respectively by Urquhart and Artis-Young (2008, 41–42) and McAfee (1998, 110). On the other hand, the units made up of random rubble, defined by Urquhart and Artis-Young (2008, 41–42), appear closer

to the squared rubble of Hendry and Khalaf (2001, 71) rather than the random rubble of Cramb (1992, 26) or Hill and David (1995, 33–37). This is similar to the case of the random rubble defined by Warland (1929, 22–25).

The evidence set out thus far reveals the subjective character of the classification currently in use. In particular, qualitative considerations behind such classification are generic, leaving space for interpretation and therefore leading to results highly dependent on personal sensibility. In order to ensure adequate interpretation of the outcomes obtained in this research, it is therefore necessary to provide more rigorous classification criteria based on quantitative parameters able to attribute masonry to categories in an objective, documentable and reproducible way. This issue is resolved in the subsequent chapters of this research.





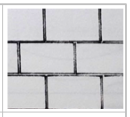
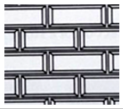
ASHLAR						
	1	2	3	4	5	6
(not further described)						
Polished						
Rusticated V-joined						

Figure 2.16: Juxtaposition of the images used to define or classify masonry types in the following six publications: (1) Warland 1929, 22–25, (2) Cramb 1992, 26, (3) Hill and David 1995, 33–37, (4) Hendry and Khalaf 2001, 71, (5) Urquhart and Artis-Young 2008, 41–42, (6) McAfee 1998, 110.The images marked with a (*) are defined as coursed rubble without determining if they are random or squared, and therefore could belong to both groups.

2.7 KEY CONTRIBUTIONS AND RESEARCH GAP

The literature review presented in this chapter serves to underline research gaps, at the same time identifying references to underpin the development of a methodology oriented towards overcoming them.

In particular, the review of history of architecture in the seventeenth and eighteenth centuries in Scotland defines this period as a time of transformation. The emergence of the architect ended the prevalence of masons and determined the development of architecture (Dunbar 1966, 11; McKean 2001). The centre of construction activity during this period centred upon the construction of stately countryside houses, driven by the initiatives of rich and noble families (Glendinning et al. 1996, 71–183). Defensive schemes of previous centuries were overcome in favour of more domestic architecture (Dunbar 1966, 53). In some cases, ancient family seats were extended and adapted for the new requirements of the owners (Dunbar 1966, 69; McKean 2001, 17; Wemyss 2014, 317–20). In others, new planned buildings were built in empty sites. The overlay of historical strata results in complex structures, which are not easy to interpret. McKean (2003) demonstrates that research based only on the study of historical documents can result in partial conceptions, and highlights analysis of existing remains as a key factor in achieving a complete understanding of architectural heritage. However, this approach has been revealed as common practice in Scotland.

Dunbar (1966, 193–97) referred to the idea of stone architecture closely related to its territory and imagined a territory defined by regional masonry patterns. The prevalence of stone as a building material has motivated the development of numerous investigations focused on the identification of local sources of material (McMillan et al. 2006, 5; McMillan and Gillanders 1997, 10), and the characteristics of lime mortars used (SLCT 2006; Schmidt 2017). However, little is yet known about the morphology of historic masonry.

The research presented here aims to contribute to this gap and study the morphology of masonry built in the elevations of countryside stately homes. The review of methods for the

characterisation of historic masonry identifies valuable references, which underpin the methodology developed. In particular, two fields are studied: archaeology and conservation.

The discipline of archaeology underwent a major transformation after the Second World War until the 1960s (Tabales Rodriguez 2002, 31–40). Approaches inherited from the field of history of art, based mainly on the study of historic records and documents, evolved towards more scientific methodologies. In the British context, contributions from groups such as the Vernacular Architecture Group and the Society of Medieval Archaeology fostered this process. Historic remains were considered a valuable source of information. The development of modern archaeology resulted in different branches, including archaeology of buildings (Morriss 2000) and archaeology of stone (Peacock 1998). However, in Scotland, the impact of these currents was discrete (Gerrard 2009). Few authors considered the study of certain features of masonry within their investigations, and in most cases, the objective was dating of built structures (Zeune 1992; Potter 2008; Uglow, Addyman, and Lowrey 2012).

The intense debate that took place in the British context during the 1960s moved to Italy in the following decades, where discussions converged about the principles and methods of conservation (Tabales Rodriguez 2002, 31–40). The result was the development of methodologies that consider existing masonry as a valuable source of information and an approach to studies focusing on identification of the techniques involved in the construction process. Especially relevant are the contributions developed within the field of archaeology of architecture by authors such as Parenti (1988b, 1994) and Mannoni (2005). Research developed in this field recognises the complexity of historic constructions and defines masonry types based on the study of the building techniques used. These are recognised based on identification of certain morphological features of masonry, including materials used, patterns, unit dimensions, section structure, finishing and binder. In addition, identification of specific techniques with a determinate chronology requires knowledge of the local context (Bianchi 1996). However, this context not only refers to historical, political and economic aspects, but also includes the structure of the relevant territory (De Minicis 1997). The series of studies by Fiorani (1996b), Esposito (1996), De Meo (2006) and Chiovelli (2017) successfully identified local building techniques, focusing on specific areas with homogeneous characteristics.

This approach is also found in the field of conservation. Giuffré (1991, 2003) and other subsequent authors including Donà and De Maria (2011) were able to evaluate the structural performance of masonry through identification of certain morphological features related to building technique. In particular, the study of the “regola d’arte”, the set of principles and rules followed by masons to build masonry structures, is highlighted as a key step in this process. The review developed from the ICCD (Mancinelli and Negri 2017; ICCD 2013a, 2013b) highlights 20 parameters used by different authors for the characterisation of masonry and referenced features. These incorporate aspects such as the percentage of different elements making up the masonry and their material properties, dimensions of units and joints, morphology of patterns, arrangement of units and bonding strategies and morphology and thickness of the wall sections. In addition, the study of 1sqm samples of masonry patterns is a notably common practice. Such conclusions are a valuable reference in the development of the research methodology.

The review of technological means used for capturing and processing data reveals a scenario involving continuous evolution in the use of quantitative methods. LIDAR and photogrammetry are the two technologies most used for data collection, despite the applicability of other alternatives also explored. In contrast, data processing is a field barely explored, which offers important research opportunities. The use of algorithms allows automation of the process and at the same time provides quantitative results and objective classifications (Esser 2012; Gonzalez Manich et al. 2016; Valero, Bosche, and Foster 2018). These techniques are therefore ideal to determine the analysis parameters discussed.

Following the example of the Italian references, the principles and rules contained within the Stonemason's Gospel (which is the term used in this thesis to refer to the "regola d'arte") were investigated in the UK context. For this purpose, two different types of publications were reviewed: historic treatises and records on stone masonry building techniques written by masons. Unlike the results obtained by Donà and De Maria (2011) in Italy, the treatises written in the UK before the nineteenth century do not refer to this specific knowledge. However, it has been found in other types of publications. Such knowledge represents a valuable set of information but the way it is organised does not follow a systematic and scientific scheme and therefore required some processing. The author of the thesis reviewed publications by masons – Warland (1929), Cramb (1992) and McAfee (1997, 1998) – and, taking as a reference the reasoning exposed by Mannoni (2005), synthesised the practical knowledge associated with the construction of masonry walls. The outcome refers to aspects related to the size and shape of the units, the principles and rules involved in the assembly process and the techniques derived from the application of such principles. This provides the necessary base of knowledge to overcome evaluations based on esthetical and formal features and study the morphology of masonry from understandings of the construction techniques involved.

This review of studies referring to masonry types has highlighted some subjectivity in the criteria used for classification. A comparison of the classification criteria defined by authors such as Warland (1929, 22–25), Cramb (1992, 26), Hill and David (1995, 33–37), Hendry and Khalaf (2001, 71), Urquhart and Artis-Young (2008, 41–42) and McAfee (1998, 110) reveals qualitative judgements, which can cause misinterpretation of the research outcomes. It is therefore necessary to define objective classification criteria for adequate interpretation of the research conclusions.

In conclusion, the literature review presented defines the state of the art of the research topic, enabling the identification of certain gaps of knowledge, as well as references for the development of a research methodology to address these. In particular, little is known about the morphology of historic masonry. No systematic and consolidated approach focused on this topic has been found, and no objective criteria for the classification of masonry exist. However, the approaches learned from the Italian references and research into the Stonemason's Gospel defines the base of knowledge necessary to underpin a methodology aiming to address these gaps and achieve the research objectives.

Chapter 3
RESEARCH METHODOLOGY

3.1 INTRODUCTION

The literature review previously presented highlights that the morphology of historic masonry has not been specifically investigated in Scotland. For example, studies such as that of Davey et al. (1981), which includes a comprehensive description of the different types of wall sections used in buildings in the New Town of Edinburgh, are rare. In particular, no systematic and consolidated approach focused on this topic is found. In addition, some subjectivity is identified in the criteria used for the classification of masonry types.

This topic has, however, been extensively researched in Italy. Particularly important for this work are investigations related to classification of masonry types and the study of the context. These two aspects are fundamental for the adequate interpretation of built heritage. For example, authors such as Parenti (1994) and Mannoni (2005), in the field of archaeology of architecture, and Giuffré (2003) in the field of conservation, have contributed to the development of criteria for the classification of masonry types based on the study of construction techniques rather than qualitative judgements based on observation of patterns. Similarly, the series of studies by Fiorani (1996b), Esposito (1996), De Meo (2006) and Chiovelli (2017) are examples that successfully define local masonry types and building techniques, based on a comprehensive analysis of context.

The methodology presented in this chapter develops from the approach that emerged in the Italian context but defines an analysis sequence tailored to the specific research framework. In particular, the analysis sequence is composed of two parts (Figure 3.1). The first part focuses on context analysis, with the objective of building the knowledge necessary to have an adequate historic–constructive understanding of the context. This includes three different aspects: (1) the structure of the territory, which is directly linked to the sources of building material, (2) the characteristics of the stately country home built, and (3) the groups of architects and masons responsible for the construction of architectural works at the time. The outcomes obtained in this part provide the criteria

necessary for selection of a group of case studies representative of the context and meaningful for the purpose of this research.

The second part focuses on the morphological analysis of masonry elevations, corresponding to each of the cases selected. This is approached through identification of morphological features related to the building technique involved in the construction. The analysis process defined first involves individual study of three main parts of the elevation (the solid portion of wall, the corner and the opening), and then considers how these are integrated within the overall system. In order to overcome the subjectivity related to the classification of masonry patterns, as previously outlined, this part of the investigation includes the development of a novel objective method for this purpose, based on the use of machine learning techniques.

Overall, the analysis sequence combines a direct survey methodology with qualitative statistical analysis and quantitative machine learning techniques, taking a novel approach to the subject studied. The following sections depict each step of the sequence in detail.

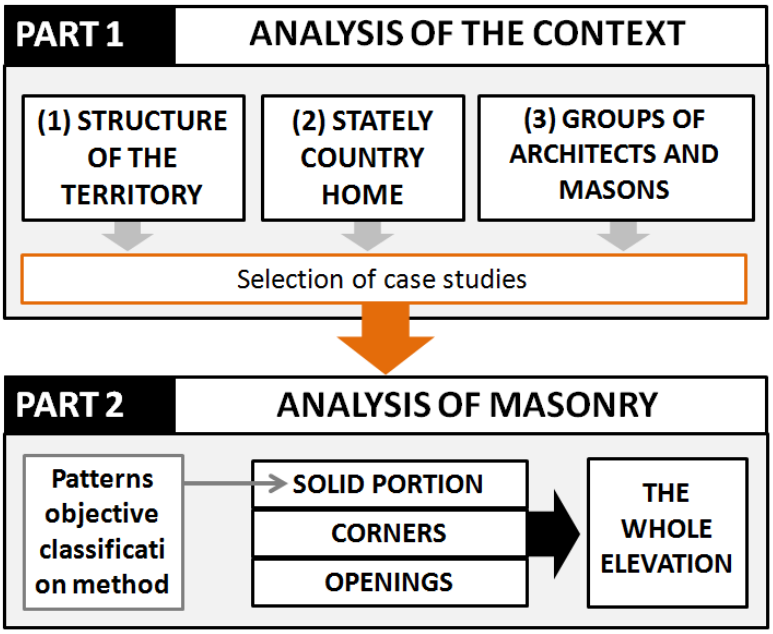


Figure 3.1: Diagram of the analysis sequence defined within the methodology.

3.2 ANALYSIS OF THE CONTEXT

The series of works directed by Giovanni Carbonara and developed by Fiorani (1996), Esposito (1996), De Meo (2006) and Chiovelli (2017) demonstrates the benefits of building a solid knowledge base for the study of masonry. Particularly illustrative of the purpose of this investigation is the work of Fiorani (1996a, 1996b), who defined local masonry typologies based on a comprehensive study of the context. This considered aspects related to the characteristics of the territory (geomorphology, geology and topography), the economic–political–historical framework, and identification of

distinctive features of local architecture. Such global understanding, which Fiorani (Fiorani 1996a, 1–2) defined as the backbone of the investigation, enabled masonry techniques to be associated with local tradition. The research presented in this thesis develops from this reference and the first part of the analysis is devoted to study of the context considered, focusing on three relevant aspects identified in the literature review.

The first aspect is related to the territory, particularly local availability of different building stones – the main construction material. The second refers to the characteristic features of the buildings constructed, particularly stately country homes, which were at the centre of construction activity. The third is related to the human factor and the socio-economic context, notably the emergence of the architect, which signified the end of the prevalence of masons in the construction industry. However, the references found specifically relating each of these aspects with the characteristics of built masonry were not sufficient to define the base of knowledge necessary for the development of the investigation. To address this gap and better contextualise masonry, it was necessary to undertake further analysis.

In particular, the territory is studied relating the location of buildings constructed during the period, with the structure of the land in terms of geography and geology. This enables identification of areas with homogeneous characteristics and relates them to the locations of built nuclei. Moreover, the main features of the stately country home are identified and related to masonry characteristics, defining groups or types of buildings. Finally, networks of active architects and masons of the time are studied to identify the most relevant for architectural production. The following sections detail the analysis sequences defined in each case.

3.2.1 STRUCTURE OF THE TERRITORY

The literature review highlights that several authors defend the idea of stone architecture closely related to territory (Scott-Moncrieff 1938; Dunbar 1966, 193–97; McMillan et al. 2006, 5; McMillan and Gillanders 1997, 10). For this reason, the link between territory and buildings requires further study. The analysis defined considers three different aspects: (1) the geography of the land, (2) the geology, and (3) the distribution of buildings on the territory. Each aspect is individually studied and plotted on a map.

The geography and geology of the land are defined based on information from secondary sources but filtered according to the focus of the investigation. In particular, the geology of Scotland takes as a reference the map defined by the BGS, but simplifies the information, defining only areas corresponding to three types of rocks: igneous, metamorphic and sandstone. This gives an idea of the distribution of stone resources for building in the territory. Similarly, the study of the geography of the land focuses on the location of the main plain and mountainous areas.

Determining the distribution of buildings on the territory involves a higher level of elaboration. First, a dataset of 592 buildings built between the mid-sixteenth century

and the end of the eighteenth century is produced based on information collected from existing literature. The geographical distribution of the buildings identified is investigated with a GIS mapping tool (ESRI 2011). This analysis provides a general picture of the distribution of the built nuclei and, consequently, construction activity in this timeframe.

The overlap of the three layers of information enables identification of centres of building activity in the period and relates these to the building resources available and the morphology of the land. In turn, this contributes to a more informed selection of case studies and interpretation of the results obtained in subsequent phases of the methodology.

3.2.2 CHARACTERISTICS OF THE STATELY COUNTRY HOME

The review of literature in the previous chapter highlights two main points related to the characteristics of the stately country home. On one hand, the time between the sixteenth and early seventeenth centuries saw a progressive abandonment of fortified structures in favour of more domestic schemes (Dunbar 1966, 53; Howard 1995, 50–107; McKean 1993, 2001). On the other hand, two different building strategies are noted: the extension and transformation of ancient family seats and the construction of new planned residences (Dunbar 1966, 69; McKean 1993, 2001; Wemyss 2014, 317–20). These points are generally treated with a descriptive approach and refer to aspects such as the geometry of the building plans and the design of other architectural features. However, the link between the characteristics of buildings and the morphology of their masonry is often not or only superficially investigated.

This step of the methodology aims to bridge this gap, as it is an aspect of crucial importance for adequate characterisation of the context and the subsequent selection of meaningful case studies to be used in the later analysis. An analysis sequence, which learns from that applied by McKean (2001, 16–22), already commented upon in the literature review chapter, goes beyond the descriptive approach commonly found in the literature. As in the work of McKean, the process starts from the development of a database with quantitative data obtained from secondary sources. However, on this occasion, the objective and type of analysis is different. In particular, the analysis used is statistical.

Development of the dataset starts with the work of MacGibbon and Ross (1888, vol. 2,3,4), which includes an extensive and exhaustive list of buildings scattered across Scotland and dated between the mid-sixteenth and early eighteenth centuries. Of all the typologies discussed in the volumes, only those with a residential function are considered on this occasion. In particular, this publication contains detailed information with respect to the history of buildings, overall plan layouts, wall thicknesses and structural features. No other research of this type includes the same level of detail about the characteristics of masonry structures. This aspect is of major importance because the final objective of the analysis is to inform the selection of cases. Thus, despite this research considering a time period until the end of the eighteenth century

while the publication does not cover the last part of this timeframe, this has been taken as a starting point in this specific step of the methodology.

Numerous investigations focused on architecture built in this timeframe refer to the published by MacGibbon and Ross. For example, Howard (1995, 6) declared that "*they laid the foundations for all future work in the field".* Nonetheless, this valuable body of knowledge contains certain inaccuracies, as highlighted by McKean (2001, 4). Despite underlining the exhaustiveness of the work, McKean disagrees with the castellated conception that guided the publication and attributes the existence of some historical inaccuracies to the magnitude of the task and the conditions in which it developed. In order to mitigate such deficiencies, each building considered from the list compiled by MacGibbon and Ross (1888, vol. 2,3,4) is studied in detail, combining different sources of information. Table 3.1 lists the sources consulted and details the types of information obtained from each. The buildings about which insufficient information was obtained were discarded. The result of this process is a dataset composed of 366 entries or cases, dated between the mid-sixteenth and eighteenth centuries and scattered across Scotland. Although the research focuses on the seventeenth and eighteenth centuries, as the emergence of the architect is dated to the beginning of the seventeenth century, the last part of the sixteenth century is also considered in order to better contextualise the analysis.

SOURCE	TYPE OF INFORMATION COLLECTED
Canmore online catalogue (HES 2017a)	• History of the building • Location • Plans and elevations • Structure and construction features
HES listing online database (HES 2017b)	
MacGibbon and Ross (1888, vol. 2, 3, 4)	• Plans and elevations • Structure and construction features
Images of buildings published by visitors online (recent and historical).	• Masonry patterns * • Construction features * *(*) Used only to verify the information obtained from previous sources.*

Table 3.1: References consulted for construction of the dataset used for the characterisation of the context in terms of building morphology.

3.2.2.1 Parameters defined for the analysis

To aid the analysis and make the cases comparable, each building was included in a dataset and characterised using ten parameters. The parameters are of two types: variables, which are numerical and continuous; and factors, which are categorical and therefore defined by levels or categories. Depending on the key aspect of the building defined, the parameters can be divided into four groups as shown in Table 3.2.

The first group defines the context of the building and includes two parameters: the period of construction (PE) and the geographical location of the building (LOR). PE is a factor defined by six categories. The first three categories determine if a building was built before the seventeenth century, between the seventeenth and eighteenth

centuries, or after the eighteenth century, while the last three are combinations of the previous categories. The LOR is determined according to the five areas defined in Figure 3.2.

The second group defines the building plan, determining its type or geometry (PL), average ground floor area (AA) and maximum span of the first floor (MS). PL is a factor determined by 11 categories: courtyard, E, F, H, L oblong, squared/rectangular tower, T, U, Vila (either compact or with flanking pavilions), and Z. AA and MS are variables defined in square metres and metres respectively.

The third group refers to the section of the building determining the number of floors (NF) and the number of vaulted levels in the building (NV). Both parameters are factors. NF can vary between one and six floors while, in the case of NV, the variation is between zero and four levels vaulted.

Finally, the masonry of the building is characterised using three parameters: the type of pattern (MT) and the first and second predominant thickness of the walls at ground floor level (T1 and T2). MT is composed of six different categories, which determine different degrees of regularity based on classification criteria generally used in Scottish literature. The first three categories are ashlar (very regular), squared rubble (mid-case) and random rubble (irregular). The remaining three categories are combinations of the previous categories. Figure 3.3 shows the images used as a reference to classify the masonry pattern of each building considered. T1 and T2 are variables. The process followed to identify the first and second prevalent thicknesses starts with the measurement of the thickness of all the walls in a building at ground floor level. This is achieved using scaled plans. The first prevalent thickness is the most common thickness identified in terms of number of linear metres of wall. The second most prevalent is the second most common thickness.

TABLE OF PARAMETERS				
GROUP	ID	PARAMETER	TYPE	LEVELS OR CATEGORIES
Context	LOR	Location (see Figure 3.2)	Factor	1=south, 2=central, 3=north-east, 4=north-west, 5=islands.
	PE	Period group	Factor	1=Before 17th century, 2=Between 17th and 18th centuries, 3=After 18th century, 4=1&2, 5=2&3, 6=1&2&3.
Plan	AA	Average ground floor area [m2]	Variable	-
	MS	Maximum span of the first floor [m]	Variable	-
	PL	Type or geometry of the plan	Factor	1=Courtyard plan, 2=E plan, 3=F plan, 4=H plan, 5=L plan, 6=Oblong, 7=Squared or rectangular tower, 8=T plan, 9=U plan, 10=Vila (compact or with flanking pavilions), 11=Z plan.
Section	NF	Average number of floors above ground floor level.	Factor	From one to six floors.

	NV	Number of vaulted levels in the building.	Factor	From zero to four vaulted levels.
Masonry	MT	Type of pattern (see Figure 3.3).	Factor	1=Ashlar, 2=Random rubble, 3=Squared rubble, 4=1&2, 5=1&3, 6=2&3.
	T1	First predominant wall thickness on the ground floor in linear metres [m].	Variable	-
	T2	Second predominant wall thickness on the ground floor in linear metres [m].	Variable	-

Table 3.2: Parameters defining the dataset used for the characterisation of the context in relation to building morphology.

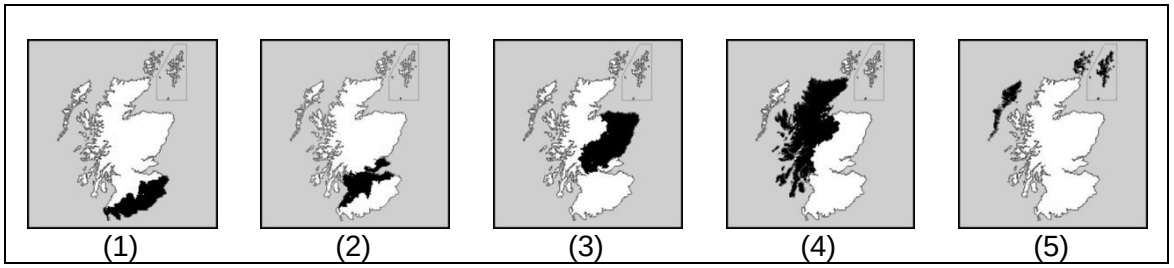


Figure 3.2: Areas corresponding to the categories of the parameter LOR. These are defined by grouping the councils according to the geographic and orographic characteristics of the territory.

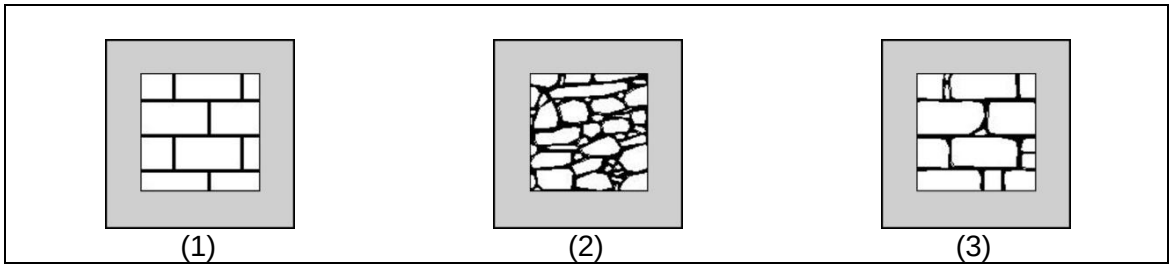


Figure 3.3: Reference images used to define masonry pattern groups. These define three different degrees of regularity, based on the classification criteria generally used in Scotland.

3.2.2.2 Statistical analysis

The statistical analysis defined determines the degree of dependency between parameters. Taking into consideration that they are variables and factors, the following three combinations of pairs of parameters are possible: (1) factor–variable, (2) factor–factor, and (3) variable–variable. As a result of the different types of data paired, the approach applied for analysis of each combination varies according to the following:

- **Factor–variable combinations** are analysed using the Kolmogorov–Smirnov test (KS-test) (Marsaglia, Tsang, and Wang 2003). This test is a general procedure used to compare samples with continuous values. It is sensitive to both the location and the shape of sample distributions, and does not make any assumptions about the shape of the probability density distributions of the data

compared. This latter feature of the test was particularly suitable for analysing the relationships between the parameters in the dataset, which had very diverse probability density distributions. The test null hypothesis is that the sample distributions are equal. It computes the distance between two cumulative probability distributions (D), and then the probability (p-value), to observe a D value equal or higher. The lower the p-value, the stronger the evidence that the two samples are distributed differently. In this study, the entire sample of a variable is tested against each of its sub-samples, determined by particular factor levels or categories. One minus the average of the calculated p-values is taken as the index representing the influence of the factor on the variable. Indexes closer to one indicate higher influences. The computational routine used in the analysis is the “KS-test” function contained in the “base” package of the R software for statistical computing (R Core Team 2016).

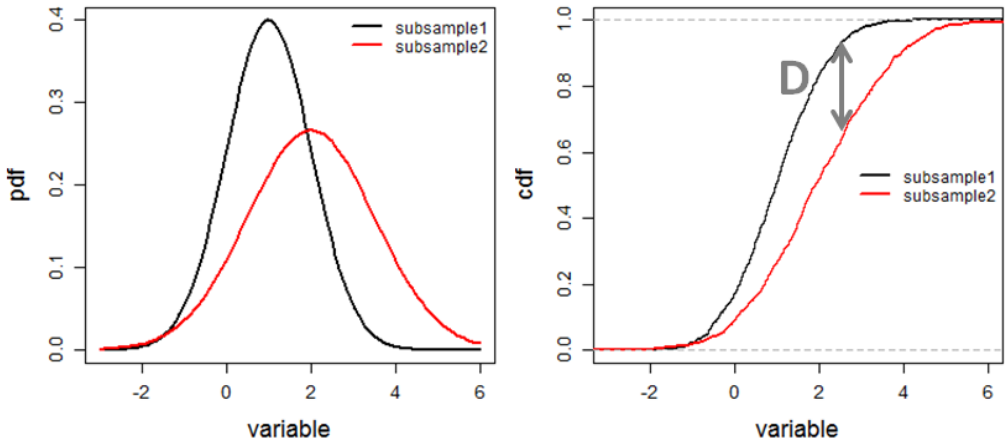


Figure 3.4: Example showing two possible sub-samples of one variable: on the left, the plot of the probability density distribution and, on the right, the corresponding cumulative probability distributions, highlighting the statistics from the KS-test (D).

- **Factor–factor combinations** are analysed using the Chi-squared test of independence. This test has been adopted because it is the procedure of reference when comparing categorical data (Agresti 2007). It assumes that two factors are independent as a null hypothesis. Similarly, as for the KS-test, a statistic (D) is computed, as well as the relative p-value. The lower the p-value, the higher the dependence between the two factors. In this case, D is the deviance between the expected number of cases for a factor level under the null hypothesis and the factor level actually observed. One minus the calculated p-value has been taken as the index summarising the degree of dependence between the two factors. Indexes closer to one indicate higher influences. The computational routine used in the analysis is the “chisq-test” function, contained in the “base” package of the R software for statistical computing (R Core Team 2016).

- **Variable–variable combinations** are analysed using smoothing techniques (Green and Silverman 1993). In particular, giving consideration to a pair of variables, X and Y, a non-parametric model is built, in order to predict Y as a

function of X. As the procedure uses non-parametric models, it tends to represent very general relationships and is not constrained to particular trends (e.g. linear). This feature has been deemed suitable for analysing the variables within the data at hand, given their characteristics. The dependence between X and Y is estimated as the fraction of variance of Y that the model built upon X explains. This index is referred to as Si. Si values closer to one indicate stronger relations. The calculations have been undertaken using the "sobolSmthSpl" function contained in the R package "sensitivity" (Iooss et al. 2020).

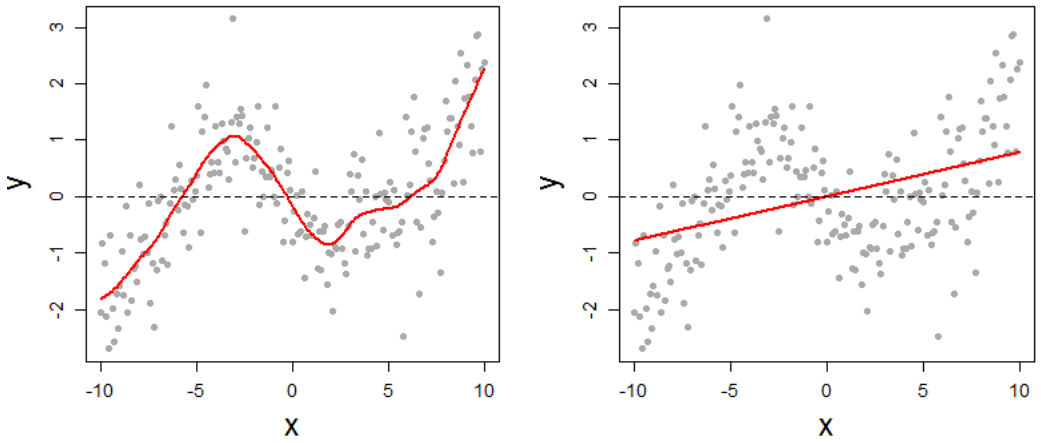


Figure 3.5: Comparison of two different model fits on the same sample of data: on the left, a non-parametric model and, on the right, a linear model. As can be noted, the non-parametric model achieves a better fit.

The indexes obtained are used to perform a qualitative analysis of the relationships between the different parameters. The objective is to identify the most significant. For this purpose, a network graph (Csardi and Nepusz 2006; Amestoy et al. 2020) depicting such relationships was built. This type of representation defines a system composed of nodes and their connections or edges. Each node corresponds to one of the parameters considered. Different colours are attributed to each node depending on the type of parameter (factor = dark grey, variable = light grey). The thickness and the colour of the edges represent the strength of dependence between two parameters. Darker and thicker lines correspond to higher correlation. To aid visualisation and comparison, the indexes deriving from the three different tests are plotted to define a map of dependency links between the parameters studied. This enables identification of the features of the buildings most relevant for later analysis of masonry, and selecting a sample of cases meaningful for the purposes of this research.

3.2.3 GROUPS OF ARCHITECTS AND MASONS

The rise of the architect as a leading figure in design and construction activity, at the expense of the mason, has been identified as an important factor of change in Scottish architecture of the period (Dunbar 1966, 11; Glendinning et al. 1996, 73; McKean 2001,

267–74; MacKechnie 1993; González-Longo 2013, 2014). This step of the analysis aims to capture this significant transformation through identification of groups of architects and masons involved in construction in the timeframe considered. This is achieved by means of network analysis.

3.2.3.1 Definition of the dataset

The data used in the analysis is obtained from the review of Glendinning et al. (1996), Walker et al. (2015) and the database of HES (2017a, 2017b), which gathered the architecture built by the most relevant people of the period in terms of amount of documented work. This process resulted in construction of a dataset connecting buildings and people involved in their construction through what is defined as an "intervention".

Interventions describe actions happening on a building at a specific time. Such actions can include construction of a building, an alteration or addition, a restoration or conservation work, or a damaging action. The year when each intervention ends is defined in the dataset as well as the roles of the people involved. In particular, the roles considered are related to masonry and correspond to people defined in literature as architects, designers, contractors, engineers, masons, carvers, stoneworkers and commissioners. This set of data is included in the ADCRU database.

3.2.3.2 Network analysis

A network is a system of nodes connected by edges. In this case, nodes identify people (each node corresponds to one person), and edges are defined by interventions. Consequently, two people participating in the same intervention are linked by one edge (Figure 3. 6).

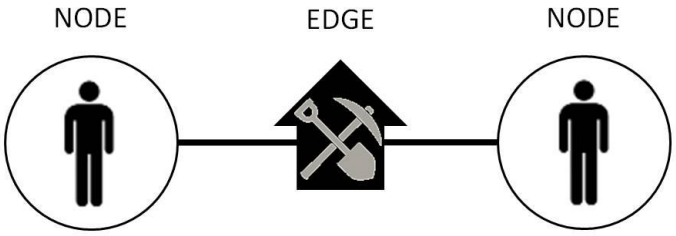


Figure 3. 6: Approach applied for the network analysis.

The R package "igraph" (Csardi and Nepusz 2006; Amestoy et al. 2020) is used in undertaking the computations necessary to identify different networks of people, according to the following steps. First, an adjacency matrix defining the links between the people based on common interventions is built (see function LINK in the annex). Second, the different networks of people are identified. In particular, the condition for a person to belong to a network involves sharing a minimum of one intervention with another. The minimum network size is therefore two nodes and one edge (see function GROUP in the annex).

Once the networks are computed, the most important in terms of number of connected people, buildings and interventions are selected for further study according to the following aspects:

- **Environment**: An environment is defined by a centre or group of centres and people linked to them through the closest level of neighbourhood.

- **Centre**: A centre is a person with a number of interventions and a number of connections equal to or greater than the 0.95 percentile within the network considered.

- **Group of centres**: A group of centres is defined by two or more centres with more than one link in common.

- **Relevant person**: A relevant person is someone sharing a large number of connections with the centres of the environment.

- **Bridge people**: A bridge person is someone connecting centres in two different environments and is defined according to different levels of neighbourhood. In this case, only bridges at neighbourhood level 1 are considered.

- **Levels of neighbourhood**:
    - **Level 0**: Two people (A and B) with a common link (e.g.: A–B).
    - **Level 1**: Two people (A and B) with no common links but linked to a third person (C) (e.g.: A–C–B).
    - **Level 2**: Two people (A and B) with no common links, each linked to a third and a fourth person (C, D) with no common links but both connected to a fifth person (E) (e.g.: A–C–E–D–B)
    - Levels higher than level 2 are not considered.

These aspects are represented in the graphical plot of the network. In addition, in the plot the node size is defined according to the number of connections. The higher the number of connections, the bigger the nodes. The edge width is proportional to the number of interventions shared by the two connected people.

The findings obtained contribute to the research in two ways. First, the individuation of the work groups, their links and the weight of each member of the group in terms of number of connections informs the identification of the chronological sequence of the most relevant work groups leading the architecture of the period, as well as highlighting their buildings, which are selected as case studies. Second, they provide the background for the correct interpretation of the outcomes obtained in the later analysis of masonry, linking the architects and masons responsible for the construction of case studies with characteristic morphological masonry features.

The information considered has already been detailed in the existing literature. However, the network analysis applied in this context is novel and enables it to be approached in a more analytical way. The results obtained highlight the critical path in the development of architecture and the extent of its influence. Such a comprehensive overview of the system of connections would otherwise be difficult to obtain. This

interpretation is particularly valuable for the selection of case studies because it locates the different buildings within the system of relationships, consequently enabling better understanding of their relevance and construction history.

3.3 SELECTION OF CASES

The sequence of three analyses detailed leads to the definition of the criteria for the selection of a group of case studies adequate for the purposes of this investigation. The cases are selected from among the buildings included in the datasets used. However, the final list is also determined by site accessibility and visibility of the masonry. Cases where the owner of the building did not grant access permission were obviously discarded. The same occurred when masonry was not visible (e.g. because of a finishing layer or leafy vegetation). Figure 3.7 summarises the factors determining the selection of cases.

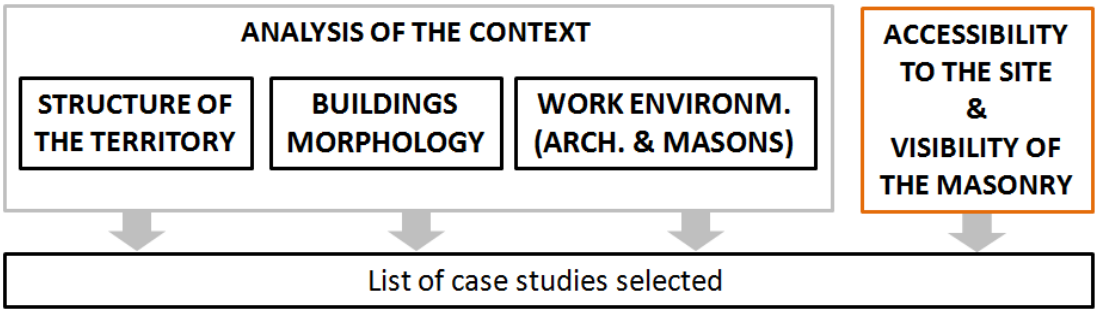


Figure 3.7: Diagram of factors determining the selection of cases.

Each of the buildings making up the final selection is further investigated in order to understand its construction history and identify the events or actions affecting the masonry. Information was obtained from secondary sources including online databases and existing literature, published and unpublished, and organised in a template form designed for this purpose.

3.4 ANALYSIS OF MASONRY

The second part of the methodology focuses on the morphological characterisation of masonry. As highlighted in the literature review chapter, studies of this topic in Scotland are scarce. In addition, classification of masonry types is generally based on identification of formal features of the pattern visible on the external face of the wall, subject to interpretation. The lack of objective criteria could cause misunderstandings of the results obtained in this part of the investigation. The analysis proposed resolves this issue.

In Italy, authors such as Mannoni (1997, 2005), Parenti (1988, 1994), Giuffré (1991, 2003), Abbaneo et. al (1996) and Donà and De Maria (2011) move beyond formal judgements by studying the technical knowledge involved in the construction of masonry. Following the example of Italian authors, the development of this part of the methodology is based on a previous study of the "Stonemason's Gospel". The literature review chapter includes a synthesis of the practical knowledge of masons in the UK, which identifies the basic principles and rules governing the construction of a masonry wall. This highlights morphological features directly related to building technique, based on which the parameters of the analysis are defined.

In particular, the analysis sequence is developed in two steps. The first step focuses on resolving issues related to classification of the masonry patterns mentioned. For this purpose, a novel method that applies machine learning techniques is defined. Machine learning techniques have already been applied for the dating of masonry and for the identification of decay or damage, as in the work of Esser (2012), Gonzalez Manich et al. (2016) and Valeroet al. (2018). However, such an approach has never been applied for the objective pursued in this study. The parameters used in the analysis represent those features of the pattern directly determined by the construction technique. The algorithms applied provide quantitative results, which allow the definition of groups of patterns based on objective criteria.

However, the pattern is only one of the features defining the morphology of the masonry wall (Mannoni 2005). A comprehensive morphological analysis of the elevations is developed in the second step of the sequence. This considers the study of the three main parts in a masonry elevation: the solid portion of wall itself, the connection of two walls defining a corner and the formation of voids or openings in the wall. The classification of patterns previously outlined is applied to the study of the solid portion of wall. The systematic application of the same analysis sequence to each of the case studies selected provides comparable data, which enables identification of groups with common features.

The analysis of the context previously defined allows the characteristic features of each group to be related to the structure of the territory, the work environments, and the typological features of the buildings. This highlights the factors of change that affected masonry and significantly contributes to the fulfilment of the research objective. The following sections detail the analysis defined within the two steps outlined.

3.4.1 CLASSIFICATION OF MASONRY PATTERNS

This section defines a method for the classification of masonry patterns based on the use of machine learning techniques. The analysis sequence starts from the definition of a set of parameters able to quantitatively represent features related to techniques involved in the construction of masonry. Such parameters are used to characterise a heterogeneous group of 426 samples of masonry patterns (see appendix 2). The information gathered defines a dataset, which is analysed using classification

algorithms and results in the objective definition of groups of patterns with common characteristics.

3.4.1.1 Data collection and processing

The review developed by the ICCD (2013) compares the forms used by different authors in Italy to collect data about masonry patterns. The conclusion of this review highlights that five of eight authors use samples of masonry of 1m x 1m size that they consider representative of the general masonry pattern. Considering this precedent, the method defined in this study uses samples of patterns of 1m x 1m size, which are directly captured on site as RGB images.

The sequence followed for the collection of these images and their transformation into data suitable for subsequent analysis is illustrated in Figure 3.8. First, each of the patterns considered is individuated using the 1sqm frame placed against the wall face and photographed with a conventional camera. Second, the RGB images obtained are individually corrected using the software defined by Miniutti (1999) and scaled and manually transformed into a binary image where black pixels identify units and white pixels identify joints. Finally, these images are processed using the "find.units" function, which implements a floodfill algorithm (Torbert 2016, 122–24). This function groups the pixels belonging to the same unit or joint while preserving their geometrical coordinates. The result is a raw set of data containing quantitative information about number and location of pixels corresponding to each of the stone units and mortar joints included within the frame.

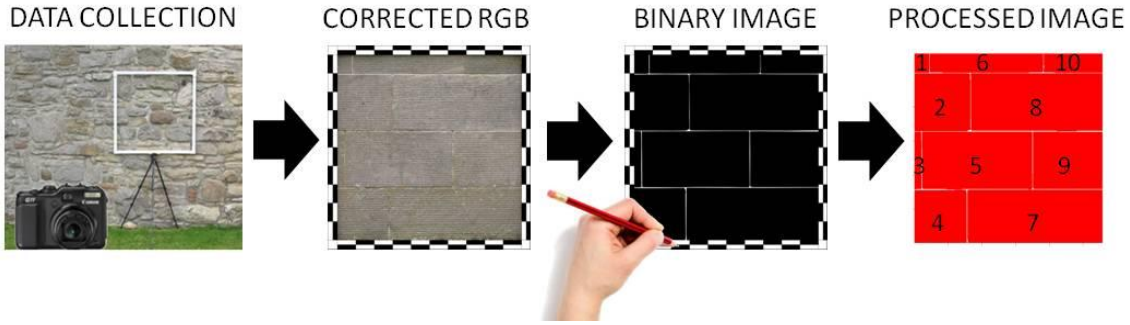


Figure 3.8: Illustration of the sequence followed from the collection of data on site until the attainment of processed images.

3.4.1.2 Parameters defined for the analysis

The set of data obtained is characterised according the seven parameters listed in Table 3.3. These parameters quantitatively determine features derived from the masonry technique used. In particular, four of the parameters define aspects related to the dimension and geometry of the units: the percentage of stone (SP), the rectangularity of the units (RC), the mean height of the units (HMN), and the standard deviation of heights of the units (HSD). The remaining three parameters are related to

the assembly process and define the face-bonding of the pattern (LMT), the regularity of the horizontal courses (CSD) and the alignment of the units within the courses (UA). The conclusions in the ICCD (2013) and the practical knowledge about masonry techniques synthesised in the literature review chapter are the references used for the definition of these parameters.

ASPECT related to the masonry technique	PARAMETER	
Dimension and geometry of the units	1	SP: Percentage of stone
	2	RC: Rectangularity of the units
	3	HMN: Mean of unit heights
	4	HSD: Standard deviation of unit heights
Assembling of the units	5	LMT: Face-bonding of patterns *(minimum trace line)*
	6	CSD: Regularity of the courses
	7	UA: Alignment of the units within the courses

Table 3.3: Parameters defined in order to quantitatively characterise masonry patterns, related to masonry technique.

PERCENTAGE OF STONE (SP)

The SP parameter determines the area of stone contained within a 1sqm sample, defined as a percentage of the total area. The stone area is calculated based on the number of black pixels identified in one frame. This parameter is related to the geometry and size of the stones used in the pattern. The reason for this is that patterns composed of units with regular geometries can be easily organised in courses and therefore tend to have a higher SP than those composed of rough stones. In addition, patterns composed of big stones include a lower amount of joints than those with small units. Figure 3.9 shows two samples with different SP percentages.


(IMG_9448)

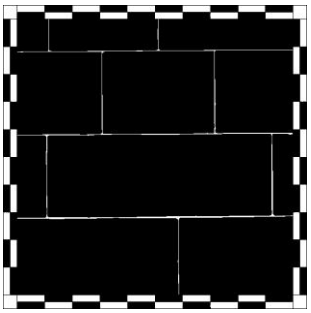

(IMG_7966)

Figure 3.9: Example of patterns with different SP values. In the left frame, SP is equal to 74.92%, while in the right frame it is equal to 98.51%.

RECTANGULARITY OF THE UNITS (RC)

The RC parameter defines the geometry of the visible face of the stone units. This is related to the dressing of the units before they are laid within the masonry. Highly

elaborate stones have rectangular faces, while rough stones are defined by irregular geometries. RC is therefore calculated as follows:

$$\mathrm{RC} = 1 - \frac{\sum_{i=1}^{n}(Ad_{\mathrm{i}})}{\sum_{i=1}^{n}(Au_{\mathrm{i}})} \qquad \mathrm{Ad} = (\mathrm{Ab} - \mathrm{Au}) \cdot \mathrm{w}$$

where *Ab* is the area of the minimum bounding box of each unit within the frame, *Au* is the area of each unit in terms of number of black pixels, and *w* is a co-efficient used to compensate for the effect of straight cut caused by the frame border on stones touching the boundaries. Table 3.4 defines the *w* values considered based on the situation of the stone units within the frame.

Situation of the unit within the frame	Value of w
Not touching the frame boundary	1
Touching one of the frame boundaries	1.33
Touching two of the frame boundaries	2

Table 3.4: w values

RC values equal to 1 define stones with perfect parallelogram faces. Figure 3.10 shows two examples of frames with different RC values.



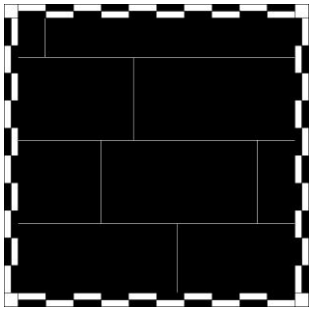


Figure 3.10: Example of patterns with different RC values. In the left frame, RC is equal to 0.68, while in the right frame it is equal to 1.

UNIT HEIGHTS (HMN AND HSD)

The two parameters referring to the size of the units are HMN and HSD, and both refer to the height of the stone units. This dimension is more relevant than the length because it is directly related to the morphology of the courses.

On one hand, HMN corresponds to the average height of the units in the frame and provides a dimensional reference. HSD, on the other hand, defines height variation by calculating standard deviation. This gives an idea of the homogeneity or heterogeneity of the units used in the pattern. Figure 3.11 shows two examples of patterns with different values.

In order to minimise the influence of the frame on the resulting values, the units touching the boundary are discarded.

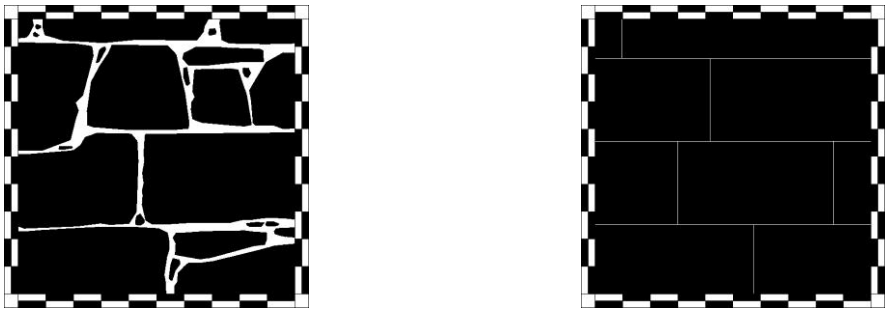


Figure 3.11: Example of patterns with different values for HMN and HSD. In the left frame, HMN is 25.36cm and HSD is 11.69cm. In the right frame, HMN is 30.16cm and HSD is 0cm.

FACE-BONDING OF THE PATTERN (LMT)

This parameter is determined with reference to the work of Doglioni and Mirabella Roberti (2003). The authors defined the LMT (minimum trace line) as the average length of all the shorter non-converging paths, which can be traced between the upper part and the lower part of a 1sqm area of wall. The higher the LMT value, the better the face-bonding of the pattern. Figure 3.12 includes two examples of patterns with different LMT values.

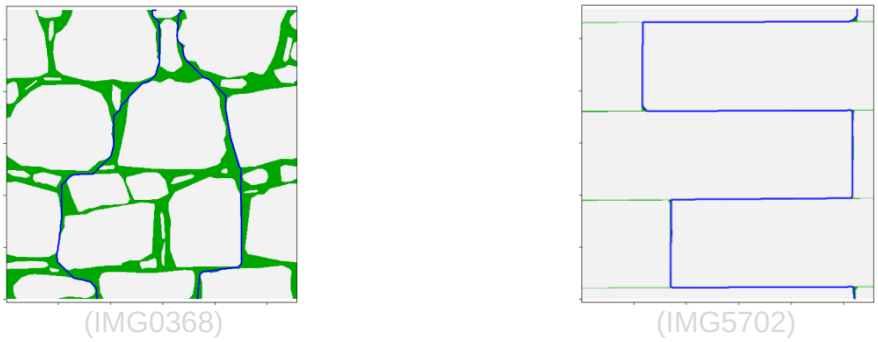


Figure 3.12: Example of patterns with different LMT values. In the left image LMT = 113.29cm, while in the right LMT = 366.85cm. The blue lines plotted correspond to the minimum paths considered to calculate the final value.

REGULARITY OF COURSES (CSD)

The CSD parameter determines course regularity. The approach followed learns from the case of the LMT and is also based in the identification of the minimum paths. However, in this case, the minimum path is calculated based on the horizontal direction, and non-convergence is not a condition. The resulting value defines path length variation by calculating their standard deviation. The lower the CSD value, the more regular the courses.



Figure 3.13: Example of patterns with different values for CSD. In the left image CSD = 11.22cm, while in the right CSD = 0.00cm. The black lines plotted correspond to the minimum paths considered to calculate the final value.

ALIGNMENT OF THE UNITS WITHIN THE FRAME (UA)

The UA parameter refers to the alignment of the units within the frame. It is defined using the function “fun_orientation” as the overall deviation of the principal inertia directions of the different units with respect to the principal inertia direction of the overall frame. The latter is calculated as the average of the formers. The closer to 1 the UA value, the higher the alignment of the units within the frame. Figure 3.14 shows an example of two patterns with different UA values.

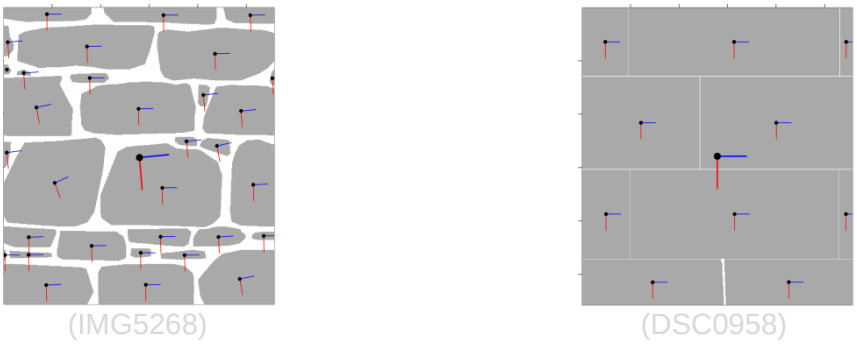


Figure 3.14: Example of patterns with different UA values, including a plot of the axis defining the principal inertia directions of each unit and the overall frame. In the left frame UA is 0.9924, while in the right frame it corresponds to 0.999.

3.4.1.3 Classification

The data characterised by the seven parameters presented defines the numerical dataset necessary to proceed with the identification of groups of patterns with similar characteristics. This is achieved through an unsupervised classification process.

The analysis sequence defined in this study comprises three steps: (1) computation of the adjacency matrix, (2) identification of the optimal number of clusters and clustering of the dataset, and (3) validation of the clusters obtained and identification of the most relevant parameters.

1) **Computation of the adjacency matrix and identification of the most relevant dimensions**: The adjacency matrix measures the similarity between two patterns with respect to the defined parameters. In particular, each pair of patterns is represented by a cell in the matrix. If two patterns are similar, the corresponding cell contains a high value and vice versa. This calculation is undertaken by applying the Random forest algorithm. This is a supervised learning algorithm commonly used for forecasting. It creates random multiple decision trees and the outcomes are averaged to obtain an accurate prediction. In this case, this algorithm is applied in an unsupervised mode according to the "randomForest" function contained in the R package with the same name (Breiman et al. 2018). By starting from the dataset containing the parameter values, this routine measures pattern similarity depending on the structures of the decision trees created. The patterns falling on the same end node of a tree of the forest have their similarity increased. Principal component analysis (PCA) is then applied to identify the most relevant principal dimensions of the matrix and discard redundancies, according to the corresponding eigenvalues. For example, Figure 3.15 shows the eigenvalues calculated during an iteration of the analysis. Although there are more than 250 eigenvalues and corresponding principal dimensions, in this case it was sufficient to consider only the first principal direction as its eigenvalue is significantly larger than the others. The principal directions retained are then considered when defining the clusters. For the computations, the "MDSplot" function in the RandomForest R package is used (Breiman et al. 2018).

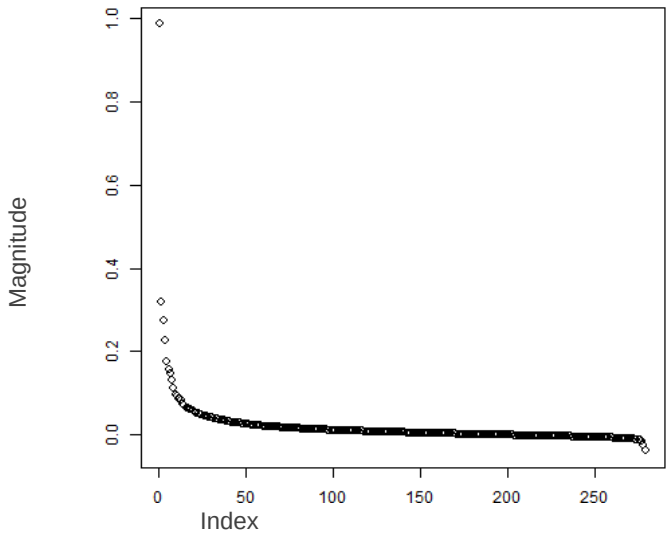


Figure 3.15: Example of a plot of eigenvalues. The x axis defines the eigenvalues computed in order of magnitude while the y axis defines the magnitude of each eigenvalue. In this case, the first eigenvalue has a magnitude significantly higher than the others.

2) **Identification of the optimal number of clusters and clustering**: The number of retained principal directions already gives an indication of the suitable number of clusters. As a rule of thumb, the number of clusters is one more than the number of directions. However, the elbow method (Cottafava et

al. 2018, 6) is used to validate and eventually refine this heuristic. This method plots a curve by calculating the within-cluster sum of squares for a k range of values. The point where the curve has its inflection is a good indicator of the best number of clusters. For example, Figure 3.16 shows a curve with an inflexion point happening at a k equal to 3.

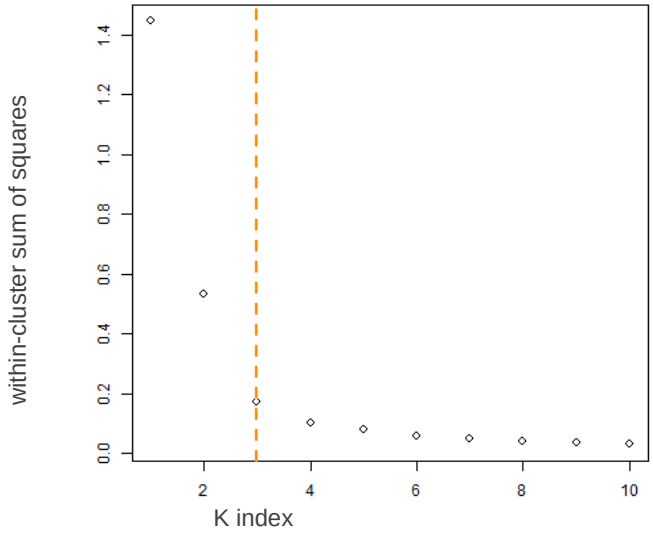


Figure 3.16*:* Example plot corresponding to the elbow method. The x axis determines the range of k values considered, which in this case is equal to ten. The y axis defines their corresponding within-cluster sum of squares. In this case, the inflexion point happens at k=3. Three is therefore the best number of clusters.

The clustering of the dataset is then defined by applying the k-means algorithm (Fox 2018). This unsupervised machine learning algorithm groups the data based on the number of optimal clusters previously determined. The algorithm randomly locates a number of centroids (locations representing the centres of the cluster) equal to the number of clusters defined. The data is then grouped according to the distance of each point with respect to these reference locations. The coordinates of the centroids are then updated as the averages of the coordinates of the points within each cluster. The iteration of this process leads to the identification of the optimal position of the centroids and consequently optimal division of the data in clusters. Figure 3.17 shows an example of data divided into three clusters, highlighting the location of their respective centroids. For the computations, the “MDSplot” function in the RandomForest R package is used (Breiman et al. 2018).

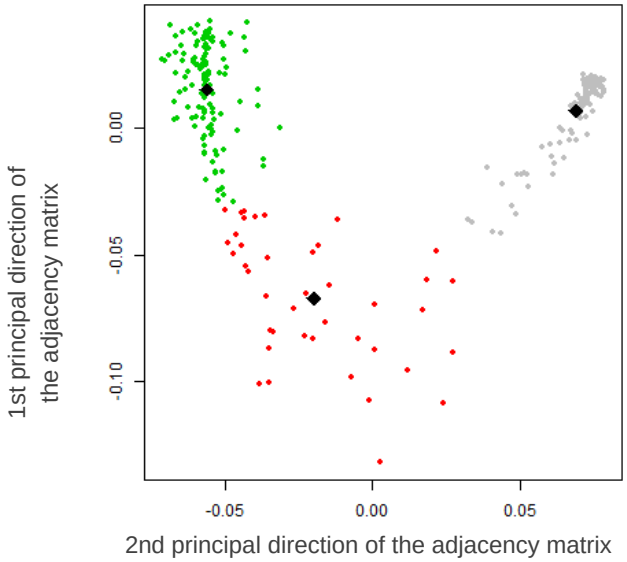


Figure 3.17: Example of a dataset divided into three clusters (green, red and grey). The x and y axis indicate the two principal directions of the adjacency matrix. The black points identify the centroids determined by the k-means algorithm.

3) **Validation of the clusters obtained and identification of the most relevant parameters**: Validation of the clusters obtained is done by verifying that a classifier can adequately identify them. To build such a classifier, the Random Forest algorithm is used again, but this time in a supervised fashion. In particular, the initial parameter dataset, augmented by adding a further column containing the classes defined with the clustering, is divided into training set (80% of the records) and test set (20% of the records). The former is used to build the classifier and the latter to validate its ability to separate the classes. The metric used in assessing the capability of the classifier is accuracy, which is defined as the fraction of correctly identified cases over the total. In the process the algorithm captures the importance of each parameter in classifying the different patterns. This importance has been measured as follows. Each parameter in the dataset is randomly shuffled in turn, so as to break its predictive power, obtaining new datasets. Afterwards, the accuracy of classifiers at making predictions on these new datasets is calculated. Parameters with little importance leave the accuracy unchanged, while very important parameters cause significant decreases in the metric. For example, the graph in Figure 3.18 shows the parameters that are shuffled one at a time on the x axis, and the accuracy of the corresponding predictions on the y axis. It is apparent that P3 is the most relevant parameter as it produces a decrease in accuracy significantly larger than the other parameters.

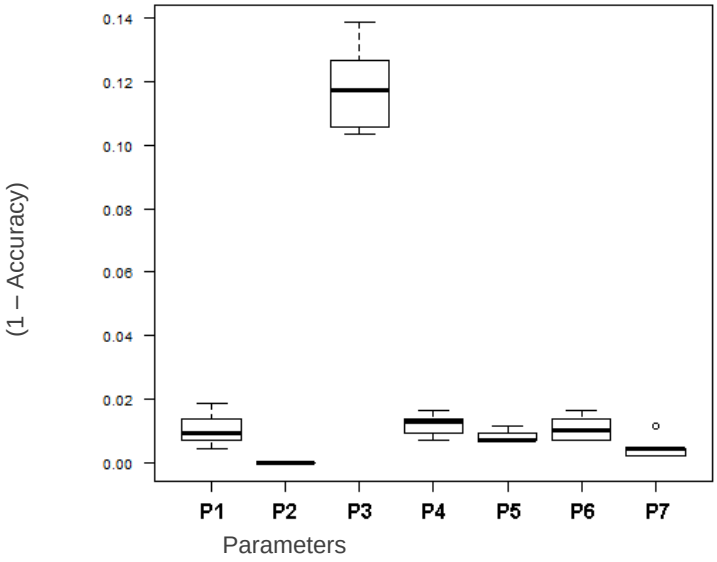


Figure 3.18: Example plot of the importance of each parameter in classifying the different patterns. The x axis defines each of the parameters considered (in this case seven). The y axis determines the value of 1-Accuracy of the classifier. In this case, the P3 parameter is the most relevant determinant for the classification.

Once the most dominant parameters are identified, the analysis is concluded by studying their distributions in order to define characteristic values for each of the clusters. Such characteristic values are defined by the peak value of the parameter (most frequent value) and the high-density interval, which is the narrowest range containing 95% of the cases. Figure 3.19 shows an example of the distributions of a parameter, depending on three different clusters. The green cluster is characterised by a peak value of 0.98 and a range going from 0.97 to 1. The red cluster has completely different characteristic values (peak value = 0.83, high density interval = [0.69, 0.90]). The black cluster is intermediate between the two, having a peak value of 0.93 and a range between 0.85 and 0.97. It is therefore possible to say that in this case the parameter is particularly powerful at distinguishing between the green and red clusters. At the same time, the separation is not so neat between the black and green clusters.

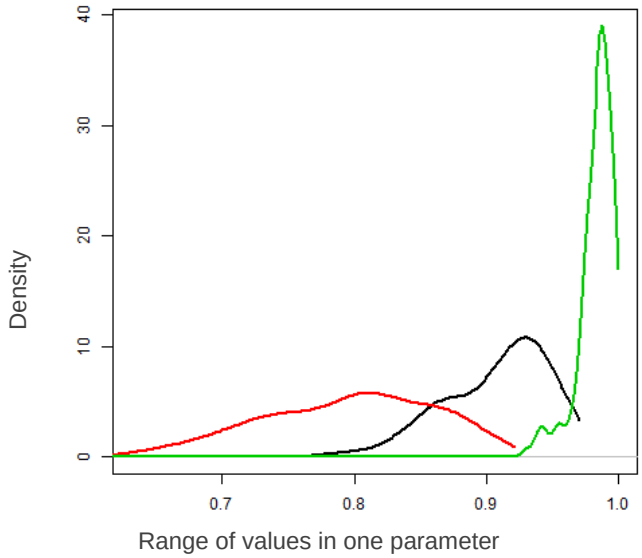


Figure 3.19: Example of distributions of three different clusters, considering one parameter. The x axis defines the range of values in the parameter, while the y axis determines the density of cases for each value. As can be appreciated, the green and red clusters have clearly differentiated distributions, while the black cluster overlaps some parts of the curves.

The result of this process is the classification of the samples of patterns considered in a number of clusters with homogeneous characteristics and objectively determined according to the parameters initially defined. Each group defined corresponds to a type of pattern, and the parameters identify morphological features derived from the construction technique used. This classification can be further refined by repeating the process so as to define sub-clusters for each of the clusters obtained. The result of this second classification leads to identification of variants within each type.

3.4.1.4 Data uncertainties

Possible uncertainties in the data used to quantify the parameters defining masonry patterns derive from limitations of the instruments used during acquisition and pre-processing. These can be divided into two groups: those derived from the fieldwork and those derived from the manual pre-processing of the images.

The former includes possible misalignments of the frame used to individuate masonry samples and decrease in image quality because of site conditions (rain, wind, light, etc.). The latter includes two different sources of uncertainty. First, the correction of raw RGB images using photogrammetric software (Miniutti 1999) involves manual matching of the pixels with the coordinates of the 1sqm frames in order to proceed with the interpolation. The uncertainty introduced in this process is estimated in the range of 15mm, which, for the purposes of this research, is not relevant. Second, the transformation of the corrected RGB images into black and white images involves manual classification of units and joints based on the interpretation of an expert

architect. Given that the 1sqm image is 557 x 557 pixels, the error introduced during this manual process is probably of the same order as the previous one.

The combination of the different sources of error in the worst-case scenario would therefore yield an inaccuracy of about 3cm. However, the author is confident in affirming that this is a very conservative estimate. The results obtained from the classification and the clear differentiation of the masonry clusters obtained further supports the argument that the quality of the data was adequate.

3.4.2 MORPHOLOGICAL CHARACTERISATION OF MASONRY ELEVATIONS

This last part of the methodology focuses on morphological analysis of the masonry elevations, corresponding to the case studies selected. The objective of the analysis sequence is identification of morphological features derived from the techniques used in the construction process. The data used in the analysis is obtained directly from the sites and analysed according to the sequence detailed in the following sections. As already mentioned, this approach, based on construction technique, was learned from Italian authors. However, the specific sequence of analysis applied has been developed within this investigation according to the objective pursued and the characteristics of the framework investigated.

3.4.2.1 Data collection and processing

The data used in this analysis was collected during a survey campaign, which consisted of one visit per case study. The duration of each visit ranged between a minimum of four hours and a maximum of nine hours depending on the characteristics of the building, accessibility and constraints defined by the owner. The team performing the survey was composed of one architect, occasionally assisted by a second person. The equipment used during the campaign was composed of a total station Leica builder 209, a conventional canon G11 camera, a rigid frame sized 1 x 1m, a laser meter, and a 5m-long tape.

The sequence followed for the collection of data consisted of the following steps:

1) General inspection of the building. During this first recognition of the site, the information previously gathered about the construction history of the building is verified, leading to identification of the parts of the building within the scope of the research.

2) Sketch of the different plans of the building including dimensions of spaces and measurement of wall thicknesses when possible, either through openings or by

accessing partially collapsed walls. In this case, the measurements were taken using the laser meter and tape.

3) Identification of the structure of the wall sections where possible.

4) Measurement and photography of the main facade using the canon G11 camera and the total station Leica builder 209. The final objective is the production of a scale-corrected image of the elevation.

5) Identification of the prevalent masonry patterns and collection of 1sqm RGB images of representative areas. The process followed for the collection of samples has already been detailed in a previous section related to the objective method for the classification of patterns. The images taken correspond to the exterior face of the elevations and also, when possible, to the interior.

6) Collection of scaled images of the quoins defining the corners. This is achieved using the same approach as for the patterns.

7) Collection of images and notes about features related to the integration of the stone units within the overall design of the elevation. These include aspects such as the finishing of the unit surfaces, the morphology of the opening's boundary and the characteristics of singular elements such as pilasters and other decorative motives.

The data gathered during the visits was processed, resulting in a set of information per case composed of the following:

- Scaled plans with indication of wall thicknesses.

- Scale-corrected elevations obtained from application of the software developed by Guerra and Miniutti (1999).

- Set of corrected and scaled images of 1sqm areas of the representative patterns composing the elevation.

- Set of corrected and scaled images of 1sqm areas of the quoins defining the corners.

- Notes and images of masonry features related to the structure of the wall section and the design and construction of the masonry.

The dataset built with the information obtained from the survey campaign was combined with the information from secondary sources regarding the dating of the different parts of the buildings and their masonry. This enabled definition of the estimated chronology used in the research. The sources consulted for this purpose were the Canmore online catalogue (HES 2017a), the HES listing online database (HES 2017b) and specific publications about different buildings.

3.4.2.2 Analysis sequence

The analysis defined for the morphologic characterisation of masonry in the elevations develops in a sequence of two steps. The first step focuses on the elevation and separately studies three main parts: (1) the solid portion of the wall, (2) the corners, and (3) the openings. The second step zooms out and proceeds with a more comprehensive vision, considering how the three parts are integrated in the overall structure and design of the elevation.

The sequence just defined is systematically applied to each of the cases selected at the beginning of the investigation. The comparison of the results obtained leads to the identification of common and distinctive features. Given the representativeness of the cases, the results can be related to the overall context initially defined, addressing the research objective. Figure 3.20 illustrates this process.

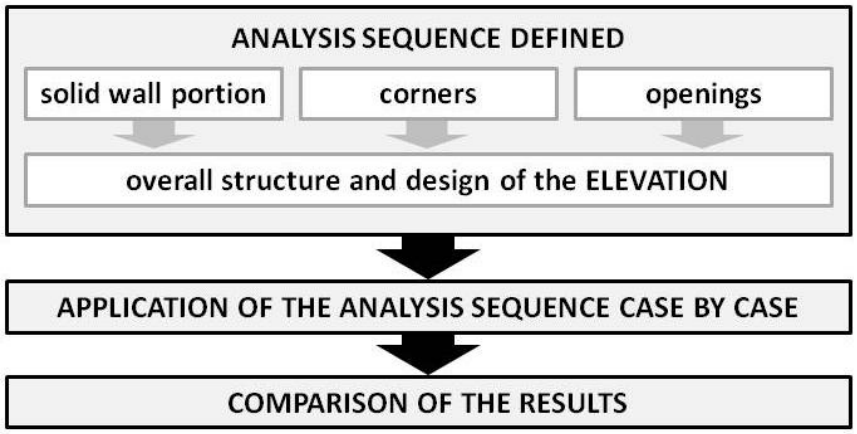


Figure 3.20: Diagram of the analysis sequence defined for the morphological characterisation of the masonry making up the elevations.

THE SOLID PORTION OF MASONRY

The solid portion of masonry is the basic element making up an elevation. This is characterised according to three points: (1) the pattern of the external wall face, (2) the pattern of the internal wall face when available, and (3) the structure and thickness of the section.

Patterns are analysed by applying the objective classification method previously defined in this thesis. The correspondence between the external pattern and the thickness of the wall already provides a first morphological characterisation. This is further complemented with the information about the wall thickness obtained on site and, when available, also verified with the data about the structure of the section.

THE CORNER

Corners define the edges resulting from the intersection of two different walls. According to the conclusions obtained from study of the Stonemason's Gospel, the way in which this edge is defined determines the morphology of the entire elevation.

The bonding of the two walls is achieved by maximising the contact of the stones or quoins composing the edge. The length of the quoin and its alternation defining headers or stretchers are two key features for this purpose. In addition, quoins are used in the construction process as references to trace the guide lines necessary for the definition of courses or lifts in the wall. Consequently, the characteristics of these stones have a direct influence on the structure of the elevation's masonry.

The characterisation of corners is therefore based on observation of the three aspects highlighted: (1) quoin length, (2) quoin height, and (3) the alternation of headers and stretchers.

THE OPENING

Openings create voids on the solid wall, which interrupt the continuity of the masonry. Techniques used to resolve such discontinuity and define the different sides of the frame affect the overall system.

Openings are composed of three main parts: the lintel, the jambs and the sill. Each of these elements fulfils a different function. In general, lintels and jambs have a central role in the distribution of loads coming from the upper levels and in the bonding of the wall section. Differently, the function of sills is oriented towards protecting the wall section from the weather. In addition, the morphology of lintels and jambs are often the cause of discontinuities in the courses or lifts structuring the masonry. For these reasons, attention is focused on studying the morphology of lintels and jambs, leaving sills to a second term.

OVERALL ELEVATION

Study of the elevation enables understanding of how the different parts are integrated, defining the overall system. The structure of this system is defined by the courses or lifts making up the pattern of each elevation. The objective is therefore the identification of these courses or lifts.

Taking as a starting point the scale-corrected elevations previously elaborated, the courses or lifts making up the elevation are highlighted following a hierarchical sequence. This starts by considering the courses determined by quoins, then the courses determined by windows, and, finally, the remaining courses. Each category is marked with a different colour. Red corresponds to courses determined by quoins, yellow identifies window-related courses, and green corresponds to the remainder. The continuity or discontinuity of courses and their correspondence with different reference elements (quoins or opening frame stones) demonstrates the logic behind layering of

masonry. Figure 3.21 shows this process applied to two different elevations. The courses in the first elevation are clearly continuous and equidistant. This is expected because the elevation is composed of very regular stone units. However, the differentiation between corner and opening referenced courses highlights that the portion of wall between the openings was built as an autonomous element within the overall system. The second elevation incorporates an irregular pattern. The analysis in this case highlights a structure of layers difficult to recognise with the naked eye. One of the window jambs follows the general system of layers, while the other jamb and the relieving arch of the lintel interrupt it.

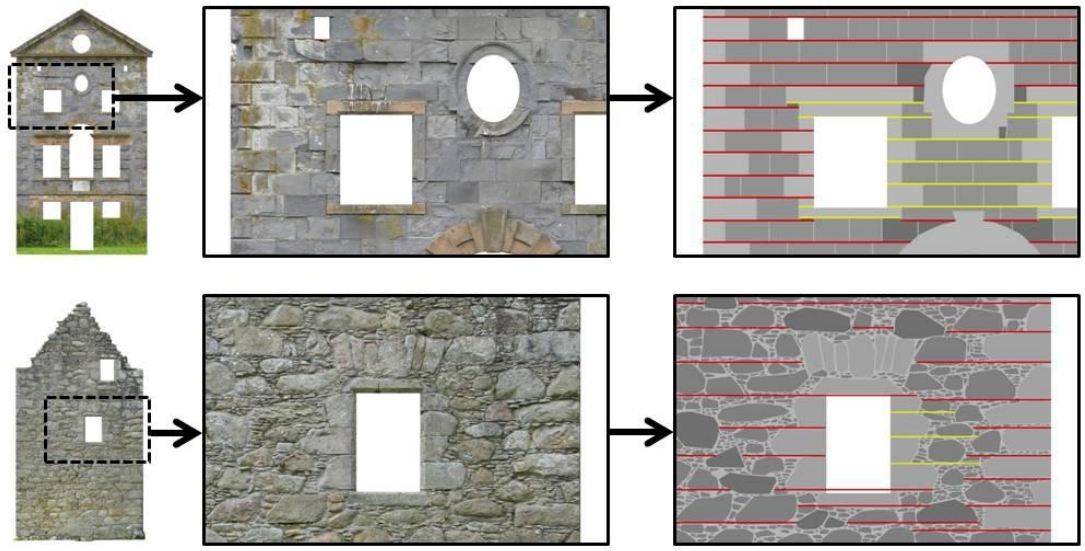


Figure 3.21: Example of identification of courses applied to two different elevations. Red lines define courses determined by quoins, while windows are determined by yellow lines.

Furthermore, identification of special features on the facade related to the design of the stone and its finishing contribute to the conclusions derived from the analysis presented. The analysis sequence highlights the morphological features characterising a masonry elevation on two scales: individually for each of the main parts making up an elevation, and globally in the overall system. This enables identification of the logic governing the building process as well as development of understandings of whether the morphological features respond directly to construction principles or if, on the contrary, these are determined by other factors – for example, related to certain design aspirations.

Chapter 4
ANALYSIS OF THE CONTEXT

4.1 INTRODUCTION

As discussed in previous chapters, achieving a comprehensive understanding of the historic–constructive context of the timeframe considered in the investigation is essential for the correct interpretation of built masonry. For this reason, the first part of the methodology focuses on building a knowledge base, considering three different aspects of this context: (1) the structure of the territory, which is directly related to sources of building material; (2) the morphological characteristics of the stately country homes built; and (3) the groups of architects and masons leading the construction of architectural works at the time.

The results obtained from analyses of the three aspects studied are presented in the following sections, leading to the achievement of a double objective. On one hand, they define for the first time a comprehensive and structured understanding of the context in terms of masonry, which was missing in the literature. On the other hand, the results provide the criteria necessary for the selection of a group of case studies, well depicting the context characterised and meaningful for the later analysis of their masonry. The list of buildings selected is presented in the last section of this chapter, where the connection of each case with the context is highlighted.

4.2 STRUCTURE OF THE TERRITORY

The structure of the terrotiry is one of the three aspects included in the analysis of the context. This is studied with consideration given to three different features: (1) geography, (2) geology, and (3) distribution of buildings in the country.

From the point of view of geography, Scotland is divided into three main areas: the northern area, the southern area, and the Central Belt. The northern area is the most mountainous. There, the Glen More or Great Glen depression separates two ranges: the North West Highlands and the Grampian mountains. The southern area is defined by the Southern Uplands, a moorland plateau with much smoother relief. Between these parts lies the Central Belt, which is an area free of rugged landforms (Figure 4.1a).

Similarly, the geological structure of the land divides Scotland into two parts. The first part largely corresponds with the northern area, defined in terms of geography, and is characterised by the predominance of metamorphic rocks. In contrast, the second part includes the Central Belt and southern geographic areas and is rich in sedimentary rocks (Figure 4.1b).

Plots of the location of 592 buildings built between the mid-sixteenth century and the end of the eighteenth century provides a general understanding of the distribution of built nuclei and construction activity in Scotland in this timeframe. As can be appreciated in Figure 4.1c, the highest density of buildings happens in the Central Belt, spreading towards the south and along the east coast. The north-west area of Scotland is, though, quite clear.

The overlap of the three layers defined (Figure 4.1d) demonstrates correspondence between the structure of the country and the location of buildings built between the mid-sixteenth century and the end of the eighteenth century. The highest concentration of buildings happens in the areas where the terrain is less rugged (Central Belt, south and north-east). In contrast, the north-west part, more mountainous, remains almost clear. Considering the geology with respect to the distribution of buildings, the majority of buildings are notably located in areas with a predominance of sedimentary rocks. As mentioned earlier in this section, they also coincide with the less rugged areas. However, a noticeable exception escapes this rule: the Aberdeen area. This location has a relevant density of construction but is located in an area where metamorphic rocks predominate. This feature makes it different from the rest of the main built-up areas and this distinction, clearly marked by the characteristics of the territory, is a point to consider for the selection of case studies as it can contribute to understand the influence of this factor on masonry characteristics.

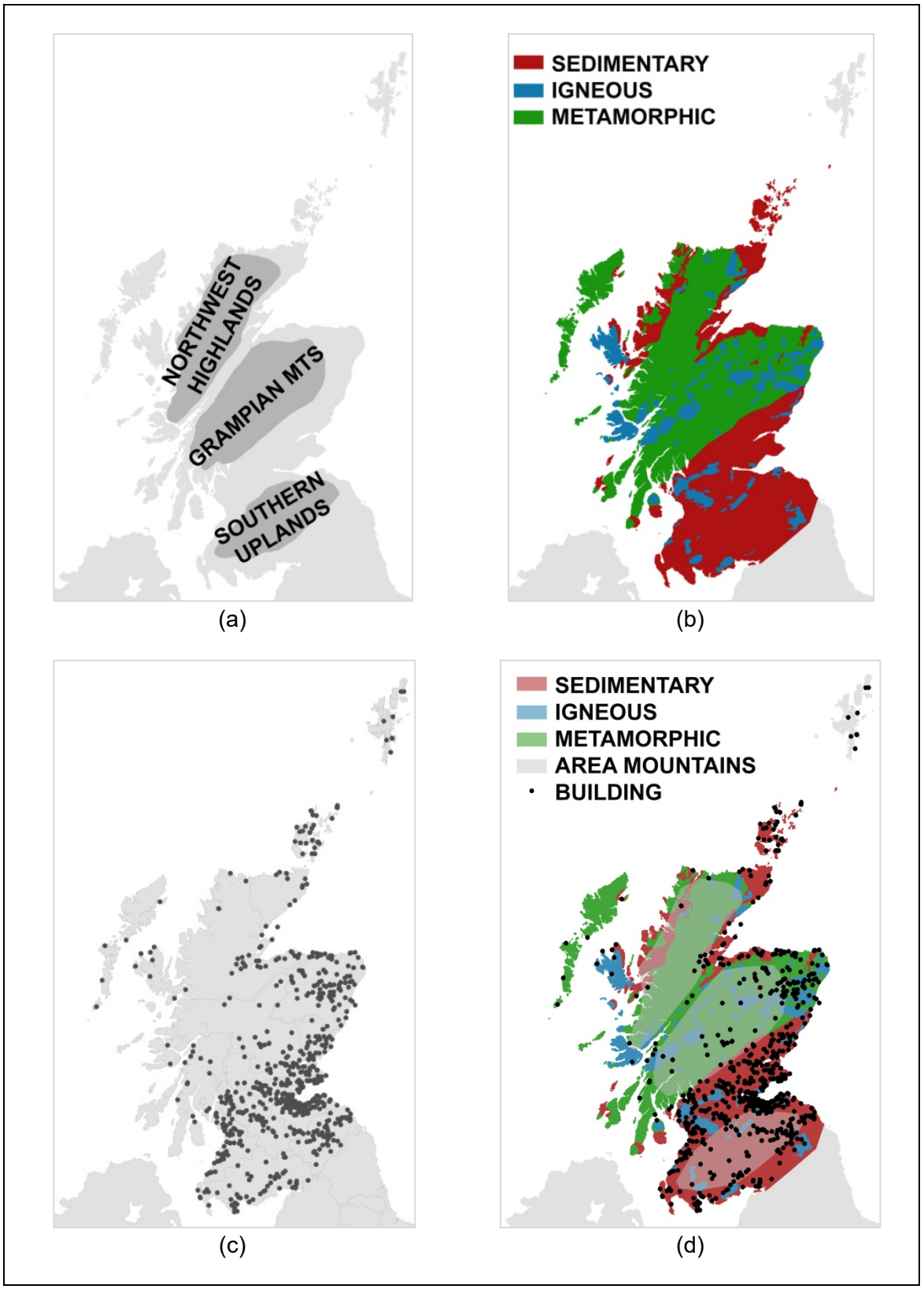


Figure 4.1: Maps of Scotland: (a) Schematic geography; (b) Simplified geology map; (c) Location of buildings built between the end of the sixteenth century and the eighteenth century; (d) Overlap of the three previous maps.

4.3 MORPHOLOGY OF THE STATELY COUNTRY HOME

The statistical analysis detailed in a previous chapter successfully related certain features of stately country homes to their masonry characteristics. In particular, four different aspects are studied: (1) the context of the buildings, including the location and period of construction; (2) the building plan, considering the average ground floor area, the maximum span of the first floor and the type of plan geometry; (3) the building section, defined through the number of floors above ground and the number of vaulted levels in the building; and (4) the stone masonry, characterised by the type of pattern and the predominant wall thicknesses at ground floor level.

The analysis sequence applied determined the degree of dependency between each pair of parameters. Table 4.1 presents the indexes defining this dependency, obtained from the statistical tests applied to each of the three possible combinations of parameters: factor–factor, factor–variable, variable–variable. The pairs with the highest rates (highlighted in red) share the highest degree of dependency and are therefore the most significant. In order to aid visualisation, Figure 4.2 gathers the pairs with the highest indexes in each combination and plots their corresponding networks of links. The abbreviations used in the plot respond to those defined in the methodology chapter.

As can be appreciated in the figure and table noted, the factor–variable combination has four different pairs of parameters scored with the highest index. Three of these (plan geometry (PL), period (PE) and masonry type (MT)) are related to the plan area (AA), while the fourth pair is defined by PL and prevalent wall thickness (T1). Instead, the highest index computed in the factor–factor combinations defines two systems of links. The first system is composed of a group of four strongly interconnected parameters: the PL, PE, MT and location (LOR). The second system is defined by one single pair of highly dependent parameters: the number of floors (NF) and number of vaulted levels in the building (NV). Finally, the highest index obtained from the variable–variable combination corresponds only to the pair of parameters defined by AA and the maximum span (MS).

Considering this system of links as a whole, two conclusions are reached. On one hand, of all the parameters highlighted, PL has the largest number of connections. Consequently, it is considered the most determinant parameter in the system. On the other hand, the pair defined by NV and NF is detached from the main network and therefore not significantly influenced by the remaining parameters. The following sections develop these findings to unravel the underlying reasons.

(a) FACTOR–VARIABLE COMBINATION

Statistical test applied: KOLMOGOROV–SMIRNOV TEST

	AA	MS	T1	T2
PL	**0.7**	0.5	**0.7**	0.6
PE	**0.7**	0.6	0.4	0.5
LOR	0.5	0.5	0.4	0.5
MT	**0.7**	0.5	0.3	0.5
NV	0.3	0.2	0.6	0.4
NF	0.4	0.3	0.3	0.5

(b) FACTOR–FACTOR COMBINATION

Statistical test applied: CHISQ TEST

	LOR	PL	MT	NF	NV	PE
LOR	NA	**1.0**	**1.0**	0.3	0.3	**1.0**
PL	**1.0**	NA	**1.0**	0.9	0.7	**1.0**
MT	**1.0**	**1.0**	NA	0.5	0.5	**1.0**
NF	0.3	0.9	0.5	NA	**1.0**	0.7
NV	0.3	0.7	0.5	**1.0**	NA	0.8
PE	**1.0**	**1.0**	**1.0**	0.7	0.8	NA

(c) VARIABLE–VARIABLE COMBINATION

Analysis applied: SMOOTHING

	AA	MS	T1	T2
AA	NA	**0.8**	0.2	0.2
MS	0.4	NA	0.0	0.0
T1	0.0	0.0	NA	0.4
T2	0.1	0.0	0.4	NA

Table 4.1: Indexes summarising the degree of dependency between the different pairs of parameters, calculated according to the methodology defined in a previous chapter. The abbreviations used respond to those defined in the methodology chapter.

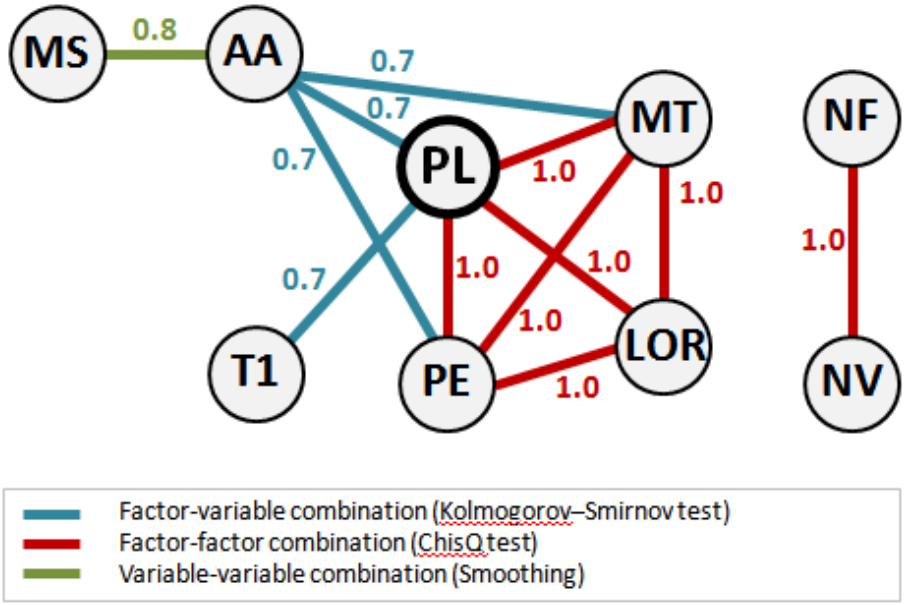


Figure 4.2: Map of the highest dependency indexes computed for each of the three different combinations of parameters respectively. The colour of the edge identifies the type of combination or test used, while the nodes represent the parameters. The abbreviations used respond to those defined in the methodology chapter.

4.3.1 PLAN TYPE (PL), PERIOD (PE), MASONRY TYPE (MT) AND LOCATION (LOR)

The PL, PE, MT and LOR parameters strongly influence each other. To understand the reasons behind this system of links, it is necessary to study each pair individually. In the case of the pair composed by the PL and PE, Figure 4.3 reveals certain complexities in the morphology of buildings as plans are generally related to multiple period groups. However, two cases stand out within the sample: towers and Vilas. In the case of towers, 86.9% of cases correspond to period groups before the seventeenth century. In contrast, all Vilas are within period groups related to the seventeenth and eighteenth centuries. This feature indicates that tower plans are clearly related to pre-seventeenth century times while Vilas appear from the seventeenth century.

The PL and MT pair shows much clearer distributions. In Figure 4.4 it is possible to appreciate that the majority of buildings (88%) are built with regular or irregular rubble masonry. However, the Vila is notable among all the plan types for being the only always including ashlar, either in one part or in the entire building.

The observations discussed are consistent with the results obtained for MT and PE. As shown in Figure 4.5, the majority of ashlar cases (50%) are related to the period between the seventeenth and eighteenth centuries while rubble masonries tend to

prevail in buildings related to earlier periods. At this point, the Vila is notable as a particular plan type in terms of masonry type and period of construction.

The observations derived from the study of LOR further contribute to this statement. In particular, Figure 4.6 demonstrates that the central and north-east areas were home to the majority of building activity in all the period groups (between 77% and 91%). The activity in the southern area also has a relevant weight in some groups (e.g. 32% for the “before seventeenth group”). On the other hand, in the north-west area and the islands, activity was much reduced in comparison. The study of LOR with respect to MT (Figure 4.7) and PL (Figure 4.8) highlights that the central area is dominated by regular masonry types (74% of cases with ashlar and regular rubble), and home to the majority of Vila type plan cases (86%). The north-west area stands out for gathering only rubble masonry, mainly irregular (75%), and no ashlar cases.

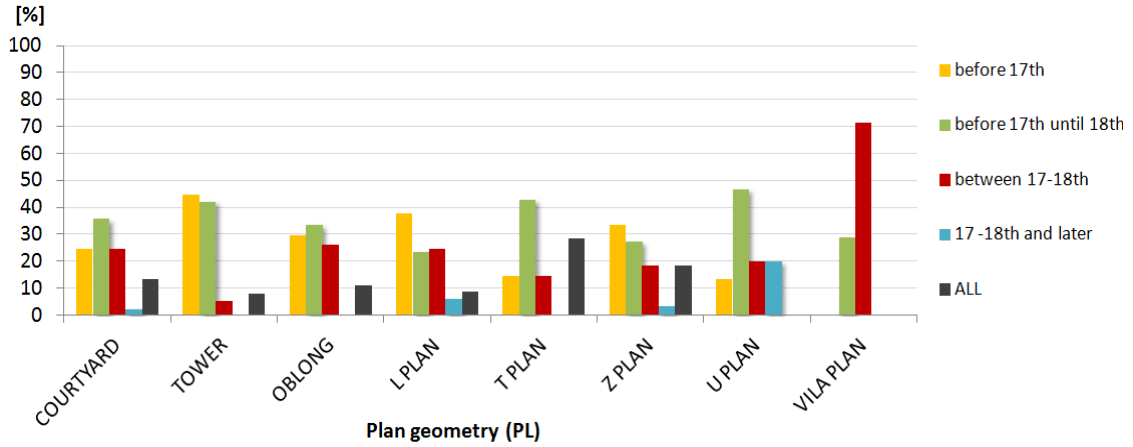


Figure 4.3: Histogram of the parameters PL according to PE.

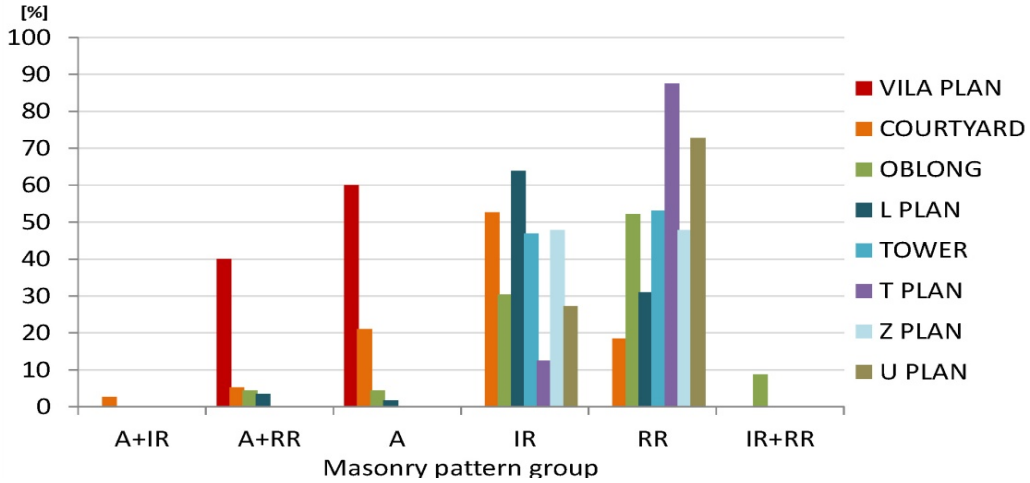


Figure 4.4: Histogram of the MT parameter according to overall building arrangement in plan (PL). X axis legend: A=ashlar masonry, RR=regular rubble, IR=irregular rubble.

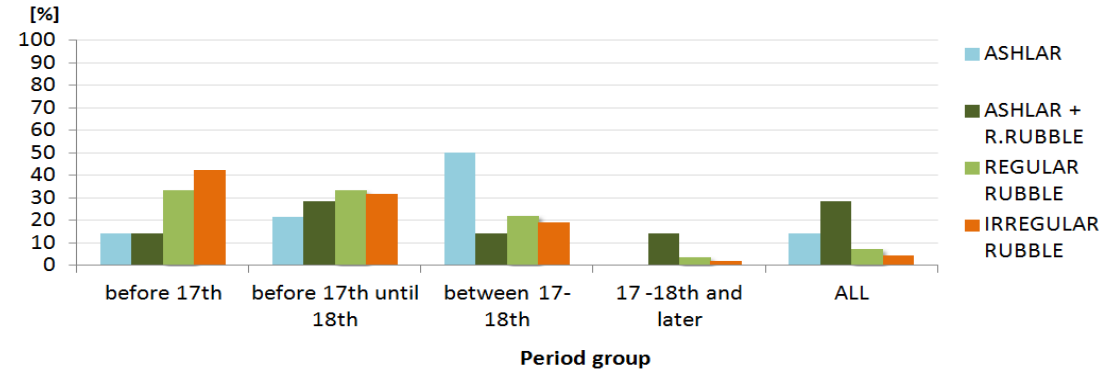


Figure 4.5: Histogram of the PE parameter according to MT.

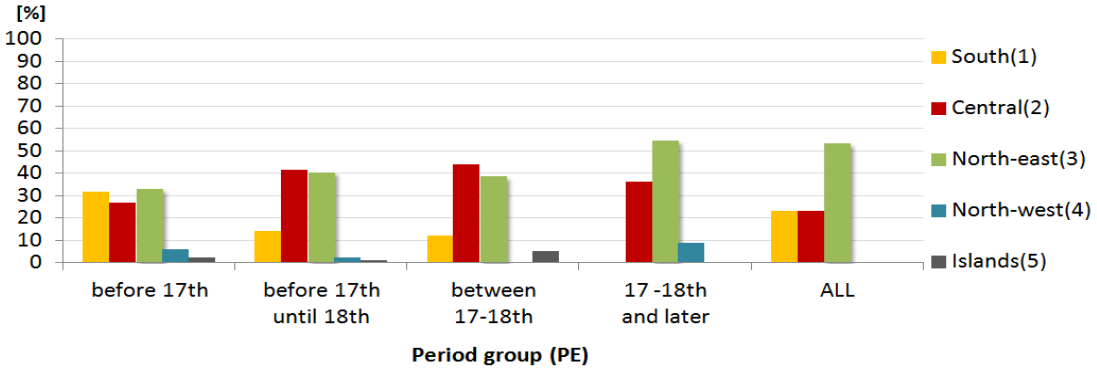


Figure 4.6: Histogram of the PE parameter according to LOR.

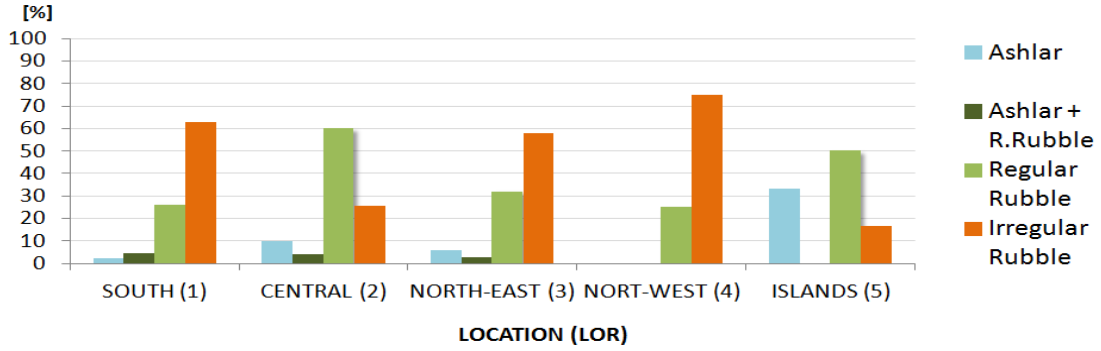


Figure 4.7: Histogram of the LOR parameter according to MT.

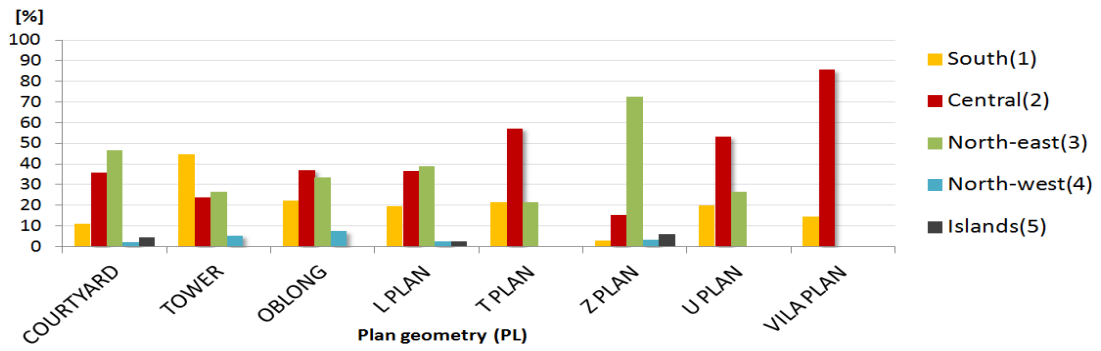


Figure 4.8: Histogram of the PL parameter according to LOR.

4.3.2 PLAN TYPE (PL) AND WALL THICKNESS (T1)

The detailed study of T1 in relation to the different types of PL plotted in Figure 4.9 highlights two extreme cases. As can be appreciated, the maximum ranges correspond to buildings with tower-type and Z-shaped plans. Ranges of tower-type plans vary between 0.6m and 2.7m, and those for Z-shaped plans vary between 0.6m and 3.3m. However, the majority of cases vary between 1.1m and 1.9m (65% of cases with a tower-type plan and 73% of cases with a Z-plan). The opposite situation is the case for buildings with Villa-type plans, with thicknesses varying between 0.7m and 1.2m (smaller range), although in most cases (71%), this figure is between 0.9m and 1.1m. The rest of the plan types have intermediate situations, with more frequent thickness between 0.8m and 1.1m, depending on the case at hand.

Considering the relevance of this feature for the purposes of this investigation, the link between thickness and plan type is further studied by considering the second prevalent thickness (T2), despite this not being among the most determining parameters (Figure 4.10). In this case distributions tend to vary with respect to the T1–PL pair and peak values usually happen with smaller thicknesses. Distributions do not have relevant variations in only three cases: tower plans, L-plans and courtyard plans. Vila plans, though, demonstrate a clear peak for thicknesses close to 0.9m (43%), and the majority of cases (71%) are between 0.8m and 1m. Considering the values of T1 and T2 together, Vila plans have the smallest thickness variations, with the majority of cases at 0.9m. In general, the differences in the distributions and peak values of T1 and T2 with respect to PL indicate the complexity of the buildings.

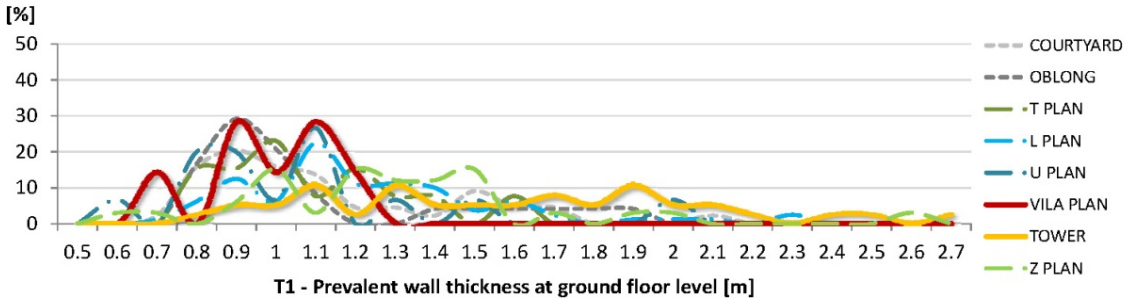


Figure 4.9: Density plot of the PL parameter according to T1. This type of plot is adopted here to aid comparison between the different groups. The complete set of histograms is provided in appendix 3, section 3.1.5.

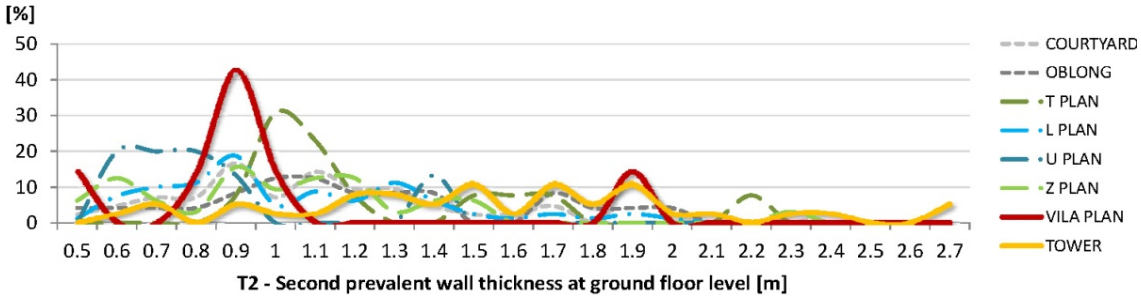


Figure 4.10: Density plot of the PL parameter according to T2. This type of plot is adopted here to aid comparison between the different groups. The complete set of histograms is provided in

appendix 3, section 3.1.5.

4.3.3 MOST RELEVANT LINKS RELATED TO GROUND FLOOR AREA (AA)

The parameter defining AA is strongly determined by the other four parameters: PL, PE, MT and MS.

The analysis of AA with respect to PL highlights different distributions. As shown in Figure 4.11, the most extreme case is the tower plan, where almost all buildings (95%) have ground floor areas smaller than 150sqm. A similar situation, but not so extreme, is found for oblong, L-, and T-plans. The majority of these cases have large ranges, which include values between 50sqm and 250sqm (85%, 80% and 79% respectively) but with a clear peak in areas smaller than 150sqm. Z-plans also have the majority of cases in the same range (74%) but their peak happens in areas bigger than 150sqm. More than half of U-plan cases range between 150sqm and 350 sqm (67%), but again a clear peak can be identified, this time on values between 250sqm and 350 sqm. Vila-type plans differ from the rest. In this case the sample appears clearly divided into two more or less equivalent groups: (1) buildings with areas between 150sqm and 350sqm, and (2) buildings of greater size, with areas between 450sqm and 650 sqm. Finally, courtyard plans have a homogeneous distribution, with cases between 50sqm and 1050 sqm.

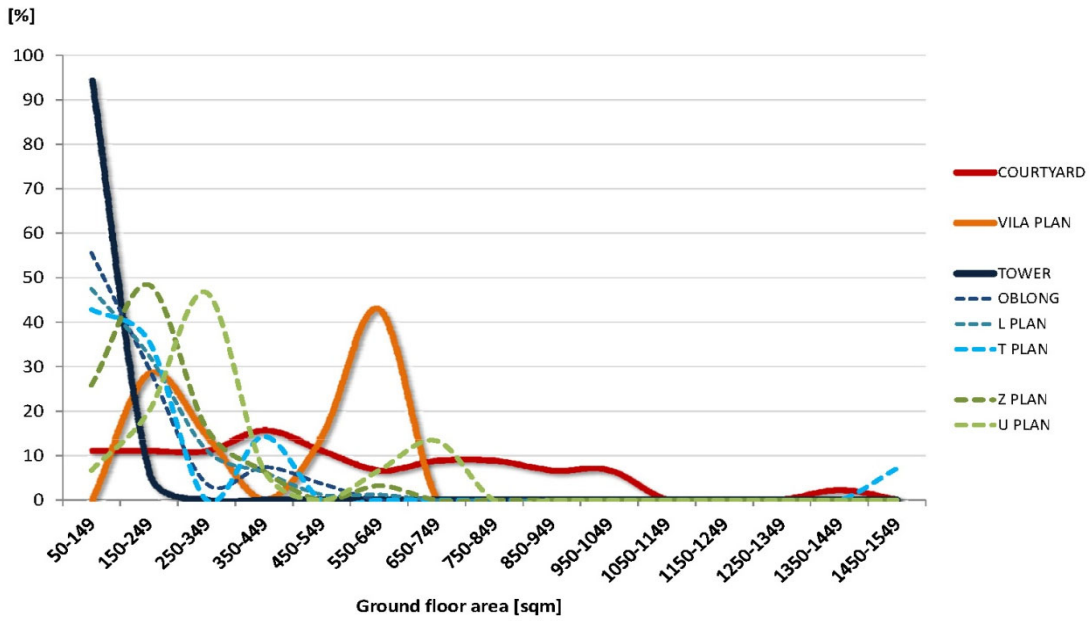


Figure 4.11: Density plot of the AA parameter according to PL. This type of plot is adopted here to aid comparison between different groups. The complete set of histograms is provided in appendix 3, section 3.1.5.

AA participates in the system of influences between PL, MT and PE previously discussed. The results therefore refer to the AA–PE and AA–MT pairs, adding to the previous conclusions. In particular, the study of AA with respect to PE shows a tendency of the plan area to grow with time. As shown in Figure 4.12, areas smaller than 150sqm were prevalent before the seventeenth century (47%) but achieved greater values in later period groups. However, analysis of the AA–MT pair in Figure 4.13 highlights that the majority of buildings constructed with rubble masonry, either regular or irregular, range between 50sqm and 250sqm (about 70%), with a clear peak between 50sqm and 150sqm. Buildings with ashlar facades, on the other hand, have the cases more homogeneously distributed, reaching larger ground floor areas.

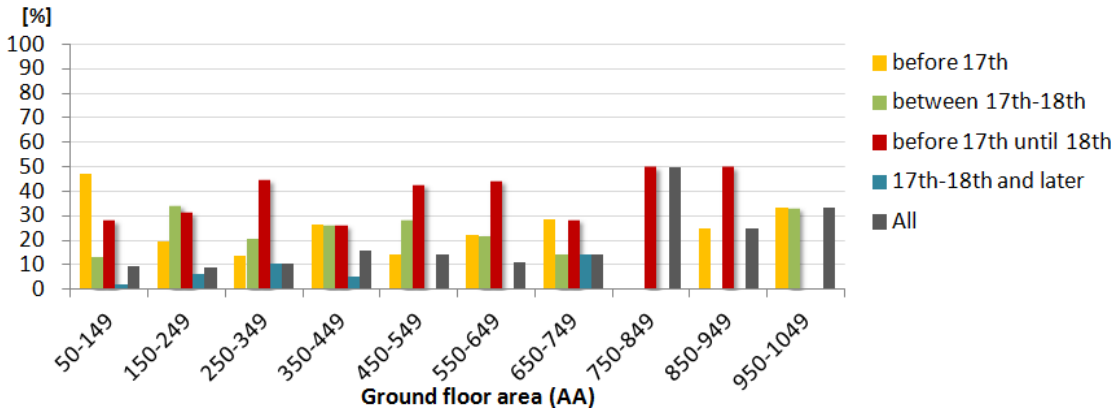


Figure 4.12: Histogram of the AA parameter according to PE.

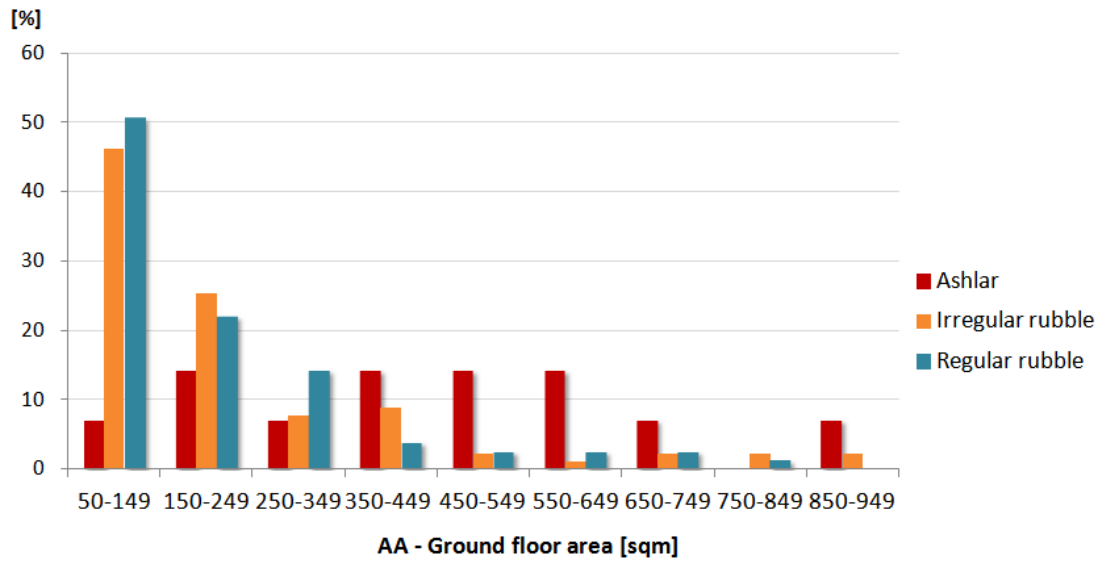


Figure 4.13: Histogram of the AA parameter according to MT.

The parameter referring to the MS of the building is only related to AA via a highly determining link. Figure 4.14 plots the histogram of AA with respect to MS. In this case, spans smaller than 4.5m are clearly related to areas lower than 150sqm. When the span value increases, the area value also tends to increase.

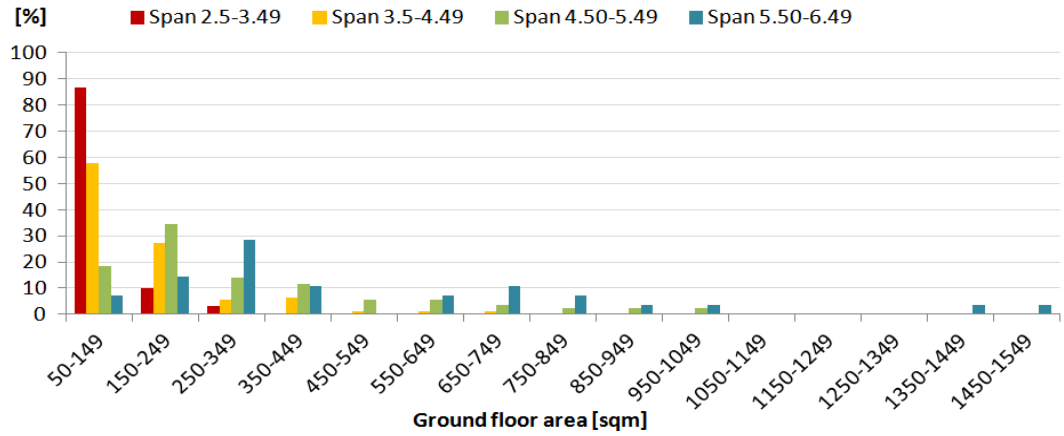


Figure 4.14: Histogram of the MS parameter according to AA.

4.3.4 NV–NF AND UNEXPECTED WEAK LINKS

The pair of parameters related to NF and NV share a clear dependency link, demonstrated in the analysis of their distributions shown in Figure 4.15. In particular, the NV has a tendency to decrease while the number of vaulted levels increases. This feature is clear when comparing the bars corresponding to 0 vaulted levels (blue) and those corresponding to two vaulted levels (red). The former concentrates the majority of cases (71%) at three floors while the latter is evenly divided among the two including the 74% of cases in total.

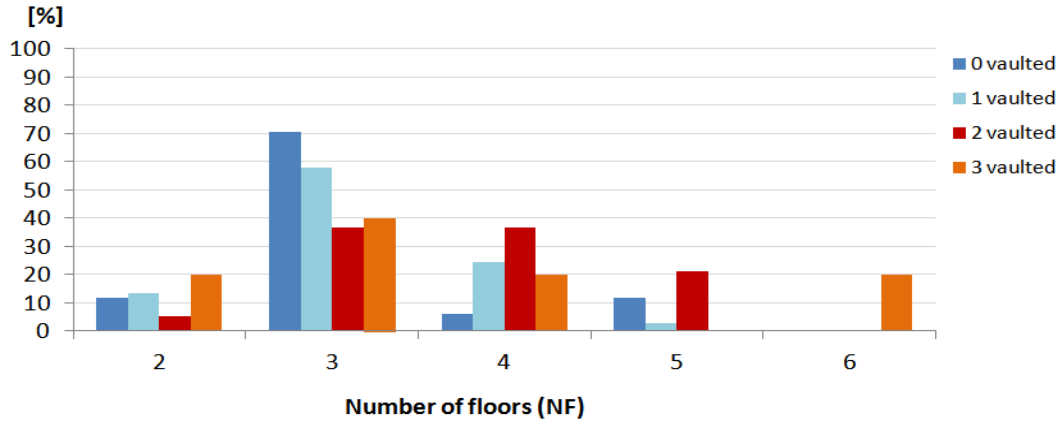


Figure 4.15: Histogram of the NF parameter according to NV.

However, this relevant dependency link appears isolated from the rest of the system. In masonry construction, parameters such as NF or MS are usually related to wall thickness as they define the structural system. Conversely, in the dependency map plotted, they do not share a relevant connection with thicknesses (T1, T2) or MT. This is because all buildings in the sample have similar values (see full set of histograms in appendix 3). In the case of NF, most of the buildings considered (81%) comprise three or four floors. Also, in the case of MS, 87% of the buildings have spans below 6.5m. Consequently, MS and NF are almost constant and T1, T2 or MT variations do not influence their values.

NV shares a discrete relation of dependency with T1, although most buildings (81%) have only one vaulted floor (usually the lower level). Detailed study of these two parameters shows a certain tendency of the wall thickness to grow when the number of vaults increases. Thus, buildings with two or more vaulted floors have wall thicknesses greater than 1.1m, while buildings without vaults usually have thicknesses between 0.9m and 1m. However, the most common situation (only one vaulted floor) has a wide range of thicknesses homogeneously distributed (between 0.7m and 2.5m), and a slight peak between 0.9m and 1.1m, which represents 42% of cases.

4.3.5 PREVALENT WALL THICKNESS (T1) AND PERIOD (PE)

The T1 and PE pair of parameters is not highlighted among the most determinant in the analysis. However, given the focus of the research, it is appropriate to dedicate a brief section to this pair. In particular, the analysis of T1 with respect to the PE demonstrates the tendency to reduce the thickness of the walls, in time quantifying it. Buildings constructed before the seventeenth century (80 cases) have wall thicknesses at ground floor level varying between 0.7m and 2.3m, with 1.1m the most common value (Figure 4. 16-A). On the other hand, those built between the seventeenth and eighteenth centuries (56 cases) have a smaller range, with thicknesses lower than 2m, and with the most common value 0.9m (Figure 4. 16-C). Finally, buildings constructed before the seventeenth century but altered or extended between the seventeenth and eighteenth centuries (81 cases) present an intermediate situation (Figure 4. 16-B).

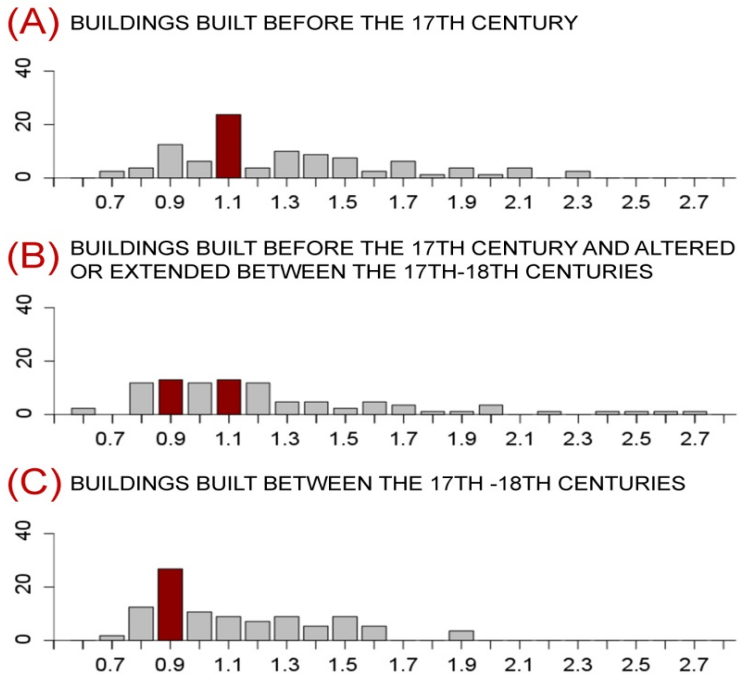


Figure 4. 16: Histograms T1 vs. PE. The x axis corresponds to the predominant wall thickness of each building (T1) in meters. The y axis defines frequency in percentages.

4.4 GROUPS OF ARCHITECTS AND MASONS

The third aspect considered in the characterisation of the context considers people developing roles related to masonry construction. The methodology presented in chapter 3 defines the sequence for the identification of a relevant network of people and later detailed study in order to individuate the main work environments. The results obtained during this process are presented now.

4.4.1 IDENTIFICATION OF NETWORKS

The dataset defined for the occasion includes a total of 539 interventions, 402 people and 402 buildings (see appendix 2). Application of the methodology previously outlined leads to the definition of a total of 31 different networks within the dataset elaborated. As shown in Figure 4.17, “Network 1” is notable its size in terms of number of people, interventions and buildings. For this reason, it is selected as the most relevant network and the subsequent analysis focuses only on this case.

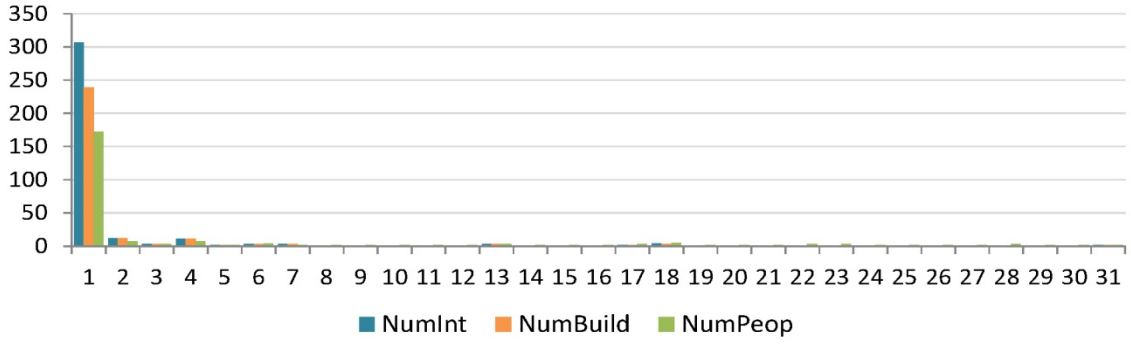


Figure 4.17: Summary of the size of the networks identified in the dataset according to the number of interventions, buildings and people. X axis defines the ID number of each network in the dataset; Y axis defines the quantity of cases.

4.4.2 DESCRIPTION OF NETWORK 1

Network 1 is composed of 172 people involved in 307 interventions. Figure 4.18 plots the network of connections where three different environments are clearly apparent. These environments correspond to successive periods of time and overlap from the late fifteenth century and early sixteenth century to the end of the eighteenth century. The bottom right environment is defined as Environment-1, that located in the middle of the plot is referred to as Environment-2, and, finally, the top-right environment is assigned the name Environment-3. The following sections develop each case, describing their main features.

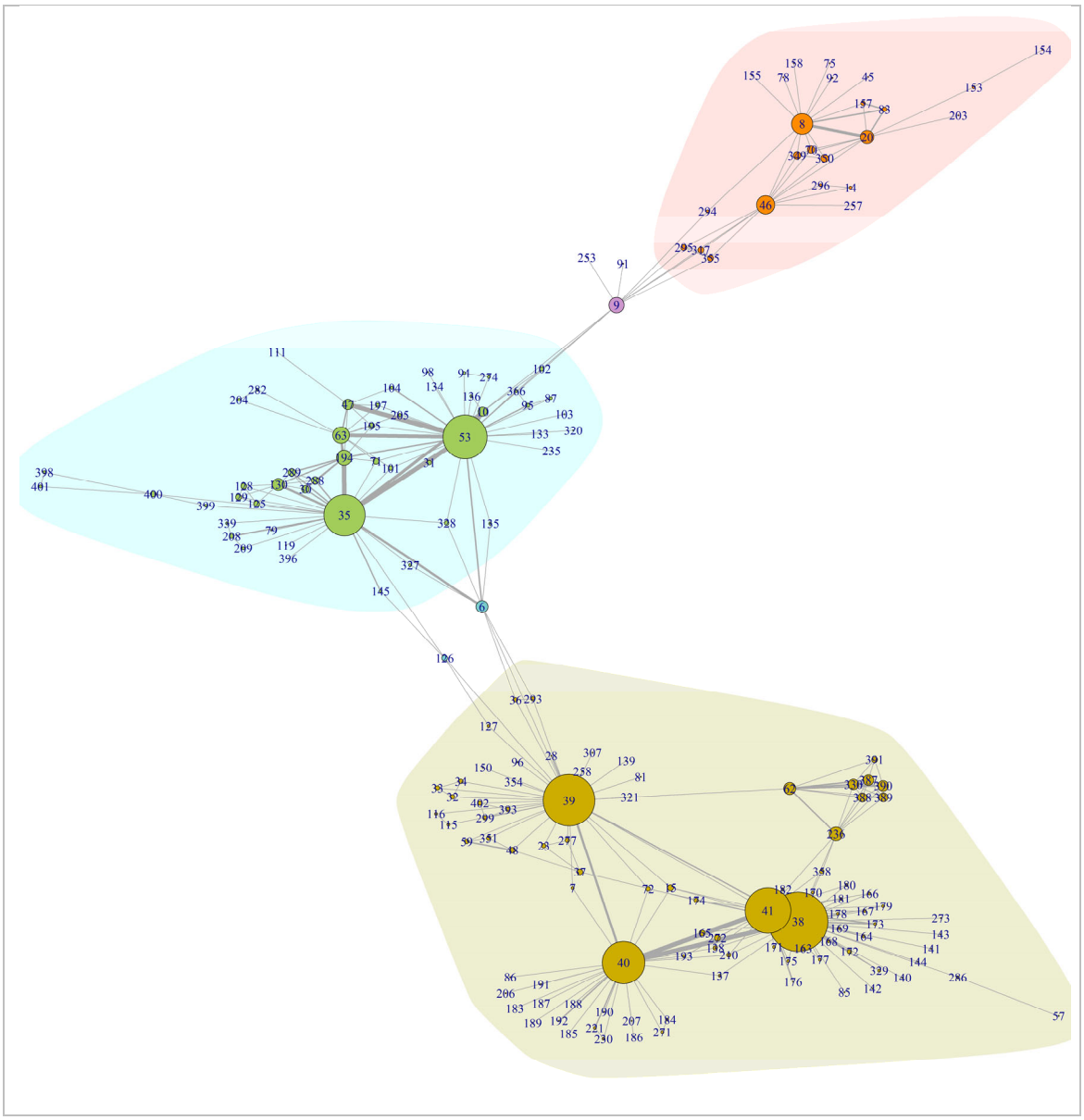


Figure 4.18: Network 1 plotted according to the analysis determined in previous chapters. The different environments identified are shaded with different colours (Environment-1 = brown, Environment-2 = green, Environment-3 = red).

4.4.2.1 Environment-1: The Adams

Environment-1 is defined by four centres corresponding to four members of the Adam family: William, John, Robert and James. The extensive work they produced and their innovative ideas marked the architecture of their time and defining what has been recognised as the “Adam style”.

- **William Adam** (1689–1748) was a building contractor and entrepreneur, recognised as an outstanding architect by his contemporaries (Gifford 1990). His excellent connections with the wealthy classes and government led him to develop an extensive work, which includes public buildings and private

residences (Colvin 1995, 62–66). At his death in 1748, his sons inherited the business, further developing it.

- **John Adam** (d.1790) was William's eldest son. He assumed the position of his father as laird of Blair Adam and Master Mason to the Board of Ordnance. He continued the family business, associated with his brother Robert. After 1770 his architectural activity appears to have ceased (Colvin 1995, 49–51).

- **Robert Adam** (1728–1792) Between 1754 and 1757 he undertook the Grand Tour, which brought him to meet prominent figures such as Charles-Louis Clérisseau and Giovanni Battista Piranesi. This gave him a vision that was essential for the development of his subsequent work. Upon his return, he settled in London, where his younger brother James joined him (Fleming 1962; Colvin 1995, 51–62).

- **James Adam** (1732–1794) was Robert's younger brother and partnered with him in most of the jobs. In 1769 he was named architect of the King's works, succeeding his brother, and he kept the position until 1782, when it was abolished (Colvin 1995, 48–49).

This environment includes interventions made throughout the eighteenth century. The earliest related to an Adam dates from 1721 and refers to the rebuilding of Hopetoun House in West Lothian (Glendinning, MacInnes, and MacKechnie 1996, 114; HES 2017a, 49127). The last dates from 1794 and refers to the designs of Robert Adam for King's Cramond, also known as Barnton House (King 2013, 158; HES 2017a, 50395).

Figure 4.19 illustrates the activity of the four members of the family, highlighting their coincidences in time. The work of William Adam developed during the first half of the eighteenth century. John took over and developed his activity as an architect mainly between 1748 and 1770. After they completed their Grand Tours, Robert, together with James, took the leadership until the end of the century, producing an extensive number of architectural works.

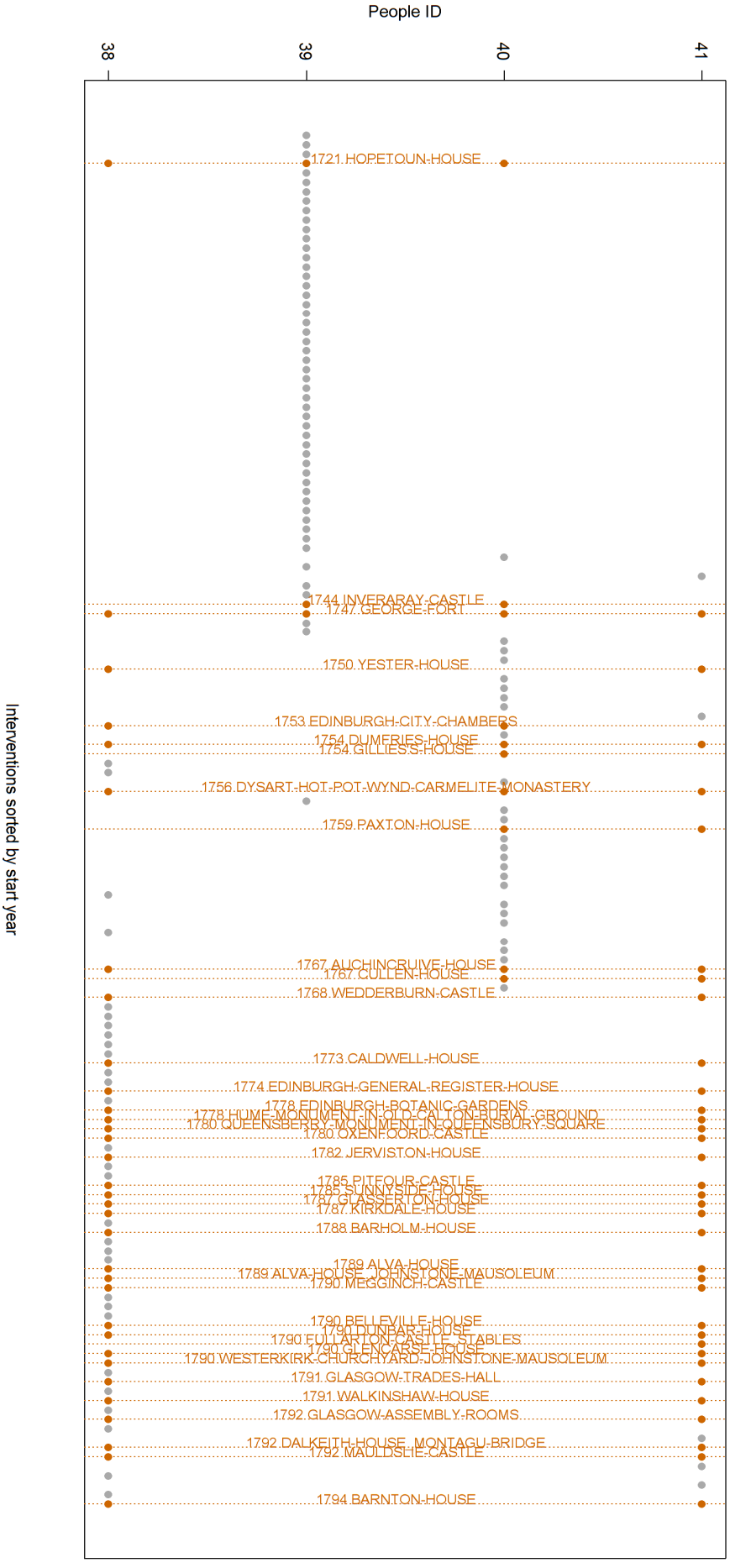

People ID
38
39
40
41
Interventions sorted by start year
1721 HOPETOUN-HOUSE
1744 INVERARAY-CASTLE
1747 GEORGE-FORT
1750 YESTER-HOUSE
1753 EDINBURGH-CITY-CHAMBERS
1754 DUMFRIES-HOUSE
1754 GILLIES'S-HOUSE
1756 DYSART-HOT-POT-WYND-CARMELITE-MONASTERY
1759 PAXTON-HOUSE
1767 AUCHINCRUIVE-HOUSE
1767 CULLEN-HOUSE
1768 WEDDERBURN-CASTLE
1773 CALDWELL-HOUSE
1774 EDINBURGH-GENERAL-REGISTER-HOUSE
1778 EDINBURGH-BOTANIC-GARDENS
1778 HUME-MONUMENT-IN-OLD-CALTON-BURIAL-GROUND
1780 QUEENSBERRY-MONUMENT-IN-QUEENSBURY-SQUARE
1780 OXENFOORD-CASTLE
1782 JERVISTON-HOUSE
1785 PITFOUR-CASTLE
1785 SUNNYSIDE-HOUSE
1787 GLASSERTON-HOUSE
1787 KIRKDALE-HOUSE
1788 BARHOLM-HOUSE
1789 ALVA-HOUSE
1789 ALVA-HOUSE-JOHNSTONE-MAUSOLEUM
1790 MEGGINCH-CASTLE
1790 BELLEVILLE-HOUSE
1790 DUNBAR-HOUSE
1790 FULLARTON-CASTLE_STABLES
1790 GLENCARSE-HOUSE
1790 WESTERKIRK-CHURCHYARD-JOHNSTONE-MAUSOLEUM
1791 GLASGOW-TRADES-HALL
1791 WALKINSHAW-HOUSE
1792 GLASGOW-ASSEMBLY-ROOMS
1792 DALKEITH-HOUSE_MONTAGU-BRIDGE
1792 MAULDSLIE-CASTLE
1794 BARNTON-HOUSE

Figure 4.19: X axis = William Adam (39), John Adam (40), Robert Adam (38) and James Adam (41); Y axis = Interventions ordered chronologically by start year; Lines and orange points highlight interventions where two or more people are involved; The label above the lines identifies the building where the intervention takes place and its start year.

4.4.2.2 Environment-2: Bruce and Smith

Environment-2 is defined by two centres corresponding to James Smith and Sir William Bruce. These two figures have different backgrounds but developed intersecting paths.

- **Sir William Bruce** (c.1630–1710) has been recognised by different authors as a prominent architect of his period (Wemyss 2014; Lowrey 2020). He was a gentleman architect who worked for the Scottish aristocracy. The origins of his education as an architect are unknown but have been related to his personal interest in the subject and his opportunities for travel. He is known to have been in England, Holland and probably France, and a foreign journey is documented in 1663. The number of buildings attributed directly to him is not large. However, his advice was usually sought by his contemporaries, spreading his influence beyond his own works. Between 1671 and 1678, Bruce assumed the position of Surveyor General and overseer of the King's buildings in Scotland. During this time, he was involved in the construction of the Palace of Holyrood where he coincided with James Smith. His projects include his own country seat at Kinross (Dunbar 1966, 75–82; Colvin 1995, 172–76).

  Mr James Smith of Whitehill (c.1645–1731) was also an important figure for the architecture of his time (Dunbar 1966, 83–88; Colvin 1995, 893–96; González-Longo 2020). The son of a master mason, he spent four years at the Scots College in Rome. By 1677, he was already in contact with Sir William Bruce, and two years later he married the eldest daughter of the Master Mason to the Scottish Crown, Robert Mylne, who was also working at Holyrood. In 1683 he became Surveyor Overseer of Royal works, a position he held until 1719. His works include a series of country houses such as Drumlanrig Castle and Dalkeith Palace. From about 1700, when the commissions he received fell notably, Smith seems to have connected with two other architects of the time: Alexander McGill (Colvin 1995, 630–31) and Colen Campbell (Colvin 1995, 209–13) .The former often worked in collaboration with Smith, but was also employed by Sir William Bruce to draw out plans for him (Glendinning et al. 1996, 74,120). The latter was strongly influenced by the work and designs produced by Smith (Glendinning et al. 1996, 109).

Of the people related to Bruce and Smith within the network obtained, some are notable for the number of coincidences in relation to centres: Robert Mylne, Tobias Bachop and William Morgan. Mylne and Bachop were two master masons who frequently collaborated with Bruce (Colvin 1995, 88–89, 678–679). Morgan was a carver who also collaborated in some projects in this circle (Dunbar 1966, 85).

The majority of interventions in this environment happened between the mid-seventeenth century and the beginning of the eighteenth century. Figure 4.20 shows the coincidences between the people mentioned in chronological order, identifying the relevant buildings.

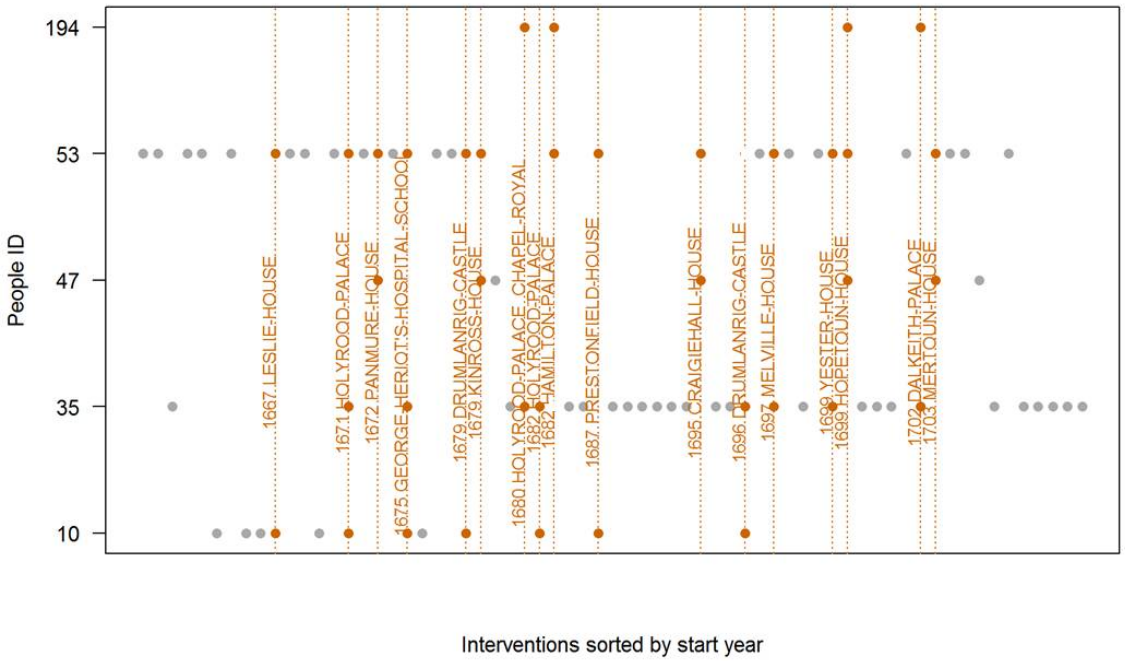


Figure 4.20: Y axis = Sir William Bruce (53), James Smith (35), Robert Mylne (10), Tobias Bachop (47) and William Morgan (194); X axis = Interventions chronologically sorted by their start year; Lines and orange points highlight interventions where two or more people were involved; The label above the lines identifies the building where the intervention takes place and its start year.

4.4.2.3 Environment-3: Sir James Murray

Environment-3 comprises one centre corresponding to Sir James Murray (d1634), a master wright appointed in 1605 as overseer of the King's works in Scotland and two years later also as the "principal master of all his majesties works in Scotland". Murray assumed the role of architect in the design and construction of a series of buildings, including his own house at Baberton. Of the people related to Murray within the network, the Master Mason to the Scottish Crown, William Wallace, highlights numerous coincidences in the same interventions (Glendinning, MacInnes, and MacKechnie 1996, 38; Colvin 1995, 674–675,1018). However, in cases such as Winton House, the direct involvement of Murray in construction works is not proven (Glendinning, MacInnes, and MacKechnie 1996, 38,56; Colvin 1995, 674–675,1018).

The majority of interventions in this environment happened before the mid-seventeenth century. Figure 4.21 shows the collaborations between the people mentioned in chronological order, identifying the relevant buildings.

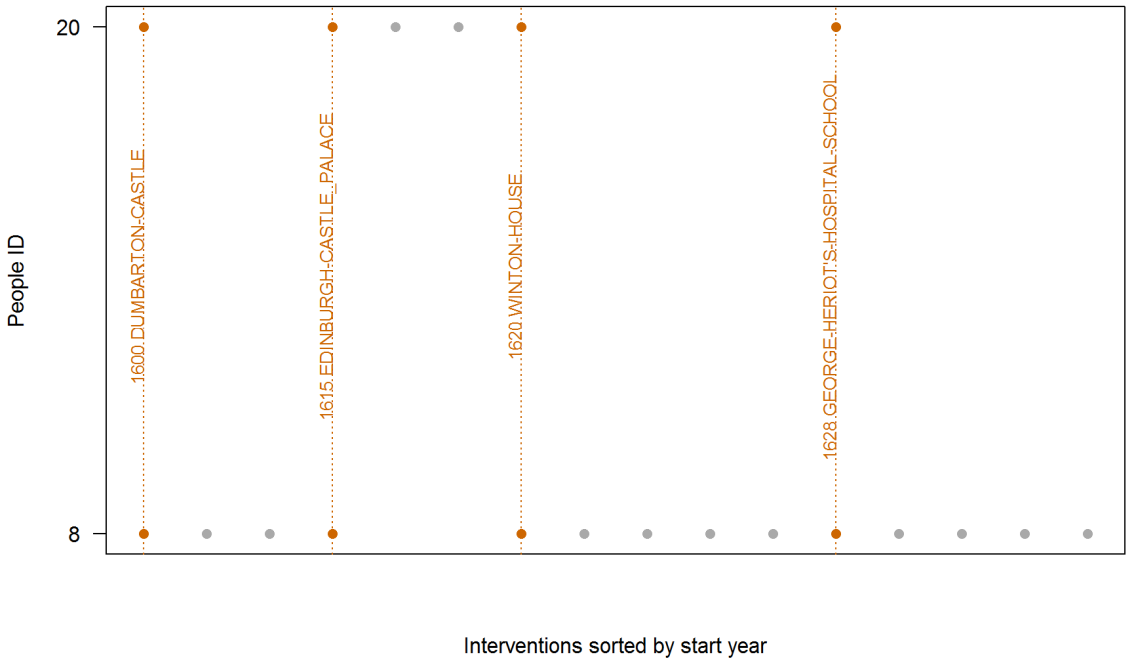


Figure 4.21: Y axis = Sir James Murray (8) and William Wallace (20); X axis = Interventions chronologically sorted by their start year; Lines and orange points highlight interventions where two or more people were involved; The label above the lines identifies the building where the intervention takes place and its start year.

4.4.2.4 Bridges between environments

The centres of Environments 1, 2 and 3 are connected by "bridge-people". These connections happen between environments 1 and 2 (two cases), and environments 2 and 3 (one case), as detailed below.

ALEXANDER MCGILL (d.1734)

Alexander McGill was an architect who collaborated with James Smith and Sir William Bruce. These two important people are at the centre of Environment-2. The works that McGill developed with them include the construction of Yester House (East Lothian), the contribution to Nairne House (Perth and Kinross) and the design of Cullen House (Moray). However, McGill also had a connection with Environment-1 through William Adam. This link is related to the project for the House of Dun although it did not involve a direct collaboration. In 1723 McGill designed a residence with its setting for Lord Dun, which was never built. Years later, Adam proposed a new design, incorporating McGill's ideas, which was finally built (Colvin 1995; Glendinning, MacInnes, and MacKechnie 1996).

JOHN LAMBERTUS ROMER (d.?1754)

John Lambertus Romer was a military engineer. He was involved in numerous works related to defensive constructions. Two of these make him a bridge between Environment-1 and Environment-2. The first is his contribution to Bernera Barracks, where James Smith (Environment-2) appears to have made a contribution (HES

2017a, 11796). The second happened during the 1730s, when he was involved in the design and improvement of the Edinburgh Castle defences. On this occasion William Adam (Environment-1) also participated in the interventions on Argyle Battery, Mills Mount Battery, the Low Defences and the Western Defences (MacIvor 1993).

JOHN MYLNE (d.1667)

John Mylne was a Master Mason of the Crown, who continued the construction of George Heriot's Hospital in Edinburgh, succeeding William Aytoun in 1943. This link with Aytoun relates him to Environment-3. However, the Earl of Rothes commissioned Mylne the extension and remodelling of Leslie House in 1667. His design was never constructed. The ideas of Sir William Bruce (Environment-2) were more successful and the house was finally completed by John's nephew: Robert Mylne. Robert had been John's apprentice and in 1668 succeeded his uncle as Master Mason of the Crown. This involvement in Leslie House made John Mylne a bridge between both environments (Colvin 1995).

4.5 DISCUSSION OF THE RESULTS

The results presented in the previous sections provide a comprehensive understanding of the context considered in the investigation in terms of masonry. The data used comes from secondary sources and is therefore is not genuine. However, innovation remains in the approach defined. The sequence of analysis enabled organisation and processing of data related to three relevant aspects of the context in terms of masonry: (1) the structure of the territory, (2) the morphology of the stately country home, (3) and the groups of architects and masons leading the architectural works. The results obtained provide an overview missing in the literature, and at the same time underpin the selection of a group of case studies meaningful for later analysis of their masonry.

The first aspect analysed is the structure of the territory. Scotland's geography can be divided into three main areas: the northern, more mountainous part; the southern part, with a much smoother relief; and the Central Belt, a flatter area located between the two. The central belt and southern areas are rich in sedimentary rocks, while metamorphic rocks prevail in the northern area. This is an important feature to note as sedimentary rocks include sandstones, which are considered stones with excellent construction characteristics because of their workability. Metamorphic rocks, on the other hand, are characterised by a hardness, which hinders the work of masons.

The structure of the land appears to determine the distribution of building activity. The highest concentration of buildings is generally identified in the less rugged areas, rich in sedimentary rocks. However, one particular case that escapes the general rule is Aberdeen. This area has a relevant density of buildings and is located in a zone of the north-east coast, which, despite having a smooth relief, is scarce in sandstone. Authors such as McMillan and Gillanders (1997, 10) and McMillan et al. (2006, 5) refer to the traditional use of local quarries as sources of building material. This highlights the link between the land and the masonry built. The criteria used for the selection of cases

therefore take into consideration the distinctive aspect of Aberdeen to assess the influence of the structure of the land on the characteristics of masonry.

The second aspect of the context considered is the stately countryside house. This is the type of building within the focus of the investigation. In particular, the aim was to identify those features that determine masonry characteristics in order to inform the selection of a meaningful group of case studies for later analysis. The statistical approach defined enabled development of the analysis based on objective criteria. In particular, the analysis considered four aspects of buildings: (1) the context, which includes the location and period of construction; (2) the building plan, which considers the average ground floor area, the maximum span of the first floor, and the type of plan geometry; (3) the building section, which is defined through the number of floors above ground and the number of vaulted levels in the building; and (4) the stone masonry, which is characterised by the type of pattern and the predominant wall thicknesses at ground floor level.

The results presented highlight plan type as the most determining parameter in the map of dependency links defined. In particular, the distributions obtained reveal certain complexities in the morphology of buildings, as plans are generally related to multiple period groups. However, one type of plan stands out among the others for its distinctive characteristics: the Vila. Vilas appear in the seventeenth century and are the only case to include always ashlar masonry in one part or in the entire building. Two possible range of sizes are identified for the ground floor area of the Vilas: one between 150sqm and 350sqm and the other between 450sqm and 650sqm. The opposite case is the tower, clearly related to before the seventeenth century and with the smallest plan size in the sample, with values below 150sqm. In addition, like most of the other cases, towers are related to rubble masonry, either regular or irregular. The rest of the plan types define intermediate situations.

The results related to the LOR and the PE match with what has been learned from previous analysis of the territory of the Central Belt, north-east areas, and, in some cases, the south, for the majority of building activity in all period groups. In contrast, activity in the north-west areas and the islands is much reduced. However, the study of the link between location and masonry type highlighted a significant feature. In particular, the north-west area stands out for incorporating only rubble masonry, mainly irregular (75%), and no ashlar cases. According to previous analysis, this area is characterised by the prevalence of metamorphic stones, which are difficult to work with. In order to further develop this aspect, the criteria used for the selection of cases will consider cases located in this area.

Regarding the parameters specifically referring to masonry, the analysis highlights certain features worth discussing. The first refers to the link between MT and the different period groups. In particular, rubble masonry is dominant before the seventeenth century. In the subsequent period group, which includes cases built prior to the seventeenth century but altered or extended during the seventeenth and eighteenth centuries, such prevalence diminishes and in the period group including buildings constructed between the seventeenth and eighteenth centuries, the dominant type becomes ashlar. This indicates variation in the construction of masonry, defining a turning point in the seventeenth century.

The second feature further develops this statement but expands the discussion to the second parameter related to masonry: the thickness. Analysis of prevalent wall thicknesses (T1) with respect to time (PE) highlights a decreasing tendency. Before the seventeenth century, the majority of the thicknesses are higher than 1m, while, afterwards, the predominant thickness is around 90cm. The seventeenth century therefore marks a changing point in this evolution. Analysis of the thicknesses (T1 and T2) corresponding to the different plan types (PL) further illustrates this observation as plan types related to before the seventeenth century have larger values of thickness (in the range of 3m), while the majority of cases of the Vila type, which is directly associated with the seventeenth and eighteenth centuries, are close to 90cm–100cm. These findings further strengthen the thesis defended by authors such as Dunbar (1966, 53) and McKean (1993, 2001), who highlighted a progressive abandonment of defensive schemes between the sixteenth and seventeenth centuries and questioned the castellated conception, which opposed such understanding.

Analysis of prevalent wall thicknesses (T1) with respect to time (PE) allows for one more observation. In particular, buildings constructed before the seventeenth century but altered or extended between the seventeenth and eighteenth centuries mostly have thicknesses varying between 80cm and 120cm. This is a distinctive feature as the groups built before the seventeenth century and between the seventeenth and eighteenth centuries have different distributions with clear peaks at 110cm and 90cm, respectively. In a study of Innes House, McKean (2003) highlighted the complexity of the construction history of buildings and identified a change in wall thickness as an indicator of different periods of construction. The building strategy of extension and alteration is a feature discussed in the literature by authors such as Dunbar (1966, 69), McKean (2001, 17) and Wemyss (2014, 317–20). The results obtained in the analysis thus provide evidence in this regard.

Finally, it is also worth highlighting a result, which, in the first instance, causes surprise. This is the weak link between parameters defining masonry characteristics (MT, T1 and T2) and those determining NF, MS and NV. These last three parameters define features of the structure which, in a system composed of load bearing walls, are known to be directly related to the thickness of walls. However, in this case, they do not appear to be relevant. The reason for this is that almost all the buildings in the dataset share similar values, as a result of the homogeneity in the cases. NF, NV and MS are therefore of secondary importance for the study of masonry morphology in this context.

In light of this, statistical analysis of the stately countryside house reveals a complex scenario in which plan type is the most determining parameter and is therefore considered critical for the selection of cases. Towers and Vilas represent the two case extremes well in terms of period of construction, plan and masonry characteristics, while the other types cover the intermediate range. The seventeenth century is highlighted as a turning point in masonry characteristics. On one hand, ashlar became the prevalent type of masonry from this century. On the other hand, the range of wall thicknesses narrowed down, reaching values close to 90–100cm. Finally, the study of the location parameter highlights the north-west area as the only place without ashlar cases. All these points emphasise determining aspects for masonry characteristics and will therefore be used to assess the selection of cases.

The third aspect of the context analysed focused on identification of the most relevant groups of architects and masons working at the time. The approach applied enabled individuating of one relevant network in terms of number of people, interventions and buildings. This network is composed of three main environments. The environments correspond to successive periods of time, which overlap from the late fifteenth and early sixteenth century until the end of the eighteenth century. The centre of the earliest environment is defined by Sir James Murray. He was a master wright who became "Principal Master of All His Majesties' Works In Scotland" and was claimed to be one of the first to act as an architect in Scotland (MacKechnie 1993). The data gathered in relation to this environment is not very extensive and the network of connections defined is therefore very limited. However, the significant feature of this environment is that all works are located before the middle of the seventeenth century and therefore related to the beginning of the transformation already outlined.

The second environment is pinned closely to the seventeenth century and has two centres. One is Sir William Bruce, a gentleman architect who worked for the Scottish aristocracy. The other is James Smith, architect, son of a Scottish master mason and educated in Rome. These two figures have been identified as architects with an important contribution to the development of Scottish architecture (Dunbar 1966; Colvin 1995; González-Longo 2012; Wemyss 2014; Lowrey 2020; González-Longo 2020). The plot of common interventions highlights a key point in the chronology: the intervention in 1670s in Holyrood Palace. This is the first documented coincidence of Bruce and Smith on a working site. The intervention at Holyrood Palace was also shared with Robert Mylne, a master mason highlighted as a relevant person in the network, who also shared other collaborations in later years with both architects. In addition to Mylne, two other people are relevant: the master mason Tobias Bachop, closely related to Bruce, and the carver William Morgan, who appears to have collaborated on different occasions with Bruce and Smith. The coincidences between the two figures on the same site and the series of connections between the three people identified as relevant define a scenario favourable for the exchange of experiences. This is an element to consider in the study of masonries built in this environment.

The latest environment is clearly related to the eighteenth century and represents the largest number of interventions. The centres in this environment are four members of the Adam family. The first contributions correspond to the father, William Adam, who started the family business. When he died, the leadership was assumed by John, his elder brother, who, years later, passed it to Robert. James, the younger brother, has always been presented as Robert's partner (Colvin 1995). This sequence characterises an environment which, despite having four heads, defines a single family project that evolved according to changes in leadership over the years. These changes could be related to variations in ways of thinking and solving work. The key dates in the chronology of this evolution are therefore considered to be: (1) 1748, the year when William Adam died and John Adam assumed the leadership; (2) 1770, the year when John Adam's activity apparently ceased; and (3) the interval of time between 1754 and 1757, when Robert Adam undertook his Grand Tour. The timeframes determined by these dates determine opportunities for change, which are worth considering in the study of masonries.

The bridges existing between the three environments do not constitute a strong channel for the direct transmission of knowledge and are therefore not considered determinant. Each environment is therefore considered independent and as its own entity.

The above discussed leads to the individuation of a number of timeframes. These timeframes are delimited by changes of leadership or coincidences between leading people. In this way, each timeframe potentially defines a period in which architecture is produced based on a specific mindset and knowledge. This mindset and knowledge can vary from one timeframe to another because of new inputs added by the event defining the transition. Comparison of the works produced in consecutive timeframes may therefore highlight variations, which can easily be related to the context framed. Figure 4.22 illustrates the timeframes derived from the discussion. With this in mind, a scenario well depicting the context defined should include works related to each of the three work environments described and distributed widely between the timeframes set out.



Figure 4.22: Diagram of the six timeframes (T1 to T6) defined according to the discussion of the three environments identified. The x axis defines years while the y axis refers to the centres of the three environments defined.

It is important to highlight that the dataset considered in the analysis was built based on the review of existing literature, which compiled the architecture built by the most relevant people of the period in terms of amount of recognised and documented work. This principally refers to the work of architects. The network analysis developed provides a good understanding of the appearance and consolidation of this role in Scotland. However, very limited references are found in the literature related to the contributions and leadership of masons. Including non-architect lead works among the

study cases considered to investigate the morphology of masonries would therefore contribute to a more complete overview of the built reality of the time.

Finally, the mapping of building locations and how these correspond to the different environments provides an understanding of the influence of each group in the territory. As can be seen in Figure 4.23, the environment linked to the earliest timeframe has cases concentrated in the areas close to Edinburgh. The subsequent environments successively cover larger areas of the territory. The scattering identified will be considered for the selection of the group of case studies in order to best represent it.

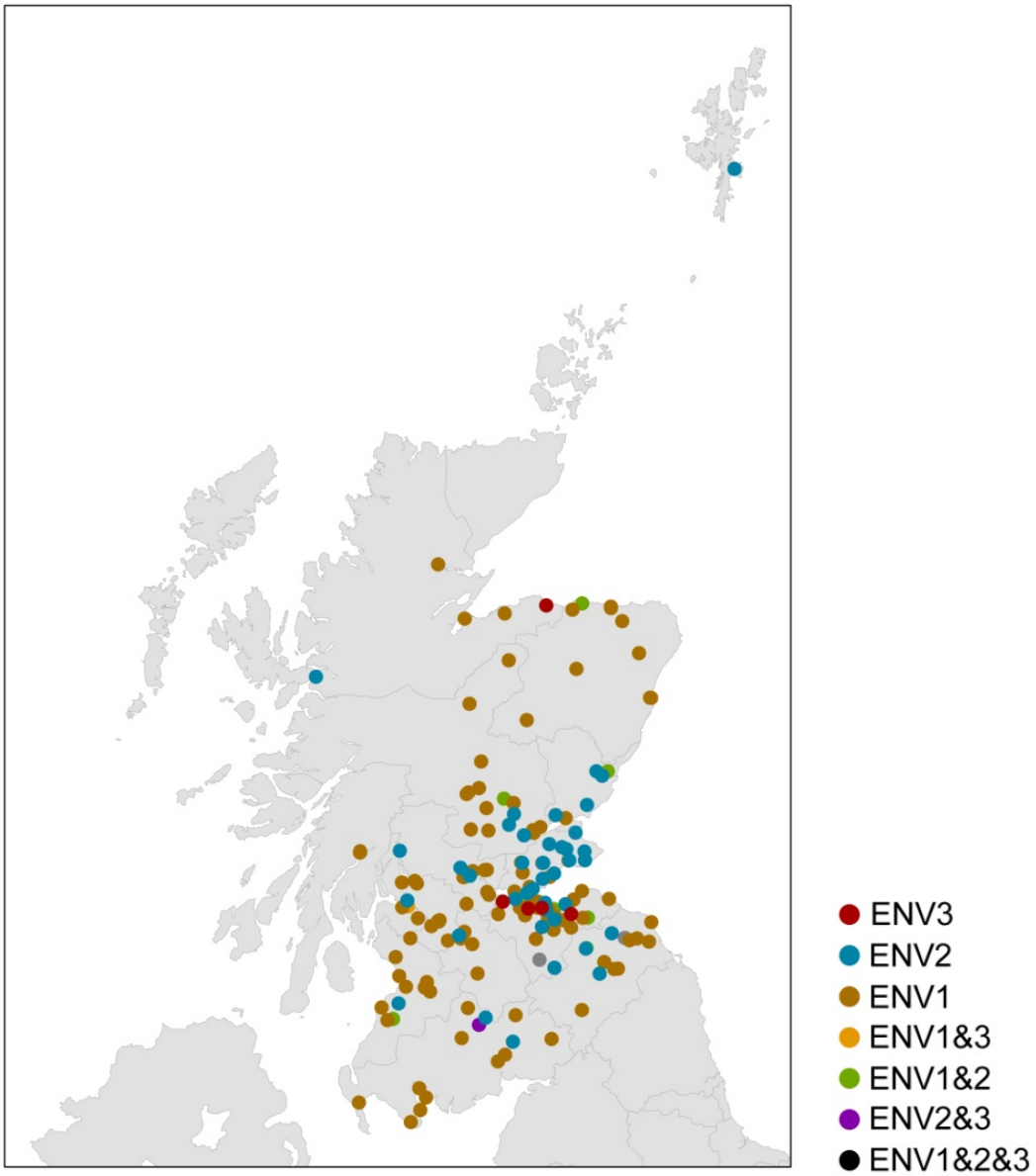


Figure 4.23: Location of buildings corresponding to the environments identified in the analysis of groups of architects and masons.

4.5.1 FINAL CONSIDERATION

The material discussed defines a meaningful context for the study of masonries. The conclusions obtained in each analysis identify factors that are determinant for the study of masonries. According to the methodology defined in this investigation, these factors are used as criteria for the selection of case studies representative of the context analysed. Table 4.2 summarises the resulting selection criteria.

Regarding the structure of the territory, three zones are considered. The first is defined by sandstone-rich areas, which include the Central Belt, south and part of the north-east. The second zone incorporates areas with high construction density but poor in sandstone, including the north-east area and the surroundings of Aberdeen. The last zone corresponds to the north-west of the territory, where no ashlar was identified.

Similarly, based on statistical analysis of stately country houses, three different categories are defined. The first and second categories define the two extreme cases identified: pre-seventeenth century towers and Vilas built between the seventeenth and eighteenth centuries. The third category includes intermediate cases, incorporating new wing additions and isolated residences with different plan types and sizes.

Instead, the results obtained from the network analysis of architects and masons define two categories: (1) non-architect-led works; and (2) architect-led works. The latter includes three sub-categories corresponding to the three different environments identified.

The criteria related to the buildings and networks define a chronological sequence, which captures the transformation of the building industry as a result of the emergence of the architect, and the evolution of the buildings designed and built between the late sixteenth and eighteenth centuries.

Finally, as discussed in the methodology section, two additional factors related to the practicalities of the investigation also determine the selection of cases. These refer to essential conditions for the study of masonries: accessibility to sites and the visibility of masonries defining the elevations. The presence of harling or vegetation prevents the adequate inspection of wall face patterns. Ruins offer an ideal opportunity in this regard as they generally enable the inspection of both external and internal wall faces and, in the case of partially collapsed walls, the structure section. The definition of the final sample of cases therefore pursues equilibrium between ruins and buildings in good condition where possible.

STRUCTURE OF THE COUNTRY	Sandstone-rich areas, including the Central Belt, south, and part of the north-east.
	Areas with high density of construction but poor in sandstone, including the north-east area and the surroundings of Aberdeen.
	Areas in the north-west of the country, where no ashlar was identified.
CHARACTERISTICS OF THE STATELY COUNTRY HOME	Towers built before the seventeenth century.
	Vilas built between the seventeenth and eighteenth centuries.
	Intermediate cases, including both new wing additions and isolated residences with different plan types and sizes.
NETWORKS OF ARCHITECTS AND MASONS	Non-architect-led works.
	Architect-led works corresponding to the three environments identified.

Table 4.2: Criteria for the selection of case studies representative of the context analysed.

4.6 CASE STUDIES

The criteria derived from the analysis of the context, in addition to the factors related to the accessibility and visibility of the masonries, lead to the definition of a sample comprising 33 buildings. These are organised in two main groups with three sub-groups each, synthesising the criteria previously presented. Table 4.3 determines the groups corresponding to each case, condition (ruin/not ruin), location in Scotland, and timeframe group. Considering the chronological character of the sample, certain key dates related to the timeframes previously determined are also highlighted. Figure 4.24 plots the distribution of the different cases in the territory, differentiating between the groups and environments defined; and Figure 4.25 overlaps with the results obtained in the analysis of the structure of the territory. As can be appreciated, they are scattered through the Central Belt, south, north-east and north-west areas and Aberdeen, fulfilling the conditions of the geographical factor.

The following sections briefly introduce the construction history of each case as well as their plans in order to justify their selection and highlight the parts of the building included within the scope of the investigation.

GROUPS		BUILDING NAME	CONDI-TION	LOCATION	TIME FRAME
NON-ARCH. LEAD WORKS	TOWERS BEFORE 17TH CENTURY	Tolquhon Castle tower	Ruin	Aberdeen	-
		Balgonie Castle tower	Not ruin	Fife	-
		Craigmillar Castle tower	Not ruin	Edinburgh	-
		Burleigh Castle tower	Ruin	Perth and Kin.	-
		Castle Campbell tower	Not ruin	Clackmannan	-
		Kilchurn Castle tower	Ruin	Argyll and Bute	-
		Holyrood Palace tower	Not ruin	Edinburgh city	-
	NEW WING ADDITIONS	Tolquhon	Ruin	Aberdeen	-
		Craigmillar	Ruin	Edinburgh	-
		Aberdour	Not ruin	Fife	-
		Balgonie	Ruin	Fife	-
		Kilchurn	Ruin	Argyll and Bute	-
	ISOLATED RESIDENC.	Glenbuchat	Ruin	Aberdeenshire	-
		Pittarthie	Ruin	Fife	-
		Gilbertfield	Ruin	South Lanarkshire	-
		Auchans	Ruin	South Ayrshire	-
		Redhouse	Ruin	East Lothian	-

ARCH. LEDWORKS	ENV.3	Linlithgow	Ruin	West Lothian	T1
		Baberton House	Not ruin	Edinburgh city	T1
	ENV.2	Holyrood Palace (front)	Not ruin	Edinburgh city	T3
		Drumlanrig	Not ruin	Dumfries & Gal.	T3
		Kinross House	Not ruin	Perth and Kinross	T3
		Craigiehall	Not ruin	Edinburgh city	T3
		Dalkeith House	Not ruin	Midlothian	T3
		Auchindinny	Not ruin	Midlothian	T3
	ENV. 1	Mellerstain (phase 1)	Not ruin	Scott.Borders	T4
		House of Dun	Not ruin	Angus	T4
		Cumbernauld House	Not ruin	North Lanarkshire	T4
		Haddo House	Not ruin	Aberdeenshire	T4
		Chatelherault Lodge	Not ruin	South Lanark.	T4
		1748: William Adam dies.			
		Dumfries House	Not ruin	East Ayrshire	T5
		1757: Robert Adam returns from his Grant Tour.			
		Penicuik	Ruin	Midlothian	T5
		Wedderburn	Not ruin	Scott.Borders	T5
		1770: The activity of John Adam seems to cease.			
		Mellerstain (phase 2)	Not ruin	Scott.Borders	T6
		Dalquharran	Ruin	South Ayrshire	T6
		Newliston	Not ruin	Edinburgh city	T6
		Gosford	Not ruin	East Lothian	T6

Table 4.3: Study cases classified according to the six categories defined.

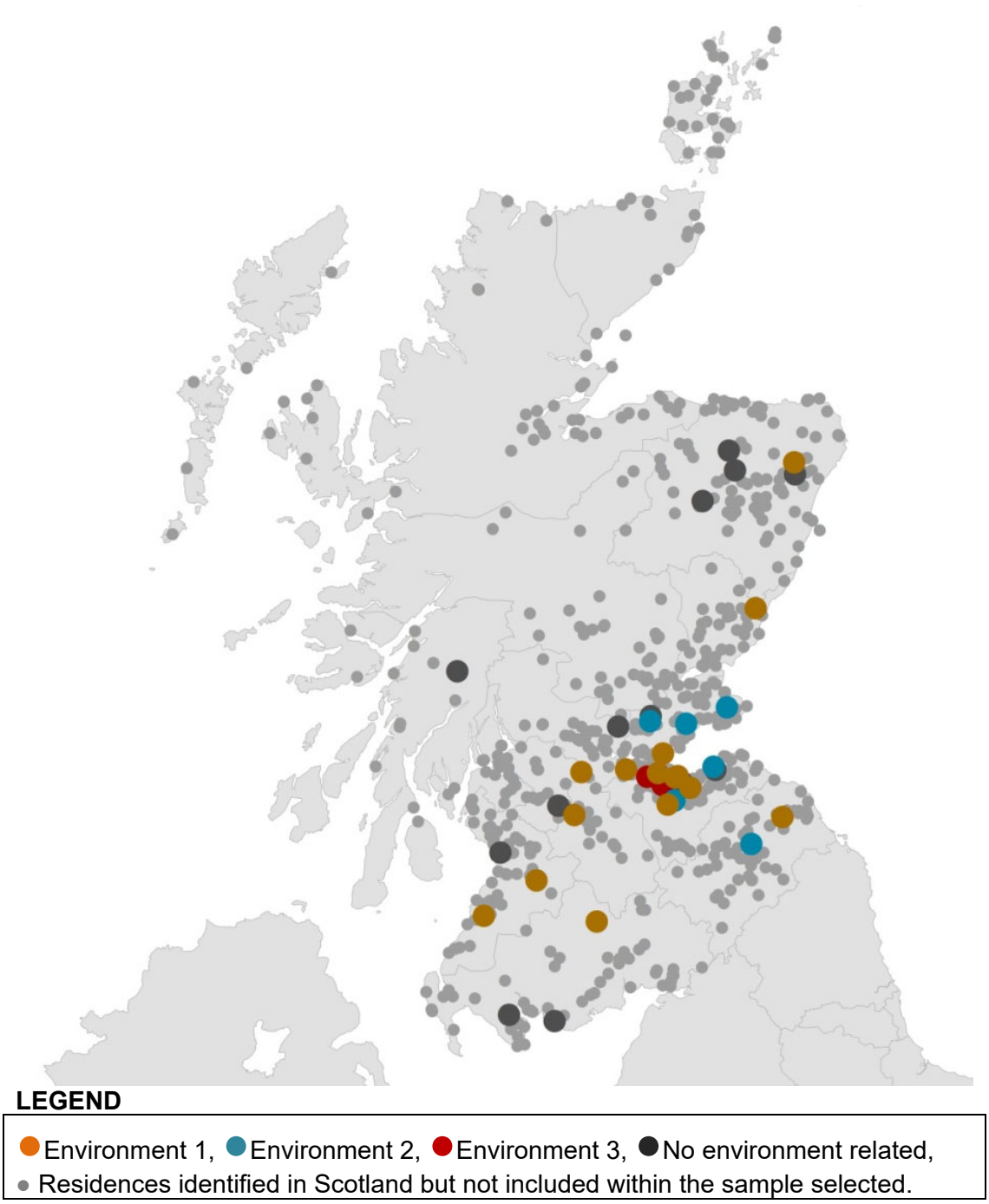
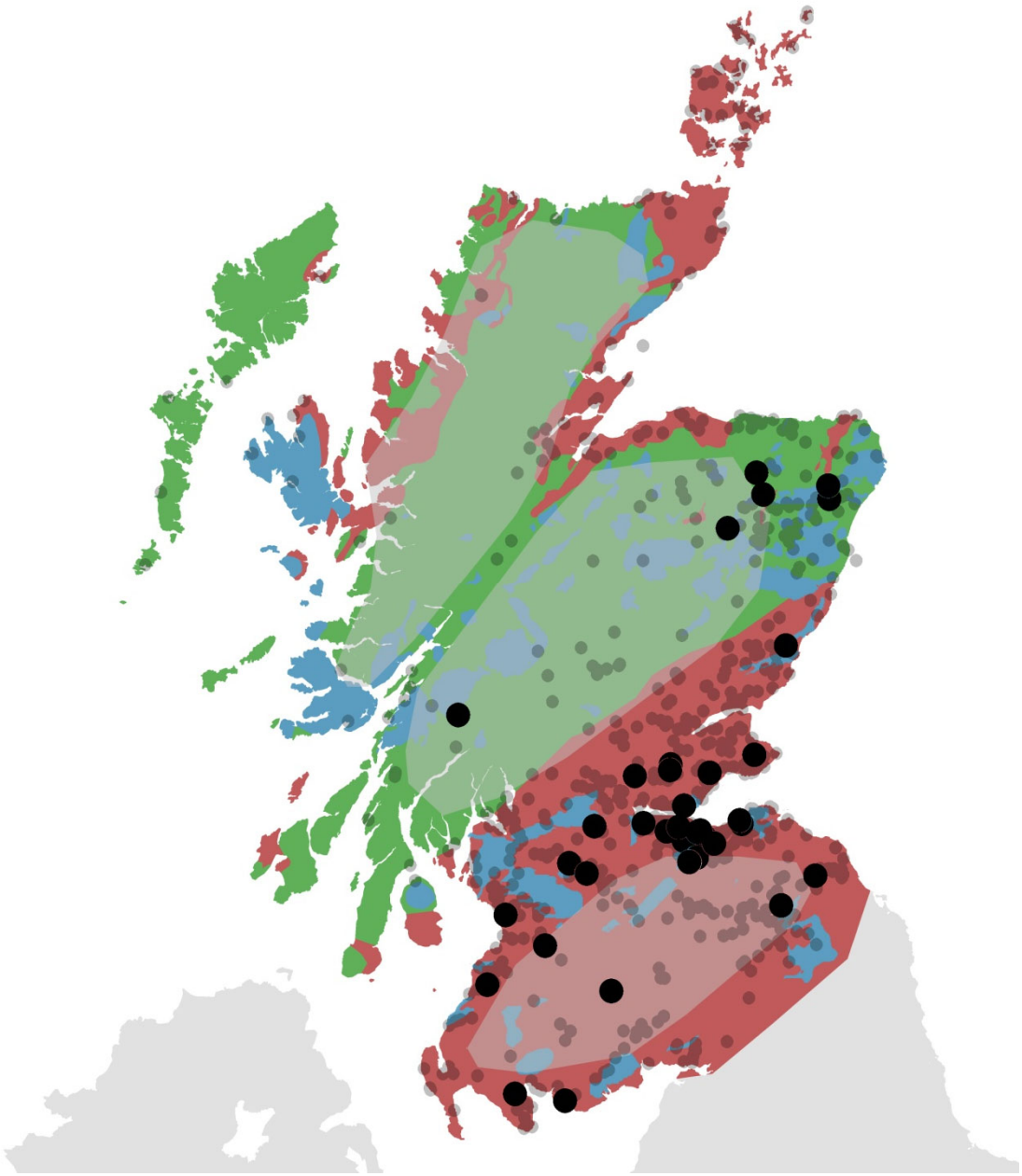


Figure 4.24: Location of the study cases considered, highlighting how they belong to the work environments defined.



LEGEND

Sedimentary Igneous Metamorphic Mountainous areas Case studies
Residences identified in Scotland but not included within the sample selected.

Figure 4.25: Location of the case studies selected, overlapped with the results obtained from the analysis of the structure of the territory.

4.6.1 NON-ARCHITECT-LED WORKS

4.6.1.1 Towers built before the seventeenth century

The first category includes seven towers built before the seventeenth century (Table 4.3). According to existing literature, the towers of Tolquhon, Balgonie and Craigmillar could have been built between the thirteenth and fifteenth centuries, while Burleigh, Campbell and Kilchurn apparently date from the fifteenth century. The old tower of Holyrood is the most recent as its construction is linked to the beginning of the sixteenth century. All the cases experienced alterations in subsequent periods. The most relevant in terms of masonry generally affected the upper part of the towers and some openings (HES 2017a, 19599, 31389, 52109, 27879, 48229, 23673, 52385, 2017b, SM90302, LB16664, SM90129, SM90045, LB1941, SM90179, LB28022).

With regard to geology, Tolquhon and Kilchurn are located in areas with a predominance of metamorphic rocks, while the remaining cases are in sandstone-rich areas. Figure 4.26 presents the plan for each of the cases, highlighting the parts considered within this category.

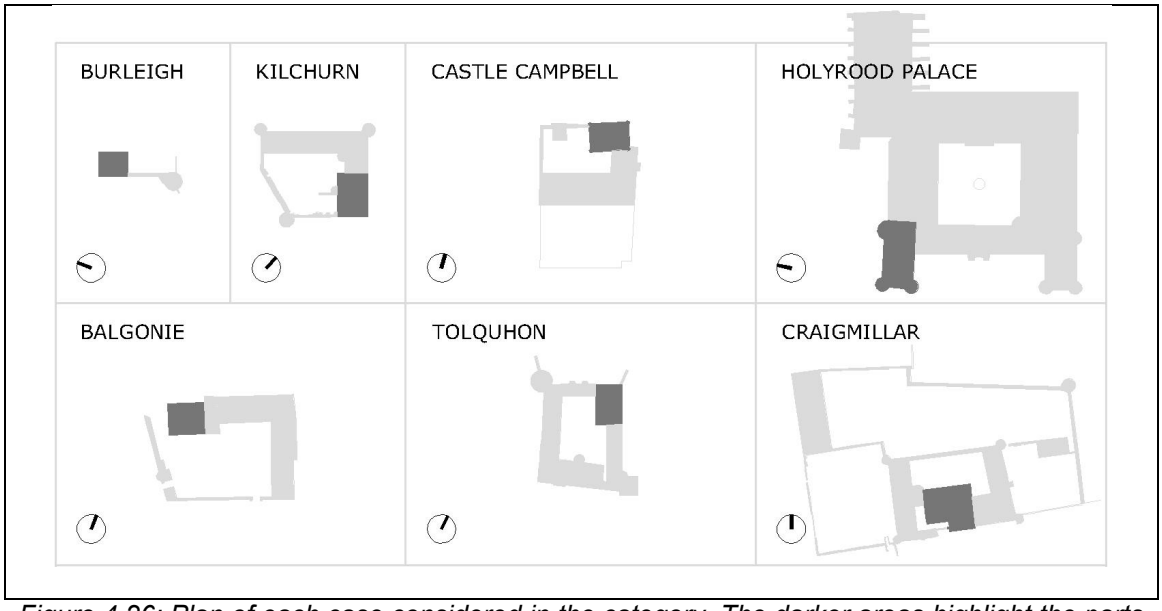


Figure 4.26: Plan of each case considered in the category. The darker areas highlight the parts within the scope of the group.

4.6.1.2 Isolated residences

The second category includes five buildings generally referred to as tower houses. These are isolated residences built or considerably altered during the seventeenth century but generally deriving from earlier construction logic. The five cases have

vaulted ground floors, while the upper levels are generally composed of lighter solutions. The plan geometries of the cases considered are either L- or Z-shaped.

Glenbuchat is the earliest case in the group. It was built in the 1590s but had some alterations in subsequent times, which affected the internal layout, windows and garrison (HES 2017a, 16780, 2017b, SM90151; Rutherford 2004). The interesting aspect of this case is its location in an area with a predominance of metamorphic rocks. The probable unaltered condition of the masonries making up the lower levels of the building is also a value. However, this is the only case that, in later times, underwent some consolidation, conservation and repair works, with the aim of opening it to the public as a historic site. The rest of the cases are wild ruins where the processes of deconstruction follow their natural course.

The construction of **Pittarthie** appears to date from the same decade (c.1598), but the later alterations of the 1680s, evident in the walls of the east part, have arguably changed its original massive morphology (HES 2017a, 34030, 2017b, LB4317). Its ruined condition and the lack of brick insertions suggest that it has probably remained unaltered since this last alteration.

The dating of **Gilbertfield** is uncertain. A date stone situates its construction in 1607 (HES 2017a, 44861, 2017b, SM5270). At some point it was used as a source of material for other construction purposes, which caused a process of deconstruction that left a section of the building completely exposed. This provides an ideal opportunity to understand the morphology of its walls. Some brick insertions identified on site may be related to subsequent alterations related to the changes in the layout or to consolidation works linked to the deconstruction process.

Auchans is the result of a sequence that started in the sixteenth century with the construction of a T-plan volume and continued during the seventeenth century with two subsequent extensions. The first was composed of a new volume at the west end of the north wall and a stair tower in the re-entrant angle. The second was an additional wing on the north side composed of an oblong volume and two round towers at its north-west and south-west angles. The original volume has the ground floor level vaulted while the two extensions mentioned had wooden floors. In later times, a south-east range was also added. The internal layout and some of the openings were also part of later alterations (HES 2017a, 41959, 2017b, LB984).

Finally, **Redhouse** is the most vertical building in the group. Its construction happened during the late sixteenth century although it was remarkably altered during the seventeenth century. Documents related to a recent consolidation action describe the repair of some structural cracks and the consolidation of certain unstable parts, which could be identified during the on-site visit (HES 2017a, 54877, 2017b, SM775).

Figure 4.27 presents the plan of each of the cases, highlighting the parts considered within this category.

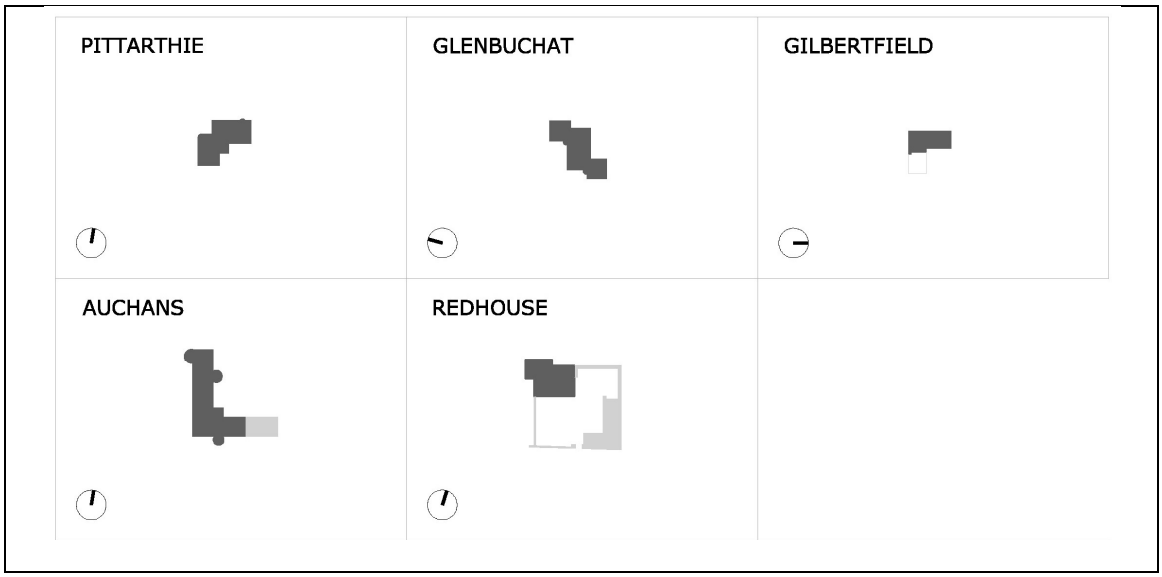


Figure 4.27: Plan of each case considered in the category. The darker areas highlight the parts within the scope of the group.

4.6.1.3 New wing additions

The third category includes new wing volumes attached to earlier towers during the seventeenth and eighteenth centuries. This group comprises five cases.

Tolquhon is a particular case for two reasons. The first refers to its location, an area with a predominance of metamorphic rocks. The second is related to the design and construction. Between 1584 and 1589 the original tower was expanded, defining a complex conceived as a single entity but built in subsequent phases. The main accommodation in the S wing was probably constructed first and built as a distinct unit. The gatehouse appears to have followed. The lateral wings would have been completed last. At the beginning of the seventeenth century Thomas Leper (mason) appears to still have been completing some works (HES 2017a, 19599, 2017b, SM90302; Rutherford 2015).

In the rest of the cases, the additions do not appear to have been conceived as unique entities, but were built individually as a sequence of extensions.

The oblong volumes added to **Craigmillar** follow a sequence, which started in the fifteenth century, continued in the sixteenth century east wing and south-west addition and ended with the seventeenth century west wing considered in this investigation (HES 2017a, 52109, 2017b, SM90129, 2015). These two last additions have very similar characteristics, but the first was built with a vaulted ground floor and the second has no trace of any vault.

The extensions at **Balgonie** happened later. Between 1635 and 1641, the fifteenth century north range was altered with the addition of one storey and the enlargement of the first-floor windows. In addition, a new volume was built in the south-east corner of the courtyard. In 1666, the grand stair linking the original tower and north range was built. Finally, in between 1702 and 1706, the three-storey range of buildings linking the

north range with the south-east block was built, incorporating earlier work. In later times, the tower and walls were garrisoned and some of the windows were altered (HES 2017a, 31389, 2017b, LB16664). More recently, the castle has been restored. The volumes at the north-west side of the courtyard are in use while the east wings are ruined and not accessible because of the risk of collapse.

Kilchurn dates from before the seventeenth century. However, during the seventeenth century, much of the castle was re-modelled and enlarged. These works included the construction of the south and south-east sides of the courtyard (now almost completely demolished), the cylindrical angle towers, and two ranges of four-storey barrack blocks situated on the north-west side of the courtyard. More recently, the castle has undergone a series of repair, consolidation and restoration works. Nowadays the site is a ruin, open to the public (HES 2017a, 23673, 2017b, SM90179; Grove 2004).

Finally, **Aberdour** is a complex site with superposed historical layers. The part considered in this investigation is the east range volume, added in the seventeenth century (HES 2017a, 50844, 2017b, SM90002, 2016).

Figure 4.28 presents the plan of each of the cases, highlighting the parts considered within this category.

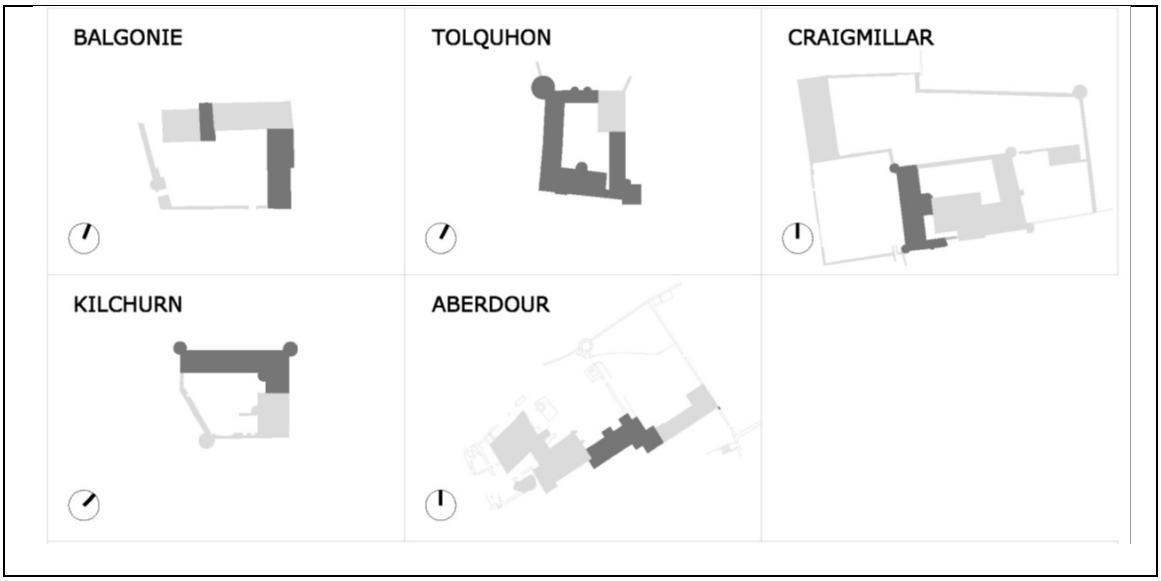


Figure 4.28: Plan of each case considered in the category. The darker areas highlight the parts within the scope of the group.

4.6.2 ARCHITECT-LED WORKS

4.6.2.1 Works within Environment-3

The fourth category includes two buildings related to the Environment-3 work previously defined.

The first is **Baberton House** and corresponds to James Murray, a centre in this environment. This was Murray's country house, built in the first quarter of the seventeenth century, in an area close to Edinburgh city, where a previous construction is known to have existed. Later, in the eighteenth century, a semi-octagonal infill was added. Nowadays, the building is the headquarters of a company (HES 2017a, 50265, 2017b, LB6129). The investigation focuses only on the seventeenth century part.

The second case is the north wing of **Linlithgow Palace** by William Wallace, who had collaborations throughout his career with Murray. The palace is a pre-seventeenth century building. However, the collapse of its north wing in 1607 was followed by Wallace's reconstruction between 1618 and 1624 (HES 2017a, 49261, 2017b, LB37469).

Figure 4.29 presents the plan of each of the cases, highlighting the parts considered within this category.

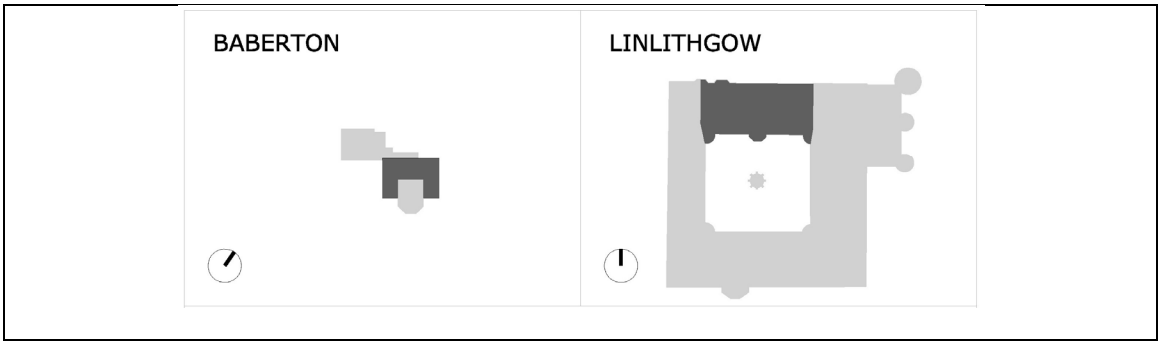


Figure 4.29: Plan of each case considered in the category. The darker areas highlight the parts within the scope of the group.

4.6.2.2 Works within Environment-2

The fifth category includes six buildings related to the Environment-2 work previously identified.

The first is **Holyrood Palace**, excluding the north tower (earlier construction). The construction of the palace took place between c.1671 and 1679, with the participation of the two centres of this environment (Sir William Bruce and James Smith) among others. The construction sequence started with the east quarter of the palace, then the south with its tower, and ended with the front quarter. Some records exist about repairs

on the fabric during the eighteenth century. However, the most important interventions masonry-wise happened in the nineteenth century. These include the re-facing of the north wall, the re-building of south-east quarter, the re-building of one of the original south towers, and the complete re-facing of the original south front (HES 2017a, 52380, 2017b, LB28022). Consequently, the area that most likely preserves the original masonry is the west elevation.

The other two cases are associated with James Smith: Drumlanrig Castle and Dalkeith House.

The early design of **Drumlanrig** dates from 1618. Despite this, the construction of the current building happened between 1679 and 1690, integrating walls from a previous construction, which can be identified in the south-east side. The author was almost certainly James Smith (González-Longo 2014, 2020), who worked with the Master of Works, William Lukup, The commissioner was the 3rd Earl and 1st Duke of Queensberry, who died ruined in 1695 (HES 2017a, 65142, 2017b, LB3886).

Dalkeith also has a complex construction history. The main part of the building as it exists today dates from 1702 to 1711, integrating the walls of an earlier construction, probably from the fifteenth century (Glendinning et al. 1996, 89) and identifiable in the west elevations. Some decades later, John Adam performed some repairs and re-facing (1762–63), and, in 1786, James Playfair and Alexander Young added the bow window of the east range. Further additions and extensions were carried out in the nineteenth century in addition to conservation and restoration works in subsequent centuries (HES 2017a, 53504, 2017b, LB1411).

The last three cases are Kinross House, Craigiehall House and Auchindinny House, all associated with Sir William Bruce.

Some authors consider **Kinross** as the masterpiece of Sir William Bruce. It was built between 1684 and 1695 as his own house, with the participation of James Smith (Wemyss 2014; González-Longo 2020) and the mason Tobias Bachop. Between 1777 and 1928 it underwent a series of internal and external alterations, affecting windows, and subtraction of surrounding terrain leaving parts of the basement walls exposed, as well as demolition of the original lodges and changes to the roof and wings. More recently (1904–2013), it had two successive conservation interventions. The first affected the interior and the second was intended to repair historic settlement cracks (HES 2017a, 27882, 2017b, LB11200; S&B 2010).

Craigiehall was built between 1695 and 1699 on the design of Sir William Bruce, replacing a castellated house. During the nineteenth and twentieth centuries it underwent a series of interventions, which include the extensions on the north side and the alterations affecting the interior, as well as oriel windows on the south elevation and the roof (HES 2017a, 50408, 2017b, LB45432). Despite this, the front and back facades appear to be in their original condition.

Finally, **Auchindinny** is one of the latest works attributed to Bruce. It was built c.1705, possibly incorporating parts of an earlier house, and appears little altered, with the exception of the twentieth century bathroom block added in the rear facade (HES 2017a, 51853, 2017b, LB13034). No certain information is available about the

construction of the lateral pavilions. Consequently, these are left out of the scope of the investigation.

Figure 4.30 presents the plan of each of the cases, highlighting the parts considered within this category.

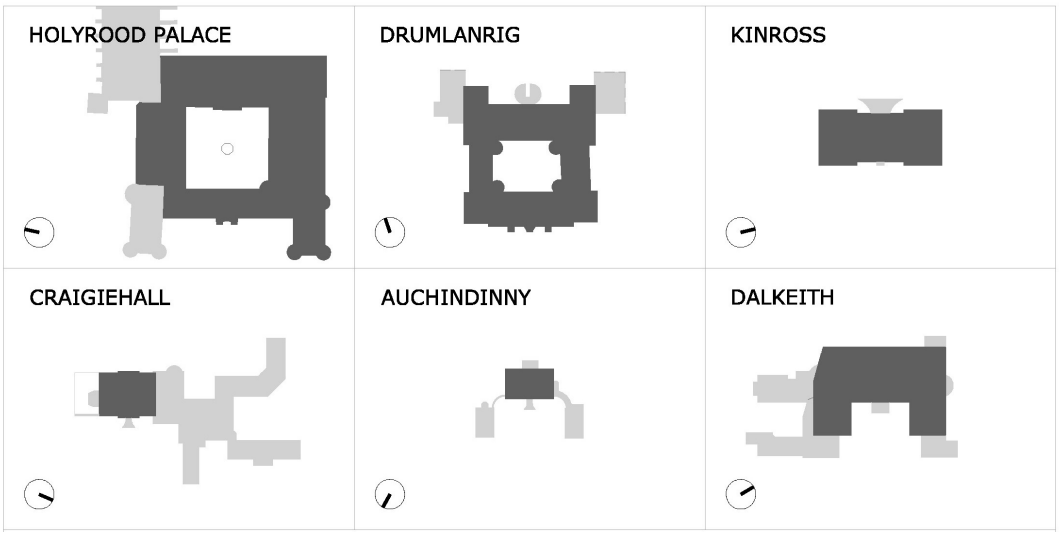


Figure 4.30: Plan of each case considered in the category. The darker areas highlight the parts within the scope of the group.

The “attributed” condition of Auchindinny could be an argument to question its adequacy as a case study in this group. However, a finding from the on-site inspections bolsters its choice. This is a common feature identified at Drumlanrig, Holyrood and Auchindinny related to the design of the stairs: the characteristic bullnose edge of James Smith. As shown in Figure 4.31, the three cases have steps with similar detailing. This is quite unique and has not been observed in any other group of buildings. Thus, it reinforces the link between Auchindinny and Environment-2.

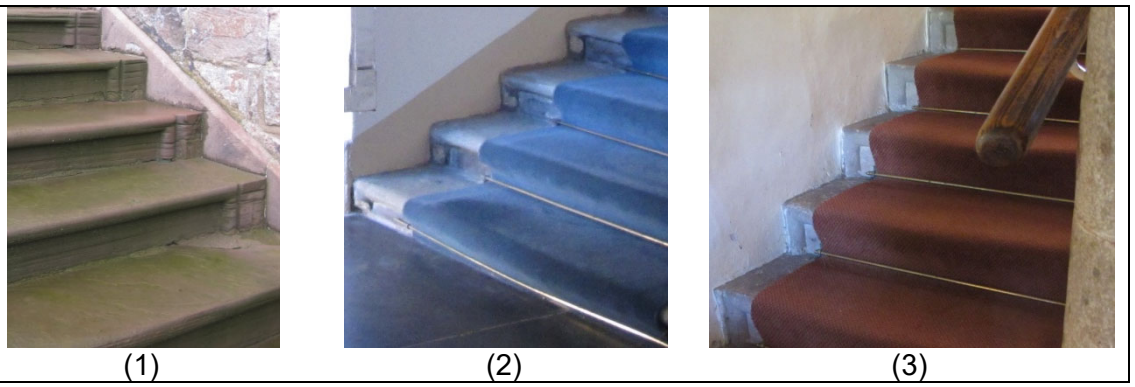


Figure 4.31: Stairs identified in different buildings related to Environment-2 and corresponding to (1) Drumlanrig, (2) Holyrood, and (3) Auchindinny. The steps have similar detailing.

4.6.2.3 Works within Environment-1

The last category includes 12 buildings related to the Environment-1 work previously identified. The first five correspond to the period when William Adam was in charge of the Adam architecture. This group includes the first phase of Mellerstain, the House of Dun, Cumbernauld, Haddo House and Chatelherault Lodge. Dumfries corresponds to a subsequent period, when his son John took the leadership. Finally, the cases built after Robert Adam's return from his Grand Tour are Penicuik, Wedderburn, the second phase of Mellerstain, Dalquharran, Newliston and Gosford.

Mellerstain was built in two phases. Between 1725 and 1738, William Adam designed a new house to take the place of a previous building, which had been demolished. The works started but were interrupted with only two wings constructed. Years later (1770–78), Robert Adam was commissioned for a new project, which integrated his father's executed work but incorporated a new central body (HES 2017a, 57171, 2017b, LB2123).

The cases of **Dun**, **Cumbernauld**, **Haddo** and **Chatelherault** happened very closely together in time, all starting between c.1730 and 1731 (HES 2017a, 35715, 45819, 19842, 110505, 2017b, LB4691, LB24086, LB3034, LB12485).

Dun and Chatelherault appear little altered, although some stone replacement has been identified on their facades. Cumbernauld was gutted c.1870 and has now been internally reconstructed and is in use. Haddo underwent a series of alterations at different points, which include extensions and changes to the interior.

Dumfries dates from 1754 to 1759. The original part includes the central body and two lateral pavilions. The wings behind were added later, between 1894 and 1900 (HES 2017a, 43609, 2017b, GDL00149).

Penicuik was built between 1761 and 1769 by Sir James Clerk, 3rd Baronet of Penicuik, and John Baxter the Elder. Certain payments to "Mr Adam" and "Mr John Adam" registered in an account book (HES 2017a, 51637: GD 18/1758a & b) highlight a possible link between the Adam family and this building. However, these references are related to consultations and the real impact of the Adams in the building finally constructed is uncertain. The original volume was extended in 1857, with a new wing at each side of the building. In 1899 a fire caused the gutting of the roof. In recent times, the building has undergone a conservation intervention (HES 2017a, 51637; 2017b, LB14634).

Wedderburn is a particular case. It was built between 1767 and 1771, including an original tower house, which can be clearly identified from the courtyard. The construction is attributed to the Adam family. The south-west (principal) and south-east elevations are probably the main concentration of Adam's work. The design of openings is very similar to that of other buildings built by the family. However, the depth of their involvement in the works is not precisely known (HES 2017a, 59748, 2017b, LB42543).

Dalquharran was built by Robert Adam for his brother-in-law, Thomas Kennedy of Dunure. As in Penicuik, new wings were added at each side of the building (1880–83). In 1970, it lost its roof and, since then, no interventions have been made. It is therefore a unique example of an unaltered Adam ruin, ideal when studying its masonry (HES 2017a, 40880, 2017b, LB125).

Newliston dates from 1789, and was also built by Robert Adam. It was built to replace an existing seventeenth century house. In 1845, some additions were made, including the wings and a balustrade. These are not considered in the investigation (HES 2017a, 50748, 2017b, LB27578).

The latest case in terms of chronology is **Gosford House**. It was built to a Robert Adam design between 1790 and 1810. At the end of the nineteenth century, it underwent a series of alterations and additions, which include new wings, the reorientation of the entrance to the south side and the addition of arcaded loggia to the east and west elevations (HES 2017a, 54909, 2017b, LB6533).

Figure 4.32 presents the plan for each of the cases, highlighting the parts considered within this category.

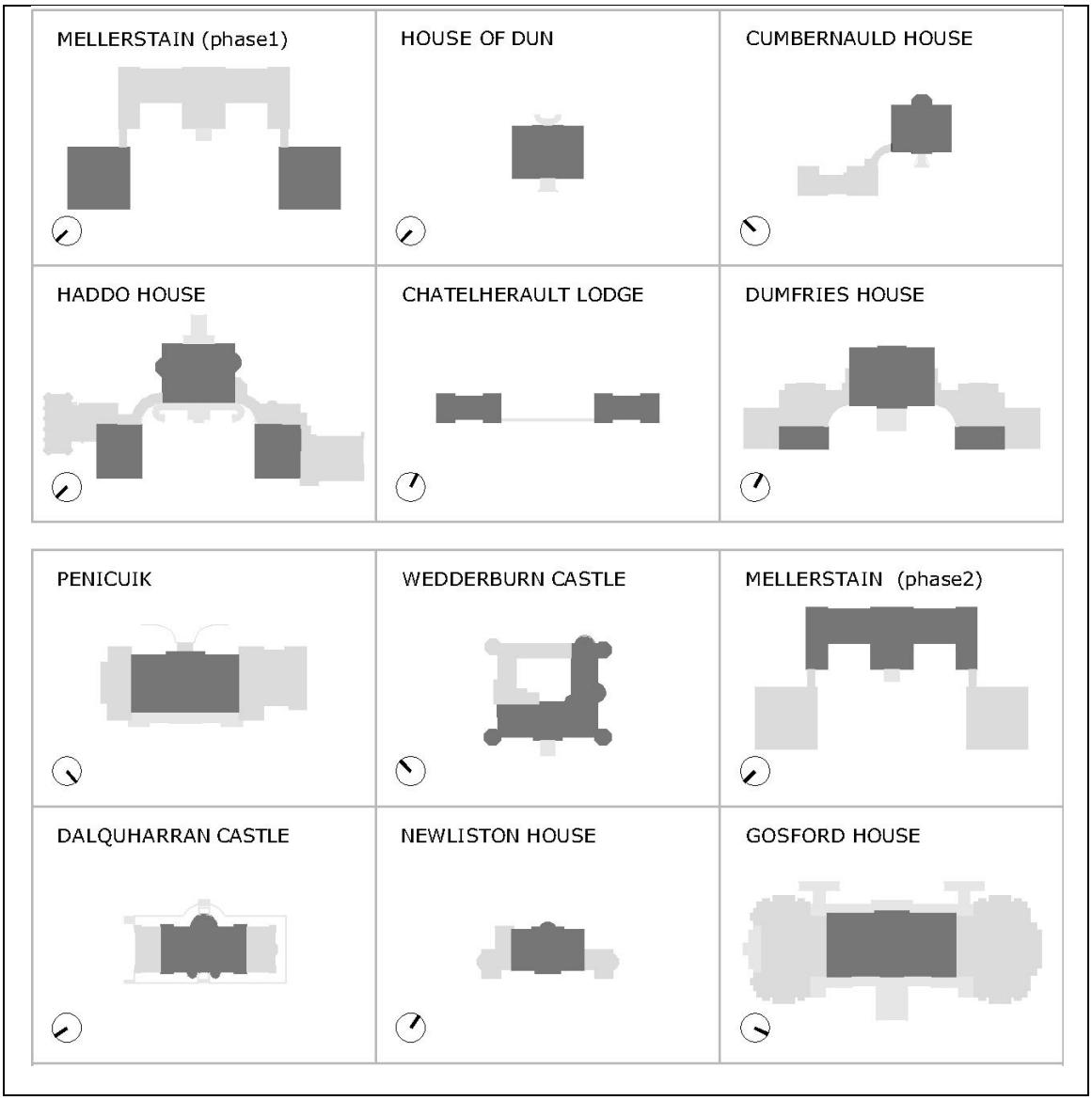


Figure 4.32: Plan of each case considered in the category. The darker areas highlight the parts within the scope of the group.

Chapter 5
MASONRY PATTERNS

5.1 INTRODUCTION

This chapter presents the results obtained from the application of the original method for the classification of masonry patterns defined in the methodology chapter. This method is based on the use of machine learning techniques and solves the issue with the lack of objective classification criteria identified in the literature review. In particular, the analysis sequence provides results in two stages.

The first stage identifies three main groups or clusters of patterns. Each cluster defines a type. Each type is quantitatively determined according to a set of parameters, which identify morphological features derived from the construction technique used. The resulting classification is therefore based on objective criteria and overcomes esthetical judgements. The second stage follows the same approach and defines sub-groups or variants within each type.

The following sections present the groups and sub-groups identified in the two steps as well as the distinctive features characterising them. The results obtained are discussed at the end of the chapter, while highlighting the contributions. Finally, the last section of the chapter relates the types defined in this part of the research to the conclusions derived from the previously undertaken analysis of the context. In this way, a framework necessary to proceed with the subsequent morphological study of the elevations is established.

5.2 FIRST CLASSIFICATION: MAIN CLUSTERS

The analysis sequence defined in the methodology chapter includes three steps for the identification of groups of patterns: (1) computation of the adjacency matrix, (2)

identification of the optimal number of clusters and clustering of the dataset, and (3) validation of the clusters obtained and identification of the most relevant parameters. This is applied to the dataset included in appendix 2.

The computation of the adjacency matrix and its analysis using PCA highlighted the first two principal dimensions as the most relevant. This is apparent in Figure 5.1, which shows the plot of the eigenvalues resulting from the PCA, corresponding to each of the dimensions in the adjacency matrix computed. The first two dimensions in the plot have a magnitude significantly higher than the rest and were therefore selected for the subsequent steps of the analysis.

In the second step, the elbow method determined that the ideal number of clusters for classification of the dataset was three. Figure 5.2 illustrates the plot of the within-cluster sum of squares for a k=10. As can be appreciated, the elbow of the curve for a k is equal to 3.

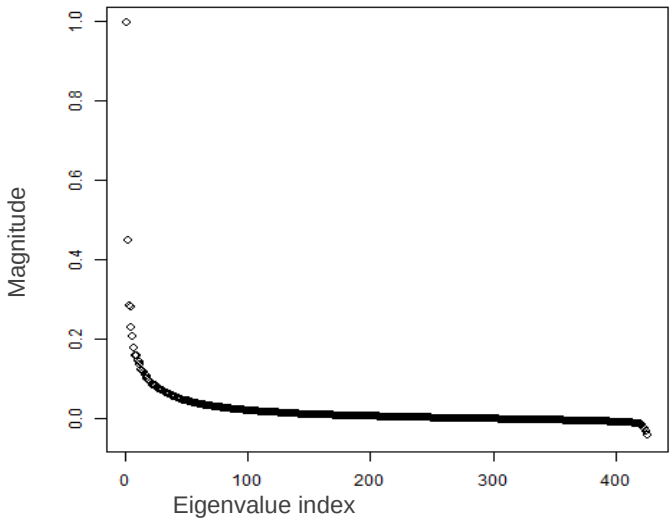


Figure 5.1: Plot of the eigenvalues (y axis) resulting from the PCA and corresponding to the index of each dimension in the adjacency matrix (x axis).

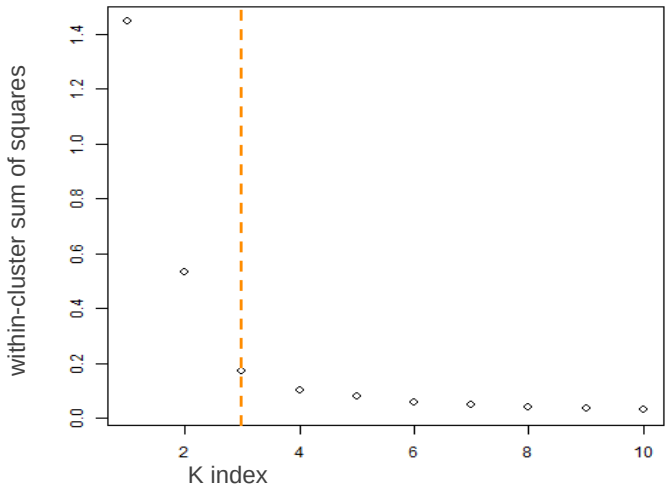


Figure 5.2: Results obtained from the application of the elbow method used to determine the most appropate number of clusters (k). The x axis determines the k values; the y value represents the within-cluster sum of squares score calculated for each k value.

Based on the results obtained, in the third step of the analysis the dataset was classified in three clusters. Figure 5.3 and Figure 5.4 illustrate the results obtained. The former figure shows the distribution of the clouds of points corresponding to each of the clusters, identifying the groups with colours. The latter figure includes a sample of the image patterns corresponding to the different clusters. This enables better understanding of the features related to the point clouds and provides some clues about the distinctive characteristics of the different groups. The full set of image patterns corresponding to each cluster is included in appendix 3.

The distribution of the clouds of points in the plot highlights two opposite and compact clusters, which are related through a third, more scattered, cluster. The two groups in the upper part of the plot are Cluster 2 (red), which is composed of 194 patterns, and Cluster 3 (green), with 147 patterns. The intermediate cluster is Cluster 1 (black) with 85 patterns. Clusters 2 and 3 gather the most irregular and most regular image patterns respectively, while Cluster 1 represents an intermediate situation.

Relating to the homogeneity of the group, Cluster 3 defines the most compact and isolated cloud of points and therefore includes the most homogeneous group of images. Clusters 2 and 1, on the other hand, define more disperse clouds, which consequently include groups of more heterogeneous images. In addition, it should be noted that these two clouds are very close at a certain edge. The points located at this edge are therefore those with smaller differences with their neighbours in the other cluster. Instead, the distance between the boundaries of the black and green clouds (Clusters 1 and 3) is bigger, meaning that the patterns belonging to the two groups are more dissimilar. It is possible to appreciate this feature visually by comparing the samples in Figure 5.4. However, a more specific analysis of the boundaries of each cluster is necessary to understand the particularities of the overlaps between groups. This is accomplished in the next step of the analysis.

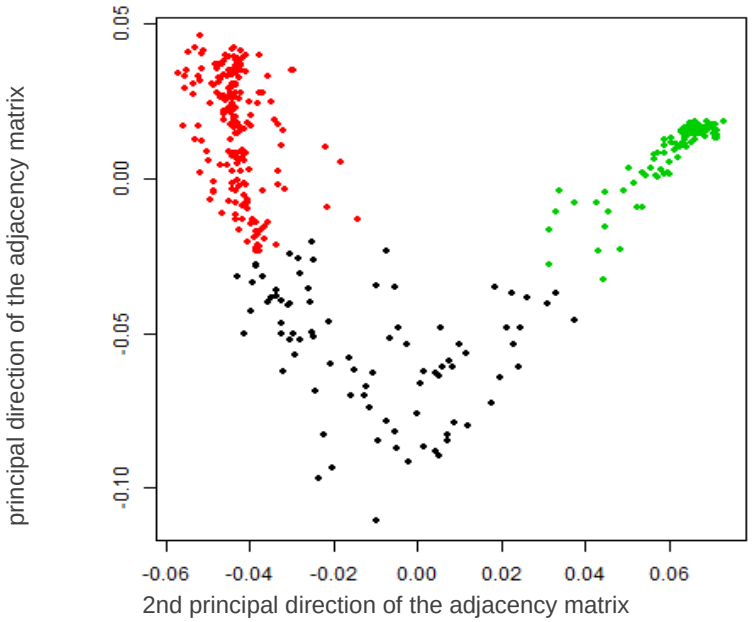


Figure 5.3: Plot of clusters obtained. Each point represents one of the patterns included in the dataset. Colours highlight the clusters computed. Cluster 1 = black, Cluster 2 = red, Cluster 3 = green.

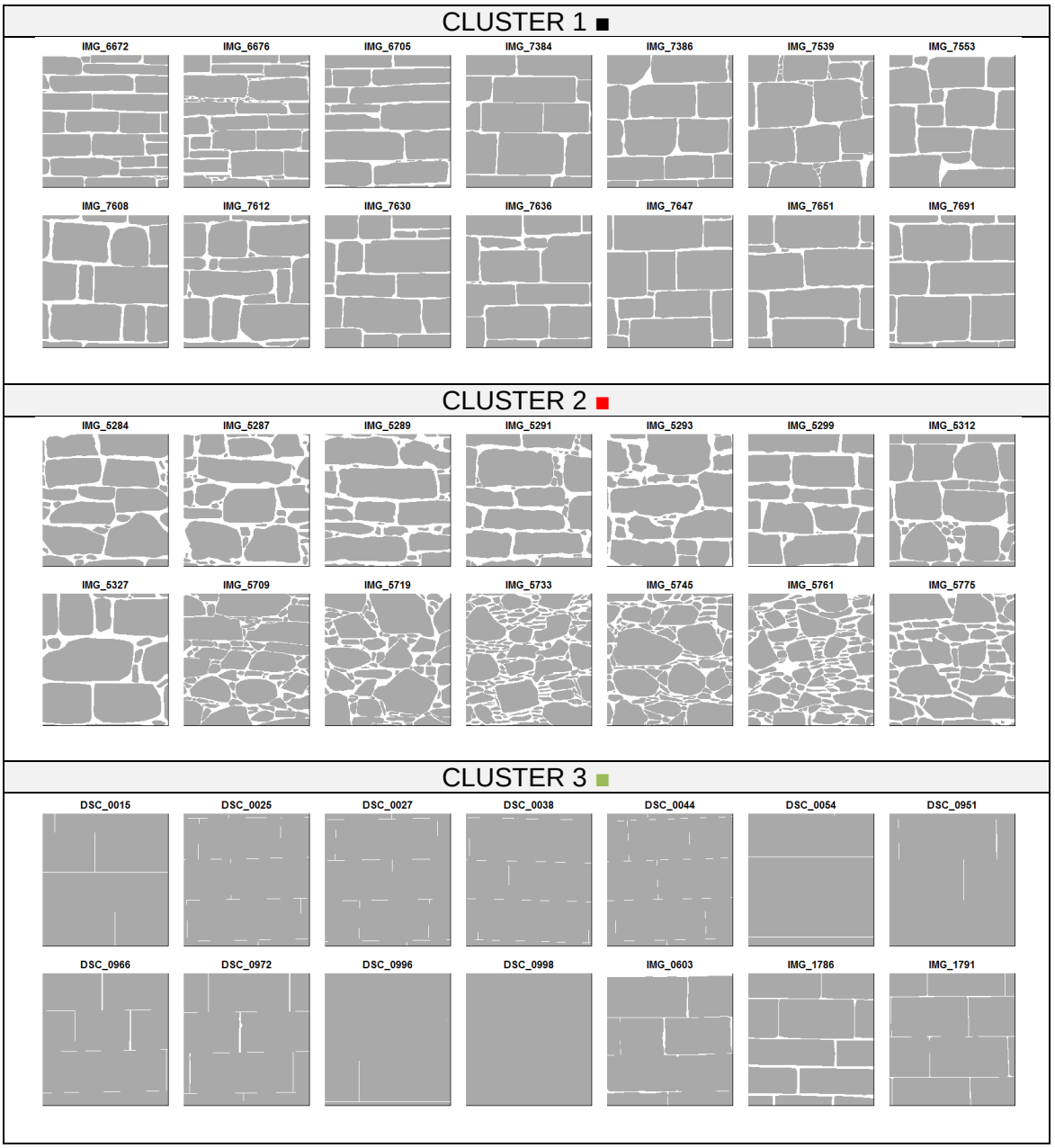


Figure 5.4: Sample of image patterns corresponding to Cluster 1 (top), Cluster 2 (middle) and Cluster 3 (bottom).

The third step of the analysis validated the groups defined, identified the most determinant parameters in the clustering and defined characteristic values for each cluster. In this case, the most determinant parameter was SP, which corresponds to the percentage of stone of each pattern. This is demonstrated in Figure 5.5, where SP significantly influences the prediction of the classifier used. After SP, a group of parameters have some influence on the classification although much more discrete. This group is headed by RC, which defines the rectangularity of the units. This is closely followed by LMT, CSD and HMN, respectively defining the face-bonding, the course regularity and the height of the stone units. The tail of the group is made up of UA (alignment of the units within the pattern) and HSD (variation of heights), which have almost no influence in the classification.

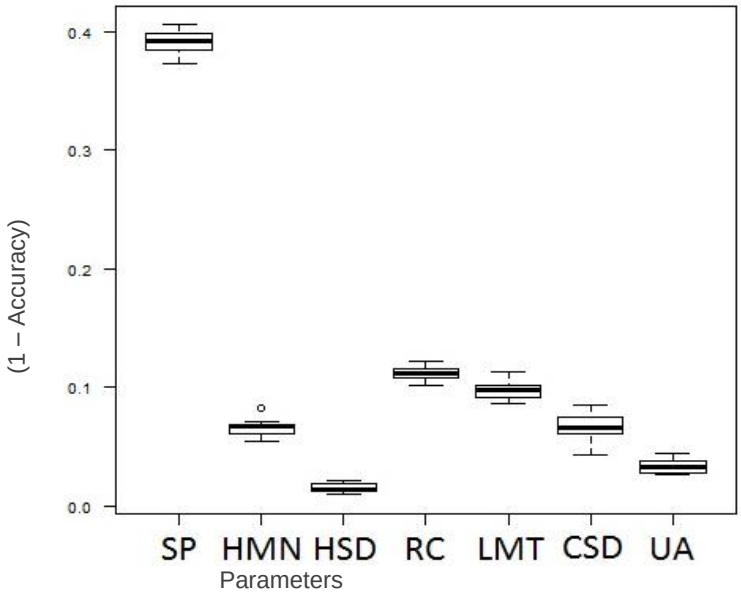


Figure 5.5: Results of the training of a classifier based on 80% of the sample, determining the relevance of each parameter for the classification.

The role of SP as a determining parameter is explained by the differentiated distributions corresponding to each of the three clusters. As shown in Figure 5.6-left and defined in Table 5.1 and Table 5.2, the overlap between Clusters 3 and 1 is minimal (from 94.10 to 94.10) and the position of the two peaks (98.5 and 87.5 respectively) defines a distribution that clearly differentiates between the two groups. This does not happen in the contact between Clusters 1 and 2, where the overlap is more noticeable (from 84.61 to 90.42). However, the clear peak in Cluster 1 contributes to differentiation between the groups.

Something similar happens in the case of RC (Figure 5.6-centre). Clusters 3 and 1 have a minimum overlap (at 0.97), while Clusters 1 and 2 have a more noticeable crossover (between 0.90 and 0.85). In this case, the lower relevance of the parameter within the group is probably related to the smoothing of the curve corresponding to Cluster 1 and the slight variations in distributions of the other two groups.

In the rest of the parameters, the overlapping of curves significantly increases, providing less clear results. For example, Figure 5.6-right plots the case of LMT, which shows a relevant curve overlap corresponding to Clusters 1 and 2.

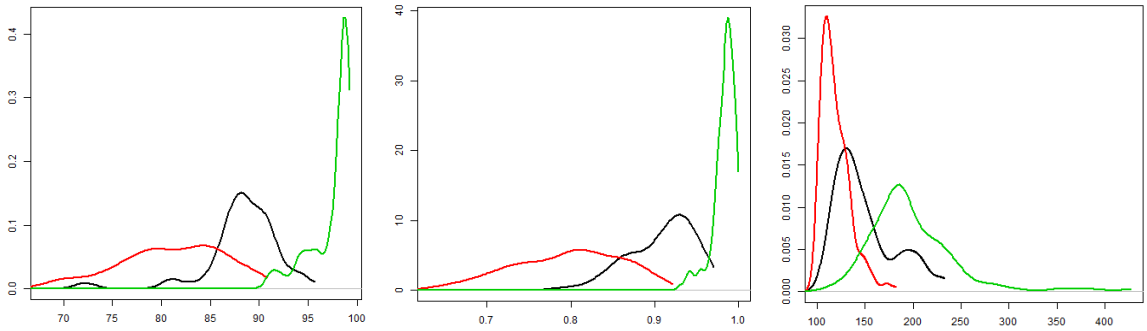


Figure 5.6: Plot of the kernel density estimation defining the distribution of each cluster. The three plots correspond to the three most determinant parameters: SP (left), RC (centre) and LMT (right). Cluster 1 = black, Cluster 2 = red, Cluster 3 = green.

Table 5.1 and Table 5.2 numerically determine the characteristics of each cluster. The former table defines per parameter and per cluster the most frequent value (peak value), while the latter table determines the boundaries (high density interval) for each type.

It is apparent that Cluster 3 is the group with higher values of SP, RC, LMT, HMN and UA and lower values of CSD and HSD. This means that the patterns in this group are defined by a high percentage of stone and composed of highly rectangular units. The height of the units varies between 24.60cm and 33.5cm, although the most common value is 31cm. The stones in the patterns have very homogeneous heights as variations are generally in the order of 5mm. Unit alignment in the wall is homogeneous, the horizontal courses are very regular, and face-bonding is well defined.

The opposite happens with Cluster 2. This group has the lowest percentage of stone in the pattern and therefore also less rectangular units. The heights of the units are heterogeneous, with variations generally around 9mm, and the mean value generally close to 15cm. These two features indicate that the pattern is composed of units of different sizes. Assembly of the units is the most irregular. The alignment of units in the wall is the most heterogeneous, courses are clearly irregular and face-bonding is generally poor.

Cluster 1 is in the intermediate position and therefore shares certain overlaps with the other two clusters. As already mentioned, the SP is the parameter that best divides the groups. The differences between Clusters 1 and 3 are quite clear, although their boundaries have a small overlap between 94.46% and 94.10%. The cases located in this range are classified according to the remaining parameters. In particular, the rectangularity of the units defines the value 0.97 as a clear border between the two groups. As noted in the plot of the clouds of points, however, Clusters 1 and 2 are closer. The overlap in the SP is more evident, falling between 90.42% and 84.61%. In this case, then, the combination of the other parameters, according to the relevance previously discussed, becomes more determining for the classification.

	Cluster 3	Cluster 1	Cluster 2
SP	**98.5**	**87.5**	**79**
RC	0.985	0.93	0.825
LMT	175	130	105
CSD	1	15	25
HMN	31	22.5	15
UA	0.999	0.999	0.995
HSD	0.5	5	9

Table 5.1: Peak value for each parameter and cluster.

		Cluster 3	Cluster 1	Cluster 2
SP	**upper**	**99.10**	**94.46**	**90.42**
	lower	**94.10**	**84.61**	**73.54**
RC	upper	1.00	0.97	0.90
	lower	0.97	0.85	0.69
LMT	upper	254.33	203.24	138.41
	lower	138.64	111.67	100.00
CSD	upper	4.01	45.75	62.87
	lower	0.00	2.86	19.39
HMN	upper	33.50	29.71	21.45
	lower	24.60	12.09	8.53
UA	upper	1.0000	0.9999	0.9985
	lower	0.9995	0.9919	0.9751
HSD	upper	2.41	11.67	11.34
	lower	0.00	1.57	3.70

Table 5.2: Lower and upper values defining the 95% high density interval for each parameter and cluster.

It can therefore be concluded that patterns can be classified in three main types, which correspond to the clusters defined. Cluster 3 includes cases generally identified as “ashlar” in the existing literature, while Clusters 1 and 2 incorporate patterns corresponding with “rubble squared” and “rubble random” masonries, respectively. However, unlike examples in the literature, the classification in this study is not based on formal characteristics but on parameters that define morphological features derived from the construction technique. The boundaries of the groups are numerically defined and the classification is quantitative and reproducible.

5.3 SECOND CLASSIFICATION: VARIANTS

The classification presented in the previous section resulted in the definition of three main types or clusters of patterns. In this section, each group is further investigated, applying the same analysis sequence in order to identify sub-clusters or variants within each type. The following points present the results obtained in this process.

5.3.1 VARIANTS IN CLUSTER 1

According to the previous section, Cluster 1 was composed of 85 cases. The computation of the adjacency matrix corresponding to this specific sub-set of data and its analysis by means of PCA led to the identification of three relevant dimensions. Figure 5.7 shows the plot of the eigenvalues resulting from the PCA and corresponding to each dimension in the adjacency matrix. The curve obtained is smooth and has the first three indexes separated by similar distances. The gap between indexes 3 and 4 and the short distance between indexes 4 and 5 justified the selection of the first three dimensions and the move to proceed with the analysis.

In the second step, the optimal number of clusters for the classification was defined using the elbow method. In this case, the k value considered was equal to 4. Although the curve in Figure 5.8 is quite smooth, an inflexion point happens at k=4. This value determined the number of clusters considered for the application of the k-means algorithm.

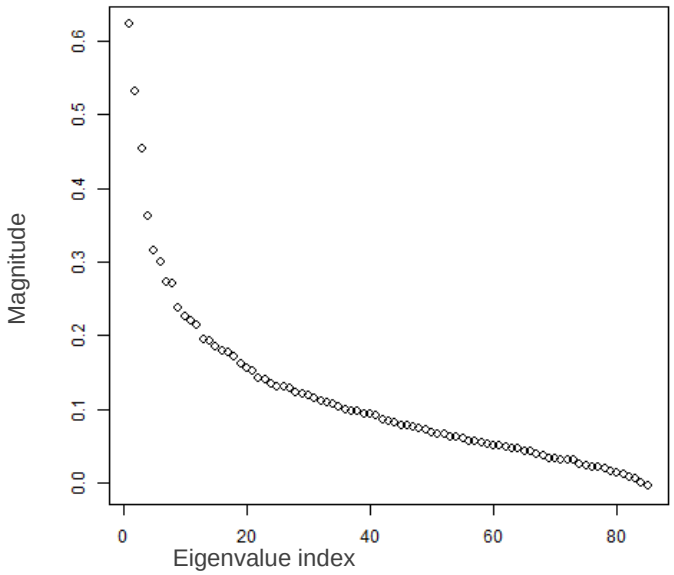


Figure 5.7: Plot of the eigenvalues (y axis) resulting from the PCA and corresponding to the index of each dimension in the adjacency matrix (x axis).

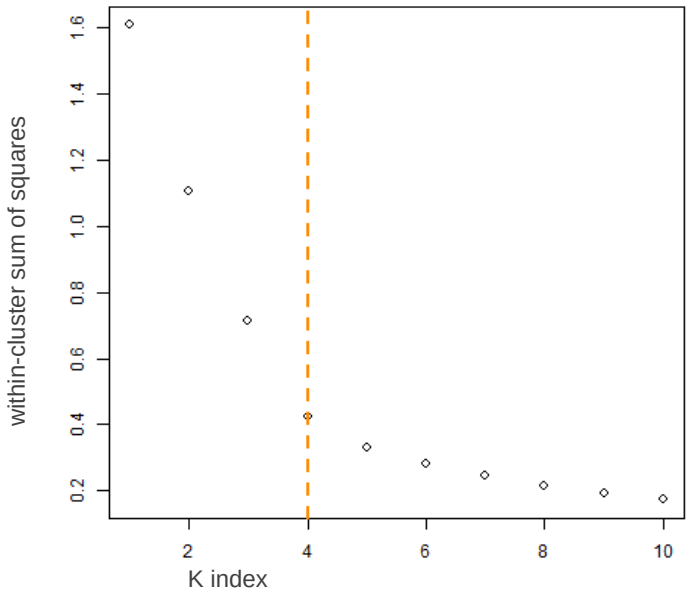


Figure 5.8: Results obtained from the application of the elbow method used to determine the optimal number of clusters. The x axis determines the k values considered (in this case ten); the y value represents the within-cluster sum of squares score calculated for each k value.

The groups resulting from the clustering were as follows: sub-cluster 1.1, composed of 26 cases; sub-cluster 1.2, with 13 cases; sub-cluster 1.3, with 15 cases; and finally sub-cluster 1.4, which included 31 cases. Figure 5.9 plots the point clouds corresponding to each sub-cluster using the three dimensions considered, highlighting each group with a different colour.

In the plot of dimensions 1 and 2, the blue cluster (sub-cluster 1.4) appears detached from a long cloud defined by the other three clusters. A similar situation happens in the plot of dimensions 2 and 3, where the green cloud (sub-cluster 1.3) appears detached from the rest. Instead, the plot of dimensions 1 and 3 shows a different distribution. In this case three clouds can be individuated: the black cluster (sub-cluster 1.1), the red cluster (sub-cluster 1.2), and the combination of the blue and green clusters (sub-clusters 1.3 and 1.4). One aspect to highlight related to all the pairs of dimensions is the existence of overlapping in some parts of the clouds. This aspect was further studied using observation of the images included in each group and analysing the numerical values characterising each sub-cluster.

Figure 5.10 shows a sample of 14 images patterns corresponding to each of the four sub-clusters obtained (see appendix 3 for the full set of results). A quick observation of the patterns in each group provides certain clues about the determining aspects in the classification. However, a careful analysis of the range of values defining the classes is necessary to identify the boundaries of each group and their most common features. This was performed in the third step of the analysis.

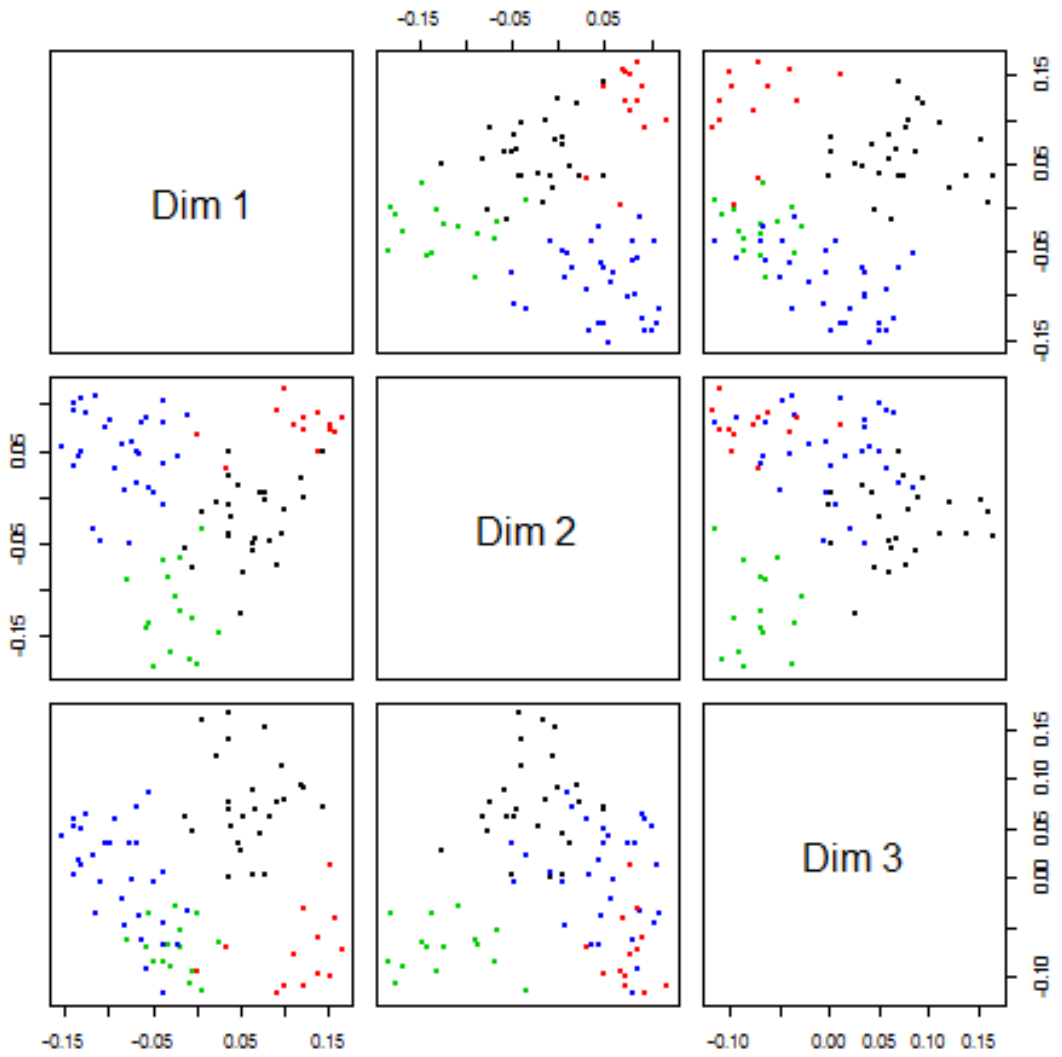


Figure 5.9: Plot of the clusters obtained. Each point represents one of the patterns included in the dataset. Colours highlight the clusters computed.

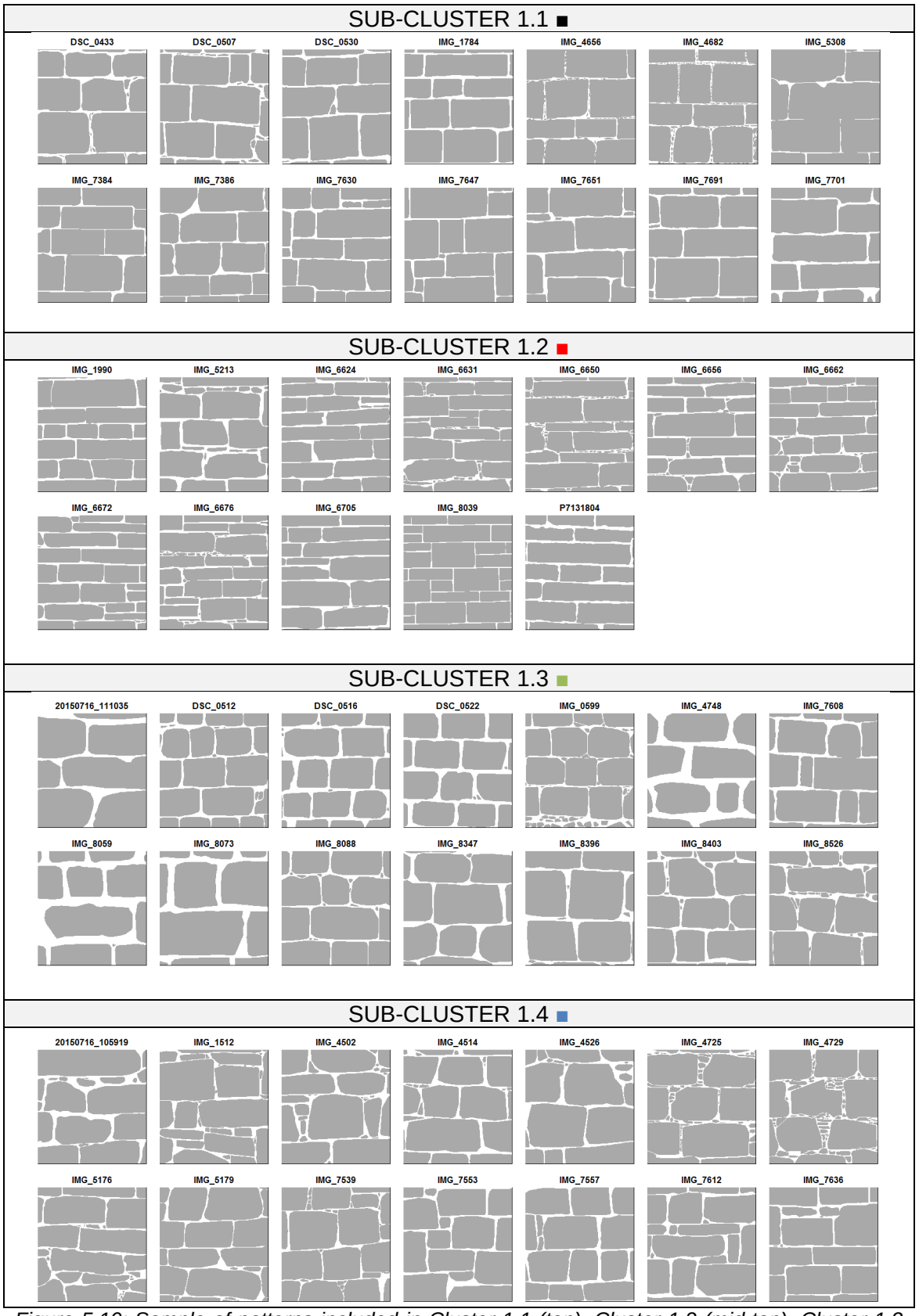


Figure 5.10: Sample of patterns included in Cluster 1.1 (top), Cluster 1.2 (mid-top), Cluster 1.3 (mid-bottom) and Cluster 1.4 (bottom).

The training of a classifier based on 80% of the sample highlighted three determinant parameters: RC (rectangularity), HMN (mean unit height) and HSD (standard variation of unit height). As shown in Figure 5.11, the influence of the remaining parameters on the classification is clearly minor.

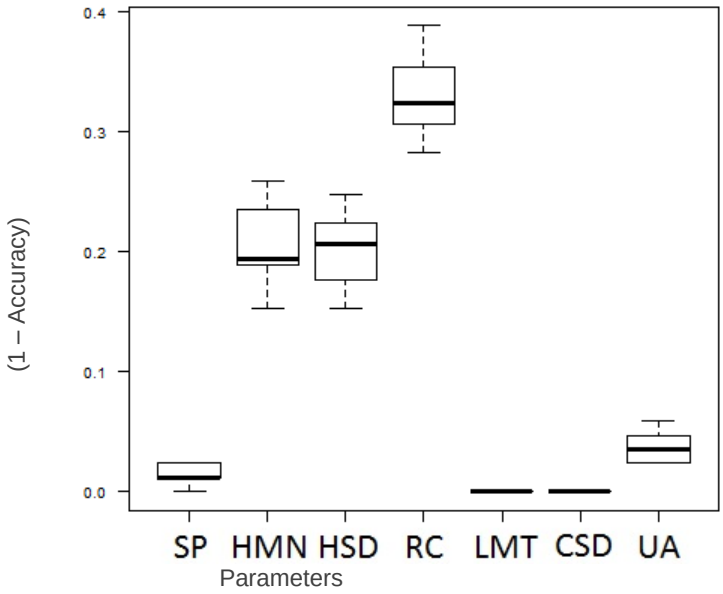


Figure 5.11: Results of the training of a classifier based on 80% of the sample, determining the relevance of each parameter for classification.

The overlapping of point clouds previously noted is identified here in the overlap of certain ranges of values. Figure 5.12 illustrates the case of the three most determining parameters. In particular, it is apparent that the overlap of the distribution curves varies depending on the pattern. For example, in the plot corresponding to RC, the black and red curves almost overlap, while for HMN their ranges differ substantially. Something similar happens with the rest of the curves. The combination of the different parameters ends up defining the classification.

Table 5.3 and Table 5.4 provide the numerical data necessary to understand the features highlighted. In particular, the tables determine the characteristics of each cluster, defining per parameter and per cluster the peak value (most common value) and the high density interval (the range). Despite the numerous overlaps, it is possible to identify differences between the groups. In particular, sub-cluster 1.4 is characterised by inclusion of the patterns with the most irregular units. This is because the cluster has less rectangular units (lower values of RC) and, at the same time, the most heterogeneous heights, with variations generally around 4.5cm (higher values of HSD).

Sub-clusters 1.1 and 1.2, however, are the most regular in terms of RC. However, in this case the differential feature between the two is the low value of HMN (mean unit height) related to sub-cluster 1.2, which is generally close to 12.5cm.

Finally, sub-cluster 1.3 is in an intermediate position in terms of rectangularity of RC but represents the group with the most homogeneous unit height (lower values of HSD), with its most common value equal to 1.5cm.

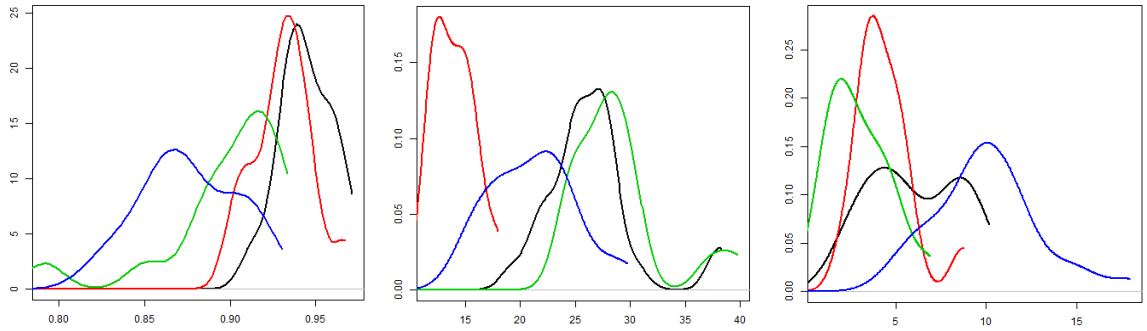


Figure 5.12: Plot of the kernel density estimation defining the distribution of each cluster. The three plots correspond to the three most determinant parameters: RC (left), HMN (centre) and HSD (right).

		Sub-cluster 1.1	Sub-cluster 1.2	Sub-cluster 1.3	Sub-cluster 1.4
RC	**upper**	**0.97**	**0.95**	**0.93**	**0.92**
	lower	**0.93**	**0.90**	**0.85**	**0.83**
HMN	**upper**	**30.59**	**16.17**	**37.25**	**24.96**
	lower	**19.24**	**11.67**	**24.12**	**14.63**
HSD	**upper**	**9.06**	**5.80**	**5.12**	**13.35**
	lower	**1.95**	**2.14**	**0.80**	**4.52**
UA	upper	0.9999	0.9999	0.9986	0.9991
	lower	0.9959	0.9985	0.9847	0.9935
SP	upper	94.46	90.61	88.58	90.81
	lower	87.89	84.61	71.72	85.58
LMT	upper	203.05	233.21	161.66	158.71
	lower	116.16	159.25	112.93	116.34
CSD	upper	63.29	27.69	34.78	45.75
	lower	4.27	2.86	5.06	8.81

Table 5.3: Lower and upper values defining 95% high density interval for each parameter and cluster.

	Sub-cluster 1.1	Sub-cluster 1.2	Sub-cluster 1.3	Sub-cluster 1.4
RC	**0.935**	**0.935**	**0.925**	**0.87**
HMN	**27.5**	**12.5**	**27.5**	**17**
HSD	**4.5**	**3.5**	**1.5**	**11**
UA	0.9990	0.9998	0.9975	0.9970
SP	91.5	87	87.5	89
LMT	130	201	115	135
CSD	5	17.5	5	25

Table 5.4: Peak value for each parameter and cluster.

Based on the results presented, it is possible to conclude that Cluster 1 has four variants. These are determined by three parameters related to the shape and size of the units: rectangularity, mean height and the homogeneity or heterogeneity of heights.

5.3.2 VARIANTS IN CLUSTER 2

According to the results of the first classification, Cluster 2 is composed of 194 cases. The computation of the adjacency matrix corresponding to this specific dataset, and its analysis by means of PCA, identified the first principal dimension as the most relevant. Figure 5.13 shows the plot of the eigenvalues resulting from the PCA and corresponding to the index of each dimension in the adjacency matrix. In this case, the first index is clearly highlighted as the most determinant. This was therefore the principal dimension considered in the subsequent steps of the analysis.

In the next step of the analysis, the number of optimal clusters for the classification was determined using the elbow method. Figure 5.14 plots the curve corresponding to the calculation of the within-cluster sum of squares. The inflexion point of the curve happens with the k index equal to 2. This was the number of groups considered for clustering.

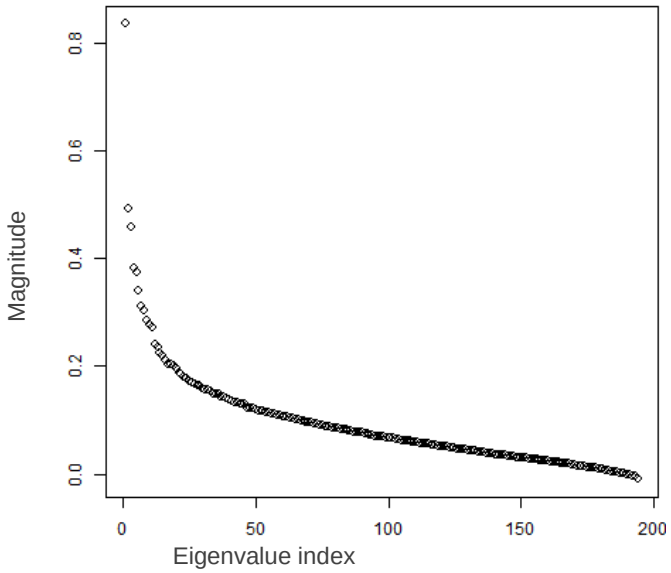


Figure 5.13: Plot of the eigenvalues (y axis) resulting from the PCA and corresponding to the index of each dimension in the adjacency matrix (x axis).

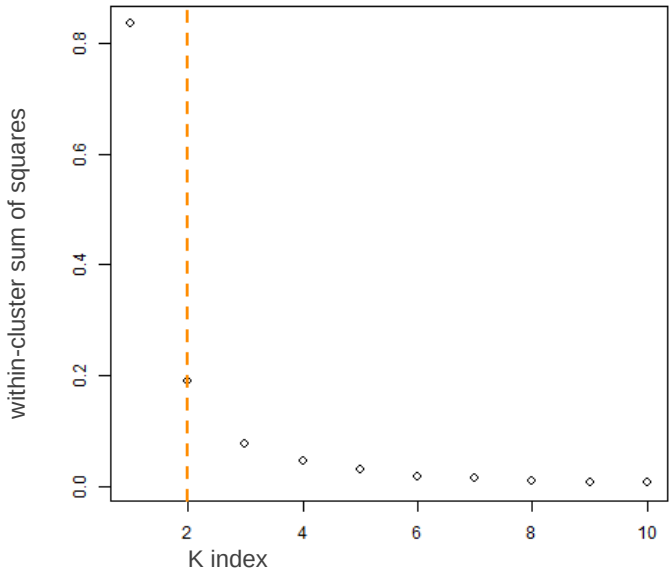


Figure 5.14: Results obtained from the application of the elbow method used to determine the most appropate number of cluster. The x axis determines the k values considered (in this case 10); the y value represents the within-cluster sum of squares score calculated for each k value.

The classification divided the sample into two groups as follows: sub-cluster 2.1 was composed of 107 cases, and sub-cluster 2.2 included 87 cases. Figure 5.15 shows the resulting cloud of points, highlighting the first cluster in black and the second in red. In this case the groups are located in the lower and upper part of the plot respectively, presenting a scattered distribution and sharing an edge of contact. The scattering indicates certain heterogeneity in the groups, while the existence of a contact edge means that the points close to the border are less dissimilar than those located in more distant areas.

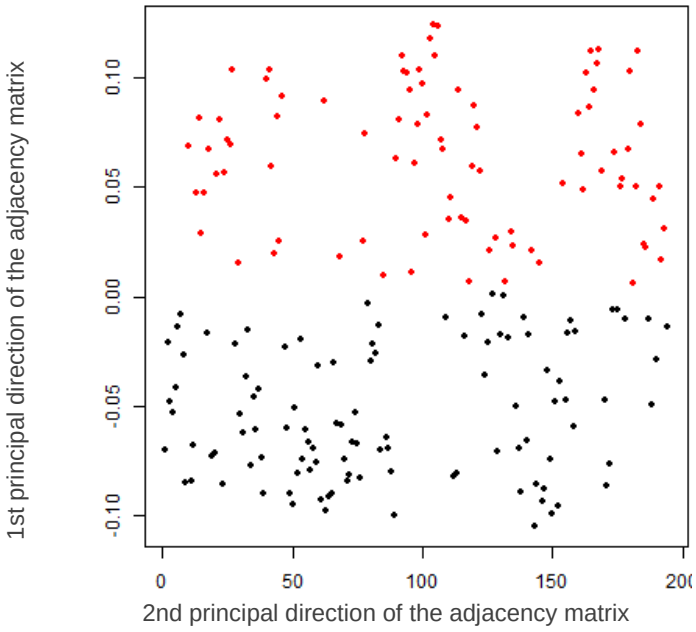


Figure 5.15: Plot of the clusters obtained. Each point represents one of the patterns included in the dataset. Colours highlight the clusters computed.

Figure 5.16 shows a sample of 14 images corresponding to each of the two sub-clusters obtained (see appendix 3 for full set of results). It is apparent that the shape and dimension of the stone units determine the grouping. However, a detailed study of the numerical values corresponding to each parameter is necessary to correctly understand the classification.

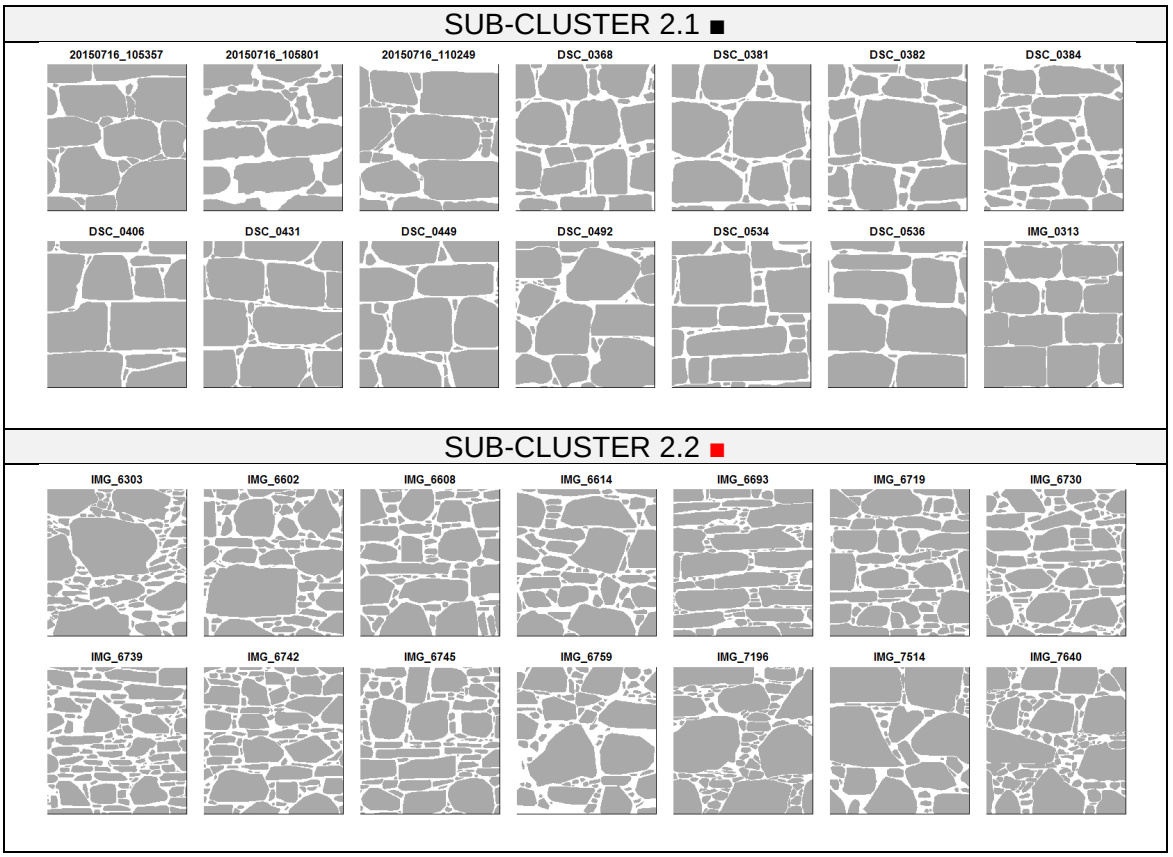


Figure 5.16: Sample of patterns included in Cluster 2.1 (top) and Cluster 2.2 (bottom).

Figure 5.17 shows the plot resulting from the training of a classifier based on 80% of the sample. The parameters most influencing the classification are those with the highest scores in the plot. In this case, RC, HMN and SP are clearly determinant while the influence of the other parameters is clearly minor. Figure 5.18 illustrates the distributions of the three relevant parameters according to the two sub-clusters identified. In all the cases, the two curves define clearly differentiated peaks. However, certain overlap occurs in the central values of the ranges. Such overlaps are related to the edge of contact previously noted in the point cloud plot.

Table 5.5 and Table 5.6 numerically determine the most repeated value (peak value) and the boundaries (high density interval) corresponding to each parameter and sub-cluster. Accordingly, sub-cluster 2.1 includes the cases with the biggest and most regular stones. In this group, rectangularity, mean unit height and SP are generally close to 0.875, 15cm and 85% respectively. These values are greater than those corresponding to the case in sub-cluster 2.2, which includes the patterns with the most irregular and smallest stones in the sample.

In conclusion, based on the results presented, Cluster 2 contains two variants, which are determined by the rectangularity of the units, their mean height and the SP in the pattern. As in the case of Cluster 1, the three parameters are related to the shape and size of the units.

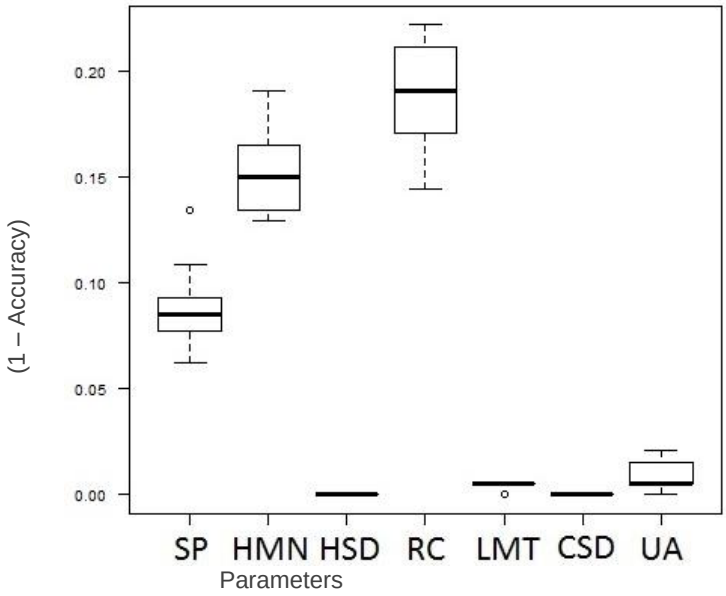


Figure 5.17: Results of the training of a classifier based on 80% of the sample, determining the relevance of each parameter for the classification.

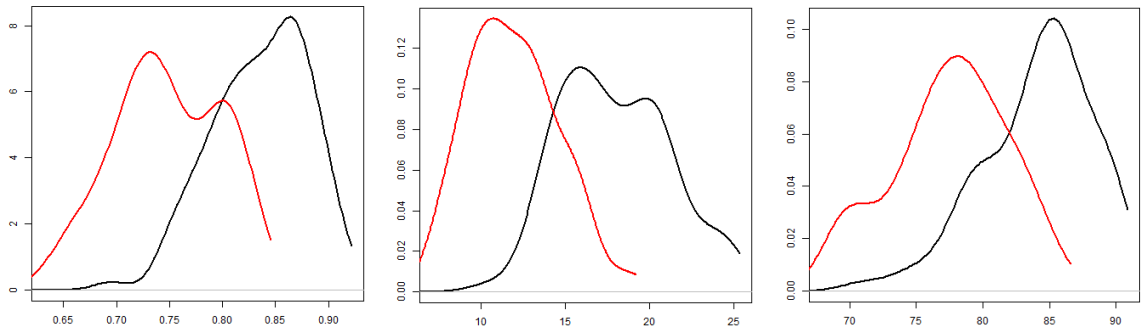


Figure 5.18: Plot of the kernel density estimation defining the distribution of each cluster. The three plots correspond to the three most determinant parameters: RC (left), HMN (centre) and SP (right).

		Sub-cluster 2.1	Sub-cluster 2.2
RC	**upper**	**0.90**	**0.83**
	lower	**0.76**	**0.68**
HMN	**upper**	**23.90**	**15.94**
	lower	**13.64**	**7.71**
SP	**upper**	**90.42**	**83.10**
	lower	**78.35**	**68.84**
UA	upper	0.9985	0.9985
	lower	0.9759	0.9740
LMT	upper	146.50	130.35
	lower	103.77	100.00
CSD	upper	62.98	55.34
	lower	16.15	15.98
HSD	upper	12.36	9.50
	lower	5.45	3.47

Table 5.5: Lower and upper values defining the 95% high density interval for each parameter and cluster.

	Sub-cluster 2.1	Sub-cluster 2.2
RC	**0.875**	**0.73**
HMN	**15**	**13**
SP	**85**	**79**
UA	0.9975	0.9850
LMT	125	105
CSD	25	32.5
HSD	9	7.5

Table 5.6: Peak value for each parameter and cluster.

5.3.3 VARIANTS IN CLUSTER 3

The sub-set corresponding to Cluster 3 is composed of 147 cases. Following the same sequence as the previous cases, the computation of the adjacency matrix and its analysis by means of PCA led to the identification of the most relevant principal dimension of the matrix. Figure 5.19 shows the plot of the eigenvalues resulting from the PCA. It is apparent that the eigenvalue corresponding to the first principal dimension is the most determinant. In this case, then, only the first principal dimension was selected to proceed with the analysis.

In the second step of the analysis, the optimal number of clusters was determined by applying the elbow method. As in the previous section, the inflexion point of the curve plotted in Figure 5.20 happens at index number 2. Accordingly, this was the value used in the k-means algorithm.

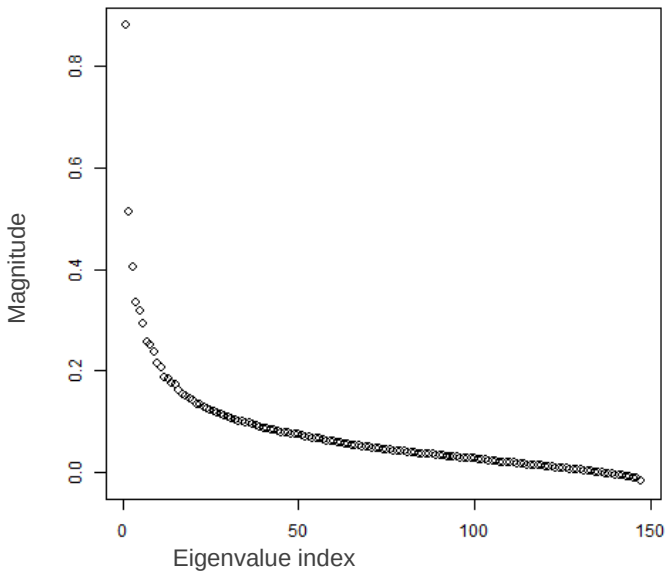


Figure 5.19: Plot of the eigenvalues (y axis) resulting from the PCA and corresponding to the index of each dimension in the adjacency matrix (x axis).

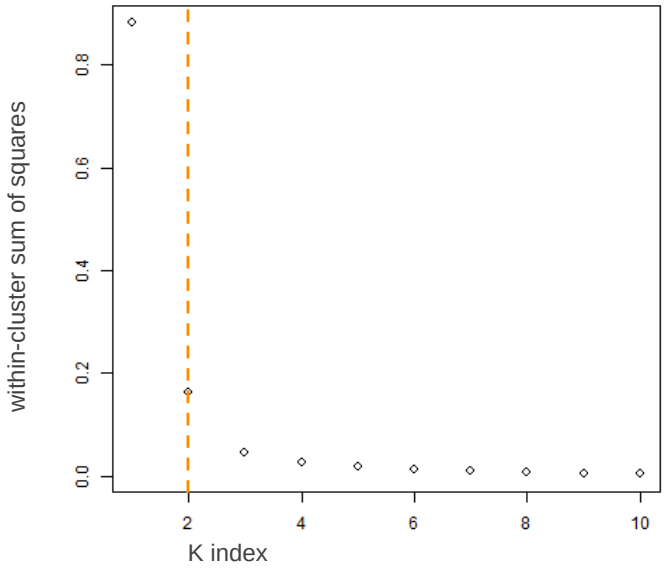


Figure 5.20: Results obtained from the application of the elbow method used to determine the most appropriate cluster number. The x axis determines the k values considered (in this case ten); the y value represents the within-cluster sum of squares score calculated for each k value.

The two groups resulting from the clustering are represented as point clouds in Figure 5.21. In this case, the two clouds are mostly located on opposite sides of the plot and quite well separated. This distribution is an indicator of differentiated groups. Sub-cluster 3.1 (black) is composed of 42 cases and represents the smallest cloud. Sub-cluster 3.2 (red) is the biggest group with 105 cases. Figure 5.22 shows a sample of 14 images corresponding to each of the two sub-clusters (see appendix 3 for full set of results). Observation of the images provides certain clues about the most determining

features. However, it is necessary to identify the values corresponding to each of the determining parameters for an objective understanding of the classification.

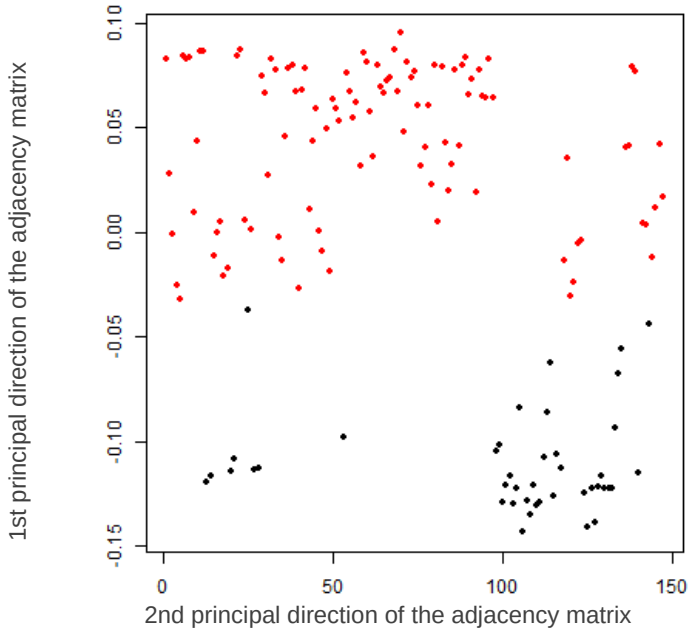


Figure 5.21: Plot of the clusters obtained. Each point represents one of the patterns included in the dataset. Colours highlight the clusters computed.

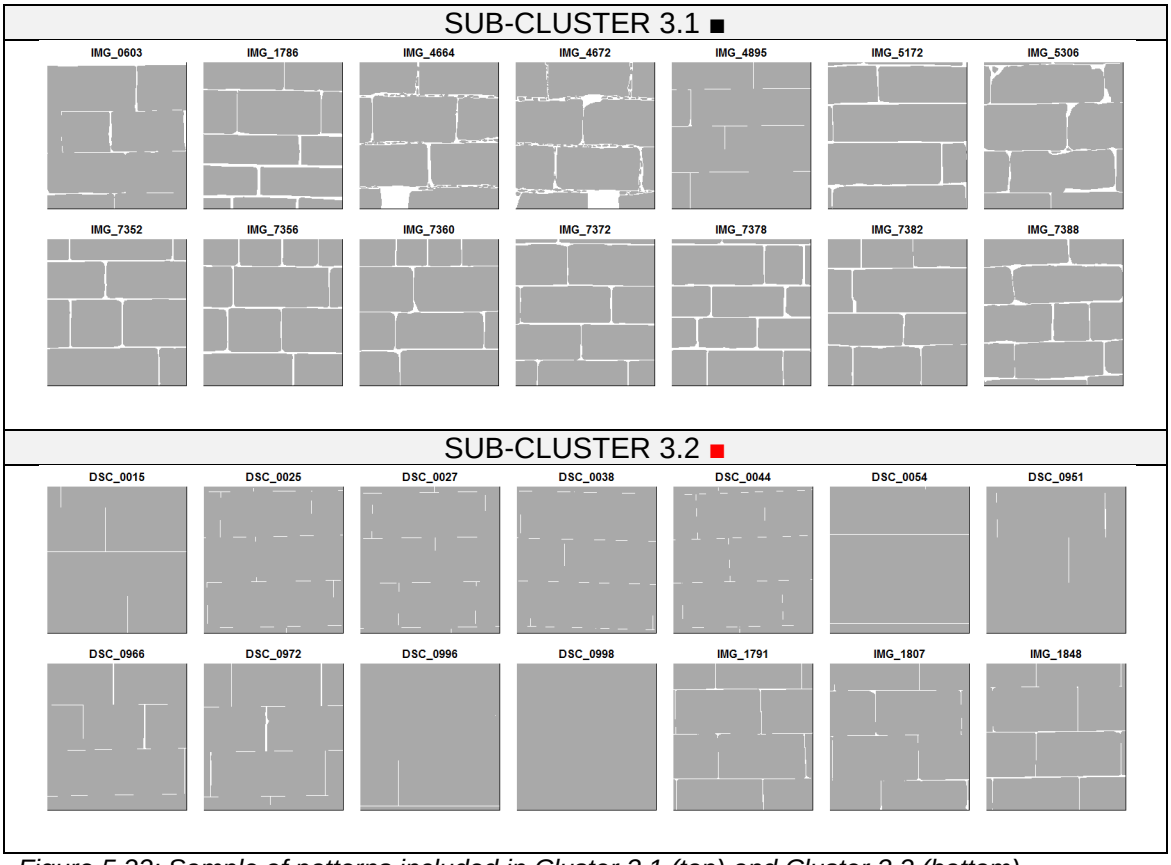


Figure 5.22: Sample of patterns included in Cluster 3.1 (top) and Cluster 3.2 (bottom).

The training of a classifier considering 80% of the sample confirms the SP as the most determinant parameter in the classification, as well as highlighting the relevant influence of the mean unit height. Figure 5.23 illustrates such result and shows that, of the remaining parameters, only the UA and HSD have an additional minimal influence. The other parameters do not count.

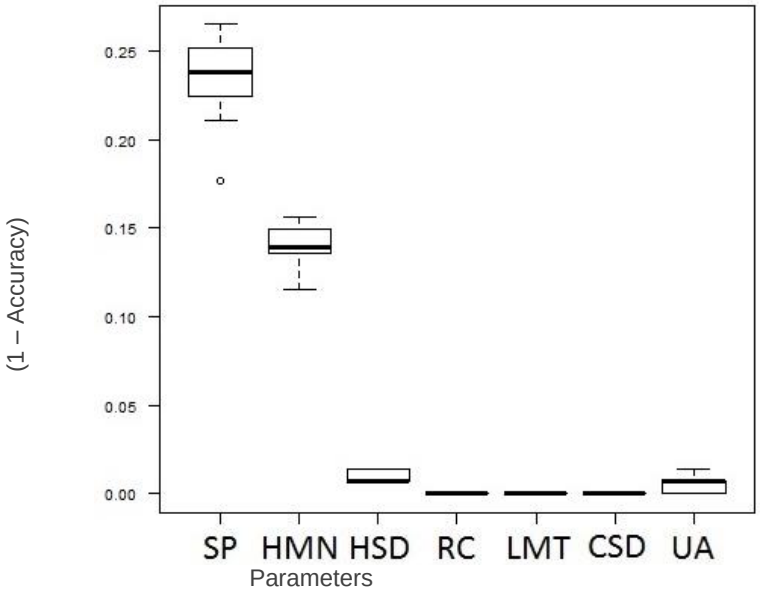


Figure 5.23: Result of the training of a classifier based on 80% of the sample, determining the relevance of each parameter for the classification.

Figure 5.24 illustrates the distributions of the two relevant parameters. It is evident that the shapes of the curves in both plots are clearly different and, despite having certain overlapping, this only affects a small section of the lines. The extent of the overlap is detailed in Table 5.7 and Table 5.8, which numerically determine the characteristics of each cluster, defining the peak value and high density interval per parameter and per cluster. According to the numbers provided, sub-cluster 3.2 has the narrowest ranges and the highest values for the two relevant parameters (SP and HMN). In particular, the overlap related to SP is located in a very narrow range (between 97.16% and 97.78%). Something similar happens with HMN, where the overlap occurs between 29.95cm and 30.23cm. These numbers show that Cluster 3.2 incorporates the patterns composed of the most perfectly shaped units.

It can therefore be concluded that the type of pattern defined by Cluster 3 includes two variants principally determined by the percentage of stone per sqm and the mean unit height.

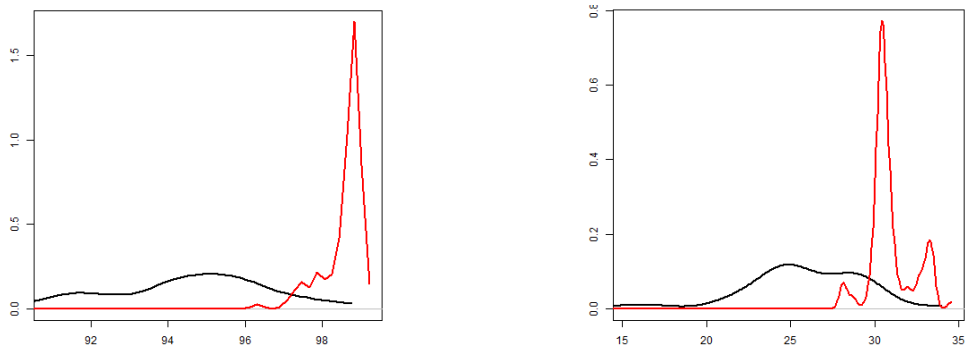


Figure 5.24: Plot of the kernel density estimation defining the distribution of each cluster. The three plots correspond to the three most determining parameters: SP (left), HMN (centre) and SP (right).

		Sub-cluster 3.1	Sub-cluster 3.2
SP	**upper**	**97.16**	**99.10**
	lower	**90.84**	**97.78**
HMN	**upper**	**30.23**	**33.50**
	lower	**21.34**	**29.95**
HSD	upper	3.85	1.25
	lower	0.76	0.07
UA	upper	1.0000	1.0000
	lower	0.9990	0.9999
RC	upper	0.99	1.00
	lower	0.94	0.98
LMT	upper	204.53	254.33
	lower	119.16	148.23
CSD	upper	6.11	3.38
	lower	0.41	0.00

Table 5.7: Lower and upper values defining the 95% high density interval for each parameter and cluster.

	Sub-cluster 3.1	Sub-cluster 3.2
SP	**95.5**	**98.75**
HMN	**25**	**30.5**
HSD	1.5	0.25
UA	0.9995	0.9999
RC	0.985	0.9875
LMT	150	175
CSD	2.5	0.5

Table 5.8: Peak value for each parameter and cluster.

5.4 DISCUSSION OF THE RESULTS

The results presented in this chapter demonstrate that the classification method detailed in the methodology chapter successfully defines types of masonry patterns based on quantitative parameters that adequately represent morphological features derived from the construction technique. This classification method did not exist before and provides objective criteria, which overcome judgements based on formal aspects subject interpretation. This was an issue identified in the literature review and needed to be solved to ensure adequate interpretation of the results presented in this thesis.

In particular, it was possible to identify three main types of patterns or clusters and their variants or sub-clusters. Figure 5.25 summarises the different types and variants, including an image of a pattern representative of each group.

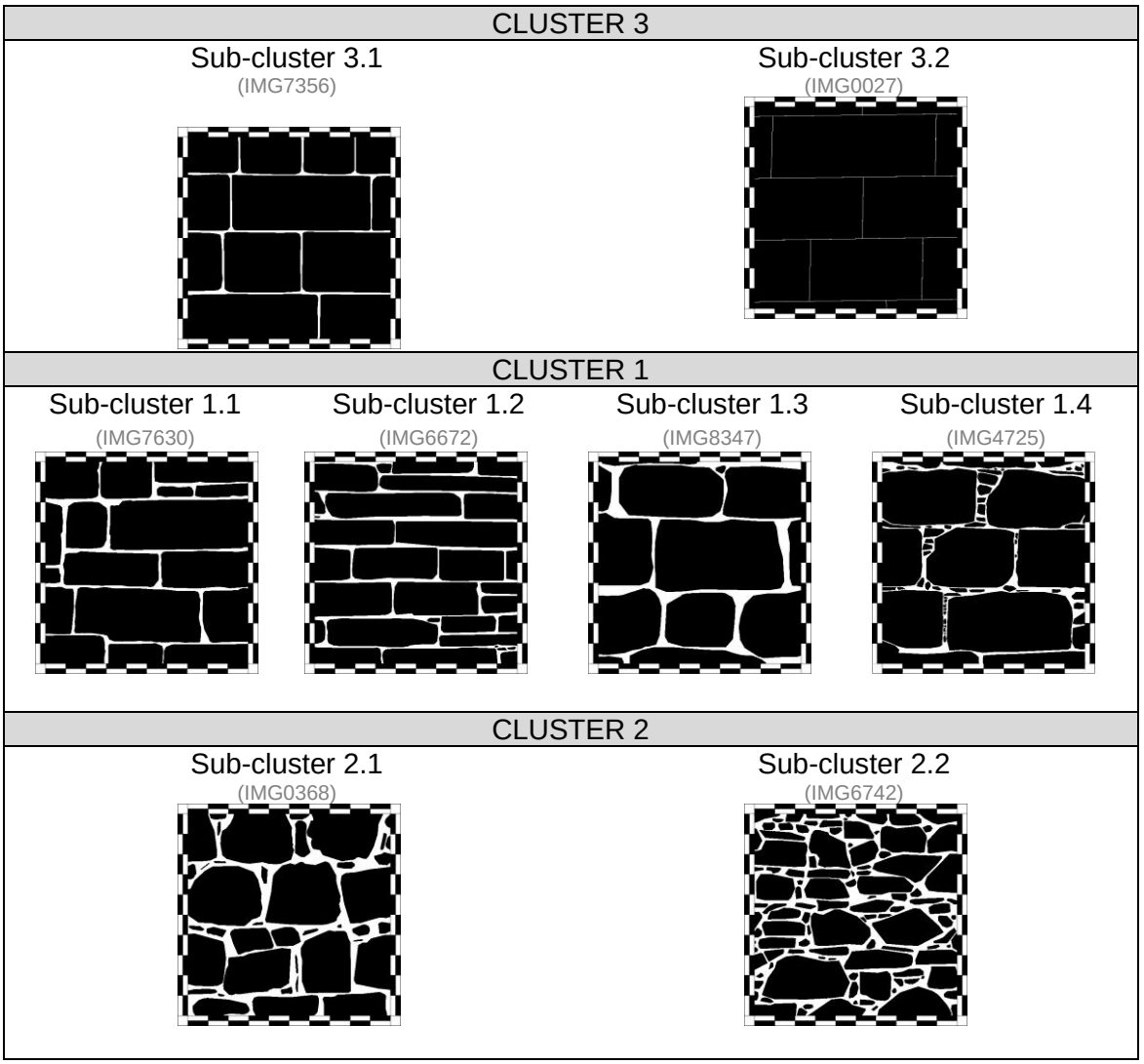


Figure 5.25: Graphic summary of the clusters and sub-clusters objectively defined.

The seven parameters defined for the classification accurately determine the main features related to the masonry technique adopted in the construction process. Four refer to the dimensions and geometry of the units: SP), RC, HMN and HSD. The remaining three are associated with the assembly strategy, and define the face-

bonding of the pattern (LMT), course regularity (CSD) and the alignment of the units within the courses (UA).

The whole classification is mostly influenced by parameters related to the geometry and size of the stones, while those linked to the arrangement of the units have only a secondary role. In the case of the three main types or clusters, the most important parameter for the classification of patterns is the percentage of stone units per sqm (SP). The most frequent value of SP for Cluster 3 is 98.5% while for Clusters 1 and 2 these figures are 87.5% and 79%. These peaks correspond to clearly different 95% high density intervals. The range of this parameter in Cluster 3 is very narrow, comprising values between 94.10% and 99.10%. In the case of Cluster 1, the interval is slightly wider, with a lower bound of 84.61% and an upper bound of 94.46%. Finally, for Cluster 2, 95% of cases lay between 73.54% and 90.42%.

The SP parameter is directly related to the RC. The more regular the stone units, the thinner the mortar joints can be and consequently the higher the percentage of stone in the pattern. Indeed, Cluster 3 is the most regular, with RC values ranging from 0.97 to 1 and the majority of cases concentrated around 0.985, meaning that their shapes resemble perfect rectangles. Cluster 1 and Cluster 2 include less regular cases. The former have a 95% high density interval between 0.97 and 0.85, with higher concentrations of cases around 0.93. Cluster 2 includes the most irregular units, with very diverse RC values. 95% of the cases in this cluster have values between 0.90 and 0.69, with a subtle peak at 0.825.

Cluster 2 includes the most irregular units and is divided into two sub-clusters (sub-cluster 2.1 and sub-cluster 2.2). These are mainly defined according to the RC and the HMN, followed by the SP. Sub-cluster 2.1 includes cases with larger sizes and less irregular units. 95% of the cases with RC therefore range between 0.9 and 0.76, with a clear peak at 0.875. The majority HMN values are within 13.64cm and 23.90cm with a higher concentration close to 15cm. Instead, the SP parameter has a 95% high density interval between 78.35 and 90.42, corresponding to higher values for Cluster 2. Sub-cluster 2.2, however, incorporates patterns with more irregular and smaller units. Thus, most of the cases in sub-cluster 2.1 have lower RC values. In particular, 95% of the samples have rectangularity of between 0.83 and 0.68 with a peak of 0.73. For HMN, the range includes values between 7.71cm and 15.94cm with a peak at 13cm.

Cluster 3 represents the opposite situation, including cases with the highest percentage of stone in the pattern and the most regular units. This cluster is divided into two groups (sub-cluster 3.1 and sub-cluster 3.2), which are mainly determined by two parameters: SP and HMN. Sub-cluster 3.1 includes patterns with the thickest joints in the group. 95% of cases range between 90.84 and 97.16, and there is a slight peak at 95.5. The HMN ranges from 21.34 cm to 30.23 cm, with a higher concentration of cases close to 25cm. Sub-cluster 3.2, though, incorporates patterns with thinner joints and therefore the most perfectly elaborated units in the group. In this case, 95% of cases of SP range from 97.78 to 99.10, forming a clear peak at the high value of 98.75. The HMN values are higher than in the previous case, ranging between 29.95 cm and 33.50 cm, with a remarkable peak at 30.50cm.

Finally, Cluster 1 represents an intermediate situation between Cluster 3 and Cluster 2. Unlike the other clusters, the second level of classification results in four sub-clusters. This is probably because it is the smallest sample of patterns and the most heterogeneous. The distributions of values corresponding to the four sub-groups reveal relevant overlaps of ranges corresponding to different parameters. However, the quantitative character of the method enables the identification of boundaries between groups. The most influential parameters for the sub-division are RC, the HMN and their HSD.

Sub-clusters 1.1 and 1.2 have very similar distributions for RC. The 95% high density interval of the former comprises values between 87.89 and 94.46, while the figures for the later ranges lie between 0.90 and 0.95. In addition, both cases have a clear peak at 0.935. Sub-clusters 1.3 and 1.4 are different. The majority of cases range between 72.00 and 88.58 in the former and 85.58 and 90.81 in the latter, with peaks at 0.925 and 0.87 respectively. Sub-cluster 1.2 highlights the HMN parameter. In this case, it has the 95% high density interval with the lowest values in the group (between 11.67cm and 16.17cm) and a clearly differentiated peak at 12.5cm. The similar sub-clusters in this case are 1.1 and 1.3, with the majority of values ranging between 19.24cm and 30.59cm in the former and 24.12cm and 37.25cm in the latter, and clear peaks at 27.5cm. Sub-cluster 1.4 is located in an intermediate position, with the 95% high density interval between 14.63cm and 24.96cm, and a peak at 17cm.

Regarding the HSD, the two more opposed sub-clusters are sub-cluster 1.3 and sub-cluster 1.4. The former has the most homogeneous units with the majority of values varying only between 0.80cm and 5.12cm, with a clear peak of standard deviation at 1.5cm. The latter has the most heterogeneous heights, with the 95% high density interval between 4.25cm and 13.35cm, and a clear peak at 11cm. Sub-cluster 1.2 is very similar to sub-cluster 1.3, but with slightly higher values. The majority of its cases have a standard deviation of heights ranging between 2.14cm and 5.80cm but with a higher concentration of cases around 3.5cm. Finally, sub-cluster 1.1 is between sub-clusters 1.3 and 1.4. Its distribution of cases ranges mainly between 1.95cm and 9.06cm, with a double peak curve with maximums around 4.5cm and 8.5cm.

These findings strictly relate to the literature review of masonry techniques in the UK presented in chapter 2. There, the geometry and size of stones is identified as a determining parameter for the construction of masonry patterns. In particular, it is highlighted that masonries are composed of horizontal courses or layers. Regular units are easy to organise in courses because of the parallelism of the faces. On the contrary, the use of irregular units hinders the definition of the layering and challenges the ability of the mason during the assembly process. This leads to the conclusion that the geometry of stones determines the strategies developed for the application of the Stonemason’s Gospel in a specific context.

The link between shape of units and their arrangement to form courses is also identifiable in the results obtained from the classification method. The parameter used to represent the regularity of horizontal courses is CSD. The lower the value of CSD, the more regular the courses. Cluster 3, which has the most rectangular units, also has the lowest peak value of CSD, while Clusters 1 and 2 have 15 and 25, respectively.

In light of the discussion so far, the objective classification method developed in this thesis successfully identifies groups or clusters of masonry patterns with common characteristics, as well as their variants or sub-clusters. The parameters defined for the classification adequately characterise the reality and techniques described in the literature, going beyond mere formal judgements. This makes the method applicable to heterogeneous datasets, including all types of patterns. In addition, the analysis sequence defined is reproducible. This allows the method to be used in future investigations.

5.5 CLUSTERS AND CONTEXT

The results presented provide a dataset that quantitatively defines and classifies a varied set of 426 masonry patterns built within 34 stately residences. This dataset, referred to here as the P-dataset (see appendix 2), offers a unique opportunity to further develop some of the conclusions derived from the analysis of the context presented in the previous chapter. In particular, this section considers two points.

The first point derives from the analysis of the countryside stately home. This was based on a series of parameters, of which three referred to the masonry characteristics. In particular, one parameter defined groups of masonry patterns based on the formal criteria generally used in Scottish literature. Six groups were defined: very regular, irregular, intermediate, and their combinations. The other two parameters defined prevalent wall thicknesses. The results of the analysis highlighted that very regular masonry patterns are clearly associated with the seventeenth and eighteenth centuries. In addition, a trend of decreasing wall thicknesses over time was noted.

The second point derives from analysis of the work groups. The results obtained defined three different work environments related to prominent architects of the time. In particular, Environment-1 was associated with the Adam family, Environment-2 revolved around the figures of Sir William Bruce and James Smith, and the main figure in Environment-3 was James Murray. These environments define a sequence that represents the progressive appearance and consolidation of the architect in Scotland.

To examine these two points further, the P-dataset was enriched by adding four additional fields of information to each pattern: (1) estimated year of construction, (2) the involvement of architects in construction, (3) the thickness of the wall section, and (4) the masonry type or cluster. The first two fields are defined according to the literature review, while the third field is obtained directly by measuring the walls on site and the fourth is the result previously presented in this chapter.

Figure 5.26 shows the distribution of patterns included in the enriched dataset according to the period of construction and the intervention of architects. It is apparent that, on this occasion, the dataset covers a wider period of time with respect to the dataset used in the morphological analysis of the stately home. In addition, 38% of the cases correspond to non-architect-related cases, while the remaining 62% are related to the three environments identified. This is divided as follows: 5% of the patterns are

related to interventions developed within Environment-3, 22% are linked to Environment-2, and 35% correspond to Environment-1.

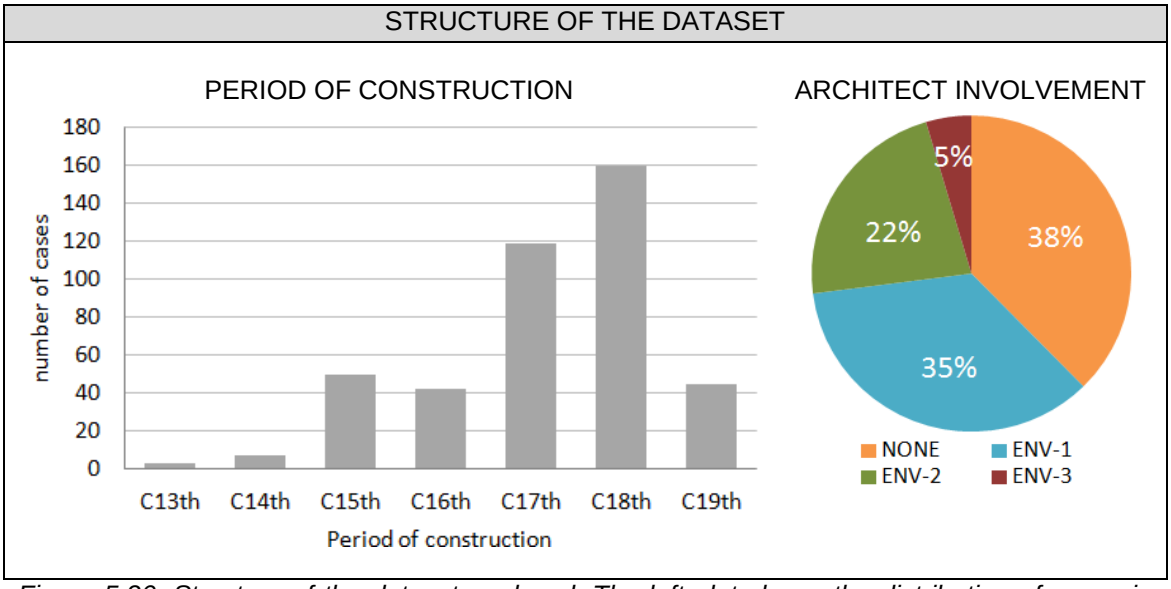


Figure 5.26: Structure of the dataset analysed. The left plot shows the distribution of cases in terms of period of pattern construction. The right plot does the same in terms of architect- and non-architect-related patterns. The category "None" determines non-architect-related cases, while the other three categories correspond to the three environments defined in the analysis of the context.

Figure 5.27 shows the four new fields. The x and y axes represent the estimated year of construction of each sample of pattern in the dataset and the wall thickness from which the pattern was obtained. The colours of the points determine the three main masonry clusters: black corresponds to Cluster 1, red to Cluster 2 and green to Cluster 3. Finally, the involvement of an architect in the construction process is defined through the shape of the point: triangles represent non-architect-related masonry while circles do the same for architect-related masonry.

The estimated year of construction for those cases not directly related to a specific year of construction in the literature but to a decade or a century is determined by rounding the decade or century defined. For example, a sample dated to the fourteenth century is assigned the year 1500, while one dated in the 1650s is assigned the year 1650.

The resulting scattering of the points shows a decreasing tendency, which coincides with the trend highlighted in the morphological analysis of the stately home. However, on this occasion the three masonry clusters respond to an objective classification. This distribution leads to two considerations. The first relates to the dissimilar distribution corresponding to the most regular masonries (green) with respect to the other two clusters (red and black). The most regular is concentrated between 1600 and 1800 and corresponds to wall thicknesses close to 1m, while the other two clusters have a scattered distribution in terms of both thickness and time. The second consideration is related to the involvement of architects in the construction. Circular points, which correspond to architect-related works, are concentrated between 1600 and 1800, while non-architect-related masonries (triangular points) are spread throughout the chart.

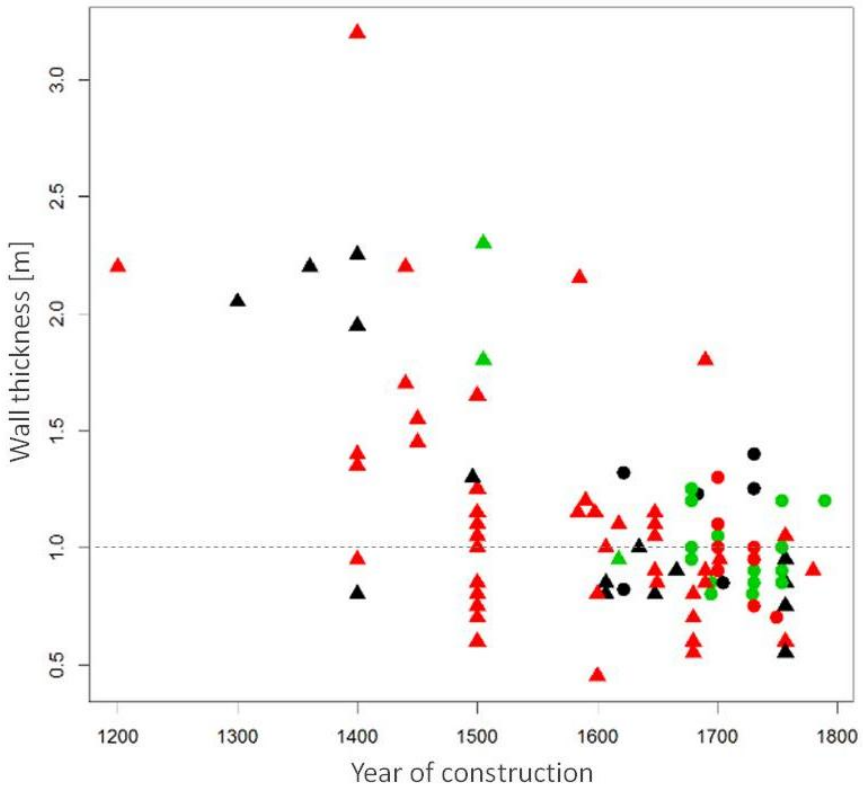


Figure 5.27: Scattered plot of the samples considered for the clustering. The x axis defines the estimated year of construction of each sample while the y axis determines the thickness of the masonry section in metres. The shape of the points defines whether the masonry is related to an intervention led by an architect: (●) or not (▲). The colour of the points determines the masonry cluster: ▬ Cluster 1, ▬ Cluster 2, ▬ Cluster 3.

An interesting aspect to note is that almost all the Cluster 3 points (green) are architect related (circular). Given that the cases studied define a time sequence that represents the architectural context of the period, the results obtained reveal that the intervention of architects is related to use of the most regular masonry cluster. This observation was already discussed in the previous chapter, focused on the analysis of the context. However, the use of objective classification as well as a sample representing a wider time range, including a higher number of architect-related cases, strengthens these conclusions and highlights the involvement of the architect as a determining factor for masonry. This finding is further investigated in the following chapter.

Chapter 6
MASONRY MORPHOLOGIES

6.1 INTRODUCTION

This chapter presents the results obtained in the second part of this investigation. The focus is on the morphological characterisation of the stone masonry in the facades of the case studies previously selected. The approach applied develops from the work of authors who confer special importance to the principles and techniques involved in the construction process, including Mannoni (1997, 2005), Parenti (1988, 1994) and Giuffré (1991, 2003). The original analysis sequence defined first separately studies the morphology of the three main parts of a wall (solid portions, corners and openings), before considering how all are integrated in the overall design of the elevation. This sequence is systematically applied to the groups of cases, enabling comparison and therefore highlighting their characteristic features.

The chapter is divided into two parts. The first part includes cases for which the construction process is not related to the work of an architect. These comprise towers built before the seventeenth century, and new wing additions and isolated residences built between the end of the sixteenth century and the seventeenth century. The second part incorporates architect-related cases, grouped according to the three work environments selected. The results are discussed in the final section. The references used to define the estimated chronologies of the different elevations and masonries correspond with those already mentioned in section 6 of chapter 4.

The outcomes obtained build historic construction knowledge for each of the groups of buildings considered, solidly founded on the building techniques involved in construction. This is missing from Scottish literature as no comprehensive study of this type exists. This study therefore contributes to a more in-depth interpretation of built heritage, which is essential for its conservation.

6.2 NON-ARCHITECT-RELATED WORKS

This section focuses on case studies that belong to the group defined as non-architect-related works. In particular, this includes three different types of buildings: (1) towers built before the seventeenth century, (2) new wing additions and (3) isolated residences. The focus for the latter two is on those built between the end of the sixteenth century and the seventeenth century. In order to avoid repetition, the section is divided into four sub-sections corresponding to the four aspects of the masonry analysed: the solid portion of wall, the corners, the openings and the elevations.

6.2.1 SOLID PORTION OF WALL

The solid portion of wall is characterised based on two different aspects. The first is the masonry pattern, which is defined according to the objective method defined in a previous chapter. The second aspect is the structure of the section, which is identified based on a visual inspection on site.

6.2.1.1 Pattern characterisation

The study of masonry patterns in the front facades of the case studies leads to two conclusions. The first conclusion is related to the type of pattern. As shown in Table 6.1, almost all the cases have patterns belonging to Clusters 1 or 2. Only the old tower of Holyrood Palace escapes this rule. The second conclusion refers to the similarities between the patterns identified in the internal and external wall faces. The internal wall face of the elevations was not visible in all the cases. However, in buildings where inspection was possible, it was found that external and internal patterns do not significantly differ. This point is demonstrated when comparing the columns corresponding to the inner and outer wall faces. The following sections detail the specific characteristics of each case.

BUILDING GROUP	BUILDING NAME	MASONRY PATTERN CLUSTER	
		Outer wall face	Inner wall face
TOWERS BUILT BEFORE THE SEVENTEENTH CENTURY	Balgonie Castle tower	1	-
	Castle Campbell tower	1–2	2
	Craigmillar Castle tower	1–2	-
	Burleigh Castle tower	2	2
	Kilchurn Castle tower	2	2
	Tolquhon Castle tower	2	-
	Holyrood old tower	3	-
ISOLATED RESIDENCES	Glenbuchat	2	2
	Pittarthie	1–2	1–2
	Gilbertfield	1–2	1–2
	Auchans	2	-
	Redhouse	2	2

NEW WING ADDITIONS	Tolquhon	2	2
	Craigmillar	2	2
	Aberdour	2	-
	Balgonie	1-2	-
	Kilchurn	2	2

Table 6.1: Classification of the masonry pattern of the elevations based on analysis of 1sqm samples according to the objective method defined in a previous chapter.

TOWERS BEFORE THE SEVENTEENTH CENTURY

As shown in the previous table, the most regular masonry among the towers is identified on the facades of Holyrood Palace's old tower. This is composed of elaborate stone units organised in regular courses and therefore classified in Cluster 3. The samples obtained from the tower of Balgonie also show regular patterns. However, in this case, the level of elaboration of the stone units is lower, meaning that they are classified in Cluster 1.

The patterns of the towers of Craigmillar and Castle Campbell vary between Clusters 1 and 2 depending on the portion of wall considered. In the case of Castle Campbell's tower, a clear difference exists between the lower part of the wall and the wall emerging from ground floor level. The lower part is more irregular and therefore classified in Cluster 2. The upper part, though, is more regular with frames and can be classified in Cluster 1 or at the boundary between Clusters 1 and 2.

Finally, the masonry patterns of Burleigh, Kilchurch and Tolquhon are part of Cluster 2. The samples from Burleigh tend to be in sub-cluster 2.1, while the other two cases are mostly part of sub-cluster 2.2. It is interesting to highlight that Kilchurn and Tolquhon are both located in areas where sandstone is not predominant. The irregularity of the pattern is therefore probably related to the characteristics of the stone available. Burleigh, however, is located in an area rich in sandstone. The stone used in its construction seems to be red sandstone, easy to dress using the tools available at the time. The reasons behind the irregularity of its pattern are therefore of another nature.

Figure 6.1 illustrates this, presenting one sample per building corresponding to the external face of the facades studied.

CLUSTER 1



Balgonie Castle
(IMG8404; built c.1360s)



Castle Campbell
(IMG0599; built C15th)



Craigmillar Castle
(IMG9405; built C14th–15th)

CLUSTER 2



Castle Campbell
(IMG0597; built C15th)



Craigmillar Castle
(IMG9417; built C14th–15th)



Burleigh Castle
(IMG5208; built c.1450–1500)



Kilchurn Castle
(IMG5775; built c.1440–60)



Tolquhon Castle
(IMG7188; built C13th)

CLUSTER 3



Holyrood Palace old tower
(IMG7382; built early sixteenth century)

Figure 6.1: Showcase of one sample per case corresponding to 1sqm of the external wall face and grouped according to the clusters defined.

ISOLATED RESIDENCES

The patterns of the isolated residences vary between Clusters 1 and 2. Figure 6.2 presents one sample per building corresponding to the external face of the facades studied. Pittarthie and Gilbertfield have the most regular patterns, belonging to Clusters 1 or 2 depending on the area of the facade (those in Cluster 2 are part of sub-cluster 2.1). However, the masonry patterns defined at Glenbuchat, Auchans and Redhouse are composed of irregular units and correspond exclusively to Cluster 2 regardless of the area of facade observed (all three are in sub-cluster 2.2). It is again worth highlighting that Glenbuchat and Auchans are located in non-sandstone sites.

CLUSTER 1



Pittarthie
(IMG1512; built c.1682)



Gilbertfield (20150716_111035; built c.1607)

CLUSTER 2



Glenbuchat
(IMG6303; built 1590s)



Pittarthie
(IMG1492; built c.1598?)



Gilbertfield
(20150716105801; built c.1607)



Auchans
(IMG1996; built 1650s)



Redhouse
(IMG2470; built lateC16th–earlyC17th)

Figure 6.2: Showcase of one sample per case corresponding to 1sqm of the external wall face and grouped according to the clusters defined.

NEW WING ADDITIONS

New wing additions are composed of patterns generally belonging to Cluster 2. The exception is Balgonie. The type of masonry pattern in this building varies depending on the area of wall observed. Figure 6.3 shows three different samples of patterns from Balgonie's new wing additions. Two of these correspond to Cluster 1 and the third, more irregular, has been classified as sub-cluster 2.1, possibly because of a complex construction history that, although no documentary evidence has been found, can be deduced from the discontinuities of elevation patterns. The remaining cases have more homogeneous patterns. Kilchurn, Tolquhon and Craigmillar have similar characteristics

and belong to sub-cluster 2.2, while masonry patterns in Aberdour correspond to sub-cluster 2.1.

CLUSTER 1



Balgonie
(IMG8306; built 1630s)



Balgonie
(built 1660s)

CLUSTER 2



Tolquhon
(IMG7640; built c.1584-89)



Craigmillar
(IMG9399; built C16th)



Craigmillar
(IMG9134: built C17th)



Balgonie
(IMG8341; built c.1702–06)



Kilchurn
(IMG5927; built 1690s)



Aberdour
(DSC0368; built c.1648)

Figure 6.3: Showcase of one sample per case corresponding to 1sqm of the external wall face and grouped according to the clusters defined.

6.2.1.2 Structure of wall sections

The study of wall sections reveals a notable difference between towers built before the seventeenth century and their subsequent new wing additions and isolated residences. The former type of building is composed of facades with thicknesses ranging between 145cm and 320cm, while, for the other two, these oscillate around 100cm.

The structure of wall sections is directly related to thickness. In this way, walls in the order of 200cm tend to have massive sections, while those close to 100cm have a clear structure formed by two outer layers and a central core. The width of the central core varies depending on the total dimension of the section.

TOWERS BUILT BEFORE THE SEVENTEENTH CENTURY

The range of wall thicknesses recorded in all the cases varies between 1.45m and 3.20m although the most repeated value is 2.20m (Table 6.2). In some cases, these thicknesses connect small rooms, stairs or other reduced spaces, not necessarily visible from the exterior of the wall.

TOWER	Thickness of the façade walls measured at ground floor level [m]
Burleigh Castle tower	1.45–1.55
Kilchurn Castle tower	1.70–2.20
Holyrood Palace tower	1.80–2.30
Tolquhon Castle tower	2.20
Balgonie Castle tower	2.20
Castle Campbell tower	2.25
Craigmillar Castle tower	3.20

Table 6.2: Thickness of the walls at ground floor level.

The wall section could only be inspected at Kilchurn and Tolquhon, where partial collapses had occurred. In the case of Kilchurn, the original structure of the section had been altered by an intervention aiming to conserve and consolidate the wall core. This therefore could not be considered for the study (Figure 6.4-left). The tower at Tolquhon Castle, though, is cut along all its height, leaving the section clearly visible (Figure 6.4-right). Despite some conservation works having also been performed, in this case it was possible to appreciate that a substantial number of stones making up the wall faces (internal and external) are bedded with the longest dimension towards the interior of the core in order to better bond the section. The central core appears large and packed, composed of stones of various sizes. The presence of mortar in the core could not be confirmed as conservation works may have altered the original situation.

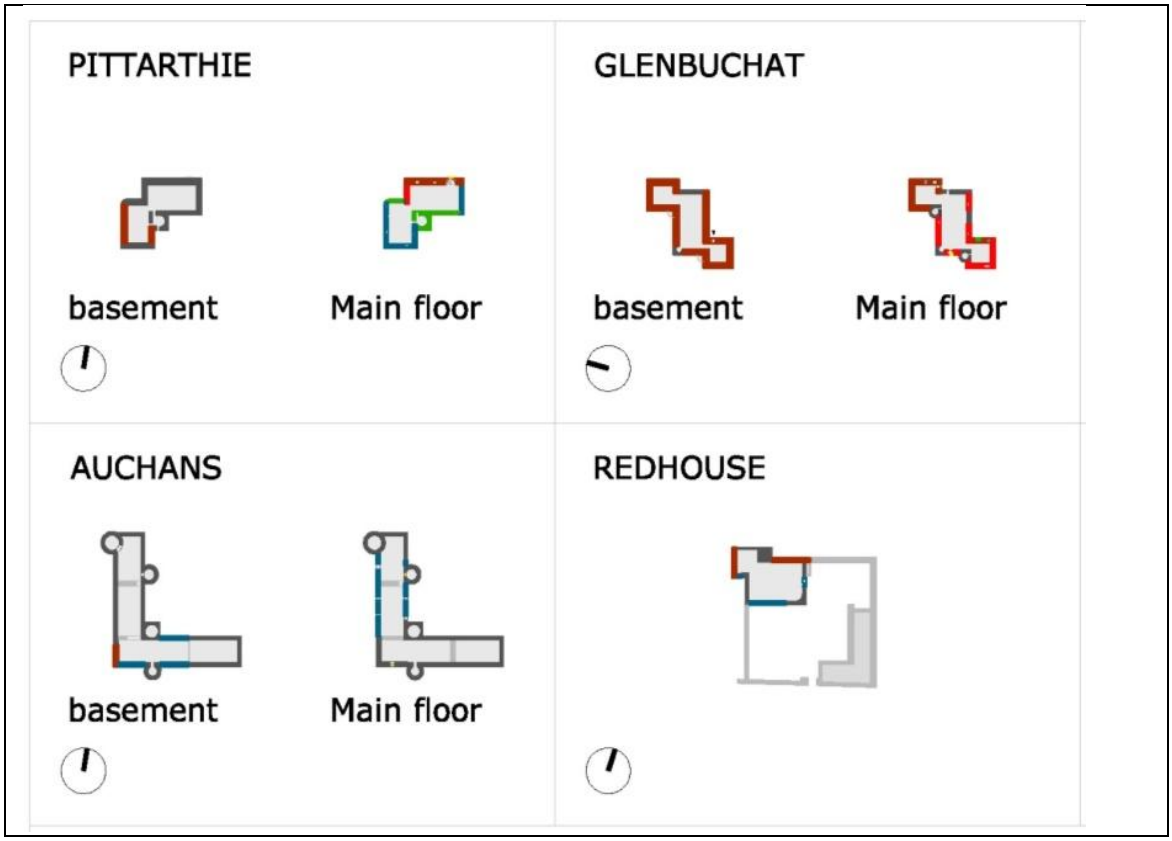


Figure 6.4: Images of sectioned walls. Left: Kilchurn Castle tower (built C15th). Right: Tolquhon Castle tower (built C13th–15th).

ISOLATED RESIDENCES

In the case of isolated residences, the thickness of facades varies around the 100cm. Given changes of thickness along the height of the walls, two situations are noted: (1) buildings where the section of the facade at ground floor level is greater than at upper levels; and (2) buildings where the section of the facade is constant. Glenbuchat, Gilbertfield and Pittarthie correspond to the first group, while Auchans and Redhouse belong to the second.

Glenbuchat has the thickest walls, ranging between 110cm and 120cm at ground floor level and rarely thinner than 100cm at first floor level. Notably, this building is related to the earliest period of construction. A similar situation exists in what was probably the earliest part of Pittarthie and in one of Gilbertfield's facades, where thicknesses are greater than 100cm at ground floor level and decrease at first floor level. However, in both cases, the values of the upper part of the wall range between 80cm and 85cm. Auchans and Redhouse, however, belong to the group of walls defined by an invariable wall section. Their thickness values are between 80cm and 85cm. Figure 6.5 classifies the wall thicknesses identified in the five cases considered.



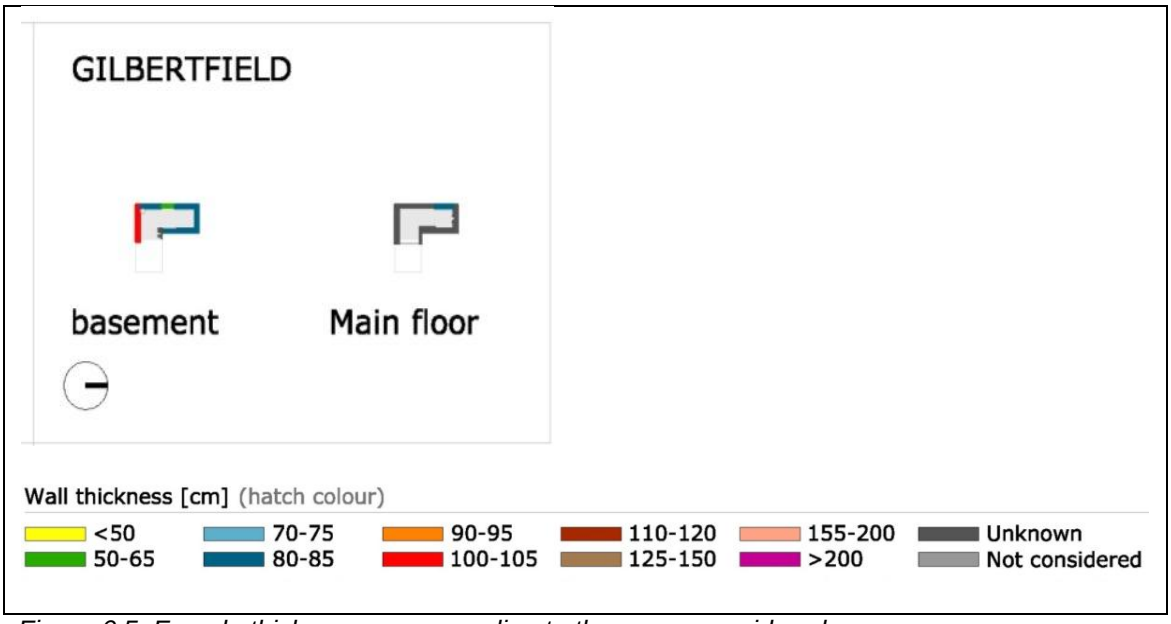


Figure 6.5: Facade thickness corresponding to the cases considered.

The section of the facades was visible in all cases with the exception of Redhouse, where no partially collapsed walls were standing. This provided a unique opportunity to examine their structure. Figure 6.6 shows images of the sections corresponding to the different buildings. In all cases the wall is formed in three layers: a central core composed of mortared smaller stones and wedges and two similar faces (internal and external) composed of larger stones, also mortared. The use of bonding stones can be clearly seen in some of the images. Figure 6.6-d illustrates the special case of a wall composed of one single layer 35cm to 40cm thick. This corresponds to the remains of a chimney. Window ledges were usually defined following the same single-layer strategy.

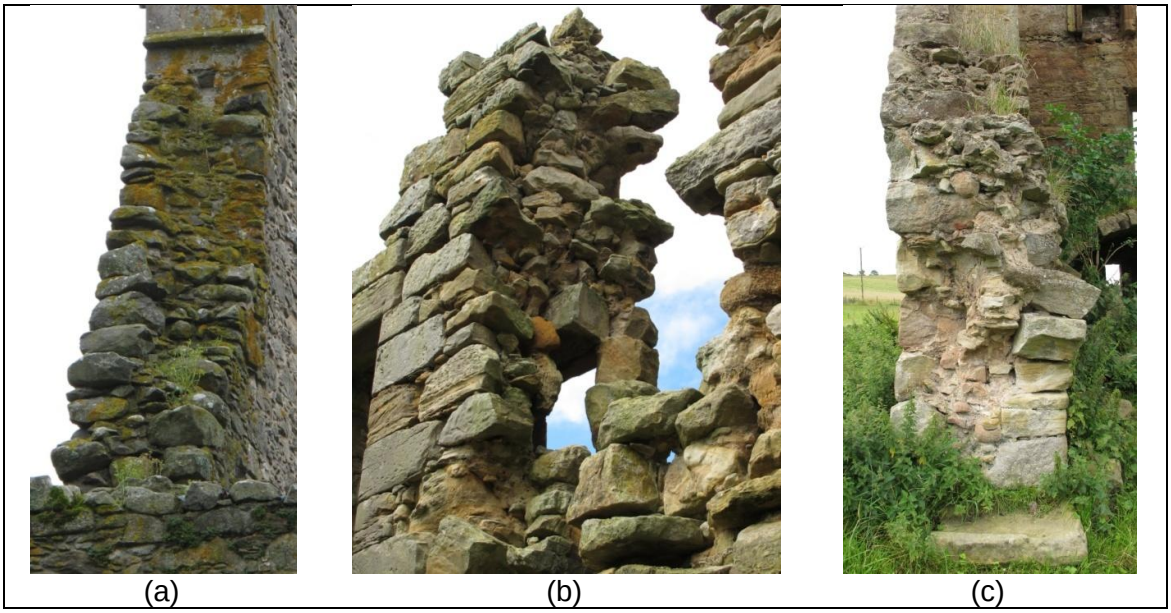




Figure 6.6: Sections of different wall sections identified on site: (a) Glenbuchat, (b) Pittarthie, (c) Gilbertfield general case, (d) Gilbertfield chimney/window, (e, f, g) Auchans.

NEW WING ADDITIONS

Analysis of the five new wing additions suggests that volumes built in decades prior to 1700 tend to be composed of walls with thicknesses greater than those built in later decades (Figure 6.7). The clearest example of this is found at Craigmillar. The sixteenth century addition (east wing) was built with walls between 100cm and 105cm thick, while the subsequent seventeenth century section (west wing) is composed of walls between 80cm and 85cm thick. Balgonie presents a similar situation. In this case the part of the building constructed in 1496 has walls between 110cm and 120cm thick, while the addition between 1635 and 1641 is composed of walls ranging from 100cm to 105cm thick and the walls of the 1666 section are 90cm to 95cm thick.

Similarly, walls built in the seventeenth century additions at Kilchurn and Aberdour also have thicknesses of around 100cm. In the case of Kilchurn, the lower part of the wall ranges between 90cm and 120cm depending on the case, while the upper levels are 80cm to 90cm thick. At Aberdour, thicknesses at ground floor level range from 90cm to 105cm, with one of the walls reaching 107cm.

The case of Tolquhon differs a little as it appears to have been designed as a whole although it was built in subsequent phases at the end of the sixteenth century. The changes of thickness in this case are especially relevant between the south volume, built during the first phase of construction with walls between 110cm and 120cm thick, and the two east and west additions, with walls ranging between 70cm and 85cm thick, corresponding to the third phase.

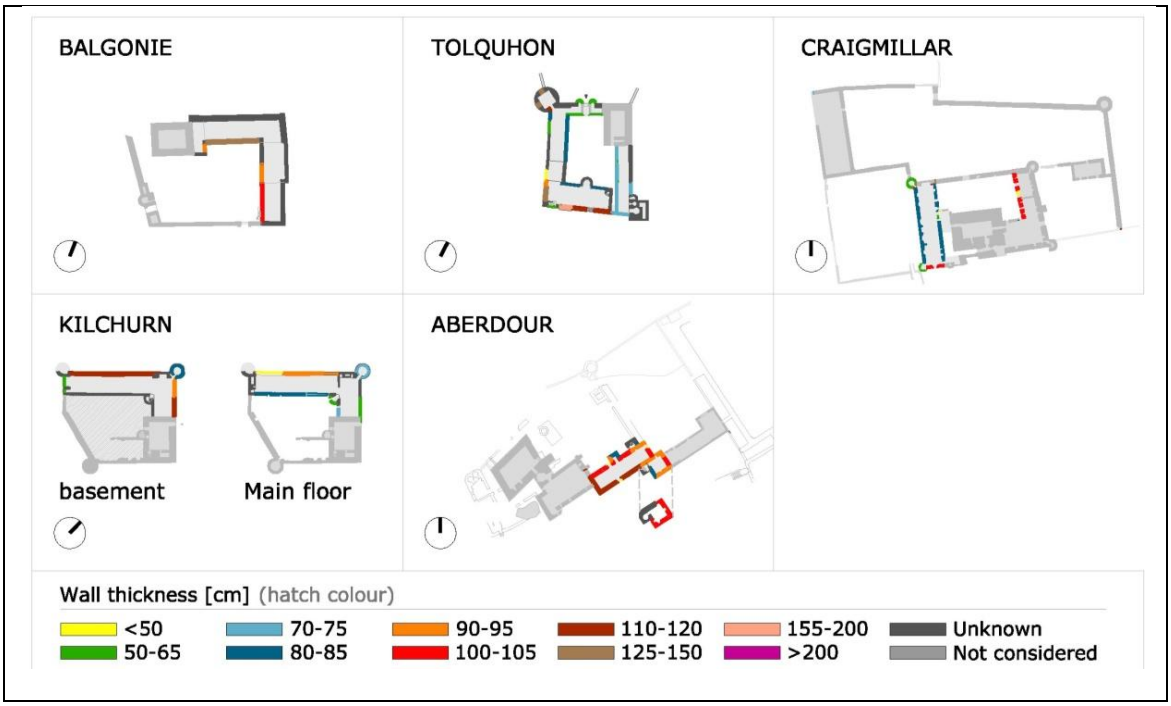


Figure 6.7: Facade thickness corresponding to the cases considered.

The structure of the wall section could be inspected in some cases, as shown in Figure 6.8. Despite the evidence of consolidation interventions, sections appear to follow a three-layer scheme. The thickness of the wall determines the size of the wall core, which is wider in sections greater than 1m and reduced to the minimum in cases close to 80cm. In addition, the use of bond and through stones can be clearly seen in some of the sections.



Figure 6.8: Different wall sections identified on site: (a) Tolquhon, (b) Craigmillar – 17th century wall, (c) Balgonie – 17th century wall, (d–e) Kilchurn – 80cm wall, (f) Kilchurn –50cm wall.

6.2.2 CORNERS

The morphology of corners is similar for the three groups of buildings. In all cases, the successive addition of quoins in height defines a simple straight and vertical edge, which has no further design intention other than the fulfilment of the Stonemason's Gospel. The shape of quoins is generally rectangular, although it is not rare to find cases with a tendency to triangular geometries. In addition, quoin heights and proportions vary along corners.

Figure 6.9Figure 6.10Figure 6.11 show 1sqm corner samples obtained from each of the cases studied according to the groups of buildings defined.

The case of Balgonie is particularly prominent as it has the most regular quoins in terms of rectangularity of shape (Figure 6.9). The corners at Holyrood are defined by round towers and quoins could not therefore be characterised.

Regarding the group of isolated residences (Figure 6.10), Pittarthie and Gilbertfield (pattern clusters 1–2) have the most regular quoins in terms of rectangularity of unit shapes. The opposite was the case for Glenbuchat and Auchans (pattern cluster 2), where the use of quoins with a tendency to triangular shapes is not rare. Redhouse, however, puts forward an intermediate situation.

Finally, in the case of new wing additions (Figure 6.11), quoins could only be identified in Balgonie, Aberdour and Tolquhon. The latter case is the most irregular in the group, while Aberdour and Balgonie are composed of regular units, showing a high degree of elaboration.

TOWERS BUILT BEFORE THE SEVENTEENTH CENTURY



Balgonie Castle
(IMG8388; built 1690s)



Castle Campbell
(IMG0315; built C15th)



Burleigh Castle
(IMG5178; built c.1450–1500)



Craigmillar Castle
(IMG9407; built C14th–15th)



Tolquhon Castle
(IMG7677; built C13th)



Kilchurn Castle
(IMG5783; built c.1440–60)

Figure 6.9: Sample of corner for each of the towers studied. Holyrood Palace tower has one rounded tower in each corner and consequently no image could be taken.

ISOLATED RESIDENCES



Glenbuchat
(IMG6282; built 1590s)



Pittarthie
(IMG1546; built c.1682)



Gilbertfield
(20150716_110444; built c.1607)



Auchans
(IMG1985; built c.1650)



Redhouse (IMG2468; built late C16th–early 17th)



Redhouse (IMG2478; built late C16th–early 17th)

Figure 6.10: Sample of corner for each of the isolated residences studied.

NEW WING ADDITIONS



Tolquhon
(IMG7633; built c.1584–89)



Balgonie
(IMG8429; built 1630s)



Balgonie
(IMG8380; built 1660s)



Aberdour
(IMG0363; built c.1648)

Figure 6.11: Sample of corner for each of the new wing additions considered.

6.2.3 OPENINGS

The openings identified in the different cases can be classified in two families. The first family includes vertical and narrow windows with a span close to 10cm to 20cm, such as embrasures. Lintels and sills are composed of one single stone, while jambs are formed by one, two or three stones depending on the case and can be either symmetric or asymmetric (Figure 6.12). This type of opening is common in towers although it has also been identified in the majority of isolated residences. It is rare in new wing cases. This suggests that this type of opening is typical from buildings following fortified schemes, generally constructed in the sixteenth century or earlier periods.



Figure 6.12: Examples of the group of vertical and narrow openings: (a) With jambs tending to symmetry; (b) With asymmetric jambs.

The second family includes the regular openings present in most of the cases. These openings have rectangular proportions and spans, which vary between 40cm and 100cm. These spans can be resolved with different lintel solutions, as shown in Figure 6.13.

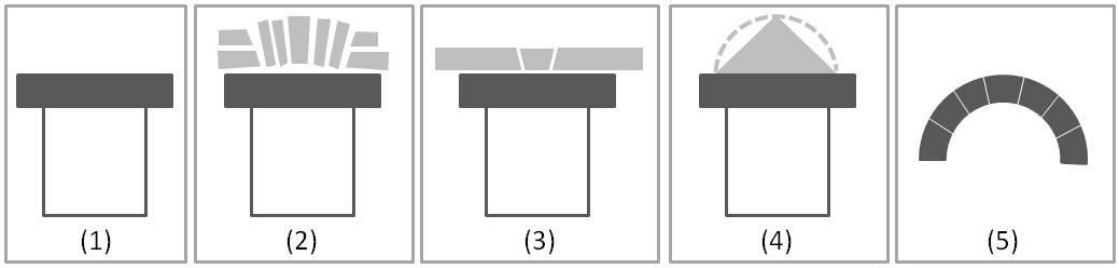


Figure 6.13: Lintel solutions identified based on observation of the external wall face.

Lintels composed of a single stone (Figure 6.13-1) are the solution most commonly used in the towers studied. This prevalence changes in the isolated residences and new wing cases, where lintels either have a single stone or a combination of a long stone and a relieving arch (Figure 6.13-1&2). Lintels combining a flat arch with a single stone (Figure 6.13-3) are occasionally identified in some of the buildings, whether towers, isolated residences or new wing additions. Finally, a reduced number of lintels respond to the schemes in Figure 6.13-4&5. This is the case for some windows in

Pittarthie, which include triangular/semi-circular stones above the lintel, or some openings in the new wing additions at Balgonie tower, Burleigh tower and Tolquhon, which have arched lintels composed of voussoirs.

Notably, lintels with one single stone on the outer face of the wall do not necessarily have the same solution in the inner face. Figure 6.14 illustrates this with two different examples. The first corresponds to a window on one of the new wing additions at Tolquhon, where the single stone lintel on the external wall face is hiding an arched solution, which supports the wall core and the internal facing layer. The second is a window from Auchans, where the single stone lintel on the external wall face is extended through all the wall thickness. In both cases, the masonry used corresponds to Cluster 2 patterns. The lintel solution is therefore not necessarily related to the masonry cluster.

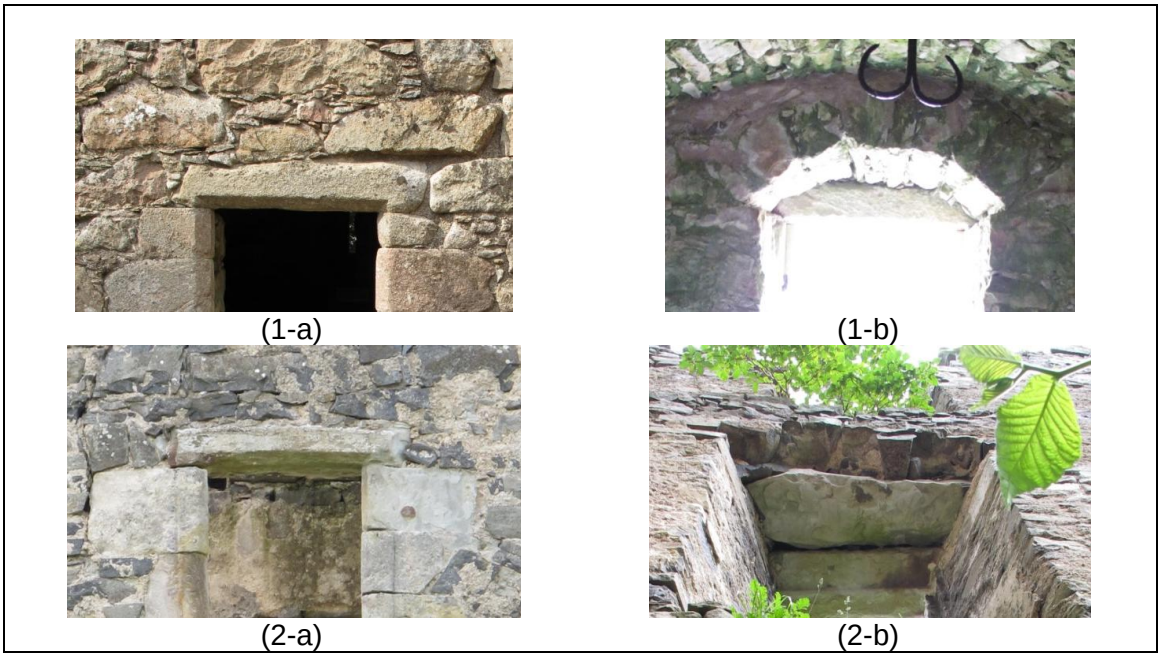


Figure 6.14: Two examples of single stone lintel solution. Top: Lintel of one of the openings from Tolquhon new wing additions: external wall face (1-a) and internal wall face (1-b). Bottom: Lintel of one of the openings from Auchans: external wall face (2-a) and internal wall face (2-b).

Jambs are generally formed by several stones of variable heights. The alternation of headers and stretchers is not always the rule and their final structure can be either symmetrical or asymmetrical, as shown in Figure 6.15. An interesting point to highlight is that, differently to what happened with corners, the edges of openings incorporate a degree of design. In the case of towers built before the seventeenth century, the perimeter of the opening is often highlighted by bevelling the edge. The same strategy is also used in later isolated residences and new wing additions. However, in these cases, apart from the bevelling, certain openings such as entrance doors are further emphasised with mouldings. The degree of complexity of the moulding varies depending on the case. In some of the buildings considered (e.g. Gilbertfield and Aberdour) the use of mouldings is extended to all openings. Figure 6.16 shows examples of the different types of edges identified.



Figure 6.15: Opening with asymmetric jambs and bevelled edges identified at Kilchurn Castle (left), and opening with jambs tending to symmetry and bevelled edges identified at Balgonie Castle (right).



Figure 6.16: Showcase of different types of mouldings identified: (1) straight edge, (2) bevelled edge, (3) simple moulding, (4) complex moulding and (5) protruding edge.

Some of the openings identified do not correspond with any of the two families defined. This is the case for the rectangular openings with spans greater than 1m on the old tower at Holyrood Palace and the pointed arched opening at Auchans. These cases are rare and therefore lack the necessary relevance to define families by themselves. However, they provide clues about interventions performed in different contexts and are therefore worth noting.

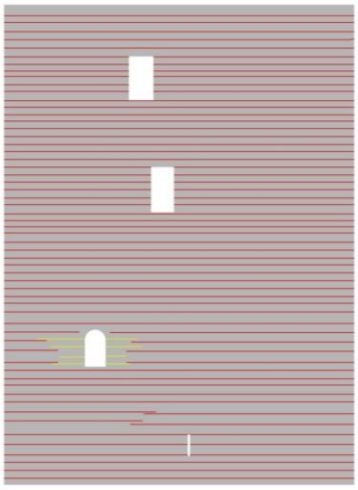
6.2.4 MASONRY ELEVATIONS

Given the overall structure of the masonry composing the elevations, the cases are grouped into the following four families: (1) masonry composed of continuous courses, (2) masonry composed of courses with discontinuities, (3) masonry built to courses and (4) masonry where the courses or lifts are difficult to identify.

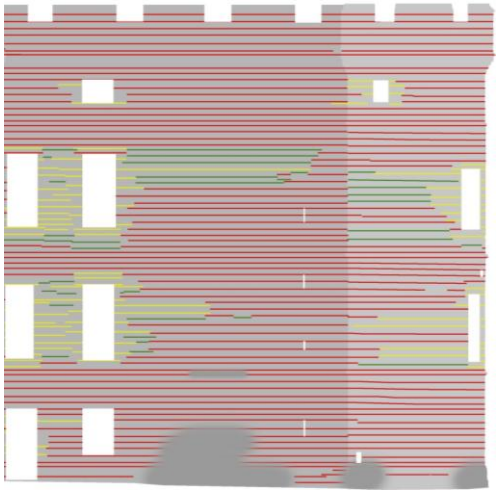
The first family includes masonry with continuous courses that develop horizontally, starting on one edge or corner and ending at the opposite one. The height of the courses is usually determined by the height of the quoins. The two cases belonging to this family are the towers at Balgonie and Holyrood, which are defined by very regular pattern clusters and quoins. Figure 6.17 highlights the coursed structure of the elevations. In the case of Balgonie, the stones defining the frame of the openings are

integrated in the courses. This does not happen in the tower at Holyrood, where openings can be understood as independent “entities” added to the overall pattern.

CONTINUOUS COURSES



Balgonie Castle tower
(south elevation; built c.1360s)

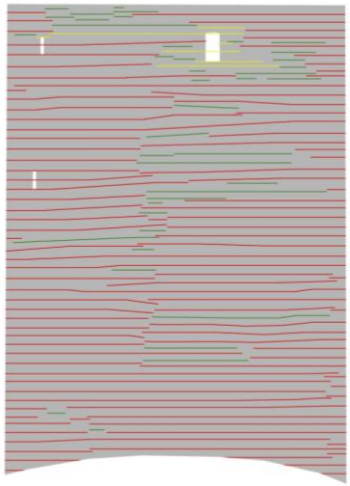


Holyrood Palace old tower
(north elevation; built early C16th and altered in subsequent centuries)

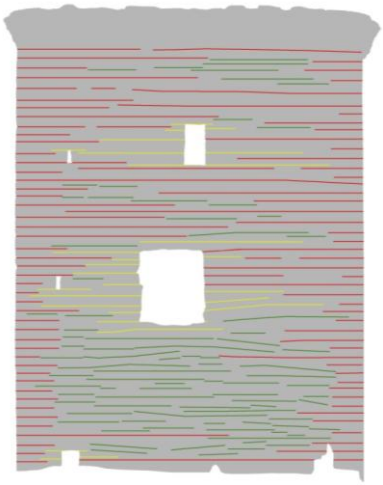
Figure 6.17: Scheme of the courses/lifts composing the masonry in the elevation. Red lines correspond to courses related to the quoins, yellow lines are related to jambs in openings and green lines show the rest of the courses.

The second family includes masonry composed of courses with discontinuities, which can result in a slight loss of the true horizontal. These are usually caused by changes in the size or regularity of stones. Within this family are the towers of Castle Campbell and Burleigh and the new wing additions at Balgonie and Aberdour, all composed of patterns within the boundaries of Clusters 1 and 2. Pittarthie and Gilbertfield, two isolated residences made up of Cluster 1 patterns are also found in this group. Figure 6.18 illustrates the coursed structure of one elevation per case. In all the schemes, openings tend to alter the continuity of the courses.

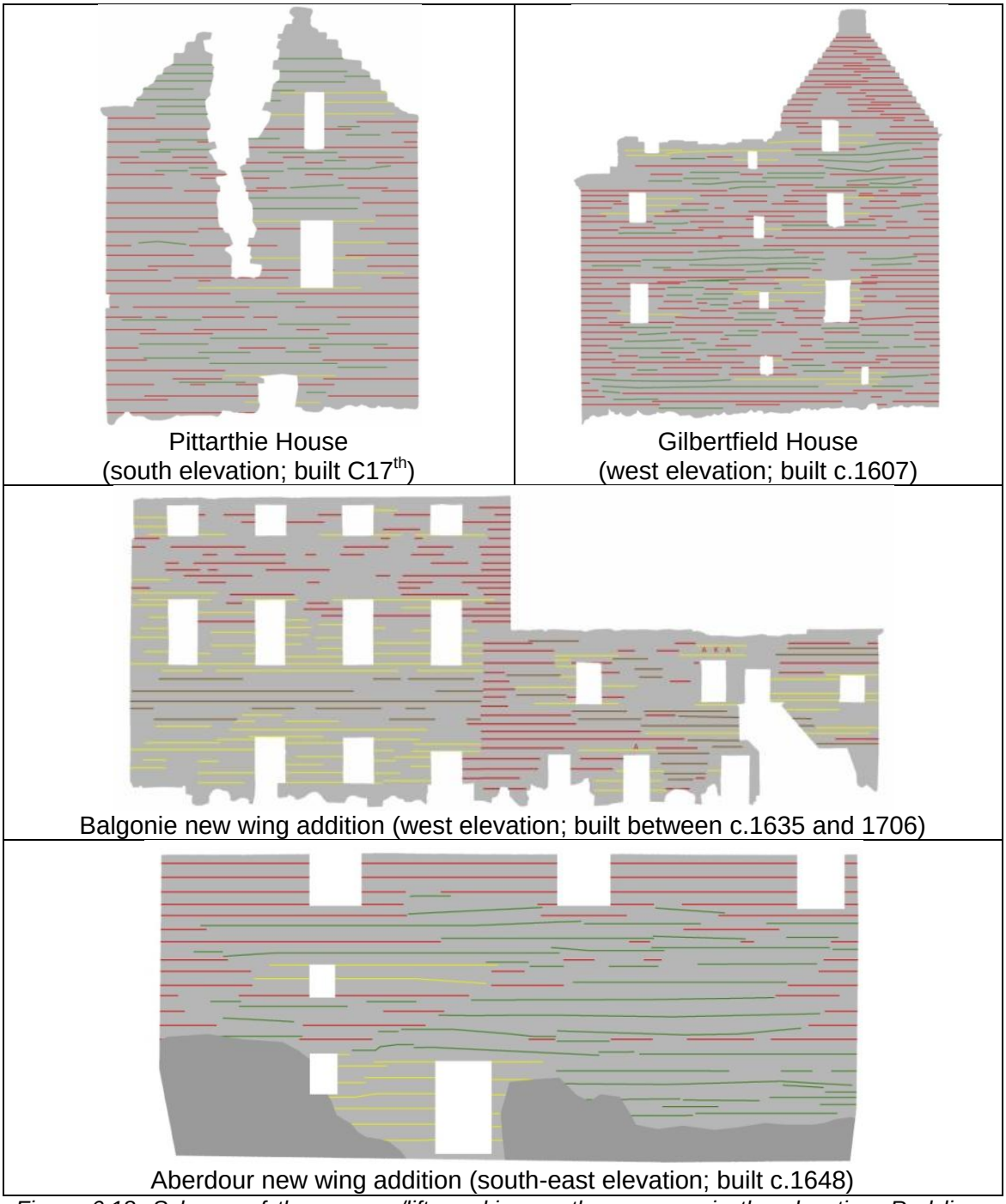
COURSES WITH DISCONTINUITIES



Castle Campbell tower
(north elevation; built C15th)



Burleigh Castle tower
(west elevation; built c.1450–1500)



Pittarthie House
(south elevation; built C17th)

Gilbertfield House
(west elevation; built c.1607)

Balgonie new wing addition (west elevation; built between c.1635 and 1706)

Aberdour new wing addition (south-east elevation; built c.1648)

Figure 6.18: Scheme of the courses/lifts making up the masonry in the elevation. Red lines correspond to courses related to the quoins, yellow lines are related to jambs in openings, and green lines define the rest of the courses.

The third family includes masonry built to courses. These are walls built in lifts, which can be identified following the alignment of quoins and window jambs. Tolquhon is the only case within this family and has Cluster 2 patterns (Figure 6.19).

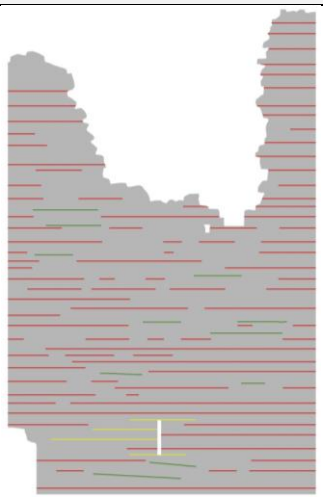
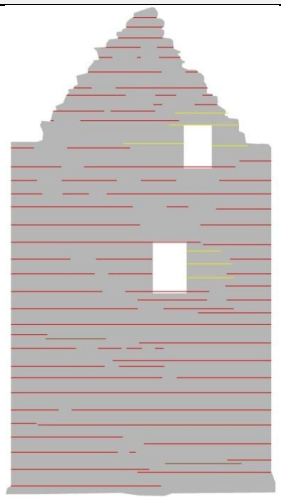
BUILT TO COURSES	
	
Tolquhon Castle tower (north elevation; built C13th)	Tolquhon new wing addition (east elevation; built c.1584–1589)

Figure 6.19: Scheme of the courses/lifts making up the masonry in the elevation. Red lines correspond to courses related to the quoins, yellow lines are related to jambs in openings, and green lines define the rest of the courses.

Finally, the fourth group incorporates masonry built in lifts or courses that is difficult to identify. The frequent discontinuities of the courses related to the irregularity of the units used in the pattern prevent a clear identification of layers. This is the case for the tower at Kilchurn and the isolated residences at Glenbuchat, Redhouse and Auchans. The new wing additions at Craigmillar and Kilchurn also belong in this family. Figure 6.20 illustrates the coursed structure of some of the elevations. All these cases have Cluster 2 patterns.

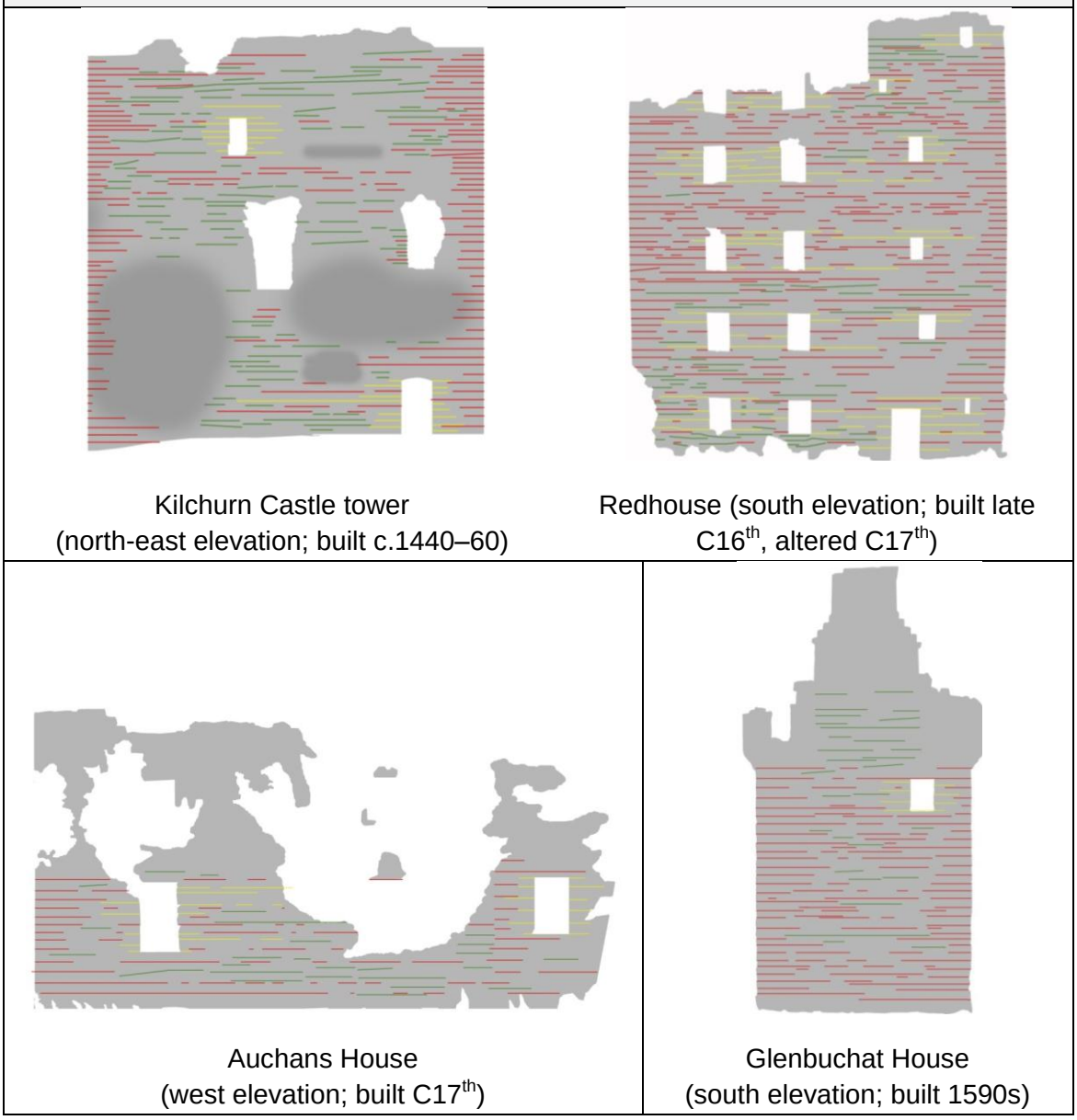


Figure 6.20: Scheme of the courses/lifts making up the masonry in the elevation. Red lines correspond to courses related to the quoins, yellow lines are related to jambs in openings, and green lines define the rest of the courses.

As well as revealing the structure of the coursing, analysis of the elevations highlighted a special feature related to the contact between the towers built before the seventeenth century and the new wing additions built in later centuries. The connection between these two construction stages was resolved with long stones, used to bond the vertical joint. Figure 6.21 shows three examples where these connections are visible.



Figure 6.21: (a) Three stone connectors at Balgonie Castle; (b) Two stone connectors at Tolquhon Castle, (c) Three stone connectors at Burleigh Castle.

6.3 ARCHITECT-RELATED WORKS

This section includes the case studies involving the work of an architect. The section is divided into three parts corresponding to the three different work environments identified in previous chapters and related to subsequent periods of time. The first part includes cases related to the environment centred on James Murray (Environment-3), while the second considers buildings linked to Sir William Bruce and James Smith (Environment-2), and the third incorporates cases built by the Adam family (Environment-1).

Unlike the previous section, where the three groups of non-architect-related buildings shared a lot of similarities, the results in this section highlight significant differences between environments. Consequently, instead of presenting the results together, each environment is presented individually in order to facilitate the identification of their distinctive features in context.

6.3.1 THE EARLIEST ENVIRONMENT (ENV-3)

Environment-3 is the earliest environment defined in previous chapters, clearly belonging to the first half of the seventeenth century. The centre of the environment is

defined by James Murray, a prominent master wright identified as an architect by authors such as Glendinning et al. (1996). Among the relevant people identified in this environment is William Wallace, a master mason to the Scottish Crown, who participated in several works with Murray.

The group of case studies associated with this environment is composed of two buildings. The first is Baberton House, built in the first quarter of the seventeenth century by James Murray himself. The second is the north wing of Linlithgow Palace, reconstructed between 1618 and 1624 by William Wallace. The following section details the morphological features of their masonry.

6.3.1.1 Solid portion of wall

The characteristics of the solid portions of walls in the facades studied vary depending on the case. The main part of the Linlithgow facade is composed of walls with thicknesses ranging between 155cm and 200cm. The wall thicknesses of the three small towers located at the two extremes and the centre of the facade tend to be lower than 100cm. These differences in thickness correspond with differences in the external wall face pattern. Patterns forming the main part of the façade therefore generally correspond to Cluster 2, while some areas of the towers can be classified as Cluster 3.

The two walls measured at Baberton, however, are 130cm (north-west facade) and 80cm (south-east facade) at ground floor level. This difference in thickness could be related to a previous construction, which is known to have existed on the site (see reference to the case in chapter 4). The patterns identified on the external wall face are similar in both cases and belong to Clusters 1 or 2 depending on the area of wall.

Figure 6.22 shows an example of the different pattern clusters identified on the external faces of the facades. The internal face could not be studied in either of the two buildings, and Figure 6.23 illustrates the different thicknesses measured at ground floor level.

CLUSTER 1	CLUSTER 2		CLUSTER 3
			
Baberton south-east (IMG4514; built first quarter of C17th)	Baberton south-east (IMG4506; built first quarter of C17th)	Linlithgow courtyard facade (IMG5142; built c.1618)	Linlitgow courtyard right tower (IMG5172; built c.1618)

Figure 6.22: Showcase of one sample per case corresponding to 1sqm of the external wall face and grouped according to the clusters defined.



Figure 6.23: Facade thickness corresponding to the cases considered.

6.3.1.2 Corners

The courtyard facade of Linlithgow does not define corners. Quoins could therefore only be studied at Baberton, where two distinctive features are identified. The first is related to the height of quoins, which tends to be constant and generally measures from 27cm to 28cm. The second is related to the distinction of the quoins located on the main facade with a carved motif. This motif is similar to that at George Heriot Hospital School, also built by Murray in later decades (Figure 6.24).

The use of the carved motif responds to a clear design strategy. Quoins have constant heights, but their lengths are variable. As mentioned in the chapter outlining the Stonemason's Gospel, the longer the quoin is and the better bounding can be created. The motif used in this case hides these variations, creating an illusion of uniformity that confers a special character on the main facade. Thus, the work of Murray includes a level of design on the corners not found in the cases previously studied within the group of non-architect-related works.

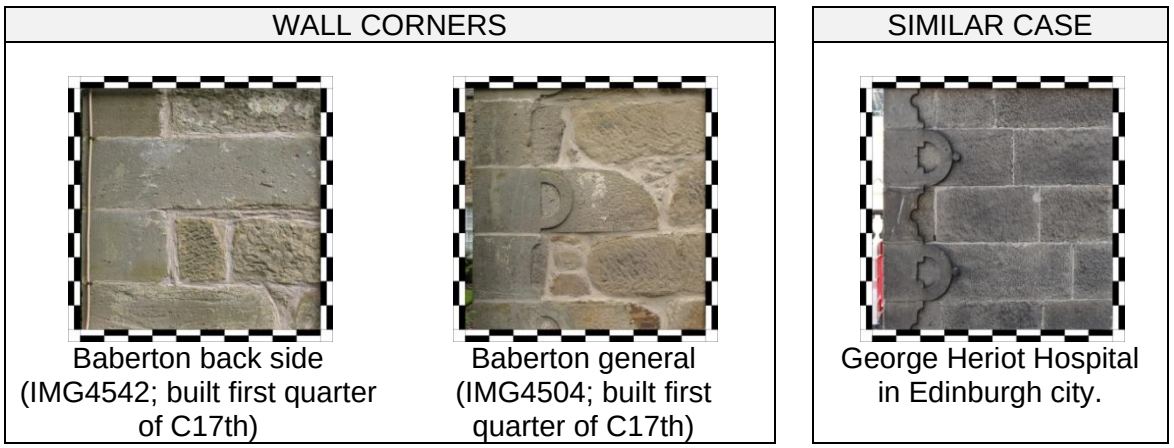


Figure 6.24: Sample of the two types of quoins identified in Baberton, and sample of the quoins at George Heriot Hospital School in Edinburgh.

6.3.1.3 Openings

The openings identified on the facades studied have rectangular proportions. Spans vary depending on the case and are defined by three different types of lintels, as shown in Figure 6.25. The first two types avoid the formation of relieving arches, favouring the continuity of horizontal courses. The third type is used at Linlithgow and has the clear intention of highlighting the opening.

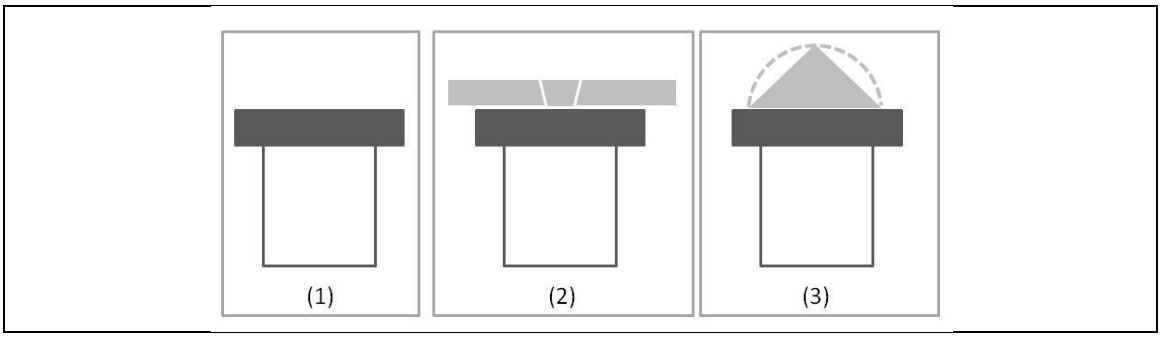


Figure 6.25: Most common lintel types identified, based on observation of the external wall face: (1) Single stone, (2) Single stone with flat arch, and (3) Single stone with carving.

The opening edges also show a degree of design, highlighted in a protruding frame. As shown in Figure 6.26, in the case of Linlithgow, the edge of the frame is also bevelled, while in Baberton it is either straight or only slightly bevelled.

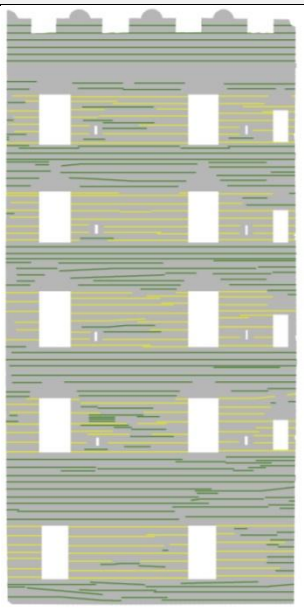


Figure 6.26: Detail sample of the opening edges identified at Baberton (1) and Linlithgow (2). In both cases the edge is highlighted with a protruding frame.

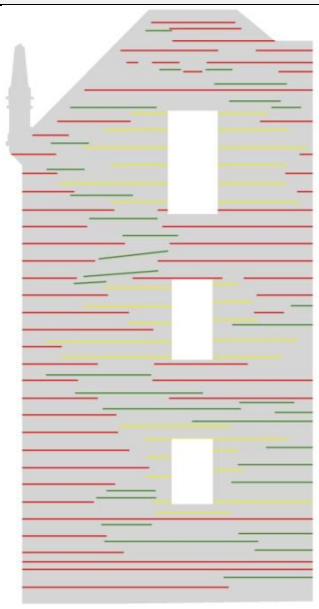
6.3.1.4 Masonry elevations

An overall view of the façades highlights that, despite the differences in the patterns, the masonry of both buildings follows a similar structure of courses with discontinuities (Figure 6.27). Such discontinuities are caused by irregularities in the pattern because of changes in the height of stones or as a result of the integration of windows in the system. This last point is evident in the case of Baberton, where the horizontal reference line defined by quoins (red) is clearly interrupted when courses reach the areas surrounding the opening jambs. However, as previously noted, the use of linear lintels in the upper part of openings favours the continuity of courses.

COURSES WITH DISCONTINUITIES



Linlithgow Palace north wing courtyard facade (left side); built c.1618



Baberton House south-east facade (left side); built first quarter of C17th

Figure 6.27: Scheme of the courses/lifts making up the masonry in the elevation. Red lines correspond to courses related to the quoins, yellow lines are related to jambs in openings, and green lines define the rest of the courses.

6.3.2 THE ENVIRONMENT OF SIR WILLIAM BRUCE AND JAMES SMITH (ENV-2)

This section considers the six case studies built between the 1670s and the first years of the 1700s, associated with Environment-2. The centres of the environment are James Smith and Sir William Bruce, two prominent architects of their time, as discussed in previous chapters. The following section detail the results of the morphological characterisation of their masonry.

6.3.2.1 Pattern characterisation

The types of masonry identified in the six buildings are varied, belonging to Clusters 1, 2 or 3 depending on the case. A distinctive aspect with respect to the groups analysed in previous sections is the regular presence of Cluster 3 patterns. Buildings are therefore divided into three groups: (1) those where Cluster 3 patterns have been used systematically on all the facades; (2) those where these patterns appear only on the main facade; and (3) those where the patterns do not belong to Cluster 3.

The first group includes Holyrood Palace, Kinross House and Craigiehall House. The masonry patterns used at Kinross and Craigiehall are very similar and belong to sub-cluster 3.2 as they are composed of highly elaborate stone units. In both cases the elevation is composed of a plinth with horizontal courses, highlighted by V-shaped joints, and an upper part where the minimal thickness of joints contributes to a plain

and continuous surface. In the case of Kinross, a later intervention left part of the walls of the basement exposed, which were probably re-faced using Cluster 1 masonry. The structure of the facades at Holyrood is somewhat different. Notably, the west facade is the only one preserving its original masonry. The others were either re-built or re-faced in subsequent centuries (see section 6.2 in chapter 4). This sequence of interventions defines patterns belonging to the same cluster but clearly distinguishable because of differences in unit sizes, finishing and joint thicknesses. The patterns used on the north and west facades therefore belong to sub-cluster 3.1, while the patterns from the south facade (the latest intervention) are included in sub-cluster 3.2.

The second group includes the cases of Drumlanrig and Dalkeith. The main facade of Drumlanrig is composed of highly elaborate units and very thin joints (sub-cluster 3.2) while the others are part of Clusters 1 and 2. The most irregular masonry is located on the east facade and almost certainly belongs to a previous construction, which was integrated into the current building. Dalkeith also presents a clear difference between the masonry of the front facade (Cluster 3) and that used in the rest of the building (Cluster 2). However, this case is somewhat controversial in terms of chronology. The differences and discontinuities in the patterns are clear, revealing a complex constructive history, which included extensions and re-facing.

Finally, Auchindinny is part of the third group as the masonry patterns used in the original volume do not reach the highest level of regularity and belong to Clusters 1 and 2. An intentional use of the masonry pattern is suggested. In the first group, the definition of the joints differentiates areas of the elevation contributing to the overall design of the elevation. In the second, the masonry is used to highlight the main facade. Figure 6.28 shows an example of the different pattern clusters identified on the external face of the facades. The internal face could not be studied in either of the two buildings.

CLUSTER 1		
		
Drumlanrig west facade (IMG8366; built c.1690)	Kinross basement (IMG1784; altered c.1777–90)	Auchindinny main facade (IMG7557; built c.1705)

CLUSTER 2



Drumlanrig east facade (IMG8461; built c.1690)



Dalkeith House main entrance lateral facade (IMG8175; built 1710s)



Dalkeith north-west facade (IMG8239; built c.1585?)



Dalkeith south-west facade (IMG8245; built c.1585?)



Auchindinny lateral facade (IMG7563; built c.1705)

CLUSTER 3



Holyrood west facade (IMG7412; built 1670s)



Holyrood south facade (IMG7459; altered before 1836)



Holyrood south tower facade (IMG7452; built c.1671–79)



Holyrood north facade (IMG7352; altered C19th)



Drumlanrig main facade (IMG8316; built c.1690)



Kinross above plinth (IMG1884; built c.1684–95)



Kinross plinth
(IMG1848; built c.1684–95)



Craigiehall above plinth
(IMG4803; built c.1695)



Craigiehall plinth
(IMG4836; built c.1695)



Dalkeith main facade
(IMG8288; built 1710s)

Figure 6.28: Showcase of one sample per case corresponding to 1sqm of the external wall face and grouped according to the clusters defined.

6.3.2.2 Structure of the wall section

The internal structure of the wall could not be inspected in either of the cases as none of the façade walls had partially collapsed portions. Nonetheless, the thicknesses identified in the different buildings define a range of variations directly related to the complexity of the construction history of the building.

In the case of Holyrood Palace, the re-faced walls of the south facade are the thickest, surpassing 120cm. The thinner walls are 95cm and correspond to the north elevation and part of the west facade. The rest of the west elevation and the east facade have thicknesses varying from 100cm to 120cm. Dalkeith presents a similar situation, with thicknesses above 2m at the west facade (almost certainly corresponding with the remains of the original construction integrated in the current building), and 95cm at the front facade. The thickness measurements for the elevations at Craigiehall and Auchindinny are, however, more homogeneous and situated below 90cm. Figure 6.29 illustrates the thicknesses identified. The walls of Kinross and Drumlanrig could not be measured. Consequently, no data is available.

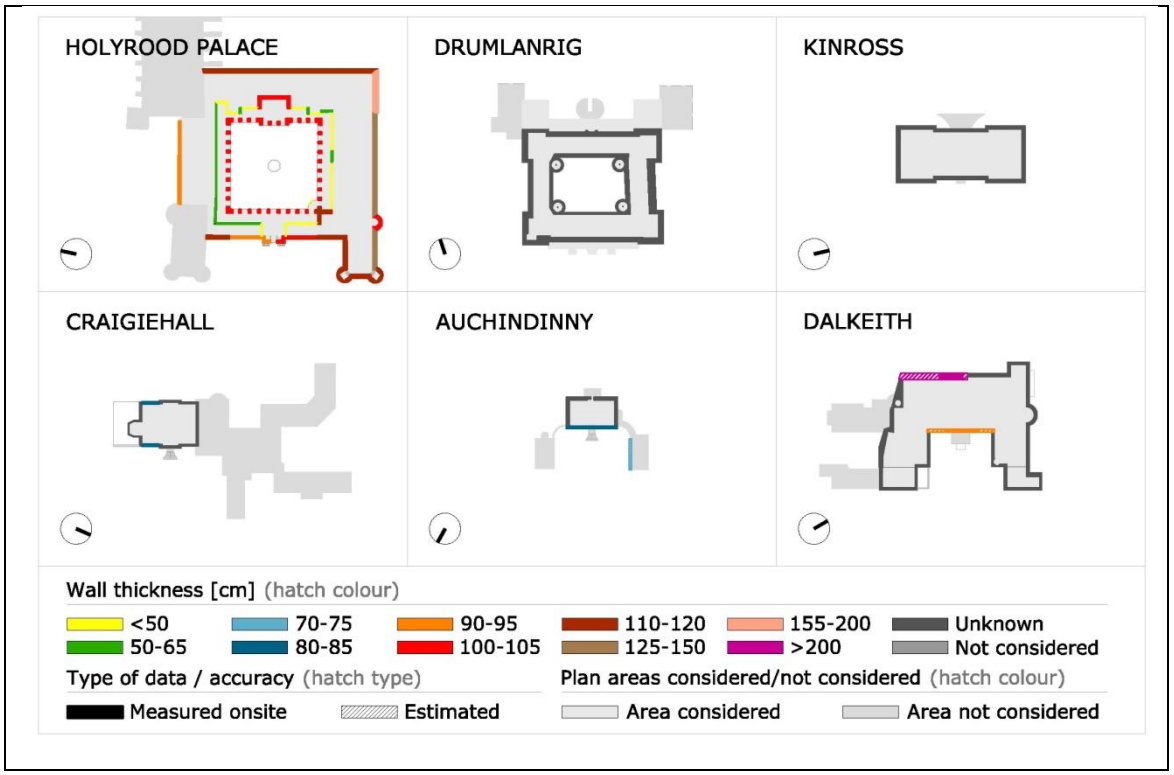


Figure 6.29: Facade thickness corresponding to the cases considered.

6.3.2.3 Corners

An intentional use of the masonry is also noted in the definition of corners. Three different strategies are identified that consider this aspect: (1) emphasise the alternation of headers and stretchers, (2) highlight the vertical edge line, and (3) define a clean edge.

The first strategy is identified on the main facades of Dalkeith and Drumlanrig and on the upper part of the elevations at Craigiehall. In all cases, quoins are dressed protruding from the wall plane. The protuberance does not necessarily correspond with the whole face of the quoin, resulting in an alternation of apparently homogeneous headers and stretchers, which creates an illusion of uniformity. In addition, the joints between quoins are defined as V-shaped in order to further emphasise the relief.

The second strategy corresponds to the lateral and back facades of Dalkeith and Drumlanrig and all the elevations at Auchindinny. In this case, quoins highlight the edge defining a protruding part, which in this case defines a continuous vertical line 15cm to 20cm thick. The upper part of the Kinross elevations is a special case, halfway between this strategy and the following one, as the edges of the corners are defined by pilasters and the width of the pilaster corresponds with the length of stretcher quoins.

The third strategy is mainly identified on the corners of Kinross and Craigiehall plinths. In these cases, quoins are integrated into the overall pattern, resulting in a clean vertical edge.

The corner defined on the west elevation at Dalkeith is out of this classification, as it does not respond to a design intention but to the mere fulfilment of the Stonemason's Gospel. This approach corresponds to that already identified in the groups of cases identified as non-architect-related works. The reason for this is probably that the masonry making up this wall is related to the earlier construction, which is known to have been integrated in the current building.

Figure 6.30 illustrates this, showing samples of 1sqm of corner obtained from each of the cases studied.

WALL CORNERS



Drumlanrig main
(IMG8322; built c.1690)



Drumlanrig lateral
(IMG8364; built c.1690)



Kinross above plinth
(IMG1896; built c.1684–95)



Kinross plinth
(IMG1946; built c.1684–95)



Kinross basement
(IMG1801; altered c.1777–90)



Craigiehall above plinth
(IMG4803; built c.1695)



Craigiehall plinth
(IMG4842; built c.1695)



Dalkeith front
(IMG8185; built 1710s)



Dalkeith NE
(IMG8221; built 1710s)



Dalkeith NW
(IMG8241; built c.1585?)



Auchindinny
(IMG7535; built c.1705)

Figure 6.30: Sample of corner for each of the cases studied.

6.3.2.4 Openings

In most of the cases, the openings have simple geometries. The proportions are generally rectangular and headed by a straight lintel. Figure 6.31 shows the types of lintels identified on the different buildings. Lintels 1 and 2 are the most common and are used in masonry with either regular or irregular patterns. Lintel 3 was only identified in Dalkeith and in the east facade of Drumlanrig, both with masonry corresponding to Clusters 1 and 2. Finally, lintel 4 corresponds to the plinths of Kinross and Craigiehall and the basement windows at Dalkeith.

Arched lintels are not common and have only been identified on four occasions: at Kinross and Holyrood, where one of the openings in each case has an arched lintel composed of voussoirs; at the arcades of the main facade of Drumlanrig; and at the arcades of the internal courtyard of Holyrood (Figure 6.32). Between the two cases with arcades lies the solution used in Drumlanrig, where voussoirs adapt to the perimeter of the portico, demonstrating a clear effort for defining continuous and straight joints.

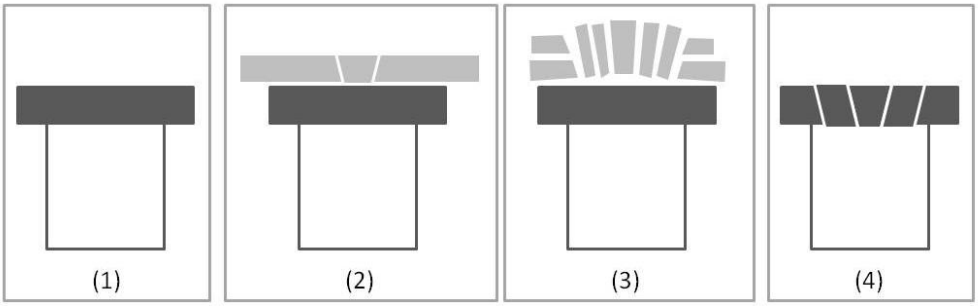


Figure 6.31: Lintel solutions corresponding to the most common type of opening (type 2). Morphology based on observations of the external wall face.



Figure 6.32: Arched solutions identified on the cases studied: (1) Drumlanrig main facade ground floor arch, (2) Holyrood internal courtyard arch, (3) Holyrood newest tower, and (4) Kinross.

In all cases, jambs are usually composed of several stone units. Depending on the morphology of the edges, the jamb design follows a strategy similar to that identified on the corners. Figure 6.33 illustrates the five different types of jambs identified. Types 1, 2 and 3 respond to the most common strategy, which consists of highlighting the opening with a protruding frame. Depending on the case, the protuberance is stripped,

plain or bevelled. On the contrary, types 4, 5 and 6 do not protrude. Types 4 and 5 correspond to Holyrood Palace, with either a bevelled edge or a clean straight edge, avoiding any protuberance. A variation of this last case is found at Kinross, where the frame of the opening is defined with a depressed profiled edge (type 5).



Figure 6.33: Showcase of the different types of mouldings identified: (1) Stripped frame, (2) Protruding plain frame, (3) Protruding bevelled frame, (4) Non-protruding bevelled frame, (5) Non-highlighted boundary, and (6) Profiled edge.

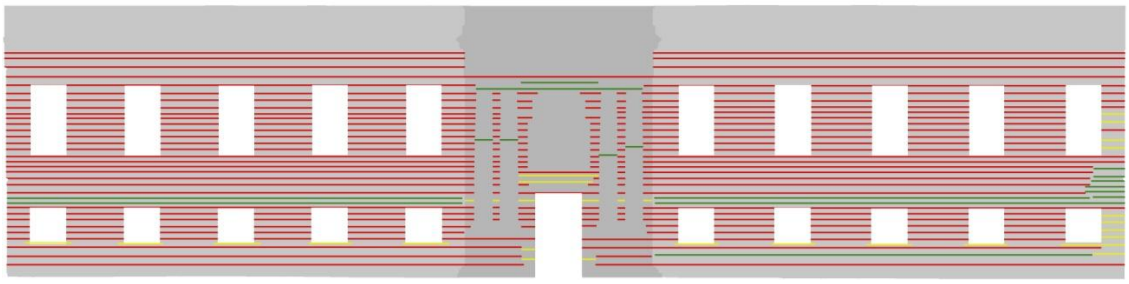
6.3.2.5 Masonry elevations

In the cases studied, the structure of the masonry is directly related to the cluster pattern. The elevations composed of Cluster 3 patterns are clearly built of horizontal continuous courses. This is achieved by keeping the height of the stone units constant through an entire course, including quoins, window jambs and the units composing the solid portion of wall. However, this height can vary from course to course. A clear example of this is the main elevation of Holyrood. The opposite case is the front tower of Drumlanrig, where the height of courses is constant. An intermediate situation is found at Kinross, Craigiehall and the front facade of Dalkeith, where the string courses or the windowsills tend to alter the homogeneity of heights.

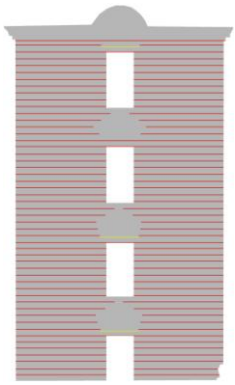
The elevations composed of patterns corresponding to Clusters 1 or 2 follow a more irregular structure. An example of Cluster 1 is the main facade of Auchindinny. In this case, courses are identifiable but tend to be interrupted by the stones at the openings. On the other hand, Cluster 2 masonry tends to be built in lifts, which are difficult to identify. This is the case for the lateral tower of Drumlanrig and the lateral facade of Dalkeith.

Figure 6.34 illustrates this, highlighting the structure of the courses for the different elevations mentioned.

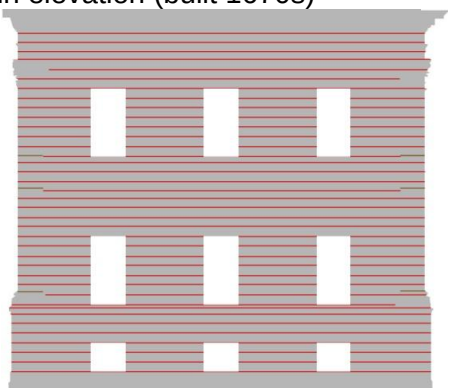
CONTINUOUS COURSES



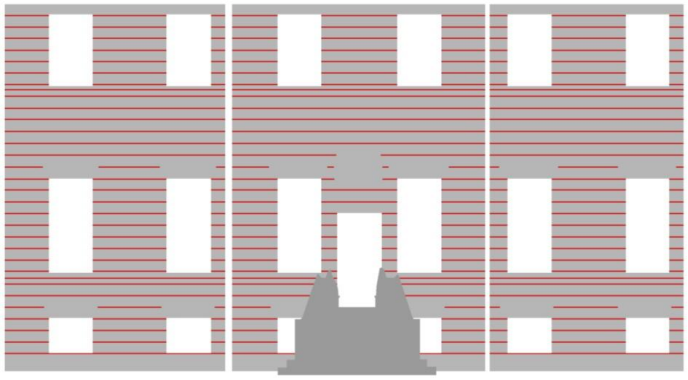
Holyrood Palace main elevation (built 1670s)



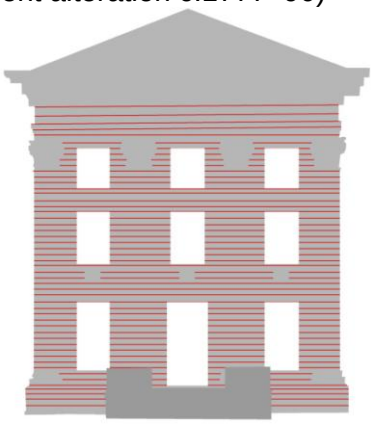
Drumlanrig front tower
(built c.1690)



Kinross
(built 1684–95, basement alteration c.1777–90)

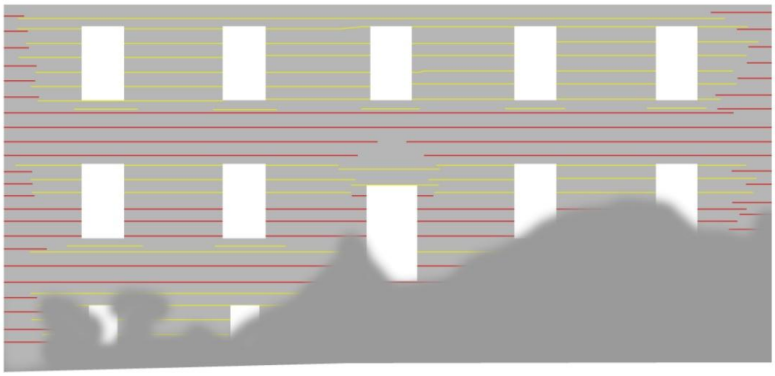


Craigiehall front facade (built c.1695)



Dalkeith front (built 1710s)

COURSES WITH DISCONTINUITIES



Auchindinny main facade (built c.1705)

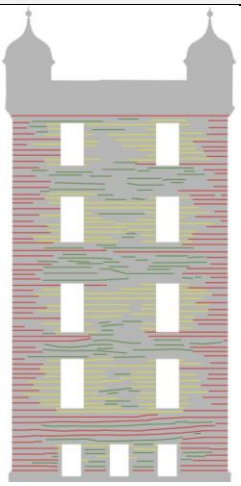
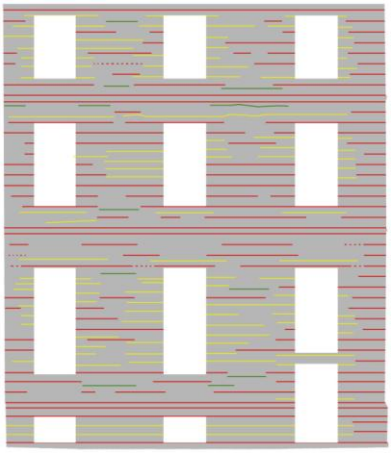
COURSES/ LIFTS DIFFICULT TO IDENTIFY	
	
Drumlanrig lateral tower (built c.1690)	Dalkeith lateral (built 1710s)

Figure 6.34: Scheme of the courses/lifts forming the masonry in the elevation. Red lines correspond to courses related to the quoins, yellow lines are related to jambs in openings, and green lines define the rest of the courses.

6.3.2.6 An outstanding design of stone

The details outlined about the structure of the masonry in the elevation, the use of patterns and the morphology of the edges of corners and openings suggests intentional design of the masonry composing the elevations, which has not been detected with this magnitude in other groups of buildings previously analysed. However, one of the six cases corresponding to Environment-2 is notable for having taken to an extreme the design of its stone masonry. This is the case of Drumlanrig.

As previously set out, the main elevation of Drumlanrig is composed of highly elaborate units, laid in continuous and horizontal courses of homogenous height. This implies a prior design of the elements composing the elevation and the planning of the construction process in order to select the adequate material, dress the units to an exact size and lay them in the position defined within the overall elevation. This process of design and planning occurs to a greater or lesser degree in all elevations with Cluster 3 masonry patterns. However, at Drumlanrig, three aspects stand out, suggesting a superior level of design of its stone masonry.

The first aspect is the evident effort to integrate joints within the design of the architecture. This affirmation derives from observation of the following features:

- Joints resulting from the addition of ashlar units composing the masonry pattern have a minimal thickness, which makes them imperceptible from a distance. In addition, the horizontal joints (those defining courses) are continuous throughout the elevation, integrating quoins and window jambs, and are only temporarily interrupted by the decorative elements (Figure 6.35).



Figure 6.35: Drumlanrig main facade left tower. The continuity of the horizontal joints through quoins and window jambs is clear, only interrupted by the decorative elements.

- Pilasters are composed of three substantially sized stones. This contributes to rendering these elements a unitary entity within the elevation, distinguishing them from the general wall pattern. The pilasters on the west facade of Holyrood have the same morphology. However, this is a rare feature as the production and manipulation of large format stone elements is complex and therefore pilasters were generally composed of the small sized stone units. Examples of this are Kinross House, the main elevation of Dalkeith and the later works of the Adam family (Figure 6.36).



(1) (2) (3) (4)

Figure 6.36: Comparison of the morphology of pilasters: (1) Holyrood Palace west facade; (2) Drumlanrig main facade; (3) Kinross; and (4) Dalkeith main.

- The construction of arches includes voussoirs, whose joints follow the direction of the radius defining them, adapting to the perimeter of the portico. Again, this was a rare feature in Scotland at the time. The arches on the interior courtyard of Holyrood Palace have a similar design. However, the morphology of voussoirs does not follow Drumlanrig's rule (Figure 6.37).

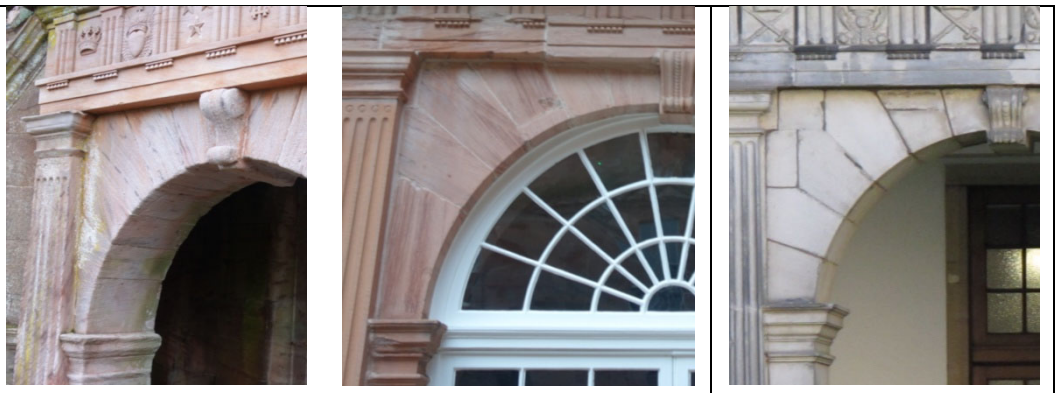


Figure 6.37: Comparison of the morphology of different arches: from the main facade of Drumlanrig (left), from one of an internal courtyard facade at Drumlanrig (centre); and from the internal courtyard facade of Holyrood Palace (right).

The second aspect is the intentional use of the face-bedded stones on the stones defining the vaults on the central clock tower of the main facade. This results in a textured surface, which, with all due caution, could resemble marbled surfaces (Figure 6.38).



Figure 6.38: Vault at Drumlanrig main facade. The intentional use of stone-bedded elements defines a textured surface.

The third aspect is the large number of carved details. Figure 6.39 shows examples of what can be found on the main facade. Observations of the work executed reveals a high level of effort and mastery on the part of the mason. This work is not limited to sculptural elements, but also includes elements of architecture, such as window frames.



Figure 6.39: Examples of the carved details that can be found on Drumlanrig's main facade.

In light of these findings, Drumlanrig is not only a system of spaces and a landmark on the landscape, but also a stonework masterpiece. It was conceived by a mind concerned not only with the overall design of the building and its surroundings, but also with the construction detail and the use of the material. The existence of such architectural work contributes to justifying theses defending the existence of architects in seventeenth century Scotland.

The authorship of Drumlanrig has been related to James Smith by authors such as González-Longo (2014, 2020). His origins as a mason and his almost certain trip to Rome probably provided him with the thorough understanding of architecture necessary to develop such a complete work.

Kinross House also includes some of the aspects of this integrated conception of the elevation design and its masonry. The masonry pattern used is very similar to Drumlanrig's main facade, with continuous courses and thin joints. In addition, the carved decorations on the facades are also done by masons with a high level of mastery. However, in this case, the showcase of stone virtuosity is more reduced.

6.3.3 THE ADAM ENVIRONMENT (ENV-1)

This section studies the masonry elevations of 11 buildings attributed to the Adam family. The work started by William Adam was continued after his death in 1748 by his eldest son John, and his brothers Robert and James. For the purposes of this investigation the year 1757 is also an important date in the chronology of the Adams' works because it corresponds to the return of Robert from his Grand Tour. Analysis of the cases based on the chronological framework defined by these milestones contributes to understandings of the evolution of the Adam architecture and its masonry.

6.3.3.1 Pattern characterisation

The type of pattern found in the masonry of the 11 buildings studied varies depending on the face of the facade. The external face patterns were always visible and, in the majority of cases, composed of regular courses with highly elaborate stone units. The

internal face of the facades could only be inspected at Penicuik, Dalquharran Castle and Gosford House, but, in all the cases, the patterns had a lower level of regularity. Table 6.3 summarises the classification of 1sqm pattern samples obtained from each case, according to the clusters defined in previous chapters.

BUILDING	Cluster pattern	
	Outer wall face pattern	Inner wall face pattern
Mellerstain (phase 1)	2	-
House of Dun	3	-
Cumbernauld House	1,3	-
Haddo House	1,2	-
Chatelherault Hunting Lodge	3	-
Dumfries House	3	-
Penicuik	3	1
Wedderburn	3	-
Mellerstain (phase 2)	1	-
Dalquharran	3	1
Newliston	3	-
Gosford	3	1

Table 6.3: Clusters corresponding to 1sqm samples of the external face of the walls previously analysed.

In general, the external faces of the facades studied are built with very regular patterns, composed of highly elaborate units corresponding to Cluster 3. However, three of the cases include masonry with lower levels of regularity.

Cumbernauld is one of the exceptions. Despite its main facade being classified as Cluster 3, the lateral and back facades are composed of less regular patterns, which belong to Cluster 1, although they are situated very close to the border with Cluster 3. The other two exceptions are Haddo and Mellerstain, with all their masonry from Cluster 3. Haddo House is located in Aberdeenshire, an area with a predominance of granite. Some authors have already identified the type of stone used in the construction as granite (HES 2017, 19842). The irregularity of the pattern is probably related to the characteristics of this type of stone, which was difficult to dress using the technology available in the period. The reasons behind the irregularities of Mellerstain masonry are of another type, probably budget related. In both cases, the principal volume of the house is composed of a Cluster 1 pattern, while the lateral pavilions belong to Cluster 2.

Figure 6.39 showcases 1sqm of masonry from each of the 11 cases studied, classified by clusters. The cases included in Cluster 3 were certainly built to remain non-rendered. The design of the pattern has a direct influence on the final image of the elevation. In this regard, two strategies are identified: (1) patterns designed to highlight joints between stones (either vertical or horizontal), and (2) patterns where the objective is to define a plain and homogeneous surface and therefore minimise the visibility of joints. Highlighting of joints is achieved by defining V-type joints. To minimise their visibility, their thickness is reduced to the minimum and sometimes even blurred by the type of finishing of the stone surface.

CLUSTER 1


Mellerstain central volume (IMG6672; R. Adam 1770s)


Cumbernauld lateral facade (IMG7691; built 1730s)


Haddo House principal volume (IMG8084; built 1730s)

CLUSTER 2


Mellerstain lateral pavilion (IMG6608; W. Adam c.1725)


Haddo house lateral pavilion (IMG8004; built 1730s)

CLUSTER 3


House of Dun general pattern (IMG7795; built 1730s)


House of Dun special case pattern (IMG7795; built 1730s)

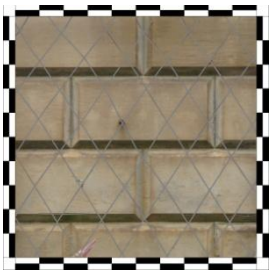

Cumbernauld main facade (IMG7667; built 1730s)


Chatelherault Lodge (IMG0980; built c.1731-43)


Dumfries House general pattern, stripped finishing (IMG6785; built c.1754)


Dumfries House general pattern with plain finishing (IMG6816; built c.1754)


Dumfries House plinth pattern, stripped finishing (IMG6890; built c.1754)


Dumfries House plinth pattern with plain finishing (IMG6828; built c.1754)


Penicuik upper part (IMG5648; built 1700s)


Penicuik plinth (IMG5777; built 1700s)


Wedderburn plinth (IMG P7131777; built c.1767)


Dalquharran Castle (IMG7979; built 1780s)


Newliston general pattern (IMG5475; built c.1789)


Gosford general pattern (IMG6370; built c.1790)


Gosford plinth (IMG6269; built c.1891)

Table 6.4: Showcase of one sample per case corresponding to 1sqm of the external wall face and grouped according to the clusters defined.

6.3.3.2 Structure of the wall section

Thicknesses of the walls defining the facades are generally between 90cm and 105cm. Gosford and Newliston reach 110cm to 120cm in some walls, while the wings of Dumfries House and Mellerstain, and the pavilions of Chatelherault, are 80cm to 85cm (Figure 6.40).

Penicuik and Dalquharran highlight a difference between facades built in the original building and additions made during the nineteenth century. Elevation patterns in old and new masonry have the same appearance and are continuous, but thicknesses change substantially. The walls built during the Adam interventions are 100cm thick, while those in the later additions always measure 85cm.

The wall section was only visible in Penicuik, where part of the facade corresponding to the nineteenth century addition had collapsed. Figure 6.41 shows a structure composed of an ashlar outer layer, an inner layer composed of less regular units, and

an intermediate core composed of smaller stones of different sizes and irregular geometry. The stones making up the outer and inner faces are usually stretchers. The bonding of the section is achieved with the periodic appearance of headers and adequate interlocking of the stones defining the frame openings (jambs and lintels).

Observations of the window jambs on the eighteenth century walls in Penicuik and Dalquharran suggest that the structure of the wall sections is probably similar to the nineteenth century case but with variations in the thickness of the core (Figure 6.42).

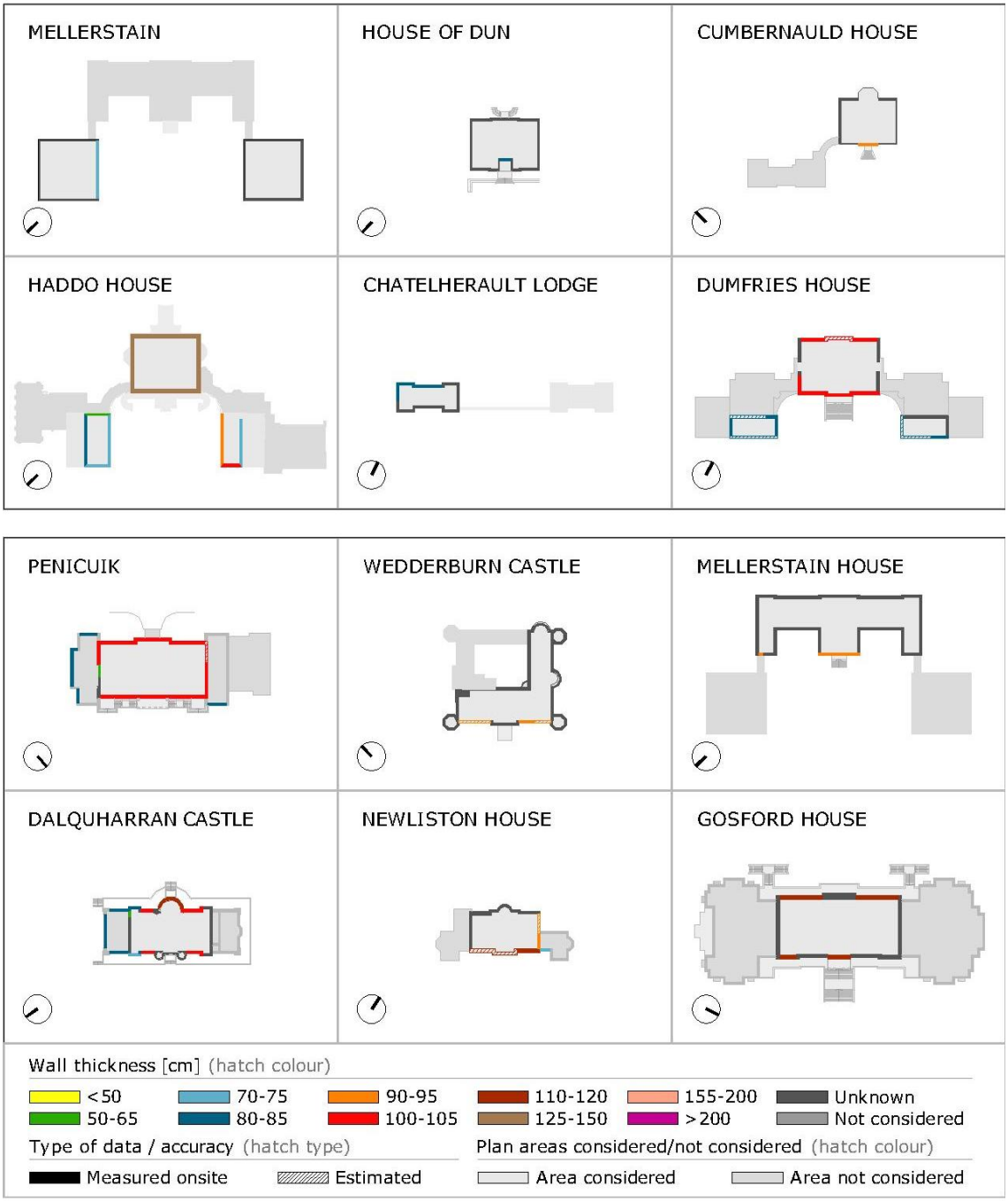


Figure 6.40: Plot of the buildings' main plan, identifying wall thicknesses identified on site.



Figure 6.41: Penicuik sectioned wall corresponding to the nineteenth century extension. Left: upper part of the wall; Right: ground floor level.



Figure 6.42: Images taken from the interior of the original volumes of Penicuik (left) and Dalquharran (right), showing the structure of window jambs in the sections.

6.3.3.3 Corners

The corners identified resulted from two different design strategies. The first strategy emphasised quoins by making them protrude from the wall plane. The dimension of the protruding volumes is constant, and they regularly alternate position from header to stretcher. However, the size of the highlighted volume does not necessarily correspond with the real dimension of the quoin and the appearance of perfection is therefore

usually just an illusion. The first phases of Mellerstain, Dun, the lateral and back facades of Cumbernauld, Haddo House and Chatelherault are examples of this. The second strategy erases the quoins in order to define a simple straight edge. Integration of the quoins in the general wall pattern offers a clue to this. The main facades of Cumbernauld, Dumfries, Penicuik, Wedderburn, Dalquharran, Newliston and Gosford apply this strategy.

Regarding more dimensional aspects, the height of quoins tends to be constant in all cases except in the second phase of Wedderburn. On the contrary, quoin lengths vary to a greater or lesser extent, sometimes distorted, according to the strategy previously mentioned. Patterns with V-shaped vertical and horizontal joints, where the lengths are kept constant to maintain the continuity of lines, represent an exception to this. Finally, the constant alternation between header and stretcher is a rule in all cases.

WALL CORNERS


Mellerstain phase 1 (IMG6715; built c.1725)


House of Dun general case (IMG7865; built 1730s)


House of Dun special case (IMG7768; built 1730s)


Cumbernauld front facade general case (IMG7685; built 1730s)


Cumbernauld front facade plinth (IMG7685; built 1730s)


Cumbernauld lateral facade general case (IMG7618; built 1730s)


Cumbernauld lateral facade plinth (IMG7707; built 1730s)


Haddo House lateral pavilions (IMG7921; built c.1730s)


Haddo House main facade general case (IMG7969; built c.1730s)


Haddo House main facade plinth (IMG8067; built c.1730s)


Chatelherault (IMG0988; built c.1731–43)


Dumfries general case (IMG6814; built c.1754)


Dumfries plinth (IMG6879; built c.1754)


Penicuik plinth (IMG5786; built 1700s)


Wedderburn plinth (IMG P7131783; built c.1767)


Wedderburn (IMG4284; built c.1767)


Mellerstain second phase (IMG6685; built 1770s)


Dalquharran (IMG7708; built 1780s)


Newliston basement (IMG5489; built c.1789)


Newliston ground floor (IMG5489; built c.1789)


Newliston upper levels main facade (IMG5444; built c.1789)


Gosford general pattern (IMG6511; built c.1790)


Gosford plinth (IMG6334; built c.1891)

Figure 6.43: Sample of 1sqm of corner for each of the buildings studied.

6.3.3.4 Openings

The openings in the buildings can be classified into three groups, according to their geometry (Figure 6.44). The first group corresponds to openings with complex geometries, which can be found in cases such as Dun, Dumfries, Dalquharran, Newliston and Gosford. The second group includes the majority of cases and refers to windows with simple geometries. These have square or rectangular proportions and are headed by a flat lintel or an arch. Finally, the third group includes special openings with linear or circular geometries, which, in some cases, are designed blind. Examples of this last group can be found at Wedderburn and Dalquharran.

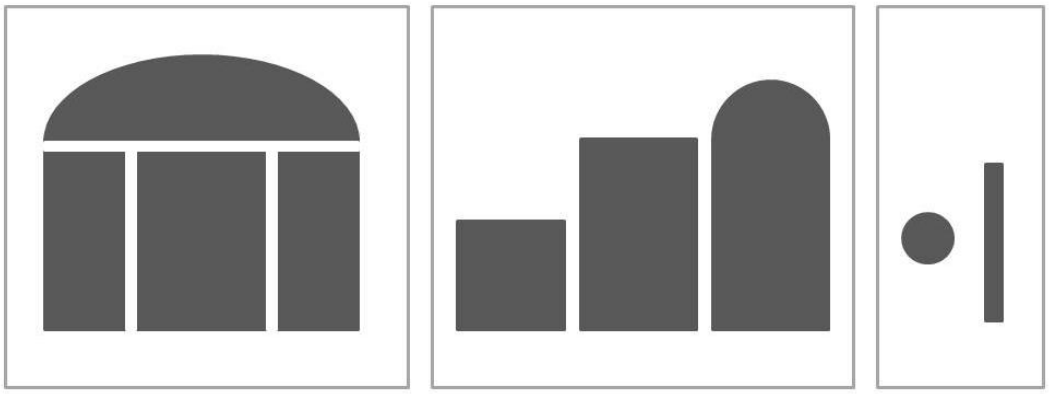


Figure 6.44: Synthesis of the three types of windows identified according to their geometry: 1- complex geometries (left) 2- simple geometry (centre) and 3- special openings (right).

LINTELS

The morphology of lintels varies depending on the case. Considering the most common type of openings (second group), seven different lintel solutions are determined based on their appearance from the external face of the façades. As shown in Figure 6.45, the first four solutions refer to lineal lintels. Cases 1, 2 and 4 are common in regular masonry, while solution 3 has been identified only in the first phase of Mellerstain and in the lateral and back facade of Cumbernauld, both composed of irregular masonry. The last three solutions define arched lintels. Solution 5 appears only at Dun whereas arched openings in subsequent buildings tend to assimilate, with greater or lesser accuracy, schemes 6 and 7. This can be understood as an indicator of a tendency towards better integration of the dovels in the courses forming the masonry elevations.

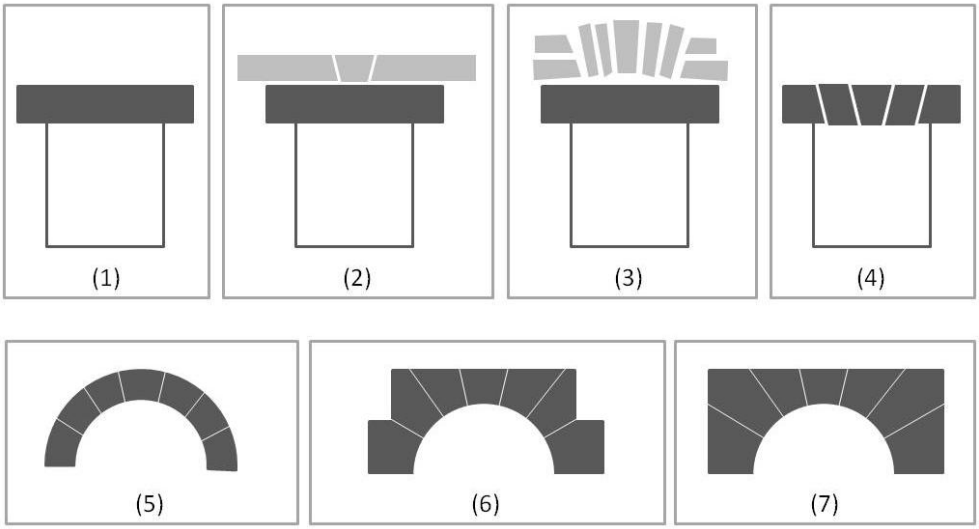


Figure 6.45: Lintel solutions corresponding to the most common type of opening (type 2). Morphology based on observations of the external wall face.

At Dalquharran, analysis of lintels could be expanded by inspecting the internal face of the facades. The information obtained in this case is valuable because of the condition of the unaltered ruin. Figure 6.46 shows the morphology of the windows identified in the building, differentiating those built during the Adam phase from those built in the nineteenth century extension. A common feature in both periods is the straight lintels visible on the exterior face of the elevations, which cover only the external layer of the wall section hiding the arched solution behind, which comprises the internal wall layer and its central core. The bonding of the wall section is therefore left to the window jambs and to other points of the wall system. Only in case 3 does the keystone above the flat lintel traverse the wall section. A differential aspect, however, involves the materials used. The solutions defined in the eighteenth century were completely based on stone, while the later extension combined stone and brick. This aspect can only be appreciated from the interior. However, a detail is visible from the outside face that, although subtle, differentiates the lintels of both phases: The “keystone” above the eighteenth century lintels has a rectangular proportion while those above the nineteenth century lintels tend to be squared.

Penicuik and Gosford also have masonry with the internal face of the wall exposed. However, the condition of the altered ruin at Penicuik and the reduced area of masonry visible at Gosford mean that these cases are not considered suitable for development of a consistent analysis.

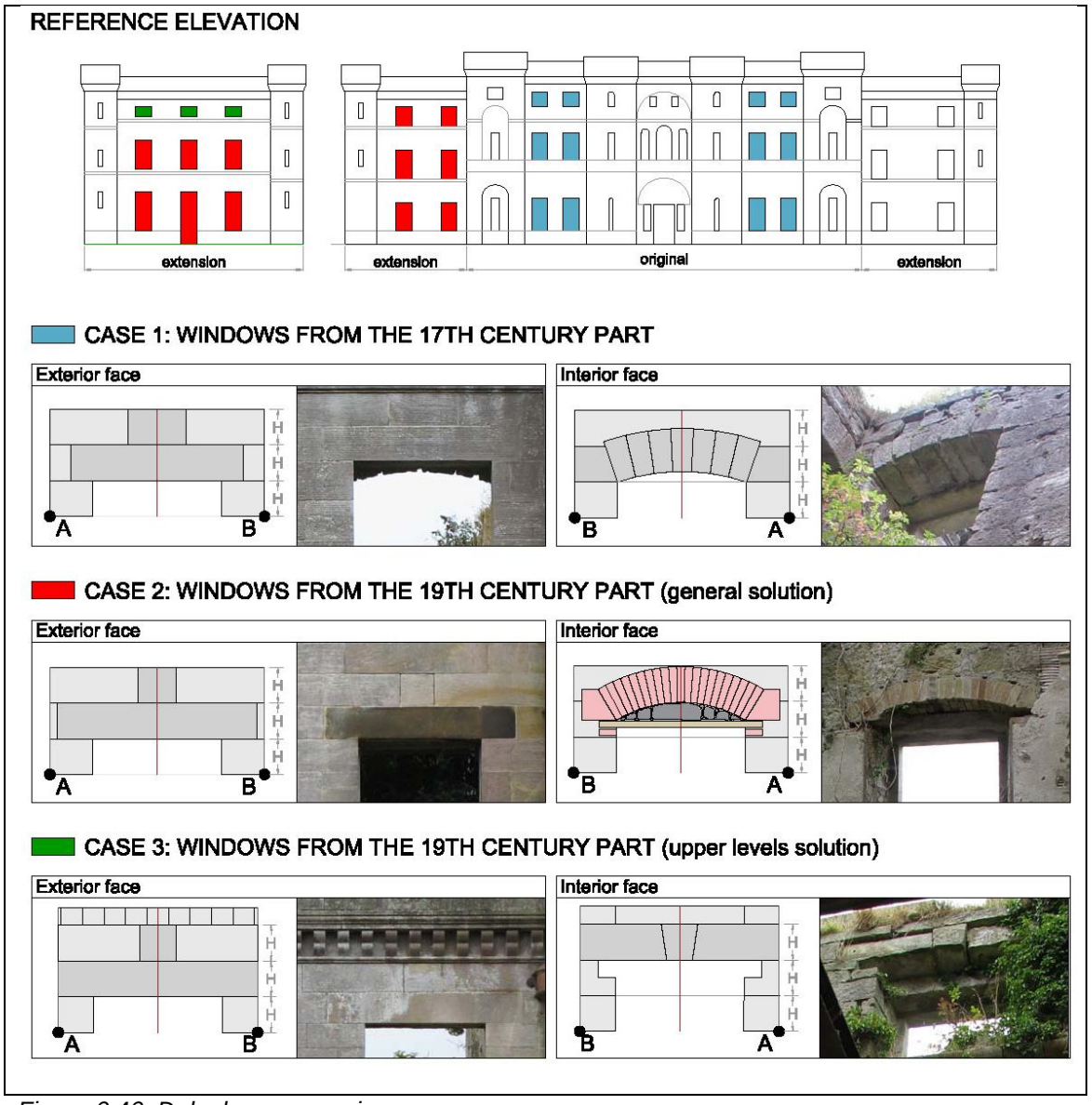


Figure 6.46: Dalquharran openings.

JAMBS

The strategies used to define jambs resemble those used in corners: (1) highlight the window frame, and (2) define a clean straight edge. Figure 6.47 summarises the eight different cases identified in the buildings inspected.

The first five cases belong to the first strategy, highlighting the window frame by dressing the stones forming protruding volumes. The complexity of the resulting frames varies depending on the case. As for quoins, the size of these dressed volumes does not necessarily correspond with the real dimension of the stone units composing the jamb and the image of regularity is therefore just an illusion.

Cases 6 and 7 belong to the second strategy. Wedderburn is the first case of those considered where the construction of jambs with non-highlighted boundaries becomes the rule. Subsequent buildings, such as Newliston and Dalquharran, followed the same

strategy, even extending it to lintels. However, what could be considered a preliminary test of non-highlighted frame can be found in the lateral facade at Dun, where the ground floor level openings had textured boundaries. Decades later, at Newliston, textured boundaries appear again, but this time as a generalised solution.

Cumbernauld differs from the rest in its use of the double-edged frame. This could be understood as the negative of a frame because, instead of protruding, it is set back from the wall plane.

At this point, the fact that Cumbernauld and Dun were built very close together in time and the other contemporary buildings tended to highlight the window frame means that they can be understood as pioneering tests of the second strategy.

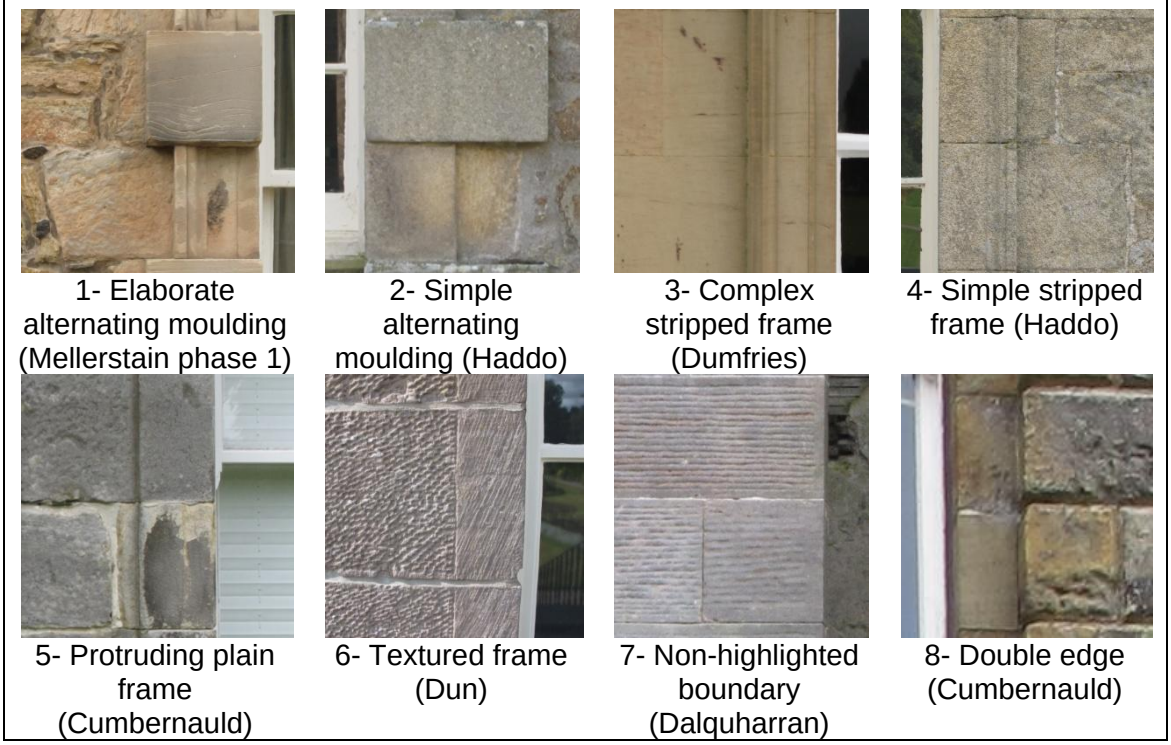


Figure 6.47: Showcase of the different strategies to define the jamb frame identified in the cases studied.

6.3.3.5 Masonry elevations

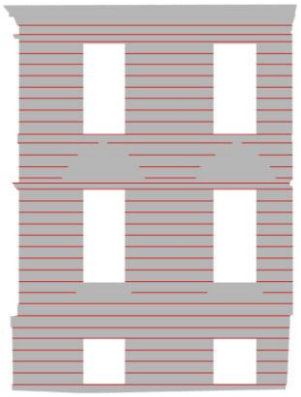
Depending on the structure of the courses or lifts making up the elevations, the different cases can be classified in three groups, as shown in Figure 6.48.

The biggest group is made up of elevations with masonry classified as Cluster 3. In these cases, courses are continuous in all the elevations integrating the stones defining openings and corners. Dalquharran is notable amongst these because of the absence of carved stones forming pilasters, lintels or other added elements, the linearity of cornices and the homogeneity of the course heights and masonry patterns used. Only one case with Cluster 3 masonry escapes the rule and belongs to a different group: Dun. Despite having a regular pattern, the courses in the elevations of Dun have some

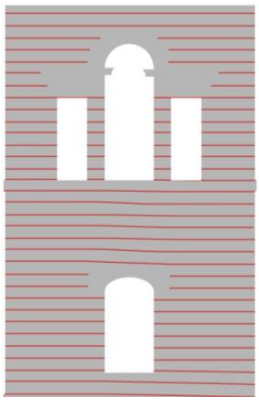
discontinuities caused by misalignments between jamb stones and quoins. The principal volume at Haddo, the lateral and back facades at Cumbernauld and the second phase of Mellerstain also belong to this group but have Cluster 1 masonry.

Finally, the first phase of Mellerstain and the lateral pavilions of Haddo, which are the two cases with Cluster 2 masonry, make up a third group. In these cases, masonry is built to courses but with discontinuities, especially in the areas near the openings.

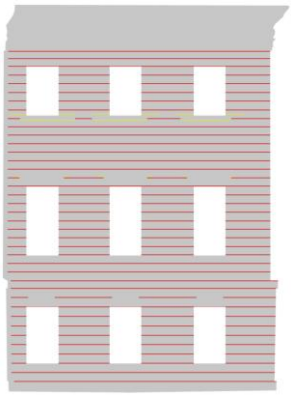
CONTINUOUS COURSES



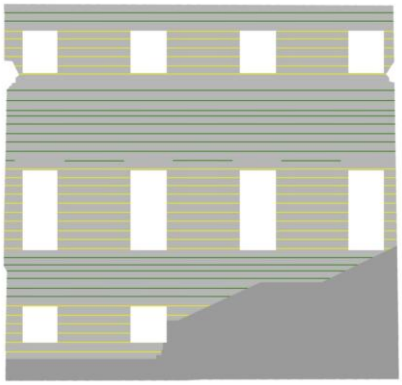
Cumbernauld main facade (built 1730s)



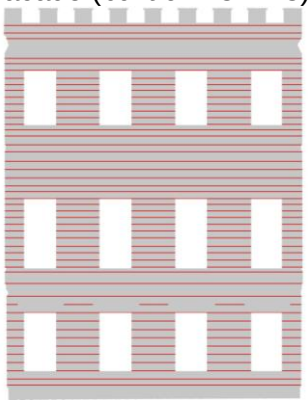
Chatelherault front facade (built c.1731–43)



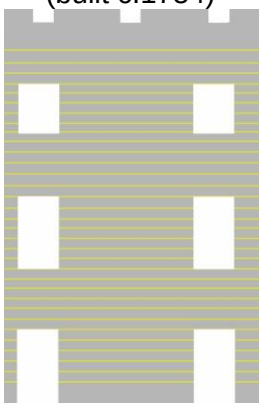
Dumfries back facade (built c.1754)



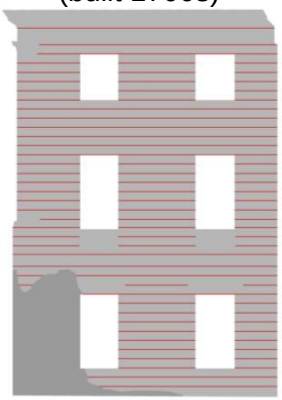
Penicuik front facade (built 1700s)



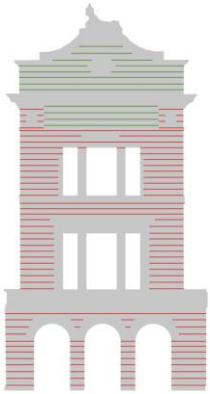
Wedderburn front facade (built c.1767)



Dalquharran front facade (built 1780s)



Newliston back facade (built c.1789)



Gosford back facade (built c.1790)

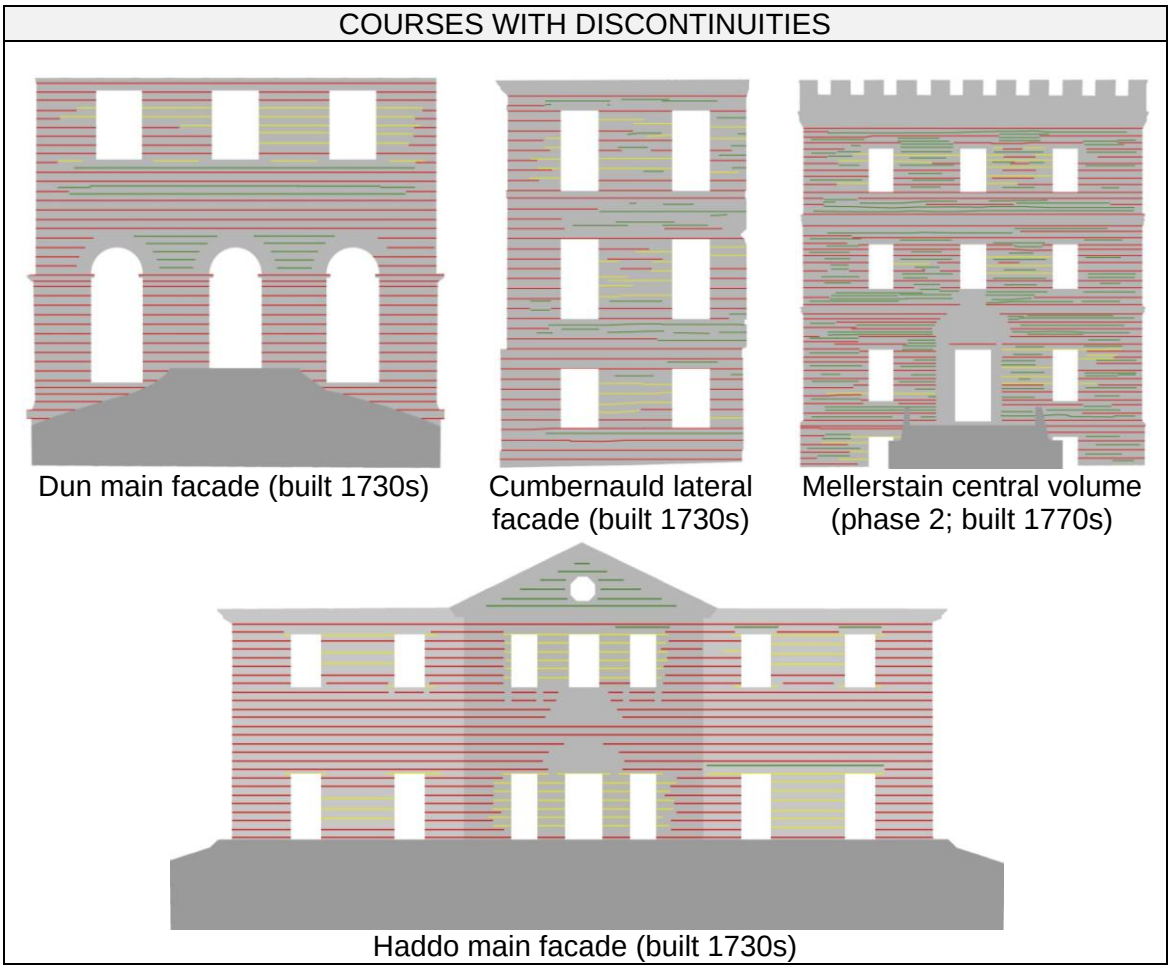


Figure 6.48: Scheme of the courses/lifts making up the masonry elevation. One portion of one of the elevations is shown for each case. Red lines correspond to courses related to the quoins, yellow lines are related to jambs in the openings, and green lines define the rest of the courses.

6.3.3.6 The finishing

The previous section related to the pattern characterisation mentions the two strategies related to the final images of the elevations: (1) highlighting the joints between stones (either vertical or horizontal), and (2) defining a plain and homogeneous surface. A detailed observation of the different buildings enables identification of some intentionality in the Adams' work in the use of stone finishing (Figure 6.49).

A plain homogeneous surface is achieved by minimising the visibility of the joints, either reducing their thickness to the minimum and/or blurring it using the finishing. The finishing of Dun, the plain surface with almost imperceptible joints at Dumfries and Penicuik, and the stripped surfaces, diagonal at Dumfries and horizontal at Penicuik, Wedderburn, Dalquharran and Newliston, are examples of this. Considering the chronology of the cases studied, the use of finishing is already noted in William Adam's work and this was further developed by his sons, who appear to have felt comfortable exploring the possibilities of the striped finishes.

In some cases, observation of the details regarding the density and depth of the finishing marks and proximity to the stone edges enables the original masonry to be distinguished from the later additions. Two examples of this are Dalquharran and Gosford (Figure 6.49). At Dalquharran, the finishing of the original masonry respects the marginal edge of the stones, while the later addition erases all marks, bringing the stripes to the border of the stone face. At Gosford, the original plain finishing leaves the manual dressing marks visible, while the finishing of the later addition, despite also being plain, follows a different pattern probably derived from the use of different tools. The case of Newliston is particularly distinct as the differences can be appreciated in the textured window frame (Figure 6.50). The original finishing follows a vertical direction while the later addition follows either a horizontal or vertical direction depending on the case, with the intersection marked with a line in the corners.

Finally, a special mention should be made of the stripped finishing of the masonry at Mellerstain, which is a result of different reasons. The marks are identifiable not only in the general pattern but also in quoins, jambs and lintels, suggesting that the overall surface was probably prepared to be rendered. Only some special elements, such as the mouldings surrounding the openings, remain unmarked, and therefore should probably have been left unrendered (Figure 6.51).



Dun general case



Dun special case



Cumbernauld



Chatelherault



Dumfries general case plain



Dumfries plinth plain



Dumfries general striped



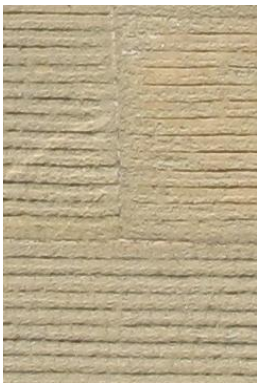
Dumfries plinth striped



Penicuik plinth



Penicuik upper part



Wedderburn general case



Wedderburn plinth



Dalquharran by Robert Adam



Dalquharran later addition



Newliston basement



Newliston ground floor level



Newliston upper levels | Gosford general case | Gosford later addition | Gosford plinth

Figure 6.49: Showcase of stone finishings identified on masonry built to be unrendered.



Figure 6.50: Images of Newliston house openings at basement level. Left: Opening in the original building. Right: Opening in the later added volumes.



Figure 6.51: Image of the masonry in the second phase of Mellerstain. Quoins, lintels, jambs and wall masonry have striped finishing and the window moulding projects from the masonry plane.

6.4 DISCUSSION OF THE RESULTS

The results presented in this chapter provide a comprehensive historical construction understanding of the masonry built between the end of the sixteenth and the eighteenth centuries. A systematic analysis of this type is absent from the literature and existing references to the topic do not define a structured body of knowledge. The analysis sequence defined provides a original approach, which effectively contributes to the interpretation of the morphological aspects of masonry from the perspective of the construction technique. The outcomes obtained enable a double discussion: one considering the evolution of masonry morphology over time, the other considering the link with the geographical territory. The following sections discuss both of these points.

6.4.1 EVOLUTION OF MASONRY MORPHOLOGY OVER TIME

The results presented further strengthen the thesis defended by authors such as Dunbar (1966, 1976), Glendinning et al. (1996) and McKean (2001), who have explained how the emergence and consolidation of the architect during the seventeenth and eighteenth centuries in Scotland altered the prevalence of masons as leading figures in the design and construction of buildings. In particular, a clear difference is highlighted regarding the morphological characteristics of masonry corresponding to the two different groups of cases: one composed of non-architect-led buildings and the other of architect-related works. The morphology of the former mainly responds to the fulfilment of the rules of the Stonemason’s Gospel, while the latter includes further design ambitions. This difference is detected on two different scales: (1) individually in each of the three basic elements making up a masonry wall (the solid

portion of masonry, the corners and the openings), and (2) globally in the structure of the overall elevation.

The first of the three basic elements analysed is the solid portion of wall. In the case of buildings not related to the work of an architect, this is composed of internal and external face patterns, which do not significantly differ from each other in the same wall and generally range between Clusters 1 and 2. The differential aspect within these groups of buildings is the thickness, which shows a clear tendency to decrease over time. In particular, towers (before the seventeenth century) are defined by walls between 145cm and 320cm thick and composed of massive sections, while the remaining cases (from the seventeenth century) are around 100cm and are composed of three layers: central core, external and internal facings.

The picture changes in the group of architect-related works. The differences in thickness among these cases are less relevant although the decreasing trend does not disappear. Instead, the most important variation relates to the pattern. The novelty is the appearance of a new masonry technique (Cluster 3) characterised by a high SP per square metre, derived from the definition of highly rectangular units and very thin joints. The use of this type of masonry progressively gains importance over time. This new type of pattern is linked to a new variant of the wall structure in sections as, in cases where the entire masonry could be examined, the new pattern applied only to the external faces. The result is an asymmetric section comprising a Cluster 3 outer facing, a central core with a dimension that varies according to thickness, and a Cluster 1 inner facing.

Figure 6.52 illustrates this, plotting the distribution of masonry clusters according to the different groups of buildings considered. Almost all non-architect-related cases (TW, AD and IS) are defined by Cluster 2 patterns. The architect-related groups, however, show a progression towards the most regular type of pattern (Cluster 3). In particular, Environment-3, which is anchored to the first half of the seventeenth century, keeps most of the cases within Cluster 2. Environment-2, including buildings constructed between the 1670s and the early years of the 1700s by James Smith and Sir William Bruce, incorporates cases in Clusters 2 and 3. Finally, the cases related to the Adam environment (Environment-1) are predominantly built with Cluster 3 patterns.

In addition to the increasing regularity of the masonry pattern, the detailed analysis of the external wall faces reveals an original feature of the architect-led cases, which also goes beyond strict compliance to the Stonemason’s Gospel. In particular, as well as involving the construction of a solid, stable and durable wall, a perfectly plain and continuous surface appears to become a priority. In the earliest cases, this is achieved using highly dressed units with very thin joints. As time passes, the dimensions and proportions of the stone units, variable at the beginning (Cluster 3.1), tend to be more homogeneous (Cluster 3.2). The cases related to the environment of Sir William Bruce and James Smith use V-shaped joints to highlight the horizontal courses on plinths and, in contrast, emphasise the plain surface of the upper levels. However, the maximum experimentation using plain surfaces is found in the work of the Adam family (Environment-1). In this environment the finishing of facing stones is used as a tool for the blurring of the joints between the stones composing the pattern. The initial trials by John Adam using dotted finishing (House of Dun), imperceptible joints (Dumfries

House) and striped surfaces (45º striping at Dumfries) were continued by Robert Adam. The latter further explored the possibilities of the horizontal striped finishing at, for example, Dalquharran Castle and Newliston House.

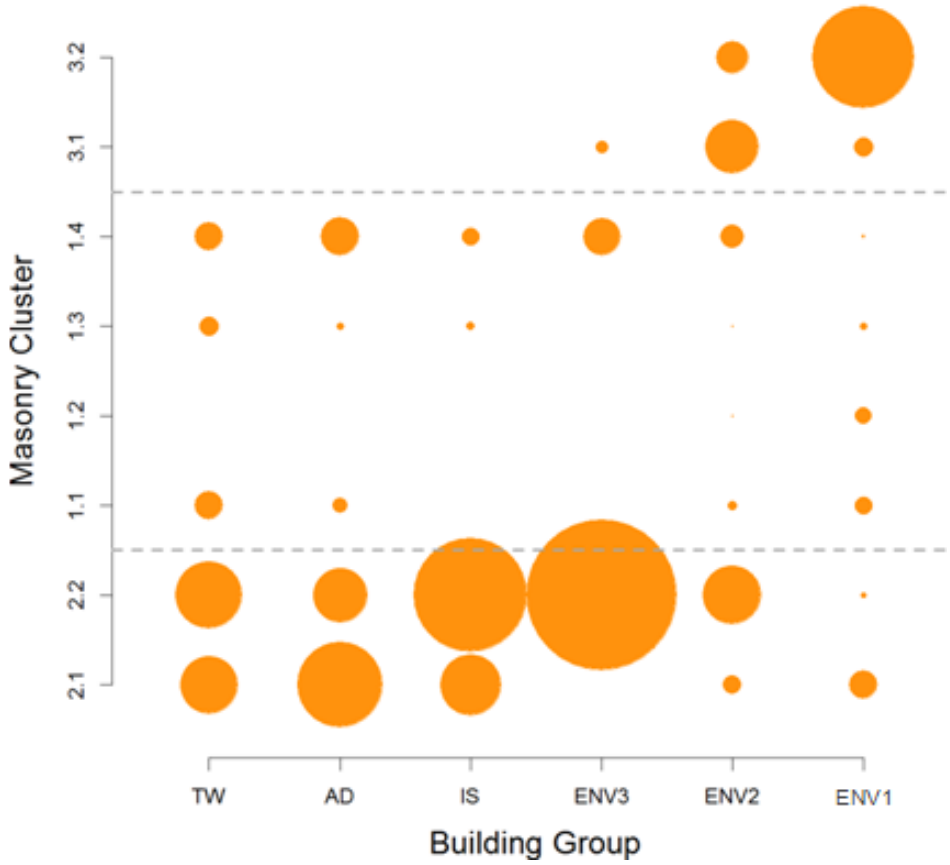


Figure 6.52: Weighted scatter plot of the distribution of masonry clusters corresponding to the six groups of case studies considered. The x axis refers to the building groups (TW = towers, AD = new wing additions, IS = isolated buildings, and buildings within the three environments = ENV3, ENV2, ENV1). The y axis refers to the six masonry sub-clusters or variants defined in a previous chapter, starting with the less regular type at the bottom and ending with the most regular at the top. The size of the circles is proportional to the percentage of cases within each group, considering each group separately.

The second basic element considered in the masonry wall is the corner. The stones at the corners are known as quoins. As well as having a bonding function, quoins are also used as a reference to trace the guide lines necessary for the construction of horizontal courses or lifts. Consequently, the characteristics of these stones have a direct influence on the general structure of the masonry wall. In pre-architect works, corners are made up of straight edges comprising alternate header and stretcher quoins. In all cases, the height and proportion of quoins vary along corners. The shape of facing quoins is generally rectangular, although cases with a tendency to triangular shapes are not rare.

The first design ventures beyond the Stonemason's Gospel appear again in the group of architect-related buildings. In particular, the earliest case where this feature is verified is Baberton House, built by James Murray in the first quarter of the seventeenth

century (Environment-3). The design strategy in this case aims to define quoins with homogeneous dimensions. In order to achieve this, the height of quoins is kept constant along the edge (27–28cm). Limiting the length of quoins would not have been convenient as the bonding of the intersecting walls depended on this. The solution defined to overcome this issue is a carved motif, which creates an illusion of uniformity and hides the length variations.

A similar approach but with different formalisation is found in later works corresponding to Environment-2 (Bruce and Smith) and Environment-1 (the Adam family). In both cases it is common to find quoins dressed protruding from the wall surface in a way that emphasises headers and stretchers. The protuberances do not necessarily correspond with the whole face of quoins, blurring the length variations. Another strategy with the aim of blurring the quoins at the corners consists of highlighting the vertical edge with a vertical protruding band approximately 20cm thick. This is observed only in buildings corresponding to the environment defined by Sir William Bruce and James Smith (Environment-2), and can therefore be considered quite characteristic of this group. Finally, a special feature identified in the latest works is the clean and straight edges achieved by integrating quoins within Cluster 3 masonry patterns. This strategy is identified in certain plinths of Environment-2 building (Bruce and Smith), but in Environment-1 (Adam) this is extended to all elevations, complementing the strategies aimed towards achieving plain and homogeneous surfaces detected in the solid portions of masonry.

After the solid wall and the corner, the opening is the third basic element of the masonry wall individually analysed. Openings create voids, which interrupt the continuity of the masonry. The techniques used to overcome this discontinuity affect the overall masonry system. Unlike the situation for solid walls and corners, openings of pre-architect buildings already include design efforts beyond the mere fulfilment of the Stonemason’s Gospel.

Regardless of the building group or period of construction, openings are generally rectangular or square in shape, and lintels are usually defined by one single, straight, long stone. However, the morphology of the lintel visible on the exterior face of the facade does not necessarily correspond with the solution supporting the core and the internal layer of the facade. This seems logical in Cluster 3 masonry facades, where the external and internal layers of the wall differ. Nonetheless, it has also been detected in buildings with less regular masonry where the inner and outer layers have very similar characteristics. An early example of this can be found in some of the openings in Tolquhon (a pre-architect case with Cluster 2 masonry), where the arched solution supporting the wall core and internal layer cannot be appreciated from the external face of the opening, which has a simple straight lintel. Two centuries later, the windows of Dalquharran (built by the architect Robert Adam and defined as Cluster 3 masonry) follow a similar approach. The use of this type of lintel is therefore not necessarily linked to a specific type of masonry, group of buildings or century.

Single stone lintels co-exist with other solutions. In the case of new wing additions and isolated buildings the single stone lintel solution is also found combined with a relieving arch. It should be noted that the relieving arch interrupts the continuity of the courses, causing irregularities in the patterns. It therefore appears logical that architect-related

buildings relegated the use of this mixed solution to irregular masonry, and substituted the relieving arch with a flat arch, favouring a solution easier to integrate in regular masonry. The differences between pre-architect and architect-led cases also affect openings with arched lintels. Despite not being common, arched lintels corresponding to pre-architect buildings are composed of a series of voussoirs, which form the shape of an arch. When this occurs, the contact between curved and straight surfaces generates irregularities. This issue is overcome in Environment-2 (Bruce and Smith) and Environment-1 (Adam), where the shape of voussoirs forms non-curved perimeters, which eliminate the irregularities mentioned. This highlights a will to control the design of the contact between the lintel and the masonry pattern.

The strategies used to define jambs resemble those used in corners. These can be divided into two groups: (1) highlighting the opening frame, or (2) showing a clean edge. However, in the case of non-architect-related buildings, openings include some level of design, which goes beyond simple compliance to the Stonemason's Gospel. In the case of towers built before the seventeenth century, the perimeter of the opening is often highlighted by bevelling the edge. The same strategy is also used in later isolated residences and new wing additions. However, in these cases, apart from the bevelling, mouldings are used to further highlight certain openings, such as the entrance doors. The degree of complexity of the moulding varies depending on the case, and, over time, the use of mouldings is extended to all openings. In the cases within Environment-3 (first half of the seventeenth century), openings are outlined with a protruding frame, which can also be bevelled. The protruding strategy is continued in the buildings related to Environment-2 (cases built between the 1670s and the early years of the 1700s), which combine its use with bevelled edges or clean straight edges. A special case is found at Kinross, where the frame opening has a depressed profiled edge. The earliest cases in Environment-1 continue the work, with protruding solutions developing schemes quite characteristic of the Adam family. However, given the sample of cases considered, this approach starts to change with the construction of two buildings constructed very close together in time: Cumbernauld and Dun (1730s). On one side, Cumbernauld uses a double-edged frame, which appears to develop the solution already used at Kinross. In this case, the solution can be understood as the negative of a frame because, instead of protruding, it is set back from the wall plane. On the other side, the openings on the lateral facade at Dun are outlined with a textured finishing. These can be understood as pioneering tests of a new approach, consolidated decades later. Wedderburn (1767–1771) is the first case study considered where the frame boundaries stopped being highlighted. Subsequent buildings, such as Newliston and Dalquharran, follow the same strategy and even extend it to lintels. At this point it is interesting to note that, according to existing literature, the activity of John Adam appears to have ceased in 1770, and Robert remained as the leader of the Adam firm. The work developed from Wedderburn therefore bears the stamp of Robert Adam.

Analysis of the structure of the elevation enables understanding of how each of the three elements commented upon are integrated within the overall system. The elevations of non-architect-related buildings follow two predominant schemes. The first is composed of masonry with discontinuous courses. Such discontinuities are related to the heterogeneity of the stones making up the pattern (generally oscillating between

Clusters 1 and 2), the variability of the quoin heights, and the morphology of the openings, which generally interrupt the horizontal courses. The second is composed of the most irregular masonry patterns (Cluster 2), where lifts or courses defined during the construction process are difficult to identify.

The scenario is reversed in the case of elevations where an architect has intervened. In such cases, the tendency towards coursed schemes is clear. The structure defined by courses with discontinuities is still predominant in the buildings of the earliest environment (Environment-3, centred on J. Murray). In later decades, this scheme receded in importance and the predominant structure came to be composed of continuous courses.

In Environment-2 (Bruce and Smith), only Auchindinny is composed of discontinuous courses. The rest of the cases use coursed schemes, representing two different situations. On one side, coursed schemes appear only on the main elevation, while the masonry of the lateral facades is composed of irregular patterns structured in courses/lifts difficult to identify. On the other side, all elevations follow the coursed scheme. A feature evident in all the cases in Environment-2 is the apparent effort to integrate openings (lintels and jambs) within the general structure of the masonry, as the continuity of courses is only interrupted by ornamental motifs.

Among all the cases making up the group of buildings within Environment-2, Drumlanrig stands out for the excellence in the design of its masonry. Aspects of its masonry are notable. The first aspect is the evident effort devoted to integrating the joints between stone units within the overall design of the elevation. As already mentioned, this feature can be identified in three points: (1) in the minimal thickness of the joints in the pattern and their continuity throughout the elevation, (2) in the use of large stones to form pilasters, and (3) in the shape of voussoirs used for arches. The second aspect is the intentional and uncommon use of face-bedded stones in the vaults of the central clock tower. The third aspect refers to the large variety of carved details, which reveal the mastery of the masons who developed them. Based on this, Drumlanrig can be considered a stonework masterpiece. It was conceived by someone concerned not only with the overall design of the building and its surroundings, but also with the construction of its masonry. Authors such as González-Longo (2014, 2020) have identified James Smith as the author of its design. His mason origin and his almost certain trip to Rome could have provided him with the knowledge necessary to develop such a complete work.

Kinross House, by Sir William Bruce, is also a prominent building within Environment-2, which also includes some of the aspects of this integrated conception of elevation and masonry. The masonry pattern used with continuous courses and thin joints is similar to Drumlanrig's main facade. In addition, the carved decorations on the facades were completed by masons with a high level of mastery. However, in this case the showcase of stone virtuosity is reduced.

The buildings in Environment-1 (Adam) form a similar framework. In this case the combination of regular courses on the main facade and irregular courses on the lateral facade still exists. However, over time, the use of coursed masonry in all the elevations has become the rule. The sequence of Adam buildings considered in this research

highlights a tendency towards masonry design composed of continuous courses that integrate quoins and opening frames and result in plain masonry surfaces and clean edges. Homogeneous surfaces are achieved by minimising the visibility of joints, either reducing their thickness to the minimum and/or blurring it with the use of the original strategy already noted: stone finishing. The stone finishing design has already been discussed in the work of William Adam, and it was further developed by his sons in later decades. Dalquharran Castle is one of the latest works completed by Robert Adam, and represents an example of prominent masonry design, which somehow completes the sequence of works developed by the Adam family, achieving complete integration of the three basic elements of masonry in the overall elevation design.

In conclusion, the method applied in this part of the investigation effectively analyses the morphology of four key aspects of a masonry elevation from the perspective of the construction technique: the solid portion, the corner, the opening and the layered structure of the system. Differences between architect- and non-architect-led works reveal that the involvement of this new role in the construction process had a clear impact on the design and morphology of the masonry in the elevations. In particular, the morphology of the three groups of pre-architect cases is characterised by strict fulfilment of the Stonemason's Gospel. Instead, the subsequent groups of buildings include further design efforts, which motivated successive developments of construction techniques. The irregularities that predominate in pre-architect buildings almost disappear in the masonry involving the work of architects, where the morphology of the solid portion of wall, quoins, lintels and jambs is successfully transformed in order to be integrated within the overall structure and design of the masonry elevation. Examples of this include the early strategy to homogenise the apparent size of quoins used by James Murray at Baberton House, the gradual introduction of a new type of masonry defined by an asymmetric section and a pattern with a high percentage of stone, the excellence of the masonry work identified in Drumlanrig's main façade and the original use of stone finishing as a blurring technique, explored by the Adam family, which is developed to the maximum at Dalquharran.

MATRIX SUMMARY OF THE RESULTS DISCUSSED RELATED TO THE EVOLUTION OF MASONRY MORPHOLOGY OVER TIME

<table>
<tr><th colspan="2"></th><th>NON-ARCHITECT-RELATED CASES</th><th>ARCHITECT-RELATED CASES</th></tr>
<tr><td rowspan="4">SOLID PORTION OF WALL</td><td rowspan="2">PATTERN</td><td rowspan="2">Generally varies between Clusters 1 and 2.</td><td>Appearance of a type of pattern: Cluster 3.</td></tr>
<tr><td>Perfectly plain and continuous surfaces appear to become a priority. This is achieved with Cluster 3 patterns. In addition, in ENV-2, V-shaped joints are used to highlight horizontal courses on plinths, emphasising the plain surface of the upper levels. In ENV-1 the joints between stones in the pattern are blurred with finishing of the unit faces.</td></tr>
<tr><td>THICKNESS & SECTION</td><td>Internal and external face patterns do not significantly differ.</td><td>Cluster 3 patterns are found only on the external wall face. The corresponding internal face is generally Cluster 1.</td></tr>
<tr><td>THICKNESS & SECTION</td><td>Decrease of thickness over time:
• Towers (previous to C17th) have walls 145–320cm thick with massive sections.
• The remaining cases (from C17th) have around 100cm thicknesses and layered sections: central core and external and internal facings.</td><td>Differences of thickness among cases are less relevant although the decreasing trend does not disappear.

The earliest cases are mainly around 100cm thickness, while the latest also include values between the 70cm and 90cm.</td></tr>
<tr><td colspan="2">CORNERS</td><td>Defined by straight edges, alternate header and stretcher quoins.</td><td>Development of strategies to define quoins with homogeneous dimensions:
• First attempt found (at Baberton House, built first quarter of C17th): height kept constant (27–28cm) and variation of lengths hidden with a carved motif. (This is also identified in later cases.)
• Highlight the vertical edge with a protruding band approximately 20cm thick (this is characteristic of ENV-2 (cases between 1670s and the early years of the 1700s).
• Building clean and straight edges, integrating quoins within Cluster 3 masonry patterns. This strategy is identified in certain cases from ENV-2 buildings (Bruce and Smith). In ENV-1 (Adam), this is extended to all the elevations.</td></tr>
<tr><td rowspan="3">OPENINGS</td><td rowspan="2">LINTELS</td><td>Generally straight and defined by one straight long stone, although mixed solutions including relieving arches are also common.</td><td>The use of mixed solutions is generally relegated to irregular masonry. Relieving arches are substituted by flat arches, favouring their integration in regular masonry.</td></tr>
<tr><td colspan="2">The morphology of lintels visible on the external face of the facade does not necessarily correspond with the solution of supporting the core and the internal layer of the facade.</td></tr>
<tr><td>Arched lintels are rare. When built, they are composed of curved voussoirs.</td><td>Arched lintels are rare. Cases with arched lintels (ENV-2 and ENV-1) use voussoirs with non-curved perimeters to ease their integration within the pattern.</td></tr>
<tr><td></td><td>JAMBS</td><td>Two strategies identified:
• Highlighting the frame with bevelled edges or mouldings → generally used to emphasise relevant openings.
• Defining a clean edge.</td><td>The use of mouldings is extended to all openings.
• ENV-3 (first half of C17th) openings are outlined with a protruding frame, which can also be bevelled.
• ENV-2 (1670s–1700s) combines protruding, bevelled and clean straight edges.
• The earliest cases in ENV-1 (C18th) continue using protruding solutions but have characteristic schemes. However, this approach changes over time and frame boundaries stop being highlighted. Robert Adam appears to be directly related to this innovation.</td></tr>
</table>

STRUCTURE OF ELEVATION	Two predominant schemes: • Masonry with discontinuous courses → related to type of pattern, dimensional variations of quoins and morphology of openings, which interrupts horizontal courses. • Masonry where lifts or courses are difficult to identify → composed of the most irregular masonry patterns (Cluster 2).	The structure of the elevation evolves over time. • ENV-3: Structure defined by courses with discontinuities is still predominant. • ENV-2: All cases except for Auchindinny have coursed schemes. On occasions these appear only in the main facade while in others they appear in all the elevations. This highlights the effort to integrate openings within the general structure of the masonry as the continuity of courses is only interrupted by ornamental motives. • ENV-1: Progressively, the use of coursed schemes has become the rule in all elevations. This highlights the tendency towards the definition of plain masonry and clean edges integrating quoins and openings. Homogeneous surfaces are achieved by minimising the visibility of joints, either reducing their thickness to the minimum and/or blurring them with finishing.

Table 6.5: Matrix summary of the results discussed regarding the evolution of masonry morphology over time.

6.4.2 THE LINK WITH THE TERRITORY

As discussed in the literature chapter, the idea of a stone architecture closely related to the territory has already been explored by Dunbar (1966, 193–97), although he never developed it further. The results obtained in this part of the investigation contribute to this observation, discussing the morphological features identified in the masonry of each case study and relating these to their location in Scotland.

Figure 6.53 illustrates the locations of the different cases considered. The three colours used in the map define areas corresponding to the three main families of rocks. Red highlights sedimentary rocks, blue shows igneous rocks, and green indicates metamorphic rocks. The location of each case study is indicated with a black dot. A relevant aspect to highlight is that the five case studies located in non-sandstone-rich areas (highlighted with bigger dots) are composed of irregular masonry patterns. Four are non-architect-related: Auchans is located in South Ayrshire, Kilchurn in Argyll and Bute and Tolquhon and Glenbuchat in Aberdeenshire. As mentioned before, non-architect-related buildings are usually composed of masonry patterns within Clusters 1 or 2. However, these four cases belong to the most irregular group (Cluster 2).

Haddo House is the fifth case, and differs from the rest as the only architect-related case. It was designed by the Adam family. The masonry identified on the Adams' buildings predominantly belongs to Cluster 3. However, the principal volume of Haddo is composed of Cluster 2 patterns and the lateral pavilions belong to Cluster 1. This is a rare feature, which suggests that the characteristics of the material available are probably the cause of the less regular masonry pattern. Sandstone is considered a good building material for its ease of use, while metamorphic rocks are characterised by an eminent hardness, which hinders the dressing process. According to research into traditional stone masonry techniques presented in a previous chapter, the geometry of the stone units is a determinant factor for the characteristics of masonry

patterns. Considering the technology available at the time, geometry was highly conditioned by the workability of the material used.

Geology and the locations of buildings are therefore factors related to masonry techniques involved in construction. However, although all cases in areas where sandstone is scarce are composed of irregular patterns, not all buildings in rich sandstone areas have regular patterns. Burleigh and Mellerstain are two examples of this. The former is non-architect-related while the latter is designed by architects. Despite the reduced number of cases considered, this observation suggests that the geographical factor determines the masonry technique in areas where sandstone is not easily available. Future work involving a larger sample of buildings would contribute to further investigation of this subject.

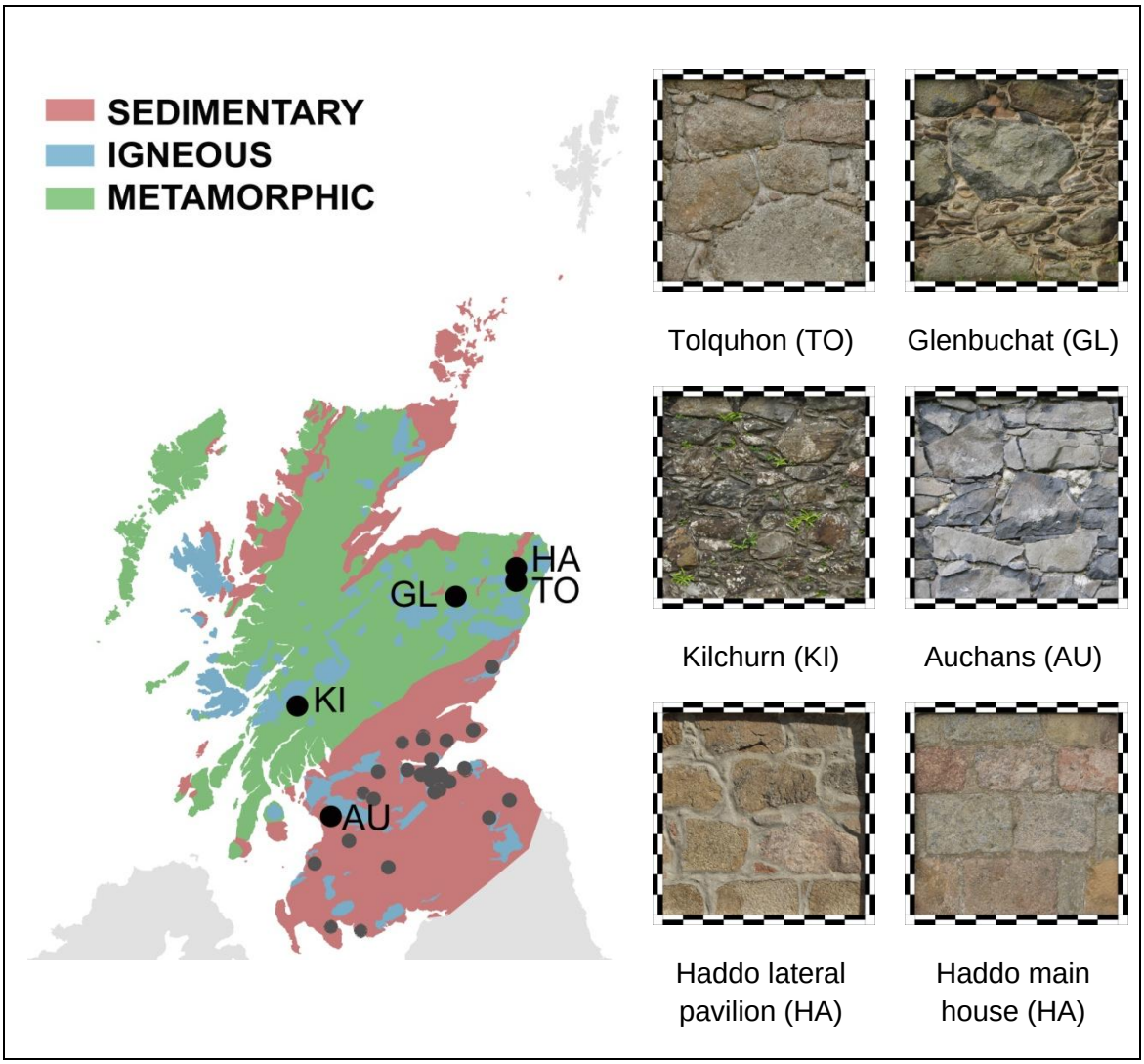


Figure 6.53: On the left: Plot of Scotland – simplified geology map. The black dots indicate the locations of the case studies. The five case studies located in non-sandstone-rich areas are highlighted with bigger dots and identified with the first two letters of their names. On the right: Showcase of the masonry patterns corresponding to the five cases discussed.

Chapter 7
CONCLUSIONS

7.1 INTRODUCTION

The initial concern that motivated this investigation related to conservation of seventeenth and eighteenth century built heritage in Scotland. The existing literature in the field of history of architecture defines this period as a time of transformation. The emergence of the new role of the architect is a factor of change, and the countryside stately home is highlighted as the centre of construction activity (Dunbar 1976, 11; Howard 1995, 211–18; Glendinning et al. 1996; González-Longo 2020). Stone was the prevalent building material, and the need to control the processes of damage and decay affecting built heritage has motivated extensive research in the field of material science and geology (Hyslop, Albornoz-Parra et al. 2006; Hyslop and Albornoz-Parra 2009; Tracey, Smith, and Lawrie 2016). However, no systematic approach has focused on understandings of building knowledge and techniques related to construction of stone masonry.

In Italy, extensive research into historical masonry building techniques has contributed to identification of types of masonry walls and related these to specific regions and historical periods (Parenti 1988b; Fiorani 1996b; Bianchi 2005; Chiovelli 2017). This has created a structured base of knowledge, which has been linked to other fields, such as structural analysis, resulting in a valuable contribution to the survey and conservation of existing heritage (Giuffré 2003; Doglioni and Mirabella Roberti 2003; Donà and De Maria 2011; ICCD 2013a, 2013b).

This investigation has therefore focused on bridging the gap identified in historic construction knowledge, considering this a necessary step for the adequate interpretation of the built heritage discussed and consequently its future conservation. In particular, the research objective is the morphological characterisation of masonry in the elevations of stately countryside residences built during the seventeenth and eighteenth centuries in Scotland. Achievement of this goal is important to adequately interpret the heritage studied not only from the point of view of history or architecture,

identifying those features characteristic of different periods and groups, but also in relation to the building techniques applied. The resulting outcome defines a valuable base of knowledge, which can be used to underpin the future conservation of this heritage. In particular, identification and adequate interpretation of morphological features associated with the building technique is essential to prevent blurring of those marks and features, enabling reconstruction of knowledge and constructive wisdom transmitted from masters to apprentices. This intangible heritage was orally transmitted from masters to apprentices and is rarely found in written documents. The existing stone masonry is therefore a valuable historic record, and its correct interpretation is important to prevent inadequate interventions.

The approach defined to achieve the research objective is composed of two consecutive parts. The first is the definition of structured and comprehensive knowledge of the historical–constructive context in terms of masonry, which provides the criteria necessary for the selection of meaningful case studies and the adequate interpretation of the results obtained in subsequent analysis. This was missing from existing literature and is achieved by considering three key aspects: (1) the structure of the territory, which is directly linked to sources of building material, (2) the morphological characteristics of the stately country home built, and (3) the groups of architects and masons responsible for the construction of architectural works at the time. The cases selected are further studied in the second part, which considers the morphological characterisation of masonry elevations. This is based on the identification and interpretation of morphological features, derived from the construction technique used. Each case is systematically analysed following a sequence that first individually studies the three main parts of a masonry wall (the solid portion, the corner and the opening), and then considers how these are integrated within the overall system of the masonry elevation. The results obtained highlight characteristic features, which are then related to the historical–constructive context previously defined, structuring a solidly based knowledge. This part of the research includes the development of a new method for the objective classification of masonry patterns based on the use of machine learning techniques, which effectively overcomes the qualitative approach generally used in Scotland.

The outcomes obtained at the end of this investigation make a contribution which can be synthesised in three main points. The first refers to the methodology, the second relates to the morphological features of masonry within the historical context, and the third is defined in terms of geographical territory. These points are developed in the following sections. Future research opportunities identified during the development of this research are presented at the end of this chapter.

7.2 A CONTRIBUTION TO THE METHODOLOGY FOR THE ANALYSIS OF HISTORIC STONE MASONRY

The absence in Scotland of a continuous and consolidated research line on the subject investigated has led to the definition of a new approach, which applies the lessons learned from Italian references but tailored to the Scottish context. In particular, the review of Italian references has led to the identification of two key points for the study of masonry.

The first point refers to the need to build a comprehensive understanding of the local historical–constructive context in order to adequately interpret the heritage studied. This is learned from authors such as Fiorani (1996a, 1996b). She started her investigation studying aspects related to characteristics of the territory (geomorphology, geology and topography), the economic–political–historical framework, and identification of the distinctive features of the architecture in the area. Such global understanding enabled masonry techniques to be linked to local tradition. Similarly, this investigation studies the local context, identifying areas with homogeneous characteristics in terms of geology and geography. In addition, the most relevant networks of architects and masons of the time are analysed, as well as different typologies of buildings. The result is a comprehensive overview of the historical–constructive context in terms of masonry, which provides the criteria necessary to develop the investigation.

The second point refers to the approach applied for the analysis of masonry. Authors such as Mannoni (1997, 2005), Parenti (1988, 1994) and Giuffré (1991, 2003) overcame formal judgements by approaching the study of masonry from the perspective of technical knowledge involved in the construction of masonry. This research follows the same approach and develops a study of local stone masonry construction techniques, applying the outcomes to the morphological analysis of masonry elevations.

The methodology defined in this investigation therefore comprises two parts, which are discussed as follows.

7.2.1 PART 1: Study of the local context

The first part of the methodology includes a sequence of analyses, which examines the local context in a systematic and structured way, making it significant from the point of view of masonry. This approach builds a thorough understanding, missing from the literature, in a comprehensive way. This is essential for two reasons: (1) to define adequate criteria for the selection of case studies, and (2) to adequately interpret the final outcomes in context. In particular, the analysis considers three aspects.

The first aspect is the structure of the territory. This is analysed by considering three different layers of information: (1) geography of the land, (2) geology, and (3) location of building activity at the time. The data used comes from secondary sources and was therefore known. However, the interpretation derived from the overlay of layers is not found in literature. It is nevertheless essential to understand the link between morphology of masonry and territory. In particular, three distinct areas are identified. The main area includes the Central Belt, south and north-east territories. This area is characterised for being less rugged, with a predominance of sedimentary rocks and the highest density of buildings. The north-west part of the country is very different. It is the most mountainous area, rich in metamorphic rocks, with a low density of construction. Finally, the Aberdeen area represents a particular case between the other two. It is located in the north-east with significant construction density, smooth relief, and a predominance of metamorphic rocks. The analysis of cases considers these three distinct areas and enables better understanding of the influence of the geographical factor on masonry characteristics. The specific contribution from this point is discussed in a later section.

The second aspect of the context considers the countryside stately home. Existing publications describe the characteristics of this typology of building from a historical-narrative perspective. Certain authors, such as Glendinning et al. (1996, 75) and Hyslopet al. (2006), include brief mentions of some features of masonry. However, such references do not derive from systematic research specifically focused on this matter. In addition, none identify the characteristics of buildings most determinant for masonry, which is essential to define criteria for the selection of meaningful case studies. This issue is addressed by means of a statistical approach specifically defined for this purpose.

Following the example of McKean (2001, 17), definition of the initial dataset starts from an existing catalogue, which includes qualitative information about a large number of buildings spread across Scotland. This is transformed into quantitative data and structured in a database, which is then analysed. However, the focus and type of analysis defined in this case is new and differs from that of McKean. In particular, the parameters considered define five features of building morphology (plan, area, span, number of floors and number of vaulted levels), two features of the context (location and period of construction), and three features of masonry (pattern and two prevalent thicknessess). The results obtained define a map of dependencies, which highlights plan typology as the most determining parameter for the characteristics of masonry (pattern and thickness). The period, location and plan size are also relevant. Surprisingly, parameters defining features of the structure, such as the number of floors or vaults, which, in a system composed of load-bearing walls, are known to determine the thickness of walls, was not identified as relevant in this analysis because almost all the buildings had the same number of floors and vaulted levels. Consequently, there was no need to consider them as selection criteria.

The third aspect focuses on the network of architects and masons active at the time. As discussed in the literature, authors such as Bianchi (1996), Cagnana (1996) and Mannoni (1997, 2005) highlight the importance of the human factor in the construction of masonry. In particular, Bianchi states that none of the actions involved in the construction of a masonry structure is a casual choice. Each decision reflects the

technical knowledge of the person undertaking the building work, their cultural–economic environment, and, indirectly, their preferences, requirements and characteristics. Knowing the work groups and their system of connections therefore contributes to the rigorous study of masonry.

The analysis defined effectively captures the context narrated in the literature, clearly showing the system of connections between architects and masons active during the timeframe studied. The new criteria established to select a significant network and then identify work environments, centres, relevant people and bridges enables focus on investigation of relevant groups of people, as well as providing a better understanding of their system of links and influences. In particular, three different environments are identified. These correspond to successive periods of time. The earliest revolves around the figure of James Murray, associated with the first half of the seventeenth century. The next environment is defined by the architects Sir William Bruce and James Smith, and is anchored to the second half of the seventeenth century and the early years of the eighteenth century. Finally, the last environment is centred on the Adam family and the eighteenth century. The existing literature highlights the prominence of these figures in the development of the history of Scottish architecture. This method has therefore proven to be an effective tool in providing a global understanding of the historical context as well as objective criteria to focus the investigation.

7.2.2 PART 2: Morphological characterisation of masonry

The second part of the methodology focuses on the morphological characterisation of masonry. As discussed in the literature review chapter, classification of masonry types defined by different UK authors is generally based on the identification of formal features of the pattern and therefore subject to interpretation. The lack of objective criteria could cause misunderstandings of the research outcomes. Authors such as Mannoni (1997, 2005), Parenti (1988, 1994) and Giuffré (1991, 2003) overcome formal judgements by studying the technical knowledge involved in the construction. This part of the research develops from their approach. In particular, the analysis defined first develops an investigation of traditional building techniques, which builds the knowledge base necessary to develop the analysis. Second, it represents a new method for the objective classification of masonry patterns, which resolves the risk of misunderstandings. Third, it integrates these approaches with the overall morphological characterisation of masonry elevations.

7.2.2.1 Findings from investigation of traditional building techniques

Investigation of traditional building techniques led to the identification of the principles and rules used by masons for the construction of a masonry wall. As discussed in Donà and De Maria (2011), such knowledge is found in two types of sources in Italy: historic treatises and from the oral tradition of masons. In Scotland, treatises from before the eighteenth century are scarce and do not include references to practical knowledge meaningful for the purpose of this research. However, a series of non-

academic publications discussed in the literature review chapter (Warland 1929; Cramb 1992; McAfee 1997, 1998; Mannoni 2005) include certain aspects of such knowledge. The study of these references enabled a synthesis to be developed, which identified two determinant factors in the morphological characteristics of masonry: the geometry and size of the units, and the assembly process followed during construction. In particular, in relation to assembly, the distribution of the units in the wall, their orientation with respect to loads and the bonding system defined are key points for the adequate performance of the wall. This finding defines the base of knowledge from which the parameters considered in the different analyses are defined.

7.2.2.2 Contribution to the objective classification of patterns

The issue related to the heterogeneous classification of masonry patterns was resolved using a quantitative method based on the use of machine learning techniques. Authors such as Esser (2012), Gonzalez Manich et al. (2016) and Valero, Bosche and Foster (2018) used classification algorithms to date brick masonry, recognise areas of decayed stone and identify decayed mortar joints. The innovative approach used in this case contributes to the developments in this field.

The parameters considered quantitatively represent features related to construction techniques. In particular, the dimension and geometry of stone units are defined by four parameters, which determine, per 1sqm of pattern, the percentage of stone, the rectangularity of the units, the mean height of the units and the standard deviation of heights. Similarly, the assembly process is determined by means of face-bonding, regularity of courses and the alignment of the units within the courses. The data analysed is composed of RGB images corresponding to 1m x 1m samples of masonry elevation, collected directly from the different sites. These are processed and characterised according to the parameters discussed and, finally, classified following an unsupervised hierarchical classification process. The results obtained are based on objective criteria and define three main groups or clusters of patterns and their corresponding sub-groups or variants.

The whole classification is mostly influenced by parameters referring to unit geometries and sizes. In particular, the most determinant parameter for the classification of the three main groups is the percentage of stone (SP). SP is directly related to the rectangularity of the units (RC), as the more rectangular the units are, the thinner the mortar joint is and, consequently, the higher the SP value. The group with the highest SP and most rectangular stone units is defined as Cluster 3. Cluster 2 represents the opposite case, with the lowest percentage of stone per sqm and the most irregular units. Cluster 1 occupies an intermediate position.

Clusters 2 and 3 have two variants each. In the case of Cluster 3, these are determined by two parameters: SP and the mean height of the stone units (HMN). Sub-cluster 3.1 includes patterns with the thicker joints and values of HMN in the majority of cases close to 25cm. Sub-cluster 3.2, meanwhile, includes patterns with the most perfectly shaped stone units (lowest SP) and a HMN value generally close to 30.5cm. In contrast, the two variants of Cluster 2 are mainly defined according to RC and HMN,

followed by SP. Sub-cluster 2.1 includes cases with less irregular and larger units in the group, while sub-cluster 2.2 does the opposite.

Cluster 1 is the most heterogeneous group and includes four variants. In this case the most influential parameters for the sub-division are RC, HMN and the standard deviation of heights (HSD). The most rectangular units (highest values of RC) are within sub-clusters 1.1 and 1.2 although the latter also has the lowest HMN values. In contrast, variants 1.3 and 1.1 have the highest HMN. The difference is that 1.3 has the most homogeneous heights (lower HSD). Finally, sub-cluster 1.4 includes patterns with the most heterogeneous heights in the group (highest HSD) and less rectangular units (lowest RC values).

Although parameters relative to the unit arrangement have only a secondary role in the classification, the outcomes obtained strictly relate to the conclusions derived from research into traditional masonry techniques. In particular, it is highlighted in the literature that the shape of the units determines the definition of courses, as regular units are easy to organise because of the parallelism of their faces, while irregular units challenge the ability of the mason. This feature is also found in the classification results. The parameter representing the regularity of horizontal courses (CSD) is linked to RC. Cluster 3, which has the most rectangular units, also has a lower peak value of CSD, while Clusters 1 and 2 have 15 and 25 respectively.

The innovative classification method presented therefore successfully defines clusters of masonry patterns with common characteristics based on objective criteria. The parameters defined for the classification adequately characterise the reality and techniques described in the literature overcoming formal judgements. This makes the method reproducible and applicable to heterogeneous datasets, including all types of patterns.

7.2.2.3 Contribution to the morphological analysis of masonry elevations

Morphological analysis of masonry elevations integrates the outcomes discussed in the previous two sections and defines a sequence that first separately studies three main parts of a wall: the solid portion, the corner and the opening. The sequence then considers how these are integrated within the overall structure of courses or layers in the elevation. The solid portion of wall is the basic element making up an elevation and is characterised by the pattern of the internal and external faces and the structure of the thickness. Corners have the main function of bonding two walls, but their quoins are also used as guides to define the wall courses or lifts during the construction process. The size and the alternation of headers and stretchers are therefore considered key features. Finally, openings create voids on the solid wall, which interrupt the continuity of masonry. The morphology of lintels and jambs therefore affect the system of courses or layers.

The systematic application of this sequence to all the case studies provides comparable data, which leads to the identification of groups with common features. The process defined for the selection of cases enabled the results obtained to be related to the global context. The findings drawn are detailed in a following section, and provide a

comprehensive understanding of the characteristic features of the masonry in context, leading to the fulfilment of the research objective.

7.2.3 FINAL CONSIDERATION

Authors such as McKean (2003) and Uglow et al. (2012) defended the value of studying the existing masonry, combining knowledge of the historical context and direct analysis of existing construction. However, this was an unresolved issue. In recent decades, extensive literature on this subject has been developed in Italy. Research into masonry morphology presented in this thesis develops from this and, for the first time in relation to Scotland, approaches the subject from a perspective of construction techniques. The unique characteristics of the Scottish context challenged the researcher, leading to the development of new analysis, which effectively resolved the specific issues identified. The outcomes obtained demonstrate the viability and benefits of applying this approach, highlighting a research path that, as already noted, contributes to better understandings of the characteristics and value of the built heritage, as well as to its adequate conservation.

7.3 FINDINGS RELATING TO THE MORPHOLOGY OF MASONRY AND HISTORICAL CONTEXT

The literature review highlighted that authors such as Dunbar (1966), Glendinning et al. (1996) and McKean (2001, 2006) defined the seventeenth and eighteenth centuries as a period of transformation for Scottish architecture. The results obtained in this investigation provide evidence that such transformation not only affected the architectural design of the countryside stately home, but also the morphology of its masonry. The sequence of analyses within the methodology enabled the outcomes obtained to be related to the wider context, providing a comprehensive understanding of the characteristic features of masonry, previously missing from the literature.

The statistical analysis presented in chapter 4 set out a first approach to the subject. The map of dependency links highlighted factors which are determining for two characteristics of masonry: pattern and wall thickness. In particular, the study of both characteristics in this period of construction revealed a changing trend, which had its turning point in the seventeenth century. Buildings constructed before the seventeenth century were mainly built with rubble masonry patterns and wall thicknesses greater than 1m. In contrast, for cases built in the seventeenth and eighteenth centuries, ashlar patterns are dominant, and the values of prevalent wall thicknesses are mostly close to 90cm.

Two types of buildings clearly represent the two extremes of this transition: (1) towers built before the seventeenth century, and (2) Vilas, which appear in the seventeenth century. The former generally has rubble patterns, either regular or irregular, and the range of prevalent wall thicknesses includes the larger values registered (reaching the

3m). Vilas are the only type including ashlar either in one part or in the entire building, and almost all the cases are between 90cm and 110cm. The picture is less clear for building typologies not so directly related with a specific timeframe. This denotes a complex scenario. Such complexity is related to the extension and alteration of family seats, which became a common practice in the seventeenth century (Dunbar 1966, 69; Wemyss 2014, 317–20). McKean (2001, 17) studied this fact from a quantitative perspective and identified the years between 1600 and 1630 as the point in time in which the extension of family seats became the most common strategy. This point of inflexion corresponds in time with the change of tendency identified. A line is traced between pre- and post-seventeenth century construction, which is further studied in subsequent steps of this research.

At the end of chapter 5, the group of 426 samples of masonry pattern, corresponding to 34 stately residences and used to develop the objective classification method, was further characterised. As well as identifying the cluster group corresponding to each case, the year of construction of the masonry in question was determined, as well as whether an architect was involved in the process, and the total thickness of the wall section. The resulting plot showed that the majority of cases belonging to the most regular group of masonry correspond to interventions led by an architect. In addition, as noted in the previous analysis, these are concentrated between 1600 and 1800 and have thicknesses of around 1m. Authors such as Dunbar (1966, 1976), Glendinning et al. (1996) and McKean (2001, 276–275) related the emergence of the architect in Scotland to the seventeenth century, and explained that this altered the prevalence of masons as leading figures in the design and construction of buildings. The result suggested a connection between the emergence of the architect and the change in masonry characteristics.

Chapter 6 further explores this question, studying in detail the masonry morphology of 37 case studies divided into six groups representative of the context considered. In particular, the first three groups are defined as non-architect-related and include: (1) pre-seventeenth century towers, (2) new wing additions built in the seventeenth century, (3) isolated residences with different plan types and sizes built or considerably altered during the seventeenth century. The remaining three groups include buildings related to the work of prominent architects in the three successive work environments defined in the first part of the investigation. Environment-3 is anchored to the first half of the seventeenth century and centred on James Murray. Environment-2 is defined by the figures of James Smith and Sir William Bruce and includes cases between the 1670s and the early years of the 1700s. Finally, Environment-1 is associated with the Adam family and clearly linked to the eighteenth century.

The results show clear differences between non-architect-related masonry and architect-related masonry. In particular, the construction of the former responds mainly to the fulfilment of the rules of the Stonemason’s Gospel, while the latter includes further design ambitions. This evidence is verified individually in each of the three basic elements making up a masonry wall and globally in the structure of the overall elevation.

For non-architect-related masonry, the solid portion of wall is mostly defined by patterns corresponding to Clusters 1 or 2, which do not significantly differ in the internal

and external face of the wall. The differential aspect is the thickness, as the decreasing trend previously noted is verified. In particular, towers (before the seventeenth century) are defined by walls between 145cm and 320cm thick, composed of massive sections, while the rest of the cases (related to the seventeenth century) are around 100cm and are composed of a central core and two facings. Corners are generally defined by rectangular quoins of variable height and length, although cases with a tendency to triangular shapes are not rare. On the other hand, openings include certain design features beyond the simple compliance of the Stonemason's Gospel. The perimeter is often enhanced with a bevelling edge, and the use of mouldings to further highlight entrance doors or other openings is quite common. Other than this, lintels are generally defined by one single stone. This solution can be found combined with a relieving arch. However, the lintel visible on the exterior face of the walls does not necessarily correspond with the solution supporting the core and the internal layer of the wall.

The heterogeneity of the stone units in a pattern, and the variability of quoin height and morphology openings, which interrupts the layered structure of the system, result in elevations either with discontinuous courses or built in lifts, which are difficult to recognise. The picture changes in the three groups of architect-related cases, where a progressive evolution towards a more sophisticated masonry construction is clearly identifiable.

The earliest group belongs to the environment centred on Sir James Murray (d.1634), a master wright who became Principal Master of all His Majesties' Works in Scotland, and is claimed to be one of the first architects in Scotland (Colvin 1995, 674; Glendinning et al. 1996, 73). The morphology of the masonry used to build his country house in the first half of the seventeenth century does not show significant differences to non-architect-led buildings. However, a new feature not observed in earlier cases is found in the corners. Quoins appear to be homogeneous in size. Heights are kept constant along the edge (27–28cm) but lengths are variable. According to the Stonemason's Gospel, the longer the quoins, the better their bonding. Cutting the stones would contravene this principle. Apparent homogeneity is thus achieved using a carved motif, which hides the length variations, creating an illusion of uniformity. The design effort behind this feature clearly goes beyond compliance with the building principles and determines the construction technique.

The subsequent group of cases is related to Sir William Bruce (c.1630–1710) and James Smith (c.1645–1731), two eminent architects of the seventeenth century of varied origins (Colvin 1995, 172–176, 893–896). The former was a well-travelled gentlemen architect, while the latter was the son of a master mason probably educated in Rome. Their contribution to Scottish architecture is recognised by numerous authors such as Dunbar (1966), Glendinning (et al. 1996), Wemyss (2014), González-Longo (2013, 2014, 2020) and Lowrey (2020). The masonry built in their works includes a new feature related to the solid portion of walls: the use of a masonry type characterised by an asymmetric section and composed of a Cluster 3 external facing, a central core and an inner facing defined by a Cluster 1 pattern. Elevations including this type of masonry are defined by clearly identifiable and continuous courses. This finding does not mean that Cluster 3 patterns are introduced for the first time in Scotland with this work environment. Further research is necessary to verify this point. However, its use compared to previous groups corresponds with the points made in chapters 5 and 6

regarding the use of a new type of masonry in the seventeenth century, and highlights the progression towards more elaborated masonry construction.

In contrast, corner design follows an approach similar to that identified in the preceding environment but with different formalisation. It is common to find quoins dressed protruding from the wall surface, emphasising the alternation of headers and stretchers, but in such a way that the protuberances do not necessarily correspond with the real length of the stones. Likewise, in other cases the edge of the corner is emphasised with a vertical protruding band approximately 20cm thick, quite characteristic of this work environment. Finally, the morphology of openings varies depending on the case. Façades composed of continuous courses include solutions easy to integrate in the coursed scheme, such as flat arches or single stone lintels, while, in the more irregular schemes, the historic strategies continued in use.

The new features discussed developed further during the eighteenth century. Numerous authors highlight the prominent role of the Adam family in the architectural production of this period (Colvin 1995, 48–66; Glendinning et al. 1996, 147–68). The analysis of masonry presented here contributes to this knowledge, focusing the study on a sequence of 12 cases representative of this group. The first five cases correspond to the period led by William Adam. The following three represent the timeframe between 1748 and 1770, when John Adam assumed the leadership of the firm. The last four cases define the last period, directed by Robert Adam.

The use of ashlar masonry (Cluster 3) is clearly predominant in this group as well as the structure of elevations defined by continuous courses. However, a new feature takes masonry construction one step further: the use of finishing textures as a resource for blurring the joints in the pattern and defining plain surfaces. This is already noted in the work of William Adam, but was further developed by his sons in later decades. In relation to corners, the protruding strategy used in the previous century continued to be used in the earliest works by the family, but with a characteristic design. Certain signs of change are noted from the 1970s, when the edges of corners were gradually no longer emphasised and the use of finishing textures as a resource for blurring the joints of masonry gained in importance. This also applies to the morphology of openings. The use of very regular patterns, clean edges in corners and openings, and blurring textures suggests a design intention focused on flat and homogeneous masonry surfaces in elevations. Dalquharran (1782) is one of the latest works by Robert Adam and somehow culminates the sequence of works, achieving the complete integration of the three basic elements of masonry in the overall design of the elevation. Glendinning et al. (1996, 166) distinguish between two phases in the work of Robert Adam. The authors define a turning point in the mid-1770s, describing the second phase as a period of experimentation. The particular approach for the achievement of plain masonry surfaces just described further strengthens this statement.

The sequence discussed reveals an evolution in the morphology of masonry towards more sophisticated masonry construction. The involvement of the architect appears to have challenged the work of masons, motivating the development of new building strategies and techniques, which comprised more elaborate stone units and more accurate planning of construction in order to achieve the excellence of design sought after. The knowledge built contributes to better understandings of seventeenth and

eighteenth century Scottish stone masonry architecture, highlighting its characteristic features. Chronological indicators are provided and a knowledge base of construction techniques developed, which, if expanded, can effectively contribute to conservation purposes.

7.4 FINDINGS RELATED TO THE STRUCTURE OF THE WIDER TERRITORY

The idea of stone architecture closely related to Scottish territory is shared by numerous authors. For example, Scott-Moncrieff (1938) highlighted the stone character of Scottish architecture in the title of his book *The Stones of Scotland*. Similarly, Dunbar (1966, 193–97) referred to the geological richness of the architecture, imagining a *"regional pattern no less significant than that delineated by local administrative boundaries".* More recently, several studies have contributed to identifying areas with different geological characteristics and building resources as well as locating historical quarries active in previous centuries (McMillan and Gillanders 1997; BGS 2001; McMillan et al. 2006). However, the link between the morphology of masonry and the characteristics of the territory was never studied. The outcomes obtained in this thesis contribute to this aspect, adding one layer of information to the map imagined by Dunbar.

The analysis of the territory presented in chapter 4 overlaid the geography and geology of Scotland with the location of 366 buildings built between the mid-sixteenth century and the end of the eighteenth century (either architect- or mason-led). The results obtained reveal an association between distribution of architecture and structure of the territory. Built nuclei tend to develop in zones with smooth geography. The highest concentration of buildings is in the Central Belt. Some are also spread to the south, scattered through the Southern Uplands, while others follow the east coast along the Grampian Mountains. This distribution coincides with sandstone-rich areas, except for the north-east (close to Aberdeen), which is predominantly composed of metamorphic rock and yet hosts a number of buildings.

The research on traditional masonry techniques presented in chapter 2 highlights the geometry of stone units as a key factor for building technique. Given that the industrial revolution took place after the eighteenth century and therefore the power of the tools available was limited, the final geometry of the stones used to build was highly conditioned by the workability of the material available. According to the literature discussed, the usual practice at the time was the use of stone obtained from local quarries. Sandstone is considered a good building material because of its ease of work, while metamorphic rock is characterised by an eminent hardness, which hinders the dressing process.

Given the aspects explored, the last section of chapter 6 studied the link between the morphological characteristics identified and the geographic location of each case. The results obtained suggest that the geographical factor determines the masonry

technique in areas where sandstone is not easily available. Five of the 37 cases are located in areas where sandstone is scarce and all are composed of irregular masonry (Cluster 2). It is interesting to note that one, Haddo House, involved the work of architects – this building was constructed by the Adam family. As mentioned in the previous section, the architectural works of this family are notable for the predominant use of very regular masonry (Cluster 3). This rare feature and the coincidence of the masonry cluster used in the five cases suggests that the characteristics of the material available in the different sites probably determined the definition of less regular masonry patterns. Dunbar's idea of a territory divided into areas according to masonry therefore fits with reality. Future work considering a larger sample of cases would provide further evidence on this subject.

7.5 FUTURE RESEARCH

The content of this thesis refers to the specific framework defined at the beginning of the document. However, development of the investigation has highlighted further research paths, which are summarised in the following points for future studies.

7.5.1 Further investigation of network analysis

The network analysis presented in chapter 4 defined numerous networks of people, of which only one was further investigated. Future research could consider studying those discarded in order to build a wider understanding of historic masonry construction. For example, this could contribute to better tracing of the development of the new type of masonry, composed of a Cluster 3 external face pattern and an asymmetric section. Likewise, within the network selected, the selection of cases directly related to the centres of each work environment was prioritised. Focusing the analysis on other relevant people in the network would further contribute to better understandings of the contribution of each individual as well as identifying bridges of knowledge between groups.

7.5.2 Extension of timeframe to nineteenth century masonry

Analysis of a group of case studies including buildings dated before the seventeenth century provided the necessary context to identify the seventeenth century as a turning point in the morphology of masonry. In the opposite end of the chronology, the timeframe was limited to the end of the eighteenth century. However, the inspection of Penicuik and Dalquharran Castle revealed a feature that invites further extension of this research beyond the eighteenth century. In particular, the masonry in the original elevations and that belonging to later nineteenth century additions appears to have the same pattern and looks continuous, but the wall thicknesses notably differ. Those from the seventeenth and eighteenth centuries are 100cm thick, while later walls measure

85cm. This suggests that technical masonry developments continued beyond the eighteenth century. The curve of wall thicknesses derived from the statistical analysis presented in chapter 4 shows a decreasing tendency, matching with this observation. Studying the morphology of masonry built during the nineteenth century would therefore further develop the results obtained, offering a more complete understanding.

7.5.3 Further investigation of the link with territory

The findings related to territory add to the idea of Dunbar (1966, 193–97) about a map of masonry. The results obtained suggest that the geographical factor determines masonry technique in areas where sandstone is not easily available. The distribution of case studies across Scotland represents the actual distribution of buildings mapped in chapter 4. However, the limited size of the sample means that the result is only indicative. Analysis of a larger sample of cases is necessary in order to confirm the outcomes obtained.

7.5.4 Creation of a “comprehensive masonry database”

The pattern classification method defined in chapter 3 defines groups or clusters based on objective criteria. The parameters considered identify features related to construction technique. Inclusion of aspects related to the characteristics of the material is the object of future research. The databases developed by the SLCT and the BGS referred to in chapter 2 already include some of this information. Combining the different datasets in a “comprehensive masonry database” could be a path to follow. The outcomes would define a valuable base of knowledge for conservation purposes.

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APPENDIX 1
FUNCTIONS

1.1 FUNCTION “LINK”

The function “LINK” is part of the network analysis referred in Chapter 3. The objective of this function is to determine the links between different people based on their coincidence in the same interventions.

```
link <- function () {
        LINKS = matrix(0, nrow = max(DATA[,'codeIDPE']), ncol = max(DATA[,'codeIDPE']))
        iii = unique(DATA[,'IDIN'])
        for (i in iii) {
                jjj = DATA[,'codeIDPE'][which(DATA['IDIN'] == i)]
                for (j in jjj) {
                        for (jj in jjj) {
                                if (j != jj) LINKS[j,jj] = LINKS[j,jj] + 1
                        }
                }
        }
        return(LINKS)
}
LINKS = link()
```

1.2 FUNCTION “GROUP”

Function used to group people belonging to the same network.

The function “GROUP” is part of the network analysis referred in Chapter 3. The objective of this function is to group people belonging to the same network based on the links identified in a previous step of the analysis sequence.

```
groups <- function (LINKS) {
        g = list()
        p = 1:nrow(LINKS)
        j = 0
        while (sum(p) > 0) {
                k = min(p[p > 0])
                i = 0
                while(i < length(k)) {
                        i = i + 1
                        k = unique(c(k, which(LINKS[k[i],] > 0)))
                }
                if (length(k) > 1) {
                        j = j + 1
                        g[[j]] = k
                }
                p[k] = 0
        }
        return(g)
}
```

1.3 FUNCTION “find.units”

The function “find.units” is part of the analysis sequence defined for the objective classification of patterns and referred in Chapter 3. The objective of this function is to group the pixels belonging to the same unit or joint while preserving their geometrical coordinates.

```
find.units <- function (IMG, uval, tol=50, tol.x = 5, tol.y = 5) {
    unit.pxs = which(IMG == uval, arr.ind = T)
    npx = nrow(unit.pxs)
    unit.list = list()
    ui = 0   #index of the current unit
    k = 0
    ar = 0
  if (npx>0) {

    for (ipx in 1:npx) {
        rw = unit.pxs[ipx,][1]
        cl = unit.pxs[ipx,][2]
        px = IMG[rw,cl]
        if (px == uval) {          #if finds a not assigned px
            ui = ui + 1
            IMG[rw,cl] = -ui
            cat(paste('* UNIT:', ui, '\n'))
            Q = matrix(c(NA, NA, rw,cl), nrow = 2, ncol = 2)
            unit.list[[ui]] = as.matrix(c(NA, NA))
            while (length(Q) > 2) {
                rw = Q[1,2]
                cl = Q[2,2]
                Q = Q[,-2]
```

```
unit.list[[ui]] = cbind(unit.list[[ui]], c(rw,cl))
k = k + 1
if (rw > 1 ) {
        mv = rw - 1
        if (IMG[mv,cl] == uval) {
                Q = cbind(Q, c(mv, cl))         #south
                IMG[mv,cl] = -ui
        }
}
if (rw < nrow(IMG)) {
        mv = rw + 1
        if (IMG[mv,cl] == uval) {
                Q = cbind(Q, c(mv, cl))         #north
                IMG[mv,cl] = -ui
        }
}
if (cl < ncol(IMG)) {
        mv = cl + 1
        if (IMG[rw,mv] == uval) {
                Q = cbind(Q, c(rw, mv))         #east
                IMG[rw,mv] = -ui
        }
}
if (cl > 1) {
        mv = cl - 1
        if (IMG[rw,mv] == uval) {
                Q = cbind(Q, c(rw, mv))         #west
                IMG[rw,mv] = -ui
        }
```

```
                                }
                                cat(paste('\r size unit:', length(unit.list[[ui]])/2, ' =>
processed:', (k + ar), '/', npx, '(k: ', round(k/npx*100, 2),
                                        '% art:', round(ar/npx*100, 4), ')'))
                        }
                        unit.list[[ui]] = unit.list[[ui]][,-1]
                        if (
                                length(unit.list[[ui]]) <= tol ||
                                diff(range(unit.list[[ui]][1,])) <= tol.x ||
                                diff(range(unit.list[[ui]][2,])) <= tol.y
                        ) {
                                ar = ar + length(unit.list[[ui]]) / 2
                                unit.list[[ui]] = NULL
                                ui = ui - 1
                                cat('\n classified as artifact \n')
                        } else {
                                cat('\n')
                        }
                }
        }
        return(unit.list)
    } else {
        return(NULL)
    }
}
```

1.4 FUNCTION “fun_orientation”

The function “fun_orientation” is part of the analysis sequence defined for the objective classification of patterns and referred in Chapter 3. This function computes the values of the parameter defining the alignment of the units within a frame (UA).

```
fun_orientation <- function (j) {

#1. Call the cluster list already saved:

namlis = j


CL = dget(paste0(RFimgLists, '/',namlis,'.list'))

IMG = readJPEG(paste0(RFimgJpeg, '/',namlis))

if (length(dim(IMG)) > 2) IMG = IMG[,,1]

m = nrow(IMG)

n = ncol(IMG)

frm = 29          # frm = frame width

IMG = IMG[-c(1:frm, (m-frm):m),-c(1:frm, (n-frm):n)]


##2. Conditions

cutx = sapply(CL$units, function (x) (max(x[1,]) == nrow(IMG) || min(x[1,]) == 1))

cuty = sapply(CL$units, function (x) (max(x[2,]) == ncol(IMG) || min(x[2,]) == 1))

square = sapply(CL$units, function (x) abs(diff(range(x[1,])) - diff(range(x[2,]))) < 7)

toDrop = which(square & (cutx | cuty))


sizes = sapply(CL$units, ncol)

MU = sapply(CL$units, function(x)apply(x, 1, mean))

MMUU = apply(do.call(cbind, CL$units), 1, mean)


SVD = lapply(1:length(CL$units), function(i) {
```

```
        x = CL$units[[i]]
        x[1,] = x[1,] - MU[1,i]
        x[2,] = x[2,] - MU[2,i]
        svd(x)$u #* sizes[i]  #unit sizes
})

angx = sapply(SVD, function(x) apply(x, 1, function(xx) angCalc(xx, c(0,1))))
angx = apply(angx, 2, function(x)x[which.min(abs(x))])
angx[toDrop] = NA
sizes[toDrop] = NA

Ax = sum(angx*sizes, na.rm = TRUE)/sum(sizes, na.rm = TRUE)

##3. Dispersion of direction x (regular = 1)
Dx = sum(abs(cos(angx - Ax)) * sizes, na.rm = TRUE) / sum(sizes, na.rm = TRUE)

nu = length(CL$units)
ANS.units = data.frame('IMBW' = rep(imgnam, nu), 'IDunit' = 1:nu, 'angx' = angx)
ANS.frame = c('IMBW' = imgnam, 'Ax' = Ax, 'Dx' = Dx)

return(list(units = ANS.units, frame = ANS.frame))
 }
```

APPENDIX 2
DATASETS USED IN THE ANALYSIS

2.1 DATASET USED IN THE STATISTICAL ANALYSIS OF THE BUILDINGS MORPHOLOGY

LEGEND

PARAMETER	CODE	CATEGORIES
PL	1	Courtyard plan
	2	E plan
	3	F plan
	4	H plan
	5	L plan
	6	oblong
	7	Squared or rectangular towerhouse
	8	T plan
	9	U plan
	10	Vila (compact or with flanking pavilions)
	11	Z plan
PE	1	Before 17th century
	2	Between 17th and 18th century
	3	After 18th century
	4	1&2
	5	2&3
	6	1&2&3
MT	1	Ashlar
	2	Rabdom rubble
	3	Squared rubble
	4	1&2
	5	1&3
	6	2&3
LOR	1	SOUTH: The Scottish Borders; Dumfries And Galloway
	2	CENTRAL: Clackmannan; Fife; East Lothian; Midlothian; Edinburgh City; West Lothian; Falkirk; North Lanarkshire; East Dunbartonshire; West Dumbartonshire; Glasgow City; East Renfrewshire; Renfrewshire; Inverclyde; North Ayrshire; South Ayrshire; East Ayrshire; South Lanarkshire
	3	NORTH EAST: Highland; Moray; Aberdeenshire; Aberdeen City; Angus, Dundee City; Perth And Kinross; Stirling
	4	NORTH WEST: Argyll And Bute
	5	ISLANDS: Orkney Islands; Shetland Islands; Western Isles

DATASET USED IN THE STATISTICAL ANALYSIS OF THE BUILDINGS MORPHOLOGY

	BUILDING	LOR	PL	MT	AA	MS	NF	NV	T1	T2	PE
1	BIRSAY EARL'S PALACE	5	1	1	879.9	5.7	2	0	1.4	1.4	1
2	BARNES CASTLE	2	1	2	1014.6	5.7	3	3	1.1	0.85	1
3	NEWARK CASTLE	2	9	3	317.9	6.5	2	1	1.1	0.7	1
4	TOLQUHON CASTLE	3	1	2	662.4	6	2	1	0.8	1.35	1
5	BOYNE CASTLE	3	1	2	730.6	6.5	3	1	1.5	1.1	1
6	INVERUGIE CASTLE	3	1	2			4	1			1
7	INVERALLOCHY CASTLE	3	1	2	362.9	5	2	1	1.6	2.1	1
8	MAINS CASTLE	3	1	3	489.2	5.7	2	1	0.85	1.1	1
9	BALLINBREICH CASTLE	2	1	1	594.5	5.5	3		1.7	1.1	1
10	RANFURLY CASTLE	2	1	2	221.05	4.6	3	1	0.9	1.3	1
11	TOWARD CASTLE	4	1	2	374.39	5.83	4	1	1.05	1.7	1
12	SEAGATE CASTLE	2	1	3	263.61	6.18	2	1	1.1	0.7	1
13	FORSE CASTLE	3	1	3	63.59	3.5	2		2.1		1
14	GEORGE HERIOT'S HOSPITAL SCHOOL	2	1	1	1364.6	6.7	4		0.9	1.2	2
15	PINKIE HOUSE	2	1	3	526.8	5.6	3		1.2	0.95	2
16	HAYSTON HOUSE	1	1		147.96	4.25	2	1	0.8	1	2
17	CRAIG HOUSE	3	1	2	304.78	6.12	2	1	0.85	1.15	2
18	CULLEN HOUSE	3	1	3			3				2
19	CULROSS PALACE	2	1	3	561.5	5.6	2	1	0.95	0.45	2
20	KIRKWALL EARL'S PALACE	5	1	1	425.5	6.1	2	1	1.3	0.9	2
21	ROYSTON HOUSE	2	1	1	677	6.1	3	1	0.75	1.1	2
22	FORDELL CASTLE	2	1	2	140.47	5.1	3	1	0.95	1.2	2
23	CASTLE GIRNIGOE	3	1	1	1030.2	6.1	3	2	1.45	1	2
24	ALLARDICE CASTLE	3	1				2				2
25	MENSTRIE CASTLE	2	1	3			2				2
26	TORWOODLEE TOWER	1	1	2	346.76	6.1	2	1	1.25	1.25	2
27	TALLA CASTLE	3	1		399.7	6.71	3	1	0.9	0.9	2
28	THURSO CASTLE	3	1	1			2				3
29	HOLYROOD PALACE	2	1	1	4515.7	8.76	4		1.15	1.9	4
30	ARGYLL'S LODGING	3	1		529.7	5.6	2	1	1	0.75	4
31	RUTHVEN BARRACKS	3	1	2	487	5.2	3	1	0.75	0.6	4
32	MUCHALLS CASTLE	3	1		244.4	5.8	2	1	0.9	0.6	4
33	GRANT CASTLE	3	1				4				4
34	TRAQUAIR HOUSE	1	1	2	908.3	7.1	3	1	1	1.5	4

35	MONKTON HOUSE	2	1	2	357.28	5.89	3		1.05	0.85	4
36	ROWALLAN CASTLE	2	1	2	771.3	5.5	3	1	0.85	1.1	4
37	DUDHOPE CASTLE	3	5	2	537.25	7.5	4	1	0.95	0.7	4
38	MURTHLY CASTLE	3	1	4	592.69	6.8	3		1	1.7	4
39	MOUNTQUHANIE CASTLE	2	1	2	98.1	4.41	4	1	1.7		4
40	REDHOUSE CASTLE	2	1	2	179.15	5.1	5	2	1.1	0.85	4
41	BALCOMIE CASTLE	2	1	1	206.3	4.7	6	1	0.9	1.6	4
42	STOBHALL CASTLE	3	1	2	188.1	5.2	3	0	0.95	0.7	4
43	BARRA CASTLE	3	1	2	377.9	5.4	3		1.1	0.7	4
44	MEGGERNIE CASTLE	3	1				4				4
45	HAWTHORNDEN CASTLE	2	1	5					0.8	1.5	4
46	NEWARK CASTLE ST MONANCE	2	1	3	303.97	5.86	3	1	1.65	1.15	4
47	ARDBLAIR CASTLE	3	1				2				4
48	PITSLIGO CASTLE	3	1	2	948		3	1			4
49	DUNTULM CASTLE	3	1	2			4	1			4
50	LOCHWOOD TOWER	1	1	2				1			4
51	GLASGOW OLD COLLEGE HIGH STREET	2	1	1			3				5
52	LEITH HALL	3	1				3				5
53	LESLIE HOUSE	2	1								5
54	HOUSTON HOUSE	2	1		317	5.5	4	1	0.95	1.3	5
55	DRUMLANRIG CASTLE	1	1	5	1037.5	6.8	4	1	1.5	1.1	6
56	FYVIE CASTLE	3	1		775	6.7	4		1.45	0.85	6
57	DRUM CASTLE	3	1	2	771.4	6.3	2	1	1	3.45	6
58	DUNROBIN CASTLE	3	1			6.6	3	4	1.25	0.75	6
59	ETHIE CASTLE	3	1	5	669.4	7.1	3	1	0.7	1	6
60	MIDMAR CASTLE	3	1		447	5	4	1	0.95	0.8	6
61	DORNOCH BISHOPS' PALACE	3	1	3			3				6
62	AIRTH CASTLE	2	1	1			2				6
63	DUNTREATH CASTLE	3	1	1	481.69	6.1	3	1	1	0.9	6
64	CAWDOR CASTLE	3	1	3	829.2	6.6	3	3	1.2	2.4	4
65	HILLS TOWER	1	1	2	139.15	4.6	4	1	0.75	1.3	4
66	COWANE'S HOSPITAL	3	2		322.01	6.5	2		1.25	1.1	5
67	CARBERRY TOWER	2	2	2			3	2			6
68	BALLINDALLOCH CASTLE	3	2		910.41	6.1	3		0.7	1	6
69	STENHOUSE	2	3	3	192.95	5	3	1	0.9	0.75	2
70	BASSENDEAN HOUSE	1	3	3			3				5
71	CORSINDAE HOUSE	3	3				3				6

72	WESTHALL	3	3				3				6
73	GARGUNNOCK HOUSE	3	4				3				4
74	CARSLUITH CASTLE	1	5	2	85.62	4.84	3	1	1.25	1.25	1
75	GREENKNOWE CASTLE	1	5	2	93.05	4.85	4	1	1.25	1.25	1
76	MACLELLAN'S CASTLE	1	5	2	363.5	5.8	4	1	1.4	0.95	1
77	JERVISTON HOUSE OLD	2	5	3	69.97	4.9	3	1	0.9	0.75	1
78	ALDIE CASTLE	3	5		208.36	5	3	1	1.35	0.7	1
79	SORBIE TOWER	1	5	2	118.63		4	1	1.1	1.25	1
80	TORWOOD CASTLE	2	5	3			2	1			1
81	DUNSKEY CASTLE	1	5	3	255.66	5.08	3	1	1.2	1.35	1
82	BALTERSAN CASTLE	2	5	3	147.57	5.69	3	1	1.4	1.4	1
83	ELGIN_BISHOP'S HOUSE	3	5	2	146.3	5.5	3	1	1.1	0.55	1
84	DELGATIE CASTLE	3	5		115.77	4.7	4	2	2.3	0.9	1
85	BRAIKIE CASTLE	3	5	3	41.1	5.1	3	1	1.3	0.5	1
86	MUCKRACH CASTLE	3	5		93.6	5.6	3	1	1	1	1
87	BLAIRFINDY CASTLE	3	5	2	102.4	5.5	3	1	0.8	0.6	1
88	EVELICK CASTLE	3	5	3	121.4	7.4	3		1.3	1.3	1
89	OCHILTREE CASTLE	2	5	3	154.9	4.5	3	1	1	0.7	1
90	KIRKHILL CASTLE	2	5	2	114.4	5.3	3		1.1	0.55	1
91	DRUMINNOR CASTLE	3	5				4	2			1
92	HORSBURGH CASTLE	1	5	2							1
93	SEAFIELD TOWER	2	5	3	93.9	4.6	4	1	1.65	1.65	1
94	LOCHRANZA CASTLE	2	5	2	233.24	6.86	3	1	2.3	1.5	1
95	PINWHERRY CASTLE	2	5	2	82.3	4.43	3	1	1.4	1.4	1
96	GALDENOCH CASTLE	1	5	2		4.4	3	1	1.15	1.15	1
97	EVELAW TOWER	1	5	2	86.62	4.48	3	2	1.1	0.9	1
98	HILLSLAP TOWER	1	5	2	80.23	4.49	4	1	1.3	1.1	1
99	BUCKHOLM TOWER	1	5	2	80.35	5.02	3	1	1.1	1.1	1
100	CARDRONA TOWER	1	5	2	75.21	4.45	3	1	1.15	1.3	1
101	CREICH CASTLE	2	5	2			3				1
102	BLAIRLOGIE CASTLE	3	5				2		0.7	0.7	1
103	BALMANNO CASTLE	3	5		229.38	5.65	4	1	1.5	0.6	1
104	COMRIE CASTLE	3	5	2	55.82	3.86	3	1	0.8	1	1
105	PITHEAVLIS CASTLE	3	5				3				1
106	FORTER CASTLE	3	5	2	129.78	5.6	4	1	1.1	1.1	1
107	BALFLUIG CASTLE	3	5	2			3				1
108	TILLYCAIRN CASTLE	3	5		89.17	4.88	4	2			1

109	ESSLEMONT CASTLE	3	5	2	144.6	5.23	2	0	0.75	0.85	1
110	FINDOCHTY CASTLE	3	5	2			2				1
111	BRIMS CASTLE	3	5	3	45.64	4.06	3	1	0.9	0.9	1
112	DOUNREAY CASTLE	3	5	2	112.4	4.92	3	0	1.05	0.95	1
113	ARDVRECK CASTLE	3	5	2				1	1.25	1.25	1
114	ELIBANK CASTLE	1	5	2	195.65	4.52	3	2	1.15	1.15	1
115	BUITTLE PLACE	1	5								1
116	PITFICHIE CASTLE	3	5				4	1			1
117	CRAIGIEVAR CASTLE	3	5		171.5	10.5	5	2	1.6	1.2	2
118	INNES HOUSE	3	5		337.28	6.6	3		1.4	0.95	2
119	BALBITHAN HOUSE	3	5				3				2
120	PEFFERMILL HOUSE	2	5		236.7	5.1	3	1	1	0.75	2
121	NORTHFIELD HOUSE	2	5		215.6	5.3	2		1.1	0.4	2
122	AUCHANS CASTLE	2	5	2	393	5.3	3	1	0.85	1.1	2
123	BRECKNESS HOUSE	5	5	3	141.4	4.5	2		0.8	0.65	2
124	GILBERTFIELD CASTLE	2	5	3	101.8	4.7	3	1	0.85	0.35	2
125	SCALLOWAY CASTLE	5	5	3	247.8	6.9	4	1	1.5	1.1	2
126	GOGAR CASTLE	2	5		223.8	5.7	4	1	1.15	1.15	2
127	INVERESK LODGE	2	5								2
128	SCOTSTARVIT TOWER	2	5	1	84	4.8	5	2	1.9	1.9	2
129	INNERPEFFRAY CASTLE	3	5	2	227.5	6.1	3	1	1.4	0.85	2
130	LICKLEYHEAD CASTLE	3	5				3				2
131	DALCROSS CASTLE	3	5	2	205	6.1	4	1	1.2	0.7	2
132	OLD BISHOPTON	2	5	3	189.74	4.8	3	1	1	0.75	2
133	BARSCOBE HOUSE	1	5	2			2	0			2
134	FINLARIG CASTLE	3	5	2	155.29	5.26	3	1	1.55	1.2	2
135	FLEMINGTON CASTLE	3	5	2	102.63	4.8	2	1	1.1	0.75	2
136	INVERGARRY CASTLE	3	5	2	246.8	6.62	5	0	1.55	0.85	2
137	CASTLE LEOD	3	5	2	202.98	6.1	5		1.1	1.8	2
138	WOOLMET HOUSE	2	5		251.24	5.92	3	0	0.9	0.9	2
139	CASTLE KENNEDY	1	5	2	380.88	6.63	4	1	1.25	0.7	2
140	TONGUE HOUSE	3	5				3				2
141	PITTARTHIE CASTLE	2	5	2	182.56	5.96	3	1	1.15	1.2	4
142	PITFIRRANE CASTLE	2	5		371.26	6.35	4	1	1	1.25	4
143	CALDER HOUSE	2	5	3			3				4
144	FOUNTAINHALL HOUSE	2	5		318.6	5.2	3	0	0.85	0.85	4
145	GYLEN CASTLE	4	5	2	53.6	4.2	4		1.1	0.8	4

146	BALBEGNO CASTLE	3	5		209.2	5.8	3	2	2	2	4
147	KILLOCHAN CASTLE	2	5		176.9	5.7	5	1	1.4	0.9	4
148	KNOCKHALL CASTLE	3	5	2	142.15	4.9	3	1	1.2	1.4	4
149	KILHENZIE CASTLE	2	5	2			3				4
150	STAIR HOUSE	2	5	2			3	1			4
151	BARHOLM CASTLE	1	5	2	99.47	4.99	4	2	1.5	1.1	4
152	EARLSTOUN CASTLE	1	5	2	83.01	4.6	3	1	1.1	0.9	4
153	BAVELAW CASTLE	2	5		114.13	4.49	3	1	1.1	0.8	4
154	COLINTON CASTLE	2	5	3	230.24	5.5	3	1	1.35	1.05	4
155	FRENCHLAND TOWER	1	5	2	74.58	4.6	3	0	0.9	0.7	4
156	QUEEN MARY'S HOUSE ST ANDREWS	2	5	5	135.98	4.12	3	1	1.1	1.25	4
157	FERNIE CASTLE	2	5	2	272.12	6.27	4	1	0.85	1.85	4
158	OLD NEWTON HOUSE	3	5				3				4
159	PITTULIE CASTLE	3	5	2	184.62		3		0.8	0.8	4
160	CRAIG HOUSE OLD	2	5		277.76	2.3	3	1	1.65	0.8	4
161	BALLENCRIEFF HOUSE	2	5								4
162	HERDMANSTON	2	5		269.97		3				4
163	LESLIE CASTLE	3	5		223.6	5.8	3	1	1.1	0.9	5
164	MAYBOLE CASTLE	2	5		112.75	5.49	4	1	1.2	1.2	5
165	MELDRUM HOUSE	3	5	3			3	1			5
166	EASTER COATES HOUSE	2	5	4			2				5
167	HODDOM CASTLE	1	5	1			4	1			5
168	ERCHLESS CASTLE	3	5				4				5
169	CLEISH CASTLE	3	5	3	157.66	5.68	4	1	2.1	1.45	5
170	BALHOUSIE CASTLE	3	5	5	131.45	5.5	3	1	1.4	1.55	5
171	BARCALDINE CASTLE	4	5	2	189.44	5.96	3	1	1.6	0.9	5
172	HAGGS CASTLE	2	5	3	144.4	5.3	3	1	0.9	0.6	6
173	CRATHES CASTLE	3	5		193.4	5.6	4	2	1.7	0.7	6
174	REDCASTLE	3	5	2	300	5.94	3	1	1.1	1.1	6
175	ELSHIESHIELDS TOWER	1	5		63.2	4.4	3		1.2	1.7	6
176	ABERUCHILL CASTLE	3	5		123.12	4.72	5		1.3	1.3	6
177	BANNATYNE HOUSE	3	5				3				6
178	CRAIGCROOK CASTLE	2	5	3	295.79	5.64	2	1	1.2	0.75	6
179	BRANXHOLME CASTLE	1	5		632.67	4.99	3	1	0.85	1.4	6
180	GRANTON CASTLE	2	5	3	222.9	5.2	3	1	1.2	0.95	4
181	BLAIR HOUSE	2	5	3	437.11	6.1	3		1.3	0.85	2
182	COWDENKNOWES HOUSE	1	6	5	390.18	4.57	3	1	0.9	1.2	1

183	CARNASSARIE CASTLE	4	6	2	220.74	5.9	3	1	1.7	1.15	1
184	CORSBIE TOWER	1	6	6	95.9	4.57	3	1	1.5	2.05	1
185	BANNACHRA CASTLE	4	6	3	93.22	5.19	3	1	0.9	1.15	1
186	COLMSLIE TOWER	1	6	2	108.36		3				1
187	MELGUND CASTLE	3	6	2	400.14	6.45	3	1	1.1	1.25	1
188	MURROES HOUSE	3	6								1
189	UTTERSHILL CASTLE	2	6	3	143.81	5.53	1	1	1.05	1.1	1
190	BLANERNE CASTLE	1	6	3	65				0.9	0.9	1
191	CASTLE NEWE	3	6				2	1			5
192	POWRIE CASTLE	3	6	3	153.82	4.74	2	1	0.8	0.8	2
193	CALDA HOUSE	3	6		222.75		2				2
194	WILLIAMSTON HOUSE	3	6				2				2
195	OLD FAIRNILEE HOUSE	1	6	2	188	5.4	3	1	0.9	1.2	2
196	BUSBIE CASTLE	2	6	3		4.7	3		1.4	0.4	2
197	CLONBEITH CASTLE	2	6	3	79.35	5.3		1	0.8	0.3	2
198	KILLUNDINE CASTLE	3	6	2	132.13		3		0.9	0.9	2
199	KIPPS HOUSE	2	6	3	138.35	5.08	3	1	1	0.6	2
200	CONZIE CASTLE	3	6	2	172.52	5.7	3	0	0.95	0.95	2
201	MIDHOPE CASTLE	2	6	3	223.6	7.4	5	1	0.85	1.3	4
202	ABERDOUR CASTLE	2	6	3	706	5	2	1	1	1.7	4
203	GARDYNE CASTLE	3	6	3			3				4
204	FARNELL CASTLE	3	6	2	118.6	4.5	3		0.8	1.4	4
205	GREENAN CASTLE	2	6	3	84.73	5.86	4	1	1.4	1.4	4
206	PITEADIE CASTLE	2	6	3	91.95	6.1	4	1	1.8	1.8	4
207	BALLINSHOE CASTLE	3	6	3	64.2	4.74	3	0	1	1	4
208	FORDYCE CASTLE	3	6	2			3				4
209	ABBOT HOUSE	2	6	3	323.36	5.44	3	1	0.85	0.65	4
210	DOWHILL CASTLE	3	6	1	238.4	5.9	2	1	1.55	1	4
211	AIKET CASTLE	2	6		109.29	4.96	4	1	1.05	1.75	4
212	LOGIE HOUSE	3	6				3	1			5
213	MEGGINCH CASTLE	3	6	3			3				6
214	CRANSHAWS CASTLE	1	6	6	95.57	4.35	5	0	1.9	1.9	6
215	BEDLAY CASTLE	2	6		174.3	4.1	3	1	0.8	0.5	6
216	DUCHRAY CASTLE	3	6		70		3	1			6
217	MONIMAIL TOWER	2	7	2			4				1
218	BROUGHTY CASTLE	3	7	3			4	1			1
219	HALLBAR TOWER	2	7	3	56.9	4.5	4	3	1.5	1.5	1

220	LOCHHOUSE TOWER	1	7	2	98.8	4.6	3	1	1.9	1.9	1
221	REPENTANCE TOWER	1	7	3	49.7	3.8	2	1	1.7	1.7	1
222	NEWMILNS TOWER	2	7	2	59.34	4.2	3	1	1.25	1.25	1
223	CRAIGCAFFIE TOWER	1	7		57.1	4.14	4	1	1.1	0.85	1
224	EDINGHAM CASTLE	1	7	3	52.46	3.78	2	1	0.9	1.4	1
225	KIRKHOPE TOWERKIRKHOPE TOWER	1	7	2	57.5	4.27	4	1	1.8	1.8	1
226	GOLDIELANDS TOWER	1	7	2	71.02	4.52	4	1	1.35	1.35	1
227	BARNS TOWER	1	7		52.95	4.4	3	1	1.1	1.5	1
228	CASTLEHILL TOWER	1	7	2	96.31	5.4	2	2	2.05	2.05	1
229	WRAE CASTLE	1	7	2			2				1
230	FATLIPS CASTLE	1	7	2	80.64	5	4	1	1.85	1.85	1
231	CRAMOND TOWER	2	7	3	50.95	4	4	1	1.45	1.45	1
232	LAMINGTON TOWER	2	7	2	116.48	4.68	3	1	2.15	2.25	1
233	CASTLE SHUNA	4	7	2	85.84		3	1	1.1	1.1	1
234	BANDON TOWER	2	7	3	86.37	4.6	3	1	1.15	1.15	1
235	GARTH CASTLE	3	7	3	114.3		4	1	2	2	1
236	CASTLECRAIG	3	7	3			4	3			1
237	NEWBYRES CASTLE	2	7	2	85.86	4.47	3	1	1.65	1.65	1
238	COXTON TOWER	3	7		3.6	5.2	3	4	1.7	1.7	2
239	OAKWOOD TOWER	1	7	2	81.28	4.79	3	1	1.3	0.65	2
240	CORGARFF CASTLE	3	7		78	3.8	3	0	1.4	0.95	4
241	KILMAHEW CASTLE	4	7	3	106.75	5.6	4	0	1	1.2	4
242	SPEDLINS TOWER	1	7	3	162.4	5.9	4	2	2.7	2.7	4
243	SMAILHOLM TOWER	1	7	3	119	5.5	3	2	2.4	2.4	4
244	KINNAIRD HEAD CASTLE AND LIGHTHOUSE	3	7	2	111.5	3.4	2	3	1.7	1.5	4
245	INCHDREWER CASTLE	3	7	2	229.4	4.5	3		0.8	0.4	4
246	FAIRBURN TOWER	3	7	3	64	4.6	5	1	1.6	1.6	4
247	KNOCK CASTLE	3	7	3	56.2	5.1	3	1	1.3	1.3	4
248	UDNY CASTLE	3	7		52.5	6.1	4	1	1.9	2.7	4
249	TOWIE BARCLAY CASTLE	3	7		55.8	6.1	3	1	2.5	0.6	4
250	KNOCKDOLIAN CASTLE	2	7	2	81	4.8	4	1	1.7	1.7	4
251	FOURMERKLAND TOWER	1	7	3	44.66	4.1	4	1	0.9	0.9	4
252	DRYHOPE TOWER	1	7	2	35.8	2.97	4		1	1	4
253	TIMPENDEAN TOWER	1	7	3	62.64	4.69	3	2	1.3	1.3	4
254	CASTLE CARY	2	7	3	131.94	4.63	4	1	1.2	0.75	4
255	ROSSDHU CASTLEROSSDHU CASTLE	4	7	3					2.25	2.6	4
256	INVERMARK CASTLE	3	7	2	110.3	6.27	4	1	2.2	1.7	4

257	ABERGELDIE CASTLE	3	7		91		3				6
258	CAKEMUIR CASTLE	2	7	3	76.6	5.1	3	0	1.8	1.8	6
259	STRANRAER CASTLE	1	7	3	101.9	4.27	4	4	2	1.2	6
260	KELLY CASTLE	3	7	2			4				6
261	AMISFIELD TOWER	1	7	3	84.9	6.5	3	1	1.9	1.9	2
262	ILLIESTON CASTLE	2	8	3			3				1
263	QUEEN MARY'S HOUSE JEDBURGH	1	8	3	126.19	4.7	3	1	1.15	0.9	1
264	MONK CASTLE	2	8	3	90.82	3.63	3	1	0.95	0.95	1
265	KILNMAICHLIE HOUSE	3	8				2				1
266	KINKELL CASTLE	3	8				3	1			1
267	CROSBIE CASTLE	2	8	3	147	5.73	3		0.9	1.1	2
268	HALLYARDS CASTLE	2	8	3	104.39	5.24	3	1	0.95	1.1	2
269	MAINS OF HALLHEAD	3	8				3				2
270	TULLIBOLE CASTLE	3	8		173.69	5.44	4		1.3	1	4
271	KELLIE CASTLE	2	8	3	369.3	6.1	5	1	1.2	1.6	4
272	LECKIE HOUSE OLD	3	8		234.15	5.6	3	1	1.15	1	4
273	BLACKHALL	2	8	3	99.64	5.43	3	1	0.8	1.05	4
274	AIRDRIE HOUSE	2	8		171.72		2				4
275	ABOYNE CASTLE	3	8								5
276	EASTER ELCHIES	3	8				3				5
277	THIRLESTANE CASTLE	1	8	2	1488.32	6.5	4		1.65	1.65	6
278	LUFFNESS HOUSE	2	8	3	211.63	6.1	3	1	1.4	2.25	6
279	KENMURE CASTLE	1	8		368.04	6.29	3	1	1	1.2	6
280	PITKERRO HOUSE	3	8		205.54	5.37	3	1	1	1.45	6
281	CRAIGENTINNY HOUSE	2	8	2			3				6
282	KININVIE HOUSE	3	8				3				6
283	HOUSE OF SCHIVAS	3	8	2			3				6
284	MELVILLE MANSE	2	8		134.71	4.79	3	1	0.8	0.95	4
285	HUTTON CASTLE	1	9	3	309.56	5.2	3	1	0.9	1.45	1
286	STEWART CASTLE	3	9	3	343.4	7.6	3	1	1.5	0.55	2
287	BABERTON HOUSE	2	9	3	226.87	5.16	3	1	0.95	0.8	2
288	DUNTARVIE CASTLE	2	9	3	125	4.2	3	1	0.75	0.65	2
289	BARGANY HOUSE	2	9	3			2				2
290	FRASER CASTLE	3	9	2	288.6	6.5	3	1	2	2.8	4
291	BRUNSTANE HOUSE	2	9	3	586.47	5.8	4		0.6	0.9	4
292	CARESTON CASTLE	3	9		711.37	6.29	4	1	1.1	0.75	4
293	LINHOUSE	2	9		191.98	5	3	0	1.1	0.65	4

294	CESSNOCK CASTLE	2	9		300.04	6.5	4	2	0.8	0.65	4
295	WEDDERLIE HOUSE	1	9	2	277.76	5.49	3	0	1	1.4	4
296	CARSCREUGH CASTLE	1	9	2	247.55	7.78	4		0.75	0.75	4
297	BALNAKEIL HOUSE	3	9				2	1			4
298	DUNBEATH CASTLE	3	9			5.8	3	1	1.6	1.15	4
299	FRENDRAUGHT HOUSE	3	9				2				4
300	PITCULLO CASTLE	2	9				3	1			4
301	MORAY HOUSE	2	9	3	687.2	7.2	2	1	1.1	0.75	5
302	PITREAVIE CASTLE	2	9	3		5.6	3		1.05	0.7	5
303	CRAIGHALL CASTLE	2	9	3	360.8	4.8	3	1	1.3	0.85	5
304	BINNS HOUSE	2	9				3				5
305	CRAIGSTON CASTLE	3	9		252.7	4.2	5	1	0.9	0.4	5
306	BARNBOUGLE CASTLE	2	9	3			3				5
307	DALKEITH PALACE	2	9				3				6
308	AUCHTERHOUSE	3	9				3	1			6
309	ELLON CASTLE	3	9	2			4				6
310	AUCHINLECK HOUSE	2	10	1	346.62	6.35	3	0	1.15	0.5	2
311	DRUM HOUSE	2	10	5	598.6	5.9	2	1	0.9	0.9	4
312	GREENOCK MANSION HOUSE	2	10	1	585.57		3	1	1.1	1.9	4
313	CRAWFURDLAND CASTLE	2	10	1			3	1			6
314	DARLEITH HOUSE	4	10				2	1			6
315	GARRION TOWER	2	10	3			2				6
316	TORWOODLEE HOUSE	1	10	1	485.36	5.61	3		0.95	0.95	2
317	BRISBANE HOUSE	2	10		578.56	6	4		0.65	0.85	2
318	TOUCH HOUSE	3	10	1			3				4
319	METHVEN CASTLE	3	10				4				1
320	CUPAR PRESTON LODGE	2	10	5	214.27	5.96	3		1.1	0.8	2
321	HALKERSTON LODGE	2	10		174.5	5.37	3	1	0.85	0.85	2
322	WINTON HOUSE	2	10	1			3				5
323	ROBGILL TOWER	1	10	5			3	2			6
324	DROCHIL CASTLE	1	11	2	631.6	6.7	3	1	1.7	1.1	1
325	CLAYPOTTS CASTLE	3	11	2	138.5	5.1	4	1	1.3	0.4	1
326	MUNESS CASTLE	5	11	2	230.5	5.5	3	1	1.3	1	1
327	KILMARTIN CASTLE	4	11	2	130.67	5.23	3	1	0.75	1.15	1
328	TERPERSIE CASTLE	3	11		99.1	3.8	2	1	0.95	0.7	1
329	CORSE CASTLE	3	11	3	100.5	4	4	1	1	0.6	1
330	FENTON TOWER	2	11		158.8	4.8	3	1	1.2	0.9	1

331	TILQUHILLIE CASTLE	3	11		167.2	3.8	3	1	1.45	1.15	1
332	DAIRSIE CASTLE	2	11	3	201.36	6.29	3	1	1.9	1.35	1
333	HATTON CASTLE	3	11		180.82	5.19	3	1	1.15	0.9	1
334	VAYNE CASTLE	3	11	3	216.34	6.1	3	1	1.4	1.2	1
335	RAVELSTON HOUSE OLD	2	11	3							2
336	BURGIE CASTLE	3	11	2	47.6	4	6	3	1.5	1.5	2
337	HARTHILL CASTLE	3	11		184.4	5.5	4	1	0.95	1.4	2
338	BALLONE CASTLE	3	11	3	175.9	5.6	3	1	1.45	1.1	2
339	BLERVIE CASTLE	3	11	2	42.9	4.2	4	2	1.2		2
340	GLENDEVON CASTLE	3	11		219.1	5.31	3	1	1.4	1	2
341	GLASCLUNE CASTLE	3	11	2	176.3	3.78	2		0.85	0.6	2
342	HUNTLY CASTLE	3	11	2	331.9	7.4	3	2	2.6	0.9	4
343	GLENBUCHAT CASTLE	3	11	2	192.1	5.3	3	1	1.2	0.55	4
344	ELCHO CASTLE	3	11	3	287.4	5.8	3	1	1.5	0.9	4
345	NOLTLAND CASTLE	5	11	3	300.8	6.6	3	1	2	2.3	4
346	KELBURN CASTLE	2	11		421.43	5.6	4	1	0.6	1.2	4
347	MENZIES CASTLE	3	11	3	322.86	6.25	4	1	1.2	1.5	4
348	KEISS CASTLE	3	11	3	92.8	5.2	4	1	1	0.8	4
349	MONCUR CASTLE	3	11	3	221.5	5.7	2	1	1.2	1.4	4
350	EDEN CASTLE	3	11	3	142.4	6	3		1.4	0.45	4
351	NEWTON CASTLE	3	11				3	1			4
352	ASLOUN CASTLE	3	11	2			4	1			4
353	KILCOY CASTLE	3	11	2	191.5	5.5	4	1	1.4	0.6	5
354	EARLSHALL	2	11	2	241.5	5.8	3	1	1.3	0.95	6
355	GLAMIS CASTLE	3	11	1	367.8	6.7	5	2	3.3	1.1	6
356	PITCAPLE CASTLE	3	11				4	1			6
357	BRODIE CASTLE	3	11				4				6
358	KEITH HALL	3	11			4.71	4		1.4	1.1	6
359	GRANDTULLY CASTLE	3	11	3	224.3	6.3	3	1	1.5	0.7	6
360	DARGAVEL HOUSE	2	11		121.02	4.91	3		1	0.5	6
361	CORTACHY CASTLE	3	11		341.05	6.75	3	1	1.3	0.85	6
362	COLLISTON CASTLE	3	11		148.17	5.13	3	1	0.95	1.1	6
363	ARDROSS CASTLE	3		1							1
364	AITHERNIE CASTLE	2									2
365	SETON HOUSE	2		1			3				2
366	ARNAGE CASTLE	3		6			2	1			6

2.2 DATASET USED IN THE ANALYSIS OF NETWORKS AND WORK ENVIRONMENTS

DATASET USED IN THE ANALYSIS OF NETWORKS AND WORK ENVIRONMENTS

LEGEND

IDIN	Intervention identification code
INBE	Intervention start year
INFI	Intervention end year
IDBU	Building identification code
BUNA	Building Name
IDPE	Person identification code
PENA	Person name

IDIN	INBE	INFI	IDBU	BUNA	IDPE	PENA
917	1633	NA	705	ACHESON HOUSE	219	ACHESON_SIR-ARCHIBALD
649	1793	NA	538	EDINBURGH 7 YORK PLACE	41	ADAM_JAMES
365	1767	NA	109	AUCHINCRUIVE HOUSE	41	ADAM_JAMES
69	1721	1748	18	HOPETOUN HOUSE	40	ADAM_JOHN
90	1759	1763	26	PAXTON HOUSE	40	ADAM_JOHN
133	1744	1761	40	INVERARAY CASTLE	40	ADAM_JOHN
141	1747	1769	43	GEORGE FORT	40	ADAM_JOHN
144	1756	NA	45	INVERARAY TOWN	40	ADAM_JOHN
338	1753	1761	96	EDINBURGH CITY CHAMBERS	40	ADAM_JOHN
352	1754	1759	102	DUMFRIES HOUSE	40	ADAM_JOHN
485	1765	NA	226	GRANT CASTLE	40	ADAM_JOHN
562	1750	1752	212	BANFF CASTLE	40	ADAM_JOHN
564	1751	NA	214	BUCHANAN OLD HOUSE	40	ADAM_JOHN
566	1753	1755	215	ARNISTON HOUSE	40	ADAM_JOHN
567	1757	1761	216	DOUGLAS CASTLE	40	ADAM_JOHN
569	1757	NA	217	HAWKHILL HOUSE	40	ADAM_JOHN
571	1760	NA	220	BALLOCHMYLE HOUSE	40	ADAM_JOHN
573	1761	NA	221	MOFFAT HOUSE	40	ADAM_JOHN
574	1761	NA	222	WHIM HOUSE	40	ADAM_JOHN
575	1763	NA	223	KERSE HOUSE	40	ADAM_JOHN
576	1763	1765	224	MOY HOUSE	40	ADAM_JOHN
577	1764	1767	225	BANFF TOLBOOTH STEEPLE	40	ADAM_JOHN
578	1766	1771	227	BROOMHALL	40	ADAM_JOHN
580	1767	1769	229	CULLEN HOUSE	40	ADAM_JOHN
723	1766	NA	547	ABERDOUR QUARRY	40	ADAM_JOHN
675	1750	NA	338	LARGO HOUSE	40	ADAM_JOHN
741	1756	1757	519	DYSART HOT POT WYND CARMELITE MONASTERY	40	ADAM_JOHN
977	1767	NA	171	CRAIG CASTLE	40	ADAM_JOHN
655	1754	NA	350	GILLIES'S HOUSE	40	ADAM_JOHN
1121	1750	1753	490	INVERARAY ARGYLL ARMS HOTEL	40	ADAM_JOHN
1258	1750	1753	454	STUC-AN-T-SAGAIRT FARMHOUSE	40	ADAM_JOHN
1580	1761	1764	377	BUCHANAN PARISH CHURCH	40	ADAM_JOHN
949	1748	NA	385	BRAEMAR CASTLE	40	ADAM_JOHN
655	1754	NA	350	GILLIES'S HOUSE	40	ADAM_JOHN
563	1750	1756	213	TWEEDDALE HOUSE	40	ADAM_JOHN
365	1767	NA	109	AUCHINCRUIVE HOUSE	40	ADAM_JOHN
1916	1762	1763	8	DALKEITH PALACE	40	ADAM_JOHN
692	1741	1765	437	MILTON HOUSE	40	ADAM_JOHN
2301	1762	1765	14	GEORGE HERIOT'S HOSPITAL SCHOOL	40	ADAM_JOHN
8	1790	1791	3	ARCHERFIELD HOUSE	38	ADAM_ROBERT
24	1794	NA	8	DALKEITH PALACE	38	ADAM_ROBERT
69	1721	1748	18	HOPETOUN HOUSE	38	ADAM_ROBERT
91	1773	NA	26	PAXTON HOUSE	38	ADAM_ROBERT

139	1776	1782	42	CULZEAN CASTLE	38	ADAM_ROBERT
160	1790	NA	51	THIRLESTANE CASTLE	38	ADAM_ROBERT
174	1765	NA	54	DUNKELD HOUSE	38	ADAM_ROBERT
218	1789	NA	77	EDINBURGH NEW UNIVERSITY COLLEGE	38	ADAM_ROBERT
259	1784	NA	231	BLACKADDER HOUSE	38	ADAM_ROBERT
282	1792	NA	210	STOBS CASTLE	38	ADAM_ROBERT
291	1768	1769	238	WEDDERBURN CASTLE	38	ADAM_ROBERT
338	1753	1761	96	EDINBURGH CITY CHAMBERS	38	ADAM_ROBERT
340	1763	NA	97	EDINBURGH RIDING SCHOOL	38	ADAM_ROBERT
342	1792	1796	98	GLASGOW ASSEMBLY ROOMS	38	ADAM_ROBERT
345	1791	1794	99	GLASGOW TRADES HALL	38	ADAM_ROBERT
348	1792	NA	100	GLASGOW ROYAL INFIRMARY	38	ADAM_ROBERT
352	1754	1759	102	DUMFRIES HOUSE	38	ADAM_ROBERT
355	1770	1778	103	MELLERSTAIN HOUSE	38	ADAM_ROBERT
356	1789	NA	104	SETON HOUSE	38	ADAM_ROBERT
357	1789	1792	105	NEWLISTON HOUSE	38	ADAM_ROBERT
359	1782	1790	106	DALQUHARRAN CASTLE	38	ADAM_ROBERT
361	1790	NA	107	AIRTHREY CASTLE	38	ADAM_ROBERT
363	1793	NA	108	BALBARDIE HOUSE	38	ADAM_ROBERT
365	1767	NA	109	AUCHINCRUIVE HOUSE	38	ADAM_ROBERT
506	1771	NA	189	KINROSS OLD COUNTY BUILDING	38	ADAM_ROBERT
507	1773	1774	190	CALDWELL HOUSE	38	ADAM_ROBERT
509	1774	1792	191	EDINBURGH GENERAL REGISTER HOUSE	38	ADAM_ROBERT
510	1778	NA	192	EDINBURGH BOTANIC GARDENS	38	ADAM_ROBERT
513	1778	NA	193	HUME MONUMENT IN OLD CALTON BURIAL GROUND	38	ADAM_ROBERT
514	1780	NA	194	QUEENSBERRY MONUMENT IN QUEENSBURY SQUARE	38	ADAM_ROBERT
516	1780	1782	195	OXENFOORD CASTLE	38	ADAM_ROBERT
519	1782	NA	196	JERVISTON HOUSE	38	ADAM_ROBERT
520	1785	NA	197	PITFOUR CASTLE	38	ADAM_ROBERT
522	1785	1787	198	SUNNYSIDE HOUSE	38	ADAM_ROBERT
524	1787	NA	199	GLASSERTON HOUSE	38	ADAM_ROBERT
527	1787	1788	200	KIRKDALE HOUSE	38	ADAM_ROBERT
530	1788	NA	201	BARHOLM HOUSE	38	ADAM_ROBERT
532	1750	1761	162	YESTER HOUSE	38	ADAM_ROBERT
533	1789	NA	202	ALVA HOUSE	38	ADAM_ROBERT
535	1789	NA	636	ALVA HOUSE_JOHNSTONE MAUSOLEUM	38	ADAM_ROBERT
536	1790	1796	203	BELLEVILLE HOUSE	38	ADAM_ROBERT
537	1790	1792	204	DUNBAR HOUSE	38	ADAM_ROBERT
541	1790	NA	206	GLENCARSE HOUSE	38	ADAM_ROBERT
548	1790	NA	207	WESTERKIRK CHURCHYARD JOHNSTONE MAUSOLEUM	38	ADAM_ROBERT
551	1791	NA	208	WALKINSHAW HOUSE	38	ADAM_ROBERT
553	1792	NA	361	DALKEITH HOUSE_MONTAGU BRIDGE	38	ADAM_ROBERT
555	1792	1796	209	MAULDSLIE CASTLE	38	ADAM_ROBERT
558	1794	NA	211	BARNTON HOUSE	38	ADAM_ROBERT
587	1772	NA	532	ABERDEEN RECORD OFFICE	38	ADAM_ROBERT
628	1772	NA	288	BLAIR ADAM	38	ADAM_ROBERT
741	1756	1757	519	DYSART HOT POT WYND CARMELITE MONASTERY	38	ADAM_ROBERT
549	1791	1807	71	EDINBURGH 10, 11 CHARLOTTE SQUARE	38	ADAM_ROBERT
1026	1770	1771	188	EDINBURGH 8 QUEEN ST	38	ADAM_ROBERT
681	1773	NA	314	LETTERFOURIE HOUSE	38	ADAM_ROBERT
625	1755	1762	285	AUCHINLECK HOUSE	38	ADAM_ROBERT

1173	1790	1799	598	MEGGINCH CASTLE	38	ADAM_ROBERT
1911	1755	NA	42	CULZEAN CASTLE	38	ADAM_ROBERT
1914	1784	1792	42	CULZEAN CASTLE	38	ADAM_ROBERT
141	1747	1769	43	GEORGE FORT	38	ADAM_ROBERT
2145	1788	1790	162	YESTER HOUSE	38	ADAM_ROBERT
2241	1772	1777	235	FLOORS CASTLE	38	ADAM_ROBERT
2820	1790	1800	341	GOSFORD HOUSE	38	ADAM_ROBERT
15	1731	1743	5	CHATELHERAULT HUNTING LODGE	39	ADAM_WILLIAM
29	1735	1740	10	DUFF HOUSE	39	ADAM_WILLIAM
31	1730	1742	11	DUN HOUSE	39	ADAM_WILLIAM
69	1721	1748	18	HOPETOUN HOUSE	39	ADAM_WILLIAM
84	1723	1726	24	MAVISBANK HOUSE	39	ADAM_WILLIAM
102	1733	NA	30	TAYMOUTH CASTLE	39	ADAM_WILLIAM
112	1732	NA	32	GLASGOW OLD COLLEGE HIGH STREET	39	ADAM_WILLIAM
133	1744	1761	40	INVERARAY CASTLE	39	ADAM_WILLIAM
141	1747	1769	43	GEORGE FORT	39	ADAM_WILLIAM
143	1747	NA	45	INVERARAY TOWN	39	ADAM_WILLIAM
169	1735	1744	53	BRUNSTANE HOUSE	39	ADAM_WILLIAM
211	1731	1734	69	DUNDEE HIGH STREET TOWN HOUSE	39	ADAM_WILLIAM
277	1721	1726	235	FLOORS CASTLE	39	ADAM_WILLIAM
318	1730	1737	245	EDINBURGH CASTLE	39	ADAM_WILLIAM
354	1725	1738	103	MELLERSTAIN HOUSE	39	ADAM_WILLIAM
391	1733	NA	249	ABERFELDY TAY BRIDGE	39	ADAM_WILLIAM
621	1730	NA	16	HAMILTON PALACE	39	ADAM_WILLIAM
627	1733	NA	288	BLAIR ADAM	39	ADAM_WILLIAM
952	1719	NA	740	BROOMLANDS HOUSE	39	ADAM_WILLIAM
1006	1726	1734	642	DRUM HOUSE	39	ADAM_WILLIAM
2919	1728	NA	641	HADDO HOUSE	39	ADAM_WILLIAM
1151	1744	NA	310	KILKERRAN HOUSE	39	ADAM_WILLIAM
1238	1731	1732	431	ROBERT GORDON'S COLLEGE	39	ADAM_WILLIAM
1248	1740	1741	724	ROYSTON HOUSE	39	ADAM_WILLIAM
1249	1735	NA	779	SANQUHAR TOLBOOTH	39	ADAM_WILLIAM
1270	1757	1762	733	TOUCH HOUSE	39	ADAM_WILLIAM
1281	1731	1734	222	WHIM HOUSE	39	ADAM_WILLIAM
1285	1729	1748	162	YESTER HOUSE	39	ADAM_WILLIAM
1430	1726	1733	215	ARNISTON HOUSE	39	ADAM_WILLIAM
1642	1729	1732	412	HAMILTON PARISH CHURCH	39	ADAM_WILLIAM
1261	1740	NA	747	TINWALD HOUSE	39	ADAM_WILLIAM
1267	1740	NA	746	TORRANCE HOUSE	39	ADAM_WILLIAM
631	1743	1745	177	BLAIR CASTLE	39	ADAM_WILLIAM
2029	1729	NA	1331	CRAIGDARROCH HOUSE	39	ADAM_WILLIAM
709	1747	1752	169	POLLOK HOUSE	39	ADAM_WILLIAM
2202	1730	NA	1380	BALGREGGAN HOUSE	39	ADAM_WILLIAM
2208	1725	NA	1381	DALMAHOY HOUSE	39	ADAM_WILLIAM
2221	1724	NA	300	CAMMO HOUSE	39	ADAM_WILLIAM
2225	1730	NA	92	CRAIGIEHALL HOUSE	39	ADAM_WILLIAM
2227	1731	NA	745	CUMBERNAULD HOUSE	39	ADAM_WILLIAM
2238	1729	NA	742	EGLINTON CASTLE	39	ADAM_WILLIAM
2248	1735	NA	1383	HAMILTON HALL HOUSE	39	ADAM_WILLIAM
2258	1724	1725	1385	LAWERS HOUSE	39	ADAM_WILLIAM
2259	1737	1744	1385	LAWERS HOUSE	39	ADAM_WILLIAM
2277	1723	NA	1392	NEWHALL HOUSE LOTHIAN	39	ADAM_WILLIAM
2279	1735	NA	717	NIDDRIE MARISCHAL HOUSE	39	ADAM_WILLIAM
2283	1734	1736	1393	EDINBURGH ORPHANS' HOSPITAL	39	ADAM_WILLIAM
2287	1740	NA	744	PRESTON HALL HOUSE	39	ADAM_WILLIAM
2290	1738	1748	777	EDINBURGH ROYAL INFIRMARY	39	ADAM_WILLIAM

2294	1738	1741	1396	EDINBURGH WATSON HOSPITAL	39	ADAM_WILLIAM
2303	1721	1740	17	HOLYROOD PALACE	39	ADAM_WILLIAM
2417	1742	1749	213	TWEEDDALE HOUSE	39	ADAM_WILLIAM
2915	1733	NA	164	CRAIGSTON CASTLE	39	ADAM_WILLIAM
90	1759	1763	26	PAXTON HOUSE	41	ADAM_JAMES
113	1743	1745	32	GLASGOW OLD COLLEGE HIGH STREET	41	ADAM_JAMES
123	1793	1794	36	GLASGOW TRON CHURCH	41	ADAM_JAMES
291	1768	1769	238	WEDDERBURN CASTLE	41	ADAM_JAMES
342	1792	1796	98	GLASGOW ASSEMBLY ROOMS	41	ADAM_JAMES
350	1792	1794	101	ST GEORGE'S CHAPEL	41	ADAM_JAMES
507	1773	1774	190	CALDWELL HOUSE	41	ADAM_JAMES
509	1774	1792	191	EDINBURGH GENERAL REGISTER HOUSE	41	ADAM_JAMES
510	1778	NA	192	EDINBURGH BOTANIC GARDENS	41	ADAM_JAMES
513	1778	NA	193	HUME MONUMENT IN OLD CALTON BURIAL GROUND	41	ADAM_JAMES
514	1780	NA	194	QUEENSBERRY MONUMENT IN QUEENSBURY SQUARE	41	ADAM_JAMES
516	1780	1782	195	OXENFOORD CASTLE	41	ADAM_JAMES
519	1782	NA	196	JERVISTON HOUSE	41	ADAM_JAMES
520	1785	NA	197	PITFOUR CASTLE	41	ADAM_JAMES
522	1785	1787	198	SUNNYSIDE HOUSE	41	ADAM_JAMES
524	1787	NA	199	GLASSERTON HOUSE	41	ADAM_JAMES
527	1787	1788	200	KIRKDALE HOUSE	41	ADAM_JAMES
530	1788	NA	201	BARHOLM HOUSE	41	ADAM_JAMES
532	1750	1761	162	YESTER HOUSE	41	ADAM_JAMES
533	1789	NA	202	ALVA HOUSE	41	ADAM_JAMES
535	1789	NA	636	ALVA HOUSE_JOHNSTONE MAUSOLEUM	41	ADAM_JAMES
536	1790	1796	203	BELLEVILLE HOUSE	41	ADAM_JAMES
537	1790	1792	204	DUNBAR HOUSE	41	ADAM_JAMES
539	1790	NA	205	FULLARTON CASTLE_STABLES	41	ADAM_JAMES
539	1790	NA	205	FULLARTON CASTLE_STABLES	41	ADAM_JAMES
541	1790	NA	206	GLENCARSE HOUSE	41	ADAM_JAMES
548	1790	NA	207	WESTERKIRK CHURCHYARD JOHNSTONE MAUSOLEUM	41	ADAM_JAMES
551	1791	NA	208	WALKINSHAW HOUSE	41	ADAM_JAMES
553	1792	NA	361	DALKEITH HOUSE_MONTAGU BRIDGE	41	ADAM_JAMES
555	1792	1796	209	MAULDSLIE CASTLE	41	ADAM_JAMES
558	1794	NA	211	BARNTON HOUSE	41	ADAM_JAMES
580	1767	1769	229	CULLEN HOUSE	41	ADAM_JAMES
741	1756	1757	519	DYSART HOT POT WYND CARMELITE MONASTERY	41	ADAM_JAMES
1089	1753	NA	303	GUNSGREEN HOUSE	41	ADAM_JAMES
1173	1790	1799	598	MEGGINCH CASTLE	41	ADAM_JAMES
141	1747	1769	43	GEORGE FORT	41	ADAM_JAMES
345	1791	1794	99	GLASGOW TRADES HALL	41	ADAM_JAMES
352	1754	1759	102	DUMFRIES HOUSE	41	ADAM_JAMES
2171	1742	1749	1370	ST MICHAEL'S AND SOUTH CHURCH	335	AFFLECK_ALEXANDER
146	1787	NA	46	ULLAPOOL TOWN	88	AITKEN_DAVID
116	1632	NA	34	ARGYLL'S LODGING	45	ALEXANDER_SIR-ANTHONY
190	1630	1639	59	PITREAVIE CASTLE	45	ALEXANDER_SIR-ANTHONY
424	1659	NA	266	BURNTISLAND PARISH CHURCH	149	ALISON_ANDREW
741	1756	1757	519	DYSART HOT POT WYND CARMELITE MONASTERY	210	ANDERSON_GEORGE
713	1693	1696	182	RAITH HOUSE	208	ANDERSON_JOHN
1599	1716	1729	424	DURISDEER PARISH CHURCH	208	ANDERSON_JOHN

45	1628	1631	14	GEORGE HERIOT'S HOSPITAL SCHOOL	46	AYTOUN_WILLIAM
115	1640	1653	33	INNES HOUSE	46	AYTOUN_WILLIAM
1078	1625	NA	697	GOGAR CASTLE	46	AYTOUN_WILLIAM
1955	1631	1647	14	GEORGE HERIOT'S HOSPITAL SCHOOL	46	AYTOUN_WILLIAM
610	1696	1711	170	BRECHIN CASTLE	282	BACHOP_JOHN
325	1708	1714	186	STIRLING CASTLE	128	BACHOP_THOMAS
68	1699	1701	18	HOPETOUN HOUSE	47	BACHOP_TOBIAS
236	1680	1683	118	ALLOA CHURCH	47	BACHOP_TOBIAS
330	1695	1699	92	CRAIGIEHALL HOUSE	47	BACHOP_TOBIAS
74	1679	1693	20	KINROSS HOUSE	47	BACHOP_TOBIAS
186	1703	1707	58	MERTOUN HOUSE	47	BACHOP_TOBIAS
594	1672	NA	328	PANMURE HOUSE	47	BACHOP_TOBIAS
646	1707	NA	603	DUMFRIES MIDSTEEPLE	47	BACHOP_TOBIAS
354	1725	1738	103	MELLERSTAIN HOUSE	139	BAILLIE_GEORGE
1589	1775	1799	7	DAIRSIE OLD CHURCH	241	BALFOUR_ROBERT
1320	1800	1801	997	FALKLAND TOWN HALL	231	BARCLAY_THOMAS
1572	1786	1788	1149	MARKINCH ST DROSTAN'S PARISH CHURCH	231	BARCLAY_THOMAS
654	1740	NA	306	GALLOWAY HOUSE	48	BAXTER_JOHN-THE-ELDER
1092	1732	1736	641	HADDO HOUSE	48	BAXTER_JOHN-THE-ELDER
1143	1764	NA	773	KENMORE HOTEL	48	BAXTER_JOHN-THE-ELDER
1241	1774	NA	335	ROSSDHU HOUSE	48	BAXTER_JOHN-THE-ELDER
84	1723	1726	24	MAVISBANK HOUSE	48	BAXTER_JOHN-THE-ELDER
270	1791	1798	233	DUNS CASTLE	49	BAXTER_JOHN-THE-YOUNGER
1023	1790	NA	815	EDINBURGH 124 HIGH ST	49	BAXTER_JOHN-THE-YOUNGER
1056	1788	NA	534	FOCHABERS BELLIE MANSE	49	BAXTER_JOHN-THE-YOUNGER
1057	1790	NA	827	FOCHABERS TOWNHOUSE	49	BAXTER_JOHN-THE-YOUNGER
658	1769	1782	307	GORDON CASTLE	49	BAXTER_JOHN-THE-YOUNGER
1216	1788	NA	818	PETERHEAD TOLBOOTH	49	BAXTER_JOHN-THE-YOUNGER
1949	1785	1787	37	EDINBURGH TRON CHURCH	49	BAXTER_JOHN-THE-YOUNGER
1290	1777	1782	976	BALBIRNIE HOUSE	49	BAXTER_JOHN-THE-YOUNGER
1570	1773	1774	1147	KINGLASSIE PARISH CHURCH	240	BAXTER_ROBERT
749	1540	1565	687	MONIMAIL TOWER	211	BEATON_CARDINAL-DAVID
1072	1791	NA	809	GAYFIELD PLACE TENEMENT BLOCK	50	BEGG_JAMES
11	1617	1618	4	FRASER CASTLE	51	BEL_JOHN
18	1610	1626	6	CRAIGIEVAR CASTLE	51	BEL_JOHN
984	1604	1607	164	CRAIGSTON CASTLE	51	BEL_JOHN
1570	1773	1774	1147	KINGLASSIE PARISH CHURCH	239	BLACK_ROGER
2127	1774	NA	1361	KINGHORN PARISH CHURCH	239	BLACK_ROGER
839	1791	1793	128	DUNNIKIER HOUSE	217	BLANE_ROGER
1986	1790	NA	1319	DUNVEGAN CASTLE	303	BOAK_WALTER
2927	1775	NA	1681	LOGIE-BUCHAN MANSE	394	BOWMAN_JAMES
118	1625	1627	35	GLASGOW TOLBOOTH	52	BOYD_JOHN
2217	1794	NA	292	CALLY HOUSE	348	BOYD_THOMAS
1134	1722	NA	718	KELBURN CASTLE	300	BOYLE_DAVID-1ST-EARL-OF-GLASGOW
433	1567	NA	269	BRODIE CASTLE	152	BRODIE_ALEXANDER-12-BRODIE
162	1664	NA	52	CULROSS ABBEY MANSION HOUSE	93	BRUCE_ALEXANDER-2ND-EARL-OF-KINCARDINE
161	1608	NA	52	CULROSS ABBEY MANSION HOUSE	92	BRUCE_EDWARD-1ST-LORD-OF-KINLOSS
440	1597	1611	271	CULROSS PALACE	316	BRUCE_GEORGE-SIR-OF-CULROSS-AND-CARNOCK
26	1679	1690	9	DRUMLANRIG CASTLE	53	BRUCE_SIR-WILLIAM
61	1682	1713	16	HAMILTON PALACE	53	BRUCE_SIR-WILLIAM
66	1671	1678	17	HOLYROOD PALACE	53	BRUCE_SIR-WILLIAM
68	1699	1701	18	HOPETOUN HOUSE	53	BRUCE_SIR-WILLIAM

74	1679	1693	20	KINROSS HOUSE	53	BRUCE_SIR-WILLIAM
111	1632	NA	32	GLASGOW OLD COLLEGE HIGH STREET	53	BRUCE_SIR-WILLIAM
152	1668	1674	50	BALCASKIE HOUSE	53	BRUCE_SIR-WILLIAM
156	1670	1679	51	THIRLESTANE CASTLE	53	BRUCE_SIR-WILLIAM
168	1672	1674	53	BRUNSTANE HOUSE	53	BRUCE_SIR-WILLIAM
171	1679	NA	54	DUNKELD HOUSE	53	BRUCE_SIR-WILLIAM
179	1679	NA	55	MONCRIEFFE HOUSE	53	BRUCE_SIR-WILLIAM
181	1673	1674	56	LAUDER PARISH CHURCH	53	BRUCE_SIR-WILLIAM
184	1702	1707	57	AUCHINDINNY HOUSE	53	BRUCE_SIR-WILLIAM
186	1703	1707	58	MERTOUN HOUSE	53	BRUCE_SIR-WILLIAM
194	1697	1703	61	MELVILLE HOUSE	53	BRUCE_SIR-WILLIAM
233	1703	1705	85	STIRLING TOLBOOTH	53	BRUCE_SIR-WILLIAM
241	1667	1672	88	LESLIE HOUSE	53	BRUCE_SIR-WILLIAM
251	1697	1699	90	CRAIGHALL CASTLE	53	BRUCE_SIR-WILLIAM
328	1696	NA	91	HILL OF TARVIT HOUSE FORMERLY WEMYSS HALL	53	BRUCE_SIR-WILLIAM
330	1695	1699	92	CRAIGIEHALL HOUSE	53	BRUCE_SIR-WILLIAM
334	1707	1708	93	ABERCORN CHURCH HOPETOUN AISLE	53	BRUCE_SIR-WILLIAM
335	1710	NA	94	NAIRNE HOUSE	53	BRUCE_SIR-WILLIAM
337	1687	NA	95	PRESTONFIELD HOUSE	53	BRUCE_SIR-WILLIAM
590	1600	1699	645	CASSILIS HOUSE	53	BRUCE_SIR-WILLIAM
594	1672	NA	328	PANMURE HOUSE	53	BRUCE_SIR-WILLIAM
600	1698	NA	646	KINNAIRD CASTLE	53	BRUCE_SIR-WILLIAM
757	1653	NA	112	PITTARTHIE CASTLE	53	BRUCE_SIR-WILLIAM
1279	1664	NA	213	TWEEDDALE HOUSE	53	BRUCE_SIR-WILLIAM
2414	1671	1687	186	STIRLING CASTLE	53	BRUCE_SIR-WILLIAM
578	1766	1771	227	BROOMHALL	207	BRUCE_THOMAS-7TH-EARL-OF-ELGIN
33	1546	NA	12	EARLSHALL	53	BRUCE_SIR-WILLIAM
1284	1699	1715	162	YESTER HOUSE	53	BRUCE_SIR-WILLIAM
330	1695	1699	92	CRAIGIEHALL HOUSE	53	BRUCE_SIR-WILLIAM
1958	1675	NA	14	GEORGE HERIOT'S HOSPITAL SCHOOL	53	BRUCE_SIR-WILLIAM
29	1735	1740	10	DUFF HOUSE	34	BURN_JOHN
130	1781	NA	39	CAIRNESS HOUSE	54	BURN_ROBERT
1110	1785	NA	801	HERMITAGE OF BRAID	54	BURN_ROBERT
435	1645	NA	269	BRODIE CASTLE	68	BURN_WILLIAM
1695	1773	1780	1153	BARNS HOUSE	247	BURNET-OF-BARNS_JAMES
1717	1615	NA	706	EASTER COATES HOUSE	254	BYERS_JOHN
1428	1799	1801	791	ARDGOWAN HOUSE	238	CAIRNCROSS_HUGH
230	1624	NA	83	PILMUIR HOUSE	110	CAIRNS_WILLIAM
2922	1692	1703	718	KELBURN CASTLE	55	CALDWELL_THOMAS
574	1761	NA	222	WHIM HOUSE	86	CAMPBELL_ARCHIBALD-3RD-DUKE-OF-ARGYLL
2420	1737	NA	1449	ISLAY HOUSE	357	CAMPBELL_DANIEL-1ST-OF-SHAWFIELD-AND-WOODHALL
301	1746	NA	242	WILLIAM FORT	56	CAMPBELL_DUGAL
1038	1740	1742	759	EDINBURGH CASTLE_GOVERNOR'S HOUSE	56	CAMPBELL_DUGAL
1953	1746	NA	43	GEORGE FORT	56	CAMPBELL_DUGAL
2419	1680	NA	1449	ISLAY HOUSE	356	CAMPBELL_HUGH-SIR-OF-CAWDOR
225	1690	1698	79	KILCHURN CASTLE	106	CAMPBELL_JOHN
1248	1740	1741	724	ROYSTON HOUSE	354	CAMPBELL_JOHN-2ND-DUKE-OF-ARGYLL,-1ST-DUKE-OF-GREENWICH
102	1733	NA	30	TAYMOUTH CASTLE	81	CAMPBELL_JOHN-2ND-EARL-OF-BREADALBANE
103	1799	1810	30	TAYMOUTH CASTLE	82	CAMPBELL_JOHN-4TH-EARL-OF-BREADALBANE

101	1525	1575	30	TAYMOUTH CASTLE	80	CAMPBELL_SIR-COLIN
519	1782	NA	196	JERVISTON HOUSE	166	CANNISON_JAMES
555	1792	1796	209	MAULDSLIE CASTLE	181	CARMICHAEL_THOMAS-5TH-EARL-OF-HYNDFORD
600	1698	NA	646	KINNAIRD CASTLE	205	CARNEGIE_CHARLES-4TH-EARL-OF-SOUTHESK
2052	1520	NA	1344	KILMARTIN CASTLE	311	CARSWELL_JOHN
210	1740	1757	68	GLASGOW ST ANDREW'S IN THE SQUARE CHURCH	390	CATION_DAVID
2909	1735	1760	625	GLASGOW TOWN HALL TONTINE HOTEL	390	CATION_DAVID
392	1752	NA	250	INVERCAULD BRIDGE OLD	146	CAULFIELD_MAJOR-WILLIAM
645	1763	1767	491	DUDDINGSTON HOUSE	57	CHAMBERS_SIR-WILLIAM
1912	1759	NA	42	CULZEAN CASTLE	57	CHAMBERS_SIR-WILLIAM
923	1755	NA	752	ARBIGLAND HOUSE	220	CLARK-OF-ARBIGLAND_WILLIAM
1804	1707	NA	1195	SMAILHOLM HOUSE	249	CLERK-OF-KELSO_JAMES-DON
663	1765	NA	301	HAILES HOUSE	58	CLERK-OF-PENICUIK_SIR-JAMES
84	1723	1726	24	MAVISBANK HOUSE	59	CLERK-OF-PENICUIK_SIR-JOHN-2-BARONET
1241	1774	NA	335	ROSSDHU HOUSE	59	CLERK-OF-PENICUIK_SIR-JOHN-2-BARONET
1111	1734	NA	763	HERMITS AND TERMITS	261	CLIFTON_WILLIAM
1078	1625	NA	697	GOGAR CASTLE	257	COWPER_JOHN
1044	1776	NA	500	EDINBURGH OBSERVATORY HOUSE	60	CRAIG_JAMES
1337	1773	NA	1001	ST ANSREWS ST SALVATOR'S COLLEGE_CHAPEL	60	CRAIG_JAMES
1566	1773	NA	1145	ST ANDREWS ST LEONARD'S CHAPEL	60	CRAIG_JAMES
626	1775	NA	622	BAILLIE CRAIG'S HOUSE	236	CRAIG_JOHN
345	1791	1794	99	GLASGOW TRADES HALL	236	CRAIG_JOHN
2908	1732	1735	1677	GLASGOW TOWN HOSPITAL	236	CRAIG_JOHN
2909	1735	1760	625	GLASGOW TOWN HALL TONTINE HOTEL	236	CRAIG_JOHN
1192	1767	NA	751	MOSSKNOWE HOUSE	61	CRAIG-OF-ARBIGLAND_WILLIAM
1192	1767	NA	751	MOSSKNOWE HOUSE	265	CRAIK-OF-ARBIGLAND_WILLIAM
196	1686	1719	62	NEWHAILES HOUSE	400	CRIGHTON_JAMES
198	1733	1751	62	NEWHAILES HOUSE	400	CRIGHTON_JAMES
197	1717	1723	62	NEWHAILES HOUSE	400	CRIGHTON_JAMES
2172	1751	1753	1371	MOORHEAD HOSPITAL	338	CROMBIE_ALEXANDER
1136	1645	1655	309	KEMNAY HOUSE	262	CROMBIE_SIR-THOMAS
2909	1735	1760	625	GLASGOW TOWN HALL TONTINE HOTEL	387	CROSS_JAMES
210	1740	1757	68	GLASGOW ST ANDREW'S IN THE SQUARE CHURCH	387	CROSS_JAMES
148	1783	NA	48	NEW LANARK MILL VILLAGE	90	DALE_DAVID
516	1780	1782	195	OXENFOORD CASTLE	164	DALRYMPLE_SIR-JOHN
352	1754	1759	102	DUMFRIES HOUSE	138	DALRYMPLE-CRICHTON_WILLIAM-5TH-EARL-OF-DUMFRIES-&-4TH-EARL-OF-STAIR
468	1621	1630	149	BINNS HOUSE	155	DALYELL-OF-THE-BINNS_THOMAS-(TAM)
196	1686	1719	62	NEWHAILES HOUSE	399	DAVIDSON_JAMES
2627	1795	NA	1551	CLEISH SCHOOL AND SCHOOLHOUSE	378	DAVISON_THOMAS
295	1652	NA	240	PERTH CITADEL	122	DEANE_RICHARD
562	1750	1752	212	BANFF CASTLE	183	DESKFORD_LORD
337	1687	NA	95	PRESTONFIELD HOUSE	136	DICK_SIR-JAMES-BARONET-OF-PRESTONFIELD
2191	1780	NA	1377	DOLLAR PARISH SCHOOL	346	DICKSON_JAMES

567	1757	1761	216	DOUGLAS CASTLE	187	DOUGLAS_ARCHIBALD-1ST-DUKE-OF-DOUGLAS
98	1700	NA	28	QUEENSBERRY HOUSE	79	DOUGLAS_JAMES-2ND-DUKE-OF-QUEENSBERRY
931	1570	NA	399	ABERDOUR CASTLE	212	DOUGLAS_JAMES-4TH-EARL-OF-MORTON
7	1744	NA	3	ARCHERFIELD HOUSE	37	DOUGLAS_JOHN
581	1737	1738	282	ABERCAIRNY	37	DOUGLAS_JOHN
1053	1764	NA	396	FINLAYSTONE HOUSE	37	DOUGLAS_JOHN
654	1740	NA	306	GALLOWAY HOUSE	37	DOUGLAS_JOHN
1194	1753	NA	515	MURRAYFIELD HOUSE	37	DOUGLAS_JOHN
1574	1743	1752	376	AMULREE CHURCH OF SCOTLAND AND CHURCHYARD	37	DOUGLAS_JOHN
630	1736	NA	177	BLAIR CASTLE	37	DOUGLAS_JOHN
632	1747	1758	177	BLAIR CASTLE	37	DOUGLAS_JOHN
2621	1735	1738	699	MURTHLY CASTLE	37	DOUGLAS_JOHN
2415	1755	NA	17	HOLYROOD PALACE	37	DOUGLAS_JOHN
723	1766	NA	547	ABERDOUR QUARRY	206	DOUGLAS_SHOLTO-15TH-EARL-OF-MORTON
26	1679	1690	9	DRUMLANRIG CASTLE	31	DOUGLAS_WILLIAM-1ST-DUKE-OF-QUEENSBERRY
27	1696	1698	9	DRUMLANRIG CASTLE	31	DOUGLAS_WILLIAM-1ST-DUKE-OF-QUEENSBERRY
618	1618	NA	9	DRUMLANRIG CASTLE	203	DOUGLAS_WILLIAM-1ST-EARL-OF-QUEENSBERRY
773	1635	NA	399	ABERDOUR CASTLE	213	DOUGLAS_WILLIAM-7TH-EARL-OF-MORTON
87	1623	NA	25	MORAY HOUSE	78	DOWAGER_MARY-COUNTESS-OF-HOME
210	1740	1757	68	GLASGOW ST ANDREW'S IN THE SQUARE CHURCH	62	DREGHORN_ALLAN
709	1747	1752	169	POLLOK HOUSE	62	DREGHORN_ALLAN
2908	1732	1735	1677	GLASGOW TOWN HOSPITAL	62	DREGHORN_ALLAN
2909	1735	1760	625	GLASGOW TOWN HALL TONTINE HOTEL	62	DREGHORN_ALLAN
2911	1752	NA	1679	DREGHORN HOUSE	62	DREGHORN_ALLAN
2038	1610	NA	1337	INNERPEFFRAY CASTLE	309	DRUMMOND-1ST-LORD-MADDERTY_JAMES
2174	1754	NA	1372	ST MUNGO OLD PARISH CHURCH	340	DRYDEN_WALTER
29	1735	1740	10	DUFF HOUSE	32	DUFF_WILLIAM
1177	1786	1791	787	MELVILLE CASTLE	227	DUNDAS_HENRY-VISCOUNT-MELVILLE
566	1753	1755	215	ARNISTON HOUSE	186	DUNDAS_ROBERT-LORD-ARNISTON
1430	1726	1733	215	ARNISTON HOUSE	321	DUNDAS_ROBERT-LORD-ARNISTON
575	1763	NA	223	KERSE HOUSE	191	DUNDAS_SIR-LAWRENCE
317	1708	1713	245	EDINBURGH CASTLE	125	DURY_CAPTAIN-THEODORE
325	1708	1714	186	STIRLING CASTLE	125	DURY_CAPTAIN-THEODORE
1036	1708	NA	974	EDINBURGH CASTLE_OLD BARRACKS	125	DURY_CAPTAIN-THEODORE
494	1636	NA	157	PEFFERMILL HOUSE	267	EDGAR_EDWARD
68	1699	1701	18	HOPETOUN HOUSE	63	EDWARD_ALEXANDER
600	1698	NA	646	KINNAIRD CASTLE	63	EDWARD_ALEXANDER
74	1679	1693	20	KINROSS HOUSE	63	EDWARD_ALEXANDER
194	1697	1703	61	MELVILLE HOUSE	63	EDWARD_ALEXANDER
603	1690	1700	328	PANMURE HOUSE	63	EDWARD_ALEXANDER
61	1682	1713	16	HAMILTON PALACE	63	EDWARD_ALEXANDER
610	1696	1711	170	BRECHIN CASTLE	63	EDWARD_ALEXANDER
31	1730	1742	11	DUN HOUSE	293	ERSKINE_DAVID-LORD-DUN
473	1633	NA	616	AUCHTERHOUSE	156	ERSKINE_JAMES-7TH-EARL-OF-BUCHAN

4	1690	1699	2	ALLOA HOUSE	36	ERSKINE_JOHN-11TH-EARL-OF-MAR
31	1730	1742	11	DUN HOUSE	36	ERSKINE_JOHN-11TH-EARL-OF-MAR
607	1680	NA	650	GALLERY HOUSE	196	FALCONER_SIR-JOHN
1599	1716	1729	424	DURISDEER PARISH CHURCH	339	FARR_JOHN
1412	1794	1797	1046	MONIMAIL PARISH CHURCH	237	FAULKNER_THOMAS
338	1753	1761	96	EDINBURGH CITY CHAMBERS	137	FERGUS_JOHN
2029	1729	NA	1331	CRAIGDARROCH HOUSE	307	FERGUSON-OF-CRAIGDARROCH_ALEXANDER
1284	1699	1715	162	YESTER HOUSE	328	FINLAYSON_GEORGE
169	1735	1744	53	BRUNSTANE HOUSE	96	FLETCHER_ANDREW-LORD-MILTON
18	1610	1626	6	CRAIGIEVAR CASTLE	27	FORBES_WILLIAM
1002	1600	1799	150	DOWER HOUSE	222	FORRESTER_JAMES
1607	1782	1784	803	EDINBURGH ST ANDREW'S AND ST GEORGE'S CHURCH	64	FRAZER_MAJOR-ANDREW
582	1755	1756	282	ABERCAIRNY	65	FREEBAIRN_CHARLES
1321	1539	1541	998	ST ANDREWS ST MARY'S COLLEGE	232	FRENCH_THOMAS
79	1534	1536	21	LINLITHGOW PALACE	76	FRENSSH_THOMAS
539	1790	NA	205	FULLARTON CASTLE_STABLES	176	FULLARTON_WILLIAM
2133	1744	1745	1362	ANTIBURGHER CHURCH (FIFE)	324	GARDNER_JAMES
1324	1764	1767	999	ST ANDREWS UNIVERSITY LIBRARY	233	GARDNER_JOHN
2133	1744	1745	1362	ANTIBURGHER CHURCH (FIFE)	323	GARDNER_WILLIAM
713	1693	1696	182	RAITH HOUSE	209	GAVINLOCK_ALEXANDER
1825	1741	1755	782	ABERDEEN ST NICHOLAS CHURCH	42	GIBBS_JAMES
2205	1723	NA	732	BALVENIE HOUSE	42	GIBBS_JAMES
689	1750	1754	319	MARCHMONT HOUSE	66	GIBSON_THOMAS
45	1628	1631	14	GEORGE HERIOT'S HOSPITAL SCHOOL	349	GILBERT_JAMES
258	1782	NA	231	BLACKADDER HOUSE	113	GILKIE_ALEXANDER
439	1617	1620	270	GLADSTONE'S LAND	255	GLADSTONE_THOMAS
613	1617	NA	654	HOLYROOD PALACE_CHAPEL ROYAL	200	GOODRICH_MATTHEW
131	1791	1797	39	CAIRNESS HOUSE	84	GORDON_CHARLES-7TH-EARL-OF-BUTHLAW
73	1550	1606	19	HUNTLY CASTLE	73	GORDON_GEORGE-4TH-EARL-OF-HUNTLY
73	1550	1606	19	HUNTLY CASTLE	198	GORDON_GEORGE-6TH-EARL-OF-HUNTLY
428	1616	NA	267	GORDONSTOUN HOUSE	256	GORDON_GEROGE-1ST-MARQUESS-OF-HUNTLY
971	1763	1769	452	COLDRACH	221	GOWAN_ALEXANDER
1258	1750	1753	454	STUC-AN-T-SAGAIRT FARMHOUSE	221	GOWAN_ALEXANDER
1580	1761	1764	377	BUCHANAN PARISH CHURCH	221	GOWAN_ALEXANDER
292	1770	1775	238	WEDDERBURN CASTLE	67	GRAHAM_JAMES-GILLESPIE
564	1751	NA	214	BUCHANAN OLD HOUSE	185	GRAHAM_WILLIAM-2ND-DUKE-OF-MONTROSE
576	1763	1765	224	MOY HOUSE	192	GRANT_JAMES
485	1765	NA	226	GRANT CASTLE	192	GRANT_JAMES
234	1785	NA	85	STIRLING TOLBOOTH	299	GRAY_GIDEON
1270	1757	1762	733	TOUCH HOUSE	299	GRAY_GIDEON
1153	1622	NA	856	LADY STAIR'S CLOSE	263	GRAY-OF-PITTENDRUM_SIR-WALTER
361	1790	NA	107	AIRTHREY CASTLE	143	HALDANE_ROBERT
753	1675	1699	181	PITFIRRANE CASTLE	268	HALKETT_SIR-CHARLES
2169	1770	NA	1369	INCH OLD PARISH CHURCH	334	HALL_THOMAS
852	1608	NA	130	TULLIBOLE CASTLE	218	HALLIDAY_JOHN

15	1731	1743	5	CHATELHERAULT HUNTING LODGE	28	HAMILTON_JAMES-5TH-DUKE-OF-HAMILTON
621	1730	NA	16	HAMILTON PALACE	28	HAMILTON_JAMES-5TH-DUKE-OF-HAMILTON
152	1668	1674	50	BALCASKIE HOUSE	94	HAMILTON_JOHN
1955	1631	1647	14	GEORGE HERIOT'S HOSPITAL SCHOOL	355	HAMILTON_JOHN
943	1680	NA	725	BARGANY HOUSE	276	HAMILTON_JOHN-2ND-LORD-OF-BARGANY
419	1628	NA	159	HAMILTON HOUSE	147	HAMILTON_SIR-JOHN-LORD-MAGDALENS
61	1682	1713	16	HAMILTON PALACE	71	HAMILTON_WILLIAM-3RD-DUKE-OF-HAMILTON
776	1632	NA	867	BLAIR CASTLE (CULROSS)	214	HAMILTON-OF-BLAIR_JOHN
79	1534	1536	21	LINLITHGOW PALACE	77	HAMILTON-OF-FINNART_SIR-JAMES
355	1770	1778	103	MELLERSTAIN HOUSE	140	HAMILTON-BAILLIE_GEORGE
2171	1742	1749	1370	ST MICHAEL'S AND SOUTH CHURCH	337	HANNA_WILLIAM
2161	1789	1790	1366	ANNAN OLD PARISH CHURCH	331	HANNAH_JOHN
2053	1550	NA	1345	SORBIE TOWER	312	HANNAY_FAMILY
527	1787	1788	200	KIRKDALE HOUSE	170	HANNAY_SIR-SAMUEL
579	1796	NA	227	BROOMHALL	1	HARRISON_THOMAS
1296	1785	NA	977	TORRIE HOUSE	1	HARRISON_THOMAS
1866	1687	NA	213	TWEEDDALE HOUSE	270	HARRWAY_JOHN
1008	1672	1675	660	DUDHOPE CASTLE	292	HATTON_CHARLES-MAITLAND-LORD
532	1750	1761	162	YESTER HOUSE	172	HAY_GEORGE-7TH-MARQUESS-OF-TWEEDDALE
2145	1788	1790	162	YESTER HOUSE	172	HAY_GEORGE-7TH-MARQUESS-OF-TWEEDDALE
2145	1788	1790	162	YESTER HOUSE	329	HAY_JOHN
2022	1665	1686	1328	NEIDPATH CASTLE	305	HAY_JOHN-1ST-MARQUESS-&-2ND-EARL-OF-TWEEDDALE
1865	1671	1674	213	TWEEDDALE HOUSE	305	HAY_JOHN-1ST-MARQUESS-&-2ND-EARL-OF-TWEEDDALE
269	1698	NA	233	DUNS CASTLE	305	HAY_JOHN-1ST-MARQUESS-&-2ND-EARL-OF-TWEEDDALE
1866	1687	NA	213	TWEEDDALE HOUSE	305	HAY_JOHN-1ST-MARQUESS-&-2ND-EARL-OF-TWEEDDALE
563	1750	1756	213	TWEEDDALE HOUSE	184	HAY_JOHN-4TH-MARQUESS-OF-TWEEDDALE
2144	1715	1728	162	YESTER HOUSE	184	HAY_JOHN-4TH-MARQUESS-OF-TWEEDDALE
270	1791	1798	233	DUNS CASTLE	114	HAY_ROBERT
479	1625	NA	628	MONKTON HOUSE	158	HAY_SIR-ALEXANDER
1123	1774	NA	811	INVERLEITH HOUSE	2	HENDERSON_DAVID
1030	1784	1787	814	EDINBURGH ASSEMBLY ROOMS	3	HENDERSON_JOHN
1351	1661	1671	1008	INVERKEITHING FORDELL'S LODGING	234	HENDERSON_JOHN-5TH-BARONETT-OF-FORDELL
2046	1580	NA	1340	FORDELL CASTLE	310	HENDERSON-OF-FORDELL_JAMES
45	1628	1631	14	GEORGE HERIOT'S HOSPITAL SCHOOL	70	HERIOT_GEORGE
357	1789	1792	105	NEWLISTON HOUSE	142	HOG_THOMAS
1865	1671	1674	213	TWEEDDALE HOUSE	269	HOOMS_GEORGE
426	1789	NA	266	BURNTISLAND PARISH CHURCH	151	HOPE_ALEXANDER
69	1721	1748	18	HOPETOUN HOUSE	72	HOPE_CHARLES-1ST-EARL-OF-HOPETOUN
2551	1786	1788	1531	YETHOLM THE MANSE	363	HOPE_JAMES
573	1761	NA	221	MOFFAT HOUSE	190	HOPE_JOHN-2ND-EARL-OF-HOPETOUN
68	1699	1701	18	HOPETOUN HOUSE	195	HOPE_LADY-MARGARET

292	1770	1775	238	WEDDERBURN CASTLE	121	HOUSE_WILLIAM
793	1798	1800	881	ERSKINE AND ST ANDREWS PARISH CHURCH	215	HOUSTON_JOHN
1367	1727	NA	386	CESSNOCK CASTLE	285	HUME-CAMPBELL_ALEXANDER-2ND-EARL-OF-MARCHMONT
1634	1750	1751	620	GLASGOW ST ANDREWS BY THE GREEN CHURCH	244	HUNTER_ANDREW
1645	1732	1740	422	KILMARNOCK OLD HIGH KIRK AND KIRKYARD WITH SOULIS MONUMENT	343	HUNTER_ROBERT
541	1790	NA	206	GLENCARSE HOUSE	177	HUNTER_THOMAS
522	1785	1787	198	SUNNYSIDE HOUSE	168	INGLIS_PATRICK
184	1702	1707	57	AUCHINDINNY HOUSE	98	INGLIS-OF-LANGBYRES_JOHN
226	1644	NA	80	COXTON TOWER	107	INNES_ALEXANDER
115	1640	1653	33	INNES HOUSE	296	INNES_SIR-ROBERT-1ST-BARONET-OF-INNES
488	1615	1621	139	DRUM CASTLE	161	IRVINE_ALEXANDER-9TH-LAIRD-OF-DRUM
1573	1788	NA	1150	ABERDEEN 110 HIGH ST	4	JAFFRAY_GEORGE
345	1791	1794	99	GLASGOW TRADES HALL	358	JAFFRAY_JAMES
29	1735	1740	10	DUFF HOUSE	33	JAMIESON_GEORGE
383	1719	1723	247	BERNERA BARRACKS	145	JELFE_ANDREW
394	1718	1719	252	INVERSNAID BARRACKS SOUTH BLOCK	145	JELFE_ANDREW
2133	1744	1745	1362	ANTIBURGHER CHURCH (FIFE)	325	JELLSON_JOHN
533	1789	NA	202	ALVA HOUSE	173	JOHNSTONE_JOHN
535	1789	NA	636	ALVA HOUSE_JOHNSTONE MAUSOLEUM	173	JOHNSTONE_JOHN
548	1790	NA	207	WESTERKIRK CHURCHYARD JOHNSTONE MAUSOLEUM	178	JOHNSTONE_SIR-JAMES
330	1695	1699	92	CRAIGIEHALL HOUSE	104	JOHNSTONE_WILLIAM-2ND-EARL-&-1ST-MARQUESS-OF-ANNANDALE
1607	1782	1784	803	EDINBURGH ST ANDREW'S AND ST GEORGE'S CHURCH	386	KAY_DAVID
1290	1777	1782	976	BALBIRNIE HOUSE	326	KAY_JAMES
139	1776	1782	42	CULZEAN CASTLE	85	KENNEDY_DAVID-10TH-EARL-OF-CASSILIS
1168	1600	1625	168	MAYBOLE CASTLE	264	KENNEDY_JOHN-6TH-EARL-OF-CASSILIS
1911	1755	NA	42	CULZEAN CASTLE	286	KENNEDY_THOMAS-9TH-EARL-OF
1912	1759	NA	42	CULZEAN CASTLE	286	KENNEDY_THOMAS-9TH-EARL-OF
198	1733	1751	62	NEWHAILES HOUSE	398	KENT_WILLIAM
2547	1784	NA	1530	LINTON PARISH CHURCH	362	KER_ANDREW
277	1721	1726	235	FLOORS CASTLE	115	KER_JOHN-1ST-DUKE-OF-ROXBURGHE
326	1594	NA	186	STIRLING CASTLE	75	KING_JAMES-VI-&-I
1930	1615	NA	245	EDINBURGH CASTLE	75	KING_JAMES-VI-&-I
2093	1501	1505	17	HOLYROOD PALACE	74	KING-OF-SCOTLAND_JAMES-IV
323	1530	1555	186	STIRLING CASTLE	131	KING-OF-SCOTLAND_JAMES-V
65	1528	1532	17	HOLYROOD PALACE	131	KING-OF-SCOTLAND_JAMES-V
2166	1732	NA	1368	GLASSERTON PARISH CHURCH	333	LAHWOOR_WILLIAM
2555	1771	1773	1532	KELSO OLD PARISH CHURCH	364	LAIDLAW_JOHN
2558	1757	1759	1533	MOREBATTLE PARISH CHURCH	364	LAIDLAW_JOHN
839	1791	1793	128	DUNNIKIER HOUSE	216	LAING_ALEXANDER
612	1795	1797	170	BRECHIN CASTLE	216	LAING_ALEXANDER
2209	1787	NA	1381	DALMAHOY HOUSE	216	LAING_ALEXANDER
1278	1595	1605	213	TWEEDDALE HOUSE	306	LAING_JOHN
2025	1600	1625	1329	REDHOUSE CASTLE	306	LAING_JOHN
1277	1576	NA	213	TWEEDDALE HOUSE	304	LAING_NEIL

584	1767	1789	605	ABERDEEN 35, 37, 37A MARISCHAL STREET	5	LAW_WILLIAM
586	1767	1789	606	ABERDEEN 49, 51, 53 MARISCHAL STREET	5	LAW_WILLIAM
210	1740	1757	68	GLASGOW ST ANDREW'S IN THE SQUARE CHURCH	391	LAWSON_GAVIN
2909	1735	1760	625	GLASGOW TOWN HALL TONTINE HOTEL	388	LAWSON_JOHN
1767	1791	1794	1190	NETHERURD HOUSE	248	LAWSON-OF-CAIRNMUIR_WILLIAM
11	1617	1618	4	FRASER CASTLE	26	LEIPER_JAMES
10	1576	NA	4	FRASER CASTLE	25	LEIPER_THOMAS
928	1550	NA	136	ARNAGE CASTLE	25	LEIPER_THOMAS
1242	1800	1825	335	ROSSDHU HOUSE	229	LEIPER_WILLIAM
1657	1774	NA	404	LANARK ST NICHOLAS CHURCH	229	LEIPER_WILLIAM
227	1645	1655	82	LEITH HALL	108	LEITH_JAMES
229	1797	NA	82	LEITH HALL	109	LEITH-HAY_GENERAL-A.
244	1765	1767	88	LESLIE HOUSE	112	LESLIE_JOHN-11TH-EARL-OF-ROTHES
241	1667	1672	88	LESLIE HOUSE	102	LESLIE_JOHN-7TH-EARL-&-1ST-DUKE-OF-ROTHES
2182	1685	1687	1374	LEIGHTON LIBRARY	344	LIGHTMAKER_EDWARD
193	1620	1623	60	CARESTON CASTLE	100	LINDSAY-OF-KINFAUNS_SIR-HENRY
233	1703	1705	85	STIRLING TOLBOOTH	235	LIVINGSTONE_HARRY
1898	1763	NA	287	BALNAGOWN CASTLE	281	LOCKHART-ROSS_SIR-JOHN
1246	1585	NA	724	ROYSTON HOUSE	353	LOGANS_ANDREW
625	1755	1762	285	AUCHINLECK HOUSE	273	LORD-AUCHINLECK_ALEXANDER-BOSWELL
551	1791	NA	208	WALKINSHAW HOUSE	179	MACDOWALL_D
563	1750	1756	213	TWEEDDALE HOUSE	271	MACK_CHARLES
300	1690	NA	242	WILLIAM FORT	124	MACKAY-OF-SCOURIE_MAJOR-GENERAL-HUGH
41	1595	1605	13	FYVIE CASTLE	69	MACKENZIE_A.-MARSHALL
356	1789	NA	104	SETON HOUSE	141	MACKENZIE_ALEXANDER
1247	1683	1696	724	ROYSTON HOUSE	352	MACKENZIE_SIR-GEORGE-1ST-EARL-OF-CROMARTIE,-2ND-BARONET-FROM-1654-TO-1685-AND-VISCOUNT-OF-TARBAT-FROM-1685-TO-1703
1986	1790	NA	1319	DUNVEGAN CASTLE	302	MACLEOD_NORMAN-'THE-GENERAL'-23RD-CHIEF-OF-MACLEOD-CLAN
1983	1623	NA	1319	DUNVEGAN CASTLE	301	MACLEOD_SIR-RODERICK-15TH-CHIEF-OF-MACLEOD-CLAN
536	1790	1796	203	BELLEVILLE HOUSE	174	MACPHERSON_JAMES
2596	1799	NA	1545	ARDGAY PARISH CHURCH	174	MACPHERSON_JAMES
2415	1755	NA	17	HOLYROOD PALACE	174	MACPHERSON_JAMES
236	1680	1683	118	ALLOA CHURCH	111	MAINE_PAT
1091	1600	1699	858	HADDINGTON HOUSE	259	MAITLAND_ALEXANDER
537	1790	1792	204	DUNBAR HOUSE	175	MAITLAND_JAMES-8TH-EARL-OF-LAUDERDALE
167	1639	NA	53	BRUNSTANE HOUSE	95	MAITLAND_JOHN-1ST-DUKE-OF-LAUDERDALE
181	1673	1674	56	LAUDER PARISH CHURCH	95	MAITLAND_JOHN-1ST-DUKE-OF-LAUDERDALE
156	1670	1679	51	THIRLESTANE CASTLE	95	MAITLAND_JOHN-1ST-DUKE-OF-LAUDERDALE
363	1793	NA	108	BALBARDIE HOUSE	144	MARJORIBANKS_ALEXANDER
334	1707	1708	93	ABERCORN CHURCH HOPETOUN AISLE	134	MATHER_DAVID
611	1688	1691	170	BRECHIN CASTLE	204	MAULE_JAMES-4TH-EARL-OF-PANMURE

610	1696	1711	170	BRECHIN CASTLE	204	MAULE_JAMES-4TH-EARL-OF-PANMURE
530	1788	NA	201	BARHOLM HOUSE	171	MCCULLOCH_JOHN
3088	1574	NA	17	HOLYROOD PALACE	397	MCDOWGALL_WILLIAME
1968	1777	NA	1316	LANARK TOLBOOTH	298	MCGHIE_THOMAS
31	1730	1742	11	DUN HOUSE	6	MCGILL_ALEXANDER
335	1710	NA	94	NAIRNE HOUSE	6	MCGILL_ALEXANDER
737	1719	NA	499	DONIBRISTLE HOUSE	6	MCGILL_ALEXANDER
739	1729	1731	407	DONIBRISTLE HOUSE_CHAPEL FAMILY VAULTS	6	MCGILL_ALEXANDER
1087	1714	1716	739	GRAY (HOUSE OF)	6	MCGILL_ALEXANDER
718	1700	1799	336	STRATHLEVEN HOUSE	6	MCGILL_ALEXANDER
1284	1699	1715	162	YESTER HOUSE	6	MCGILL_ALEXANDER
1605	1722	NA	673	EDINBURGH GREYFRIARS CHURCH	6	MCGILL_ALEXANDER
1665	1727	NA	156	NEWBATTLE PARISH CHURCH	6	MCGILL_ALEXANDER
997	1700	1725	229	CULLEN HOUSE	6	MCGILL_ALEXANDER
2213	1715	NA	289	BLAIR DRUMMOND OLD HOUSE	6	MCGILL_ALEXANDER
2627	1795	NA	1551	CLEISH SCHOOL AND SCHOOLHOUSE	379	MCKILLOP_EDWARD
181	1673	1674	56	LAUDER PARISH CHURCH	366	MEIN_ALEXANDER
2563	1638	1639	678	NEWARK CASTLE	365	MEIN_ANDREW
194	1697	1703	61	MELVILLE HOUSE	101	MELVILLE_GEORGE-1ST-EARL-OF-MELVILLE
2576	1765	NA	1539	ARDGOUR HOUSE	368	MENELAWS_JOHN
74	1679	1693	20	KINROSS HOUSE	197	MERCER_JAMES
2016	1557	NA	1326	STIRLING CASTLE_THE KING'S OLD BUILDINGS	347	MERLIOUN_WALTER
2581	1739	NA	1540	CROMARTY EAST PARISH CHURCH	369	MITCHELL_ALEXANDER
873	1791	1800	744	PRESTON HALL HOUSE	228	MITCHELL_ROBERT
299	1654	NA	242	WILLIAM FORT	123	MONK_GENERAL-GEORGE
305	1656	NA	243	LEITH CITADEL	123	MONK_GENERAL-GEORGE
2176	1628	1629	670	PORTPATRICK CHURCH	342	MONTGOMERY_ROBERT
68	1699	1701	18	HOPETOUN HOUSE	194	MORGAN_WILLIAM
22	1702	1711	8	DALKEITH PALACE	194	MORGAN_WILLIAM
61	1682	1713	16	HAMILTON PALACE	194	MORGAN_WILLIAM
620	1680	NA	654	HOLYROOD PALACE_CHAPEL ROYAL	194	MORGAN_WILLIAM
22	1702	1711	8	DALKEITH PALACE	194	MORGAN_WILLIAM
2632	1764	NA	1553	ANTIBURGHER CHURCH (PERTH AND KINROSS)	383	MORISON_JAMES
2632	1764	NA	1553	ANTIBURGHER CHURCH (PERTH AND KINROSS)	382	MORISON_ROBERT
133	1744	1761	40	INVERARAY CASTLE	7	MORRIS_ROGER
173	1753	NA	54	DUNKELD HOUSE	7	MORRIS_ROGER
2031	1760	NA	1332	RAMMERSCALES HOUSE	308	MOUNSEY_JAMES
507	1773	1774	190	CALDWELL HOUSE	163	MURE_WILLIAM
491	1605	NA	631	SCONE PALACE	162	MURRAY_DAVID-1ST-VISCOUNT-OF-STORMON
630	1736	NA	177	BLAIR CASTLE	277	MURRAY_JAMES-2ND-DUKE-OF-ATHOLL
631	1743	1745	177	BLAIR CASTLE	277	MURRAY_JAMES-2ND-DUKE-OF-ATHOLL
171	1679	NA	54	DUNKELD HOUSE	103	MURRAY_JOHN-2ND-EARL-&-1ST-MARQUESS-OF-ATHOLL
629	1629	1650	177	BLAIR CASTLE	103	MURRAY_JOHN-2ND-EARL-&-1ST-MARQUESS-OF-ATHOLL
1437	1708	NA	1057	BOWHILL HOUSE	278	MURRAY_JOHN-LORD-OF-BOWHILL

45	1628	1631	14	GEORGE HERIOT'S HOSPITAL SCHOOL	8	MURRAY_SIR-JAMES
87	1623	NA	25	MORAY HOUSE	8	MURRAY_SIR-JAMES
109	1620	1628	31	WINTON HOUSE	8	MURRAY_SIR-JAMES
190	1630	1639	59	PITREAVIE CASTLE	8	MURRAY_SIR-JAMES
199	1631	1640	63	EDINBURGH PARLIAMENT HOUSE	8	MURRAY_SIR-JAMES
455	1615	1617	281	EDINBURGH CASTLE_PALACE	8	MURRAY_SIR-JAMES
460	1630	NA	277	HOLYROOD ABBEY	8	MURRAY_SIR-JAMES
462	1622	1623	278	BABERTON HOUSE	8	MURRAY_SIR-JAMES
468	1621	1630	149	BINNS HOUSE	8	MURRAY_SIR-JAMES
161	1608	NA	52	CULROSS ABBEY MANSION HOUSE	8	MURRAY_SIR-JAMES
479	1625	NA	628	MONKTON HOUSE	8	MURRAY_SIR-JAMES
687	1635	NA	317	MALLENY HOUSE	8	MURRAY_SIR-JAMES
1919	1600	1675	113	DUMBARTON CASTLE	8	MURRAY_SIR-JAMES
1930	1615	NA	245	EDINBURGH CASTLE	8	MURRAY_SIR-JAMES
335	1710	NA	94	NAIRNE HOUSE	135	MURRAY_WILLIAM-2ND-LORD-OF-NAIRN
365	1767	NA	109	AUCHINCRUIVE HOUSE	272	MURRAY-OF-BROUGHTON_JAMES
1258	1750	1753	454	STUC-AN-T-SAGAIRT FARMHOUSE	230	MUSHET_JAMES
199	1631	1640	63	EDINBURGH PARLIAMENT HOUSE	294	MYLNE_ALEXANDER
126	1636	1647	37	EDINBURGH TRON CHURCH	294	MYLNE_ALEXANDER
126	1636	1647	37	EDINBURGH TRON CHURCH	9	MYLNE_JOHN-JUNIOR-(3)
149	1678	1681	49	METHVEN CASTLE	9	MYLNE_JOHN-JUNIOR-(3)
241	1667	1672	88	LESLIE HOUSE	9	MYLNE_JOHN-JUNIOR-(3)
593	1666	NA	328	PANMURE HOUSE	9	MYLNE_JOHN-JUNIOR-(3)
640	1637	1648	121	COWANE'S HOSPITAL	9	MYLNE_JOHN-JUNIOR-(3)
2102	1663	NA	17	HOLYROOD PALACE	9	MYLNE_JOHN-JUNIOR-(3)
1955	1631	1647	14	GEORGE HERIOT'S HOSPITAL SCHOOL	9	MYLNE_JOHN-JUNIOR-(3)
2298	1659	NA	14	GEORGE HERIOT'S HOSPITAL SCHOOL	9	MYLNE_JOHN-JUNIOR-(3)
134	1772	1785	40	INVERARAY CASTLE	87	MYLNE_ROBERT
142	1784	1790	44	INVERARAY CASTLE_MAAM STEADING	87	MYLNE_ROBERT
145	1795	1802	45	INVERARAY TOWN	87	MYLNE_ROBERT
156	1670	1679	51	THIRLESTANE CASTLE	87	MYLNE_ROBERT
202	1684	1688	65	EDINBURGH MILNE'S SQUARE	87	MYLNE_ROBERT
204	1690	1695	66	MILNE'S COURT	87	MYLNE_ROBERT
722	1763	NA	547	ABERDOUR QUARRY	87	MYLNE_ROBERT
755	1774	NA	333	PITLOUR HOUSE	87	MYLNE_ROBERT
769	1764	NA	514	ABERDOUR HOUSE	87	MYLNE_ROBERT
2216	1763	1765	292	CALLY HOUSE	87	MYLNE_ROBERT
1004	1584	NA	642	DRUM HOUSE	290	MYLNE-1_JOHN-1
26	1679	1690	9	DRUMLANRIG CASTLE	10	MYLNE-1_ROBERT-1
27	1696	1698	9	DRUMLANRIG CASTLE	10	MYLNE-1_ROBERT-1
1958	1675	NA	14	GEORGE HERIOT'S HOSPITAL SCHOOL	10	MYLNE-1_ROBERT-1
66	1671	1678	17	HOLYROOD PALACE	10	MYLNE-1_ROBERT-1
241	1667	1672	88	LESLIE HOUSE	10	MYLNE-1_ROBERT-1
307	1665	1667	244	CHARLOTTE FORT	10	MYLNE-1_ROBERT-1
314	1662	NA	245	EDINBURGH CASTLE	10	MYLNE-1_ROBERT-1
747	1665	NA	488	JOHN WOOD'S HOSPITAL	10	MYLNE-1_ROBERT-1
765	1670	NA	644	WEMYSS CASTLE	10	MYLNE-1_ROBERT-1
650	1678	NA	579	MILNE'S LAND	10	MYLNE-1_ROBERT-1
337	1687	NA	95	PRESTONFIELD HOUSE	10	MYLNE-1_ROBERT-1
2413	1682	1686	17	HOLYROOD PALACE	10	MYLNE-1_ROBERT-1

2089	1650	NA	1354	TELFER WALL	291	MYLNE-2_JOHN-2
1695	1773	1780	1153	BARNS HOUSE	246	NAESMYTH_MICHAEL
210	1740	1757	68	GLASGOW ST ANDREW'S IN THE SQUARE CHURCH	330	NAISMITH_MUNGO
2909	1735	1760	625	GLASGOW TOWN HALL TONTINE HOTEL	330	NAISMITH_MUNGO
22	1702	1711	8	DALKEITH PALACE	289	NEALE_RICHARD
425	1748	NA	266	BURNTISLAND PARISH CHURCH	150	NEILSON_SAMUEL
2082	1739	1743	735	EDINBURGH 1, 2, 3, 4 FORREST HILL	150	NEILSON_SAMUEL
2417	1742	1749	213	TWEEDDALE HOUSE	150	NEILSON_SAMUEL
2121	1793	1794	1359	CARNBEE PARISH CHURCH	322	NESS_DAVID
2022	1665	1686	1328	NEIDPATH CASTLE	361	NICHOL_JAMES
2022	1665	1686	1328	NEIDPATH CASTLE	360	NICHOL_JOHN
2617	1788	NA	1549	ORWELL HOUSE	374	NICOL_DAVID
2633	1790	NA	1553	ANTIBURGHER CHURCH (PERTH AND KINROSS)	374	NICOL_DAVID
937	1593	NA	287	BALNAGOWN CASTLE	279	NICOLSON_JAMES
1846	1672	1674	146	CAWDOR CASTLE	250	NICOLSON-OF-NAIRN_JAMES
1846	1672	1674	146	CAWDOR CASTLE	251	NICOLSON-OF-NAIRN_ROBERT
2568	1665	1667	1536	KILRAVOCK CASTLE	251	NICOLSON-OF-NAIRN_ROBERT
292	1770	1775	238	WEDDERBURN CASTLE	11	NISBET_JAMES
1021	1790	NA	806	EDINBURGH 115 GEORGE ST	11	NISBET_JAMES
1290	1777	1782	976	BALBIRNIE HOUSE	11	NISBET_JAMES
2555	1771	1773	1532	KELSO OLD PARISH CHURCH	11	NISBET_JAMES
6	1675	1699	3	ARCHERFIELD HOUSE	24	NISBET-OF-DIRLETON_WILLIAM
997	1700	1725	229	CULLEN HOUSE	327	OGILVY_JAMES-3RD-EARL-OF-FINDLATER
580	1767	1769	229	CULLEN HOUSE	193	OGILVY_JAMES-3RD-EARL-OF-SEAFIELD
365	1767	NA	109	AUCHINCRUIVE HOUSE	165	OSWALD_RICHARD
152	1668	1674	50	BALCASKIE HOUSE	274	PATERSON_ALEXANDER
2080	1791	NA	1352	MAINS OF AUQUHORTIES	274	PATERSON_ALEXANDER
1687	1789	NA	174	TIBBERMORE CHURCH	380	PATERSON_ANDREW
1166	1754	NA	320	MARLEFIELD HOUSE	12	PATERSON_GOERGE
2127	1774	NA	1361	KINGHORN PARISH CHURCH	12	PATERSON_GOERGE
939	1675	1699	727	BANNOCKBURN HOUSE	275	PATERSON_HUGH
12	1794	NA	4	FRASER CASTLE	13	PATERSON_JOHN
103	1799	1810	30	TAYMOUTH CASTLE	13	PATERSON_JOHN
258	1782	NA	231	BLACKADDER HOUSE	13	PATERSON_JOHN
1190	1785	1790	798	MONZIE CASTLE	13	PATERSON_JOHN
2164	1762	1763	1367	APPLEGARTH PARISH CHURCH	332	PATTERSON_FRANCIS
2174	1754	NA	1372	ST MUNGO OLD PARISH CHURCH	341	PATTON_JOHN
1634	1750	1751	620	GLASGOW ST ANDREWS BY THE GREEN CHURCH	245	PAULL_WILLIAM
1158	1779	1785	315	LEUCHIE	223	PEACOCK_ALEXANDER
1158	1779	1785	315	LEUCHIE	224	PEACOCK_JAMES
2619	1666	1677	699	MURTHLY CASTLE	377	PIRNIE_JAMES
2619	1666	1677	699	MURTHLY CASTLE	376	PIRNIE_JOHN
23	1786	NA	8	DALKEITH PALACE	43	PLAYFAIR_JAMES
131	1791	1797	39	CAIRNESS HOUSE	43	PLAYFAIR_JAMES
136	1792	1793	41	METHVEN PARISH CURCH AND LYNEDOCH MAUSOLEUM	43	PLAYFAIR_JAMES
258	1782	NA	231	BLACKADDER HOUSE	43	PLAYFAIR_JAMES
601	1790	NA	646	KINNAIRD CASTLE	43	PLAYFAIR_JAMES
714	1785	NA	182	RAITH HOUSE	43	PLAYFAIR_JAMES
1177	1786	1791	787	MELVILLE CASTLE	43	PLAYFAIR_JAMES
1310	1786	NA	990	RAITH HOUSE_LODGE AND GATEWAY	43	PLAYFAIR_JAMES
569	1757	NA	217	HAWKHILL HOUSE	188	PRINGLE_ANDREW-LORD-ALEMOOR

1968	1777	NA	1316	LANARK TOLBOOTH	297	PURDIE_JOHN
445	1600	NA	274	DUNFERMLINE ANNE OF DENMARK BUILDING	154	QUEEN_ANNE-OF-DENMARK
324	1550	1559	186	STIRLING CASTLE	132	QUEEN-OF-SCOTLAND_MARY-OF-GUISE
558	1794	NA	211	BARNTON HOUSE	182	RAMSAY_GEORGE
612	1795	1797	170	BRECHIN CASTLE	283	RAMSAY_WILLIAM-1ST-BARON-OF-PANMURE
2059	1500	NA	630	KIRKWALL BISHOP'S PALACE	314	REID,-BISHOP_ROBERT
520	1785	NA	197	PITFOUR CASTLE	167	RICHARDSON_JOHN
2638	1591	NA	1556	ST ADAMNAN-KILMAVEONAIG CHURCH	385	ROBERTSON_CHARLES
2619	1666	1677	699	MURTHLY CASTLE	375	ROBERTSON_JAMES
2928	1794	1795	1682	ST NINIAN PARISH CHURCH	395	ROBERTSON_JAMES
1489	1589	NA	1101	ST ANDREWS WEST PORT	105	ROBERTSON_THOMAS
2182	1685	1687	1374	LEIGHTON LIBRARY	345	ROBINSON_JAMES
2581	1739	NA	1540	CROMARTY EAST PARISH CHURCH	370	ROBSON_DONALD
421	1592	1596	266	BURNTISLAND PARISH CHURCH	148	ROCHE_JOHN
318	1730	1737	245	EDINBURGH CASTLE	126	ROMER_JOHN-LAMBERTUS
373	1735	NA	113	DUMBARTON CASTLE	126	ROMER_JOHN-LAMBERTUS
383	1719	1723	247	BERNERA BARRACKS	126	ROMER_JOHN-LAMBERTUS
396	1729	1742	253	AUGUSTUS FORT_KILIWHIMAN BARRACKS	126	ROMER_JOHN-LAMBERTUS
399	1719	NA	241	INVERNESS CASTLE FORT GEORGE	126	ROMER_JOHN-LAMBERTUS
115	1640	1653	33	INNES HOUSE	14	ROSS_WILLIAM
1897	1668	1672	287	BALNAGOWN CASTLE	280	ROSS-OF-BALNAGOWN_DAVID
1627	1796	1799	804	EDINBURGH CASTLE_NEW BARRACKS	243	RUDYERD_THOMAS
1935	1796	1799	245	EDINBURGH CASTLE	243	RUDYERD_THOMAS
640	1637	1648	121	COWANE'S HOSPITAL	253	RYND_JAMES
445	1600	NA	274	DUNFERMLINE ANNE OF DENMARK BUILDING	153	SCHAW_WILLIAM
453	1630	NA	275	DUNFERMLINE PALACE	153	SCHAW_WILLIAM
454	1594	NA	276	STIRLING CASTLE_CHAPEL ROYAL	153	SCHAW_WILLIAM
81	1618	1624	21	LINLITHGOW PALACE	153	SCHAW_WILLIAM
459	1600	NA	277	HOLYROOD ABBEY	153	SCHAW_WILLIAM
22	1702	1711	8	DALKEITH PALACE	30	SCOTT_ANNE-1ST-DUCHESS-OF-BUCCLEUCH
553	1792	NA	361	DALKEITH HOUSE_MONTAGU BRIDGE	180	SCOTT_HENRY-3RD-DUKE-OF-BUCCLEUCH
1105	1680	1690	116	HARDEN HOUSE	260	SCOTT_WALTER-1ST-EARL-OF-TARRAS
2845	1680	1683	1646	COCKENZIE HOUSE	396	SETON_GEORGE-4TH-EARL-OF-WINTON
1270	1757	1762	733	TOUCH HOUSE	402	SETON_HUGH-(SMITH)
109	1620	1628	31	WINTON HOUSE	83	SETON_ROBERT-2ND-EARL-OF-WINTON
109	1620	1628	31	WINTON HOUSE	83	SETON_ROBERT-2ND-EARL-OF-WINTON
35	1607	NA	12	EARLSHALL	44	SETON_SIR-ALEXANDER-1ST-EARL-OF-DUNFERMLINE
41	1595	1605	13	FYVIE CASTLE	44	SETON_SIR-ALEXANDER-1ST-EARL-OF-DUNFERMLINE
95	1613	NA	27	PINKIE HOUSE	44	SETON_SIR-ALEXANDER-1ST-EARL-OF-DUNFERMLINE
617	1590	NA	657	BARNES CASTLE	202	SETON_SIR-JOHN
2537	1797	NA	1529	ARBROATH ABBEY PARISH CHURCH	359	SHANK_JOHN

1164	1748	NA	765	MANOR HOUSE	226	SHIELLS_ARCHIBALD
1164	1748	NA	765	MANOR HOUSE	226	SHIELLS_ARCHIBALD
45	1628	1631	14	GEORGE HERIOT'S HOSPITAL SCHOOL	350	SHORT_ROBERT
84	1723	1726	24	MAVISBANK HOUSE	351	SILVERSTYNE_MR
147	1798	NA	47	THURSO TOWN	89	SINCLAIR_SIR-JOHN-1ST-BARONET
141	1747	1769	43	GEORGE FORT	15	SKINNER_COLONEL-WILLIAM
375	1748	NA	113	DUMBARTON CASTLE	15	SKINNER_COLONEL-WILLIAM
1039	1748	NA	964	EDINBURGH CASTLE_HOSPITAL SOUTH RANGE	15	SKINNER_COLONEL-WILLIAM
1929	1748	1754	245	EDINBURGH CASTLE	15	SKINNER_COLONEL-WILLIAM
1622	1677	1680	1309	EDINBURGH CASTLE_FOGGS GATE	242	SLEZER_CAPTAIN-JOHN
1926	1677	1680	245	EDINBURGH CASTLE	242	SLEZER_CAPTAIN-JOHN
2629	1736	NA	1552	ABERNYTE PARISH CHURCH	381	SMART_DAVID
325	1708	1714	186	STIRLING CASTLE	130	SMITH_GILBERT
22	1702	1711	8	DALKEITH PALACE	130	SMITH_GILBERT
2568	1665	1667	1536	KILRAVOCK CASTLE	367	SMITH_JAMES-SENIOR
684	1668	NA	604	LINLITHGOW CROSS TOWN HOUSE	16	SMITH_JOHN-(600)
1238	1731	1732	431	ROBERT GORDON'S COLLEGE	258	SMITH_JOHN-(700)
1861	1744	NA	307	GORDON CASTLE	258	SMITH_JOHN-(700)
2054	1550	NA	1346	BONSHAW TOWER AND HOUSE AND COURTYARD WALLS	313	SMITH_PETER
1	1688	1691	1	EDINBURGH CANONGATE PARISH CHURCH	35	SMITH-1_JAMES-1
22	1702	1711	8	DALKEITH PALACE	35	SMITH-1_JAMES-1
27	1696	1698	9	DRUMLANRIG CASTLE	35	SMITH-1_JAMES-1
66	1671	1678	17	HOLYROOD PALACE	35	SMITH-1_JAMES-1
82	1695	NA	22	DURISDEER PARISH CHURCH_MAUSOLEUM OF IST DUKE OF QUEENSBERRY	35	SMITH-1_JAMES-1
83	1601	1620	23	EDINBURGH GREYFRIARS CHURCHYARD MAUSOLEUM OF SIR GEORGE MACKENZIE	35	SMITH-1_JAMES-1
98	1700	NA	28	QUEENSBERRY HOUSE	35	SMITH-1_JAMES-1
194	1697	1703	61	MELVILLE HOUSE	35	SMITH-1_JAMES-1
196	1686	1719	62	NEWHAILES HOUSE	35	SMITH-1_JAMES-1
288	1695	1699	237	TRAQUAIR HOUSE	35	SMITH-1_JAMES-1
325	1708	1714	186	STIRLING CASTLE	35	SMITH-1_JAMES-1
383	1719	1723	247	BERNERA BARRACKS	35	SMITH-1_JAMES-1
394	1718	1719	252	INVERSNAID BARRACKS SOUTH BLOCK	35	SMITH-1_JAMES-1
620	1680	NA	654	HOLYROOD PALACE_CHAPEL ROYAL	35	SMITH-1_JAMES-1
721	1690	NA	399	ABERDOUR CASTLE	35	SMITH-1_JAMES-1
1147	1695	1705	310	KILKERRAN HOUSE	35	SMITH-1_JAMES-1
1240	1728	NA	456	ROSS MAINS	35	SMITH-1_JAMES-1
718	1700	1799	336	STRATHLEVEN HOUSE	35	SMITH-1_JAMES-1
1284	1699	1715	162	YESTER HOUSE	35	SMITH-1_JAMES-1
713	1693	1696	182	RAITH HOUSE	35	SMITH-1_JAMES-1
22	1702	1711	8	DALKEITH PALACE	35	SMITH-1_JAMES-1
1958	1675	NA	14	GEORGE HERIOT'S HOSPITAL SCHOOL	35	SMITH-1_JAMES-1
1988	1696	NA	1322	LOW PARKS MUSEUM	35	SMITH-1_JAMES-1
651	1697	NA	433	EDINBURGH OLD SURGEON'S HALL	35	SMITH-1_JAMES-1
2142	1692	1693	213	TWEEDDALE HOUSE	35	SMITH-1_JAMES-1
2143	1686	NA	162	YESTER HOUSE	35	SMITH-1_JAMES-1
997	1700	1725	229	CULLEN HOUSE	35	SMITH-1_JAMES-1

1599	1716	1729	424	DURISDEER PARISH CHURCH	35	SMITH-1_JAMES-1
2264	1715	NA	1386	LONGFORMACUS HOUSE	35	SMITH-1_JAMES-1
2413	1682	1686	17	HOLYROOD PALACE	35	SMITH-1_JAMES-1
2845	1680	1683	1646	COCKENZIE HOUSE	35	SMITH-1_JAMES-1
149	1678	1681	49	METHVEN CASTLE	91	SMYTH-OF-BRACO_PATRICK
20	1621	NA	7	DAIRSIE OLD CHURCH	29	SPOTTISWOOD_ARCHBISHOP-OF-ST-ANDREWS
1270	1757	1762	733	TOUCH HOUSE	393	STEINSON_JAMES
175	1777	NA	54	DUNKELD HOUSE	97	STEUART_GEORGE
1608	1787	NA	803	EDINBURGH ST ANDREW'S AND ST GEORGE'S CHURCH	17	STEVENS_ALEXANDER-THE-ELDER
524	1787	NA	199	GLASSERTON HOUSE	169	STEWART_ADMIRAL-KEITH
2636	1797	1798	1555	BIRNAM LITTLE DUNKELD KIRK	384	STEWART_JOHN
2638	1591	NA	1556	ST ADAMNAN-KILMAVEONAIG CHURCH	384	STEWART_JOHN
481	1601	1607	688	KIRKWALL EARL'S PALACE	159	STEWART_PATRICK-2ND-EARL-OF-ORKNEY
615	1574	1600	656	BIRSAY EARL'S PALACE	201	STEWART_ROBERT-1ST-EARL-OF-ORKNEY
1197	1600	1625	699	MURTHLY CASTLE	266	STEWART_SIR-WILLIAM
2060	1550	NA	630	KIRKWALL BISHOP'S PALACE	315	STEWART,-EARL_PATRICK
1955	1631	1647	14	GEORGE HERIOT'S HOSPITAL SCHOOL	317	STIRLING_JAMES
613	1617	NA	654	HOLYROOD PALACE_CHAPEL ROYAL	199	STONE_NICHOLAS
969	1569	1588	833	CLAYPOTTS CASTLE	252	STRACHAN_JOHN
198	1733	1751	62	NEWHAILES HOUSE	401	STRACHAN_WILLIAM
207	1706	1733	67	TAIN TOLBOOTH	18	STRONACH_ALEXANDER
288	1695	1699	237	TRAQUAIR HOUSE	119	STUART_CHARLES-4TH-EARL-OF-TRAQUAIR
289	1700	1799	237	TRAQUAIR HOUSE	120	STUART_CHARLES-5TH-EARL-OF-TRAQUAIR
287	1642	NA	237	TRAQUAIR HOUSE	118	STUART_JOHN-1ST-EARL-OF-TRAQUAIR
286	1559	1599	237	TRAQUAIR HOUSE	117	STUART_SIR-WILLIAM-5TH-LAIRD-OF-TRAQUAIR
482	1625	NA	145	STEWART CASTLE	160	STURAT_JAMES-3RD-EARL-OF-MORAY
2587	1792	1794	1542	INVERNESS GREYFRIARS FREE CHURCH	371	SUTER_HUGH
2598	1800	1801	1546	MUIRTOWN HOUSE	371	SUTER_HUGH
22	1702	1711	8	DALKEITH PALACE	288	SYLVERSTYN_ISAAC
2074	1622	NA	1350	MAGDALEN CHAPEL	318	TAILEFER_JOHN
2613	1782	1783	41	METHVEN PARISH CURCH AND LYNEDOCH MAUSOLEUM	373	TAYLOR_JOHN
2909	1735	1760	625	GLASGOW TOWN HALL TONTINE HOTEL	389	TENNANT_ROBERT
294	1652	1654	239	AYR CITADEL	19	TESSIN_HANS-EWALD
2171	1742	1749	1370	ST MICHAEL'S AND SOUTH CHURCH	336	TWADDELL_THOMAS
984	1604	1607	164	CRAIGSTON CASTLE	392	URQUHART_JOHN
277	1721	1726	235	FLOORS CASTLE	116	VANBURGH_SIR-JOHN
318	1730	1737	245	EDINBURGH CASTLE	127	WADE_GENERAL-GEORGE
393	1731	1732	251	GARVA BRIDGE	127	WADE_GENERAL-GEORGE
45	1628	1631	14	GEORGE HERIOT'S HOSPITAL SCHOOL	20	WALLACE_WILLIAM
81	1618	1624	21	LINLITHGOW PALACE	20	WALLACE_WILLIAM
109	1620	1628	31	WINTON HOUSE	20	WALLACE_WILLIAM
455	1615	1617	281	EDINBURGH CASTLE_PALACE	20	WALLACE_WILLIAM
618	1618	NA	9	DRUMLANRIG CASTLE	20	WALLACE_WILLIAM

1919	1600	1675	113	DUMBARTON CASTLE	20	WALLACE_WILLIAM
477	1614	NA	59	PITREAVIE CASTLE	99	WARDLAW_SIR-HENRY-1ST-BARONET-OF-PITREAVIE-AND-BALMULE
325	1708	1714	186	STIRLING CASTLE	129	WATSON_JAMES
912	1615	1627	132	ABERDEEN TOLBOOTH	21	WATSON_THOMAS
2613	1782	1783	41	METHVEN PARISH CURCH AND LYNEDOCH MAUSOLEUM	372	WATT_JAMES
1955	1631	1647	14	GEORGE HERIOT'S HOSPITAL SCHOOL	295	WATT_JOHN
2085	1771	NA	813	ST CUTHBERT'S CHURCH	319	WEIR_ROBERT
328	1696	NA	91	HILL OF TARVIT HOUSE FORMERLY WEMYSS HALL	133	WEMYSS_JOHN
109	1620	1628	31	WINTON HOUSE	157	WHITE_JOHN
1474	1770	NA	1089	OAKSHAW TRINITY CHURCH	157	WHITE_JOHN
1473	1754	1756	1089	OAKSHAW TRINITY CHURCH	157	WHITE_JOHN
571	1760	NA	220	BALLOCHMYLE HOUSE	189	WHITEFOORD_ALLAN
607	1680	NA	650	GALLERY HOUSE	22	WILKIE_THOMAS
2219	1693	NA	300	CAMMO HOUSE	22	WILKIE_THOMAS
1367	1727	NA	386	CESSNOCK CASTLE	284	WILLIAMSON_JAMES
1163	1775	1785	455	MAINS OF MOY	225	WILLIAMSON-OF-DYKE_COLIN
172	1744	NA	54	DUNKELD HOUSE	23	WINTER_JAMES
631	1743	1745	177	BLAIR CASTLE	23	WINTER_JAMES
632	1747	1758	177	BLAIR CASTLE	23	WINTER_JAMES
168	1672	1674	53	BRUNSTANE HOUSE	320	WOTHERSPOON_PATRICK
23	1786	NA	8	DALKEITH PALACE	287	YOUNG_ALEXANDER

2.3 DATASET USED IN THE OBJECTIVE CLASSIFICATION OF MASONRY PATTERNS

DATASET USED IN THE OBJECTIVE CLASSIFICATION OF MASONRY PATTERNS

	IMAGE NAME	SP	HMN	HSD	RC	LMT	CSD	UA
1	20150716_105357_corrected_silhouette.jpg	89.55	20.79593058	9.052020328	0.78655912	138.4095886	50.5884406	0.996029725
2	20150716_105801_corrected_silhouette.jpg	76.31	15.8245704	7.988679347	0.785962096	159.5726752	25.92654747	0.997280727
3	20150716_105919_corrected_silhouette.jpg	85.94	17.64321854	8.280390588	0.879829031	176.5423951	24.36050235	0.997586583
4	20150716_110249_corrected_silhouette.jpg	83.09	17.43584328	10.01971519	0.817234901	109.8743268	14.65754983	0.990237657
5	20150716_111035_corrected_silhouette.jpg	86.67	29.48833034	5.122992128	0.850725335	160.5320354	7.655804758	0.997611772
7	DSC_0015_corrected_silhouette.jpg	99.23	30.16157989	0	0.99999781	170.6957368	0	1
8	DSC_0023_corrected_silhouette.jpg	98.67	30.56552963	0.283866936	0.999848434	208.0458339	NA	0.999999811
9	DSC_0025_corrected_silhouette.jpg	98.97	30.81238779	0.19042373	0.976644367	239.5021683	3.487386077	0.999952294
10	DSC_0027_corrected_silhouette.jpg	98.96	30.67773788	0.115057441	0.969710152	220.283119	3.248279259	0.999667069
11	DSC_0038_corrected_silhouette.jpg	98.96	31.01436266	1.246615936	0.965716719	231.4376782	5.009537591	0.999872584
12	DSC_0044_corrected_silhouette.jpg	98.96	30.58797128	0.479222544	0.954921791	209.2844837	6.088082763	0.999420415
13	DSC_0054_corrected_silhouette.jpg	99	30.2513465	0.599298356	0.999996699	194.6792486	0	1
14	DSC_0368_corrected_silhouette.jpg	80.89	16.92100539	10.33119662	0.812503245	113.2854578	24.58483805	0.995241767
15	DSC_0381_corrected_silhouette.jpg	82.37	17.77378815	13.02215043	0.802944099	108.0789946	32.17623562	0.992079856
16	DSC_0382_corrected_silhouette.jpg	80.54	15.3700379	10.78134189	0.811421021	118.3123878	75.26510472	0.963422145
17	DSC_0384_corrected_silhouette.jpg	77.51	15.16628195	9.155598785	0.799470361	129.2379928	30.97640799	0.994847895
18	DSC_0385_corrected_silhouette.jpg	78.08	15.21757716	9.145257799	0.807512097	123.4241898	35.87293307	0.994962357
19	DSC_0406_corrected_silhouette.jpg	88.25	25.35906643	11.68513583	0.835154551	128.072482	11.22060904	0.987115772
20	DSC_0417_corrected_silhouette.jpg	77.97	13.56373429	8.97788426	0.667336832	110.2333932	42.59386059	0.989026573
21	DSC_0431_corrected_silhouette.jpg	88.54	24.50628366	7.004754046	0.852255784	109.8743268	19.42599997	0.993688218
22	DSC_0433_corrected_silhouette.jpg	88.98	25.79293836	8.386814859	0.929247864	128.7253142	4.271134568	0.999218439
23	DSC_0449_corrected_silhouette.jpg	86.4	18.18181818	12.07848731	0.816764093	112.3877917	15.14725996	0.997969301
24	DSC_0464_corrected_silhouette.jpg	78.28	15.94065955	7.555004453	0.785185144	106.1041293	32.90465024	0.977605755
25	DSC_0477_corrected_silhouette.jpg	71.06	11.37587727	5.851174831	0.781451887	107.8994614	24.42773604	0.99151368
26	DSC_0483_corrected_silhouette.jpg	77.51	15.58770726	9.356039585	0.770014779	114.1831239	40.59000309	0.986954454
27	DSC_0485_corrected_silhouette.jpg	78.74	15.71813285	9.178765212	0.786603784	102.3339318	43.21852541	0.973415033
28	DSC_0492_corrected_silhouette.jpg	84.02	19.50927588	10.23449074	0.771658837	101.9748654	64.68427877	0.9854159
29	DSC_0494_corrected_silhouette.jpg	76.72	12.65376687	7.567206652	0.782440489	115.1705566	26.62063402	0.988677746
30	DSC_0507_corrected_silhouette.jpg	87.35	26.78037104	5.783104694	0.93435219	119.9281867	39.26201698	0.999470317
31	DSC_0512_corrected_silhouette.jpg	86.86	24.90125673	1.56981809	0.915507119	114.5421903	8.831228913	0.994242543
32	DSC_0516_corrected_silhouette.jpg	81.02	24.90125673	2.137794249	0.912737428	138.5543215	27.18825225	0.998604216
33	DSC_0522_corrected_silhouette.jpg	82.7	24.11729503	1.590668325	0.931410382	118.1328546	5.055610286	0.996703072
35	DSC_0530_corrected_silhouette.jpg	89.58	27.34889288	9.062426905	0.930265654	142.9084381	6.981858671	0.997223606

36	DSC_0534_corrected_silhouette.jpg	83.34	16.50708159	8.936327644	0.858120899	148.6535009	49.94579345	0.998118747
37	DSC_0536_corrected_silhouette.jpg	84.7	22.3967684	9.555461491	0.89536339	108.438061	7.126388551	0.983642687
38	DSC_0538_corrected_silhouette.jpg	80.26	13.29293836	9.137498942	0.802052723	101.7953321	53.41219571	0.978077715
39	DSC_0542_corrected_silhouette.jpg	74.72	11.25250818	6.295033598	0.801285867	127.3345365	33.87553498	0.976858653
56	DSC_0951_corrected_silhouette.jpg	98.79	30.56552962	0.185834527	0.998220488	215.0477948	0	0.999997187
57	DSC_0958_corrected_silhouette.jpg	99.09	30.41292639	0.590006345	0.998549931	185.2987867	0	0.999999546
58	DSC_0966_corrected_silhouette.jpg	98.41	30.84979055	0.287626925	0.985263975	172.5875495	3.403806654	0.999975898
59	DSC_0972_corrected_silhouette.jpg	98.27	30.5924596	0.098334389	0.985898396	206.5761236	2.59252177	0.999970537
60	DSC_0980_corrected_silhouette.jpg	98.94	30.65529623	0.314640784	0.978638612	NA	3.201704785	0.999965613
61	DSC_0986_corrected_silhouette.jpg	99.02	30.70017953	0.468165344	0.948265748	193.9518541	NA	0.999891376
62	DSC_0996_corrected_silhouette.jpg	99.1	30.52064632	0.278131658	0.99999451	228.9827605	0	1
63	DSC_0998_corrected_silhouette.jpg	98.99	30.81238779	0.650420856	0.999996699	200.4882287	0	1
76	IMG_0313_corrected_silhouette.jpg	89.11	20.72326237	5.867495606	0.9008047	123.1597846	63.7192097	0.99541585
77	IMG_0320_corrected_silhouette.jpg	82.97	12.05592732	7.148449364	0.770368046	108.7971275	47.93172234	0.989831052
78	IMG_0586_corrected_silhouette.jpg	82.2	11.27981534	6.411872727	0.798496765	103.9497307	55.34287476	0.967918855
80	IMG_0597_corrected_silhouette.jpg	78.46	14.42602176	9.497023014	0.683477363	100.1795332	62.21563756	0.985013913
81	IMG_0599_corrected_silhouette.jpg	87.13	25.13464991	3.084629313	0.913667388	120.6463196	11.06898732	0.997312203
82	IMG_0603_corrected_silhouette.jpg	95.04	28.9561426	1.50820112	0.9771316	131.4454612	2.83875589	0.999537496
96	IMG_0685_corrected_silhouette.jpg	79.16	10.59936473	6.130575464	0.656251168	104.8473968	33.93066299	0.98081818
97	IMG_0687_corrected_silhouette.jpg	85.76	13.72901046	7.399926349	0.832760984	106.6427289	42.52196216	0.990144084
98	IMG_0691_corrected_silhouette.jpg	74.9	16.14901257	6.850916068	0.800895171	133.0317167	37.79872088	0.991685724
99	IMG_1492_corrected_silhouette.jpg	88.42	13.15317018	11.32464908	0.837684531	154.0729826	26.24831451	0.998328141
100	IMG_1503_corrected_silhouette.jpg	88.98	20.7153708	10.63106963	0.779907376	172.5022368	20.18742517	0.991546022
101	IMG_1505_corrected_silhouette.jpg	86.62	12.66706563	10.30074609	0.811586883	108.6175943	49.31450171	0.993862252
102	IMG_1508_corrected_silhouette.jpg	85.92	13.69135899	9.700869375	0.771631708	155.2628731	43.61500171	0.978101097
103	IMG_1512_corrected_silhouette.jpg	88.55	17.67119774	11.66757958	0.873860958	151.7055655	27.07974047	0.996302614
104	IMG_1533_corrected_silhouette.jpg	88.94	18.57171355	8.621852962	0.827493901	112.2082585	61.54396135	0.994581792
105	IMG_1540_corrected_silhouette.jpg	87.18	14.53096948	9.798954763	0.786604741	111.1310592	38.00068116	0.994133395
106	IMG_1542_corrected_silhouette.jpg	88.64	14.25044883	9.355701828	0.807470509	134.3821665	41.54575311	0.993822009
107	IMG_1554_corrected_silhouette.jpg	86.27	20.95642239	14.65217423	0.764529999	121.1849192	41.57833901	0.97488043
108	IMG_1568_corrected_silhouette.jpg	90.85	13.80011969	10.25493848	0.84998367	146.4991023	72.59393443	0.996220651
109	IMG_1571_corrected_silhouette.jpg	87.55	16.11310593	9.458634848	0.873299356	134.3364974	35.56895404	0.997328669
112	IMG_1774_corrected_silhouette.jpg	90.68	25.0577071	6.039415776	0.964327354	NA	6.782288819	0.999730804
113	IMG_1784_corrected_silhouette.jpg	87.89	22.7316669	4.743516696	0.970835371	119.5691203	65.88275652	0.999434709
114	IMG_1786_corrected_silhouette.jpg	92.99	24.00615542	5.046889379	0.969544568	181.9543701	2.857605398	0.999979858
115	IMG_1791_corrected_silhouette.jpg	97.46	30.31119091	0.264265735	0.983020519	182.5852783	1.470679748	0.99997732
116	IMG_1805_corrected_silhouette.jpg	91.25	21.1101137	3.658938254	0.954622011	188.7591085	NA	0.998789365

117	IMG_1807_corrected_silhouette.jpg	98	30.52064632	0.253898306	0.986665652	178.6355476	1.428724792	0.999693509
118	IMG_1846_corrected_silhouette.jpg	78.04	10.04072339	3.832390816	0.75204446	105.6552962	32.70758874	0.986981936
119	IMG_1848_corrected_silhouette.jpg	97.41	30.37103531	0.176515635	0.987021609	184.9192101	1.989169449	0.999911017
120	IMG_1851_corrected_silhouette.jpg	69.22	9.207005183	4.506987512	0.720878665	102.1543986	32.89990915	0.969223416
121	IMG_1864_corrected_silhouette.jpg	97.38	30.48473968	0.15020826	0.979628547	187.7356928	2.184599124	0.999812445
122	IMG_1895_corrected_silhouette.jpg	82.66	13.24955117	7.412678328	0.727614863	122.6211849	45.61152535	0.980140443
123	IMG_1936_corrected_silhouette.jpg	97.39	29.94614003	0.196668783	0.976199593	188.0633669	3.148620721	0.99998689
124	IMG_1990_corrected_silhouette.jpg	89.16	16.16921005	4.093183378	0.943200548	209.8563293	2.856132272	0.999563792
125	IMG_1996_corrected_silhouette.jpg	86.58	13.67017184	7.687419167	0.717289257	110.7121484	59.65518698	0.985776061
126	IMG_1999_corrected_silhouette.jpg	84.11	11.02225124	6.596767611	0.709720922	105.1166966	50.86717859	0.979238192
127	IMG_2470_corrected_silhouette.jpg	81.4	14.67447794	8.358496519	0.754081654	120.2872531	41.20325141	0.989625167
137	IMG_2986_corrected_silhouette.jpg	75.87	7.839616996	5.935466878	0.799171033	111.7594255	38.93160075	0.987322323
139	IMG_4493_corrected_silhouette.jpg	84.84	21.15927161	8.27468117	0.773211475	114.3626571	21.61354582	0.981509234
140	IMG_4500_corrected_silhouette.jpg	83.68	17.1454219	7.672346744	0.844012014	115.2603232	59.91593271	0.99157108
141	IMG_4502_corrected_silhouette.jpg	87.59	21.42973723	11.69401483	0.855100556	127.8276481	13.59472928	0.994980448
142	IMG_4506_corrected_silhouette.jpg	86	19.58194409	8.983691291	0.869174443	132.4499602	30.9079885	0.991125322
143	IMG_4510_corrected_silhouette.jpg	88.51	21.45421903	9.624721835	0.889567999	124.2369838	46.97974193	0.996053908
144	IMG_4514_corrected_silhouette.jpg	86.72	22.95032914	7.655640916	0.882070739	136.6247756	11.94100464	0.997726809
145	IMG_4518_corrected_silhouette.jpg	89.34	19.07540395	8.113964178	0.798003333	149.0730892	31.70873662	0.979663968
146	IMG_4522_corrected_silhouette.jpg	85.93	15.7390784	8.254032361	0.865706262	145.2423698	31.81344753	0.995223422
147	IMG_4526_corrected_silhouette.jpg	88.57	23.96768402	13.35459576	0.831248038	137.3429084	32.31569406	0.997483908
148	IMG_4530_corrected_silhouette.jpg	83.15	20.47961016	10.38251474	0.763832867	118.491921	25.83767861	0.950995842
149	IMG_4532_corrected_silhouette.jpg	86.03	24.9551167	6.232802635	0.841199106	130.9802498	19.6293731	0.993689702
150	IMG_4544_corrected_silhouette.jpg	89.46	13.64452424	7.444797865	0.88888895	147.5768141	27.53293084	0.997514418
154	IMG_4632_corrected_silhouette.jpg	89.2	21.08517854	12.35917359	0.787562284	125.1346499	51.64425695	0.988168641
156	IMG_4637_corrected_silhouette.jpg	90.33	24.9551167	9.703813498	0.840804249	122.0535433	29.31192667	0.983831543
159	IMG_4641_corrected_silhouette.jpg	85.59	19.00059845	8.926195123	0.902956969	105.9245961	61.16572965	0.991075136
160	IMG_4647_corrected_silhouette.jpg	87.26	19.25901746	8.497097011	0.845498384	124.7210573	37.98045194	0.986790107
162	IMG_4656_corrected_silhouette.jpg	93.7	25.04488331	9.036604166	0.953215746	132.3159785	7.279044413	0.996389983
165	IMG_4664_corrected_silhouette.jpg	91.51	30.23339318	1.316848892	0.949079058	157.6550153	10.41235571	0.99952138
166	IMG_4672_corrected_silhouette.jpg	90.84	30.48473968	1.010821419	0.93859201	157.0915619	12.14548816	0.996419246
169	IMG_4682_corrected_silhouette.jpg	91.66	27.63016158	7.074535081	0.949510066	131.2387792	18.5161518	0.997590357
175	IMG_4699_corrected_silhouette.jpg	84.37	20.76600838	9.79592099	0.807523466	107.2710952	46.28530651	0.972412493
177	IMG_4721_corrected_silhouette.jpg	90.28	18.81834503	12.0002391	0.848349793	117.7737882	52.64262537	0.995988787
178	IMG_4725_corrected_silhouette.jpg	89.85	22.81867145	10.57552396	0.865211527	150.7856911	25.75401492	0.998311061
180	IMG_4729_corrected_silhouette.jpg	89.16	24.79802513	11.57932066	0.838511338	129.6871126	18.86302289	0.99694823
181	IMG_4733_corrected_silhouette.jpg	68.84	10.80651844	5.738106028	0.762033699	128.4893089	38.46984739	0.990149237

185	IMG_4740_corrected_silhouette.jpg	88.65	16.38539796	5.870122969	0.864150618	137.7917415	34.35141593	0.999084606
186	IMG_4748_corrected_silhouette.jpg	72.73	27.25912627	2.828241746	0.791320804	130.6156474	9.157124847	0.998337177
188	IMG_4757_corrected_silhouette.jpg	87.37	19.21005386	10.75077703	0.895743138	122.9802513	53.88461057	0.995569638
191	IMG_4762_corrected_silhouette.jpg	89.96	21.10512667	10.20149645	0.858408229	114.3626571	16.52492976	0.994362265
192	IMG_4782_corrected_silhouette.jpg	85.72	19.22287766	10.4515388	0.836621637	137.2759181	33.93115938	0.994851423
193	IMG_4836_corrected_silhouette.jpg	98.91	30.46080192	0.126949153	0.998341998	187.8819708	0.358075447	0.999991086
194	IMG_4852_corrected_silhouette.jpg	98.93	30.44085378	0.09462231	0.999692643	189.0187316	0.206734956	0.999999266
195	IMG_4885_corrected_silhouette.jpg	99.07	29.86235787	0.270295387	0.984287607	148.2276044	3.178588646	0.999978491
196	IMG_4887_corrected_silhouette.jpg	98.32	27.97725913	4.618460662	0.982205438	200.3590664	NA	0.99998284
197	IMG_4895_corrected_silhouette.jpg	98.76	28.27648115	3.627874224	0.984360076	192.6411578	2.190626075	0.999952774
198	IMG_4902_corrected_silhouette.jpg	98.83	28.58168761	4.402043102	0.98654078	214.7890768	2.134147253	0.999994228
199	IMG_5141_corrected_silhouette.jpg	80.18	17.29930752	8.212648584	0.869234871	116.469443	28.87995913	0.974776852
200	IMG_5142_corrected_silhouette.jpg	83.1	14.89180762	8.60896105	0.892902162	133.3216349	26.96124271	0.985578712
201	IMG_5168_corrected_silhouette.jpg	79.64	11.8491921	5.865747896	0.845873379	103.2315978	27.21846431	0.998131538
202	IMG_5172_corrected_silhouette.jpg	93.88	25.97247157	1.804881844	0.964082348	224.7755835	2.375203809	0.99993946
203	IMG_5174_corrected_silhouette.jpg	87.16	14.36265709	7.399349831	0.88774335	107.3608618	45.93460853	0.998302819
204	IMG_5176_corrected_silhouette.jpg	88.51	16.10669402	7.498660844	0.860130787	158.7073609	31.71579497	0.998838648
205	IMG_5179_corrected_silhouette.jpg	90.66	21.49502203	4.515601822	0.874215378	133.0341113	65.7526429	0.993648432
206	IMG_5205_corrected_silhouette.jpg	82.93	15.87073609	9.64737198	0.875097867	113.1059246	20.2131869	0.995473839
207	IMG_5206_corrected_silhouette.jpg	84.8	17.36983842	9.755993774	0.86151281	121.1691323	26.47860747	0.998154951
208	IMG_5211_corrected_silhouette.jpg	84.85	14.81149013	9.809162952	0.879471816	129.5332136	30.13539215	0.996501066
209	IMG_5213_corrected_silhouette.jpg	84.61	17.98094186	8.738875197	0.90784333	159.6210596	13.60210136	0.999152997
210	IMG_5217_corrected_silhouette.jpg	85.14	23.89587074	5.449752312	0.86602675	125.6732496	20.44346088	0.990628901
212	IMG_5243_corrected_silhouette.jpg	79.49	18.59451141	7.880202221	0.893637195	122.7714794	23.61743253	0.989403777
213	IMG_5245_corrected_silhouette.jpg	80.83	20.72112507	8.450885431	0.921865102	122.8828268	18.02206763	0.997916886
214	IMG_5249_corrected_silhouette.jpg	83.81	19.53647789	7.152012955	0.901916374	131.059246	23.5692184	0.996725859
215	IMG_5253_corrected_silhouette.jpg	69.85	12.93921518	6.983699748	0.811296438	115.2603232	20.43483543	0.99854769
216	IMG_5255_corrected_silhouette.jpg	67.86	12.63913824	7.785498449	0.793212647	100.3590664	50.13466067	0.978728672
217	IMG_5266_corrected_silhouette.jpg	78.74	14.20424543	9.57727714	0.835430963	103.7701975	12.10772941	0.959371388
218	IMG_5268_corrected_silhouette.jpg	80.92	12.37881508	8.897405965	0.859303633	129.443447	16.61701367	0.992476523
219	IMG_5284_corrected_silhouette.jpg	83.33	14.37462597	7.880046399	0.805523086	114.7217235	33.52479633	0.998516188
220	IMG_5287_corrected_silhouette.jpg	76.46	15.4510772	7.454547864	0.831164597	128.994614	42.60259704	0.996095624
221	IMG_5289_corrected_silhouette.jpg	79.18	14.64478071	5.541069282	0.867618259	151.7055655	16.15080856	0.998361855
222	IMG_5291_corrected_silhouette.jpg	81.13	19.88330341	6.690911235	0.875186749	131.7773788	16.49155742	0.996632967
223	IMG_5293_corrected_silhouette.jpg	79.91	13.51885099	7.166454406	0.814410333	106.8222621	48.687717	0.995694203
224	IMG_5299_corrected_silhouette.jpg	84.91	19.42222948	4.879089283	0.904494163	114.51704	45.93626403	0.99655248
225	IMG_5306_corrected_silhouette.jpg	94.1	28.68043088	2.31660465	0.941922004	219.8411948	4.862719936	0.999001304

226	IMG_5308_corrected_silhouette.jpg	95.68	30.59245961	3.719848469	0.942523623	206.4631957	63.29239023	0.999874532
227	IMG_5312_corrected_silhouette.jpg	85.83	19.75810262	9.552725508	0.861472022	107.3608618	22.17523219	0.978548885
228	IMG_5323_corrected_silhouette.jpg	85.99	21.1101137	14.31615991	0.863116891	128.2967219	29.99167505	0.983587727
229	IMG_5327_corrected_silhouette.jpg	85.06	20.90065829	10.76585929	0.86181265	117.4147217	52.21045984	0.996442381
230	IMG_5475_corrected_silhouette.jpg	98.84	30.65529623	0.269299821	0.996721336	194.0928566	0.53378736	0.999966281
234	IMG_5485_corrected_silhouette.jpg	98.76	30.62836625	0.098334389	0.977245281	NA	3.177401143	0.999878001
237	IMG_5494_corrected_silhouette.jpg	98.83	30.55056852	0.135147691	0.979488237	NA	3.598690155	0.999984199
242	IMG_5509_corrected_silhouette.jpg	98.8	30.61041293	0.098334389	0.983330395	NA	1.953326262	0.999988513
245	IMG_5519_corrected_silhouette.jpg	98.74	30.57194152	0.247779375	0.993224358	NA	1.29024091	0.999997594
254	IMG_5550_corrected_silhouette.jpg	98.38	30.01196888	0.176515635	0.982336898	NA	2.474913989	0.999994022
264	IMG_5625_corrected_silhouette.jpg	98.5	30.44370352	0.095964537	0.998961321	NA	0.206734956	0.999992277
265	IMG_5627_corrected_silhouette.jpg	98.81	30.49072412	0.264265735	0.985551137	389.4274533	1.691346978	0.999997855
266	IMG_5633_corrected_silhouette.jpg	98.58	30.36676071	0.24150546	0.975868166	243.828702	2.915371042	0.999984978
267	IMG_5634_corrected_silhouette.jpg	98.47	30.34111311	0.146588256	0.996894864	242.6102489	0.206734956	0.999998797
268	IMG_5640_corrected_silhouette.jpg	98.76	30.64033513	0.092710551	0.992109767	307.5460873	0.990593975	0.999998006
269	IMG_5648_corrected_silhouette.jpg	98.64	28.13541934	2.864505331	0.986957115	191.3431977	1.232044956	0.99999431
270	IMG_5665_corrected_silhouette.jpg	98.74	28.81508079	2.722164028	0.983389687	243.0609139	2.287414569	0.999990008
271	IMG_5672_corrected_silhouette.jpg	98.77	30.44370351	0.203571528	0.981056347	253.6343565	1.953326262	0.999985636
272	IMG_5680_corrected_silhouette.jpg	98.79	30.49499872	0.191929078	0.994734517	231.6221646	0.620204867	0.99997668
273	IMG_5686_corrected_silhouette.jpg	98.57	30.54629392	0.444969262	0.998874381	260.5620859	0	0.999999238
274	IMG_5702_corrected_silhouette.jpg	98.6	30.37103531	0.176515635	0.988749759	366.8543415	1.184042968	0.999993858
275	IMG_5709_corrected_silhouette.jpg	84.64	8.782953794	5.087971785	0.727506901	115.978456	35.67191052	0.99075336
276	IMG_5719_corrected_silhouette.jpg	82.21	10.72846962	6.761909162	0.631272238	105.7450628	62.87071393	0.976901058
277	IMG_5724_corrected_silhouette.jpg	97.95	30.52064632	0	0.992615157	NA	0.54609114	0.999682559
278	IMG_5733_corrected_silhouette.jpg	76.07	9.98857516	6.560001228	0.707614298	106.3734291	38.86190901	0.97397826
279	IMG_5737_corrected_silhouette.jpg	97.78	30.41805591	0.203571527	0.973275084	245.3186091	2.819322683	0.999666684
280	IMG_5744_corrected_silhouette.jpg	98.12	30.49072412	0.073294126	0.990232147	274.806714	0.923715618	0.999999075
281	IMG_5745_corrected_silhouette.jpg	81.66	10.18275561	6.679015117	0.691681724	108.2585278	45.47132639	0.982273735
282	IMG_5755_corrected_silhouette.jpg	98.99	30.43087971	0.188296022	0.993007971	426.8263097	0.773531374	0.999998997
283	IMG_5760_corrected_silhouette.jpg	97.09	30.49820467	0.243483425	0.987602652	174.5062837	0.652871667	0.999984142
284	IMG_5761_corrected_silhouette.jpg	73.24	9.356603065	5.640479824	0.660375238	130.351014	38.18245384	0.979684152
285	IMG_5774_corrected_silhouette.jpg	98.33	30.62836625	0.098334389	0.986407417	179.3536804	2.729974672	0.999988541
286	IMG_5775_corrected_silhouette.jpg	80.32	11.12544883	5.630533793	0.734051816	123.8779174	34.94102922	0.989047953
287	IMG_5777_corrected_silhouette.jpg	98.01	30.2962298	0.249323186	0.996966245	234.7992013	0	0.999915567
288	IMG_5797_corrected_silhouette.jpg	98.42	30.54629392	0.191929075	0.975577424	226.7601834	6.443142214	0.999945306
289	IMG_5799_corrected_silhouette.jpg	98.61	32.67504488	3.852650579	0.976644199	206.750059	2.628846372	0.9998961
290	IMG_5805_corrected_silhouette.jpg	98.8	30.43087972	0.098334389	0.980277882	349.5503921	2.379048132	0.999981979

291	IMG_5811_corrected_silhouette.jpg	97.73	30.01196888	1.187726757	0.982533081	287.4999396	3.377195384	0.999978254
292	IMG_5817_corrected_silhouette.jpg	98.57	30.61041293	0.235064156	0.988242702	232.8533537	1.515644483	0.999987177
300	IMG_6040_corrected_silhouette.jpg	98.69	30.54308797	0.115057438	0.986994925	185.188532	1.88654378	0.999988317
301	IMG_6042_corrected_silhouette.jpg	98.87	30.48473968	0.23408267	0.992357372	NA	0.799841221	0.999998979
308	IMG_6065_corrected_silhouette.jpg	98.75	30.59758912	0.095964537	0.988773649	217.5567473	1.487178374	0.999901653
316	IMG_6110_corrected_silhouette.jpg	79.79	13.01306259	7.474710659	0.829477769	110.2333932	29.93773678	0.991565908
330	IMG_6176_corrected_silhouette.jpg	95.26	16.99037049	7.102018392	0.984274584	168.7467989	20.30675175	0.999992097
331	IMG_6241_corrected_silhouette.jpg	98.79	31.02333932	0.529546901	0.994813149	195.9772087	1.039681445	0.999978481
332	IMG_6245_corrected_silhouette.jpg	98.69	30.80789946	0.894068196	0.992553017	218.1251277	1.012790307	0.999983984
333	IMG_6255_corrected_silhouette.jpg	98.85	30.91561939	0.627082555	0.9891253	184.1492898	2.080058013	0.999946497
334	IMG_6263_corrected_silhouette.jpg	98.92	30.95152603	0.590006345	0.975241654	NA	2.848749388	0.99997891
335	IMG_6269_corrected_silhouette.jpg	98.94	30.74506284	0.574786734	0.991430207	NA	1.28194336	0.999981613
336	IMG_6273_corrected_silhouette.jpg	98.92	31.41831239	0.732941275	0.983486825	207.4901896	1.81801424	0.999998052
337	IMG_6288_corrected_silhouette.jpg	94.46	24.52872531	7.716012953	0.961056868	189.4075404	12.0395728	0.999861757
338	IMG_6303_corrected_silhouette.jpg	78.57	9.170004143	8.923927419	0.731209307	108.8868941	40.34228725	0.991012296
339	IMG_6311_corrected_silhouette.jpg	98.97	32.76481149	1.248154017	0.977315516	234.9964238	2.82213182	0.99998623
340	IMG_6320_corrected_silhouette.jpg	98.98	32.56732496	0.349974661	0.995875166	221.5301346	0.337596769	0.999998861
341	IMG_6326_corrected_silhouette.jpg	98.9	31.02333932	0.883186636	0.994000297	189.9890177	0.892336682	0.999993548
342	IMG_6332_corrected_silhouette.jpg	99.01	31.32854578	1.454846891	0.990932976	195.2603651	1.093118971	0.999992288
343	IMG_6338_corrected_silhouette.jpg	98.86	31.19389587	0.884098545	0.983047365	233.5192528	2.696943868	0.999955785
344	IMG_6351_corrected_silhouette.jpg	98.92	31.10412927	0.987432675	0.996375781	254.3257279	0.337596769	0.999997058
345	IMG_6364_corrected_silhouette.jpg	98.87	30.87971275	0.253898305	0.986815065	274.558547	1.306722999	0.999993019
346	IMG_6370_corrected_silhouette.jpg	98.74	31.46319569	1.561452464	0.993541584	NA	0.852390059	0.999976186
347	IMG_6376_corrected_silhouette.jpg	98.85	31.5978456	1.343503549	0.994557769	286.3122343	0.462273414	0.99999374
348	IMG_6378_corrected_silhouette.jpg	98.66	30.2064632	0.269299821	0.99536912	218.9236635	0.337596769	0.999981706
349	IMG_6387_corrected_silhouette.jpg	98.31	30.26929982	0.240869082	0.993785487	221.4633637	0.53378736	0.999992914
350	IMG_6389_corrected_silhouette.jpg	98.86	30.43087971	0.310960647	0.999812356	205.938787	0	0.999999872
351	IMG_6481_corrected_silhouette.jpg	98.93	31.23877917	0.38783607	0.990266259	NA	1.597842879	0.999994182
352	IMG_6487_corrected_silhouette.jpg	98.85	30.8438061	0.447034096	0.99650506	174.7253441	0.238716965	0.999940502
353	IMG_6493_corrected_silhouette.jpg	98.97	30.87971275	0.491671956	0.999382097	219.7687734	0	0.999999698
354	IMG_6499_corrected_silhouette.jpg	99	30.98743267	0.562027857	0.995659925	166.4074115	0.337596769	0.999870168
355	IMG_6504_corrected_silhouette.jpg	98.99	30.73608618	0.321158774	0.986794804	NA	1.721672219	0.999998217
356	IMG_6515_corrected_silhouette.jpg	98.78	32.94434471	0.103653547	0.990241621	228.5448317	1.21638063	0.999996935
357	IMG_6518_corrected_silhouette.jpg	99.01	33.07899461	0.171889962	0.988649445	249.7532124	1.411452354	0.999995595
358	IMG_6520_corrected_silhouette.jpg	98.93	33.21364452	0.146588256	0.991243785	200.8106273	1.557271959	0.999984196
359	IMG_6522_corrected_silhouette.jpg	98.83	32.79473369	0.2073071	0.985994037	NA	2.534328003	0.999977686
360	IMG_6526_corrected_silhouette.jpg	99.06	32.79473369	0.103653553	0.990431191	NA	1.383665269	0.99999868

361	IMG_6530_corrected_silhouette.jpg	98.99	30.47576302	0.306611335	0.994353841	NA	0.652871667	0.999999591
362	IMG_6538_corrected_silhouette.jpg	98.81	30.92459605	0.593184546	0.991805076	164.6319569	1.825447106	0.999990151
363	IMG_6544_corrected_silhouette.jpg	98.87	30.8438061	0.367933598	0.993180589	NA	0.53378736	0.999893336
367	IMG_6602_corrected_silhouette.jpg	78.14	10.1997307	7.617827865	0.754360481	104.3087971	59.42732209	0.985060358
368	IMG_6608_corrected_silhouette.jpg	79.45	11.66185309	5.674364619	0.741481017	116.5170557	32.84444556	0.982873635
369	IMG_6614_corrected_silhouette.jpg	77.06	11.55203368	6.652820132	0.68100226	105.8348294	23.07671361	0.984951549
370	IMG_6624_corrected_silhouette.jpg	87.44	12.5	3.484902618	0.936762283	233.2136445	9.635188035	0.999123186
371	IMG_6631_corrected_silhouette.jpg	89.27	11.66965889	5.221917262	0.901468148	208.6962814	16.51890711	0.999510124
372	IMG_6650_corrected_silhouette.jpg	90.61	15.27413341	5.799257002	0.929353524	205.9245961	16.87846642	0.998961527
373	IMG_6656_corrected_silhouette.jpg	87.51	14.97030797	3.639360443	0.912964556	191.561939	4.31923622	0.999389832
374	IMG_6662_corrected_silhouette.jpg	88.67	13.41113106	3.061277512	0.923627349	142.9084381	27.68716636	0.997602508
375	IMG_6668_corrected_silhouette.jpg	90.44	13.76069279	3.19709109	0.926253706	203.2382625	20.73070959	0.998521775
376	IMG_6672_corrected_silhouette.jpg	87.07	12.18132855	3.620435495	0.948428641	228.1867145	11.72151005	0.999822776
377	IMG_6676_corrected_silhouette.jpg	86.32	12.30700179	4.356360914	0.933351569	159.2459605	22.0353724	0.999570258
378	IMG_6693_corrected_silhouette.jpg	80.97	10.16314105	4.027870446	0.81652741	182.5852783	15.98310572	0.998146567
379	IMG_6705_corrected_silhouette.jpg	88.34	14.44551858	5.194902135	0.941463154	187.3034144	15.64645504	0.999850198
381	IMG_6719_corrected_silhouette.jpg	79.21	11.8553829	5.859238851	0.756731673	113.2854578	18.5900172	0.975547641
382	IMG_6730_corrected_silhouette.jpg	73.36	9.53466932	5.076517237	0.72864907	112.7468582	28.85375008	0.976596379
383	IMG_6734_corrected_silhouette.jpg	73.54	9.77957311	5.789690432	0.725062569	104.1292639	29.24683888	0.979288325
384	IMG_6739_corrected_silhouette.jpg	68.99	7.978007182	4.545479211	0.746374008	110.05386	25.84495772	0.979193655
385	IMG_6742_corrected_silhouette.jpg	75.38	9.308106615	5.065178	0.719848322	111.3105925	28.88596369	0.977810412
386	IMG_6745_corrected_silhouette.jpg	76.58	8.529915244	6.070641726	0.814881537	113.7043686	49.95324725	0.982798955
387	IMG_6759_corrected_silhouette.jpg	71.2	15.33213645	8.342790797	0.706152892	102.8725314	53.4147342	0.978077659
388	IMG_6780_corrected_silhouette.jpg	98.79	30.23339318	0.16057939	0.979625156	183.5756339	3.148620721	0.999989868
389	IMG_6786_corrected_silhouette.jpg	98.73	30.10173549	0.092710551	0.994288384	149.4284984	1.679788903	0.999940085
390	IMG_6795_corrected_silhouette.jpg	98.8	30.2812687	0.146588257	0.997816974	153.8599641	0.53378736	0.999988455
391	IMG_6812_corrected_silhouette.jpg	98.74	29.94614004	0.080289697	0.98885612	187.0601479	2.080058013	0.998872552
392	IMG_6816_corrected_silhouette.jpg	98.71	30.27378815	0.164474935	0.991115581	247.3619753	1.232044956	0.999996697
393	IMG_6824_corrected_silhouette.jpg	98.81	30.26929982	0.098334394	0.975101661	209.6046971	3.971022438	0.999968493
394	IMG_6828_corrected_silhouette.jpg	98.73	30.12567325	0.196668783	0.999032925	187.5850445	0.238716965	0.999998077
395	IMG_6834_corrected_silhouette.jpg	98.81	29.87432675	0.098334394	0.991662161	184.6869225	1.520238263	0.999911389
396	IMG_6848_corrected_silhouette.jpg	98.73	30.16157989	0.113546775	0.97471415	205.1371609	3.562882931	0.999994264
397	IMG_6852_corrected_silhouette.jpg	98.64	29.77686587	0.616965668	0.955536469	201.281489	NA	0.999891113
398	IMG_6858_corrected_silhouette.jpg	98.88	29.98204668	0.2073071	0.9857436	190.5648587	2.729974672	0.999984272
399	IMG_6869_corrected_silhouette.jpg	98.8	32.45960503	0.196668778	0.990483798	184.5819432	1.639009019	0.999990681
400	IMG_6875_corrected_silhouette.jpg	97.78	32.76481149	0.31610084	0.990556608	185.0987433	0.892336682	0.999945847
401	IMG_6881_corrected_silhouette.jpg	98.85	33.21364452	0.219882382	0.994732856	186.5097791	0.860706256	0.999972368

402	IMG_6887_corrected_silhouette.jpg	98.8	33.1059246	0.272275599	0.99326611	187.6592761	0.98425526	0.99998214
403	IMG_6890_corrected_silhouette.jpg	98.77	33.39317774	0.179533215	0.98973217	189.00072	2.327935048	0.99997431
404	IMG_6901_corrected_silhouette.jpg	98.78	33.50089767	0.098334389	0.992552321	179.7739968	1.383665269	0.999988502
405	IMG_6913_corrected_silhouette.jpg	98.8	33.32136445	0.300416525	0.976391638	188.864993	3.878736832	0.999970001
406	IMG_6917_corrected_silhouette.jpg	98.82	33.39317774	0.126949154	0.989741561	188.3453719	1.856402089	0.999992169
407	IMG_6921_corrected_silhouette.jpg	98.78	33.42908438	0.389218735	0.98900237	186.2690728	1.979573506	0.999993036
408	IMG_6928_corrected_silhouette.jpg	98.75	33.24955116	0.080289697	0.994753644	187.7917415	0.583858567	0.999936845
409	IMG_6934_corrected_silhouette.jpg	98.79	33.28545781	0.098334394	0.993370202	185.6264608	0.980611466	0.999975371
410	IMG_6940_corrected_silhouette.jpg	98.75	33.46499102	0.204699361	0.989638931	184.2235214	1.856402089	0.999977772
429	IMG_7188_corrected_silhouette.jpg	88.02	15.84679833	10.65065168	0.69449831	124.5923383	42.66567303	0.990085172
432	IMG_7196_corrected_silhouette.jpg	84.34	12.25812887	10.8078057	0.715599723	102.513465	33.09850643	0.982010787
450	IMG_7352_corrected_silhouette.jpg	95.4	29.62298025	3.852650582	0.986039317	155.0547247	0.893197094	0.999846757
451	IMG_7356_corrected_silhouette.jpg	94.93	28.69539198	1.165814469	0.985690424	139.4559165	0.860706256	0.999969571
452	IMG_7360_corrected_silhouette.jpg	95.91	27.50448833	2.948392366	0.982491641	119.1616019	1.737075003	0.999783279
453	IMG_7372_corrected_silhouette.jpg	94.78	25.87843037	1.630456068	0.975042888	180.182458	1.38321824	0.999388425
454	IMG_7378_corrected_silhouette.jpg	92.4	22.8406144	3.24996994	0.983035094	173.3342357	0.620204867	0.999795604
455	IMG_7382_corrected_silhouette.jpg	95.68	25.76301616	4.566641777	0.976964667	142.1903052	2.445440292	0.99983907
456	IMG_7384_corrected_silhouette.jpg	93.3	24.97506483	5.579588171	0.935739118	171.6027171	4.701703984	0.997953629
457	IMG_7386_corrected_silhouette.jpg	90.88	23.71633752	4.29001325	0.938588186	145.7809695	4.450687288	0.998834216
458	IMG_7388_corrected_silhouette.jpg	93.66	25.02244165	1.194507977	0.9307816	204.5318522	6.110895294	0.99860984
459	IMG_7400_corrected_silhouette.jpg	95.97	21.34201077	1.874228233	0.987143776	158.6929774	1.054145573	0.999989069
460	IMG_7402_corrected_silhouette.jpg	92.63	21.63375225	2.647299704	0.957097265	151.5341875	3.079532967	0.999828814
461	IMG_7406_corrected_silhouette.jpg	94.37	24.37163375	1.850274958	0.982785285	175.6459657	0.900390663	0.999938563
462	IMG_7408_corrected_silhouette.jpg	94.32	24.59605027	1.282123596	0.967288942	139.4251688	2.617290936	0.995035499
463	IMG_7412_corrected_silhouette.jpg	93.86	24.63195691	1.243266604	0.978303891	153.6401418	0.876225918	0.999944848
464	IMG_7418_corrected_silhouette.jpg	95.66	24.61849192	0.990052249	0.9694643	171.2324643	3.673402466	0.999696654
465	IMG_7422_corrected_silhouette.jpg	94.31	24.66337522	1.167212476	0.971545712	204.4989193	3.228292257	0.999896243
466	IMG_7426_corrected_silhouette.jpg	94.51	24.64734547	1.61484873	0.972077001	189.0020001	2.505953302	0.999964992
467	IMG_7430_corrected_silhouette.jpg	96.76	29.47935368	1.200324213	0.984078038	168.7828221	0.893197094	0.999929893
468	IMG_7432_corrected_silhouette.jpg	96.19	29.11430281	1.120705319	0.985012651	165.4032874	0.412540485	0.999918219
469	IMG_7434_corrected_silhouette.jpg	95.89	28.65798923	1.840762717	0.973181285	145.2423698	3.525272428	0.9999052
470	IMG_7438_corrected_silhouette.jpg	96.03	29.59305805	1.301667387	0.980055528	138.6393691	1.470853939	0.999950693
471	IMG_7442_corrected_silhouette.jpg	96.51	29.35368043	1.674574337	0.981047443	115.0450268	1.411452354	0.999911927
472	IMG_7452_corrected_silhouette.jpg	98.66	29.53321365	1.554803241	0.990430791	152.3314433	0.823222128	0.999902633
473	IMG_7455_corrected_silhouette.jpg	98.26	29.98204668	0.82272454	0.995752754	NA	0.754889325	0.999992956
474	IMG_7459_corrected_silhouette.jpg	98.86	33.66247756	1.379020783	0.992945421	NA	0.823222128	0.999982433
475	IMG_7463_corrected_silhouette.jpg	99.06	33.66247756	1.379020783	0.98690185	NA	1.116021068	0.999977614

476	IMG_7467_corrected_silhouette.jpg	98.7	34.2010772	1.554803236	0.996928251	NA	0	0.999997985
477	IMG_7471_corrected_silhouette.jpg	98.62	34.56014363	1.554803241	0.9913517	229.5098422	0.716150894	0.999985439
478	IMG_7514_corrected_silhouette.jpg	84.78	12.43503732	10.71212202	0.68236948	100.5385996	60.55259845	0.93028997
479	IMG_7539_corrected_silhouette.jpg	90.81	23.93177738	10.16018061	0.900154758	124.7755835	44.0941996	0.998099173
480	IMG_7543_corrected_silhouette.jpg	90.15	20.76600838	7.126990989	0.882173645	132.4403143	48.83566118	0.987829702
481	IMG_7553_corrected_silhouette.jpg	88.32	21.64871334	9.513091615	0.918433424	149.9203844	45.75412421	0.995916621
482	IMG_7557_corrected_silhouette.jpg	87.81	23.15978456	6.380800013	0.908573473	154.7224152	60.00910766	0.984028392
483	IMG_7563_corrected_silhouette.jpg	86.11	23.42092378	9.120345085	0.861666254	134.8539333	23.45830788	0.987001446
484	IMG_7608_corrected_silhouette.jpg	86.92	28.70899298	1.216208782	0.933449117	161.6613355	9.474517889	0.993856293
485	IMG_7612_corrected_silhouette.jpg	87.09	21.65939985	9.390701899	0.896473569	183.2430593	14.46944829	0.996869623
486	IMG_7630_corrected_silhouette.jpg	90.51	19.24269626	9.052754033	0.958232278	123.518851	16.30068374	0.99912778
487	IMG_7636_corrected_silhouette.jpg	90.36	21.77737882	9.662249314	0.930513666	143.0879713	42.67066914	0.990182205
488	IMG_7640_corrected_silhouette.jpg	81.89	9.893562452	7.484513497	0.688553823	100.7181329	35.77031888	0.978851714
489	IMG_7647_corrected_silhouette.jpg	92.46	25.19449431	8.708286243	0.959414856	143.5867728	88.15055609	0.999407335
490	IMG_7650_corrected_silhouette.jpg	79.41	10.99640934	10.26822033	0.752209568	119.6460272	24.64193559	0.98543971
491	IMG_7651_corrected_silhouette.jpg	91.55	25.19449432	10.17727956	0.943414338	135.3680431	40.37220081	0.995863026
492	IMG_7667_corrected_silhouette.jpg	97.85	30.3111909	0.348436305	0.974700011	161.9675328	3.460981878	0.999984825
493	IMG_7669_corrected_silhouette.jpg	97.85	30.46080192	0.404115932	0.986373165	162.4775583	2.398274938	0.999952834
494	IMG_7675_corrected_silhouette.jpg	86.47	15.94853381	13.62926511	0.749281038	113.1059246	62.98170365	0.975942211
495	IMG_7681_corrected_silhouette.jpg	97.54	30.46080192	0.293176511	0.988097967	162.2980251	1.754204269	0.999936719
496	IMG_7683_corrected_silhouette.jpg	98.48	30.2812687	0.245289067	0.989587762	149.1921005	0.98425526	0.999840631
497	IMG_7691_corrected_silhouette.jpg	91.21	28.18671454	4.139843934	0.956049031	184.021544	13.81226759	0.993976813
498	IMG_7695_corrected_silhouette.jpg	91.44	25.70317175	1.005492855	0.961771492	202.513465	3.771973275	0.999014193
499	IMG_7701_corrected_silhouette.jpg	88.01	24.68581688	2.883171497	0.941169197	203.0520646	28.64763593	0.998051436
500	IMG_7713_corrected_silhouette.jpg	90.97	26.08361118	1.49028532	0.942671873	177.2017386	5.641897837	0.999676974
501	IMG_7715_corrected_silhouette.jpg	91.62	26.21184919	2.769703521	0.936964243	151.0624207	5.688544917	0.998030482
502	IMG_7727_corrected_silhouette.jpg	91.36	25.62836625	0.943922349	0.952653765	191.6594157	5.052008088	0.999813966
503	IMG_7733_corrected_silhouette.jpg	89.32	22.18232595	9.815850645	0.945487305	137.7019749	36.56123202	0.999744289
504	IMG_7741_corrected_silhouette.jpg	90.38	28.22661081	2.2846929	0.939257171	169.4065174	6.229590986	0.986292527
505	IMG_7745_corrected_silhouette.jpg	91.99	27.07959306	2.985690063	0.955840827	161.7492084	6.436061765	0.99952547
506	IMG_7749_corrected_silhouette.jpg	85.49	27.19928187	6.919435915	0.903098169	117.7737882	17.7021844	0.990333779
507	IMG_7770_corrected_silhouette.jpg	97.32	23.60045699	2.540713589	0.975322304	149.7307002	4.076653559	0.999395208
508	IMG_7784_corrected_silhouette.jpg	94.13	15.21045282	1.671520808	0.979877696	191.470559	1.729668735	0.999857632
509	IMG_7793_corrected_silhouette.jpg	95.91	24.21703571	1.238793631	0.984382149	146.2303597	1.132333987	0.998412912
510	IMG_7795_corrected_silhouette.jpg	95.22	24.61400359	0.759104511	0.977666132	167.7202929	2.301268425	0.999209939
511	IMG_7803_corrected_silhouette.jpg	94.11	21.82325953	5.838357662	0.971109643	211.1657455	16.71163152	0.99992252
512	IMG_7807_corrected_silhouette.jpg	94.25	21.56642729	1.793888881	0.983730694	157.4077534	3.88296084	0.999955354

513	IMG_7838_corrected_silhouette.jpg	97.86	23.33931777	2.399753161	0.980133904	178.4560144	1.627832669	0.999845793
514	IMG_7847_corrected_silhouette.jpg	98.13	23.6727366	0.876032381	0.975356911	214.1831239	6.049737766	0.999743408
515	IMG_7907_corrected_silhouette.jpg	77.24	15.81273305	11.33726812	0.731303248	100	41.35110557	0.987831931
516	IMG_7915_corrected_silhouette.jpg	78.1	18.3722322	13.13001163	0.66349845	126.9359086	62.3208475	0.983653462
517	IMG_7919_corrected_silhouette.jpg	76.36	14.84456203	8.980859307	0.701295203	100	27.90830054	0.987343681
518	IMG_7930_corrected_silhouette.jpg	75.65	13.81589685	7.596464124	0.725277746	110.05386	36.19450738	0.980708105
519	IMG_7934_corrected_silhouette.jpg	75.12	14.80789946	8.073859662	0.699805356	101.0771993	31.29109509	0.972572776
520	IMG_7938_corrected_silhouette.jpg	74.88	15.89296401	9.49383093	0.68650329	105.5655296	62.10266183	0.9750679
521	IMG_7947_corrected_silhouette.jpg	90.32	27.70197486	8.39275903	0.928973257	116.1579892	12.66506337	0.99843453
522	IMG_7965_corrected_silhouette.jpg	91.84	34.00872019	1.648245089	0.943048494	127.5071919	4.007844809	0.999065191
523	IMG_7966_corrected_silhouette.jpg	98.51	30.07181328	0.150208264	0.989477701	173.0636868	1.383665269	0.999978331
524	IMG_7970_corrected_silhouette.jpg	79.66	16.29263914	9.068234292	0.791439175	131.0566666	33.53101514	0.987359466
525	IMG_7973_corrected_silhouette.jpg	98.23	30.52064632	0.113546772	0.989931626	166.0682226	1.039681445	0.99995871
526	IMG_7979_corrected_silhouette.jpg	98.71	30.5924596	0.160579385	0.997086519	168.8803408	0.716150894	0.999992314
527	IMG_7981_corrected_silhouette.jpg	98.42	27.79772591	2.504257736	0.980950477	NA	1.872064646	0.999969539
528	IMG_7988_corrected_silhouette.jpg	98.01	30.48473968	0.196668778	0.996889247	193.2837698	0.238716965	0.999999836
529	IMG_7990_corrected_silhouette.jpg	95.02	27.88749252	2.413147237	0.986048605	171.4147655	1.729668735	0.999912764
530	IMG_7992_corrected_silhouette.jpg	81.73	23.82895381	13.63438415	0.826858563	105.02693	19.85548501	0.997682866
531	IMG_7996_corrected_silhouette.jpg	79.68	16.61210265	11.16541392	0.825581287	109.5152603	46.27642239	0.953977166
532	IMG_8004_corrected_silhouette.jpg	76.18	15.27413341	9.451379785	0.762390764	101.7953321	21.46195011	0.994067806
533	IMG_8011_corrected_silhouette.jpg	70.57	22.67014852	9.037528256	0.744351084	127.8510673	23.98474509	0.94906277
537	IMG_8025_corrected_silhouette.jpg	79.7	16.34949132	9.950385952	0.727450605	110.1436266	23.1165126	0.981866415
541	IMG_8039_corrected_silhouette.jpg	92.21	12.09335727	4.812327428	0.967084039	192.1746664	33.81672409	0.999927191
545	IMG_8059_corrected_silhouette.jpg	71.72	30.16157989	3.408767962	0.887727601	125.3256484	34.78423203	0.997935061
546	IMG_8073_corrected_silhouette.jpg	80.44	39.71274686	0.796852459	0.915025615	111.6696589	5.636017897	0.99187694
547	IMG_8084_corrected_silhouette.jpg	91.35	27.34034368	3.89868859	0.933114388	123.8779174	9.985451819	0.998603345
548	IMG_8088_corrected_silhouette.jpg	90.46	27.5583483	1.798023119	0.930064962	112.9263914	8.437675279	0.98474628
549	IMG_8155_corrected_silhouette.jpg	83.37	14.47037702	10.48702117	0.874746547	115.9858452	35.99190143	0.99604377
550	IMG_8159_corrected_silhouette.jpg	79.26	21.41574763	8.593069459	0.787978056	105.2064632	29.58132255	0.995592352
551	IMG_8161_corrected_silhouette.jpg	72.92	23.45900658	6.387615805	0.827351017	105.02693	33.56219883	0.988642925
552	IMG_8175_corrected_silhouette.jpg	76.52	19.21005386	5.184059323	0.794211962	108.2585278	19.38966047	0.987441551
553	IMG_8179_corrected_silhouette.jpg	81.09	20.28725314	6.78475627	0.75915955	126.945367	24.30143999	0.993047006
554	IMG_8187_corrected_silhouette.jpg	77.79	16.85816876	5.659933062	0.714058562	117.9533214	47.13207751	0.966953799
555	IMG_8195_corrected_silhouette.jpg	78.96	13.36923998	5.937354301	0.809281607	113.6445242	19.50270783	0.99560489
556	IMG_8197_corrected_silhouette.jpg	81.76	14.19944508	8.447015587	0.862301057	111.4901257	37.01942436	0.99571324
557	IMG_8201_corrected_silhouette.jpg	84.97	19.60901656	11.00282954	0.807342817	122.0825853	67.42753398	0.995792779
558	IMG_8213_corrected_silhouette.jpg	84.56	16.94140689	11.38423851	0.886751724	120.4667864	38.78924147	0.993001676

559	IMG_8219_corrected_silhouette.jpg	84.69	16.8655613	7.18005784	0.751356104	132.2632886	50.60259588	0.977296505
560	IMG_8229_corrected_silhouette.jpg	83.17	17.90544584	7.628869032	0.869661266	118.8509874	52.44953841	0.990269833
561	IMG_8235_corrected_silhouette.jpg	79.75	16.51705566	9.042249909	0.805498734	104.4883303	38.0288563	0.996580591
562	IMG_8239_corrected_silhouette.jpg	79.42	13.71066805	7.21670186	0.822246189	114.7217235	38.42333187	0.988995765
563	IMG_8245_corrected_silhouette.jpg	87.59	19.47935368	8.595623298	0.838325417	119.0091433	50.42291813	0.992277977
564	IMG_8306_corrected_silhouette.jpg	88.53	24.9551167	10.15561485	0.899102444	123.53908	12.44309563	0.993504557
565	IMG_8312_corrected_silhouette.jpg	84.96	24.3940754	7.548596218	0.894160659	115.529623	61.41944494	0.996045951
566	IMG_8316_corrected_silhouette.jpg	97.29	28.16106694	0.218130307	0.987652998	215.1676954	0.685662279	0.999987881
567	IMG_8319_corrected_silhouette.jpg	97.87	28.18671454	0.126949154	0.987147914	162.9378188	1.367962695	0.999981881
568	IMG_8320_corrected_silhouette.jpg	88.58	28.930495	11.33072623	0.909044258	133.2871569	8.811379672	0.996821303
569	IMG_8323_corrected_silhouette.jpg	97.16	27.97725913	0.209882441	0.978642958	196.2275608	2.160280477	0.999958639
570	IMG_8324_corrected_silhouette.jpg	88.3	24.27688011	11.35388887	0.87040238	129.9866767	24.06953531	0.99634485
571	IMG_8328_corrected_silhouette.jpg	83.78	12.28520133	7.12445419	0.751462792	130.7001795	48.41138154	0.992370282
572	IMG_8340_corrected_silhouette.jpg	96.57	27.94733693	0.334272653	0.977449173	NA	2.066513113	0.999891454
573	IMG_8341_corrected_silhouette.jpg	83.51	18.32521159	10.64987733	0.840178183	138.4201077	20.81521226	0.994471543
574	IMG_8344_corrected_silhouette.jpg	97.24	28.33034112	0.080289697	0.985552871	NA	1.67952272	0.999978638
575	IMG_8347_corrected_silhouette.jpg	86.49	30.02194295	4.781096035	0.879296839	116.1579892	13.99475176	0.980567438
576	IMG_8348_corrected_silhouette.jpg	96.33	28.03282893	0.067857175	0.983086087	180.4308797	1.032838374	0.999982889
577	IMG_8354_corrected_silhouette.jpg	86.7	16.44524237	8.903471834	0.870117293	130.604269	37.14337532	0.990762696
578	IMG_8356_corrected_silhouette.jpg	86.51	16.66490654	6.940019826	0.871456923	134.1318143	31.00049615	0.97068051
579	IMG_8359_corrected_silhouette.jpg	91	23.29035417	14.60038689	0.853927549	140.8601359	28.53428245	0.997938396
580	IMG_8360_corrected_silhouette.jpg	85.95	17.49976377	8.736128815	0.914574517	106.8222621	62.71831721	0.994131548
581	IMG_8366_corrected_silhouette.jpg	87.64	16.03830042	9.619795729	0.887203385	129.8025135	10.29470704	0.997252343
582	IMG_8368_corrected_silhouette.jpg	89.6	27.1294634	5.734845917	0.91711922	152.9700598	37.02752386	0.999568156
583	IMG_8372_corrected_silhouette.jpg	90.08	15.02094554	11.26121885	0.878341027	130.47427	27.05068089	0.996177151
584	IMG_8376_corrected_silhouette.jpg	94.06	21.29916762	8.11850412	0.965026035	116.5170557	31.59685801	0.996513078
585	IMG_8382_corrected_silhouette.jpg	90.13	19.48751428	9.469543518	0.836537796	131.0937824	46.20895099	0.992144879
586	IMG_8388_corrected_silhouette.jpg	85.48	15.61938959	6.544017369	0.874598651	120.4667864	25.23878313	0.991473263
587	IMG_8390_corrected_silhouette.jpg	91.81	28.48593657	1.949127754	0.911230254	191.2028725	14.41727565	0.999299379
588	IMG_8392_corrected_silhouette.jpg	94.28	24.86535009	9.914883253	0.929290157	NA	14.31077763	0.999700944
589	IMG_8393_corrected_silhouette.jpg	85.58	19.61400359	5.698524683	0.915676657	141.4968324	36.65677353	0.997498491
590	IMG_8394_corrected_silhouette.jpg	90.41	38.28545781	3.761281527	0.960527367	134.6628914	50.982493	0.999135626
591	IMG_8396_corrected_silhouette.jpg	88.09	37.25314183	3.898393311	0.920468914	128.4054315	50.86132382	0.994864225
592	IMG_8399_corrected_silhouette.jpg	85.68	18.62657092	6.672492529	0.915761981	124.9551167	40.09143796	0.998871737
593	IMG_8400_corrected_silhouette.jpg	89.73	37.11849192	3.460771441	0.934240397	NA	7.73692122	0.998222356
594	IMG_8403_corrected_silhouette.jpg	87.52	29.08438061	2.029201895	0.896800126	118.491921	9.126053683	0.989052914
595	IMG_8404_corrected_silhouette.jpg	89.46	37.85158588	4.825960537	0.944711234	135.1885099	5.986242187	0.999527428

596	IMG_8408_corrected_silhouette.jpg	87.3	19.22501496	8.216360559	0.909635744	153.4048984	29.55644483	0.997588932
597	IMG_8411_corrected_silhouette.jpg	86.25	20.21244764	8.792449145	0.858578438	108.438061	39.96358592	0.993218442
598	IMG_8415_corrected_silhouette.jpg	84.68	16.82824656	4.695141294	0.873237322	123.8779174	32.60042344	0.991946178
599	IMG_8419_corrected_silhouette.jpg	82.21	12.72691003	7.166763371	0.752657948	106.2836625	45.37490434	0.991091362
600	IMG_8421_corrected_silhouette.jpg	90.42	15.56552962	13.19648503	0.815738448	171.8021248	51.41381591	0.98927739
601	IMG_8427_corrected_silhouette.jpg	84.2	20.64631957	12.67840115	0.850989906	194.9576331	49.02987813	0.991948488
602	IMG_8431_corrected_silhouette.jpg	81.44	10.33900095	9.097051488	0.861416526	145.0628366	54.58067801	0.997719909
603	IMG_8433_corrected_silhouette.jpg	81.33	14.62505179	8.662862162	0.863862582	158.2246757	15.80695345	0.998187299
604	IMG_8441_corrected_silhouette.jpg	82.66	14.4442631	8.190872528	0.765311101	140.9335727	24.83723523	0.979023945
605	IMG_8443_corrected_silhouette.jpg	83.86	17.63272634	8.870013798	0.811334914	113.9138241	26.6147348	0.995067016
606	IMG_8445_corrected_silhouette.jpg	75.19	17.91107825	9.523202499	0.827879691	104.6678636	19.8726107	0.992331565
607	IMG_8449_corrected_silhouette.jpg	76.9	13.07328219	7.789821875	0.702897427	105.02693	39.34287932	0.990027761
608	IMG_8450_corrected_silhouette.jpg	88.22	19.23570146	10.23517555	0.860170988	117.5344105	18.7457427	0.995303058
609	IMG_8455_corrected_silhouette.jpg	77.52	13.32626081	7.48214366	0.696028498	134.8264634	37.85083417	0.981524346
610	IMG_8461_corrected_silhouette.jpg	80.59	12.93636545	7.946239682	0.728456619	125.6732496	31.88429433	0.968551415
611	IMG_8526_corrected_silhouette.jpg	88.58	27.73788151	4.430870985	0.88949891	115.6193896	15.37643709	0.996272366
612	IMG_8528_corrected_silhouette.jpg	87.88	27.33393178	9.45421192	0.86976515	116.3375224	16.91977398	0.996256425
613	IMG_8734_corrected_silhouette.jpg	72.41	7.065159996	3.69834579	0.655567963	106.7324955	35.27468141	0.976046312
614	IMG_8744_corrected_silhouette.jpg	70.7	7.448718438	4.079734781	0.648014574	118.6714542	44.6596697	0.990475236
618	IMG_8779_corrected_silhouette.jpg	80.78	8.669564396	4.057632668	0.744419456	115.6193896	31.88039222	0.979281659
619	IMG_8787_corrected_silhouette.jpg	78.24	8.889083505	4.425069799	0.741204339	116.1579892	31.64585563	0.991259944
620	IMG_8789_corrected_silhouette.jpg	80.25	7.711948933	3.725624972	0.736918952	112.3877917	26.15031796	0.985727739
621	IMG_8800_corrected_silhouette.jpg	77.56	7.465317447	3.973189394	0.708295536	112.0287253	29.70092866	0.972433773
622	IMG_8808_corrected_silhouette.jpg	84.48	9.796690766	6.350636291	0.739383035	118.8509874	36.72519418	0.988570846
623	IMG_9040_corrected_silhouette.jpg	83.73	15.21543986	12.2603353	0.796118136	140.1445724	23.10001019	0.995748589
624	IMG_9042_corrected_silhouette.jpg	83.31	17.28904847	11.65877441	0.861405477	108.7971275	48.9959837	0.996596969
625	IMG_9055_corrected_silhouette.jpg	84.35	16.57315979	11.64130769	0.833679986	122.4607244	43.36620576	0.992484366
626	IMG_9057_corrected_silhouette.jpg	78.71	14.29426349	8.061916157	0.822108052	107.7199282	24.74004313	0.996369169
627	IMG_9072_corrected_silhouette.jpg	75.31	11.05206463	4.930924734	0.80206038	112.4775583	52.00107892	0.990651421
628	IMG_9074_corrected_silhouette.jpg	74.35	16.21783363	9.604607451	0.820506885	106.3734291	24.99965589	0.995164558
629	IMG_9093_corrected_silhouette.jpg	69.85	9.948252191	3.90949371	0.822734625	119.0305206	23.18887003	0.996006475
630	IMG_9095_corrected_silhouette.jpg	69.98	8.965779882	3.472569699	0.801780015	159.4378533	19.53209686	0.996847017
631	IMG_9097_corrected_silhouette.jpg	78.35	14.99102334	9.100893428	0.794541478	114.1831239	50.11899423	0.996103246
632	IMG_9103_corrected_silhouette.jpg	73.94	12.02182019	7.331021667	0.800791228	106.4631957	23.49163148	0.986193366
633	IMG_9105_corrected_silhouette.jpg	71.19	10.38197239	5.244369654	0.7958464	126.7504488	31.43277142	0.988616765
634	IMG_9107_corrected_silhouette.jpg	76.07	12.40340332	8.432314203	0.828811793	110.2333932	22.39195204	0.998323731
635	IMG_9114_corrected_silhouette.jpg	69.96	10.83413893	5.131998238	0.76504597	133.5063088	20.12360125	0.996558988

636	IMG_9116_corrected_silhouette.jpg	73.7	10.87253142	4.40041974	0.720240526	114.7217235	22.28324595	0.985868215
637	IMG_9134_corrected_silhouette.jpg	76.92	9.677419355	4.486499888	0.809533226	126.2118492	28.49806357	0.98683363
638	IMG_9136_corrected_silhouette.jpg	82.01	11.29678221	7.490288004	0.829953276	108.9766607	34.04016918	0.986564152
641	IMG_9381_corrected_silhouette.jpg	90.29	17.47456613	15.4758255	0.830058555	132.8545781	25.52997614	0.997776141
642	IMG_9383_corrected_silhouette.jpg	90.65	29.71274686	17.94245632	0.818134492	146.1367589	24.24278904	0.997693849
643	IMG_9405_corrected_silhouette.jpg	86.92	18.64383372	9.658109929	0.847092502	137.432675	25.16469038	0.997989192
644	IMG_9407_corrected_silhouette.jpg	91.83	13.58467983	11.41060341	0.912715451	NA	9.360323228	0.995360365
645	IMG_9417_corrected_silhouette.jpg	72.83	14.43447038	9.907333675	0.769237378	114.5421903	26.5672646	0.985351322
646	IMG_9419_corrected_silhouette.jpg	78.52	22.67014852	17.64001138	0.750009133	118.6810166	33.89981273	0.965461331
647	IMG_9425_corrected_silhouette.jpg	79.6	20.94554159	14.4157244	0.862478227	108.6735818	47.30460467	0.993756008
648	IMG_9448_corrected_silhouette.jpg	74.92	8.423504294	2.980941754	0.820421799	111.8491921	18.90634644	0.997315057
649	IMG_9456_corrected_silhouette.jpg	85.95	14.90125673	6.419829243	0.781538397	142.7289048	23.16294402	0.995232646
650	IMG_9462_corrected_silhouette.jpg	81.88	14.75763016	6.010475981	0.736343169	105.7450628	34.4023024	0.989187905
651	IMG_9464_corrected_silhouette.jpg	83.1	13.40514662	6.446840656	0.736331967	134.9404485	58.06656017	0.991353441
652	IMG_9466_corrected_silhouette.jpg	82.75	9.671776458	4.456883027	0.790591132	150.3325759	30.61297588	0.993597476
653	IMG_9468_corrected_silhouette.jpg	78.15	12.95332137	5.903017061	0.888536906	117.5942549	23.90563937	0.997264519
655	P7131773_corrected_silhouette.jpg	98.93	32.02872532	0.204699358	0.975216188	185.4292383	4.271253093	0.999946658
656	P7131777_corrected_silhouette.jpg	98.73	31.98255963	0.350412953	0.984988235	194.5255099	NA	0.999995263
657	P7131781_corrected_silhouette.jpg	98.72	32.11079764	0.067857175	0.975427825	186.0283664	NA	0.999767556
658	P7131791_corrected_silhouette.jpg	98.73	31.77737882	0.393337563	0.953319856	196.9114715	NA	0.999925946
659	P7131797_corrected_silhouette.jpg	98.83	31.99281867	0.321158776	0.982773716	198.7650759	1.938685385	0.999958508
660	P7131804_corrected_silhouette.jpg	86.08	15.39089277	2.142533017	0.933673315	232.1364452	8.170380747	0.999851509
661	P7131832_corrected_silhouette.jpg	98.7	31.95691203	0.191929077	0.979864663	230.8003417	2.581374693	0.999618729

2.4 P-DATASET USED TO RELATE THE PATTERN CLUSTERS WITH THE CONTEXT

Num.	Pattern image name	SP	HMN	HSD	RC	LMT	CSD	UA	Pattern cluster	Pattern subcluster	Building name	Work environment	Wall thickness	Pattern estimated construction year
1	20150716_105357_corrected_silhouette.jpg	89.55	20.79593058	9.052020328	0.78655912	138.4095886	50.5884406	0.996029725	2	2.1	GILBERTFIELD CASTLE	0	0.85	1607
2	20150716_105801_corrected_silhouette.jpg	76.31	15.8245704	7.988679347	0.785962096	159.5726752	25.92654747	0.997280727	2	2.1	GILBERTFIELD CASTLE	0	0.85	1607
3	20150716_105919_corrected_silhouette.jpg	85.94	17.64321854	8.280390588	0.879829031	176.5423951	24.36050235	0.997586583	1	1.4	GILBERTFIELD CASTLE	0	0.85	1607
4	20150716_110249_corrected_silhouette.jpg	83.09	17.43584328	10.01971519	0.817234901	109.8743268	14.65754983	0.990237657	2	2.1	GILBERTFIELD CASTLE	0	1	1607
5	20150716_111035_corrected_silhouette.jpg	86.67	29.48833034	5.122992128	0.850725335	160.5320354	7.655804758	0.997611772	1	1.3	GILBERTFIELD CASTLE	0	0.8	1607
6	DSC_0015_corrected_silhouette.jpg	99.23	30.16157989	0	0.99999781	170.6957368	0	1	3	3.2	CHATELHERAULT HUNTING LODGE	1	0.85	1731
7	DSC_0025_corrected_silhouette.jpg	98.97	30.81238779	0.19042373	0.976644367	239.5021683	3.487386077	0.999952294	3	3.2	CHATELHERAULT HUNTING LODGE	1	0.85	1731
8	DSC_0027_corrected_silhouette.jpg	98.96	30.67773788	0.115057441	0.969710152	220.283119	3.248279259	0.999667069	3	3.2	CHATELHERAULT HUNTING LODGE	1	0.85	1731
9	DSC_0038_corrected_silhouette.jpg	98.96	31.01436266	1.246615936	0.965716719	231.4376782	5.009537591	0.999872584	3	3.2	CHATELHERAULT HUNTING LODGE	1	0.85	1731
10	DSC_0044_corrected_silhouette.jpg	98.96	30.58797128	0.479222544	0.954921791	209.2844837	6.088082763	0.999420415	3	3.2	CHATELHERAULT HUNTING LODGE	1	0.85	1731
11	DSC_0054_corrected_silhouette.jpg	99	30.2513465	0.599298356	0.999996699	194.6792486	0	1	3	3.2	CHATELHERAULT HUNTING LODGE	1	0.85	1731
12	DSC_0368_corrected_silhouette.jpg	80.89	16.92100539	10.33119662	0.812503245	113.2854578	24.58483805	0.995241767	2	2.1	ABERDOUR CASTLE	0	1.1	1648
13	DSC_0381_corrected_silhouette.jpg	82.37	17.77378815	13.02215043	0.802944099	108.0789946	32.17623562	0.992079856	2	2.1	ABERDOUR CASTLE	0	1.15	1648
14	DSC_0382_corrected_silhouette.jpg	80.54	15.3700379	10.78134189	0.811421021	118.3123878	75.26510472	0.963422145	2	2.1	ABERDOUR CASTLE	0	1.05	1500
15	DSC_0384_corrected_silhouette.jpg	77.51	15.16628195	9.155598785	0.799470361	129.2379928	30.97640799	0.994847895	2	2.1	ABERDOUR CASTLE	0	1.05	1500
16	DSC_0385_corrected_silhouette.jpg	78.08	15.21757716	9.145257799	0.807512097	123.4241898	35.87293307	0.994962357	2	2.1	ABERDOUR CASTLE	0	1.05	1500
17	DSC_0406_corrected_silhouette.jpg	88.25	25.35906643	11.68513583	0.835154551	128.072482	11.22060904	0.987115772	2	2.1	ABERDOUR CASTLE	0	1.05	1648
18	DSC_0417_corrected_silhouette.jpg	77.97	13.56373429	8.97788426	0.667336832	110.2333932	42.59386059	0.989026573	2	2.2	ABERDOUR CASTLE	0	0.8	1648
19	DSC_0431_corrected_silhouette.jpg	88.54	24.50628366	7.004754046	0.852255784	109.8743268	19.42599997	0.993688218	2	2.1	ABERDOUR CASTLE	0	1.05	1648
20	DSC_0433_corrected_silhouette.jpg	88.98	25.79293836	8.386814859	0.929247864	128.7253142	4.271134568	0.999218439	1	1.1	ABERDOUR CASTLE	0	0.8	1648
21	DSC_0449_corrected_silhouette.jpg	86.4	18.18181818	12.07848731	0.816764093	112.3877917	15.14725996	0.997969301	2	2.1	ABERDOUR CASTLE	0	1.05	1648
22	DSC_0464_corrected_silhouette.jpg	78.28	15.94065955	7.555004453	0.785185144	106.1041293	32.90465024	0.977605755	2	2.2	ABERDOUR CASTLE	0	1.05	1500
23	DSC_0477_corrected_silhouette.jpg	71.06	11.37587727	5.851174831	0.781451887	107.8994614	24.42773604	0.99151368	2	2.2	ABERDOUR CASTLE	0	0.6	1500
24	DSC_0483_corrected_silhouette.jpg	77.51	15.58770726	9.356039585	0.770014779	114.1831239	40.59000309	0.986954454	2	2.2	ABERDOUR CASTLE	0	1.25	1500
25	DSC_0485_corrected_silhouette.jpg	78.74	15.71813285	9.178765212	0.786603784	102.3339318	43.21852541	0.973415033	2	2.2	ABERDOUR CASTLE	0	0.9	1648
26	DSC_0492_corrected_silhouette.jpg	84.02	19.50927588	10.23449074	0.771658837	101.9748654	64.68427877	0.9854159	2	2.1	ABERDOUR CASTLE	0	0.9	1648
27	DSC_0494_corrected_silhouette.jpg	76.72	12.65376687	7.567206652	0.782440489	115.1705566	26.62063402	0.988677746	2	2.2	ABERDOUR CASTLE	0	0.9	1648
28	DSC_0507_corrected_silhouette.jpg	87.35	26.78037104	5.783104694	0.93435219	119.9281867	39.26201698	0.999470317	1	1.1	ABERDOUR CASTLE	0	0.8	1400
29	DSC_0512_corrected_silhouette.jpg	86.86	24.90125673	1.56981809	0.915507119	114.5421903	8.831228913	0.994242543	1	1.3	ABERDOUR CASTLE	0	2.05	1300
30	DSC_0516_corrected_silhouette.jpg	81.02	24.90125673	2.137794249	0.912737428	138.5543215	27.18825225	0.998604216	1	1.3	ABERDOUR CASTLE	0	2.05	1300
31	DSC_0522_corrected_silhouette.jpg	82.7	24.11729503	1.590668325	0.931410382	118.1328546	5.055610286	0.996703072	1	1.3	ABERDOUR CASTLE	0	2.05	1300
32	DSC_0530_corrected_silhouette.jpg	89.58	27.34889288	9.062426905	0.930265654	142.9084381	6.981858671	0.997223606	1	1.1	ABERDOUR CASTLE	0	1.95	1400
33	DSC_0534_corrected_silhouette.jpg	83.34	16.50708159	8.936327644	0.858120899	148.6535009	49.94579345	0.998118747	2	2.1	ABERDOUR CASTLE	0	0.95	1400
34	DSC_0536_corrected_silhouette.jpg	84.7	22.3967684	9.555461491	0.89536339	108.438061	7.126388551	0.983642687	2	2.1	ABERDOUR CASTLE	0	0.95	1400
35	DSC_0538_corrected_silhouette.jpg	80.26	13.29293836	9.137498942	0.802052723	101.7953321	53.41219571	0.978077715	2	2.2	ABERDOUR CASTLE	0	1.65	1500
36	DSC_0542_corrected_silhouette.jpg	74.72	11.25250818	6.295033598	0.801285867	127.3345365	33.87553498	0.976858653	2	2.2	ABERDOUR CASTLE	0	1.15	1500
37	DSC_0951_corrected_silhouette.jpg	98.79	30.56552962	0.185834527	0.998220488	215.0477948	0	0.999997187	3	3.2	CHATELHERAULT HUNTING LODGE	1	0.85	1731
38	DSC_0958_corrected_silhouette.jpg	99.09	30.41292639	0.590006345	0.998549931	185.2987867	0	0.999999546	3	3.2	CHATELHERAULT HUNTING LODGE	1	0.85	1731
39	DSC_0966_corrected_silhouette.jpg	98.41	30.84979055	0.287626925	0.985263975	172.5875495	3.403806654	0.999975898	3	3.2	CHATELHERAULT HUNTING LODGE	1	0.85	1731
40	DSC_0972_corrected_silhouette.jpg	98.27	30.5924596	0.098334389	0.985898396	206.5761236	2.59252177	0.999970537	3	3.2	CHATELHERAULT HUNTING LODGE	1	0.85	1731
41	DSC_0996_corrected_silhouette.jpg	99.1	30.52064632	0.278131658	0.99999451	228.9827605	0	1	3	3.2	CHATELHERAULT HUNTING LODGE	1	0.85	1731
42	DSC_0998_corrected_silhouette.jpg	98.99	30.81238779	0.650420856	0.999996699	200.4882287	0	1	3	3.2	CHATELHERAULT HUNTING LODGE	1	0.85	1731
43	IMG_0313_corrected_silhouette.jpg	89.11	20.72326237	5.867495606	0.9008047	123.1597846	63.7192097	0.99541585	2	2.1	CASTLE CAMPBELL	0	NA	1400
44	IMG_0320_corrected_silhouette.jpg	82.97	12.05592732	7.148449364	0.770368046	108.7971275	47.93172234	0.989831052	2	2.2	CASTLE CAMPBELL	0	NA	1400
45	IMG_0586_corrected_silhouette.jpg	82.2	11.27981534	6.411872727	0.798496765	103.9497307	55.34287476	0.967918855	2	2.2	CASTLE CAMPBELL	0	1.05	1500
46	IMG_0597_corrected_silhouette.jpg	78.46	14.42602176	9.497023014	0.683477363	100.1795332	62.21563756	0.985013913	2	2.2	CASTLE CAMPBELL	0	2.25	1400
47	IMG_0599_corrected_silhouette.jpg	87.13	25.13464991	3.084629313	0.913667388	120.6463196	11.06898732	0.997312203	1	1.3	CASTLE CAMPBELL	0	2.25	1400
48	IMG_0603_corrected_silhouette.jpg	95.04	28.9561426	1.50820112	0.9771316	131.4454612	2.83875589	0.999537496	3	3.1	CASTLE CAMPBELL	0	NA	1590
49	IMG_0685_corrected_silhouette.jpg	79.16	10.59936473	6.130575464	0.656251168	104.8473968	33.93066299	0.98081818	2	2.2	CASTLE CAMPBELL	0	NA	1500
50	IMG_0687_corrected_silhouette.jpg	85.76	13.72901046	7.399926349	0.832760984	106.6427289	42.52196216	0.990144084	2	2.1	CASTLE CAMPBELL	0	NA	1500
51	IMG_0691_corrected_silhouette.jpg	74.9	16.14901257	6.850916068	0.800895171	133.0317167	37.79872088	0.991685724	2	2.2	CASTLE CAMPBELL	0	NA	1500
52	IMG_1492_corrected_silhouette.jpg	88.42	13.15317018	11.32464908	0.837684531	154.0729826	26.24831451	0.998328141	2	2.1	PITTARTHIE CASTLE	NA	NA	1598
53	IMG_1503_corrected_silhouette.jpg	88.98	20.7153708	10.63106963	0.779907376	172.5022368	20.18742517	0.991546022	2	2.1	PITTARTHIE CASTLE	NA	NA	1598
54	IMG_1505_corrected_silhouette.jpg	86.62	12.66706563	10.30074609	0.811586883	108.6175943	49.31450171	0.993862252	2	2.1	PITTARTHIE CASTLE	2	NA	1682
55	IMG_1508_corrected_silhouette.jpg	85.92	13.69135899	9.700869375	0.771631708	155.2628731	43.61500171	0.978101097	2	2.1	PITTARTHIE CASTLE	2	NA	1682
56	IMG_1512_corrected_silhouette.jpg	88.55	17.67119774	11.66757958	0.873860958	151.7055655	27.07974047	0.996302614	1	1.4	PITTARTHIE CASTLE	2	NA	1682
57	IMG_1533_corrected_silhouette.jpg	88.94	18.57171355	8.621852962	0.827493901	112.2082585	61.54396135	0.994581792	2	2.1	PITTARTHIE CASTLE	2	NA	1682
58	IMG_1540_corrected_silhouette.jpg	87.18	14.53096948	9.798954763	0.786604741	111.1310592	38.00068116	0.994133395	2	2.1	PITTARTHIE CASTLE	2	NA	1682
59	IMG_1542_corrected_silhouette.jpg	88.64	14.25044883	9.355701828	0.807470509	134.3821665	41.54575311	0.993822009	2	2.1	PITTARTHIE CASTLE	2	NA	1682
60	IMG_1554_corrected_silhouette.jpg	86.27	20.95642239	14.65217423	0.764529999	121.1849192	41.57833901	0.97488043	2	2.1	PITTARTHIE CASTLE	NA	1.15	1598
61	IMG_1568_corrected_silhouette.jpg	90.85	13.80011969	10.25493848	0.84998367	146.4991023	72.59393443	0.996220651	2	2.1	PITTARTHIE CASTLE	NA	1.15	1598

62	IMG_1571_corrected_silhouette.jpg	87.55	16.11310593	9.458634848	0.873299356	134.3364974	35.56895404	0.997328669	2	2.1	PITTARTHIE CASTLE	NA	NA	1598
63	IMG_1784_corrected_silhouette.jpg	87.89	22.7316669	4.743516696	0.970835371	119.5691203	65.88275652	0.999434709	1	1.1	KINROSS HOUSE	2	1.23	1684
64	IMG_1786_corrected_silhouette.jpg	92.99	24.00615542	5.046889379	0.969544568	181.9543701	2.857605398	0.999979858	3	3.1	KINROSS HOUSE	2	1.23	1684
65	IMG_1791_corrected_silhouette.jpg	97.46	30.31119091	0.264265735	0.983020519	182.5852783	1.470679748	0.99997732	3	3.2	KINROSS HOUSE	2	1.23	1684
66	IMG_1807_corrected_silhouette.jpg	98	30.52064632	0.253898306	0.986665652	178.6355476	1.428724792	0.999693509	3	3.2	KINROSS HOUSE	2	1.23	1684
67	IMG_1846_corrected_silhouette.jpg	78.04	10.04072339	3.832390816	0.75204446	105.6552962	32.70758874	0.986981936	2	2.2	AUCHANS CASTLE	0	0.85	1650
68	IMG_1848_corrected_silhouette.jpg	97.41	30.37103531	0.176515635	0.987021609	184.9192101	1.989169449	0.999911017	3	3.2	KINROSS HOUSE	2	1.23	1684
69	IMG_1851_corrected_silhouette.jpg	69.22	9.207005183	4.506987512	0.720878665	102.1543986	32.89990915	0.969223416	2	2.2	AUCHANS CASTLE	0	0.85	1650
70	IMG_1864_corrected_silhouette.jpg	97.38	30.48473968	0.15020826	0.979628547	187.7356928	2.184599124	0.999812445	3	3.2	KINROSS HOUSE	2	1.23	1684
71	IMG_1895_corrected_silhouette.jpg	82.66	13.24955117	7.412678328	0.727614863	122.6211849	45.61152535	0.980140443	2	2.2	AUCHANS CASTLE	0	0.85	1650
72	IMG_1936_corrected_silhouette.jpg	97.39	29.94614003	0.196668783	0.976199593	188.0633669	3.148620721	0.99998689	3	3.2	KINROSS HOUSE	2	1.23	1684
73	IMG_1990_corrected_silhouette.jpg	89.16	16.16921005	4.093183378	0.943200548	209.8563293	2.856132272	0.999563792	1	1.2	KINROSS HOUSE	2	1.23	1684
74	IMG_1996_corrected_silhouette.jpg	86.58	13.67017184	7.687419167	0.717289257	110.7121484	59.65518698	0.985776061	2	2.2	AUCHANS CASTLE	0	0.85	1650
75	IMG_1999_corrected_silhouette.jpg	84.11	11.02225124	6.596767611	0.709720922	105.1166966	50.86717859	0.979238192	2	2.2	AUCHANS CASTLE	0	1.1	1500
76	IMG_2470_corrected_silhouette.jpg	81.4	14.67447794	8.358496519	0.754081654	120.2872531	41.20325141	0.989625167	2	2.2	REDHOUSE CASTLE	0	NA	1600
77	IMG_2986_corrected_silhouette.jpg	75.87	7.839616996	5.935466878	0.799171033	111.7594255	38.93160075	0.987322323	2	2.2	BARNBARROCH HOUSE	0	0.9	1780
78	IMG_4493_corrected_silhouette.jpg	84.84	21.15927161	8.27468117	0.773211475	114.3626571	21.61354582	0.981509234	2	2.1	BABERTON HOUSE	3	1.32	1622
79	IMG_4500_corrected_silhouette.jpg	83.68	17.1454219	7.672346744	0.844012014	115.2603232	59.91593271	0.99157108	2	2.1	BABERTON HOUSE	3	1.32	1622
80	IMG_4502_corrected_silhouette.jpg	87.59	21.42973723	11.69401483	0.855100556	127.8276481	13.59472928	0.994980448	1	1.4	BABERTON HOUSE	3	1.32	1622
81	IMG_4506_corrected_silhouette.jpg	86	19.58194409	8.983691291	0.869174443	132.4499602	30.9079885	0.991125322	2	2.1	BABERTON HOUSE	3	NA	1622
82	IMG_4510_corrected_silhouette.jpg	88.51	21.45421903	9.624721835	0.889567999	124.2369838	46.97974193	0.996053908	2	2.1	BABERTON HOUSE	3	NA	1622
83	IMG_4514_corrected_silhouette.jpg	86.72	22.95032914	7.655640916	0.882070739	136.6247756	11.94100464	0.997726809	1	1.4	BABERTON HOUSE	3	0.82	1622
84	IMG_4518_corrected_silhouette.jpg	89.34	19.07540395	8.113964178	0.798003333	149.0730892	31.70873662	0.979663968	2	2.1	BABERTON HOUSE	3	NA	1622
85	IMG_4522_corrected_silhouette.jpg	85.93	15.7390784	8.254032361	0.865706262	145.2423698	31.81344753	0.995223422	2	2.1	BABERTON HOUSE	3	NA	1622
86	IMG_4526_corrected_silhouette.jpg	88.57	23.96768402	13.35459576	0.831248038	137.3429084	32.31569406	0.997483908	1	1.4	BABERTON HOUSE	3	NA	1622
87	IMG_4530_corrected_silhouette.jpg	83.15	20.47961016	10.38251474	0.763832867	118.491921	25.83767861	0.950995842	2	2.1	BABERTON HOUSE	3	NA	1622
88	IMG_4532_corrected_silhouette.jpg	86.03	24.9551167	6.232802635	0.841199106	130.9802498	19.6293731	0.993689702	2	2.1	BABERTON HOUSE	3	NA	1622
89	IMG_4544_corrected_silhouette.jpg	89.46	13.64452424	7.444797865	0.88888895	147.5768141	27.53293084	0.997514418	2	2.1	BABERTON HOUSE	3	NA	1622
90	IMG_4632_corrected_silhouette.jpg	89.2	21.08517854	12.35917359	0.787562284	125.1346499	51.64425695	0.988168641	2	2.1	WARDHOUSE	0	0.75	1757
91	IMG_4637_corrected_silhouette.jpg	90.33	24.9551167	9.703813498	0.840804249	122.0535433	29.31192667	0.983831543	2	2.1	WARDHOUSE	0	0.6	1757
92	IMG_4641_corrected_silhouette.jpg	85.59	19.00059845	8.926195123	0.902956969	105.9245961	61.16572965	0.991075136	2	2.1	WARDHOUSE	0	0.6	1757
93	IMG_4647_corrected_silhouette.jpg	87.26	19.25901746	8.497097011	0.845498384	124.7210573	37.98045194	0.986790107	2	2.1	WARDHOUSE	0	0.6	1757
94	IMG_4656_corrected_silhouette.jpg	93.7	25.04488331	9.036604166	0.953215746	132.3159785	7.279044413	0.996389983	1	1.1	WARDHOUSE	0	0.95	1757
95	IMG_4664_corrected_silhouette.jpg	91.51	30.23339318	1.316848892	0.949079058	157.6550153	10.41235571	0.99952138	3	3.1	WARDHOUSE	0	0.85	1757
96	IMG_4672_corrected_silhouette.jpg	90.84	30.48473968	1.010821419	0.93859201	157.0915619	12.14548816	0.996419246	3	3.1	WARDHOUSE	0	0.85	1757
97	IMG_4682_corrected_silhouette.jpg	91.66	27.63016158	7.074535081	0.949510066	131.2387792	18.5161518	0.997590357	1	1.1	WARDHOUSE	0	0.95	1757
98	IMG_4699_corrected_silhouette.jpg	84.37	20.76600838	9.79592099	0.807523466	107.2710952	46.28530651	0.972412493	2	2.1	WARDHOUSE	0	0.6	1757
99	IMG_4721_corrected_silhouette.jpg	90.28	18.81834503	12.0002391	0.848349793	117.7737882	52.64262537	0.995988787	2	2.1	WARDHOUSE	0	0.75	1757
100	IMG_4725_corrected_silhouette.jpg	89.85	22.81867145	10.57552396	0.865211527	150.7856911	25.75401492	0.998311061	1	1.4	WARDHOUSE	0	0.75	1757
101	IMG_4729_corrected_silhouette.jpg	89.16	24.79802513	11.57932066	0.838511338	129.6871126	18.86302289	0.99694823	1	1.4	WARDHOUSE	0	0.85	1757
102	IMG_4733_corrected_silhouette.jpg	68.84	10.80651844	5.738106028	0.762033699	128.4893089	38.46984739	0.990149237	2	2.2	WARDHOUSE	0	0.45	1850
103	IMG_4740_corrected_silhouette.jpg	88.65	16.38539796	5.870122969	0.864150618	137.7917415	34.35141593	0.999084606	1	1.4	WARDHOUSE	0	0.55	1757
104	IMG_4748_corrected_silhouette.jpg	72.73	27.25912627	2.828241746	0.791320804	130.6156474	9.157124847	0.998337177	1	1.3	WARDHOUSE	0	0.95	1757
105	IMG_4757_corrected_silhouette.jpg	87.37	19.21005386	10.75077703	0.895743138	122.9802513	53.88461057	0.995569638	2	2.1	WARDHOUSE	0	1.05	1757
106	IMG_4762_corrected_silhouette.jpg	89.96	21.10512667	10.20149645	0.858408229	114.3626571	16.52492976	0.994362265	2	2.1	WARDHOUSE	0	0.65	1850
107	IMG_4782_corrected_silhouette.jpg	85.72	19.22287766	10.4515388	0.836621637	137.2759181	33.93115938	0.994851423	2	2.1	WARDHOUSE	0	0.55	1850
108	IMG_4836_corrected_silhouette.jpg	98.91	30.46080192	0.126949153	0.998341998	187.8819708	0.358075447	0.999991086	3	3.2	CRAIGIEHALL HOUSE	2	0.85	1695
109	IMG_4852_corrected_silhouette.jpg	98.93	30.44085378	0.09462231	0.999692643	189.0187316	0.206734956	0.999999266	3	3.2	CRAIGIEHALL HOUSE	2	0.8	1695
110	IMG_4885_corrected_silhouette.jpg	99.07	29.86235787	0.270295387	0.984287607	148.2276044	3.178588646	0.999978491	3	3.2	CRAIGIEHALL HOUSE	2	0.85	1695
111	IMG_4895_corrected_silhouette.jpg	98.76	28.27648115	3.627874224	0.984360076	192.6411578	2.190626075	0.999952774	3	3.1	CRAIGIEHALL HOUSE	2	0.85	1695
112	IMG_4902_corrected_silhouette.jpg	98.83	28.58168761	4.402043102	0.98654078	214.7890768	2.134147253	0.999994228	3	3.2	CRAIGIEHALL HOUSE	2	0.85	1695
113	IMG_5141_corrected_silhouette.jpg	80.18	17.29930752	8.212648584	0.869234871	116.469443	28.87995913	0.974776852	2	2.1	BURLEIGH CASTLE	0	1.45	1450
114	IMG_5142_corrected_silhouette.jpg	83.1	14.89180762	8.60896105	0.892902162	133.3216349	26.96124271	0.985578712	2	2.1	LINLITHGOW PALACE	3	1.1	1618
115	IMG_5168_corrected_silhouette.jpg	79.64	11.8491921	5.865747896	0.845873379	103.2315978	27.21846431	0.998131538	2	2.2	BURLEIGH CASTLE	0	1.55	1450
116	IMG_5172_corrected_silhouette.jpg	93.88	25.97247157	1.804881844	0.964082348	224.7755835	2.375203809	0.99993946	3	3.1	LINLITHGOW PALACE	3	0.95	1618
117	IMG_5174_corrected_silhouette.jpg	87.16	14.36265709	7.399349831	0.88774335	107.3608618	45.93460853	0.998302819	2	2.1	LINLITHGOW PALACE	NA	NA	1424
118	IMG_5176_corrected_silhouette.jpg	88.51	16.10669402	7.498660844	0.860130787	158.7073609	31.71579497	0.998838648	1	1.4	LINLITHGOW PALACE	NA	NA	1424
119	IMG_5179_corrected_silhouette.jpg	90.66	21.49502203	4.515601822	0.874215378	133.0341113	65.7526429	0.993648432	1	1.4	LINLITHGOW PALACE	NA	NA	1424
120	IMG_5205_corrected_silhouette.jpg	82.93	15.87073609	9.64737198	0.875097867	113.1059246	20.2131869	0.995473839	2	2.1	LINLITHGOW PALACE	NA	NA	1437
121	IMG_5206_corrected_silhouette.jpg	84.8	17.36983842	9.755993774	0.86151281	121.1691323	26.47860747	0.998154951	2	2.1	BURLEIGH CASTLE	0	1.45	1450
122	IMG_5211_corrected_silhouette.jpg	84.85	14.81149013	9.809162952	0.879471816	129.5332136	30.13539215	0.996501066	2	2.1	LINLITHGOW PALACE	NA	NA	1437
123	IMG_5213_corrected_silhouette.jpg	84.61	17.98094186	8.738875197	0.90784333	159.6210596	13.60210136	0.999152997	1	1.2	LINLITHGOW PALACE	NA	NA	1437
124	IMG_5217_corrected_silhouette.jpg	85.14	23.89587074	5.449752312	0.86602675	125.6732496	20.44346088	0.990628901	2	2.1	LINLITHGOW PALACE	NA	NA	1437

125	IMG_5243_corrected_silhouette.jpg	79.49	18.59451141	7.880202221	0.893637195	122.7714794	23.61743253	0.989403777	2	2.1	LINLITHGOW PALACE	NA	NA	1437
126	IMG_5245_corrected_silhouette.jpg	80.83	20.72112507	8.450885431	0.921865102	122.8828268	18.02206763	0.997916886	2	2.1	LINLITHGOW PALACE	NA	NA	1437
127	IMG_5249_corrected_silhouette.jpg	83.81	19.53647789	7.152012955	0.901916374	131.059246	23.5692184	0.996725859	2	2.1	LINLITHGOW PALACE	NA	NA	1437
128	IMG_5253_corrected_silhouette.jpg	69.85	12.93921518	6.983699748	0.811296438	115.2603232	20.43483543	0.99854769	2	2.2	LINLITHGOW PALACE	NA	NA	1437
129	IMG_5255_corrected_silhouette.jpg	67.86	12.63913824	7.785498449	0.793212647	100.3590664	50.13466067	0.978728672	2	2.2	LINLITHGOW PALACE	NA	NA	1437
130	IMG_5266_corrected_silhouette.jpg	78.74	14.20424543	9.57727714	0.835430963	103.7701975	12.10772941	0.959371388	2	2.1	LINLITHGOW PALACE	3	NA	1618
131	IMG_5268_corrected_silhouette.jpg	80.92	12.37881508	8.897405965	0.859303633	129.443447	16.61701367	0.992476523	2	2.1	LINLITHGOW PALACE	3	NA	1618
132	IMG_5284_corrected_silhouette.jpg	83.33	14.37462597	7.880046399	0.805523086	114.7217235	33.52479633	0.998516188	2	2.1	LINLITHGOW PALACE	NA	NA	1424
133	IMG_5287_corrected_silhouette.jpg	76.46	15.4510772	7.454547864	0.831164597	128.994614	42.60259704	0.996095624	2	2.1	LINLITHGOW PALACE	NA	NA	1424
134	IMG_5289_corrected_silhouette.jpg	79.18	14.64478071	5.541069282	0.867618259	151.7055655	16.15080856	0.998361855	2	2.1	LINLITHGOW PALACE	NA	NA	1424
135	IMG_5291_corrected_silhouette.jpg	81.13	19.88330341	6.690911235	0.875186749	131.7773788	16.49155742	0.996632967	2	2.1	LINLITHGOW PALACE	NA	NA	1424
136	IMG_5293_corrected_silhouette.jpg	79.91	13.51885099	7.166454406	0.814410333	106.8222621	48.687717	0.995694203	2	2.2	LINLITHGOW PALACE	NA	NA	1424
137	IMG_5299_corrected_silhouette.jpg	84.91	19.42222948	4.879089283	0.904494163	114.51704	45.93626403	0.99655248	2	2.1	LINLITHGOW PALACE	NA	NA	1424
138	IMG_5306_corrected_silhouette.jpg	94.1	28.68043088	2.31660465	0.941922004	219.8411948	4.862719936	0.999001304	3	3.1	LINLITHGOW PALACE	NA	NA	1424
139	IMG_5308_corrected_silhouette.jpg	95.68	30.59245961	3.719848469	0.942523623	206.4631957	63.29239023	0.999874532	1	1.1	LINLITHGOW PALACE	NA	NA	1424
140	IMG_5312_corrected_silhouette.jpg	85.83	19.75810262	9.552725508	0.861472022	107.3608618	22.17523219	0.978548885	2	2.1	LINLITHGOW PALACE	NA	NA	1424
141	IMG_5323_corrected_silhouette.jpg	85.99	21.1101137	14.31615991	0.863116891	128.2967219	29.99167505	0.983587727	2	2.1	LINLITHGOW PALACE	NA	NA	1424
142	IMG_5327_corrected_silhouette.jpg	85.06	20.90065829	10.76585929	0.86181265	117.4147217	52.21045984	0.996442381	2	2.1	LINLITHGOW PALACE	NA	NA	1424
143	IMG_5475_corrected_silhouette.jpg	98.84	30.65529623	0.269299821	0.996721336	194.0928566	0.53378736	0.999966281	3	3.2	NEWLISTON HOUSE	1	NA	1789
144	IMG_5627_corrected_silhouette.jpg	98.81	30.49072412	0.264265735	0.985551137	389.4274533	1.691346978	0.999997855	3	3.2	PENICUIK HOUSE	NA	0.85	1857
145	IMG_5633_corrected_silhouette.jpg	98.58	30.36676071	0.24150546	0.975868166	243.828702	2.915371042	0.999984978	3	3.2	PENICUIK HOUSE	NA	0.85	1857
146	IMG_5634_corrected_silhouette.jpg	98.47	30.34111311	0.146588256	0.996894864	242.6102489	0.206734956	0.999998797	3	3.2	PENICUIK HOUSE	NA	0.85	1857
147	IMG_5640_corrected_silhouette.jpg	98.76	30.64033513	0.092710551	0.992109767	307.5460873	0.990593975	0.999998006	3	3.2	PENICUIK HOUSE	NA	1	1857
148	IMG_5648_corrected_silhouette.jpg	98.64	28.13541934	2.864505331	0.986957115	191.3431977	1.232044956	0.99999431	3	3.2	PENICUIK HOUSE	1	1.05	1701
149	IMG_5665_corrected_silhouette.jpg	98.74	28.81508079	2.722164028	0.983389687	243.0609139	2.287414569	0.999990008	3	3.2	PENICUIK HOUSE	1	1.05	1701
150	IMG_5672_corrected_silhouette.jpg	98.77	30.44370351	0.203571528	0.981056347	253.6343565	1.953326262	0.999985636	3	3.2	PENICUIK HOUSE	NA	1.05	1857
151	IMG_5680_corrected_silhouette.jpg	98.79	30.49499872	0.191929078	0.994734517	231.6221646	0.620204867	0.99997668	3	3.2	PENICUIK HOUSE	NA	0.85	1857
152	IMG_5686_corrected_silhouette.jpg	98.57	30.54629392	0.444969262	0.998874381	260.5620859	0	0.999999238	3	3.2	PENICUIK HOUSE	NA	0.85	1857
153	IMG_5702_corrected_silhouette.jpg	98.6	30.37103531	0.176515635	0.988749759	366.8543415	1.184042968	0.999993858	3	3.2	PENICUIK HOUSE	NA	0.85	1857
154	IMG_5709_corrected_silhouette.jpg	84.64	8.782953794	5.087971785	0.727506901	115.978456	35.67191052	0.99075336	2	2.2	KILCHURN CASTLE	0	1.7	1440
155	IMG_5719_corrected_silhouette.jpg	82.21	10.72846962	6.761909162	0.631272238	105.7450628	62.87071393	0.976901058	2	2.2	KILCHURN CASTLE	0	0.9	1690
156	IMG_5733_corrected_silhouette.jpg	76.07	9.98857516	6.560001228	0.707614298	106.3734291	38.86190901	0.97397826	2	2.2	KILCHURN CASTLE	0	NA	1690
157	IMG_5737_corrected_silhouette.jpg	97.78	30.41805591	0.203571527	0.973275084	245.3186091	2.819322683	0.999666684	3	3.2	PENICUIK HOUSE	NA	0.85	1857
158	IMG_5744_corrected_silhouette.jpg	98.12	30.49072412	0.073294126	0.990232147	274.806714	0.923715618	0.999999075	3	3.2	PENICUIK HOUSE	NA	0.85	1857
159	IMG_5745_corrected_silhouette.jpg	81.66	10.18275561	6.679015117	0.691681724	108.2585278	45.47132639	0.982273735	2	2.2	KILCHURN CASTLE	0	1.8	1690
160	IMG_5755_corrected_silhouette.jpg	98.99	30.43087971	0.188296022	0.993007971	426.8263097	0.773531374	0.999998997	3	3.2	PENICUIK HOUSE	NA	1.05	1857
161	IMG_5760_corrected_silhouette.jpg	97.09	30.49820467	0.243483425	0.987602652	174.5062837	0.652871667	0.999984142	3	3.2	PENICUIK HOUSE	1	1.05	1701
162	IMG_5761_corrected_silhouette.jpg	73.24	9.356603065	5.640479824	0.660375238	130.351014	38.18245384	0.979684152	2	2.2	KILCHURN CASTLE	0	0.85	1690
163	IMG_5774_corrected_silhouette.jpg	98.33	30.62836625	0.098334389	0.986407417	179.3536804	2.729974672	0.999988541	3	3.2	PENICUIK HOUSE	1	1.05	1701
164	IMG_5775_corrected_silhouette.jpg	80.32	11.12544883	5.630533793	0.734051816	123.8779174	34.94102922	0.989047953	2	2.2	KILCHURN CASTLE	0	2.2	1440
165	IMG_5777_corrected_silhouette.jpg	98.01	30.2962298	0.249323186	0.996966245	234.7992013	0	0.999915567	3	3.2	PENICUIK HOUSE	1	1.05	1701
166	IMG_5797_corrected_silhouette.jpg	98.42	30.54629392	0.191929075	0.975577424	226.7601834	6.443142214	0.999945306	3	3.2	PENICUIK HOUSE	1	1.05	1701
167	IMG_5799_corrected_silhouette.jpg	98.61	32.67504488	3.852650579	0.976644199	206.750059	2.628846372	0.9998961	3	3.2	PENICUIK HOUSE	1	1.05	1701
168	IMG_5805_corrected_silhouette.jpg	98.8	30.43087972	0.098334389	0.980277882	349.5503921	2.379048132	0.999981979	3	3.2	PENICUIK HOUSE	NA	1	1857
169	IMG_5811_corrected_silhouette.jpg	97.73	30.01196888	1.187726757	0.982533081	287.4999396	3.377195384	0.999978254	3	3.2	PENICUIK HOUSE	NA	0.85	1857
170	IMG_5817_corrected_silhouette.jpg	98.57	30.61041293	0.235064156	0.988242702	232.8533537	1.515644483	0.999987177	3	3.2	PENICUIK HOUSE	NA	0.85	1857
171	IMG_6040_corrected_silhouette.jpg	98.69	30.54308797	0.115057438	0.986994925	185.188532	1.88654378	0.999988317	3	3.2	PENICUIK HOUSE	1	1.05	1701
172	IMG_6065_corrected_silhouette.jpg	98.75	30.59758912	0.095964537	0.988773649	217.5567473	1.487178374	0.999901653	3	3.2	PENICUIK HOUSE	1	1.1	1701
173	IMG_6110_corrected_silhouette.jpg	79.79	13.01306259	7.474710659	0.829477769	110.2333932	29.93773678	0.991565908	2	2.2	PENICUIK HOUSE	1	1	1701
174	IMG_6176_corrected_silhouette.jpg	95.26	16.99037049	7.102018392	0.984274584	168.7467989	20.30675175	0.999992097	3	3.1	PENICUIK HOUSE	NA	0.85	1857
175	IMG_6241_corrected_silhouette.jpg	98.79	31.02333932	0.529546901	0.994813149	195.9772087	1.039681445	0.999978481	3	3.2	GOSFORD HOUSE	NA	NA	1891
176	IMG_6245_corrected_silhouette.jpg	98.69	30.80789946	0.894068196	0.992553017	218.1251277	1.012790307	0.999983984	3	3.2	GOSFORD HOUSE	NA	NA	1891
177	IMG_6255_corrected_silhouette.jpg	98.85	30.91561939	0.627082555	0.9891253	184.1492898	2.080058013	0.999946497	3	3.2	GOSFORD HOUSE	NA	NA	1891
178	IMG_6273_corrected_silhouette.jpg	98.92	31.41831239	0.732941275	0.983486825	207.4901896	1.81801424	0.999998052	3	3.2	GOSFORD HOUSE	1	NA	1790
179	IMG_6288_corrected_silhouette.jpg	94.46	24.52872531	7.716012953	0.961056868	189.4075404	12.0395728	0.999861757	1	1.1	GOSFORD HOUSE	1	NA	1790
180	IMG_6303_corrected_silhouette.jpg	78.57	9.170004143	8.923927419	0.731209307	108.8868941	40.34228725	0.991012296	2	2.2	GLENBUCHAT CASTLE	0	1.2	1590
181	IMG_6311_corrected_silhouette.jpg	98.97	32.76481149	1.248154017	0.977315516	234.9964238	2.82213182	0.99998623	3	3.2	GOSFORD HOUSE	1	NA	1790
182	IMG_6320_corrected_silhouette.jpg	98.98	32.56732496	0.349974661	0.995875166	221.5301346	0.337596769	0.999998861	3	3.2	GOSFORD HOUSE	1	NA	1790
183	IMG_6326_corrected_silhouette.jpg	98.9	31.02333932	0.883186636	0.994000297	189.9890177	0.892336682	0.999993548	3	3.2	GOSFORD HOUSE	NA	NA	1891
184	IMG_6332_corrected_silhouette.jpg	99.01	31.32854578	1.454846891	0.990932976	195.2603651	1.093118971	0.999992288	3	3.2	GOSFORD HOUSE	NA	NA	1891
185	IMG_6338_corrected_silhouette.jpg	98.86	31.19389587	0.884098545	0.983047365	233.5192528	2.696943868	0.999955785	3	3.2	GOSFORD HOUSE	NA	NA	1891
186	IMG_6351_corrected_silhouette.jpg	98.92	31.10412927	0.987432675	0.996375781	254.3257279	0.337596769	0.999997058	3	3.2	GOSFORD HOUSE	NA	NA	1891
187	IMG_6364_corrected_silhouette.jpg	98.87	30.87971275	0.253898305	0.986815065	274.558547	1.306722999	0.999993019	3	3.2	GOSFORD HOUSE	NA	0.85	1891

188	IMG_6376_corrected_silhouette.jpg	98.85	31.5978456	1.343503549	0.994557769	286.3122343	0.462273414	0.99999374	3	3.2	GOSFORD HOUSE	1	1.2	1790
189	IMG_6378_corrected_silhouette.jpg	98.66	30.2064632	0.269299821	0.99536912	218.9236635	0.337596769	0.999981706	3	3.2	GOSFORD HOUSE	1	1.2	1790
190	IMG_6387_corrected_silhouette.jpg	98.31	30.26929982	0.240869082	0.993785487	221.4633637	0.53378736	0.999992914	3	3.2	GOSFORD HOUSE	1	1.2	1790
191	IMG_6389_corrected_silhouette.jpg	98.86	30.43087971	0.310960647	0.999812356	205.938787	0	0.999999872	3	3.2	GOSFORD HOUSE	NA	0.85	1891
192	IMG_6487_corrected_silhouette.jpg	98.85	30.8438061	0.447034096	0.99650506	174.7253441	0.238716965	0.999940502	3	3.2	GOSFORD HOUSE	NA	NA	1891
193	IMG_6493_corrected_silhouette.jpg	98.97	30.87971275	0.491671956	0.999382097	219.7687734	0	0.999999698	3	3.2	GOSFORD HOUSE	NA	NA	1891
194	IMG_6499_corrected_silhouette.jpg	99	30.98743267	0.562027857	0.995659925	166.4074115	0.337596769	0.999870168	3	3.2	GOSFORD HOUSE	NA	NA	1891
195	IMG_6515_corrected_silhouette.jpg	98.78	32.94434471	0.103653547	0.990241621	228.5448317	1.21638063	0.999996935	3	3.2	GOSFORD HOUSE	1	1.2	1790
196	IMG_6518_corrected_silhouette.jpg	99.01	33.07899461	0.171889962	0.988649445	249.7532124	1.411452354	0.999995595	3	3.2	GOSFORD HOUSE	1	1.2	1790
197	IMG_6520_corrected_silhouette.jpg	98.93	33.21364452	0.146588256	0.991243785	200.8106273	1.557271959	0.999984196	3	3.2	GOSFORD HOUSE	1	1.2	1790
198	IMG_6538_corrected_silhouette.jpg	98.81	30.92459605	0.593184546	0.991805076	164.6319569	1.825447106	0.999990151	3	3.2	GOSFORD HOUSE	NA	NA	1891
199	IMG_6602_corrected_silhouette.jpg	78.14	10.1997307	7.617827865	0.754360481	104.3087971	59.42732209	0.985060358	2	2.2	MELLERSTAIN HOUSE	1	NA	1725
200	IMG_6608_corrected_silhouette.jpg	79.45	11.66185309	5.674364619	0.741481017	116.5170557	32.84444556	0.982873635	2	2.2	MELLERSTAIN HOUSE	1	NA	1725
201	IMG_6614_corrected_silhouette.jpg	77.06	11.55203368	6.652820132	0.68100226	105.8348294	23.07671361	0.984951549	2	2.2	MELLERSTAIN HOUSE	1	NA	1725
202	IMG_6624_corrected_silhouette.jpg	87.44	12.5	3.484902618	0.936762283	233.2136445	9.635188035	0.999123186	1	1.2	MELLERSTAIN HOUSE	1	NA	1770
203	IMG_6631_corrected_silhouette.jpg	89.27	11.66965889	5.221917262	0.901468148	208.6962814	16.51890711	0.999510124	1	1.2	MELLERSTAIN HOUSE	1	NA	1770
204	IMG_6650_corrected_silhouette.jpg	90.61	15.27413341	5.799257002	0.929353524	205.9245961	16.87846642	0.998961527	1	1.2	MELLERSTAIN HOUSE	1	NA	1770
205	IMG_6656_corrected_silhouette.jpg	87.51	14.97030797	3.639360443	0.912964556	191.561939	4.31923622	0.999389832	1	1.2	MELLERSTAIN HOUSE	1	NA	1770
206	IMG_6662_corrected_silhouette.jpg	88.67	13.41113106	3.061277512	0.923627349	142.9084381	27.68716636	0.997602508	1	1.2	MELLERSTAIN HOUSE	1	NA	1770
207	IMG_6668_corrected_silhouette.jpg	90.44	13.76069279	3.19709109	0.926253706	203.2382625	20.73070959	0.998521775	1	1.2	MELLERSTAIN HOUSE	1	NA	1770
208	IMG_6672_corrected_silhouette.jpg	87.07	12.18132855	3.620435495	0.948428641	228.1867145	11.72151005	0.999822776	1	1.2	MELLERSTAIN HOUSE	1	NA	1770
209	IMG_6676_corrected_silhouette.jpg	86.32	12.30700179	4.356360914	0.933351569	159.2459605	22.0353724	0.999570258	1	1.2	MELLERSTAIN HOUSE	1	NA	1770
210	IMG_6693_corrected_silhouette.jpg	80.97	10.16314105	4.027870446	0.81652741	182.5852783	15.98310572	0.998146567	2	2.2	MELLERSTAIN HOUSE	1	NA	1770
211	IMG_6705_corrected_silhouette.jpg	88.34	14.44551858	5.194902135	0.941463154	187.3034144	15.64645504	0.999850198	1	1.2	MELLERSTAIN HOUSE	1	NA	1770
212	IMG_6719_corrected_silhouette.jpg	79.21	11.8553829	5.859238851	0.756731673	113.2854578	18.5900172	0.975547641	2	2.2	MELLERSTAIN HOUSE	1	NA	1725
213	IMG_6730_corrected_silhouette.jpg	73.36	9.53466932	5.076517237	0.72864907	112.7468582	28.85375008	0.976596379	2	2.2	MELLERSTAIN HOUSE	1	NA	1725
214	IMG_6734_corrected_silhouette.jpg	73.54	9.77957311	5.789690432	0.725062569	104.1292639	29.24683888	0.979288325	2	2.2	MELLERSTAIN HOUSE	1	NA	1725
215	IMG_6739_corrected_silhouette.jpg	68.99	7.978007182	4.545479211	0.746374008	110.05386	25.84495772	0.979193655	2	2.2	MELLERSTAIN HOUSE	1	NA	1725
216	IMG_6742_corrected_silhouette.jpg	75.38	9.308106615	5.065178	0.719848322	111.3105925	28.88596369	0.977810412	2	2.2	MELLERSTAIN HOUSE	1	NA	1725
217	IMG_6745_corrected_silhouette.jpg	76.58	8.529915244	6.070641726	0.814881537	113.7043686	49.95324725	0.982798955	2	2.2	MELLERSTAIN HOUSE	1	NA	1725
218	IMG_6759_corrected_silhouette.jpg	71.2	15.33213645	8.342790797	0.706152892	102.8725314	53.4147342	0.978077659	2	2.2	MELLERSTAIN HOUSE	1	NA	1725
219	IMG_6780_corrected_silhouette.jpg	98.79	30.23339318	0.16057939	0.979625156	183.5756339	3.148620721	0.999989868	3	3.2	DUMFRIES HOUSE	1	0.85	1754
220	IMG_6786_corrected_silhouette.jpg	98.73	30.10173549	0.092710551	0.994288384	149.4284984	1.679788903	0.999940085	3	3.2	DUMFRIES HOUSE	1	0.85	1754
221	IMG_6795_corrected_silhouette.jpg	98.8	30.2812687	0.146588257	0.997816974	153.8599641	0.53378736	0.999988455	3	3.2	DUMFRIES HOUSE	1	0.85	1754
222	IMG_6812_corrected_silhouette.jpg	98.74	29.94614004	0.080289697	0.98885612	187.0601479	2.080058013	0.998872552	3	3.2	DUMFRIES HOUSE	1	1.2	1754
223	IMG_6816_corrected_silhouette.jpg	98.71	30.27378815	0.164474935	0.991115581	247.3619753	1.232044956	0.999996697	3	3.2	DUMFRIES HOUSE	1	1	1754
224	IMG_6824_corrected_silhouette.jpg	98.81	30.26929982	0.098334394	0.975101661	209.6046971	3.971022438	0.999968493	3	3.2	DUMFRIES HOUSE	1	1	1754
225	IMG_6828_corrected_silhouette.jpg	98.73	30.12567325	0.196668783	0.999032925	187.5850445	0.238716965	0.999998077	3	3.2	DUMFRIES HOUSE	1	1.2	1754
226	IMG_6834_corrected_silhouette.jpg	98.81	29.87432675	0.098334394	0.991662161	184.6869225	1.520238263	0.999911389	3	3.2	DUMFRIES HOUSE	1	1.2	1754
227	IMG_6848_corrected_silhouette.jpg	98.73	30.16157989	0.113546775	0.97471415	205.1371609	3.562882931	0.999994264	3	3.2	DUMFRIES HOUSE	1	0.85	1754
228	IMG_6858_corrected_silhouette.jpg	98.88	29.98204668	0.2073071	0.9857436	190.5648587	2.729974672	0.999984272	3	3.2	DUMFRIES HOUSE	1	0.85	1754
229	IMG_6869_corrected_silhouette.jpg	98.8	32.45960503	0.196668778	0.990483798	184.5819432	1.639009019	0.999990681	3	3.2	DUMFRIES HOUSE	1	1.2	1754
230	IMG_6875_corrected_silhouette.jpg	97.78	32.76481149	0.31610084	0.990556608	185.0987433	0.892336682	0.999945847	3	3.2	DUMFRIES HOUSE	1	1.2	1754
231	IMG_6881_corrected_silhouette.jpg	98.85	33.21364452	0.219882382	0.994732856	186.5097791	0.860706256	0.999972368	3	3.2	DUMFRIES HOUSE	1	1.2	1754
232	IMG_6887_corrected_silhouette.jpg	98.8	33.1059246	0.272275599	0.99326611	187.6592761	0.98425526	0.99998214	3	3.2	DUMFRIES HOUSE	1	1.2	1754
233	IMG_6890_corrected_silhouette.jpg	98.77	33.39317774	0.179533215	0.98973217	189.00072	2.327935048	0.99997431	3	3.2	DUMFRIES HOUSE	1	1.2	1754
234	IMG_6901_corrected_silhouette.jpg	98.78	33.50089767	0.098334389	0.992552321	179.7739968	1.383665269	0.999988502	3	3.2	DUMFRIES HOUSE	1	1.2	1754
235	IMG_6913_corrected_silhouette.jpg	98.8	33.32136445	0.300416525	0.976391638	188.864993	3.878736832	0.999970001	3	3.2	DUMFRIES HOUSE	1	1.2	1754
236	IMG_6917_corrected_silhouette.jpg	98.82	33.39317774	0.126949154	0.989741561	188.3453719	1.856402089	0.999992169	3	3.2	DUMFRIES HOUSE	1	1.2	1754
237	IMG_6921_corrected_silhouette.jpg	98.78	33.42908438	0.389218735	0.98900237	186.2690728	1.979573506	0.999993036	3	3.2	DUMFRIES HOUSE	1	1.2	1754
238	IMG_6928_corrected_silhouette.jpg	98.75	33.24955116	0.080289697	0.994753644	187.7917415	0.583858567	0.999936845	3	3.2	DUMFRIES HOUSE	1	1.2	1754
239	IMG_6934_corrected_silhouette.jpg	98.79	33.28545781	0.098334394	0.993370202	185.6264608	0.980611466	0.999975371	3	3.2	DUMFRIES HOUSE	1	1.2	1754
240	IMG_6940_corrected_silhouette.jpg	98.75	33.46499102	0.204699361	0.989638931	184.2235214	1.856402089	0.999977772	3	3.2	DUMFRIES HOUSE	1	0.9	1754
241	IMG_7188_corrected_silhouette.jpg	88.02	15.84679833	10.65065168	0.69449831	124.5923383	42.66567303	0.990085172	2	2.1	TOLQUHON CASTLE	0	NA	1200
242	IMG_7196_corrected_silhouette.jpg	84.34	12.25812887	10.8078057	0.715599723	102.513465	33.09850643	0.982010787	2	2.2	TOLQUHON CASTLE	0	NA	1584
243	IMG_7352_corrected_silhouette.jpg	95.4	29.62298025	3.852650582	0.986039317	155.0547247	0.893197094	0.999846757	3	3.1	HOLYROOD PALACE	NA	0.95	1800
244	IMG_7356_corrected_silhouette.jpg	94.93	28.69539198	1.165814469	0.985690424	139.4559165	0.860706256	0.999969571	3	3.1	HOLYROOD PALACE	NA	0.95	1800
245	IMG_7360_corrected_silhouette.jpg	95.91	27.50448833	2.948392366	0.982491641	119.1616019	1.737075003	0.999783279	3	3.1	HOLYROOD PALACE	NA	0.95	1800
246	IMG_7372_corrected_silhouette.jpg	94.78	25.87843037	1.630456068	0.975042888	180.182458	1.38321824	0.999388425	3	3.1	HOLYROOD PALACE	NA	2.3	1800
247	IMG_7378_corrected_silhouette.jpg	92.4	22.8406144	3.24996994	0.983035094	173.3342357	0.620204867	0.999795604	3	3.1	HOLYROOD PALACE	NA	2.3	1800
248	IMG_7382_corrected_silhouette.jpg	95.68	25.76301616	4.566641777	0.976964667	142.1903052	2.445440292	0.99983907	3	3.1	HOLYROOD PALACE	NA	1.8	1505
249	IMG_7384_corrected_silhouette.jpg	93.3	24.97506483	5.579588171	0.935739118	171.6027171	4.701703984	0.997953629	1	1.1	HOLYROOD PALACE	NA	2.3	1505
250	IMG_7386_corrected_silhouette.jpg	90.88	23.71633752	4.29001325	0.938588186	145.7809695	4.450687288	0.998834216	1	1.1	HOLYROOD PALACE	NA	2.3	1505

251	IMG_7388_corrected_silhouette.jpg	93.66	25.02244165	1.194507977	0.9307816	204.5318522	6.110895294	0.99860984	3	3.1	HOLYROOD PALACE	NA	1.8	1505
252	IMG_7400_corrected_silhouette.jpg	95.97	21.34201077	1.874228233	0.987143776	158.6929774	1.054145573	0.999989069	3	3.1	HOLYROOD PALACE	NA	2.3	1505
253	IMG_7402_corrected_silhouette.jpg	92.63	21.63375225	2.647299704	0.957097265	151.5341875	3.079532967	0.999828814	3	3.1	HOLYROOD PALACE	NA	2.3	1505
254	IMG_7406_corrected_silhouette.jpg	94.37	24.37163375	1.850274958	0.982785285	175.6459657	0.900390663	0.999938563	3	3.1	HOLYROOD PALACE	2	1.2	1679
255	IMG_7408_corrected_silhouette.jpg	94.32	24.59605027	1.282123596	0.967288942	139.4251688	2.617290936	0.995035499	3	3.1	HOLYROOD PALACE	2	1.2	1679
256	IMG_7412_corrected_silhouette.jpg	93.86	24.63195691	1.243266604	0.978303891	153.6401418	0.876225918	0.999944848	3	3.1	HOLYROOD PALACE	2	0.95	1679
257	IMG_7418_corrected_silhouette.jpg	95.66	24.61849192	0.990052249	0.9694643	171.2324643	3.673402466	0.999696654	3	3.1	HOLYROOD PALACE	2	1	1679
258	IMG_7422_corrected_silhouette.jpg	94.31	24.66337522	1.167212476	0.971545712	204.4989193	3.228292257	0.999896243	3	3.1	HOLYROOD PALACE	2	1.2	1679
259	IMG_7426_corrected_silhouette.jpg	94.51	24.64734547	1.61484873	0.972077001	189.0020001	2.505953302	0.999964992	3	3.1	HOLYROOD PALACE	2	1.2	1679
260	IMG_7430_corrected_silhouette.jpg	96.76	29.47935368	1.200324213	0.984078038	168.7828221	0.893197094	0.999929893	3	3.1	HOLYROOD PALACE	2	1.2	1679
261	IMG_7432_corrected_silhouette.jpg	96.19	29.11430281	1.120705319	0.985012651	165.4032874	0.412540485	0.999918219	3	3.1	HOLYROOD PALACE	2	1.2	1679
262	IMG_7434_corrected_silhouette.jpg	95.89	28.65798923	1.840762717	0.973181285	145.2423698	3.525272428	0.9999052	3	3.1	HOLYROOD PALACE	2	1	1679
263	IMG_7438_corrected_silhouette.jpg	96.03	29.59305805	1.301667387	0.980055528	138.6393691	1.470853939	0.999950693	3	3.1	HOLYROOD PALACE	2	1.2	1679
264	IMG_7442_corrected_silhouette.jpg	96.51	29.35368043	1.674574337	0.981047443	115.0450268	1.411452354	0.999911927	3	3.1	HOLYROOD PALACE	2	1.2	1679
265	IMG_7452_corrected_silhouette.jpg	98.66	29.53321365	1.554803241	0.990430791	152.3314433	0.823222128	0.999902633	3	3.2	HOLYROOD PALACE	2	1.25	1679
266	IMG_7471_corrected_silhouette.jpg	98.62	34.56014363	1.554803241	0.9913517	229.5098422	0.716150894	0.999985439	3	3.2	HOLYROOD PALACE	NA	1.3	1836
267	IMG_7514_corrected_silhouette.jpg	84.78	12.43503732	10.71212202	0.68236948	100.5385996	60.55259845	0.93028997	2	2.2	TOLQUHON CASTLE	0	2.2	1200
268	IMG_7539_corrected_silhouette.jpg	90.81	23.93177738	10.16018061	0.900154758	124.7755835	44.0941996	0.998099173	1	1.4	AUCHINDINNY HOUSE	2	0.7	1750
269	IMG_7543_corrected_silhouette.jpg	90.15	20.76600838	7.126990989	0.882173645	132.4403143	48.83566118	0.987829702	2	2.1	AUCHINDINNY HOUSE	2	0.7	1750
270	IMG_7553_corrected_silhouette.jpg	88.32	21.64871334	9.513091615	0.918433424	149.9203844	45.75412421	0.995916621	1	1.4	AUCHINDINNY HOUSE	2	0.85	1705
271	IMG_7557_corrected_silhouette.jpg	87.81	23.15978456	6.380800013	0.908573473	154.7224152	60.00910766	0.984028392	1	1.4	AUCHINDINNY HOUSE	2	0.85	1705
272	IMG_7563_corrected_silhouette.jpg	86.11	23.42092378	9.120345085	0.861666254	134.8539333	23.45830788	0.987001446	2	2.1	AUCHINDINNY HOUSE	2	NA	1705
273	IMG_7608_corrected_silhouette.jpg	86.92	28.70899298	1.216208782	0.933449117	161.6613355	9.474517889	0.993856293	1	1.3	CUMBERNAULD HOUSE	1	NA	1731
274	IMG_7612_corrected_silhouette.jpg	87.09	21.65939985	9.390701899	0.896473569	183.2430593	14.46944829	0.996869623	1	1.4	CUMBERNAULD HOUSE	1	NA	1731
275	IMG_7630_corrected_silhouette.jpg	90.51	19.24269626	9.052754033	0.958232278	123.518851	16.30068374	0.99912778	1	1.1	CUMBERNAULD HOUSE	1	NA	1731
276	IMG_7636_corrected_silhouette.jpg	90.36	21.77737882	9.662249314	0.930513666	143.0879713	42.67066914	0.990182205	1	1.4	CUMBERNAULD HOUSE	1	NA	1731
277	IMG_7640_corrected_silhouette.jpg	81.89	9.893562452	7.484513497	0.688553823	100.7181329	35.77031888	0.978851714	2	2.2	TOLQUHON CASTLE	0	1.15	1584
278	IMG_7647_corrected_silhouette.jpg	92.46	25.19449431	8.708286243	0.959414856	143.5867728	88.15055609	0.999407335	1	1.1	CUMBERNAULD HOUSE	1	NA	1731
279	IMG_7650_corrected_silhouette.jpg	79.41	10.99640934	10.26822033	0.752209568	119.6460272	24.64193559	0.98543971	2	2.2	TOLQUHON CASTLE	0	NA	1584
280	IMG_7651_corrected_silhouette.jpg	91.55	25.19449432	10.17727956	0.943414338	135.3680431	40.37220081	0.995863026	1	1.1	CUMBERNAULD HOUSE	1	NA	1731
281	IMG_7667_corrected_silhouette.jpg	97.85	30.3111909	0.348436305	0.974700011	161.9675328	3.460981878	0.999984825	3	3.2	CUMBERNAULD HOUSE	1	0.9	1731
282	IMG_7669_corrected_silhouette.jpg	97.85	30.46080192	0.404115932	0.986373165	162.4775583	2.398274938	0.999952834	3	3.2	CUMBERNAULD HOUSE	1	NA	1731
283	IMG_7675_corrected_silhouette.jpg	86.47	15.94853381	13.62926511	0.749281038	113.1059246	62.98170365	0.975942211	2	2.1	TOLQUHON CASTLE	0	NA	1200
284	IMG_7681_corrected_silhouette.jpg	97.54	30.46080192	0.293176511	0.988097967	162.2980251	1.754204269	0.999936719	3	3.2	CUMBERNAULD HOUSE	1	NA	1731
285	IMG_7683_corrected_silhouette.jpg	98.48	30.2812687	0.245289067	0.989587762	149.1921005	0.98425526	0.999840631	3	3.2	CUMBERNAULD HOUSE	1	0.9	1731
286	IMG_7691_corrected_silhouette.jpg	91.21	28.18671454	4.139843934	0.956049031	184.021544	13.81226759	0.993976813	1	1.1	CUMBERNAULD HOUSE	1	NA	1731
287	IMG_7695_corrected_silhouette.jpg	91.44	25.70317175	1.005492855	0.961771492	202.513465	3.771973275	0.999014193	3	3.1	CUMBERNAULD HOUSE	1	NA	1731
288	IMG_7701_corrected_silhouette.jpg	88.01	24.68581688	2.883171497	0.941169197	203.0520646	28.64763593	0.998051436	1	1.1	CUMBERNAULD HOUSE	1	NA	1731
289	IMG_7713_corrected_silhouette.jpg	90.97	26.08361118	1.49028532	0.942671873	177.2017386	5.641897837	0.999676974	3	3.1	CUMBERNAULD HOUSE	1	NA	1731
290	IMG_7715_corrected_silhouette.jpg	91.62	26.21184919	2.769703521	0.936964243	151.0624207	5.688544917	0.998030482	1	1.1	CUMBERNAULD HOUSE	1	NA	1731
291	IMG_7727_corrected_silhouette.jpg	91.36	25.62836625	0.943922349	0.952653765	191.6594157	5.052008088	0.999813966	3	3.1	CUMBERNAULD HOUSE	1	NA	1731
292	IMG_7733_corrected_silhouette.jpg	89.32	22.18232595	9.815850645	0.945487305	137.7019749	36.56123202	0.999744289	1	1.1	CUMBERNAULD HOUSE	1	NA	1731
293	IMG_7741_corrected_silhouette.jpg	90.38	28.22661081	2.2846929	0.939257171	169.4065174	6.229590986	0.986292527	1	1.1	CUMBERNAULD HOUSE	1	NA	1731
294	IMG_7745_corrected_silhouette.jpg	91.99	27.07959306	2.985690063	0.955840827	161.7492084	6.436061765	0.99952547	3	3.1	CUMBERNAULD HOUSE	1	NA	1731
295	IMG_7749_corrected_silhouette.jpg	85.49	27.19928187	6.919435915	0.903098169	117.7737882	17.7021844	0.990333779	1	1.3	CUMBERNAULD HOUSE	1	NA	1731
296	IMG_7770_corrected_silhouette.jpg	97.32	23.60045699	2.540713589	0.975322304	149.7307002	4.076653559	0.999395208	3	3.1	HOUSE OF DUN	1	0.8	1730
297	IMG_7784_corrected_silhouette.jpg	94.13	15.21045282	1.671520808	0.979877696	191.470559	1.729668735	0.999857632	3	3.1	HOUSE OF DUN	1	NA	1730
298	IMG_7793_corrected_silhouette.jpg	95.91	24.21703571	1.238793631	0.984382149	146.2303597	1.132333987	0.998412912	3	3.1	HOUSE OF DUN	1	0.8	1730
299	IMG_7795_corrected_silhouette.jpg	95.22	24.61400359	0.759104511	0.977666132	167.7202929	2.301268425	0.999209939	3	3.1	HOUSE OF DUN	1	0.8	1730
300	IMG_7803_corrected_silhouette.jpg	94.11	21.82325953	5.838357662	0.971109643	211.1657455	16.71163152	0.99992252	1	1.1	HOUSE OF DUN	1	NA	1730
301	IMG_7807_corrected_silhouette.jpg	94.25	21.56642729	1.793888881	0.983730694	157.4077534	3.88296084	0.999955354	3	3.1	HOUSE OF DUN	1	NA	1730
302	IMG_7838_corrected_silhouette.jpg	97.86	23.33931777	2.399753161	0.980133904	178.4560144	1.627832669	0.999845793	3	3.1	HOUSE OF DUN	1	NA	1730
303	IMG_7847_corrected_silhouette.jpg	98.13	23.6727366	0.876032381	0.975356911	214.1831239	6.049737766	0.999743408	3	3.1	HOUSE OF DUN	1	NA	1730
304	IMG_7907_corrected_silhouette.jpg	77.24	15.81273305	11.33726812	0.731303248	100	41.35110557	0.987831931	2	2.2	HADDO HOUSE	1	0.95	1731
305	IMG_7915_corrected_silhouette.jpg	78.1	18.3722322	13.13001163	0.66349845	126.9359086	62.3208475	0.983653462	2	2.2	HADDO HOUSE	1	0.95	1731
306	IMG_7919_corrected_silhouette.jpg	76.36	14.84456203	8.980859307	0.701295203	100	27.90830054	0.987343681	2	2.2	HADDO HOUSE	1	0.95	1731
307	IMG_7930_corrected_silhouette.jpg	75.65	13.81589685	7.596464124	0.725277746	110.05386	36.19450738	0.980708105	2	2.2	HADDO HOUSE	1	0.75	1731
308	IMG_7934_corrected_silhouette.jpg	75.12	14.80789946	8.073859662	0.699805356	101.0771993	31.29109509	0.972572776	2	2.2	HADDO HOUSE	1	0.75	1731
309	IMG_7938_corrected_silhouette.jpg	74.88	15.89296401	9.49383093	0.68650329	105.5655296	62.10266183	0.9750679	2	2.2	HADDO HOUSE	1	0.75	1731
310	IMG_7947_corrected_silhouette.jpg	90.32	27.70197486	8.39275903	0.928973257	116.1579892	12.66506337	0.99843453	1	1.1	HADDO HOUSE	1	1.25	1731
311	IMG_7965_corrected_silhouette.jpg	91.84	34.00872019	1.648245089	0.943048494	127.5071919	4.007844809	0.999065191	3	3.1	HADDO HOUSE	1	1.25	1731
312	IMG_7966_corrected_silhouette.jpg	98.51	30.07181328	0.150208264	0.989477701	173.0636868	1.383665269	0.999978331	3	3.2	DALQUHARRAN CASTLE	NA	0.85	1880
313	IMG_7970_corrected_silhouette.jpg	79.66	16.29263914	9.068234292	0.791439175	131.0566666	33.53101514	0.987359466	2	2.1	HADDO HOUSE	NA	0.45	1822

314	IMG_7973_corrected_silhouette.jpg	98.23	30.52064632	0.113546772	0.989931626	166.0682226	1.039681445	0.99995871	3	3.2	DALQUHARRAN CASTLE	NA	0.85	1880
315	IMG_7979_corrected_silhouette.jpg	98.71	30.5924596	0.160579385	0.997086519	168.8803408	0.716150894	0.999992314	3	3.2	DALQUHARRAN CASTLE	NA	0.85	1880
316	IMG_7988_corrected_silhouette.jpg	98.01	30.48473968	0.196668778	0.996889247	193.2837698	0.238716965	0.999999836	3	3.2	DALQUHARRAN CASTLE	NA	0.85	1880
317	IMG_7990_corrected_silhouette.jpg	95.02	27.88749252	2.413147237	0.986048605	171.4147655	1.729668735	0.999912764	3	3.1	DALQUHARRAN CASTLE	NA	0.85	1880
318	IMG_7992_corrected_silhouette.jpg	81.73	23.82895381	13.63438415	0.826858563	105.02693	19.85548501	0.997682866	2	2.1	HADDO HOUSE	1	0.75	1731
319	IMG_7996_corrected_silhouette.jpg	79.68	16.61210265	11.16541392	0.825581287	109.5152603	46.27642239	0.953977166	2	2.1	HADDO HOUSE	1	0.75	1731
320	IMG_8004_corrected_silhouette.jpg	76.18	15.27413341	9.451379785	0.762390764	101.7953321	21.46195011	0.994067806	2	2.2	HADDO HOUSE	1	1	1731
321	IMG_8011_corrected_silhouette.jpg	70.57	22.67014852	9.037528256	0.744351084	127.8510673	23.98474509	0.94906277	2	2.1	HADDO HOUSE	1	1	1731
322	IMG_8025_corrected_silhouette.jpg	79.7	16.34949132	9.950385952	0.727450605	110.1436266	23.1165126	0.981866415	2	2.2	HADDO HOUSE	1	1	1731
323	IMG_8039_corrected_silhouette.jpg	92.21	12.09335727	4.812327428	0.967084039	192.1746664	33.81672409	0.999927191	1	1.2	HADDO HOUSE	NA	0.85	1877
324	IMG_8059_corrected_silhouette.jpg	71.72	30.16157989	3.408767962	0.887727601	125.3256484	34.78423203	0.997935061	1	1.3	HADDO HOUSE	1	1.25	1731
325	IMG_8073_corrected_silhouette.jpg	80.44	39.71274686	0.796852459	0.915025615	111.6696589	5.636017897	0.99187694	1	1.3	HADDO HOUSE	1	1.4	1731
326	IMG_8084_corrected_silhouette.jpg	91.35	27.34034368	3.89868859	0.933114388	123.8779174	9.985451819	0.998603345	1	1.1	HADDO HOUSE	1	1.25	1731
327	IMG_8088_corrected_silhouette.jpg	90.46	27.5583483	1.798023119	0.930064962	112.9263914	8.437675279	0.98474628	1	1.3	HADDO HOUSE	1	1.25	1731
328	IMG_8155_corrected_silhouette.jpg	83.37	14.47037702	10.48702117	0.874746547	115.9858452	35.99190143	0.99604377	2	2.1	DALKEITH PALACE	2	0.9	1701
329	IMG_8159_corrected_silhouette.jpg	79.26	21.41574763	8.593069459	0.787978056	105.2064632	29.58132255	0.995592352	2	2.1	DALKEITH PALACE	2	0.9	1701
330	IMG_8161_corrected_silhouette.jpg	72.92	23.45900658	6.387615805	0.827351017	105.02693	33.56219883	0.988642925	2	2.1	DALKEITH PALACE	2	0.9	1701
331	IMG_8175_corrected_silhouette.jpg	76.52	19.21005386	5.184059323	0.794211962	108.2585278	19.38966047	0.987441551	2	2.2	DALKEITH PALACE	2	0.9	1701
332	IMG_8179_corrected_silhouette.jpg	81.09	20.28725314	6.78475627	0.75915955	126.945367	24.30143999	0.993047006	2	2.1	DALKEITH PALACE	2	0.9	1701
333	IMG_8187_corrected_silhouette.jpg	77.79	16.85816876	5.659933062	0.714058562	117.9533214	47.13207751	0.966953799	2	2.2	DALKEITH PALACE	2	1.1	1701
334	IMG_8195_corrected_silhouette.jpg	78.96	13.36923998	5.937354301	0.809281607	113.6445242	19.50270783	0.99560489	2	2.2	DALKEITH PALACE	2	0.9	1701
335	IMG_8197_corrected_silhouette.jpg	81.76	14.19944508	8.447015587	0.862301057	111.4901257	37.01942436	0.99571324	2	2.1	DALKEITH PALACE	2	0.9	1701
336	IMG_8201_corrected_silhouette.jpg	84.97	19.60901656	11.00282954	0.807342817	122.0825853	67.42753398	0.995792779	2	2.1	DALKEITH PALACE	2	0.9	1701
337	IMG_8213_corrected_silhouette.jpg	84.56	16.94140689	11.38423851	0.886751724	120.4667864	38.78924147	0.993001676	2	2.1	DALKEITH PALACE	2	1.1	1701
338	IMG_8219_corrected_silhouette.jpg	84.69	16.8655613	7.18005784	0.751356104	132.2632886	50.60259588	0.977296505	2	2.1	DALKEITH PALACE	2	1.1	1701
339	IMG_8229_corrected_silhouette.jpg	83.17	17.90544584	7.628869032	0.869661266	118.8509874	52.44953841	0.990269833	2	2.1	DALKEITH PALACE	2	1.1	1701
340	IMG_8235_corrected_silhouette.jpg	79.75	16.51705566	9.042249909	0.805498734	104.4883303	38.0288563	0.996580591	2	2.1	DALKEITH PALACE	2	1.3	1701
341	IMG_8239_corrected_silhouette.jpg	79.42	13.71066805	7.21670186	0.822246189	114.7217235	38.42333187	0.988995765	2	2.2	DALKEITH PALACE	NA	2.15	1585
342	IMG_8245_corrected_silhouette.jpg	87.59	19.47935368	8.595623298	0.838325417	119.0091433	50.42291813	0.992277977	2	2.1	DALKEITH PALACE	NA	2.15	1585
343	IMG_8306_corrected_silhouette.jpg	88.53	24.9551167	10.15561485	0.899102444	123.53908	12.44309563	0.993504557	1	1.4	BALGONIE CASTLE	0	1	1635
344	IMG_8312_corrected_silhouette.jpg	84.96	24.3940754	7.548596218	0.894160659	115.529623	61.41944494	0.996045951	2	2.1	BALGONIE CASTLE	0	1	1635
345	IMG_8316_corrected_silhouette.jpg	97.29	28.16106694	0.218130307	0.987652998	215.1676954	0.685662279	0.999987881	3	3.2	DRUMLANRIG CASTLE	2	NA	1690
346	IMG_8319_corrected_silhouette.jpg	97.87	28.18671454	0.126949154	0.987147914	162.9378188	1.367962695	0.999981881	3	3.2	DRUMLANRIG CASTLE	2	NA	1690
347	IMG_8320_corrected_silhouette.jpg	88.58	28.930495	11.33072623	0.909044258	133.2871569	8.811379672	0.996821303	1	1.4	BALGONIE CASTLE	0	1	1635
348	IMG_8323_corrected_silhouette.jpg	97.16	27.97725913	0.209882441	0.978642958	196.2275608	2.160280477	0.999958639	3	3.1	DRUMLANRIG CASTLE	2	NA	1690
349	IMG_8324_corrected_silhouette.jpg	88.3	24.27688011	11.35388887	0.87040238	129.9866767	24.06953531	0.99634485	1	1.4	BALGONIE CASTLE	0	0.95	1702
350	IMG_8328_corrected_silhouette.jpg	83.78	12.28520133	7.12445419	0.751462792	130.7001795	48.41138154	0.992370282	2	2.2	BALGONIE CASTLE	0	0.95	1702
351	IMG_8341_corrected_silhouette.jpg	83.51	18.32521159	10.64987733	0.840178183	138.4201077	20.81521226	0.994471543	2	2.1	BALGONIE CASTLE	0	0.95	1702
352	IMG_8347_corrected_silhouette.jpg	86.49	30.02194295	4.781096035	0.879296839	116.1579892	13.99475176	0.980567438	1	1.3	BALGONIE CASTLE	0	1.3	1496
353	IMG_8348_corrected_silhouette.jpg	96.33	28.03282893	0.067857175	0.983086087	180.4308797	1.032838374	0.999982889	3	3.2	DRUMLANRIG CASTLE	2	NA	1690
354	IMG_8354_corrected_silhouette.jpg	86.7	16.44524237	8.903471834	0.870117293	130.604269	37.14337532	0.990762696	2	2.1	DRUMLANRIG CASTLE	2	NA	1690
355	IMG_8356_corrected_silhouette.jpg	86.51	16.66490654	6.940019826	0.871456923	134.1318143	31.00049615	0.97068051	2	2.1	DRUMLANRIG CASTLE	2	NA	1690
356	IMG_8359_corrected_silhouette.jpg	91	23.29035417	14.60038689	0.853927549	140.8601359	28.53428245	0.997938396	1	1.4	BALGONIE CASTLE	0	1.3	1496
357	IMG_8360_corrected_silhouette.jpg	85.95	17.49976377	8.736128815	0.914574517	106.8222621	62.71831721	0.994131548	2	2.1	DRUMLANRIG CASTLE	2	NA	1690
358	IMG_8366_corrected_silhouette.jpg	87.64	16.03830042	9.619795729	0.887203385	129.8025135	10.29470704	0.997252343	1	1.4	DRUMLANRIG CASTLE	2	NA	1690
359	IMG_8368_corrected_silhouette.jpg	89.6	27.1294634	5.734845917	0.91711922	152.9700598	37.02752386	0.999568156	1	1.1	DRUMLANRIG CASTLE	2	NA	1690
360	IMG_8372_corrected_silhouette.jpg	90.08	15.02094554	11.26121885	0.878341027	130.47427	27.05068089	0.996177151	1	1.4	DRUMLANRIG CASTLE	2	NA	1690
361	IMG_8376_corrected_silhouette.jpg	94.06	21.29916762	8.11850412	0.965026035	116.5170557	31.59685801	0.996513078	1	1.1	BALGONIE CASTLE	0	0.9	1666
362	IMG_8382_corrected_silhouette.jpg	90.13	19.48751428	9.469543518	0.836537796	131.0937824	46.20895099	0.992144879	2	2.1	DRUMLANRIG CASTLE	2	NA	1690
363	IMG_8388_corrected_silhouette.jpg	85.48	15.61938959	6.544017369	0.874598651	120.4667864	25.23878313	0.991473263	2	2.1	DRUMLANRIG CASTLE	2	NA	1690
364	IMG_8390_corrected_silhouette.jpg	91.81	28.48593657	1.949127754	0.911230254	191.2028725	14.41727565	0.999299379	1	1.1	BALGONIE CASTLE	0	2.2	1360
365	IMG_8393_corrected_silhouette.jpg	85.58	19.61400359	5.698524683	0.915676657	141.4968324	36.65677353	0.997498491	1	1.4	DRUMLANRIG CASTLE	2	NA	1690
366	IMG_8394_corrected_silhouette.jpg	90.41	38.28545781	3.761281527	0.960527367	134.6628914	50.982493	0.999135626	1	1.1	BALGONIE CASTLE	0	2.2	1360
367	IMG_8396_corrected_silhouette.jpg	88.09	37.25314183	3.898393311	0.920468914	128.4054315	50.86132382	0.994864225	1	1.3	BALGONIE CASTLE	0	2.2	1360
368	IMG_8399_corrected_silhouette.jpg	85.68	18.62657092	6.672492529	0.915761981	124.9551167	40.09143796	0.998871737	1	1.4	DRUMLANRIG CASTLE	2	NA	1690
369	IMG_8403_corrected_silhouette.jpg	87.52	29.08438061	2.029201895	0.896800126	118.491921	9.126053683	0.989052914	1	1.3	DRUMLANRIG CASTLE	2	NA	1690
370	IMG_8404_corrected_silhouette.jpg	89.46	37.85158588	4.825960537	0.944711234	135.1885099	5.986242187	0.999527428	1	1.1	BALGONIE CASTLE	0	2.2	1360
371	IMG_8408_corrected_silhouette.jpg	87.3	19.22501496	8.216360559	0.909635744	153.4048984	29.55644483	0.997588932	1	1.4	DRUMLANRIG CASTLE	2	NA	1690
372	IMG_8411_corrected_silhouette.jpg	86.25	20.21244764	8.792449145	0.858578438	108.438061	39.96358592	0.993218442	2	2.1	DRUMLANRIG CASTLE	2	NA	1690
373	IMG_8415_corrected_silhouette.jpg	84.68	16.82824656	4.695141294	0.873237322	123.8779174	32.60042344	0.991946178	2	2.1	DRUMLANRIG CASTLE	2	NA	1690
374	IMG_8419_corrected_silhouette.jpg	82.21	12.72691003	7.166763371	0.752657948	106.2836625	45.37490434	0.991091362	2	2.2	DRUMLANRIG CASTLE	2	NA	1690
375	IMG_8421_corrected_silhouette.jpg	90.42	15.56552962	13.19648503	0.815738448	171.8021248	51.41381591	0.98927739	2	2.1	DRUMLANRIG CASTLE	2	NA	1690
376	IMG_8427_corrected_silhouette.jpg	84.2	20.64631957	12.67840115	0.850989906	194.9576331	49.02987813	0.991948488	1	1.4	DRUMLANRIG CASTLE	2	NA	1690

377	IMG_8431_corrected_silhouette.jpg	81.44	10.33900095	9.097051488	0.861416526	145.0628366	54.58067801	0.997719909	2	2.1	DRUMLANRIG CASTLE	2	NA	1690
378	IMG_8433_corrected_silhouette.jpg	81.33	14.62505179	8.662862162	0.863862582	158.2246757	15.80695345	0.998187299	1	1.4	DRUMLANRIG CASTLE	2	NA	1690
379	IMG_8441_corrected_silhouette.jpg	82.66	14.4442631	8.190872528	0.765311101	140.9335727	24.83723523	0.979023945	2	2.1	DRUMLANRIG CASTLE	2	NA	1690
380	IMG_8443_corrected_silhouette.jpg	83.86	17.63272634	8.870013798	0.811334914	113.9138241	26.6147348	0.995067016	2	2.1	DRUMLANRIG CASTLE	2	NA	1690
381	IMG_8445_corrected_silhouette.jpg	75.19	17.91107825	9.523202499	0.827879691	104.6678636	19.8726107	0.992331565	2	2.1	DRUMLANRIG CASTLE	2	NA	1690
382	IMG_8449_corrected_silhouette.jpg	76.9	13.07328219	7.789821875	0.702897427	105.02693	39.34287932	0.990027761	2	2.2	DRUMLANRIG CASTLE	2	NA	1690
383	IMG_8450_corrected_silhouette.jpg	88.22	19.23570146	10.23517555	0.860170988	117.5344105	18.7457427	0.995303058	1	1.4	BALGONIE CASTLE	0	1	1635
384	IMG_8455_corrected_silhouette.jpg	77.52	13.32626081	7.48214366	0.696028498	134.8264634	37.85083417	0.981524346	2	2.2	DRUMLANRIG CASTLE	2	NA	1690
385	IMG_8461_corrected_silhouette.jpg	80.59	12.93636545	7.946239682	0.728456619	125.6732496	31.88429433	0.968551415	2	2.2	DRUMLANRIG CASTLE	2	NA	1690
386	IMG_8526_corrected_silhouette.jpg	88.58	27.73788151	4.430870985	0.88949891	115.6193896	15.37643709	0.996272366	1	1.3	BALGONIE CASTLE	0	1	1635
387	IMG_8528_corrected_silhouette.jpg	87.88	27.33393178	9.45421192	0.86976515	116.3375224	16.91977398	0.996256425	1	1.4	BALGONIE CASTLE	0	1	1635
388	IMG_8734_corrected_silhouette.jpg	72.41	7.065159996	3.69834579	0.655567963	106.7324955	35.27468141	0.976046312	2	2.2	BORGUE OLD HOUSE	0	0.8	1680
389	IMG_8744_corrected_silhouette.jpg	70.7	7.448718438	4.079734781	0.648014574	118.6714542	44.6596697	0.990475236	2	2.2	BORGUE OLD HOUSE	0	0.55	1680
390	IMG_8779_corrected_silhouette.jpg	80.78	8.669564396	4.057632668	0.744419456	115.6193896	31.88039222	0.979281659	2	2.2	BORGUE OLD HOUSE	0	0.8	1680
391	IMG_8787_corrected_silhouette.jpg	78.24	8.889083505	4.425069799	0.741204339	116.1579892	31.64585563	0.991259944	2	2.2	BORGUE OLD HOUSE	0	0.7	1680
392	IMG_8789_corrected_silhouette.jpg	80.25	7.711948933	3.725624972	0.736918952	112.3877917	26.15031796	0.985727739	2	2.2	BORGUE OLD HOUSE	0	0.6	1680
393	IMG_8800_corrected_silhouette.jpg	77.56	7.465317447	3.973189394	0.708295536	112.0287253	29.70092866	0.972433773	2	2.2	BORGUE OLD HOUSE	0	0.6	1680
394	IMG_8808_corrected_silhouette.jpg	84.48	9.796690766	6.350636291	0.739383035	118.8509874	36.72519418	0.988570846	2	2.2	BORGUE OLD HOUSE	0	0.8	1680
395	IMG_9040_corrected_silhouette.jpg	83.73	15.21543986	12.2603353	0.796118136	140.1445724	23.10001019	0.995748589	2	2.1	CRAIGMILLAR CASTLE	0	0.7	1500
396	IMG_9042_corrected_silhouette.jpg	83.31	17.28904847	11.65877441	0.861405477	108.7971275	48.9959837	0.996596969	2	2.1	CRAIGMILLAR CASTLE	0	0.7	1500
397	IMG_9055_corrected_silhouette.jpg	84.35	16.57315979	11.64130769	0.833679986	122.4607244	43.36620576	0.992484366	2	2.1	CRAIGMILLAR CASTLE	0	0.7	1500
398	IMG_9057_corrected_silhouette.jpg	78.71	14.29426349	8.061916157	0.822108052	107.7199282	24.74004313	0.996369169	2	2.1	CRAIGMILLAR CASTLE	0	0.7	1500
399	IMG_9072_corrected_silhouette.jpg	75.31	11.05206463	4.930924734	0.80206038	112.4775583	52.00107892	0.990651421	2	2.2	CRAIGMILLAR CASTLE	0	0.7	1500
400	IMG_9074_corrected_silhouette.jpg	74.35	16.21783363	9.604607451	0.820506885	106.3734291	24.99965589	0.995164558	2	2.1	CRAIGMILLAR CASTLE	0	0.7	1500
401	IMG_9093_corrected_silhouette.jpg	69.85	9.948252191	3.90949371	0.822734625	119.0305206	23.18887003	0.996006475	2	2.2	CRAIGMILLAR CASTLE	0	1.35	1400
402	IMG_9095_corrected_silhouette.jpg	69.98	8.965779882	3.472569699	0.801780015	159.4378533	19.53209686	0.996847017	2	2.2	CRAIGMILLAR CASTLE	0	1.35	1400
403	IMG_9097_corrected_silhouette.jpg	78.35	14.99102334	9.100893428	0.794541478	114.1831239	50.11899423	0.996103246	2	2.1	CRAIGMILLAR CASTLE	0	1.4	1400
404	IMG_9103_corrected_silhouette.jpg	73.94	12.02182019	7.331021667	0.800791228	106.4631957	23.49163148	0.986193366	2	2.2	CRAIGMILLAR CASTLE	0	1.4	1400
405	IMG_9105_corrected_silhouette.jpg	71.19	10.38197239	5.244369654	0.7958464	126.7504488	31.43277142	0.988616765	2	2.2	CRAIGMILLAR CASTLE	0	1.4	1400
406	IMG_9107_corrected_silhouette.jpg	76.07	12.40340332	8.432314203	0.828811793	110.2333932	22.39195204	0.998323731	2	2.2	CRAIGMILLAR CASTLE	0	1.4	1400
407	IMG_9114_corrected_silhouette.jpg	69.96	10.83413893	5.131998238	0.76504597	133.5063088	20.12360125	0.996558988	2	2.2	CRAIGMILLAR CASTLE	0	0.8	1600
408	IMG_9116_corrected_silhouette.jpg	73.7	10.87253142	4.40041974	0.720240526	114.7217235	22.28324595	0.985868215	2	2.2	CRAIGMILLAR CASTLE	0	0.8	1600
409	IMG_9134_corrected_silhouette.jpg	76.92	9.677419355	4.486499888	0.809533226	126.2118492	28.49806357	0.98683363	2	2.2	CRAIGMILLAR CASTLE	0	0.8	1600
410	IMG_9136_corrected_silhouette.jpg	82.01	11.29678221	7.490288004	0.829953276	108.9766607	34.04016918	0.986564152	2	2.2	CRAIGMILLAR CASTLE	0	0.8	1600
411	IMG_9381_corrected_silhouette.jpg	90.29	17.47456613	15.4758255	0.830058555	132.8545781	25.52997614	0.997776141	1	1.4	CRAIGMILLAR CASTLE	0	3.2	1400
412	IMG_9383_corrected_silhouette.jpg	90.65	29.71274686	17.94245632	0.818134492	146.1367589	24.24278904	0.997693849	1	1.4	CRAIGMILLAR CASTLE	0	3.2	1400
413	IMG_9405_corrected_silhouette.jpg	86.92	18.64383372	9.658109929	0.847092502	137.432675	25.16469038	0.997989192	1	1.4	CRAIGMILLAR CASTLE	0	3.2	1400
414	IMG_9417_corrected_silhouette.jpg	72.83	14.43447038	9.907333675	0.769237378	114.5421903	26.5672646	0.985351322	2	2.2	CRAIGMILLAR CASTLE	0	3.2	1400
415	IMG_9419_corrected_silhouette.jpg	78.52	22.67014852	17.64001138	0.750009133	118.6810166	33.89981273	0.965461331	2	2.1	CRAIGMILLAR CASTLE	0	3.2	1400
416	IMG_9425_corrected_silhouette.jpg	79.6	20.94554159	14.4157244	0.862478227	108.6735818	47.30460467	0.993756008	2	2.1	CRAIGMILLAR CASTLE	0	3.2	1400
417	IMG_9448_corrected_silhouette.jpg	74.92	8.423504294	2.980941754	0.820421799	111.8491921	18.90634644	0.997315057	2	2.2	CRAIGMILLAR CASTLE	0	0.45	1600
418	IMG_9456_corrected_silhouette.jpg	85.95	14.90125673	6.419829243	0.781538397	142.7289048	23.16294402	0.995232646	2	2.1	CRAIGMILLAR CASTLE	0	0.85	1500
419	IMG_9462_corrected_silhouette.jpg	81.88	14.75763016	6.010475981	0.736343169	105.7450628	34.4023024	0.989187905	2	2.2	CRAIGMILLAR CASTLE	0	0.75	1500
420	IMG_9464_corrected_silhouette.jpg	83.1	13.40514662	6.446840656	0.736331967	134.9404485	58.06656017	0.991353441	2	2.2	CRAIGMILLAR CASTLE	0	0.85	1500
421	IMG_9466_corrected_silhouette.jpg	82.75	9.671776458	4.456883027	0.790591132	150.3325759	30.61297588	0.993597476	2	2.2	CRAIGMILLAR CASTLE	0	0.8	1500
422	IMG_9468_corrected_silhouette.jpg	78.15	12.95332137	5.903017061	0.888536906	117.5942549	23.90563937	0.997264519	2	2.1	CRAIGMILLAR CASTLE	0	1	1500
423	P7131773_corrected_silhouette.jpg	98.93	32.02872532	0.204699358	0.975216188	185.4292383	4.271253093	0.999946658	3	3.2	WEDDERBURN CASTLE	1	NA	1767
424	P7131797_corrected_silhouette.jpg	98.83	31.99281867	0.321158776	0.982773716	198.7650759	1.938685385	0.999958508	3	3.2	WEDDERBURN CASTLE	1	NA	1767
425	P7131804_corrected_silhouette.jpg	86.08	15.39089277	2.142533017	0.933673315	232.1364452	8.170380747	0.999851509	1	1.2	WEDDERBURN CASTLE	NA	NA	1800
426	P7131832_corrected_silhouette.jpg	98.7	31.95691203	0.191929077	0.979864663	230.8003417	2.581374693	0.999618729	3	3.2	WEDDERBURN CASTLE	1	NA	1767

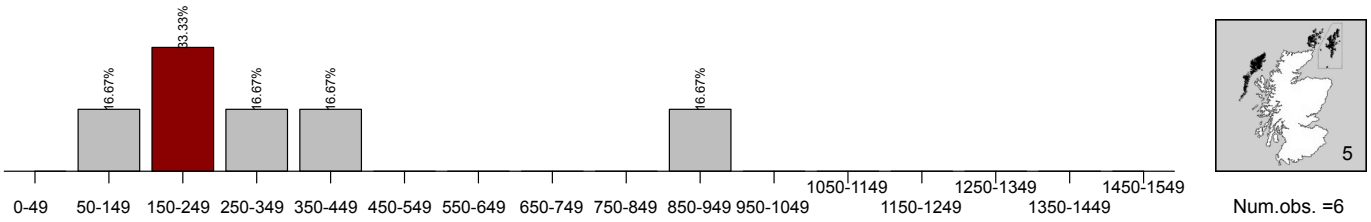
APPENDIX 3
FULL SETS OF RESULTS

3.1 RESULTS OF THE STATISTICAL ANALYSIS OF BUILDINGS MORPHOLOGY

LEGEND		
ID	PARAMETER	LEVELS OR CATEGORIES
LOR	Location	1=South, 2=Central, 3=north-east, 4=north-west, 5=Islands.
PE	Period group	1=before 17th century, 2=Between 17th and 18th centuries, 3= After 18th century, 4=1&2, 5= 2&3, 6= 1&2&3.
AAR	Average ground floor area	[m2]
MSR	Maximum span of the first floor	[m]
PL	Type or geometry of the plan	1= Courtyard plan, 2=E plan, 3=F plan, 4=H plan, 5=L plan, 6= oblong, 7= Squared or rectangular tower, 8=T plan, 9= U plan, 10= Vila (compact or with flanking pavilions), 11= Z plan.
NF	Average number of floors above ground floor level.	From 1 to 6 floors.
NV	Number of vaulted levels in the building.	From 0 to 4 vaulted levels.
MT	Type of pattern	1=Ashlar, 2= Random rubble, 3= Squared rubble, 4=1&2, 5= 1&3, 6= 2&3.
T1R1	1st predominant wall thickness in the ground floor in terms of linear meters.	[m]
T2R1	2nd predominant wall thickness in the ground floor in terms of linear meters.	[m]

3.1.1 RESULTS REFERRED TO THE PARAMETER LOR

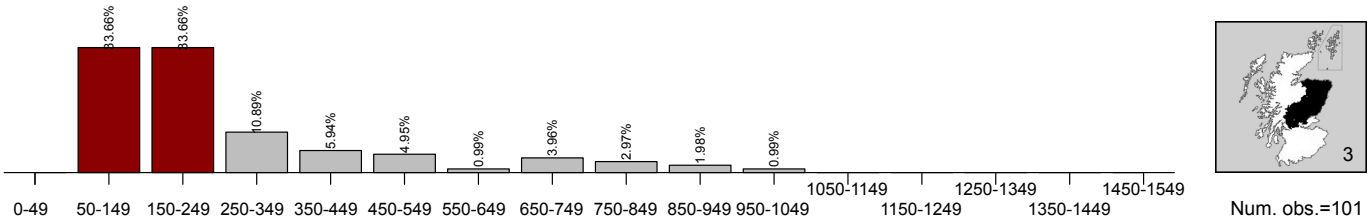
AAR



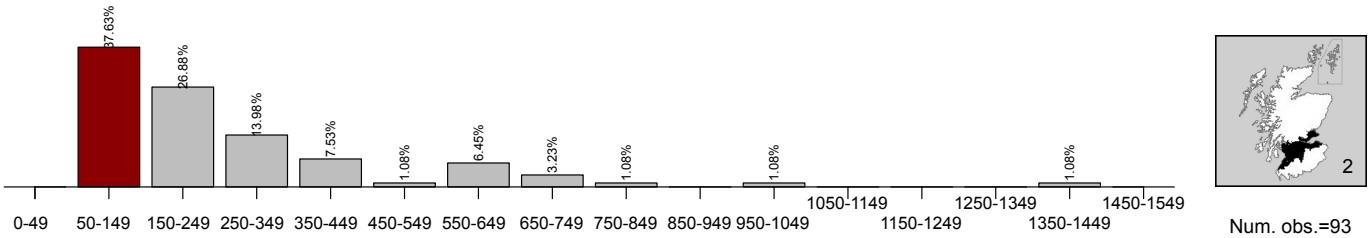
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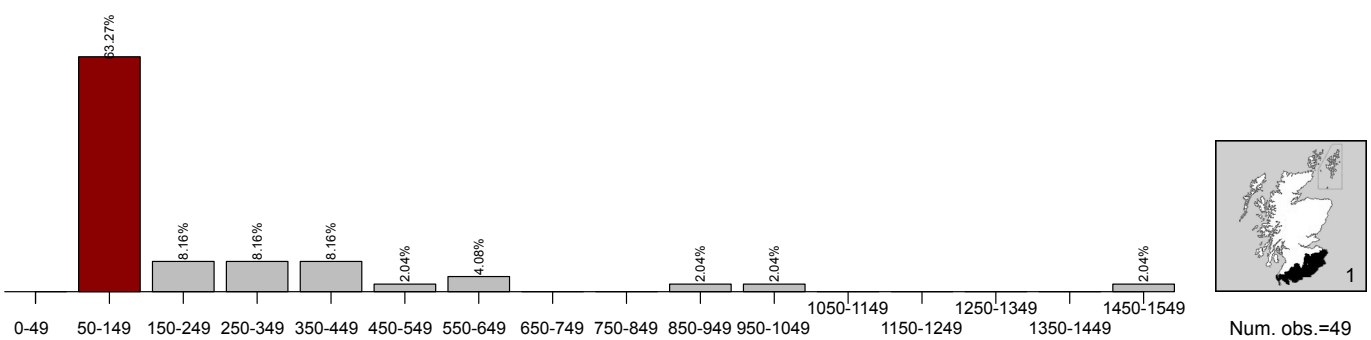
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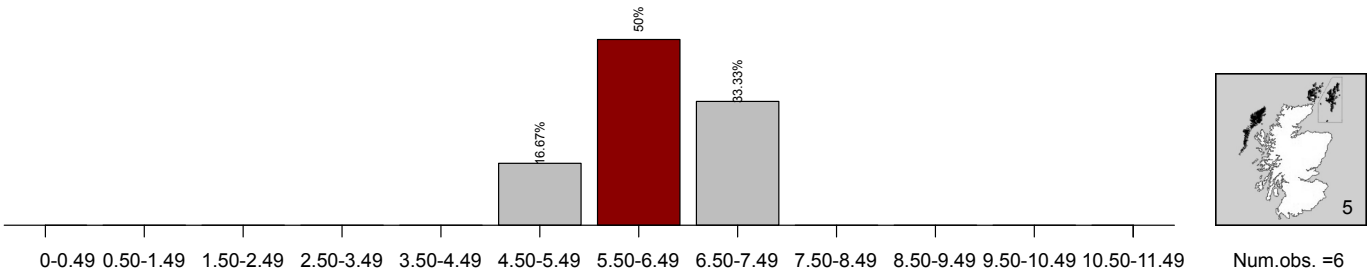


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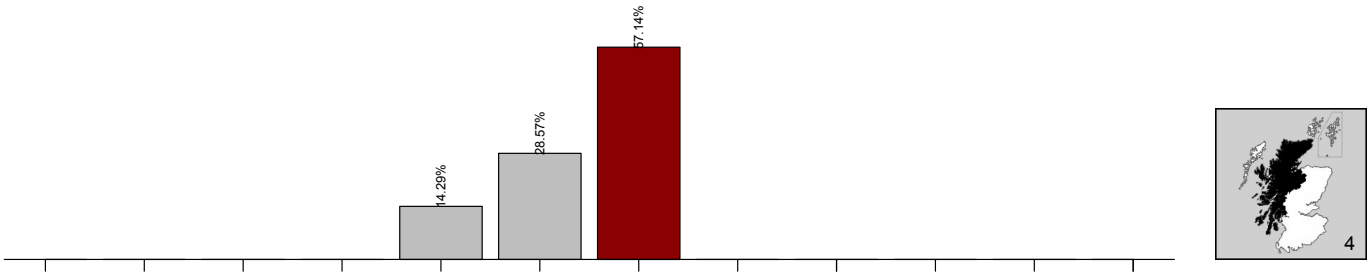


Num. obs.=49

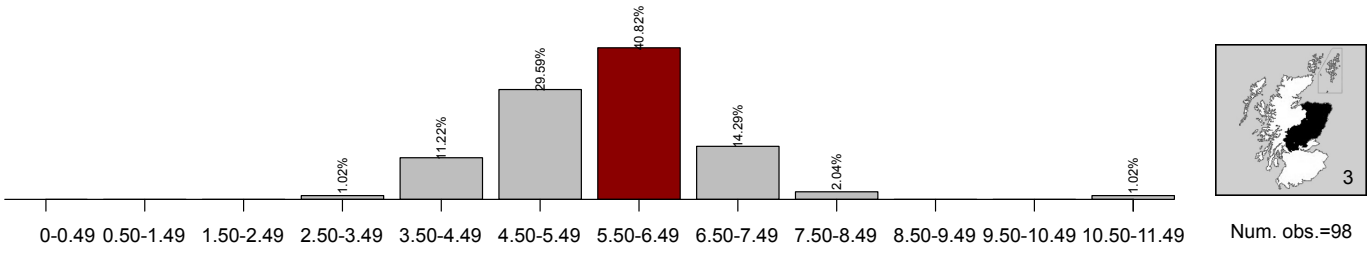
MSR



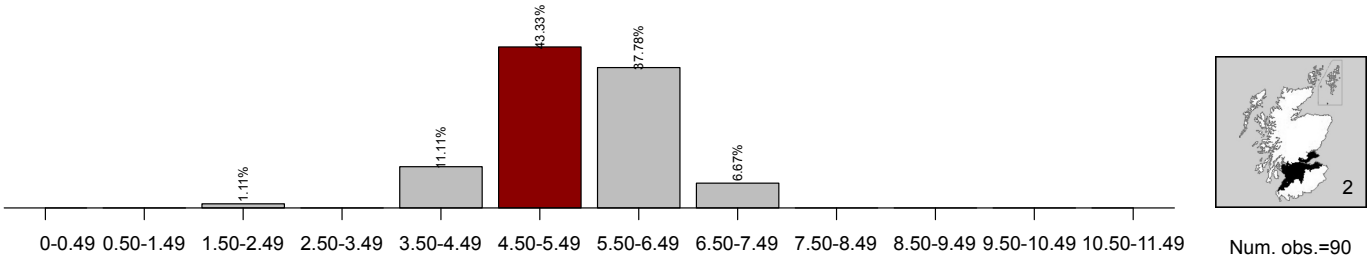
Num.obs. =6



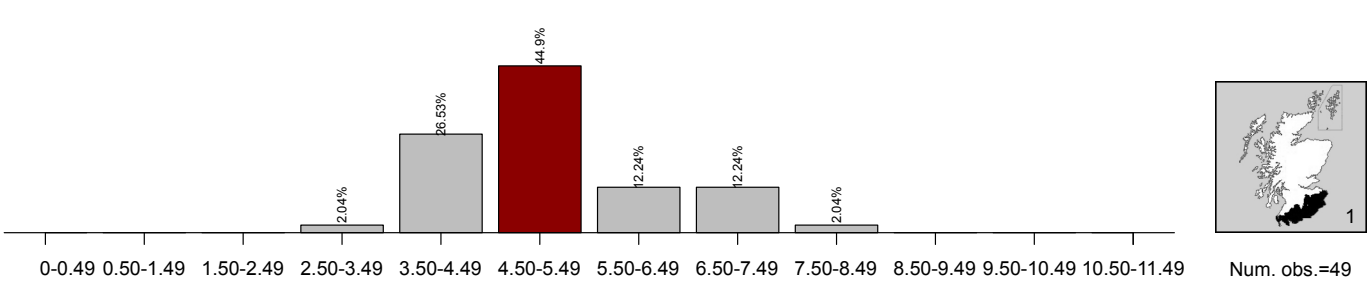
Num.obs.=7



Num. obs.=98

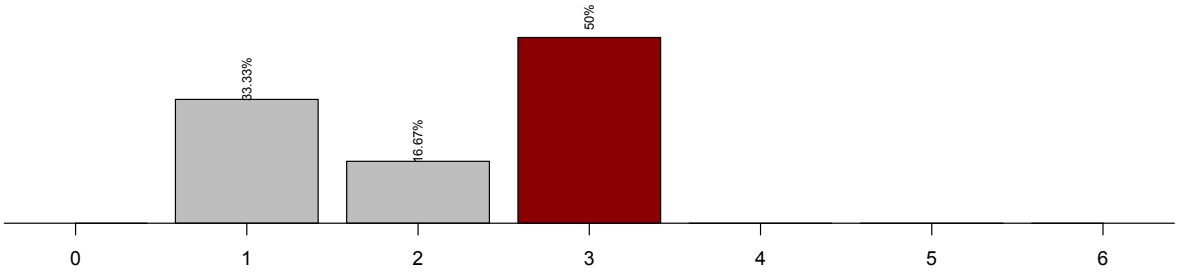


Num. obs.=90



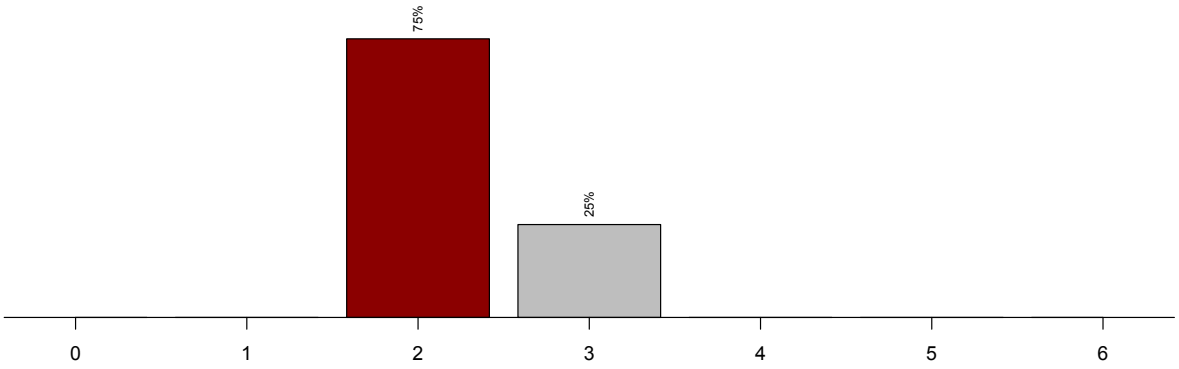
Num. obs.=49

MT



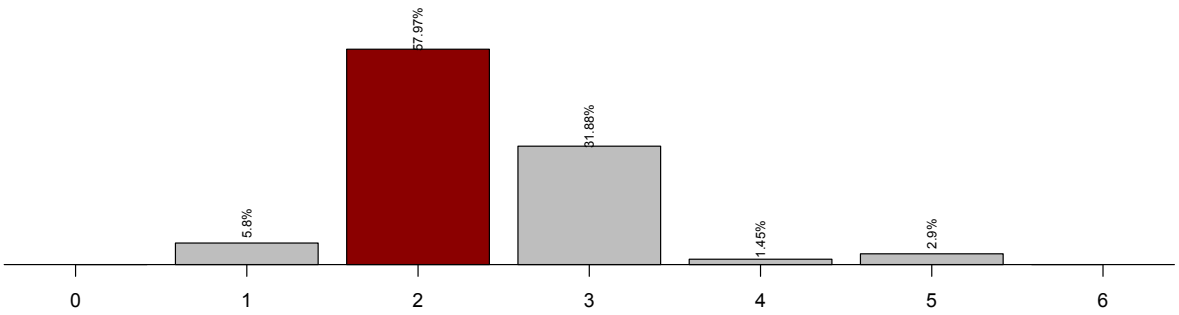


Num.obs. =6



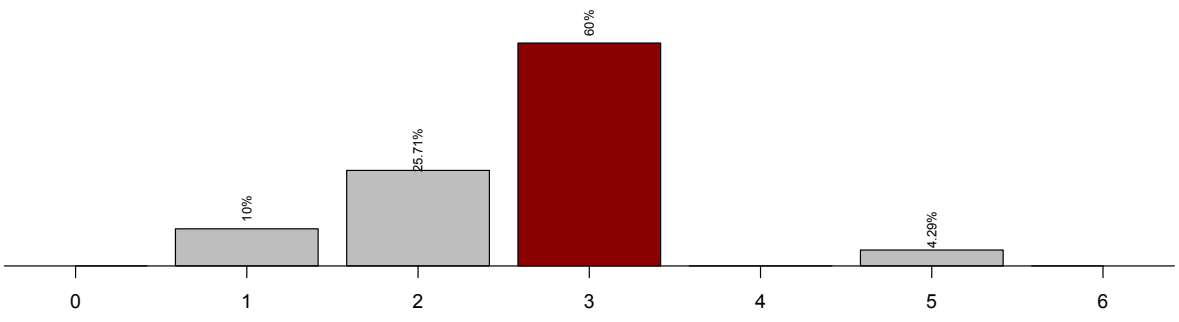


Num.obs.=8



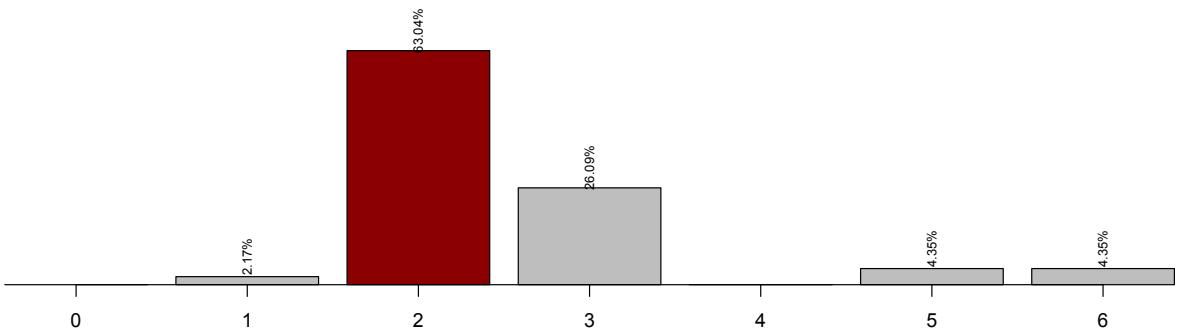


Num. obs.=69





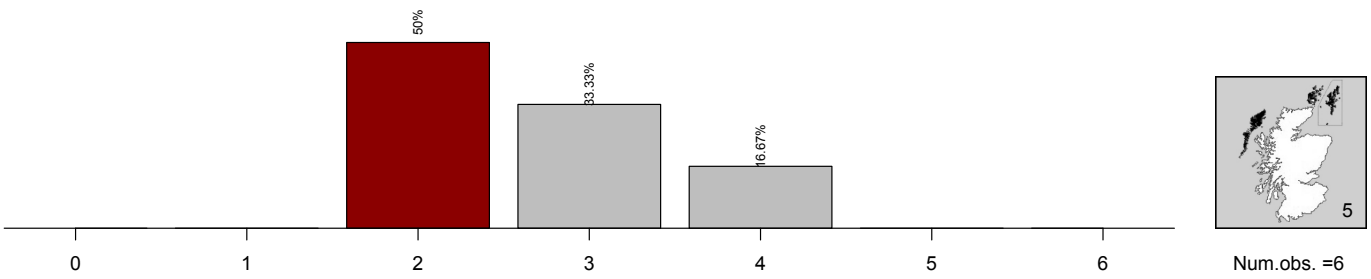
Num. obs.=70



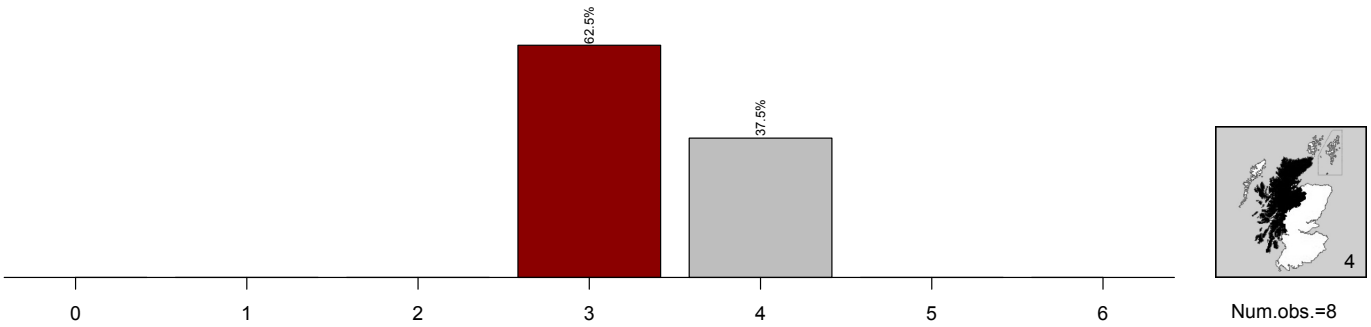


Num. obs.=46

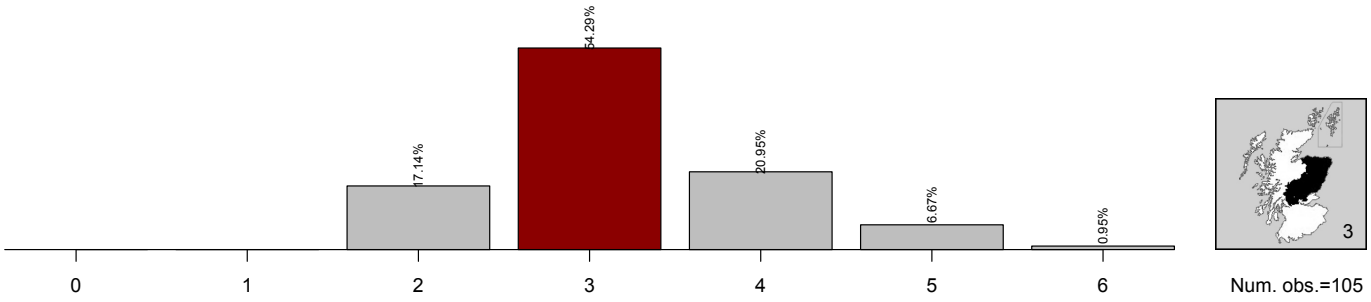
NF



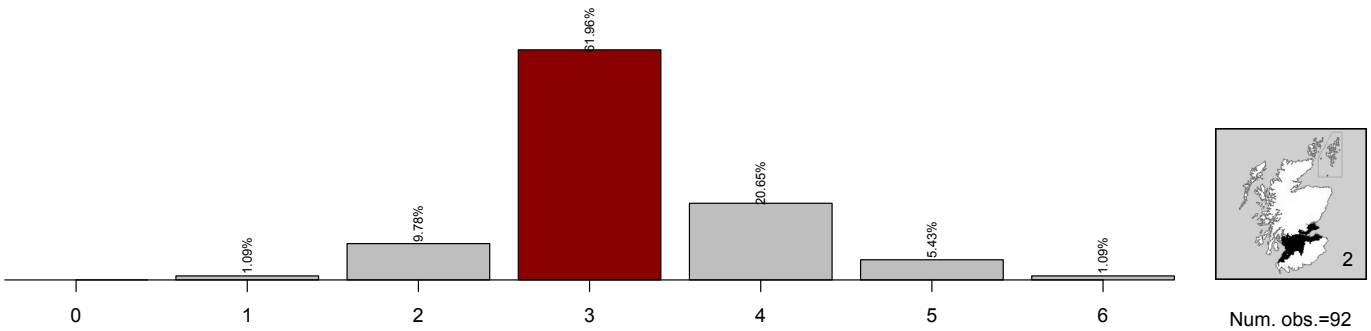
Num.obs. =6



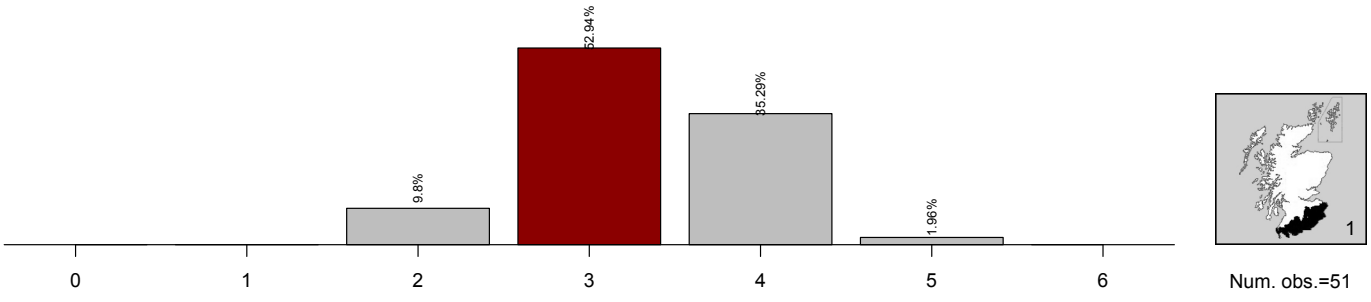
Num.obs.=8



Num. obs.=105

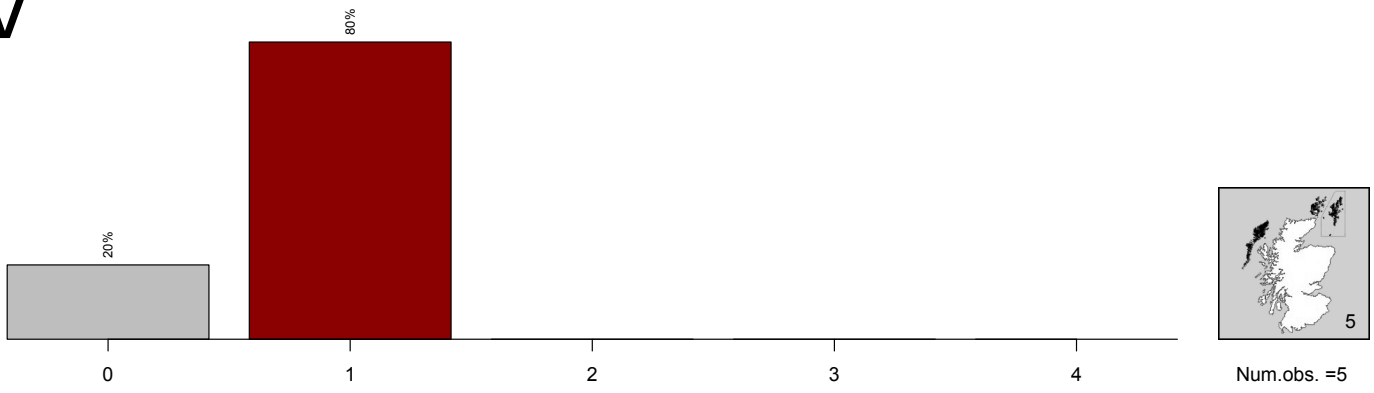


Num. obs.=92

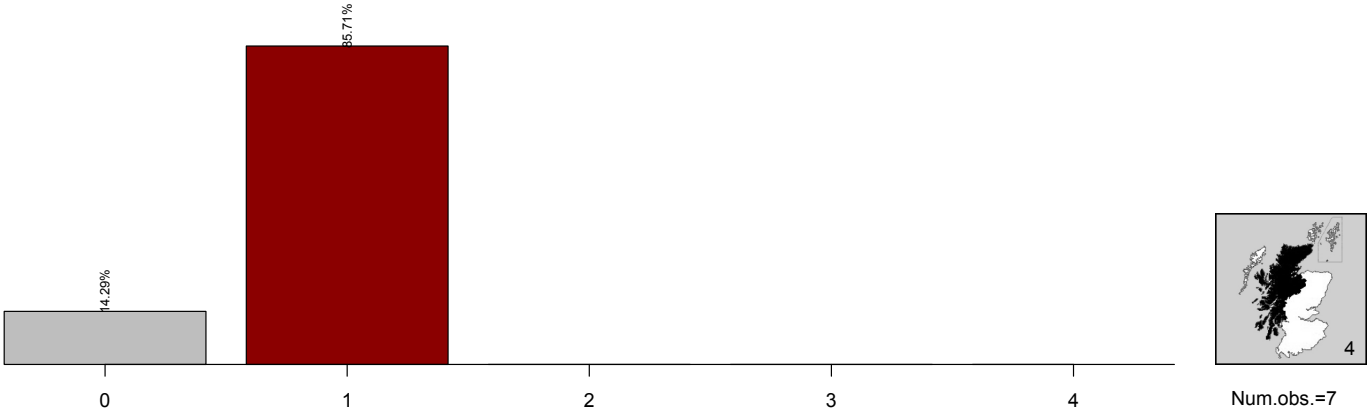


Num. obs.=51

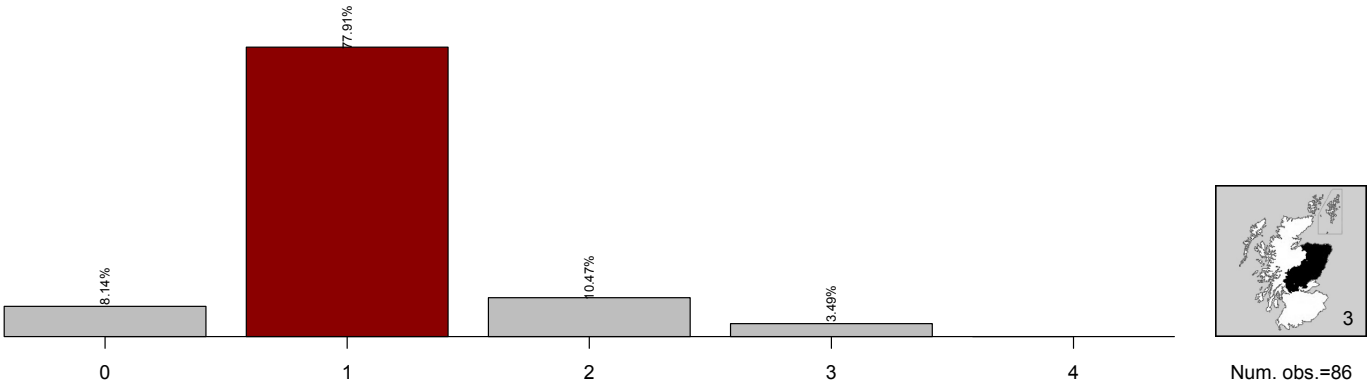
NV



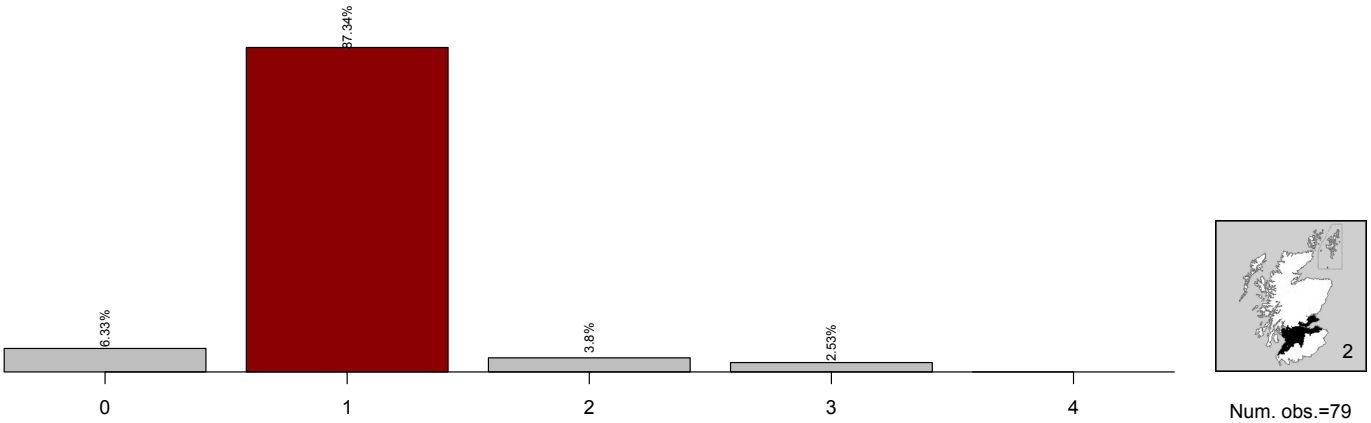
Num.obs. =5



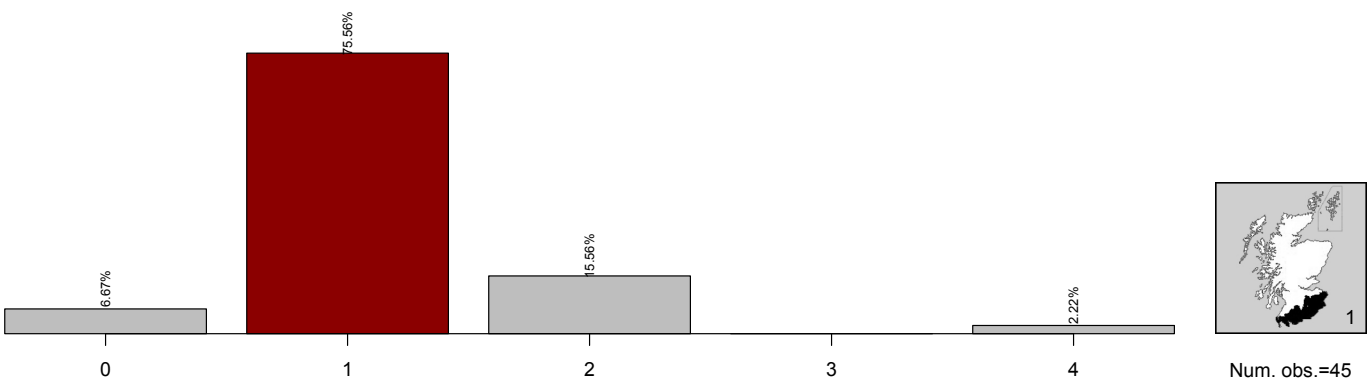
Num.obs.=7



Num. obs.=86

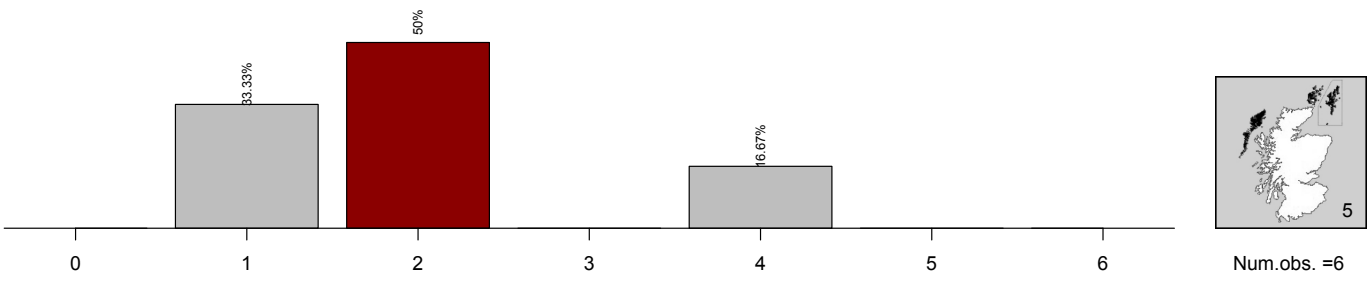


Num. obs.=79

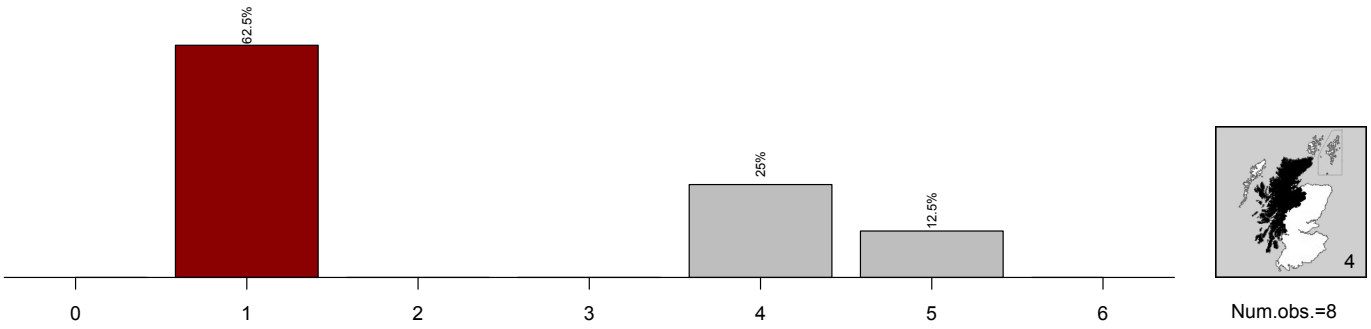


Num. obs.=45

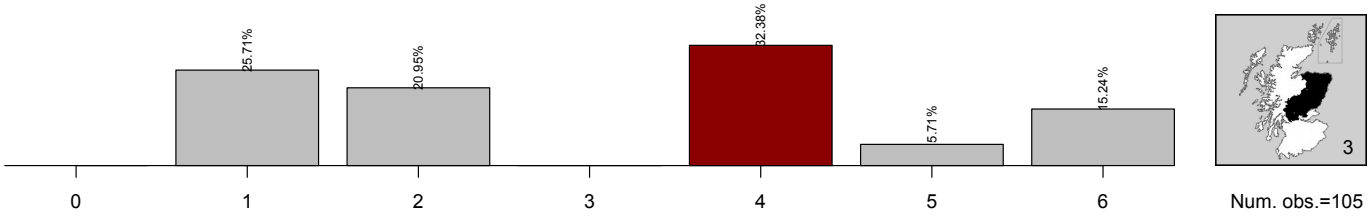
PE



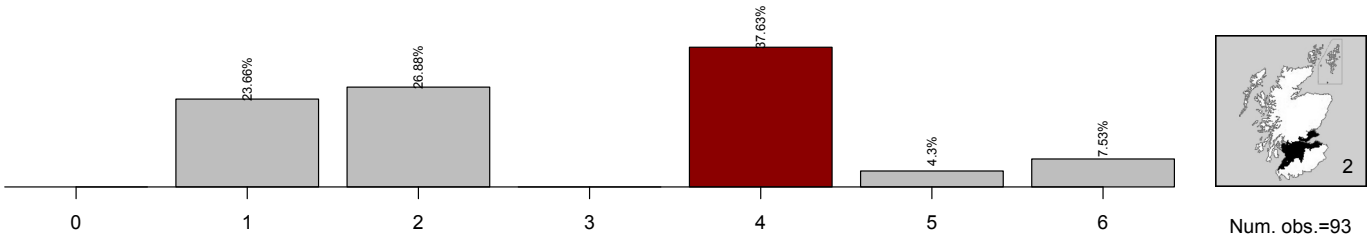
Num.obs. =6



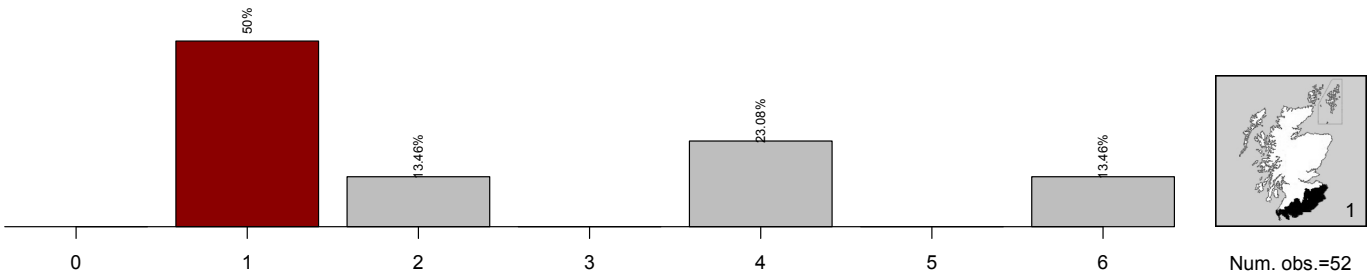
Num.obs.=8



Num. obs.=105

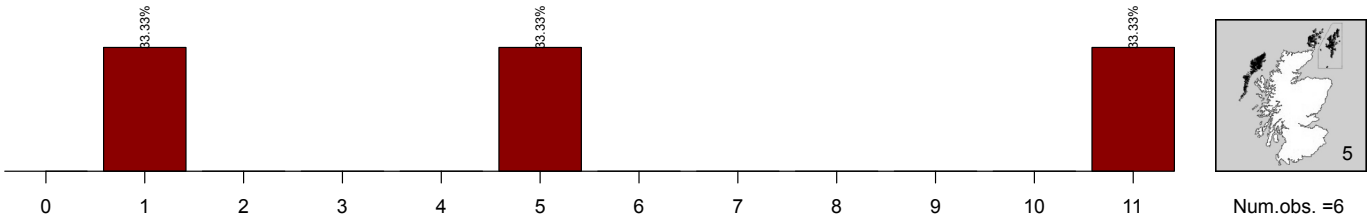


Num. obs.=93

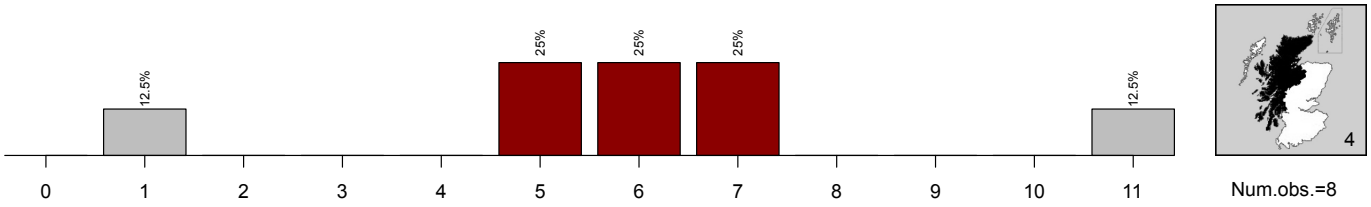


Num. obs.=52

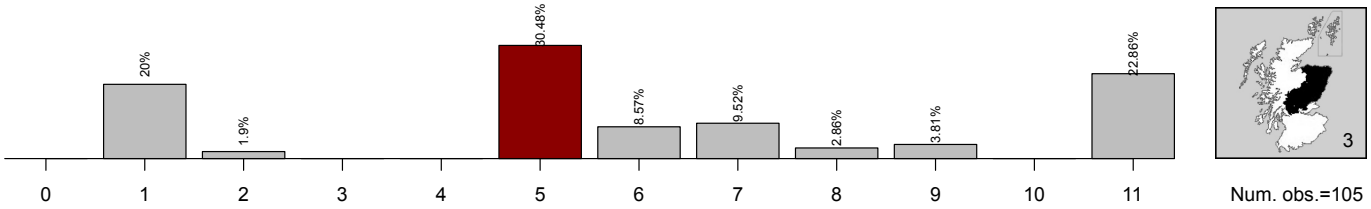
PL



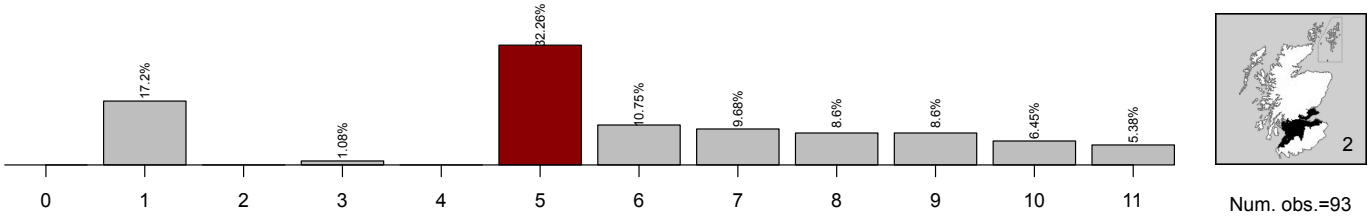
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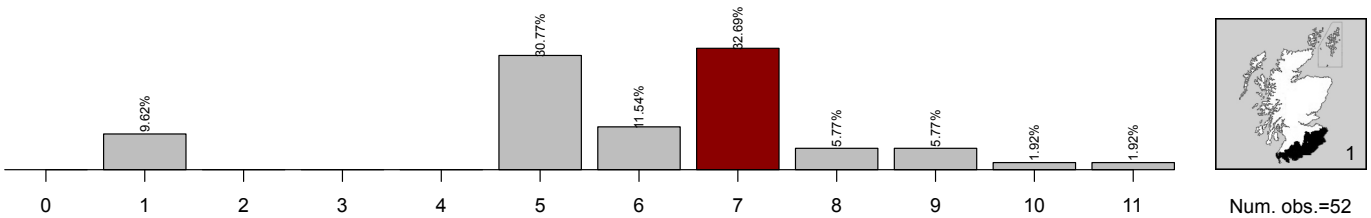
Num.obs.=8



Num. obs.=105

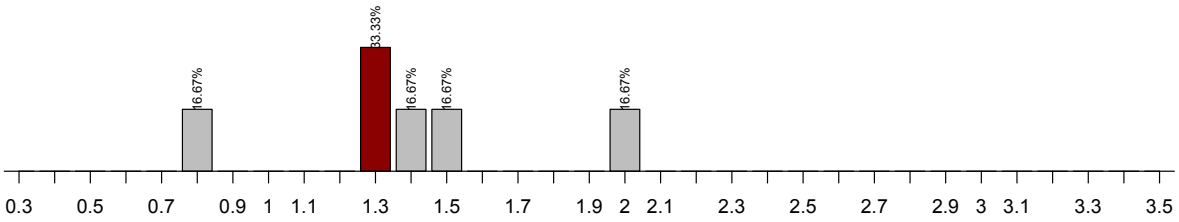


Num. obs.=93



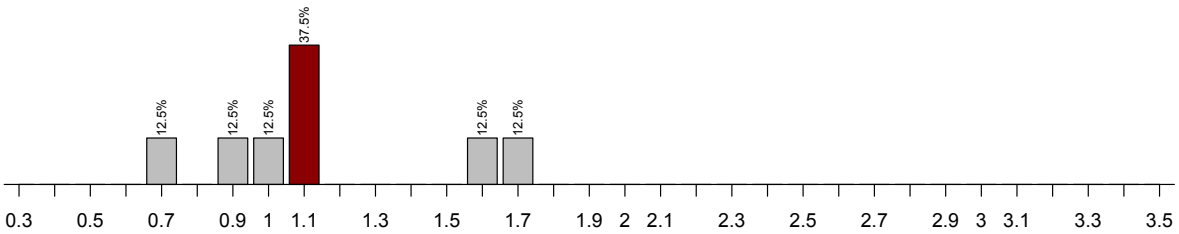
Num. obs.=52

T1R1



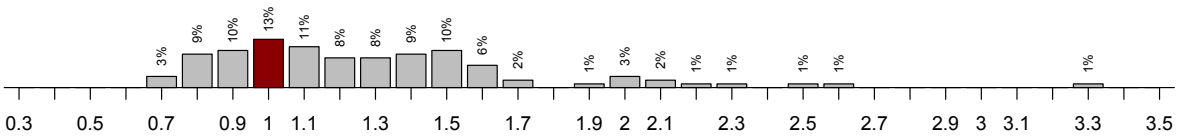


Num.obs. =6



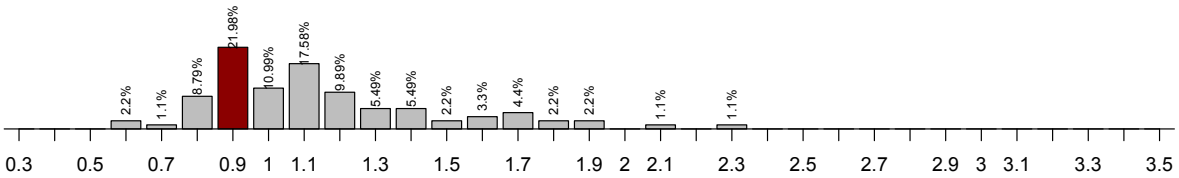


Num.obs.=8



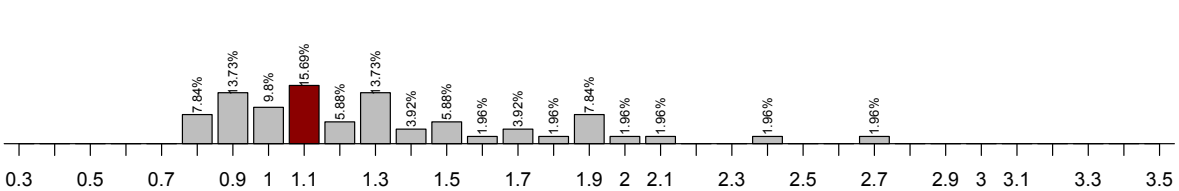


Num. obs.=100





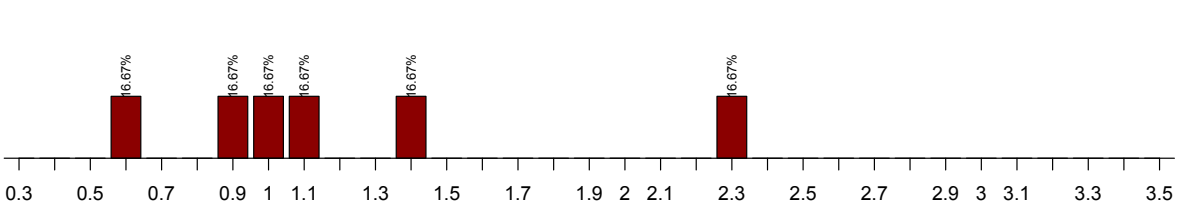
Num. obs.=91





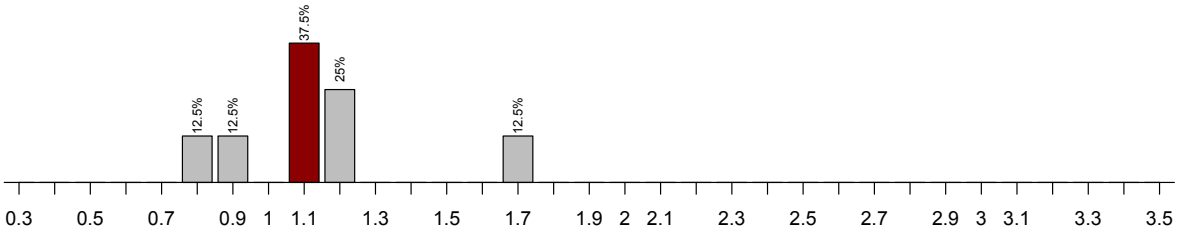
Num. obs.=51

T2R1



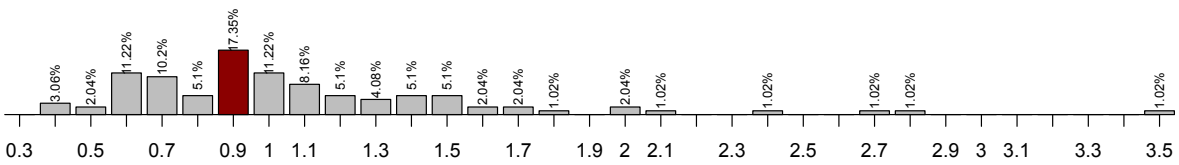


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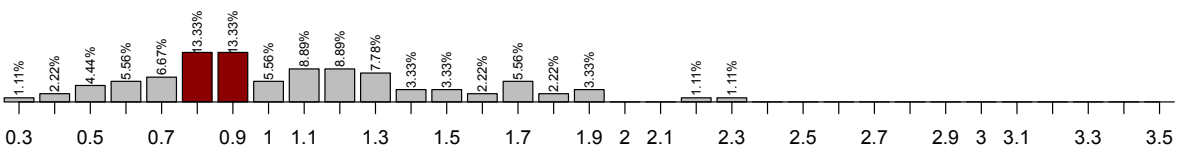


Num.obs.=8



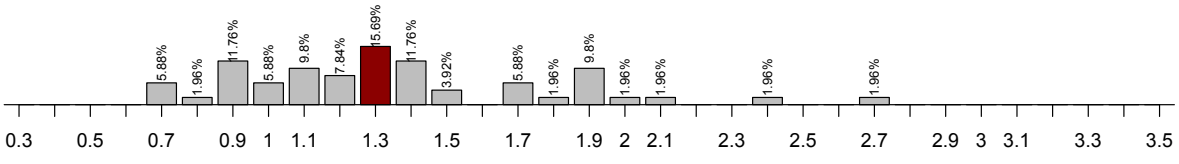


Num. obs.=98





Num. obs.=90

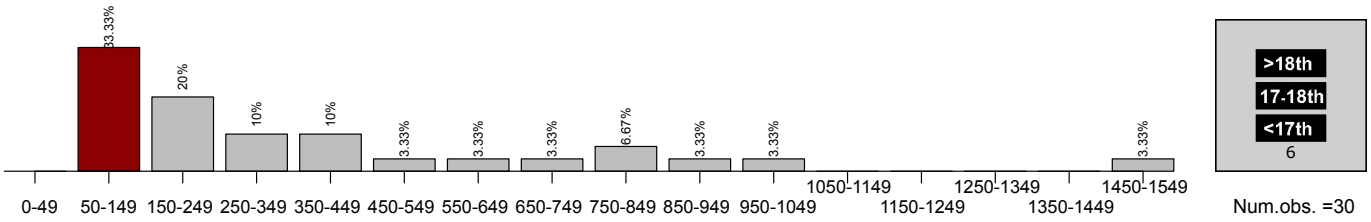




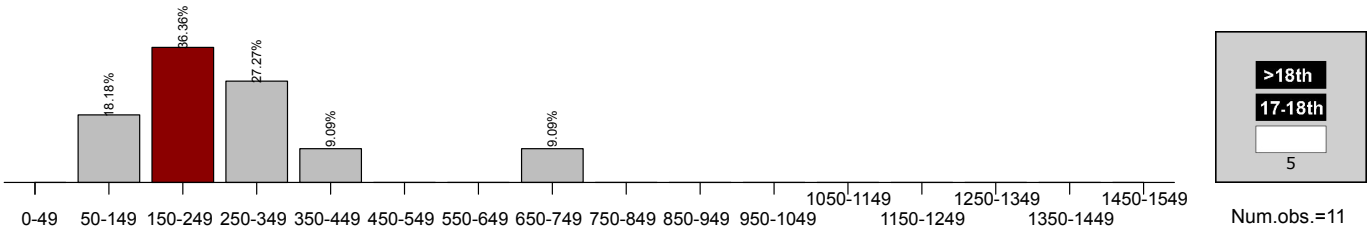
Num. obs.=51

3.1.2 RESULTS REFERRED TO THE PARAMETER PE

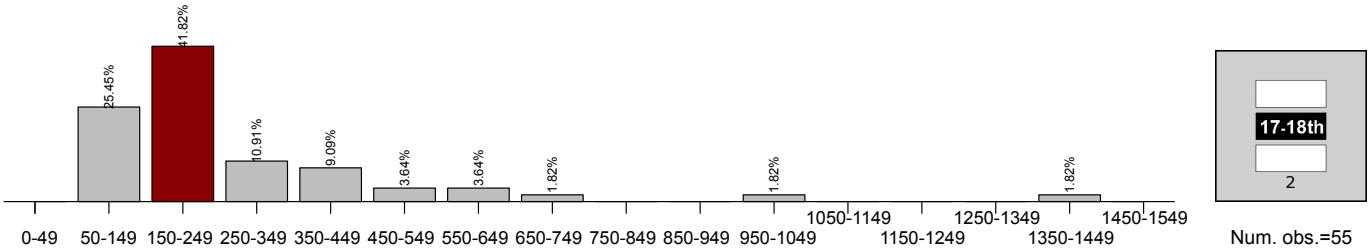
AAR



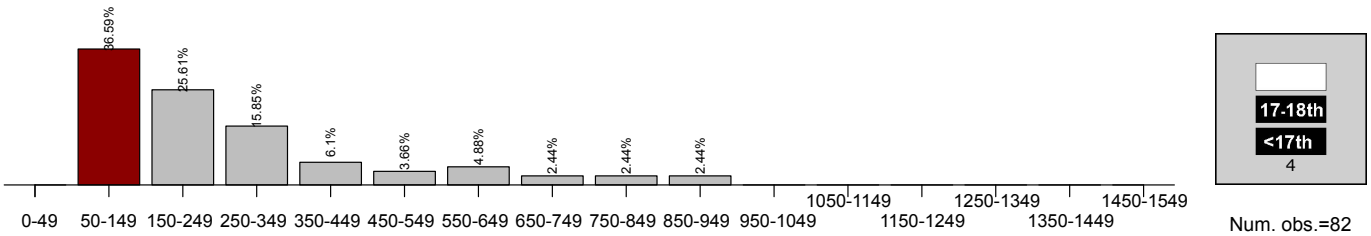
Num.obs. =30



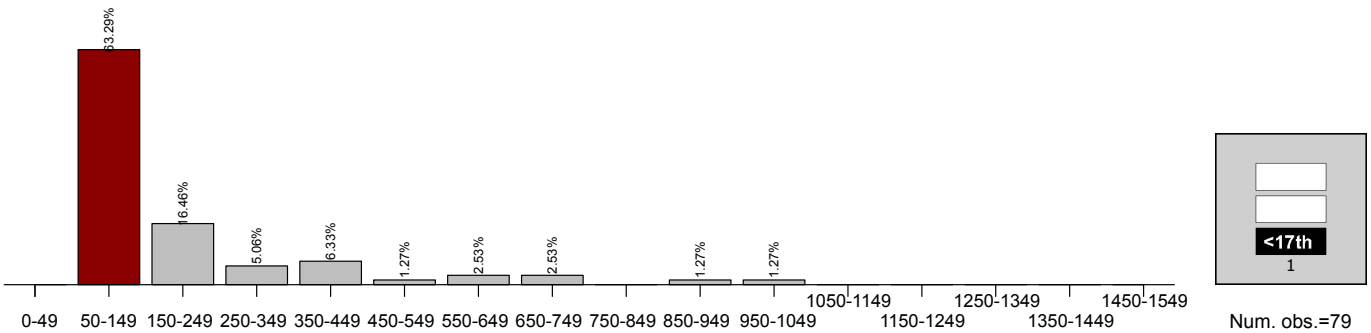
Num.obs.=11



Num. obs.=55

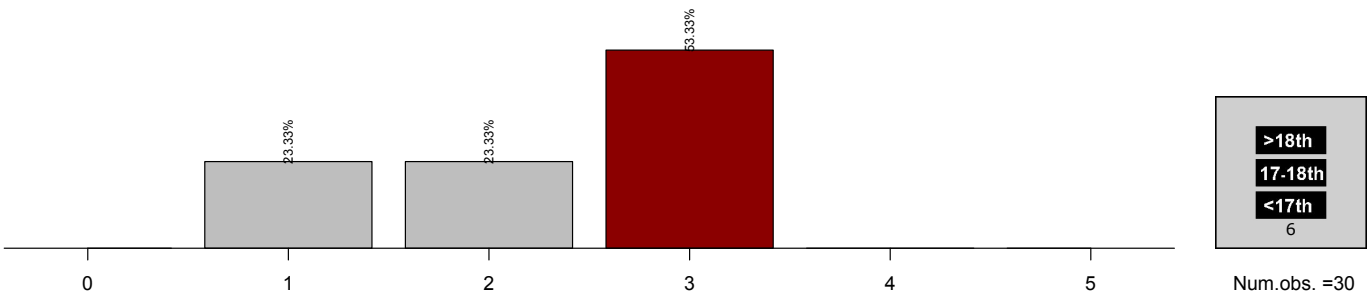


Num. obs.=82

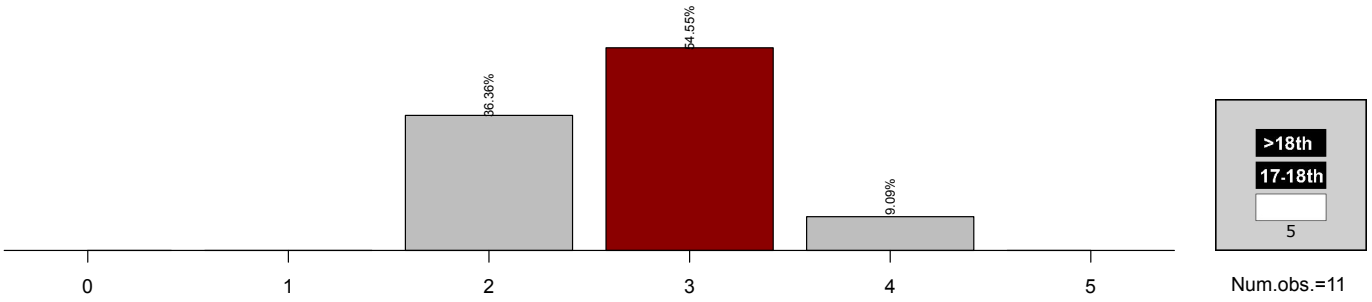


Num. obs.=79

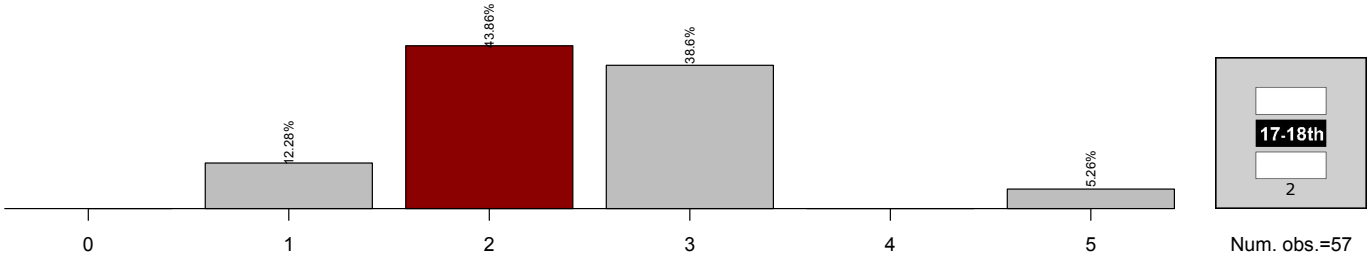
LOR



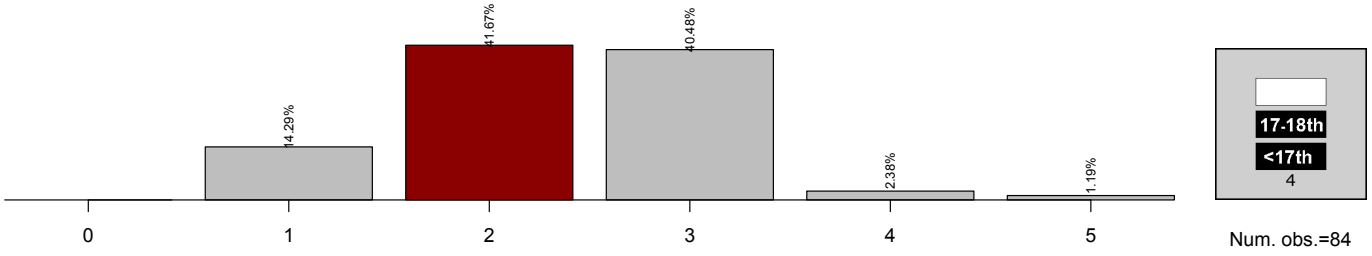
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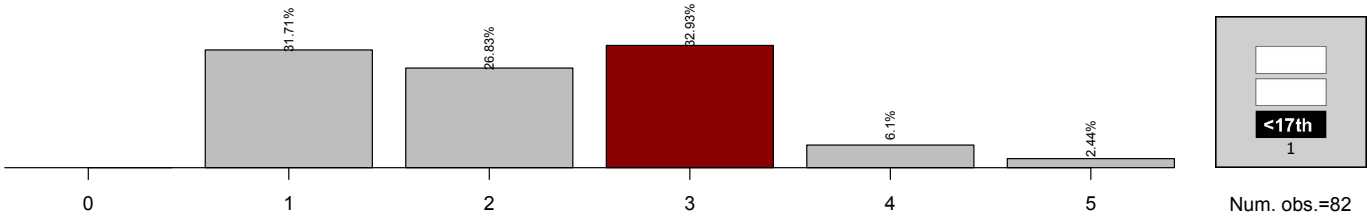
Num.obs.=11



Num. obs.=57

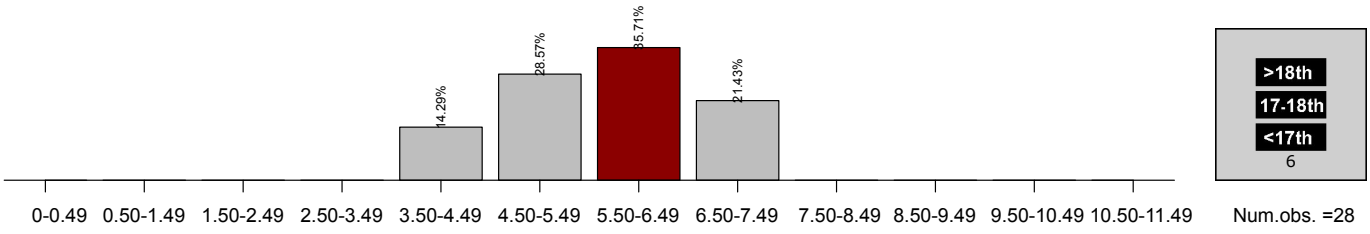


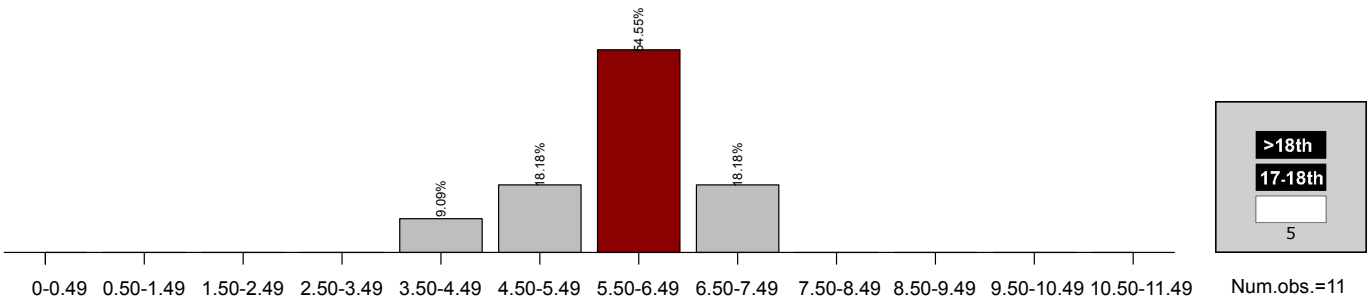
Num. obs.=84

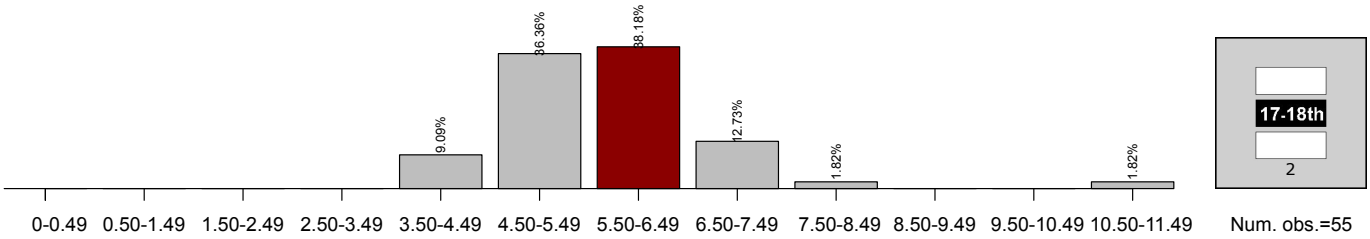


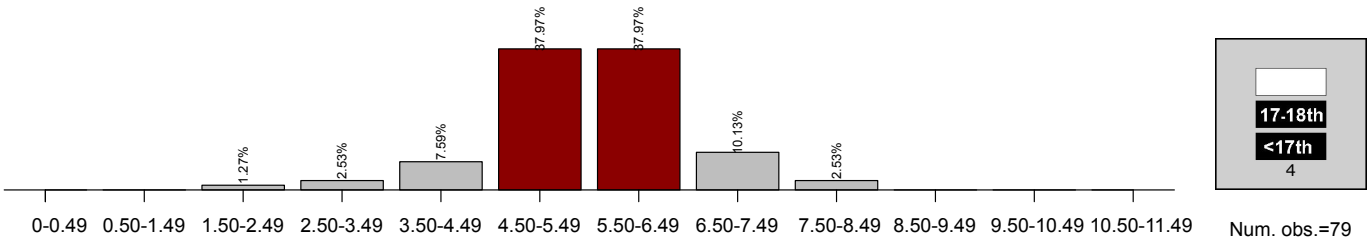
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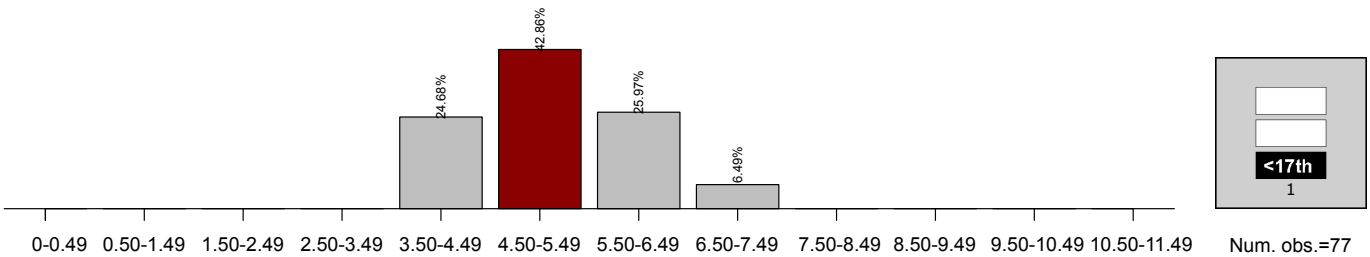
MSR


14.29%
28.57%
35.71%
21.43%
0-0.49
0.50-1.49
1.50-2.49
2.50-3.49
3.50-4.49
4.50-5.49
5.50-6.49
6.50-7.49
7.50-8.49
8.50-9.49
9.50-10.49
10.50-11.49
>18th
17-18th
<17th
6
Num.obs. =28

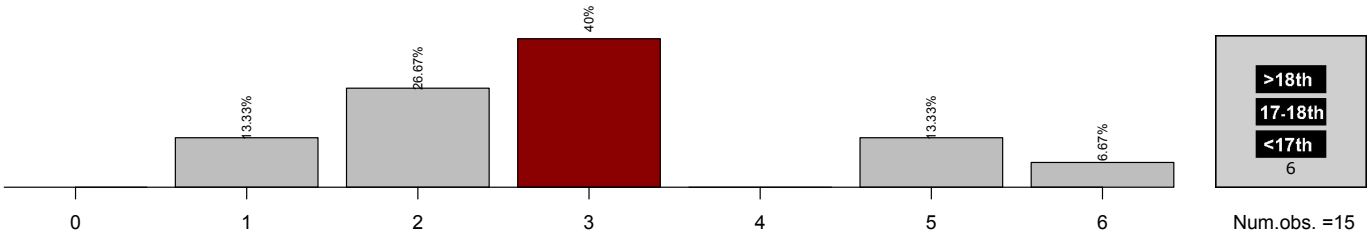

9.09%
18.18%
54.55%
18.18%
0-0.49
0.50-1.49
1.50-2.49
2.50-3.49
3.50-4.49
4.50-5.49
5.50-6.49
6.50-7.49
7.50-8.49
8.50-9.49
9.50-10.49
10.50-11.49
>18th
17-18th
5
Num.obs.=11


9.09%
36.36%
38.18%
12.73%
1.82%
1.82%
0-0.49
0.50-1.49
1.50-2.49
2.50-3.49
3.50-4.49
4.50-5.49
5.50-6.49
6.50-7.49
7.50-8.49
8.50-9.49
9.50-10.49
10.50-11.49
17-18th
2
Num. obs.=55

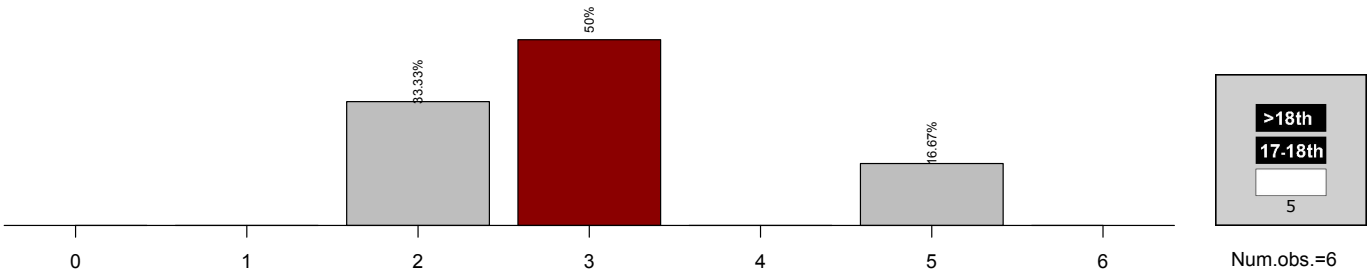

1.27%
2.53%
7.59%
37.97%
37.97%
10.13%
2.53%
0-0.49
0.50-1.49
1.50-2.49
2.50-3.49
3.50-4.49
4.50-5.49
5.50-6.49
6.50-7.49
7.50-8.49
8.50-9.49
9.50-10.49
10.50-11.49
17-18th
<17th
4
Num. obs.=79


24.68%
42.86%
25.97%
6.49%
0-0.49
0.50-1.49
1.50-2.49
2.50-3.49
3.50-4.49
4.50-5.49
5.50-6.49
6.50-7.49
7.50-8.49
8.50-9.49
9.50-10.49
10.50-11.49
<17th
1
Num. obs.=77

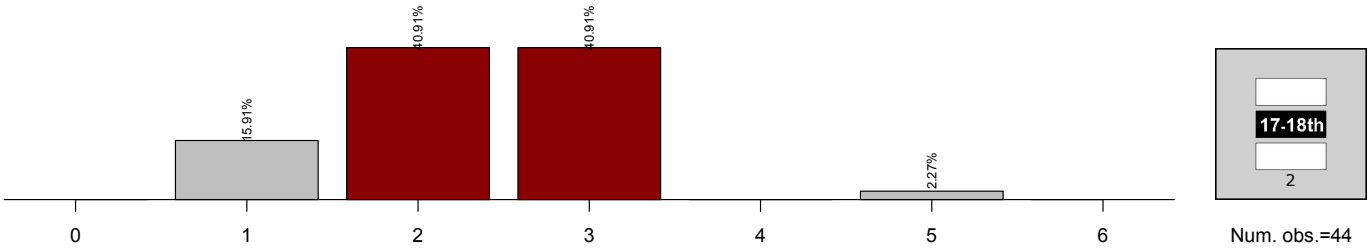
MT



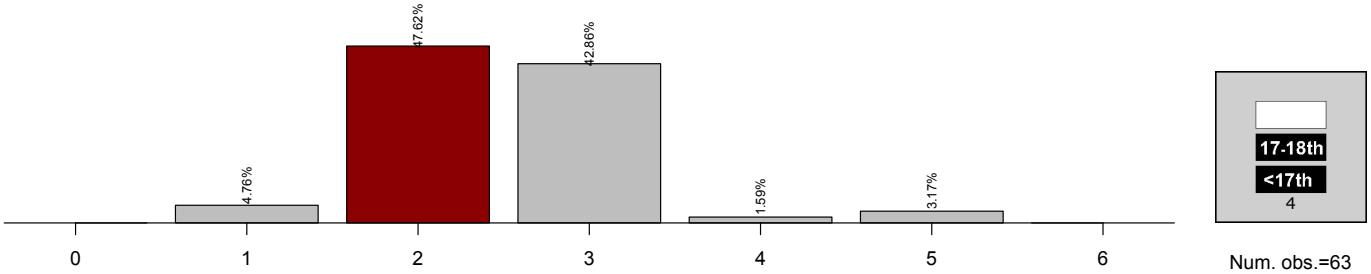
Num.obs. =15



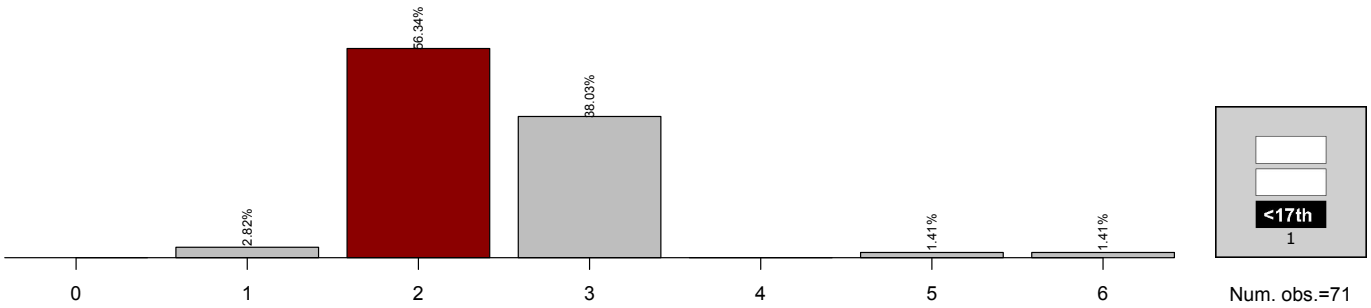
Num.obs.=6



Num. obs.=44

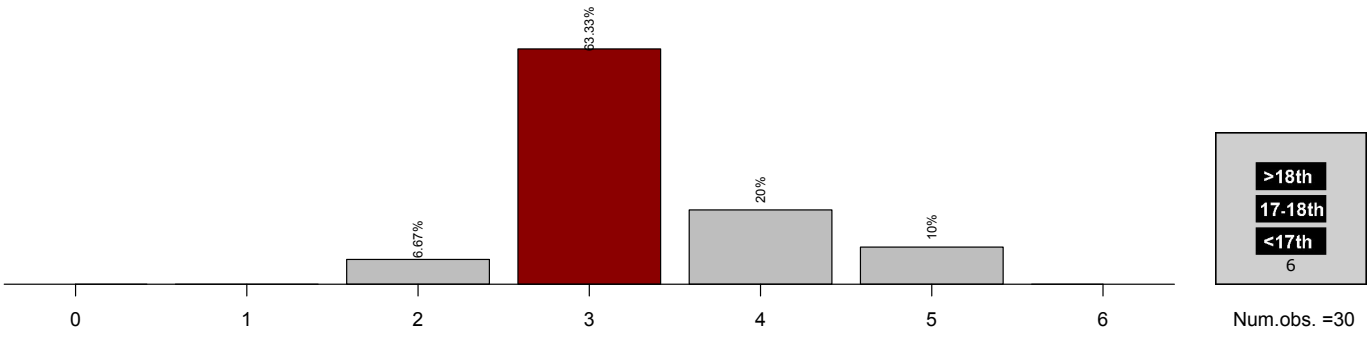


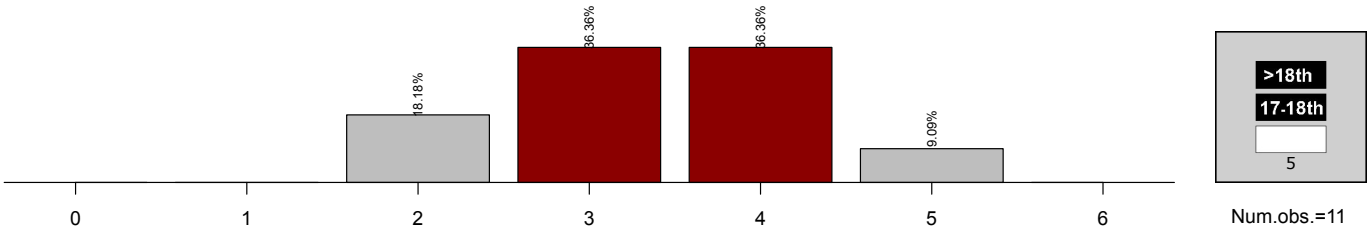
Num. obs.=63

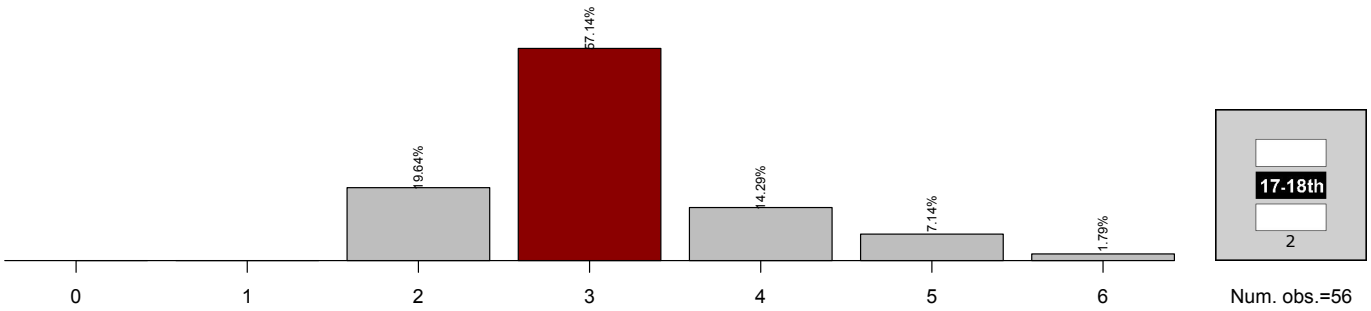


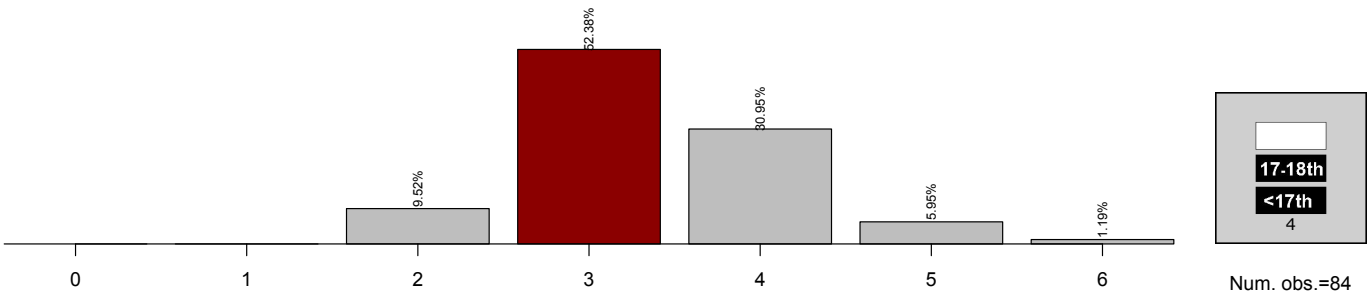
Num. obs.=71

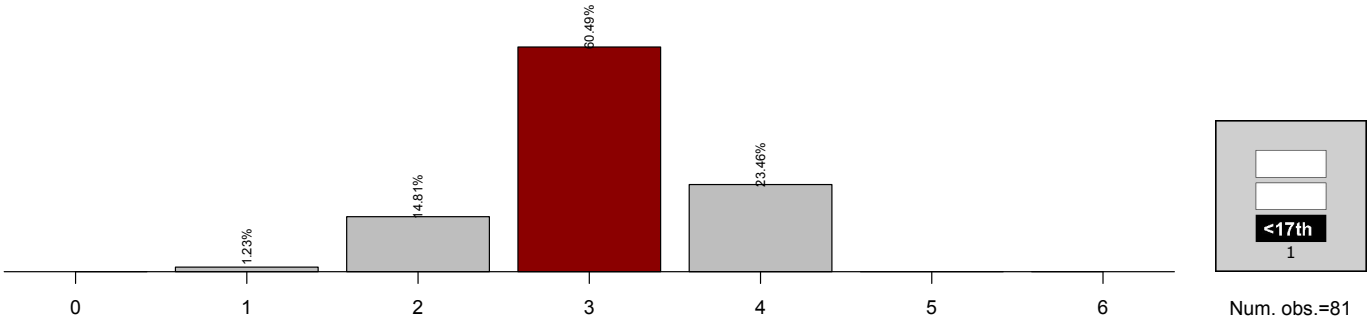
NF


6.67%
33.33%
20%
10%
0
1
2
3
4
5
6
>18th
17-18th
<17th
6
Num.obs. =30

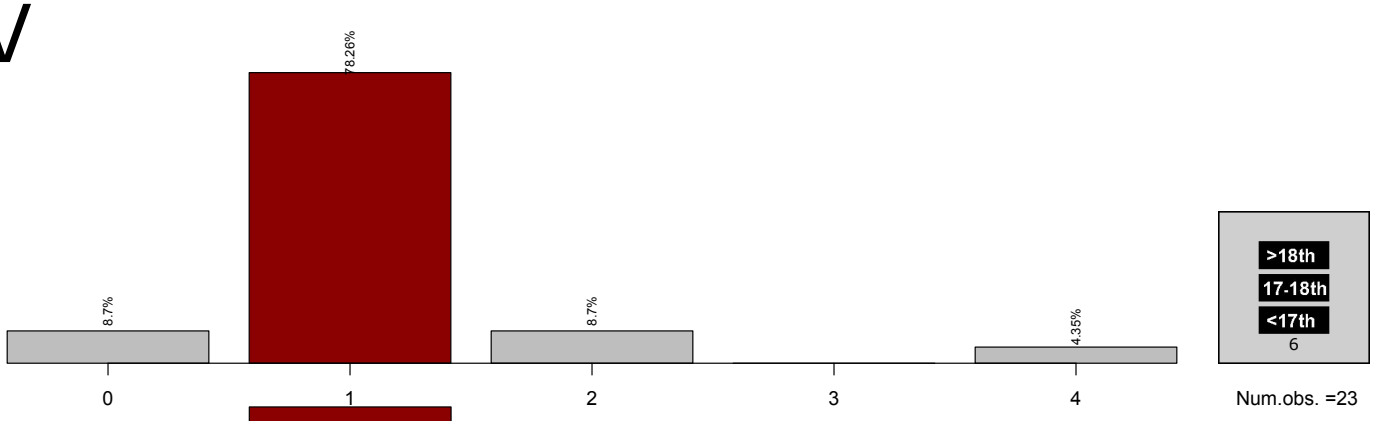

18.18%
36.36%
36.36%
9.09%
0
1
2
3
4
5
6
>18th
17-18th
5
Num.obs.=11


19.64%
57.14%
14.29%
7.14%
1.79%
0
1
2
3
4
5
6
17-18th
2
Num. obs.=56

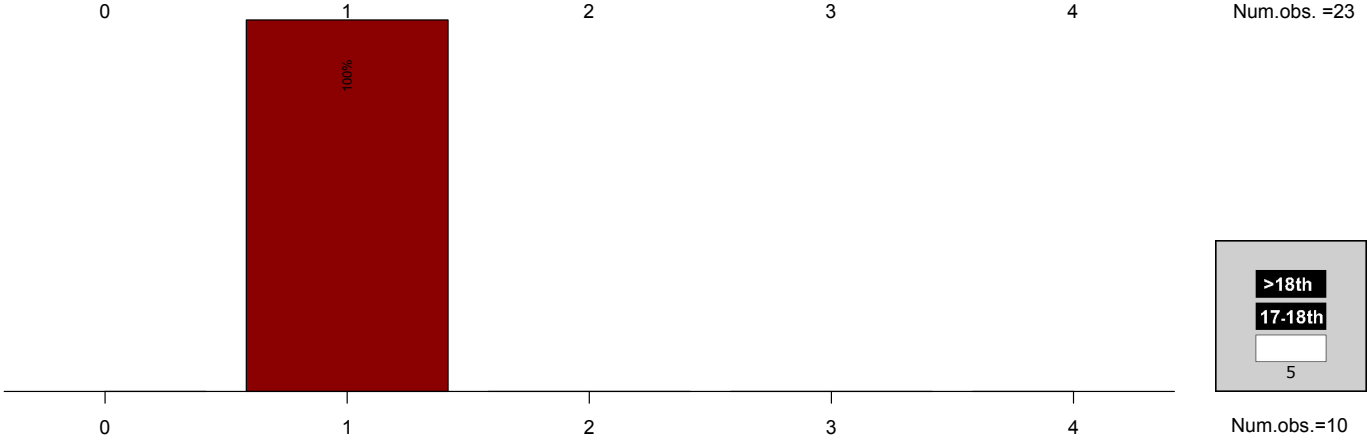

9.52%
52.38%
30.95%
5.95%
1.19%
0
1
2
3
4
5
6
17-18th
<17th
4
Num. obs.=84


1.23%
14.81%
60.49%
23.46%
0
1
2
3
4
5
6
<17th
1
Num. obs.=81

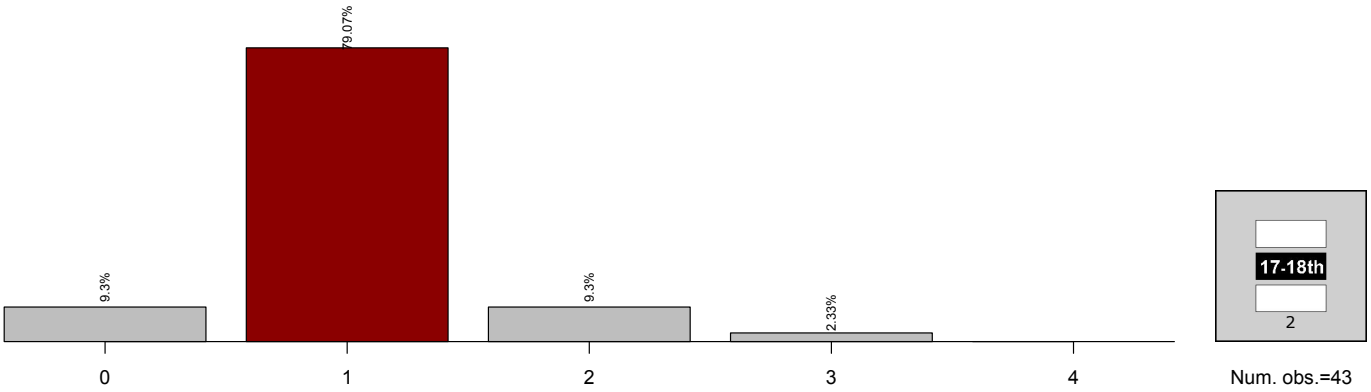
NV



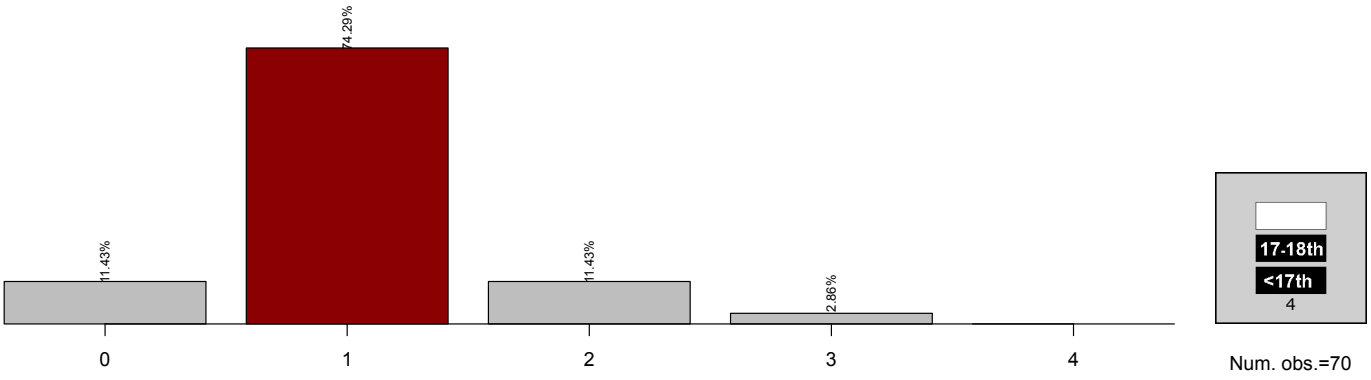
Num.obs. =23



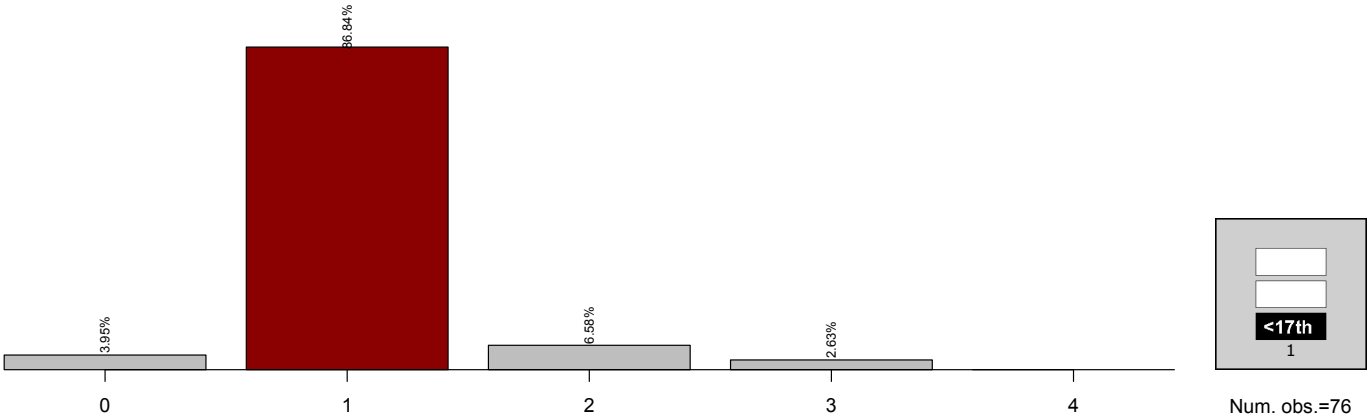
Num.obs.=10



Num. obs.=43

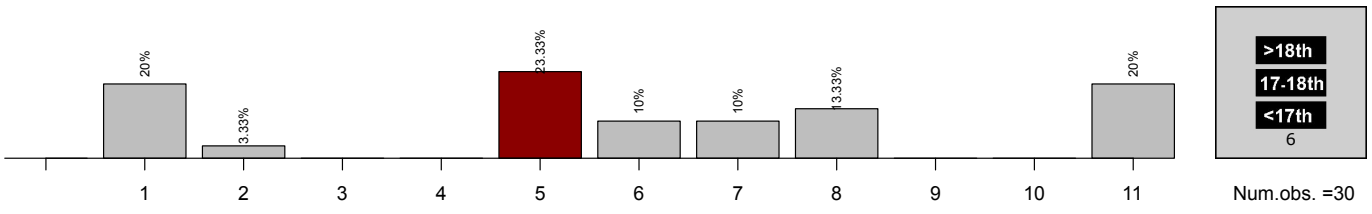


Num. obs.=70

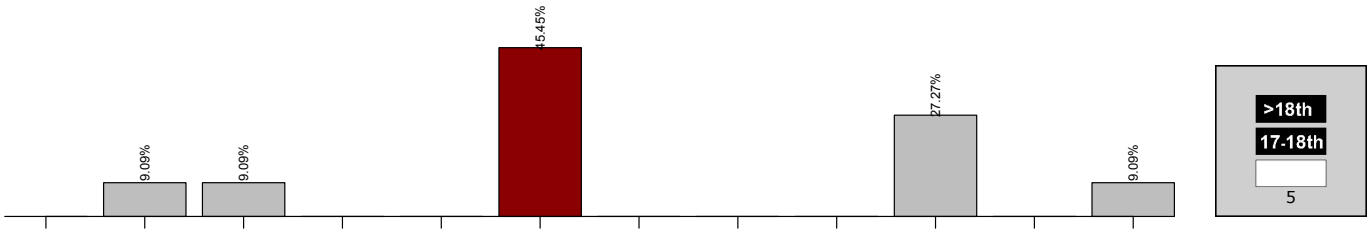


Num. obs.=76

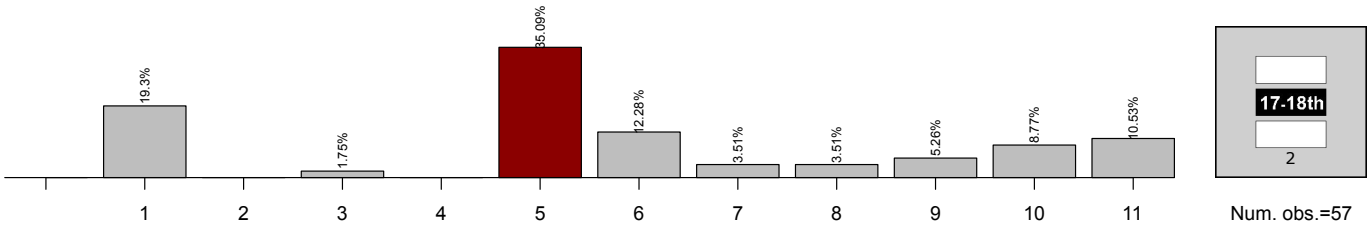
PL



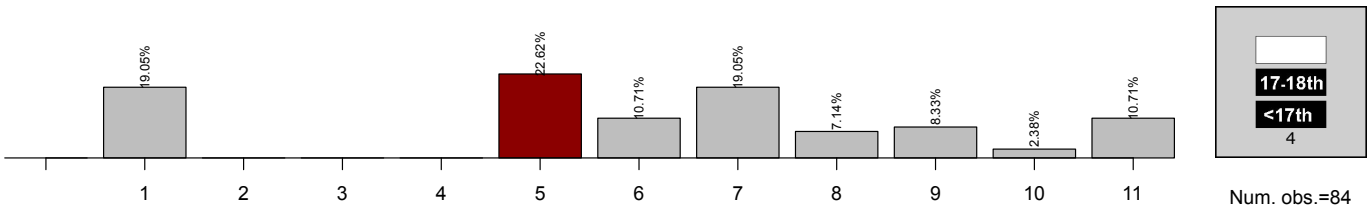
Num.obs. =30



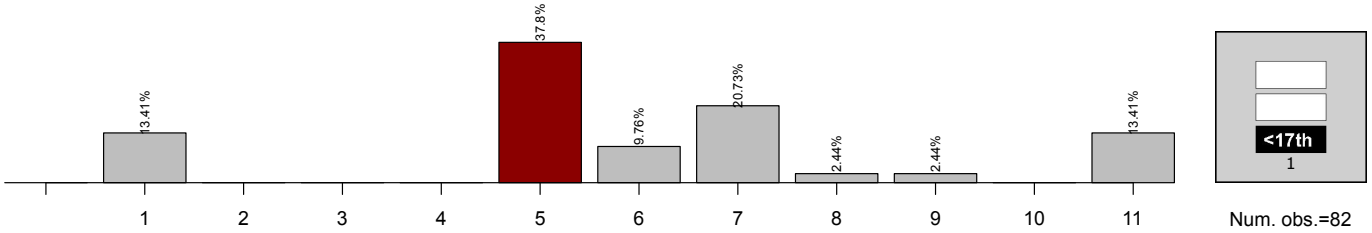
Num.obs.=11



Num. obs.=57

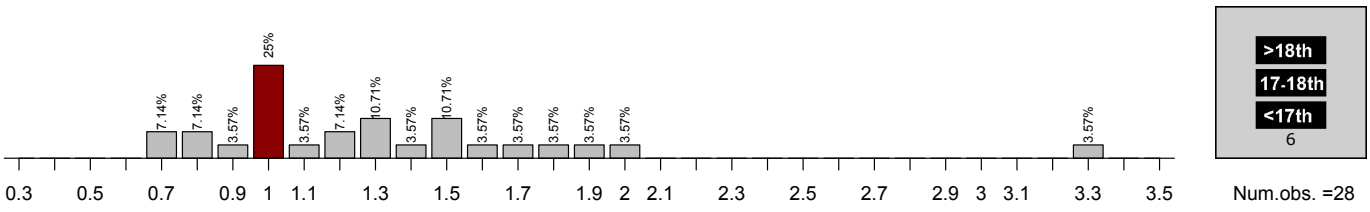


Num. obs.=84

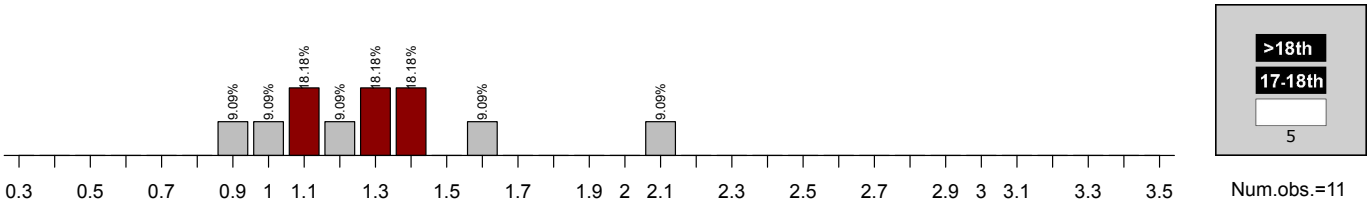


Num. obs.=82

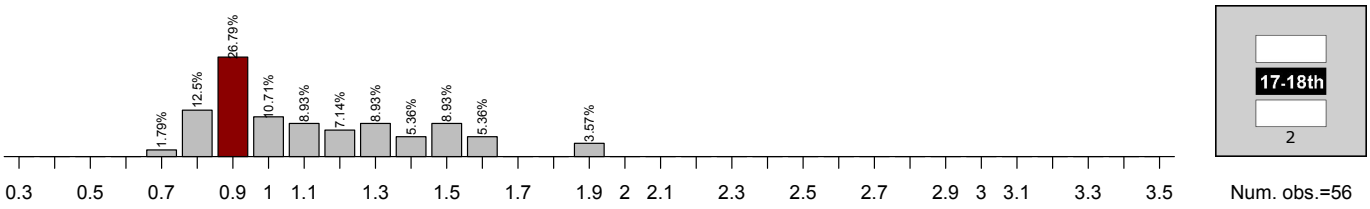
T1R1



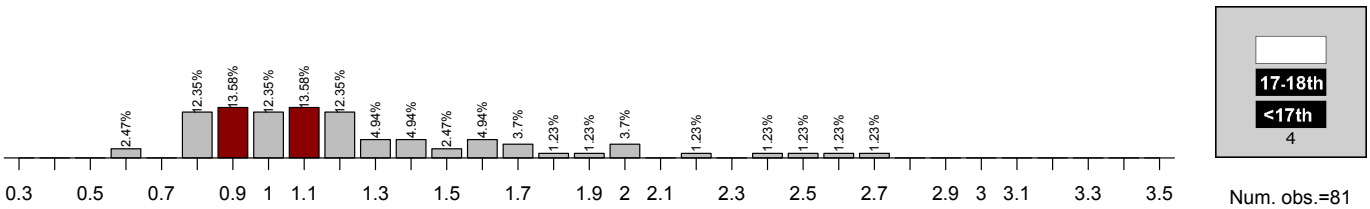
Num.obs. =28



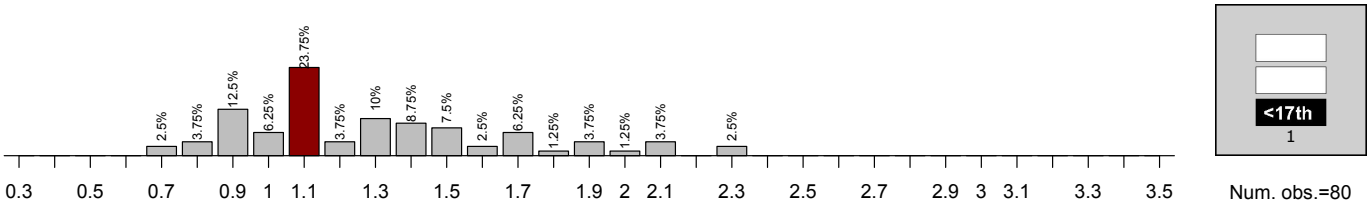
Num.obs.=11



Num. obs.=56

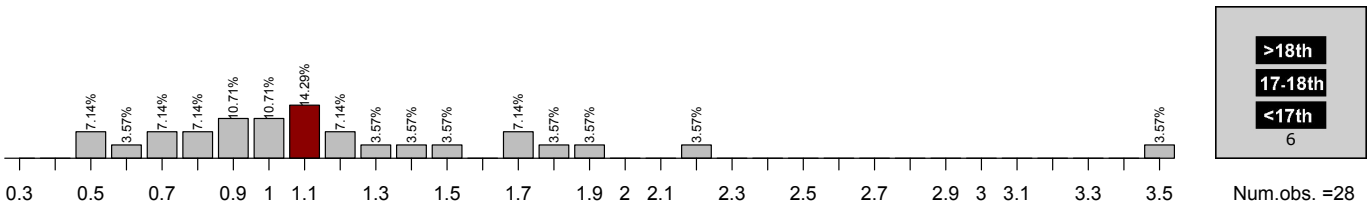


Num. obs.=81

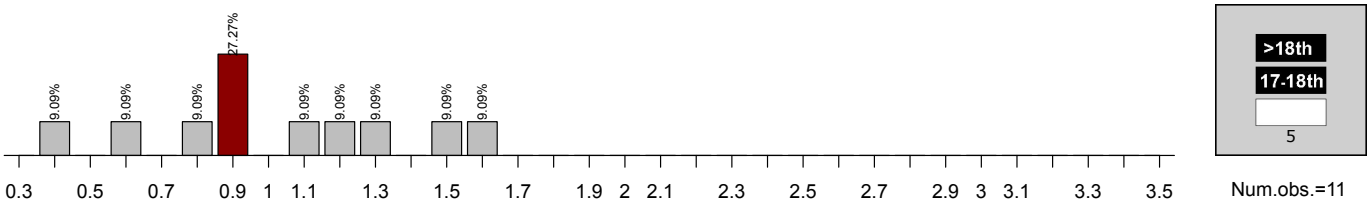


Num. obs.=80

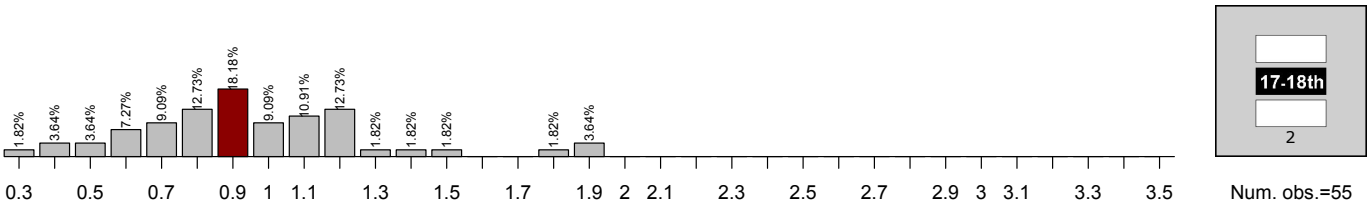
T2R1



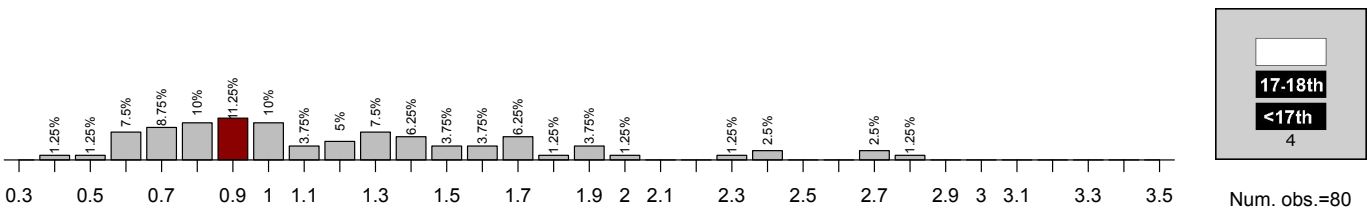
Num.obs. =28



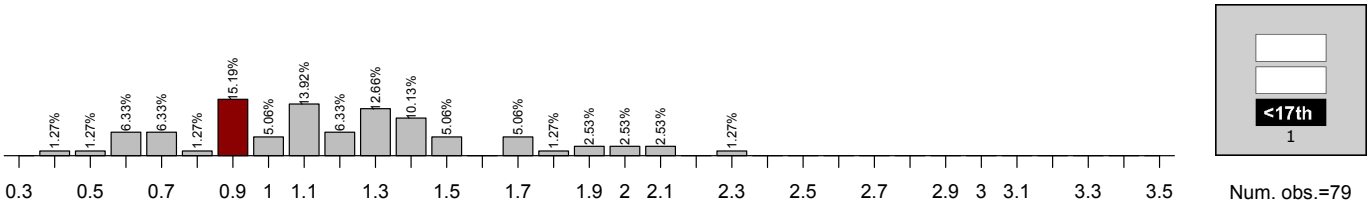
Num.obs.=11



Num. obs.=55



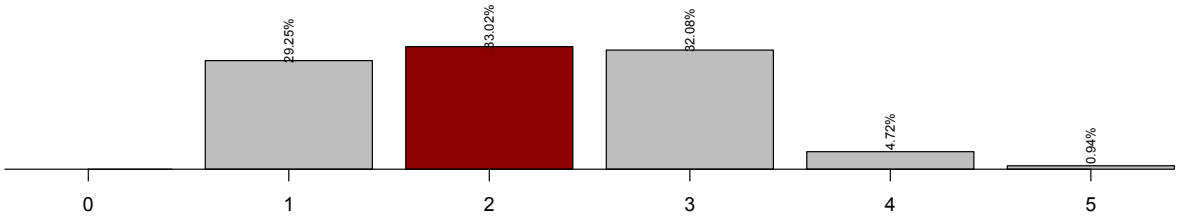
Num. obs.=80



Num. obs.=79

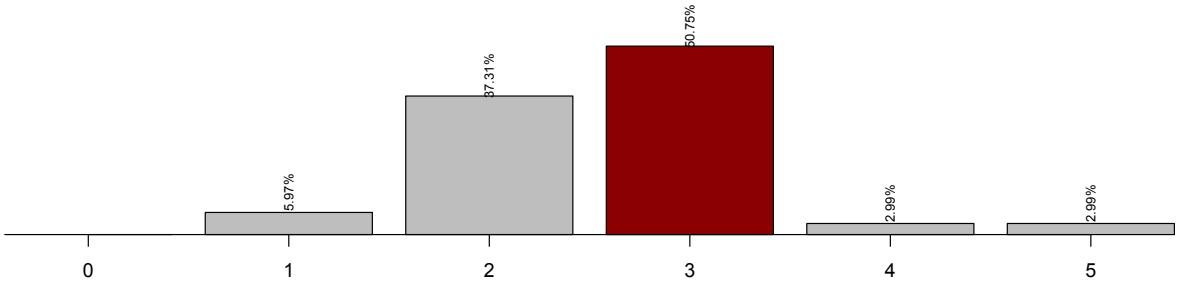
3.1.3 RESULTS REFERRED TO THE PARAMETER AAR

LOR(1)



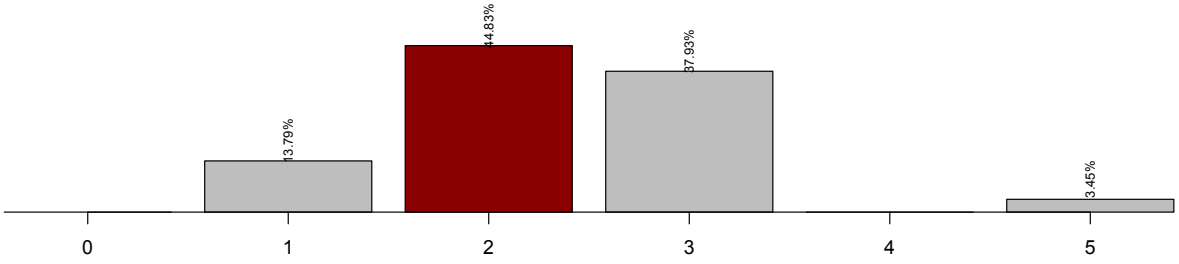
100
(50-149)

Num. obs. =106



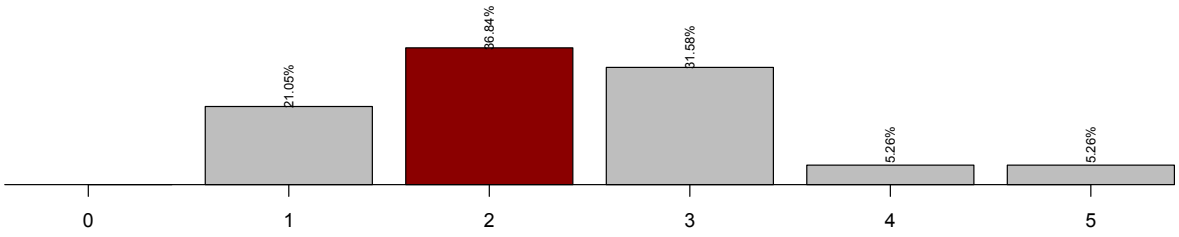
200
(150-249)

Num. obs. =67



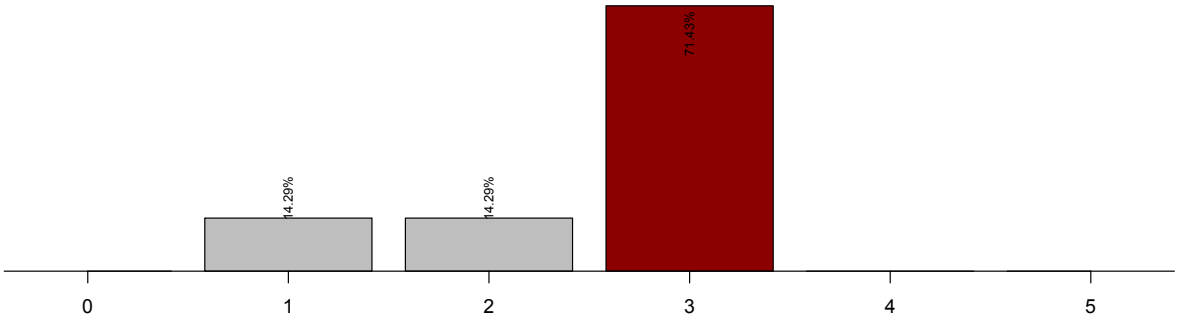
300
(250-349)

Num. obs.=29



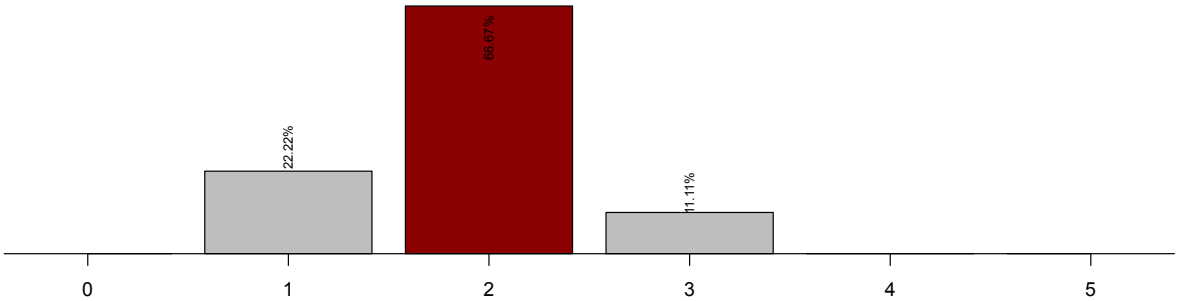
400
(350-449)

Num. obs. =19



500
(450-549)

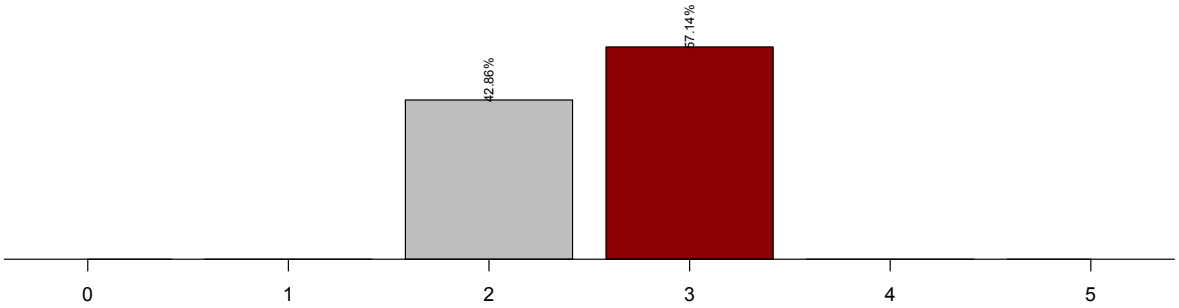
Num. obs. =7



600
(550-649)

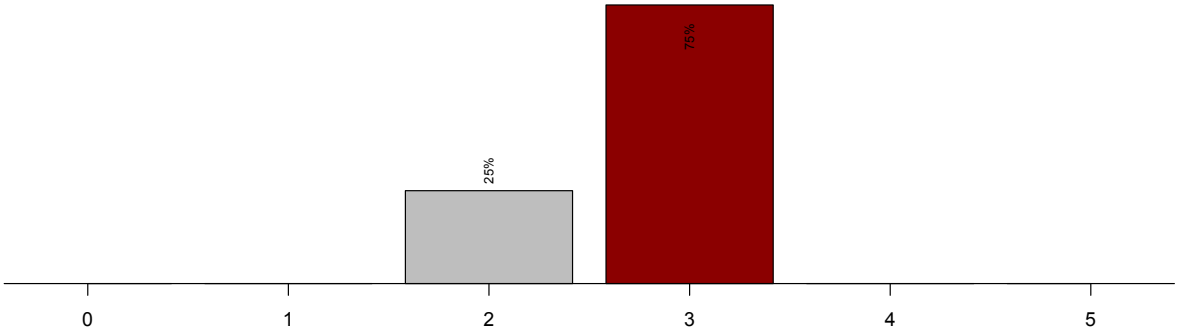
Num. obs. =9

LOR(2)



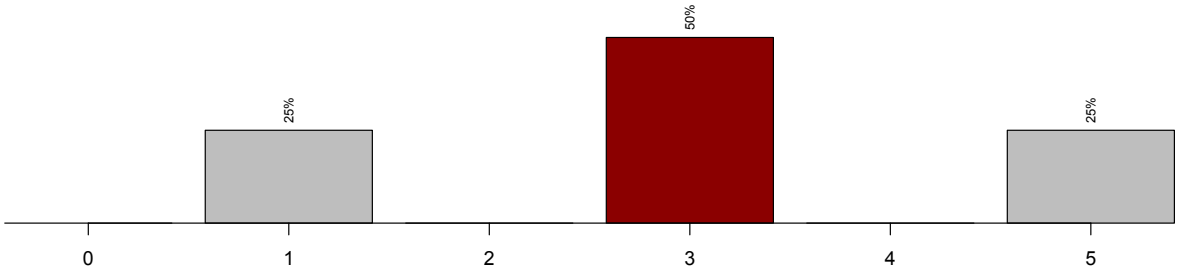
700
(650-749)

Num. obs. =7



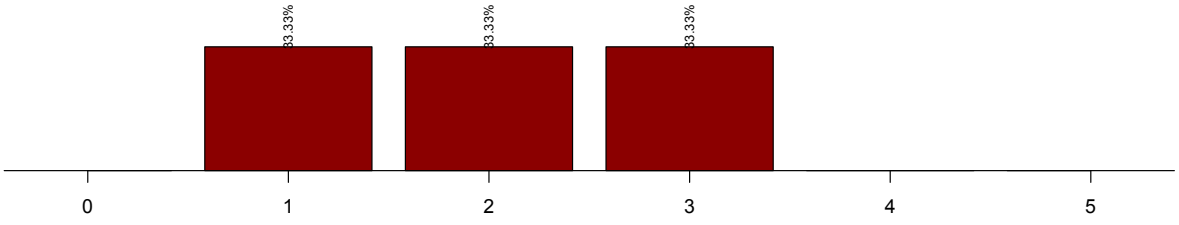
800
(750-849)

Num. obs. =4



900
(850-949)

Num. obs.=4



1000
(950-1049)

Num. obs. =3

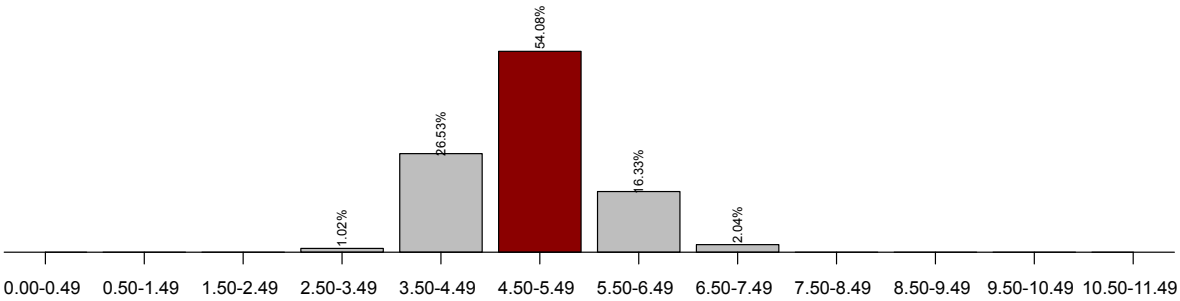
1400
(1350-1449)

Num. obs. =1

1500
(1450-1549)

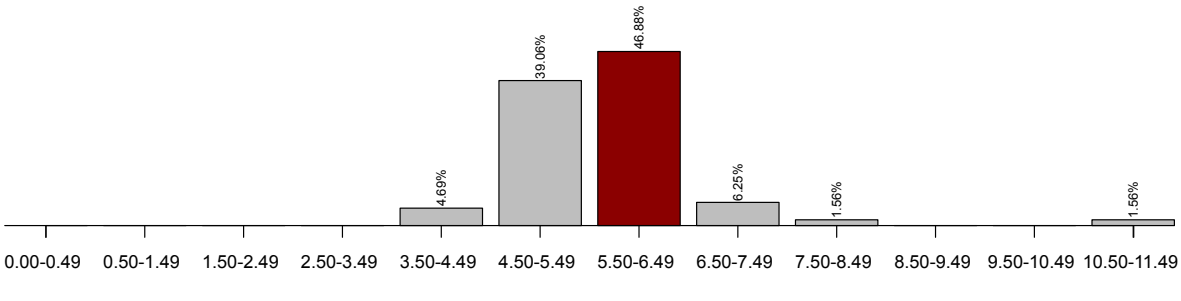
Num. obs. =1

$MSR_{(1)}$



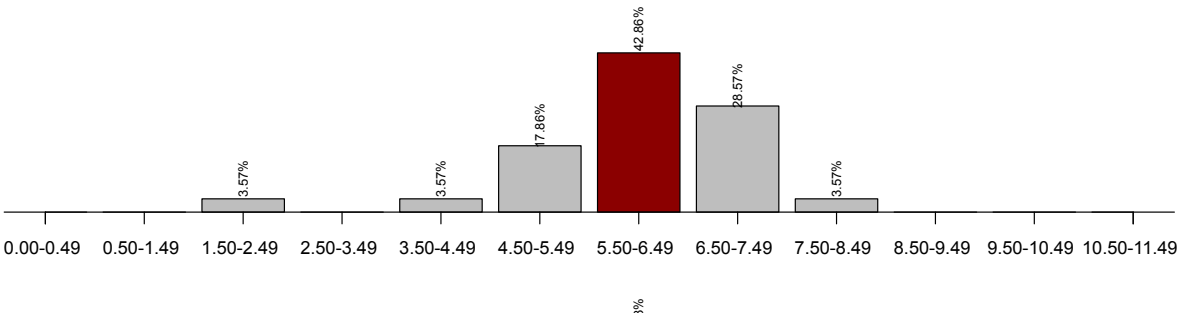
100
(50-149)

Num. obs. =98



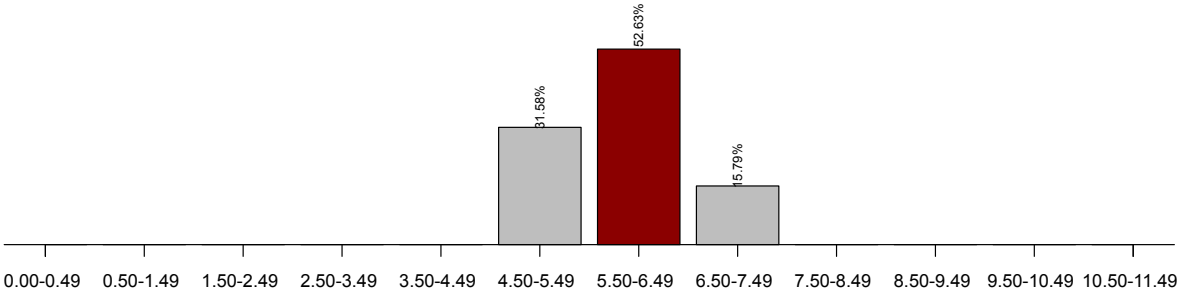
200
(150-249)

Num. obs. =64



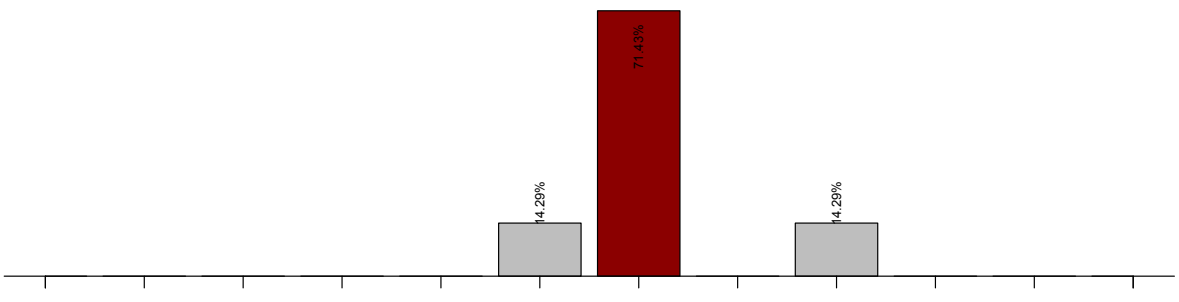
300
(250-349)

Num. obs.=28



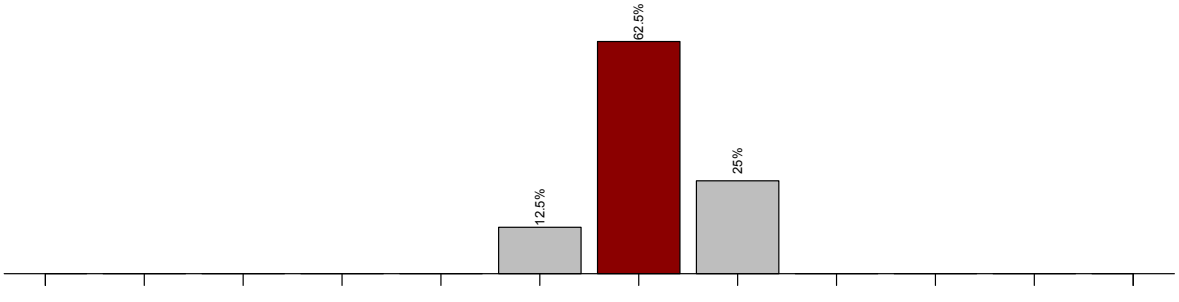
400
(350-449)

Num. obs. =19



500
(450-549)

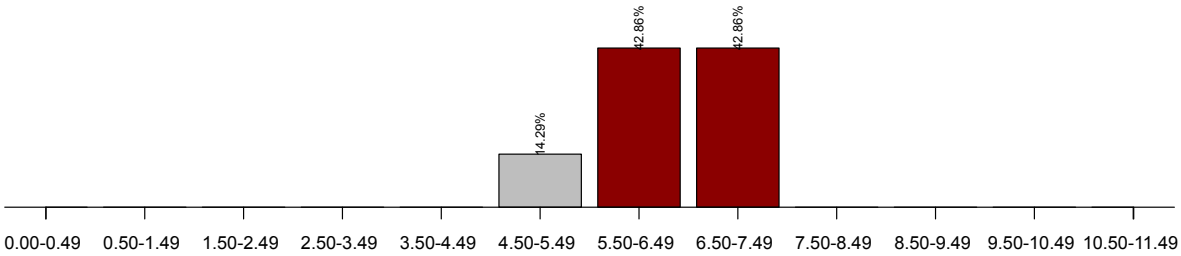
Num. obs. =7



600
(550-649)

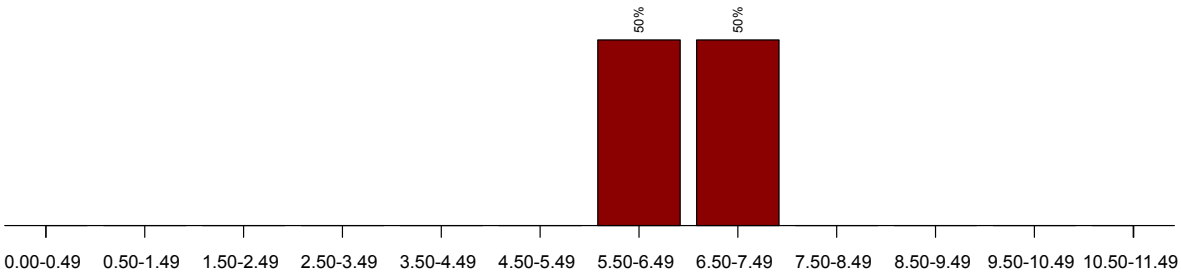
Num. obs. =8

MSR(2)



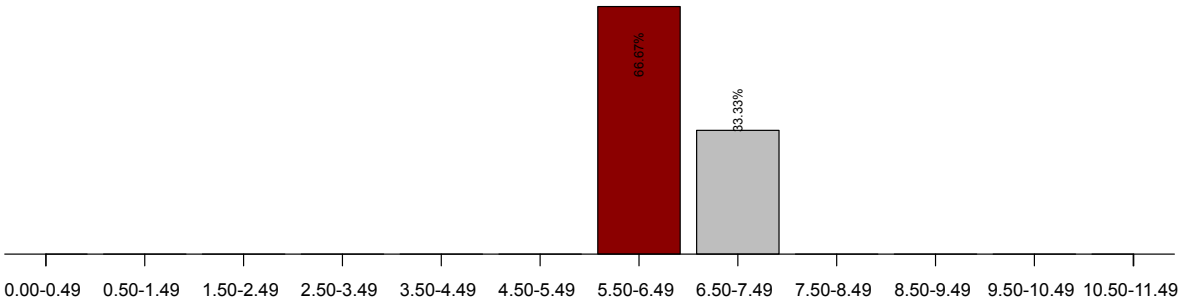
700
(650-749)

Num. obs. =7



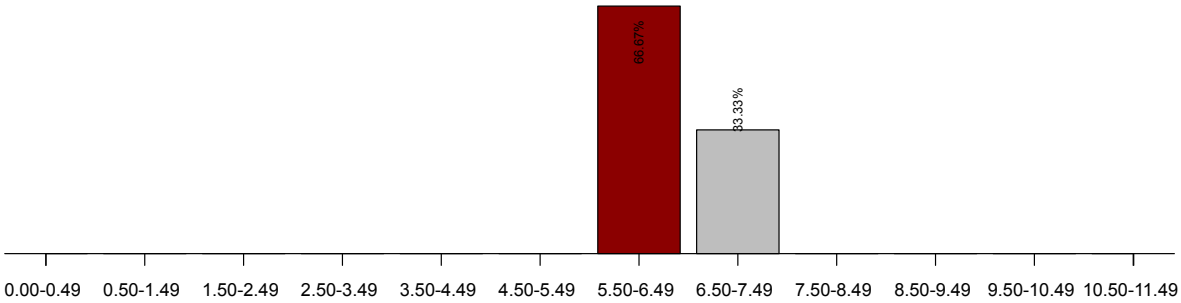
800
(750-849)

Num. obs. =4



900
(850-949)

Num. obs.=3



1000
(950-1049)

Num. obs. =3

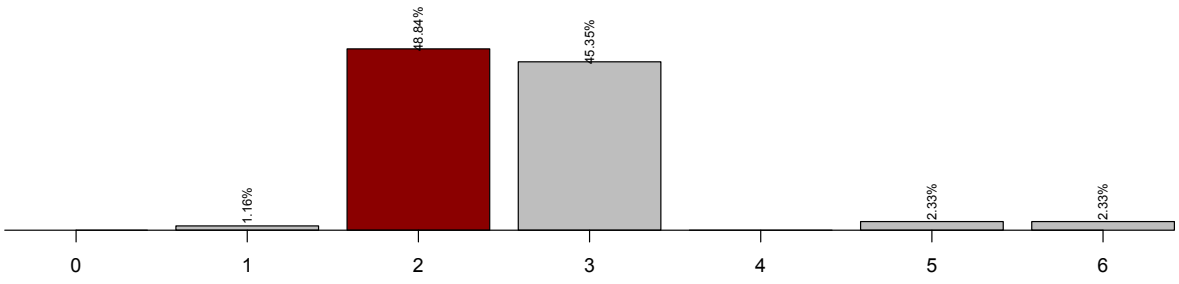
1400
(1350-1449)

Num. obs. =1

1500
(1450-1549)

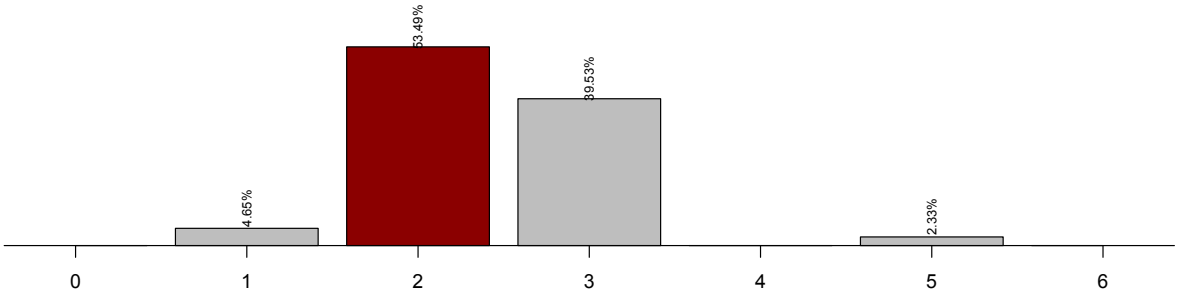
Num. obs. =1

$MT_{(1)}$



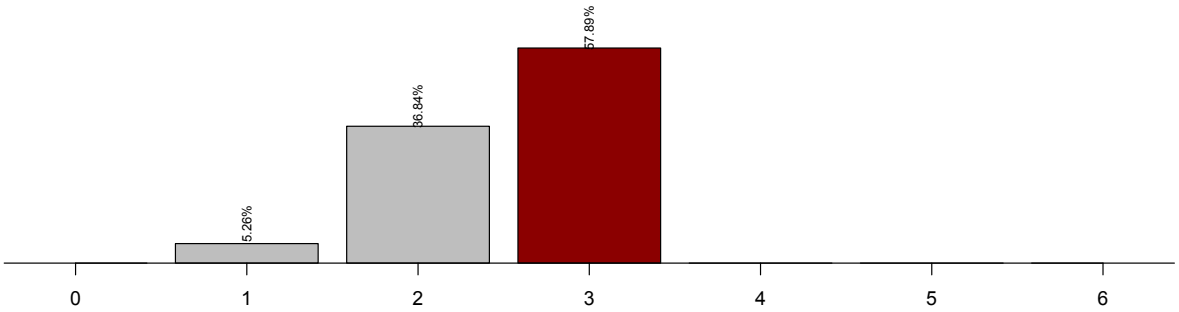
100
(50-149)

Num. obs. =86



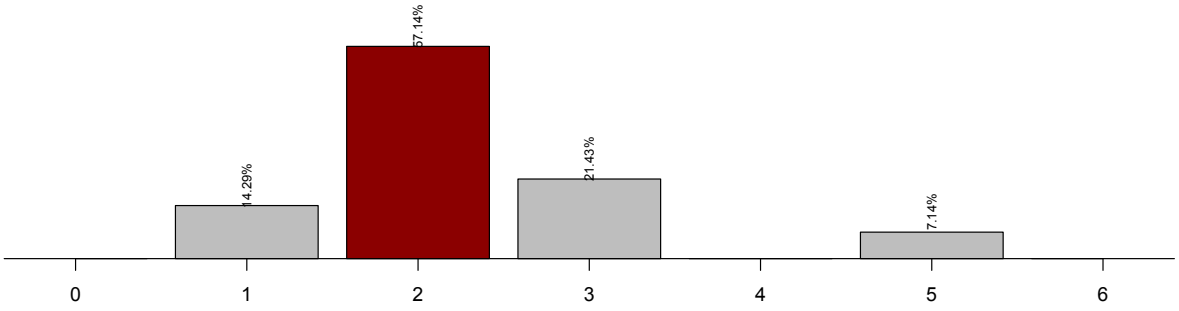
200
(150-249)

Num. obs. =43



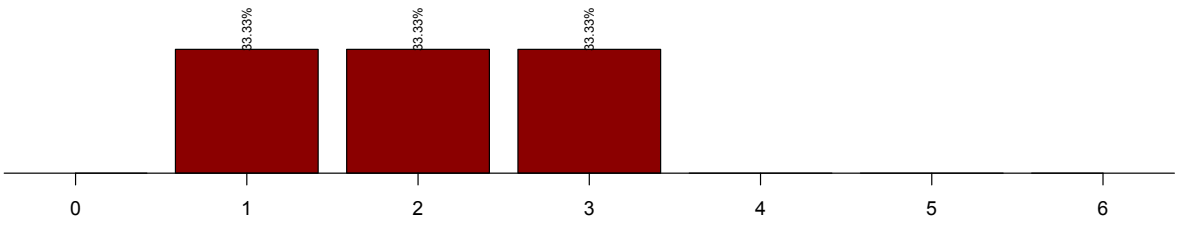
300
(250-349)

Num. obs.=19



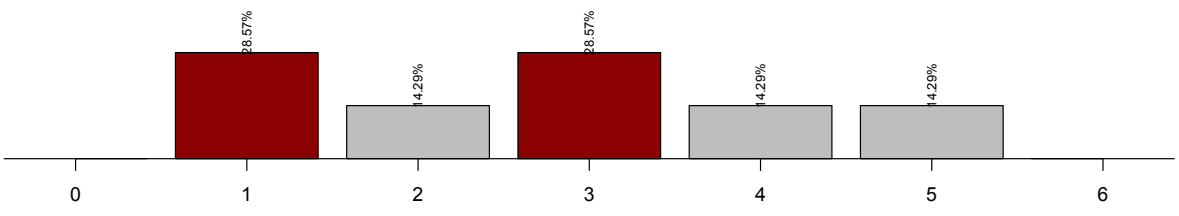
400
(350-449)

Num. obs. =14



500
(450-549)

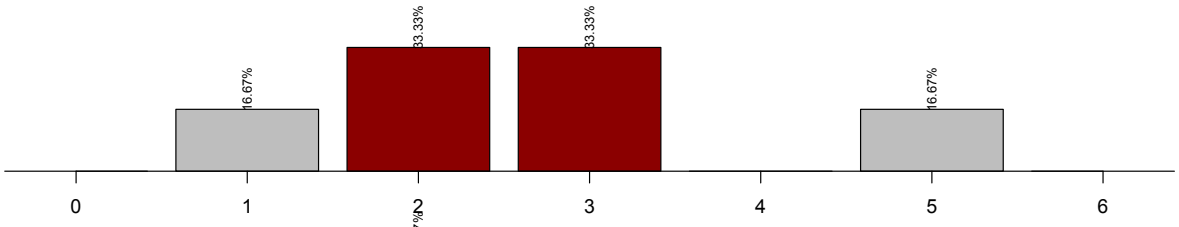
Num. obs. =6



600
(550-649)

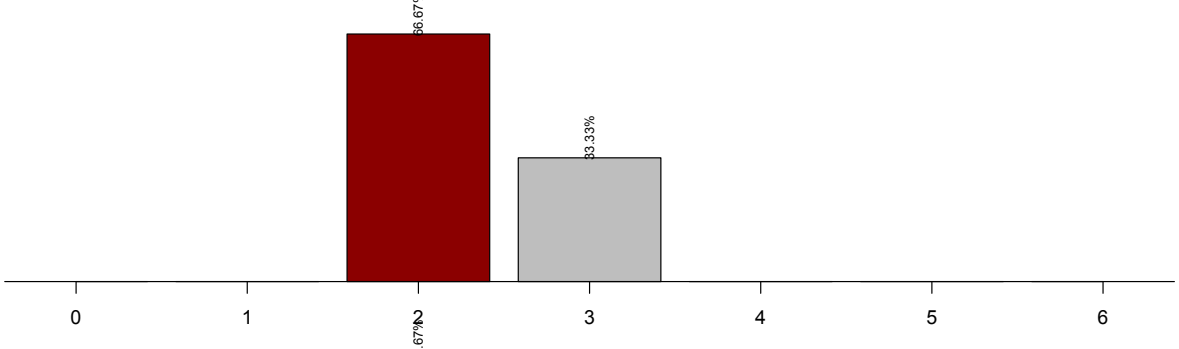
Num. obs. =7

MT(2)



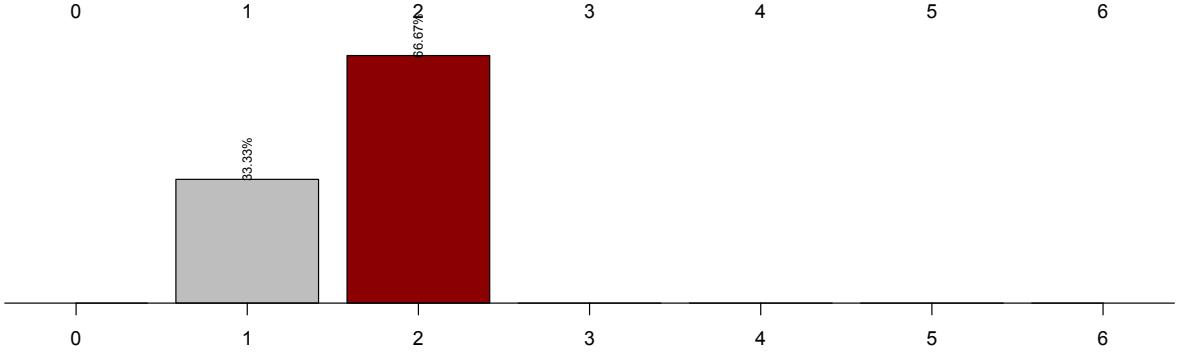
700
(650-749)

Num. obs. =6



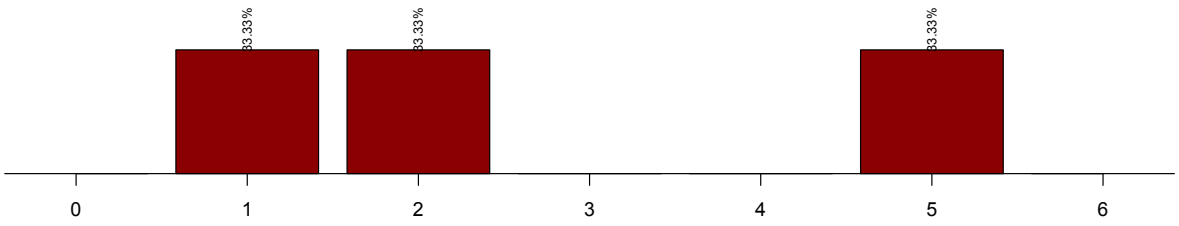
800
(750-849)

Num. obs. =3



900
(850-949)

Num. obs.=3



1000
(950-1049)

Num. obs. =3

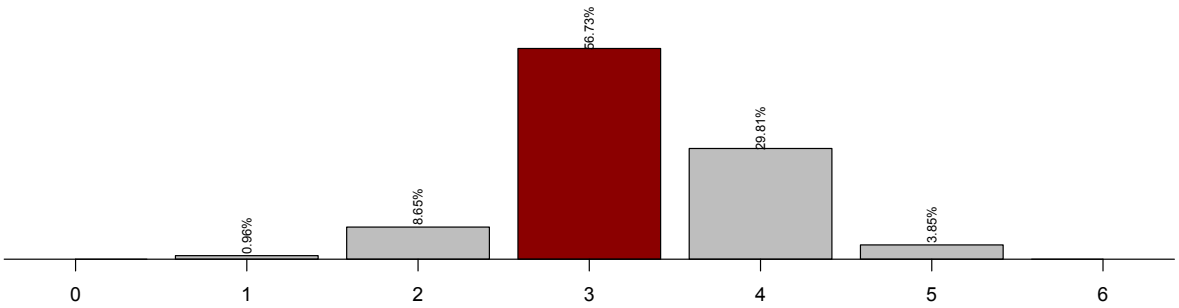
1400
(1350-1449)

Num. obs. =1

1500
(1450-1549)

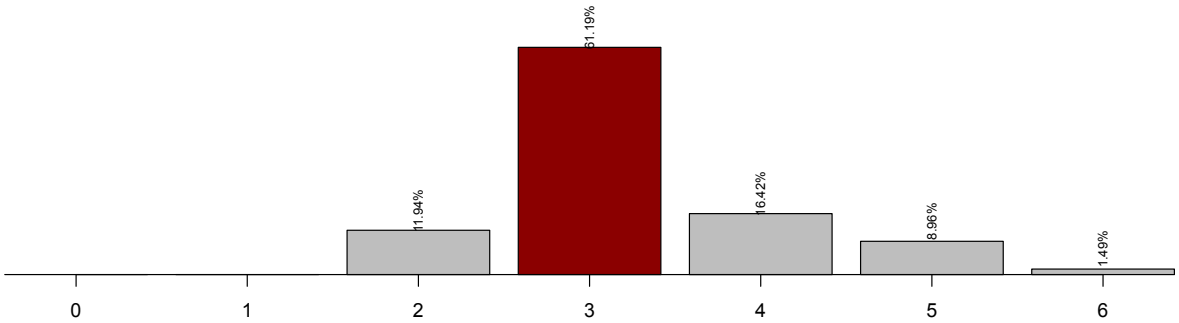
Num. obs. =1

$NF_{(1)}$



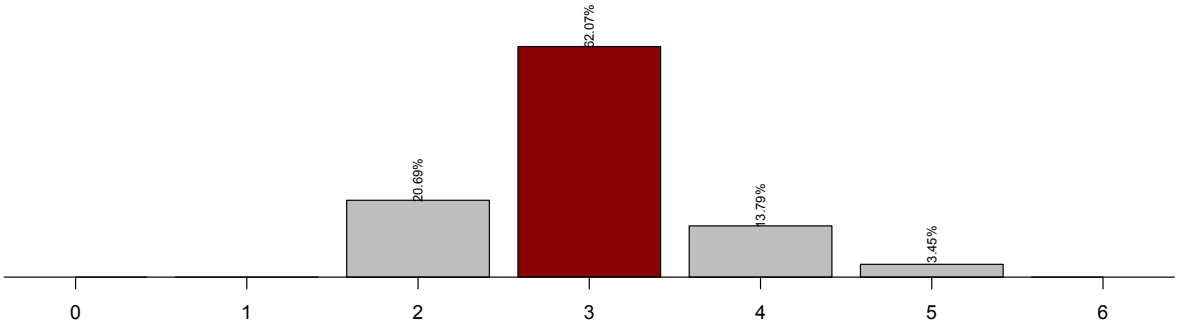
100
(50-149)

Num. obs. =104



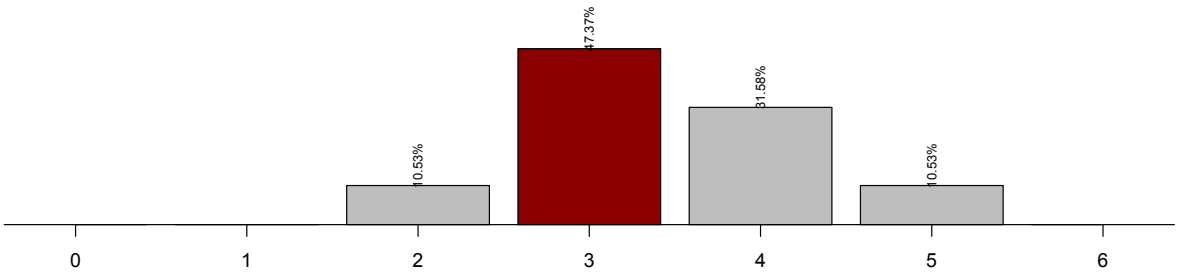
200
(150-249)

Num. obs. =67



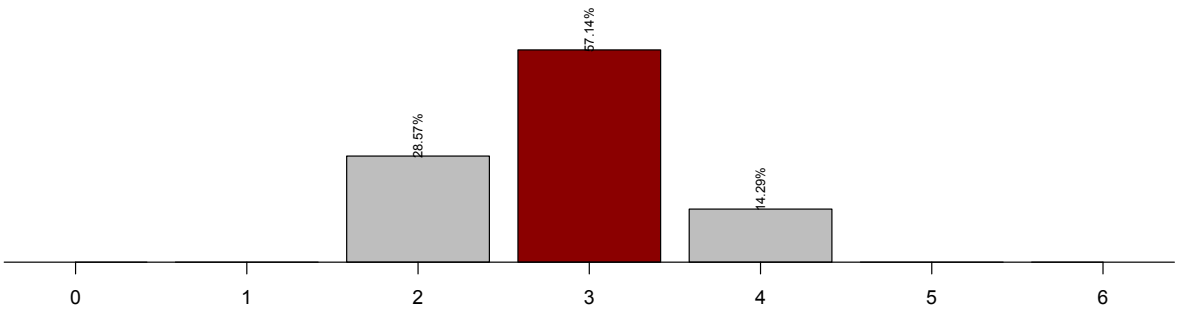
300
(250-349)

Num. obs.=29



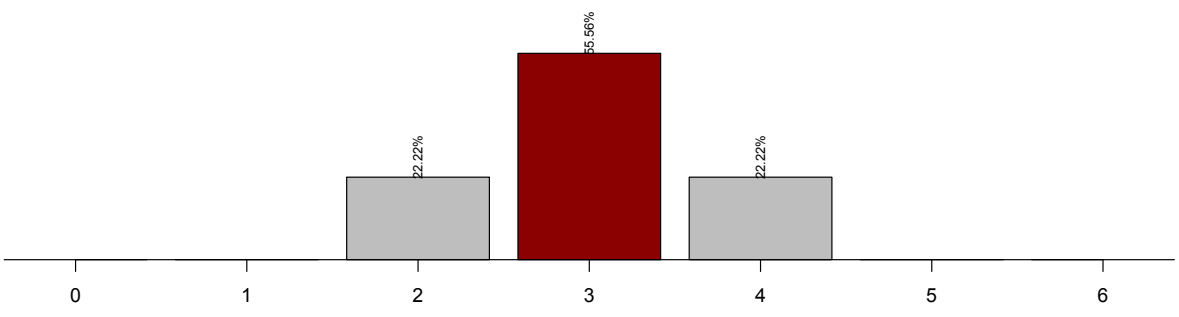
400
(350-449)

Num. obs. =19



500
(450-549)

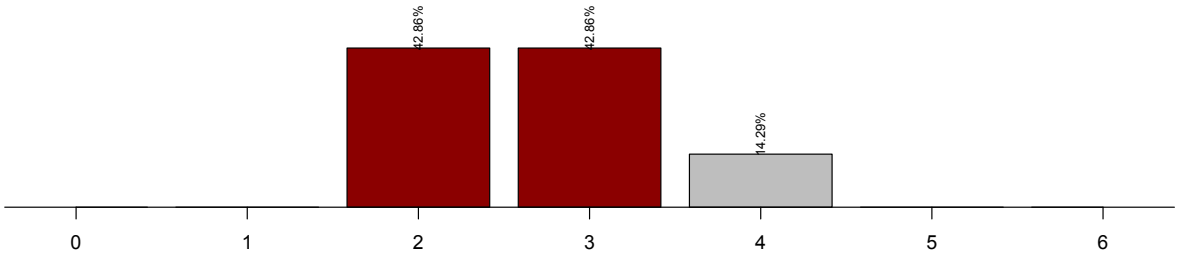
Num. obs. =7



600
(550-649)

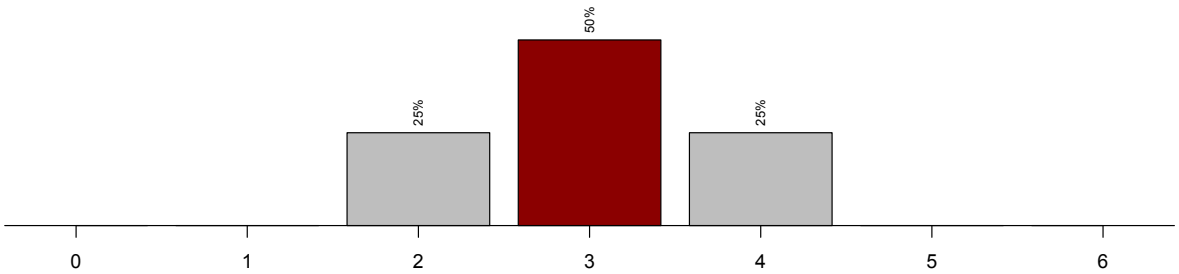
Num. obs. =9

$NF_{(2)}$



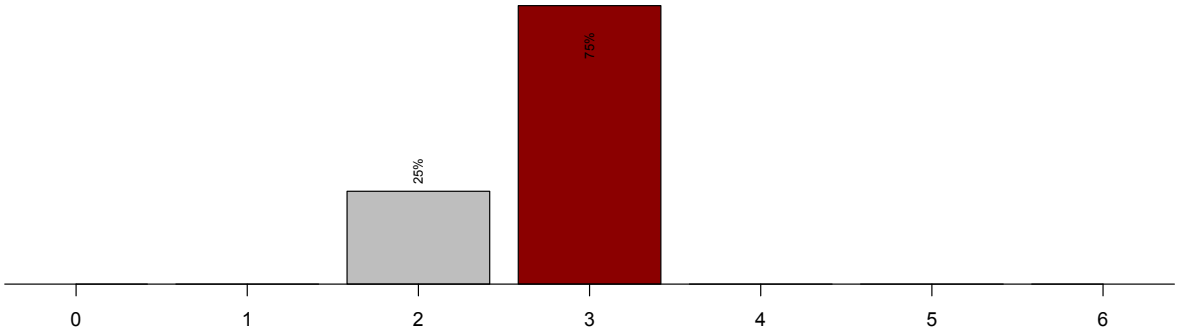
700
(650-749)

Num. obs. =7



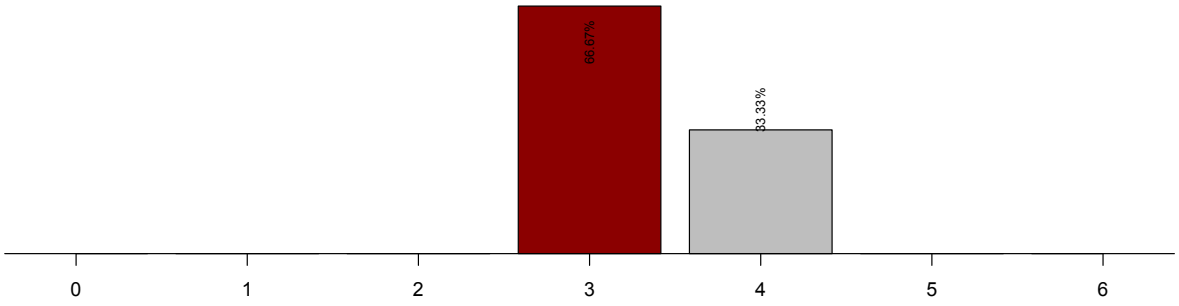
800
(750-849)

Num. obs. =4



900
(850-949)

Num. obs.=4



1000
(950-1049)

Num. obs. =3

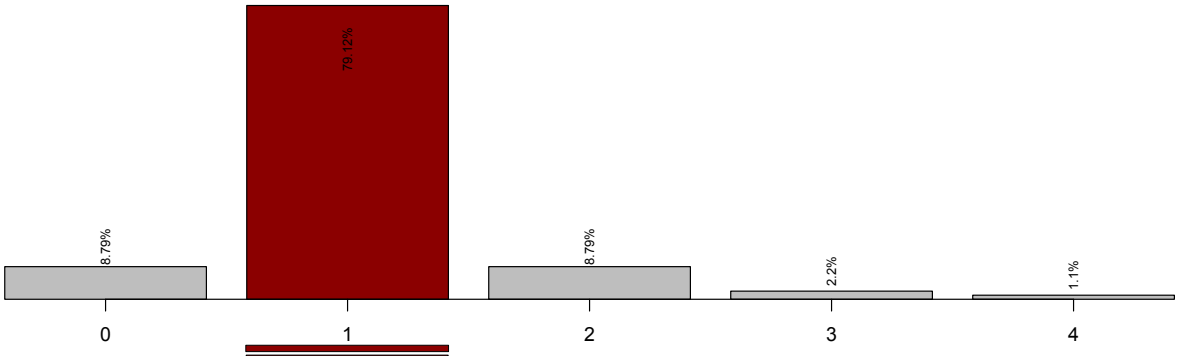
1400
(1350-1449)

Num. obs. =1

1500
(1450-1549)

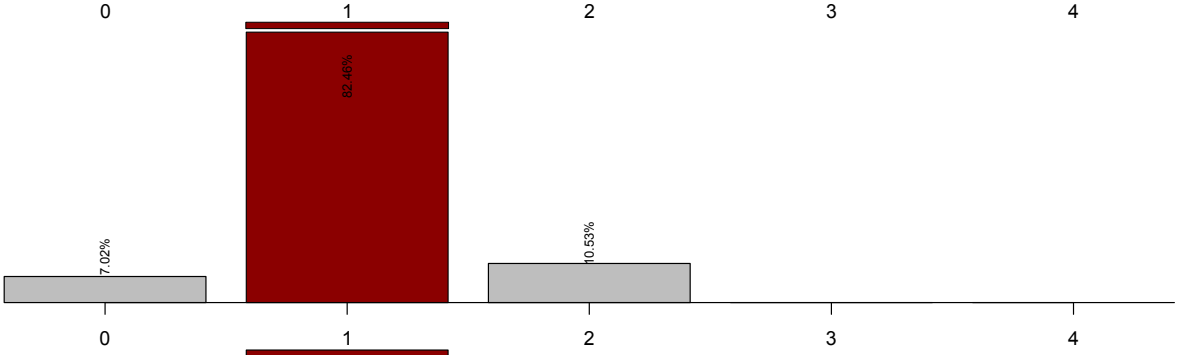
Num. obs. =1

$NV_{(1)}$



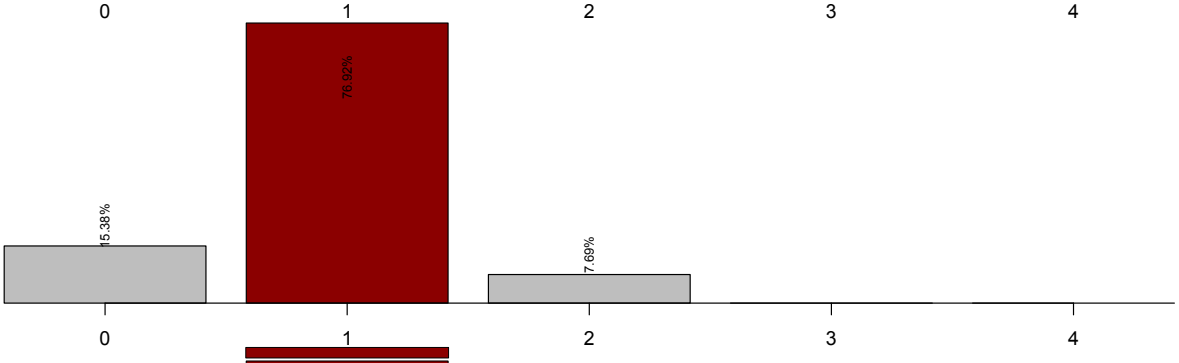
100
(50-149)

Num. obs. =91



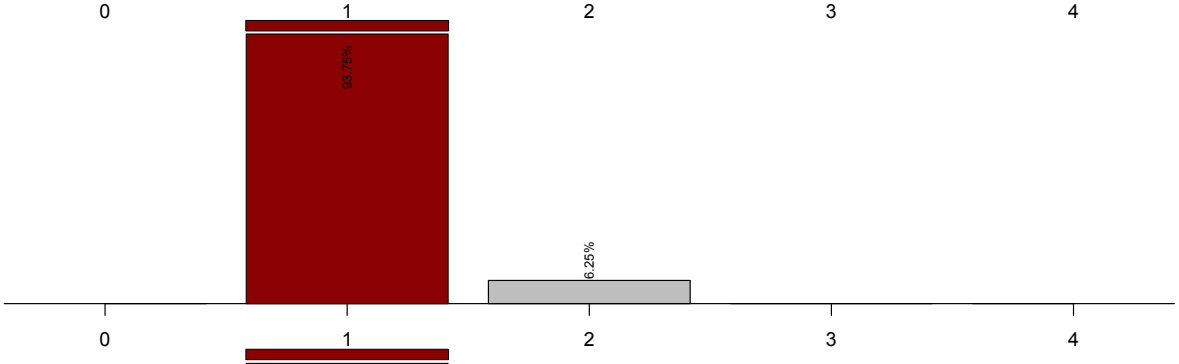
200
(150-249)

Num. obs. =57



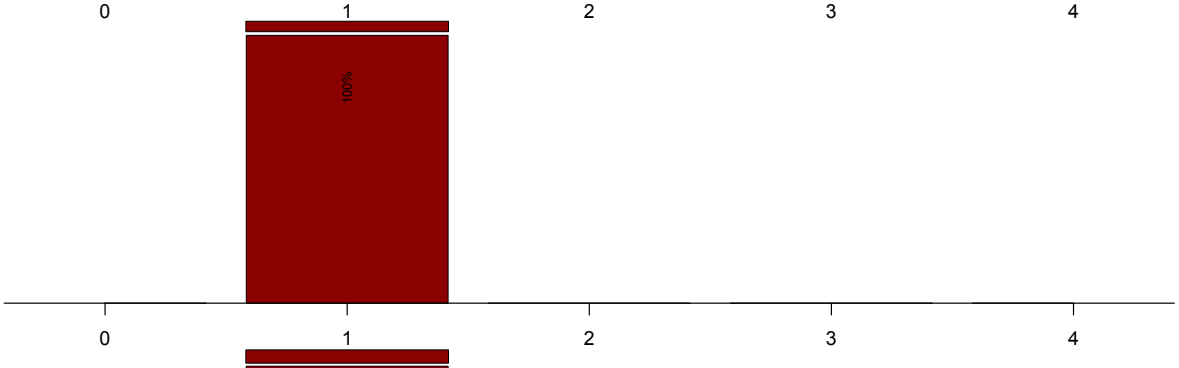
300
(250-349)

Num. obs.=26



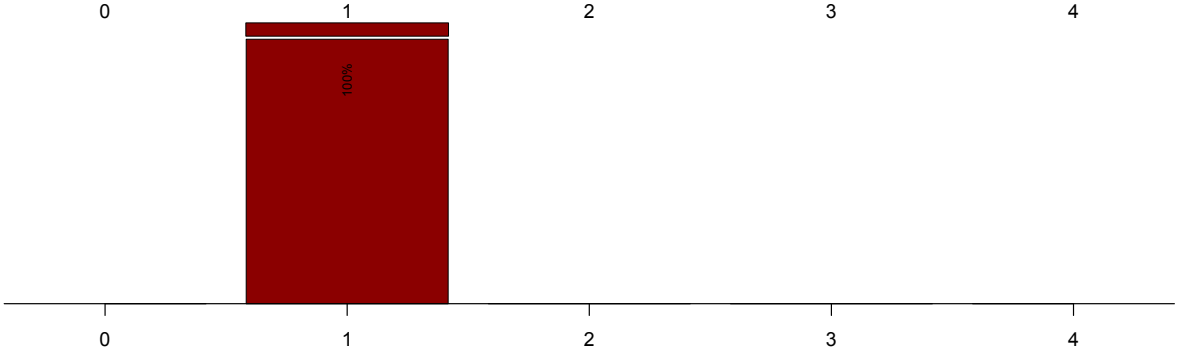
400
(350-449)

Num. obs. =16



500
(450-549)

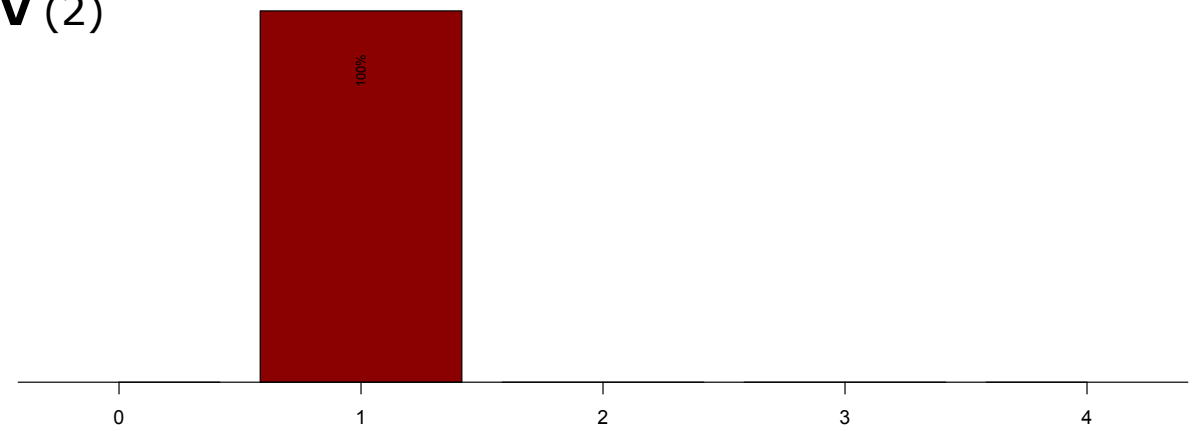
Num. obs. =5



600
(550-649)

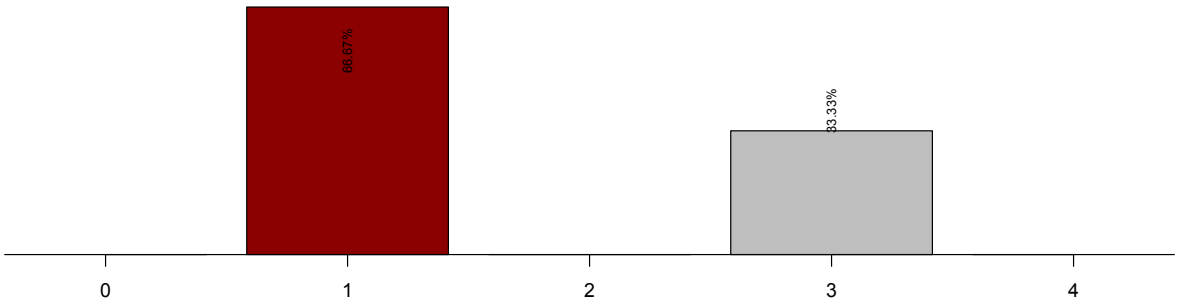
Num. obs. =5

$NV_{(2)}$



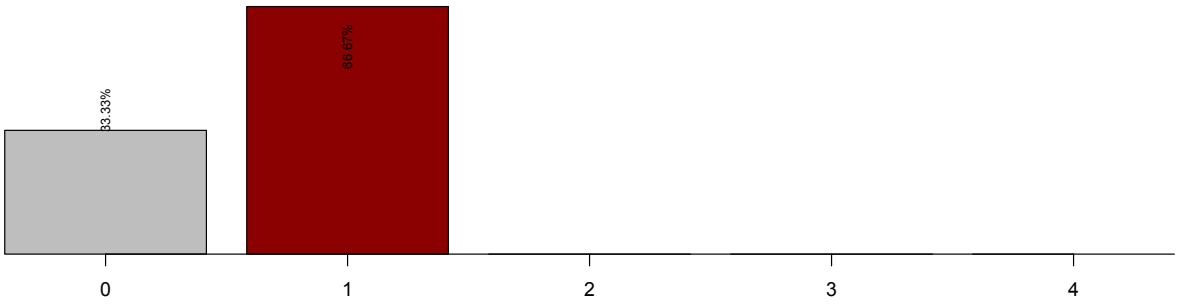
700
(650-749)

Num. obs. =7



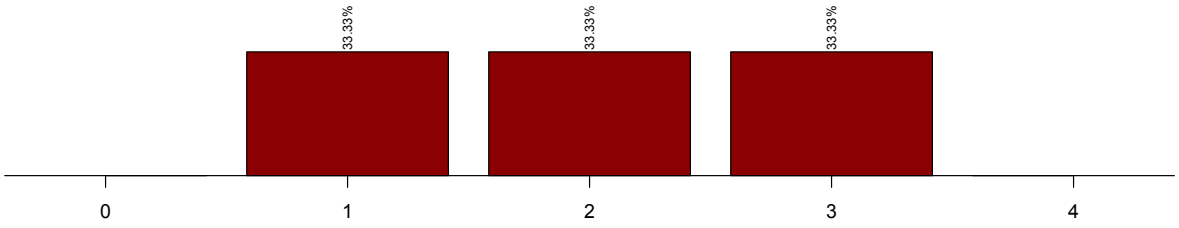
800
(750-849)

Num. obs. =3



900
(850-949)

Num. obs.=3



1000
(950-1049)

Num. obs. =3

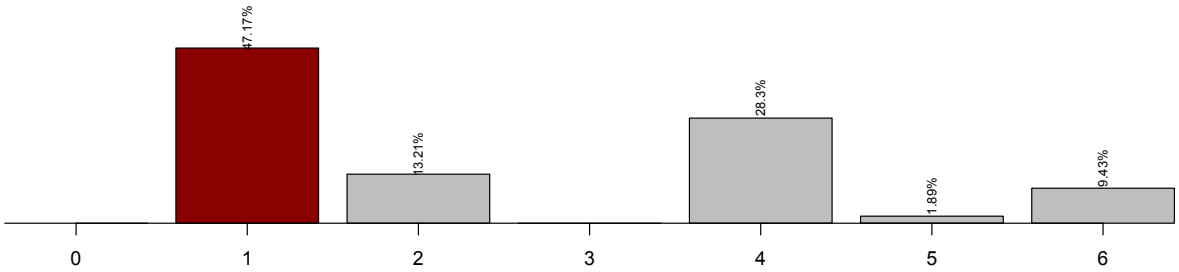
1400
(1350-1449)

Num. obs. =0

1500
(1450-1549)

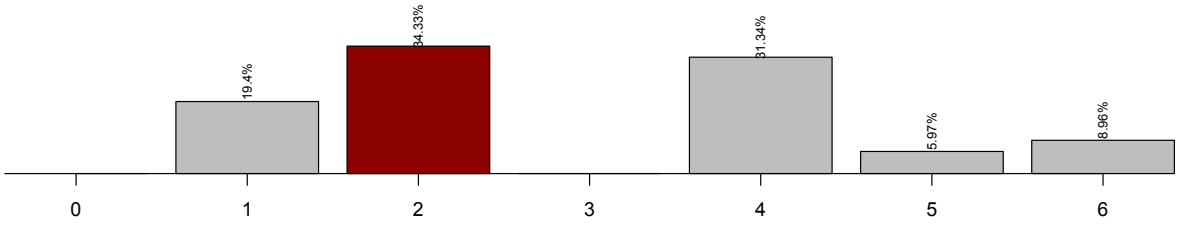
Num. obs. =0

$PE_{(1)}$



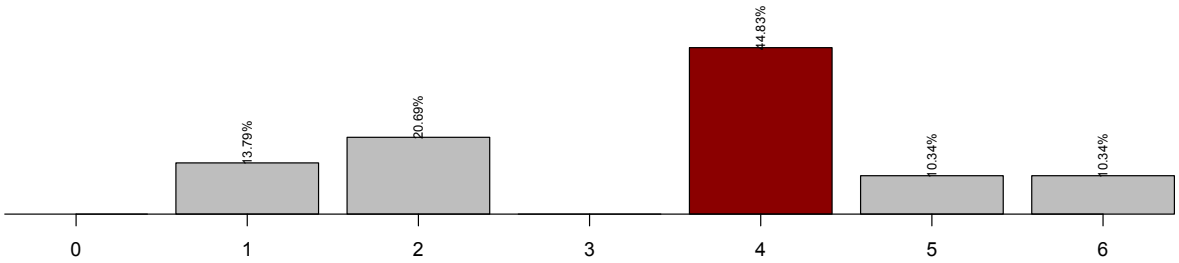
100
(50-149)

Num. obs. =106



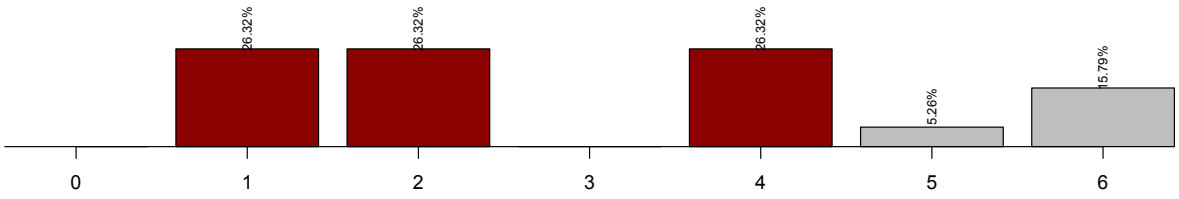
200
(150-249)

Num. obs. =67



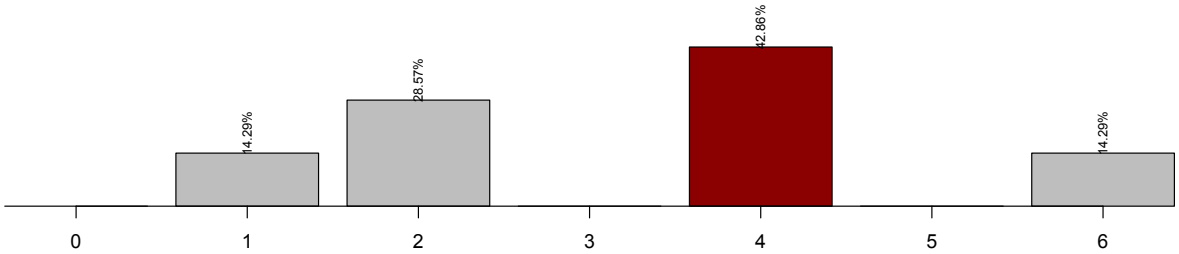
300
(250-349)

Num. obs.=29



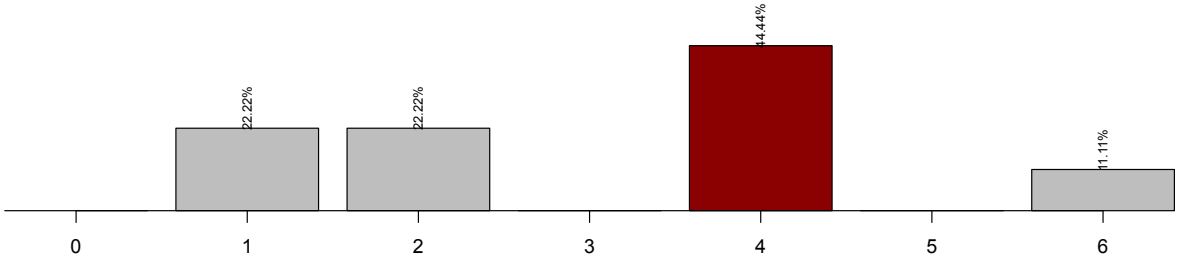
400
(350-449)

Num. obs. =19



500
(450-549)

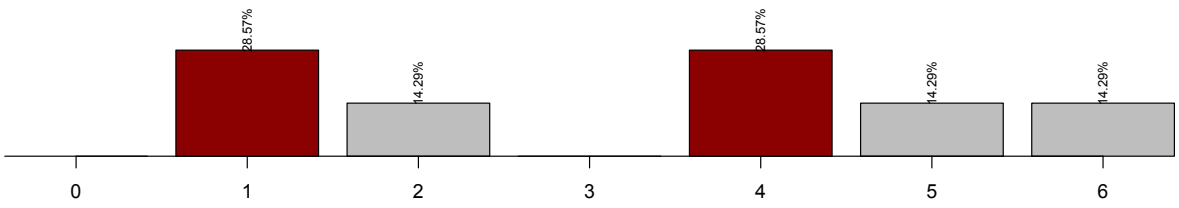
Num. obs. =7



600
(550-649)

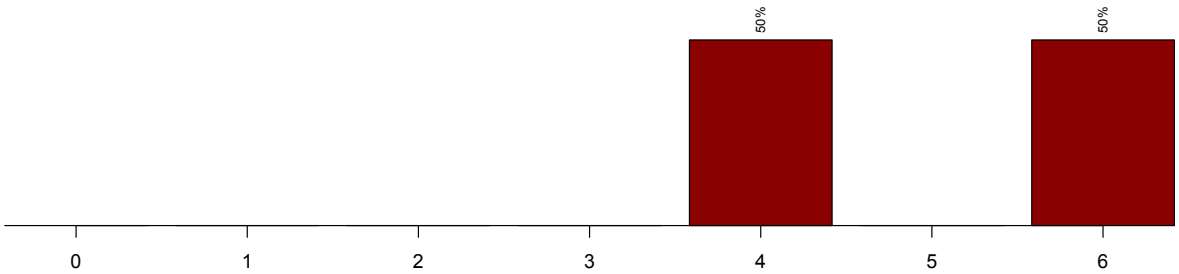
Num. obs. =9

PE(2)



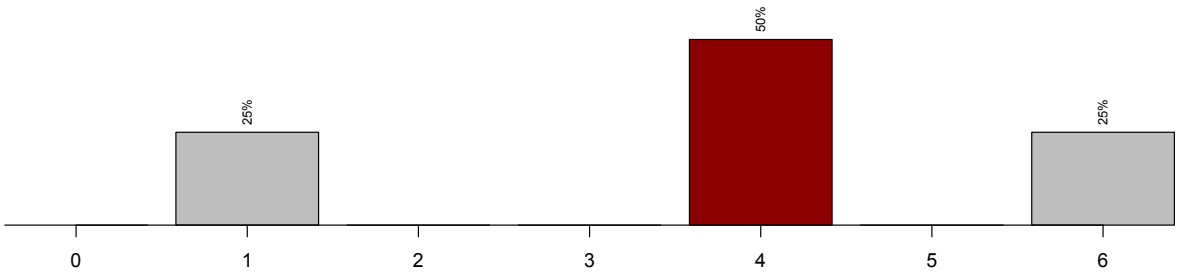
700
(650-749)

Num. obs. =7



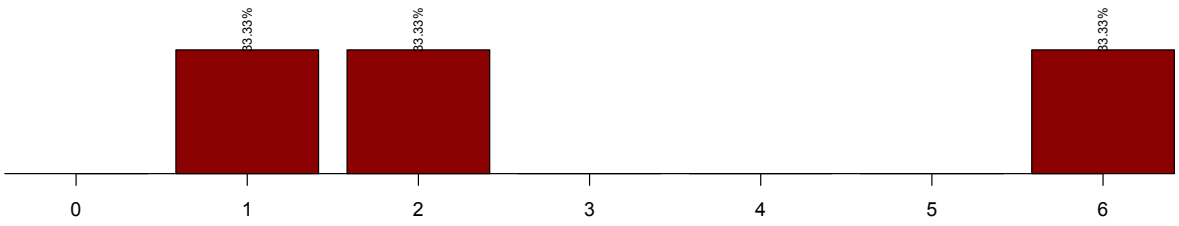
800
(750-849)

Num. obs. =4



900
(850-949)

Num. obs.=4



1000
(950-1049)

Num. obs. =3

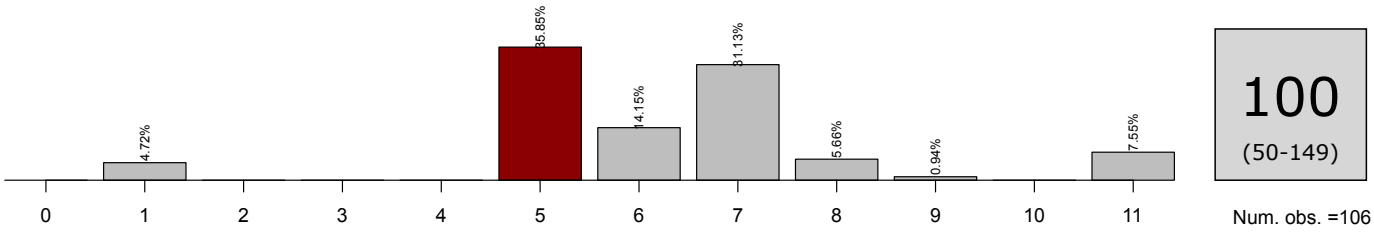
1400
(1350-1449)

Num. obs. =1

1500
(1450-1549)

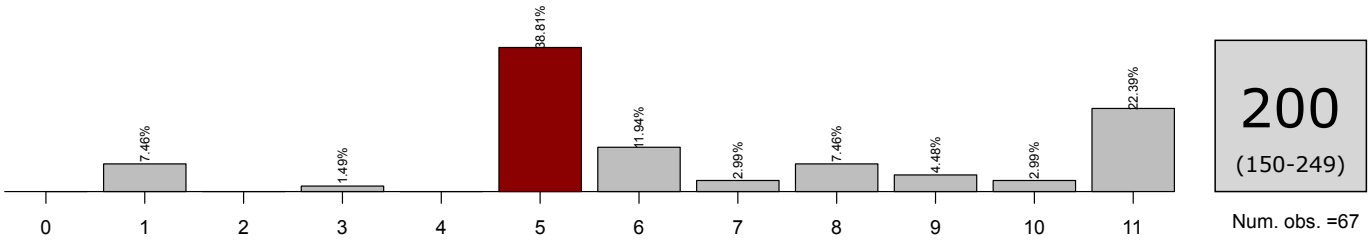
Num. obs. =1

$PL_{(1)}$



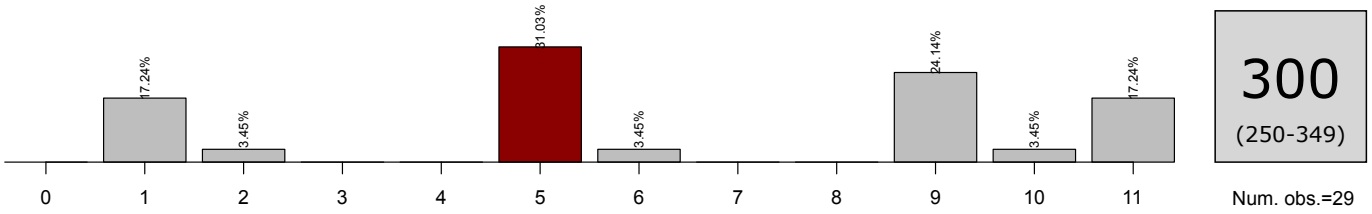
100
(50-149)

Num. obs. =106



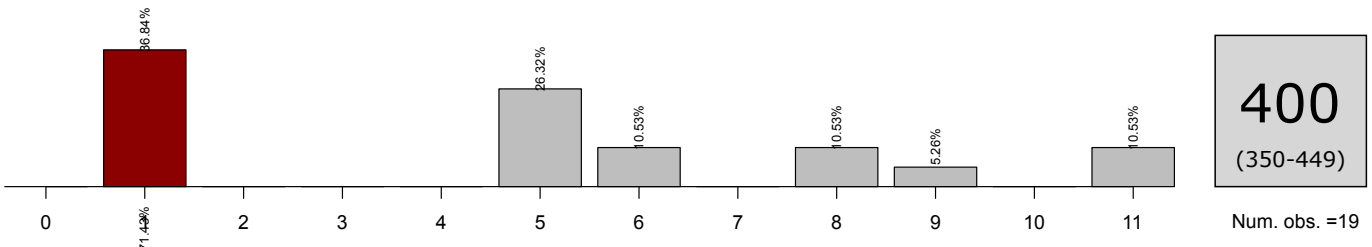
200
(150-249)

Num. obs. =67



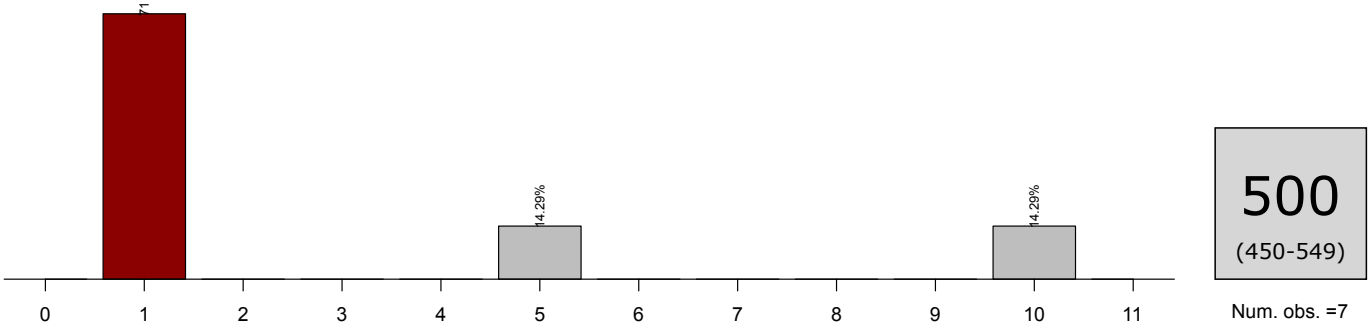
300
(250-349)

Num. obs.=29



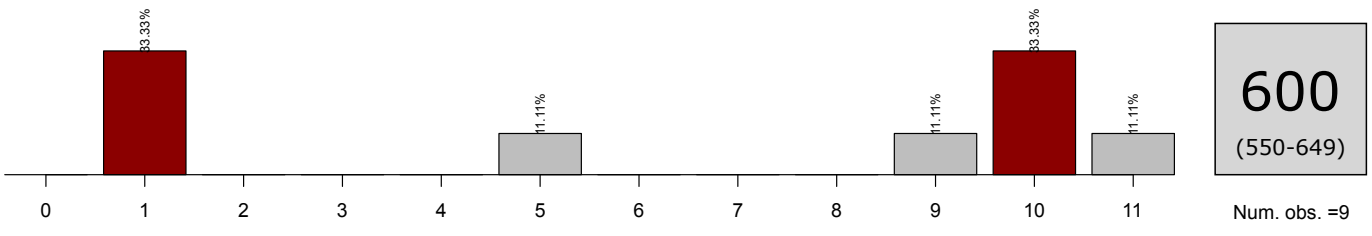
400
(350-449)

Num. obs. =19



500
(450-549)

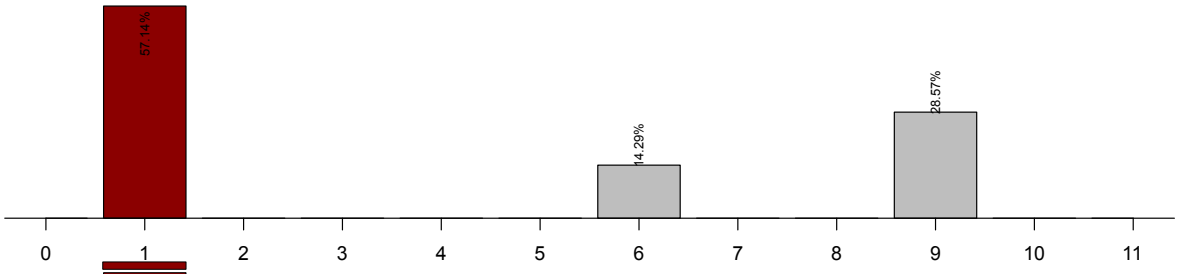
Num. obs. =7



600
(550-649)

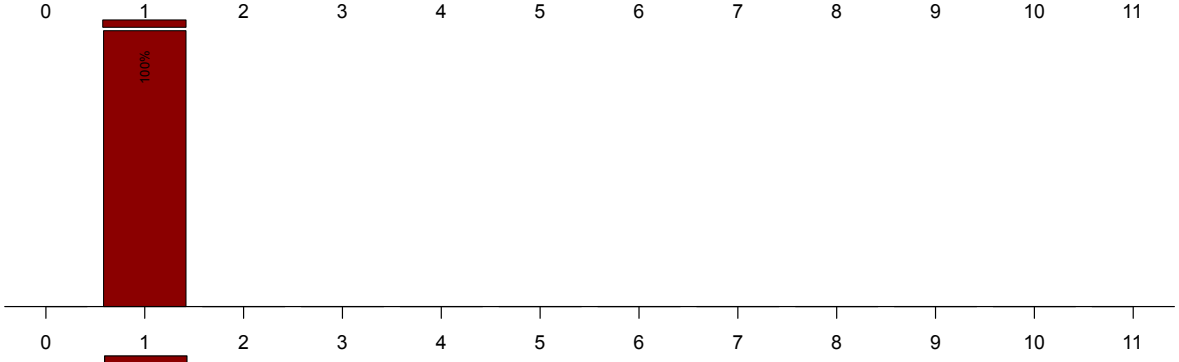
Num. obs. =9

PL(2)



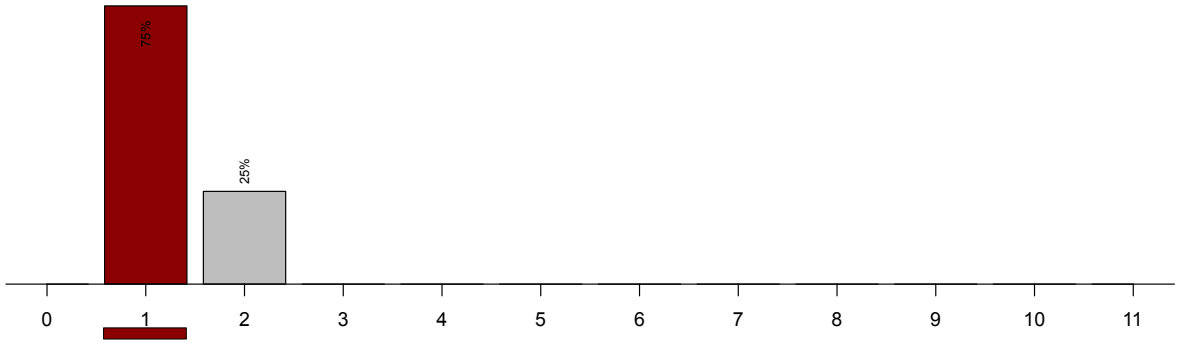
700
(650-749)

Num. obs. =7



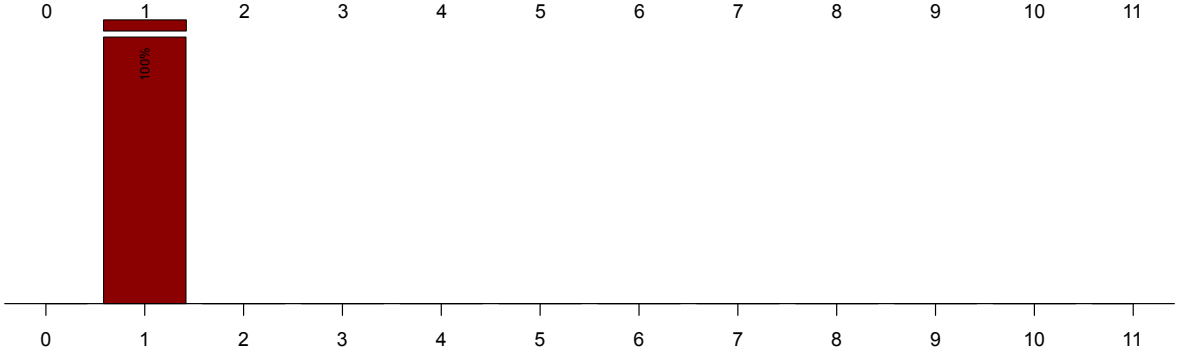
800
(750-849)

Num. obs. =4



900
(850-949)

Num. obs.=4



1000
(950-1049)

Num. obs. =3

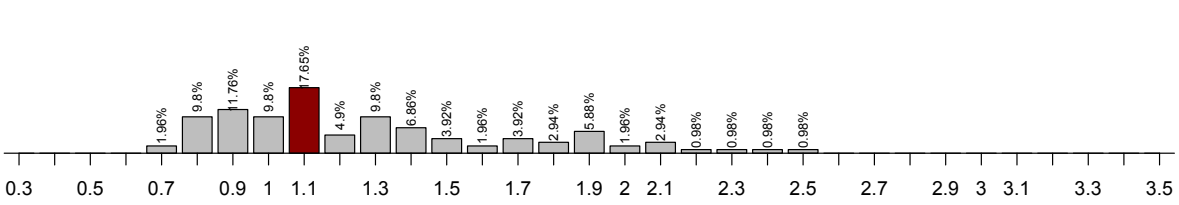
1400
(1350-1449)

Num. obs. =1

1500
(1450-1549)

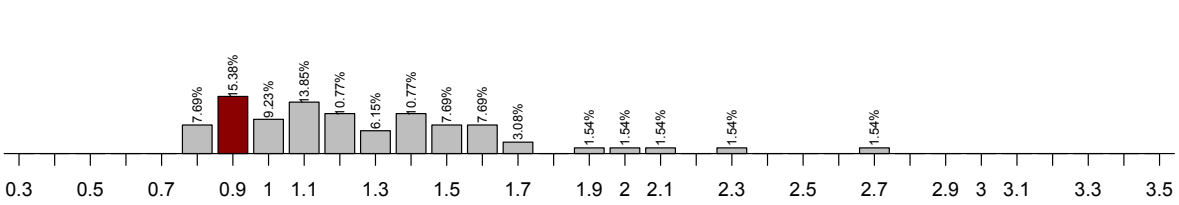
Num. obs. =1

T1R1(1)



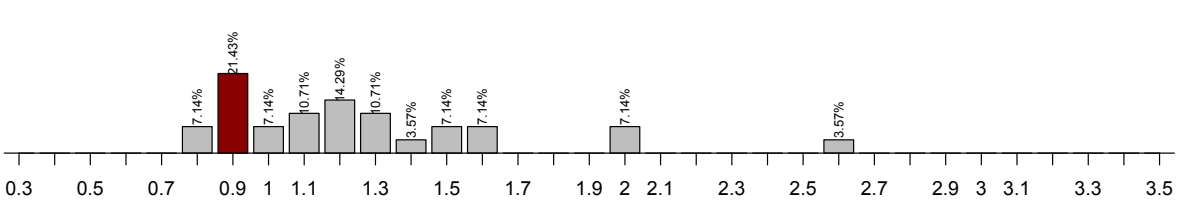
100
(50-149)

Num. obs. =102



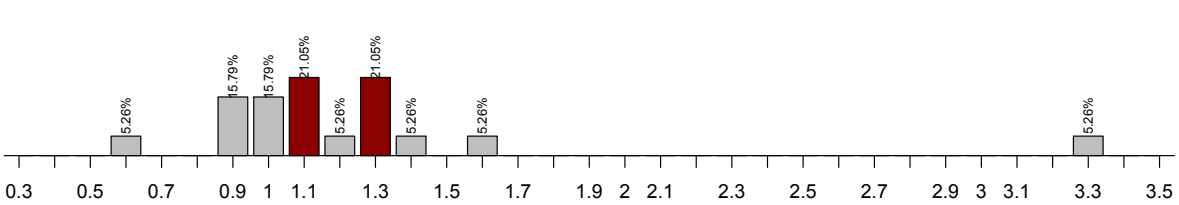
200
(150-249)

Num. obs. =65



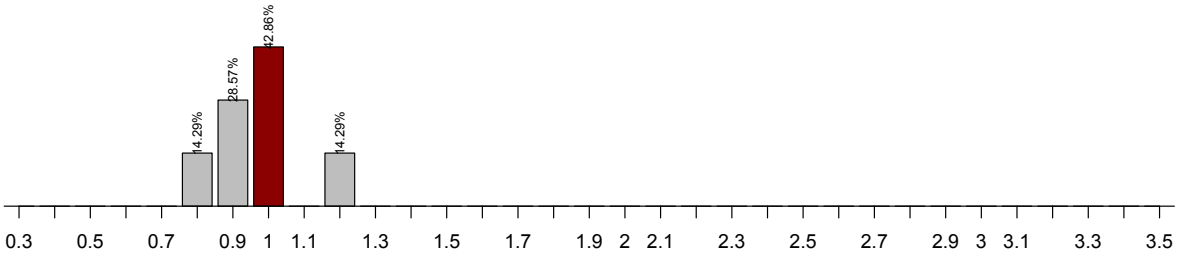
300
(250-349)

Num. obs.=28



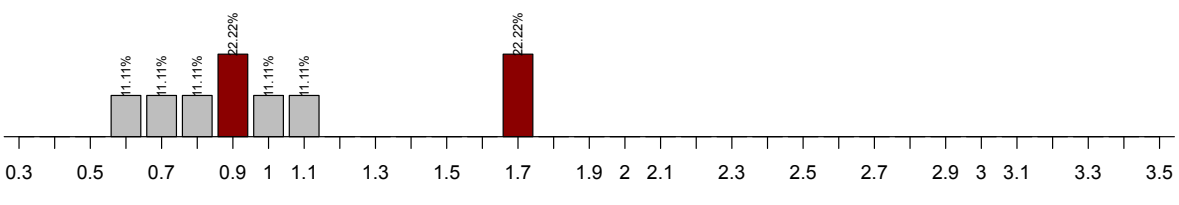
400
(350-449)

Num. obs. =19



500
(450-549)

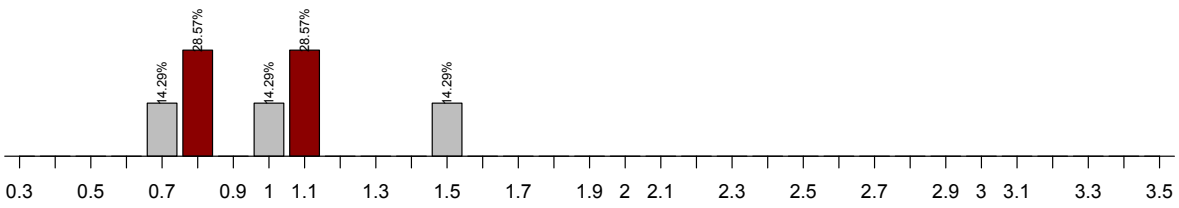
Num. obs. =7



600
(550-649)

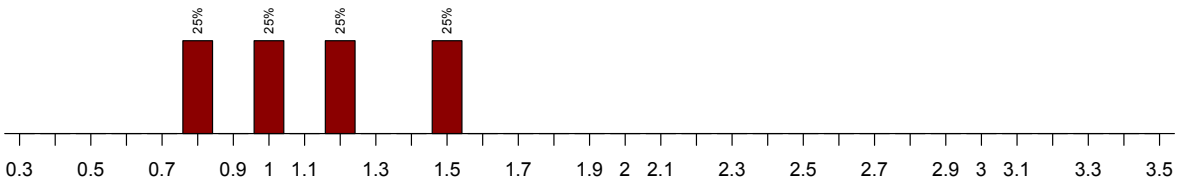
Num. obs. =9

T1R1(2)



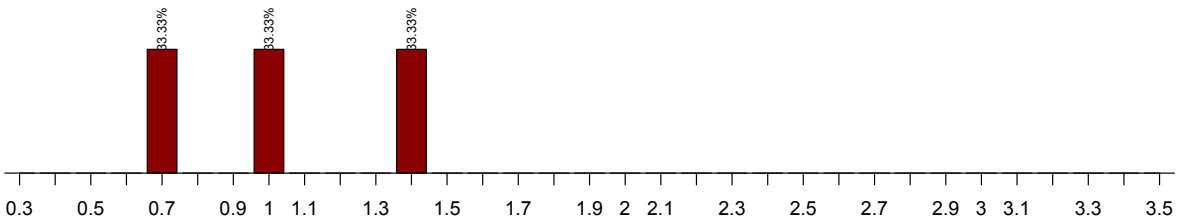
700
(650-749)

Num. obs. =7



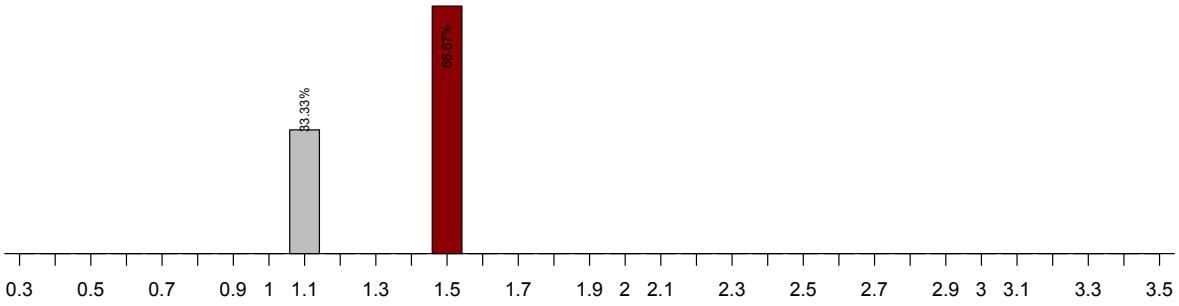
800
(750-849)

Num. obs. =4



900
(850-949)

Num. obs.=3



1000
(950-1049)

Num. obs. =3

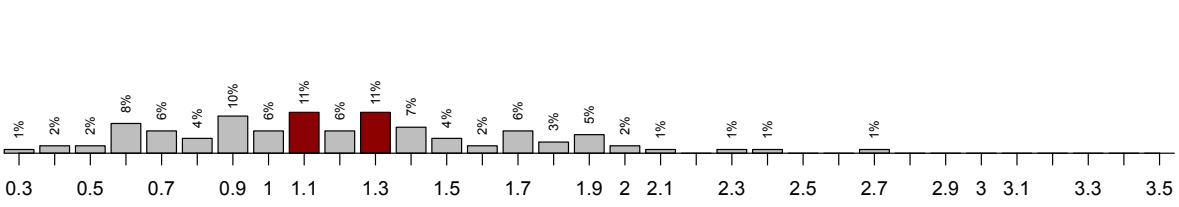
1400
(1350-1449)

Num. obs. =1

1500
(1450-1549)

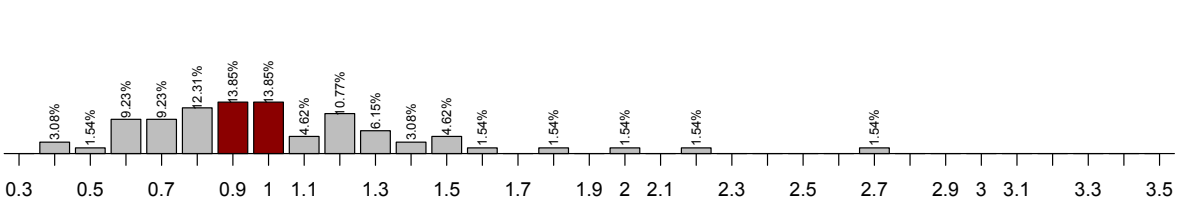
Num. obs. =1

T2R1(1)



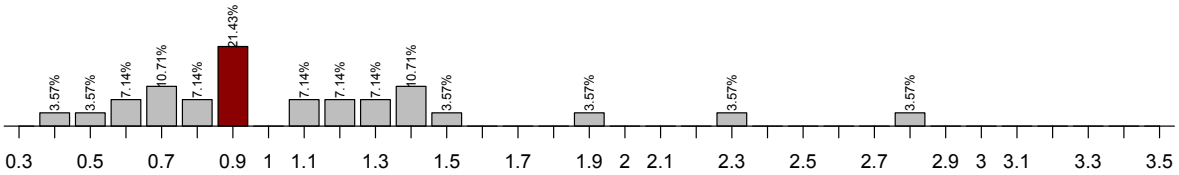
100
(50-149)

Num. obs. =100



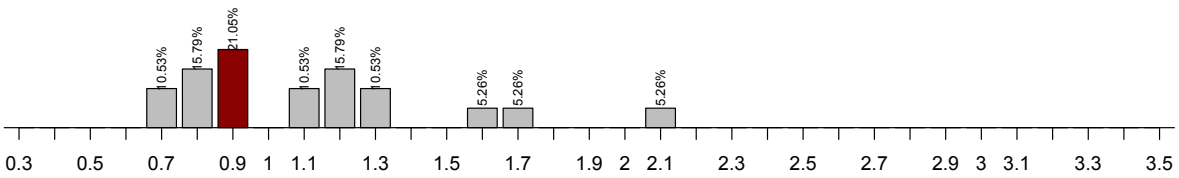
200
(150-249)

Num. obs. =65



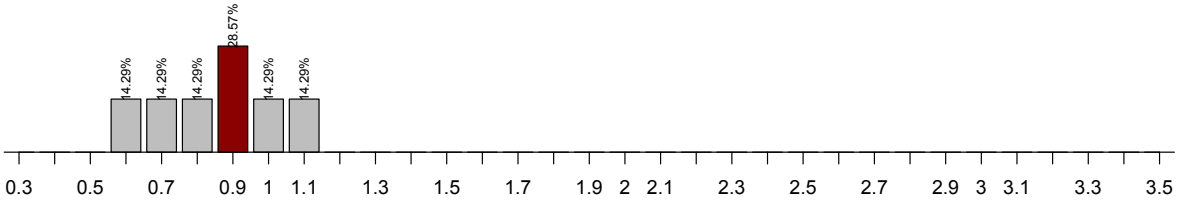
300
(250-349)

Num. obs.=28



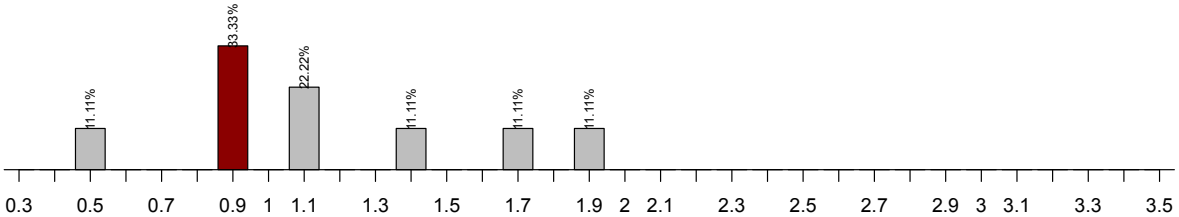
400
(350-449)

Num. obs. =19



500
(450-549)

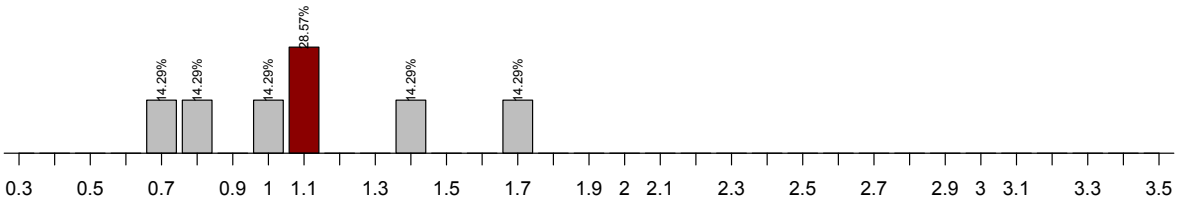
Num. obs. =7



600
(550-649)

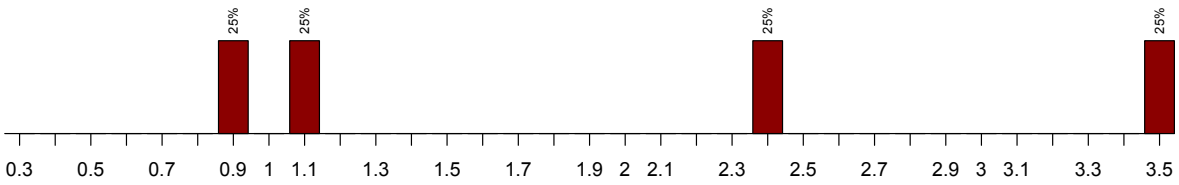
Num. obs. =9

T2R1(2)



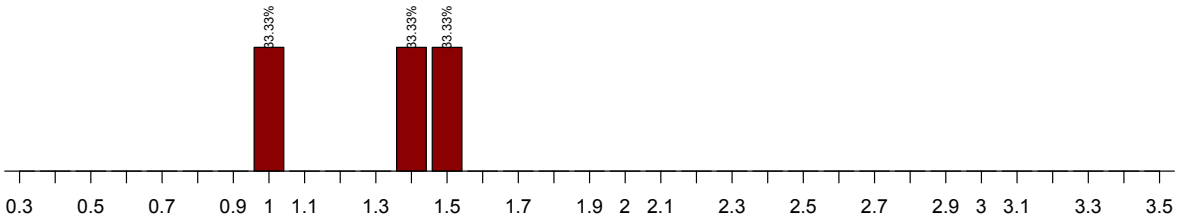
700
(650-749)

Num. obs. =7



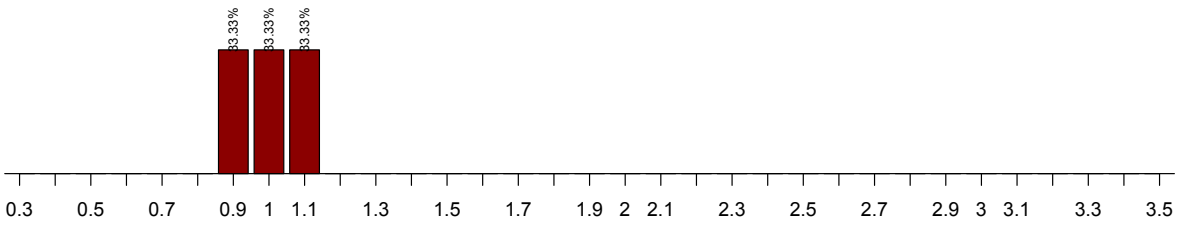
800
(750-849)

Num. obs. =4



900
(850-949)

Num. obs.=3



1000
(950-1049)

Num. obs. =3

1400
(1350-1449)

Num. obs. =1

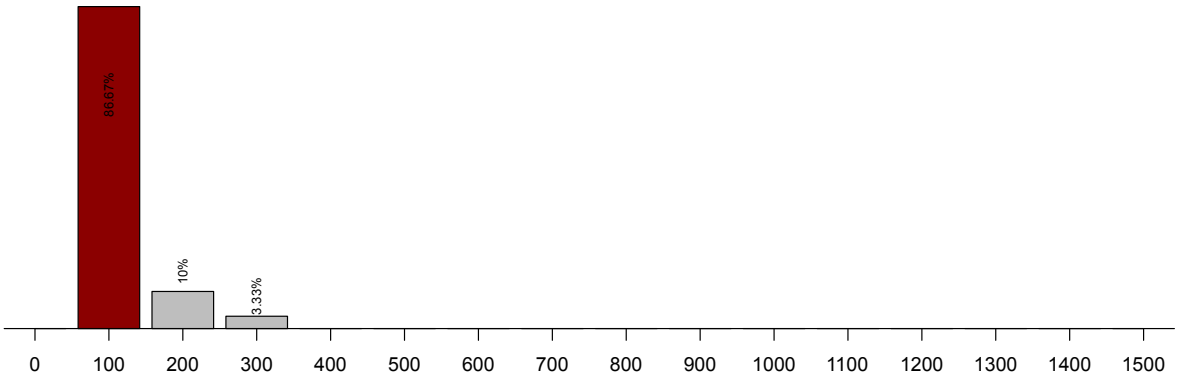
1500
(1450-1549)

Num. obs. =1

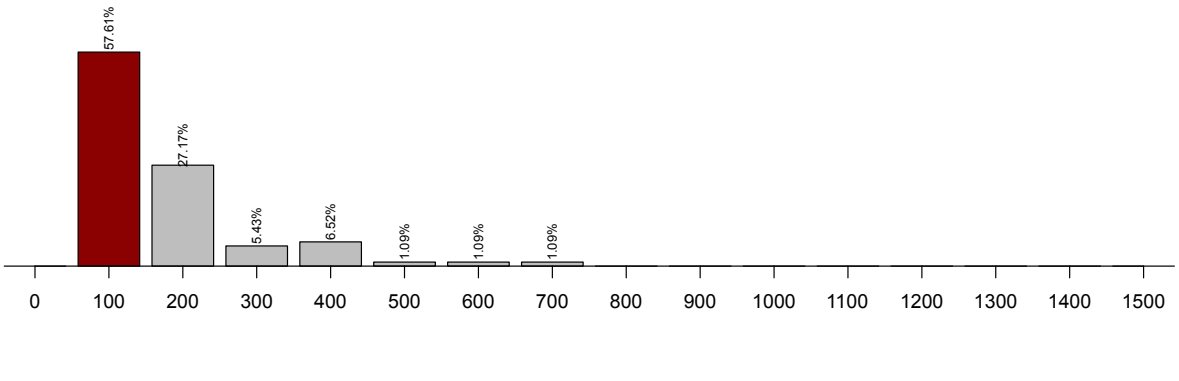
3.1.4 RESULTS REFERRED TO THE PARAMETER MSR

AAR

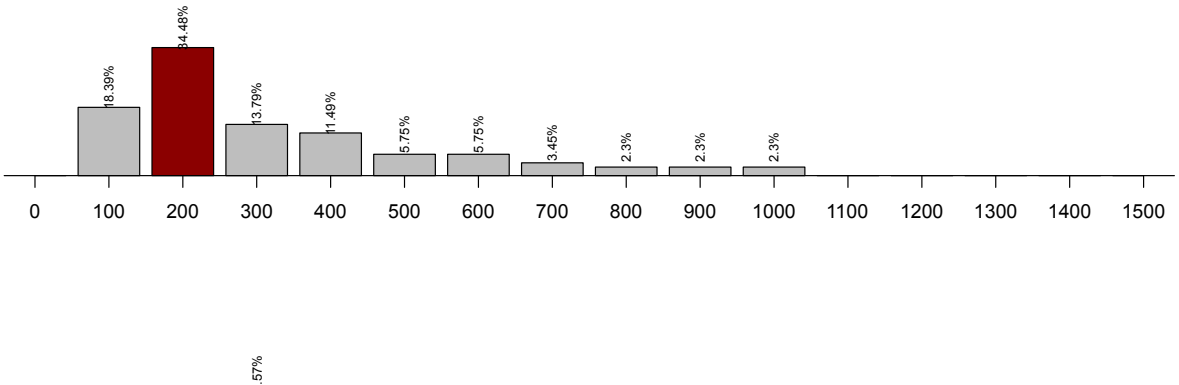
(*) MSR= 2 (1.50-2.49) and 11 (10.50-11.49) have 1 observation
(*) The cases not included have 0 observarions



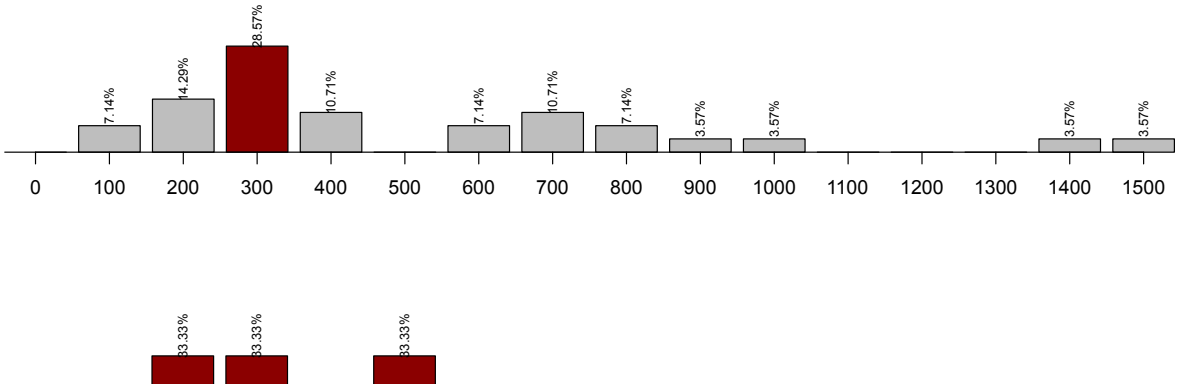
3
(2.50-3.49)
Num. obs. =1



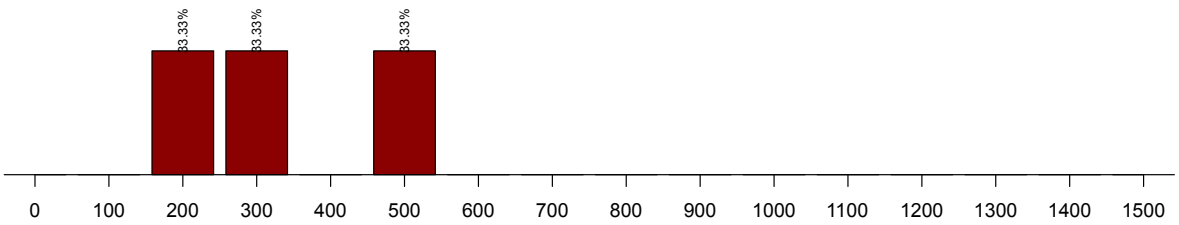
4
(3.50-4.49)
Num. obs.=30



5
(4.50-5.49)
Num. obs. =92



6
(5.50-6.49)
Num. obs. =87

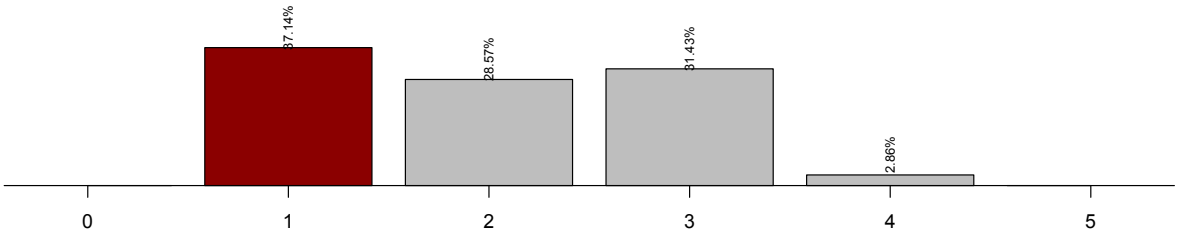


7
(6.50-7.49)
Num. obs. =28

8
(7.50-8.49)
Num. obs. =3

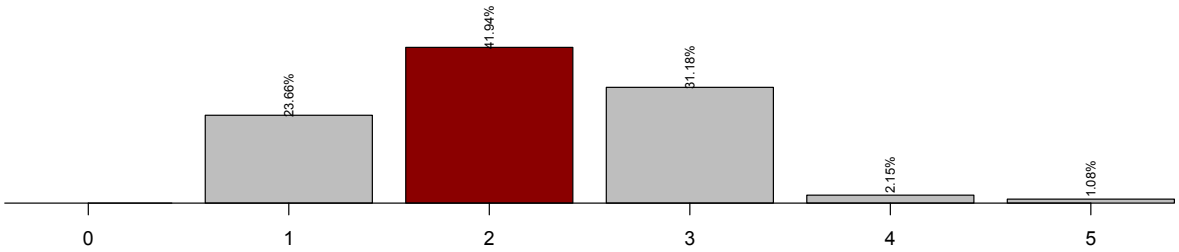
LOR

(*) MSR= 2 (1.50-2.49) and 11 (10.50-11.49) have 1 observation
(*) The cases not included have 0 observarions



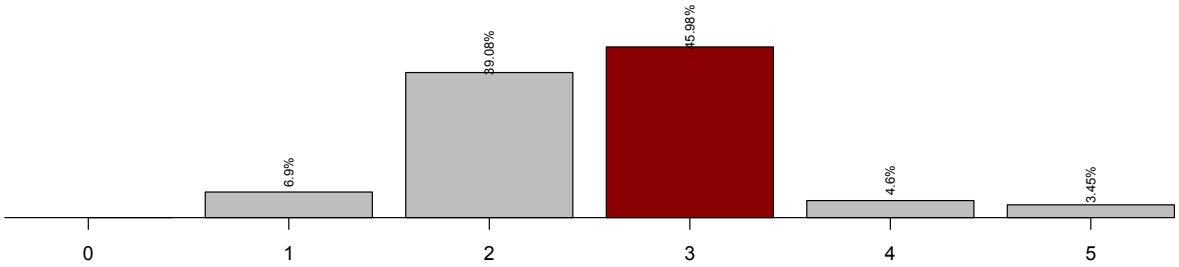
3
(2.50-3.49)

Num. obs. =2



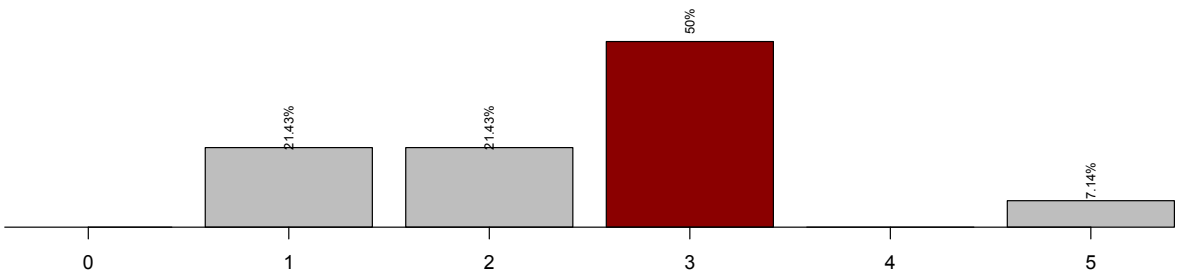
4
(3.50-4.49)

Num. obs.=35



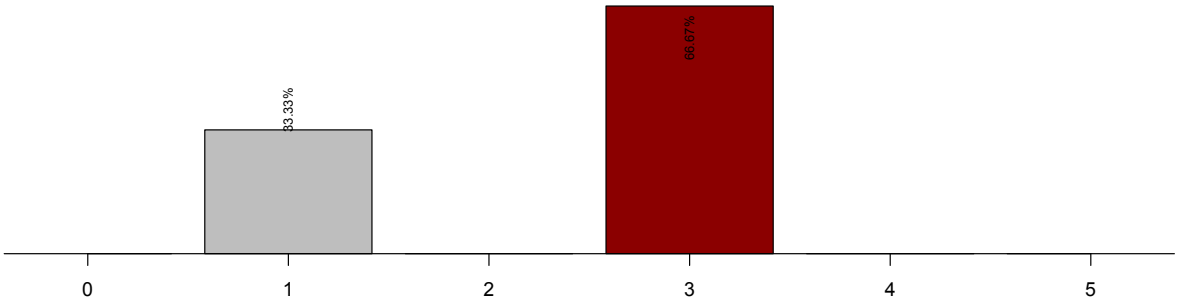
5
(4.50-5.49)

Num. obs. =93



6
(5.50-6.49)

Num. obs. =87



7
(6.50-7.49)

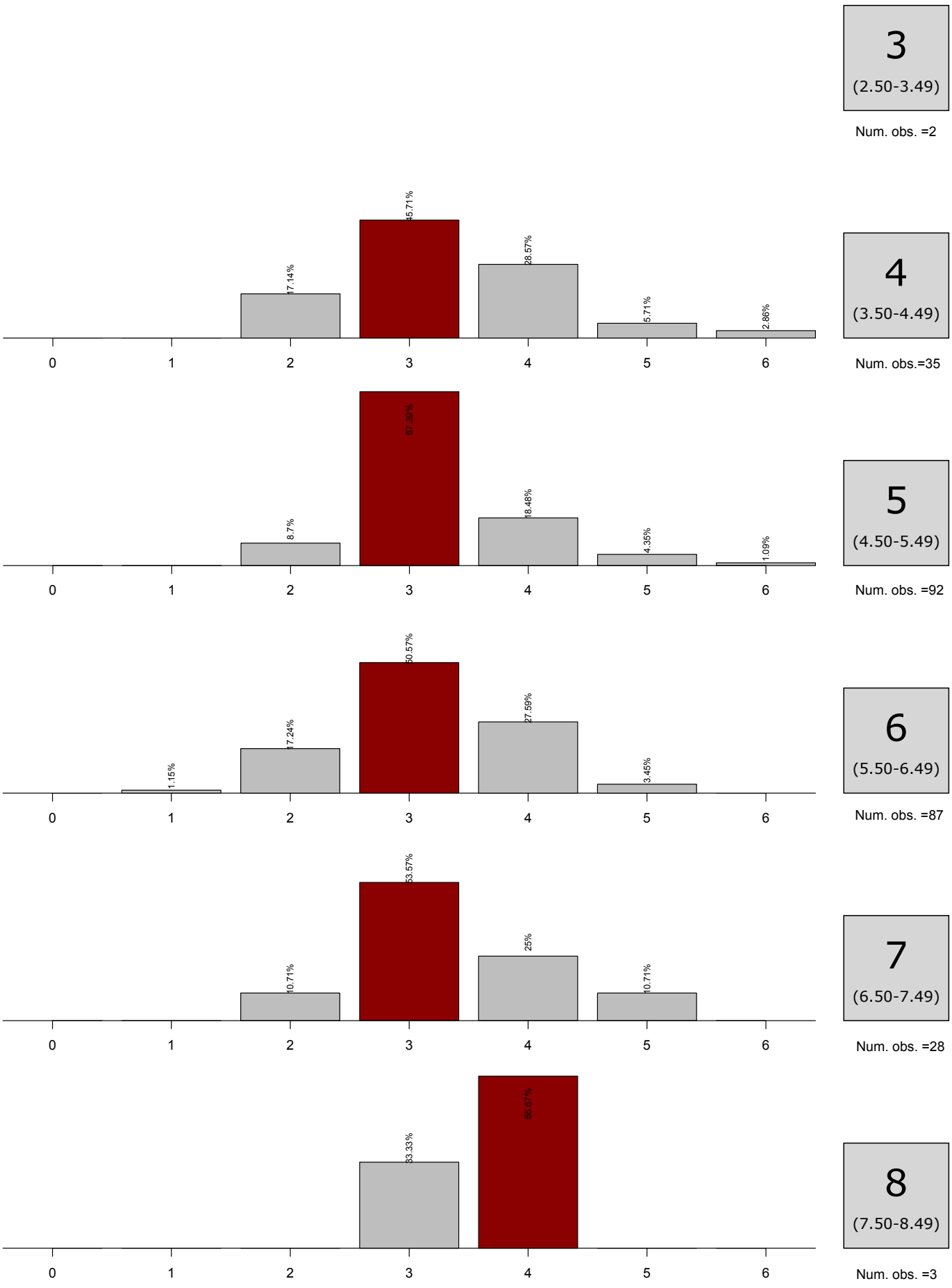
Num. obs. =28

8
(7.50-8.49)

Num. obs. =3

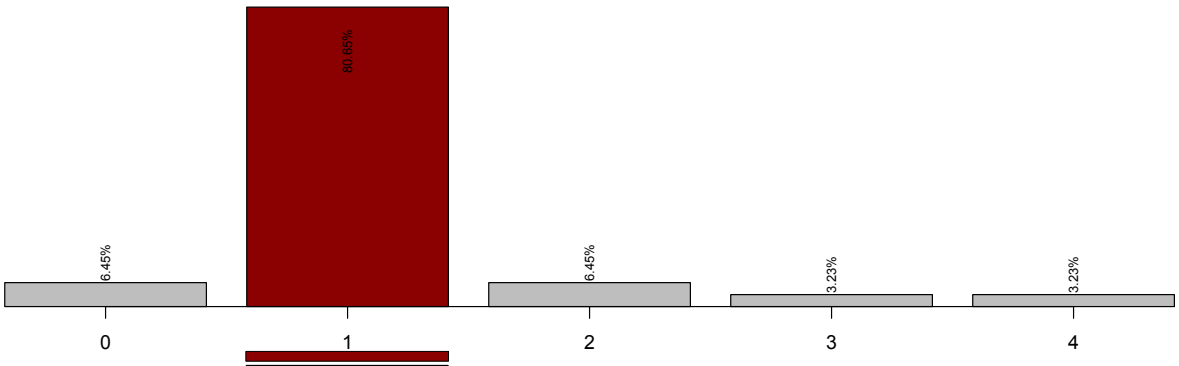
NF

(*) MSR= 2 (1.50-2.49) and 11 (10.50-11.49) have 1 observation
(*) The cases not included have 0 observarions



NV

(*) MSR= 2 (1.50-2.49) and 11 (10.50-11.49) have 1 observation
(*) The cases not included have 0 observarions

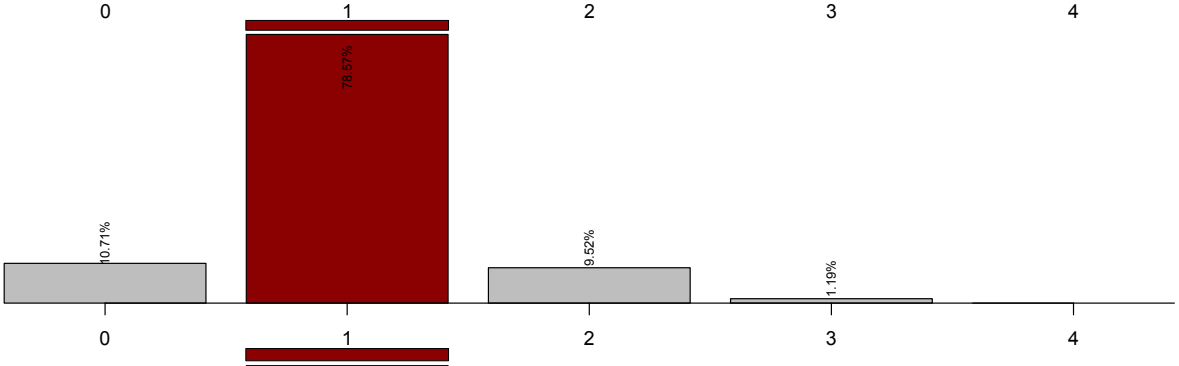


3
(2.50-3.49)

Num. obs. =1

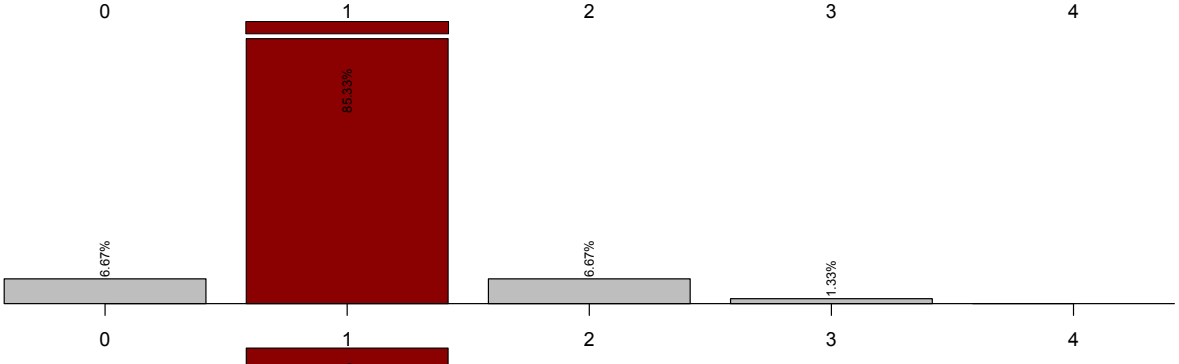
4
(3.50-4.49)

Num. obs.=31



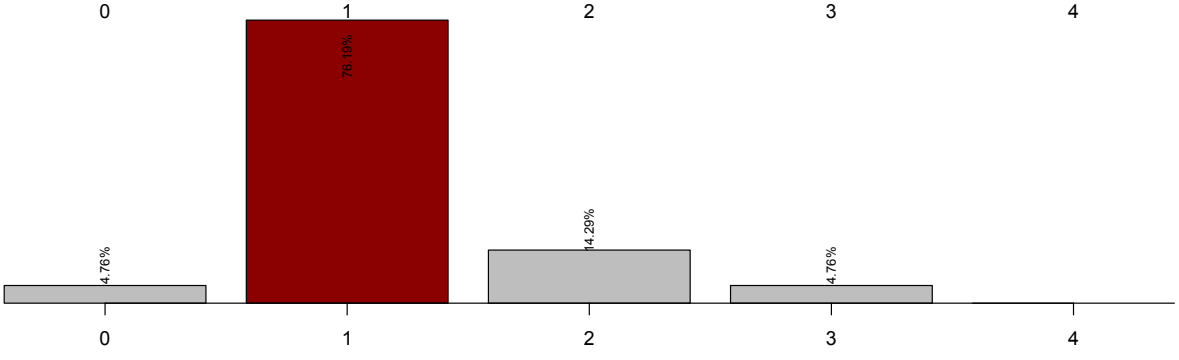
5
(4.50-5.49)

Num. obs. =84



6
(5.50-6.49)

Num. obs. =75



7
(6.50-7.49)

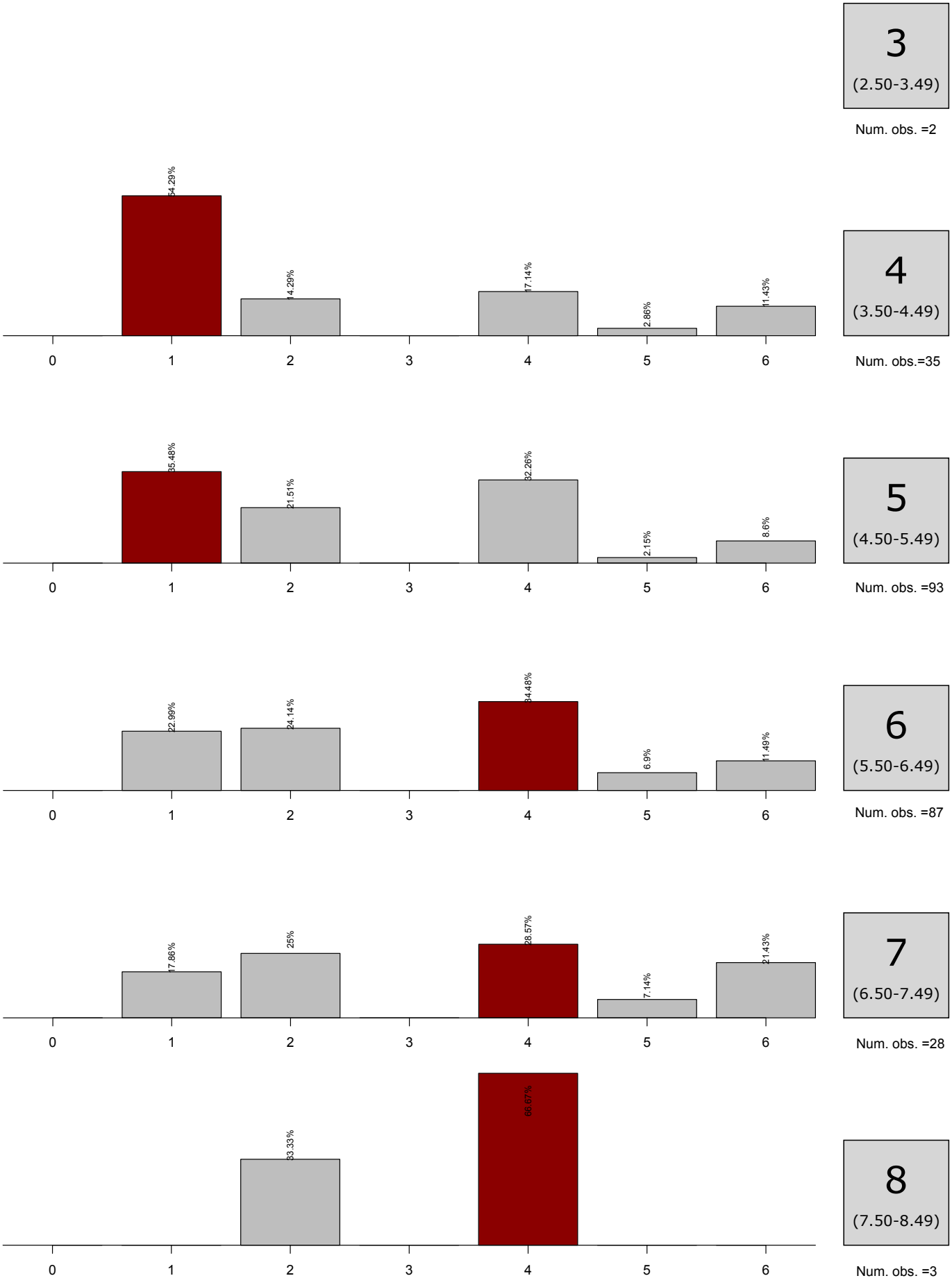
Num. obs. =21

8
(7.50-8.49)

Num. obs. =2

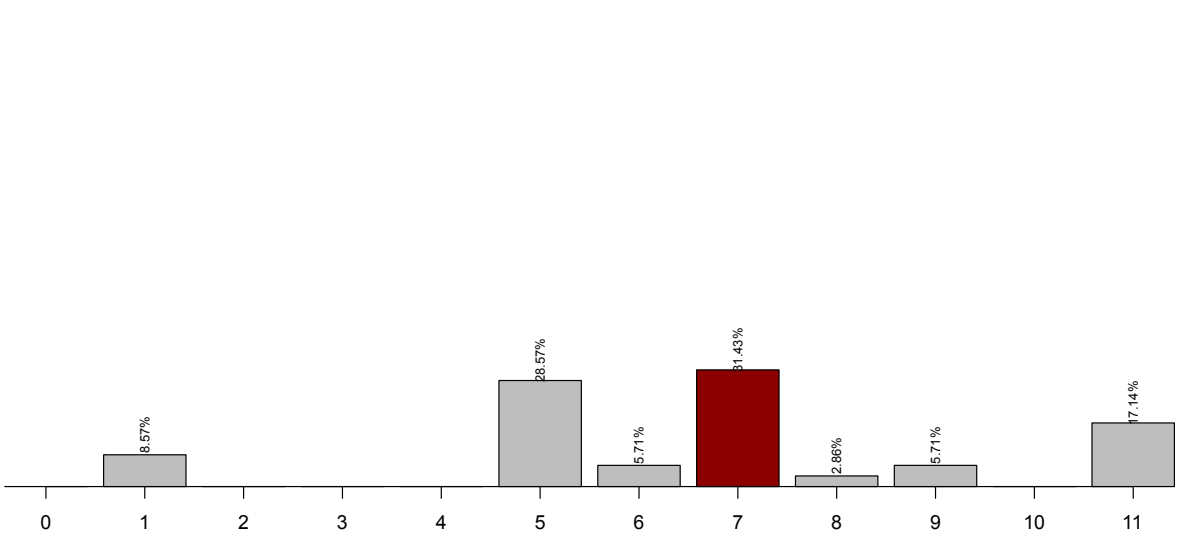
PE

(*) MSR= 2 (1.50-2.49) and 11 (10.50-11.49) have 1 observation
(*) The cases not included have 0 observarions



PL

(*) MSR= 2 (1.50-2.49) and 11 (10.50-11.49) have 1 observation
(*) The cases not included have 0 observarions

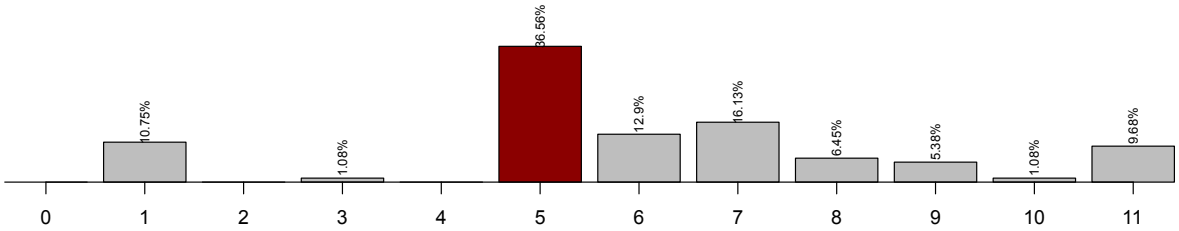


3
(2.50-3.49)

Num. obs. =2

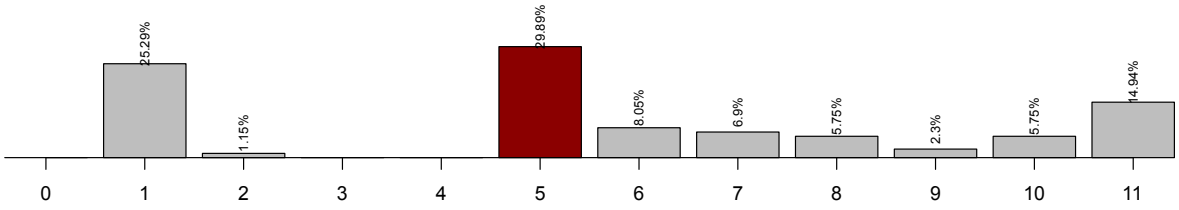
4
(3.50-4.49)

Num. obs.=35



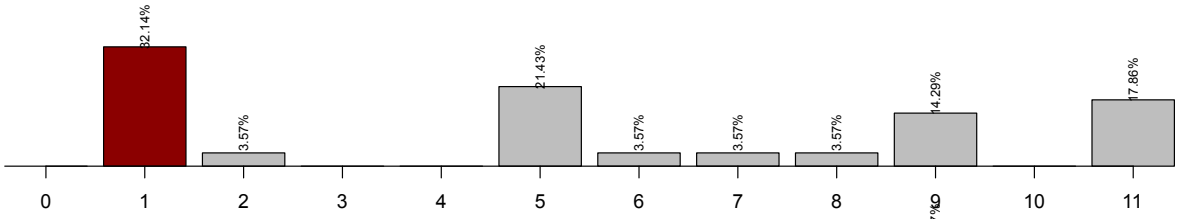
5
(4.50-5.49)

Num. obs. =93



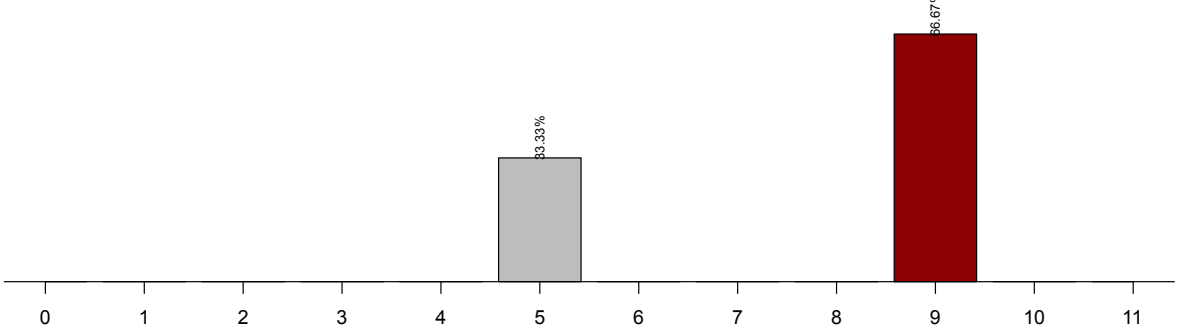
6
(5.50-6.49)

Num. obs. =87



7
(6.50-7.49)

Num. obs. =28

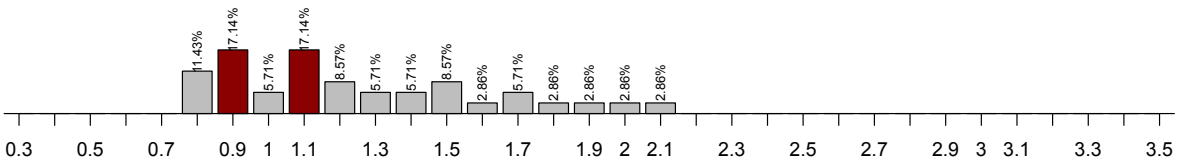


8
(7.50-8.49)

Num. obs. =3

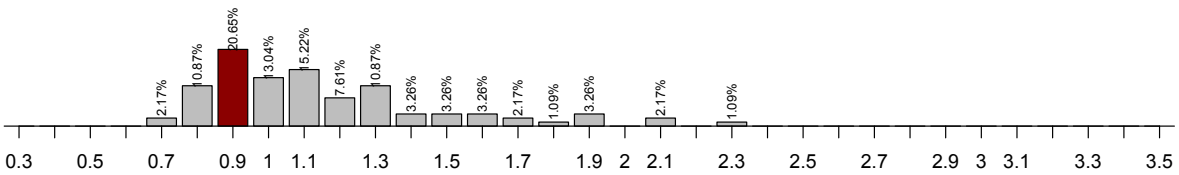
T1R1

(*) MSR= 2 (1.50-2.49) and 11 (10.50-11.49) have 1 observation
(*) The cases not included have 0 observarions



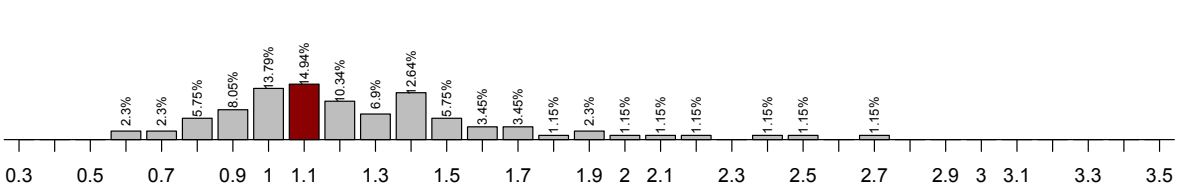
3
(2.50-3.49)

Num. obs. =2



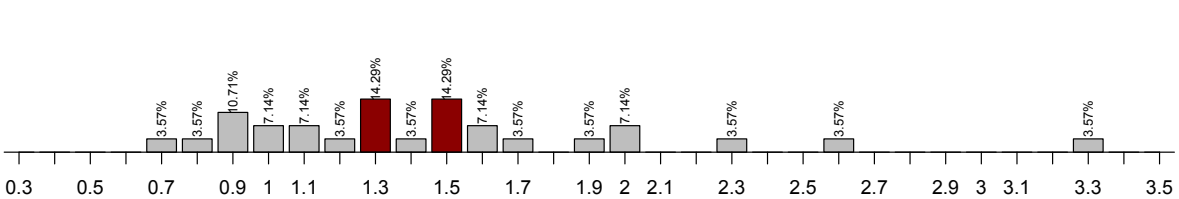
4
(3.50-4.49)

Num. obs.=35



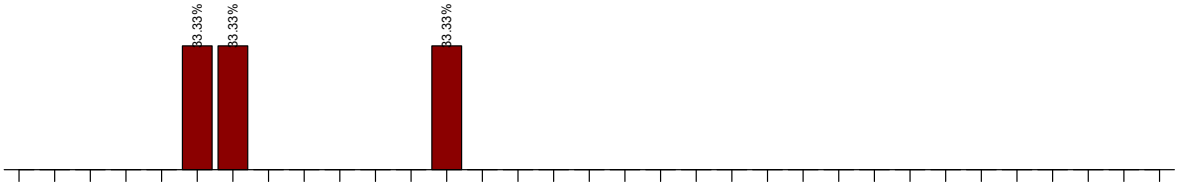
5
(4.50-5.49)

Num. obs. =92



6
(5.50-6.49)

Num. obs. =87



7
(6.50-7.49)

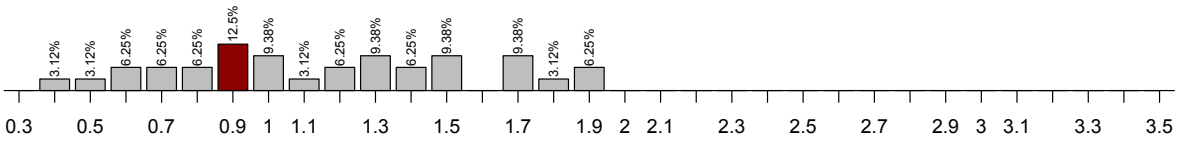
Num. obs. =28

8
(7.50-8.49)

Num. obs. =3

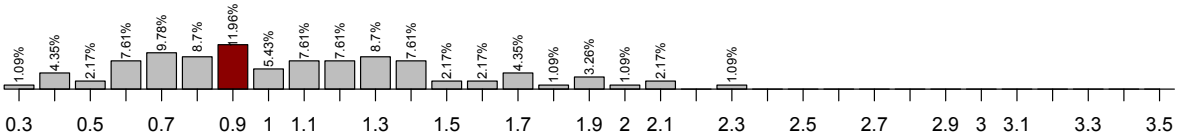
T2R1

(*) MSR= 2 (1.50-2.49) and 11 (10.50-11.49) have 1 observation
(*) The cases not included have 0 observarions



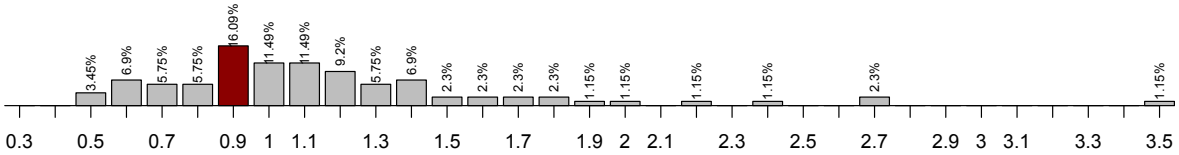
3
(2.50-3.49)

Num. obs. =2



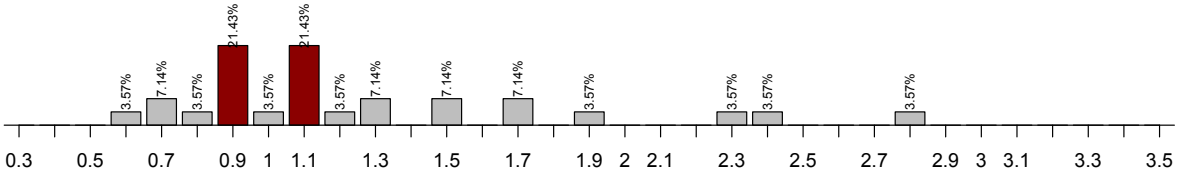
4
(3.50-4.49)

Num. obs.=32



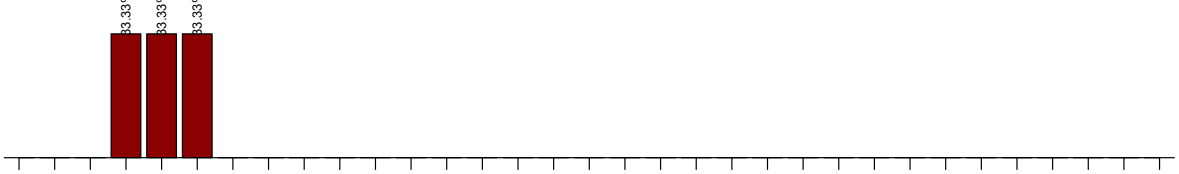
5
(4.50-5.49)

Num. obs. =92



6
(5.50-6.49)

Num. obs. =87



7
(6.50-7.49)

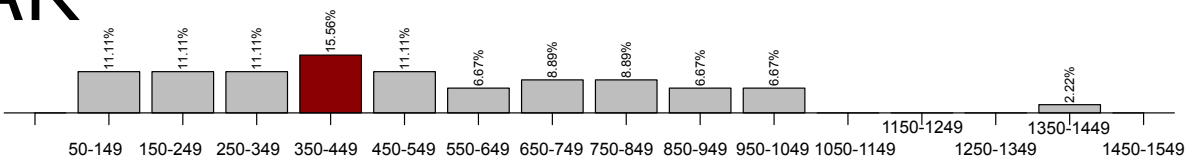
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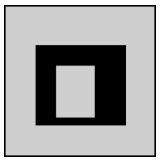
8
(7.50-8.49)

Num. obs. =3

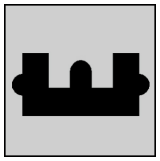
3.1.5 RESULTS REFERRED TO THE PARAMETER PL

AAR

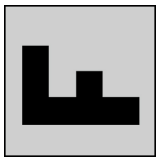




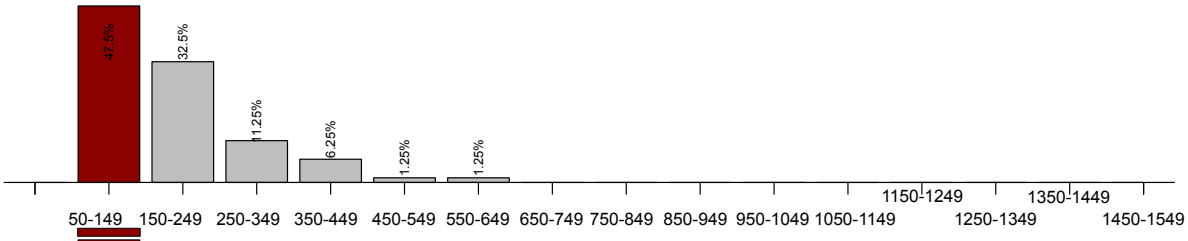
Num. obs.=45

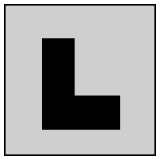


Num.obs. = 2

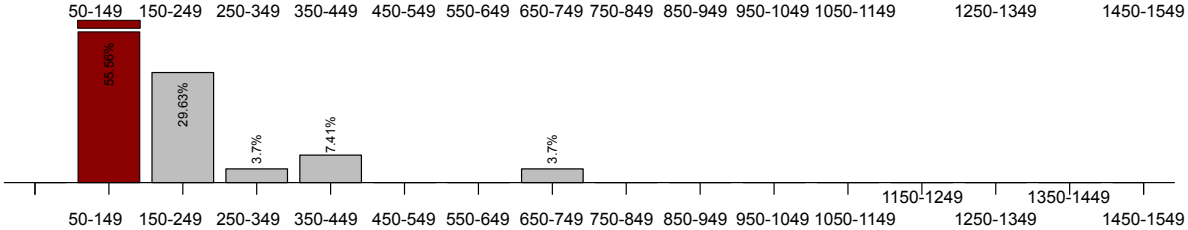


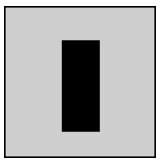
Num.obs. =1



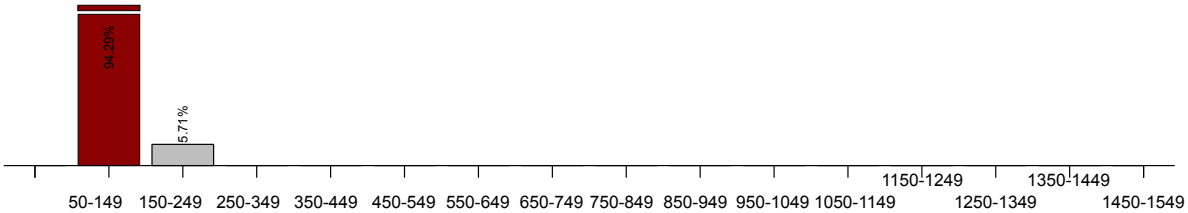


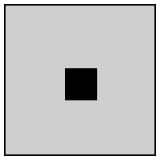
Num.obs.=80



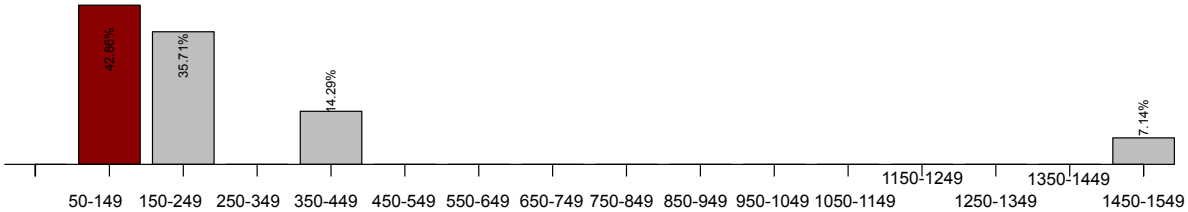


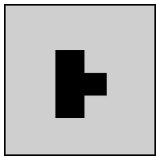
Num. obs. =27



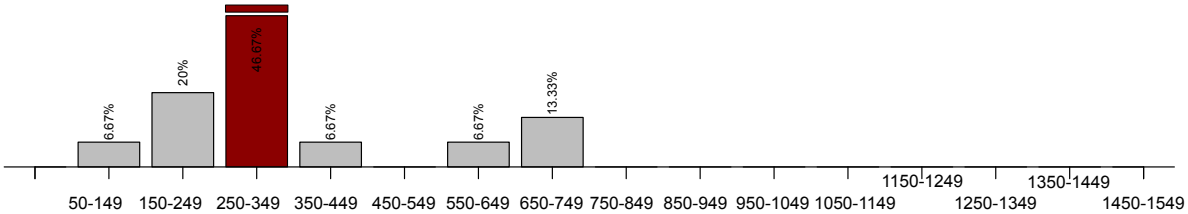


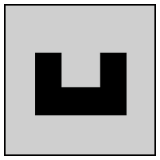
Num. obs.=35



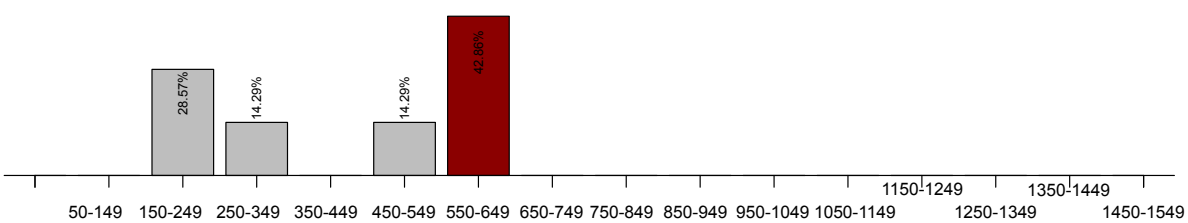


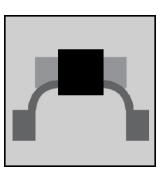
Num. obs.=14



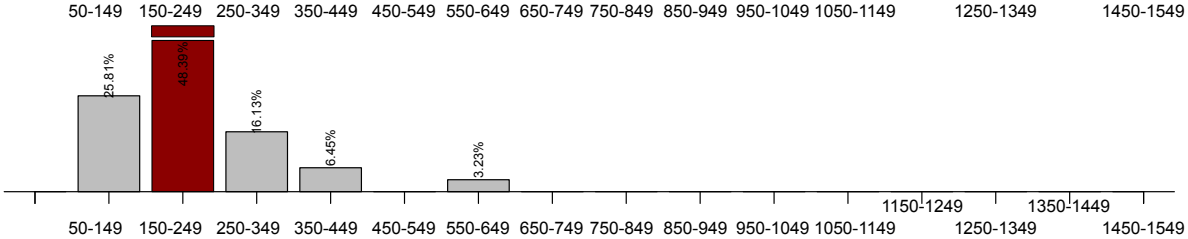


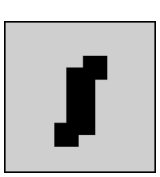
Num. obs.=15





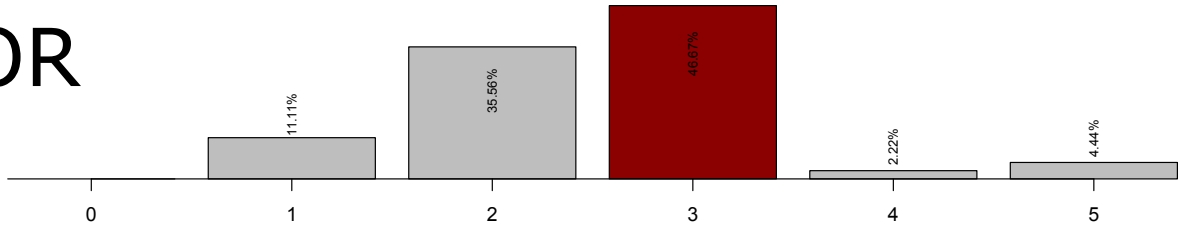
Num. obs.=7

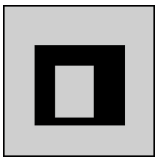




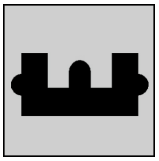
Num. obs.=31

LOR

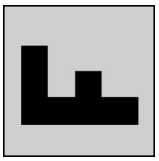




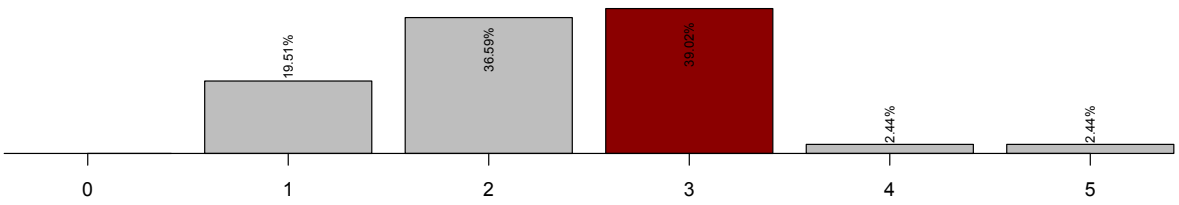
Num. obs.=45

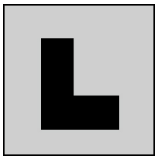


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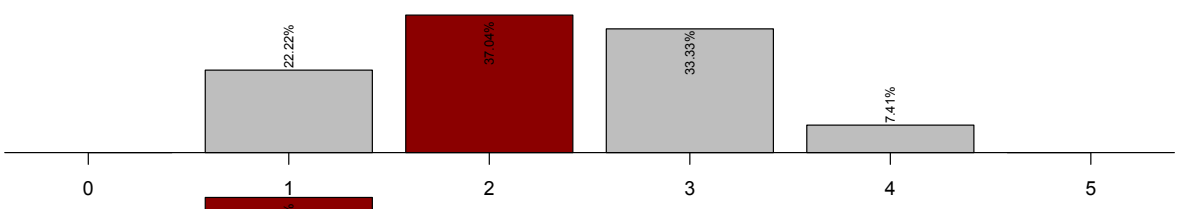


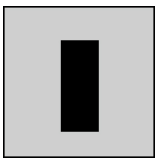
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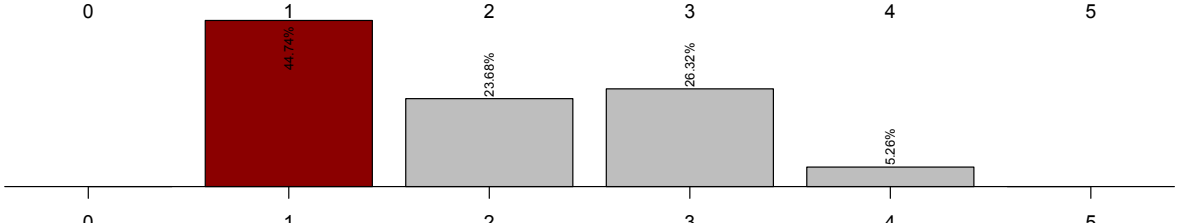


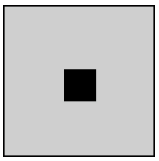
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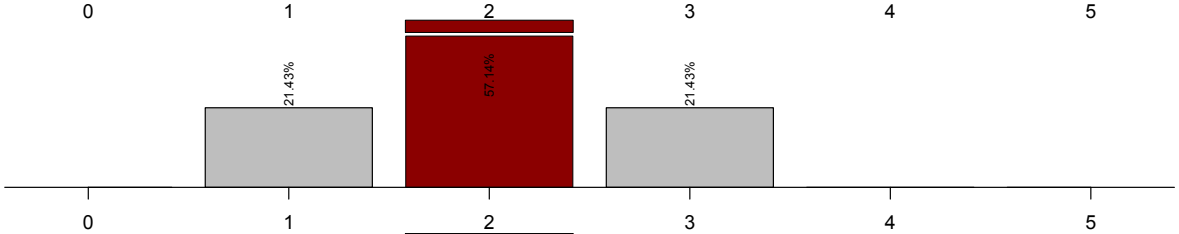


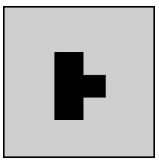
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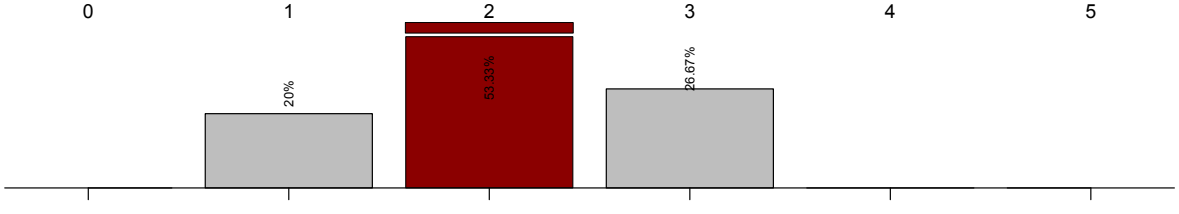


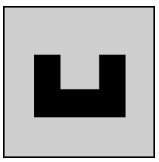
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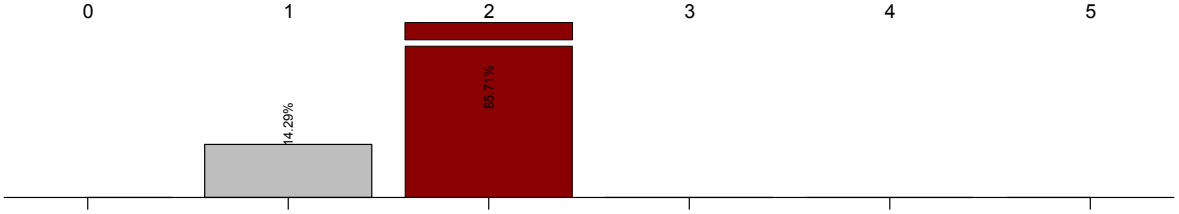


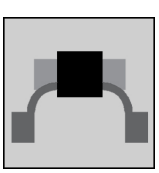
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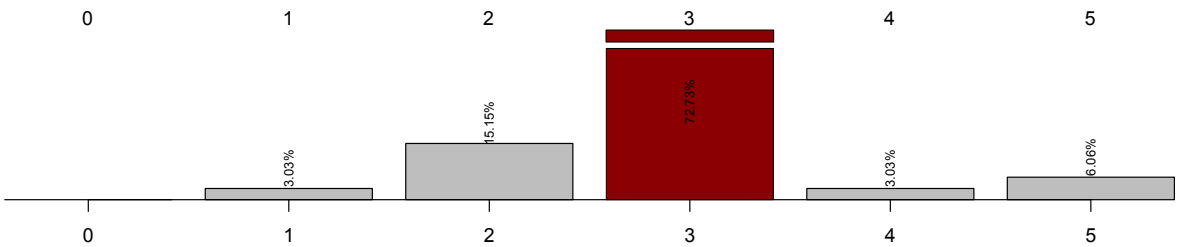


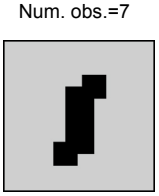
Num. obs.=15





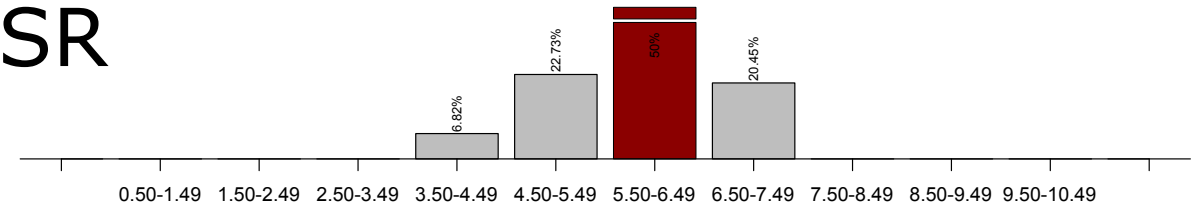
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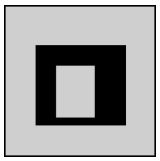




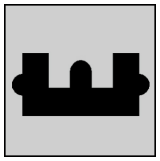
Num. obs.=33

MSR

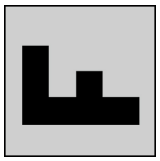




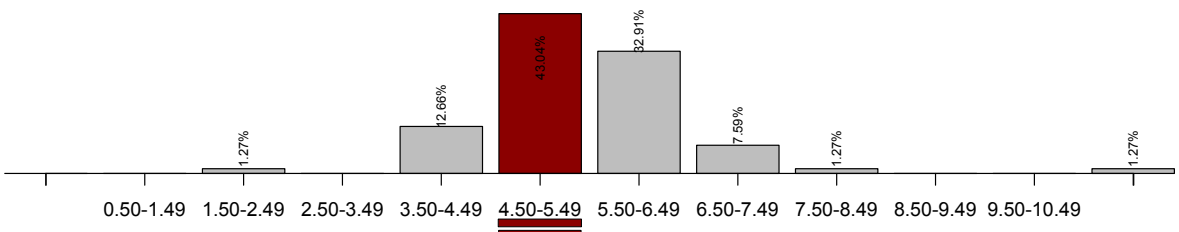
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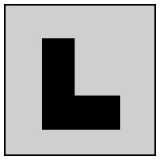


Num.obs. = 2

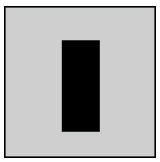


Num.obs. =1

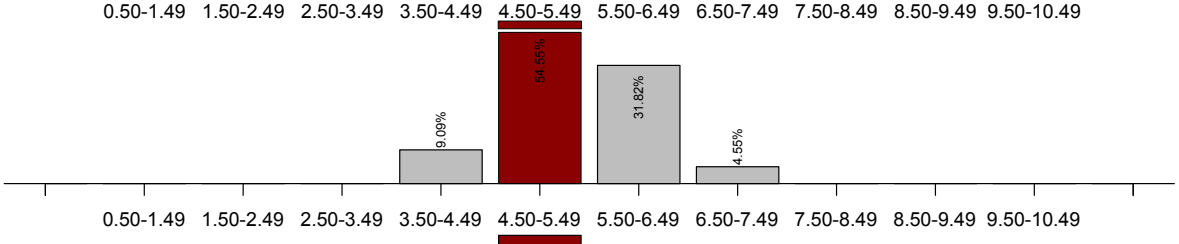


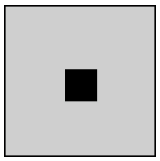


Num.obs.=79

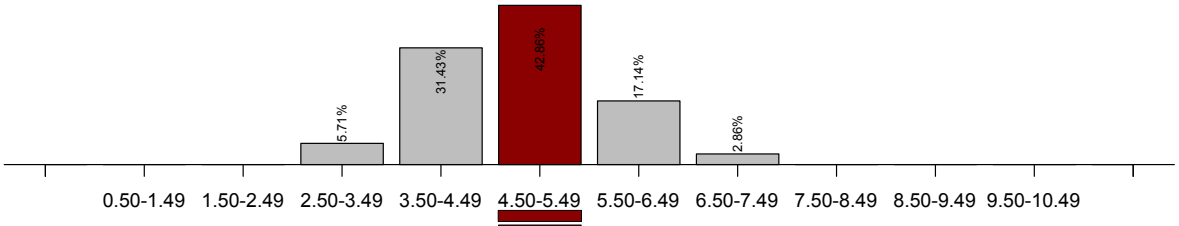


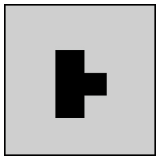
Num. obs. =22



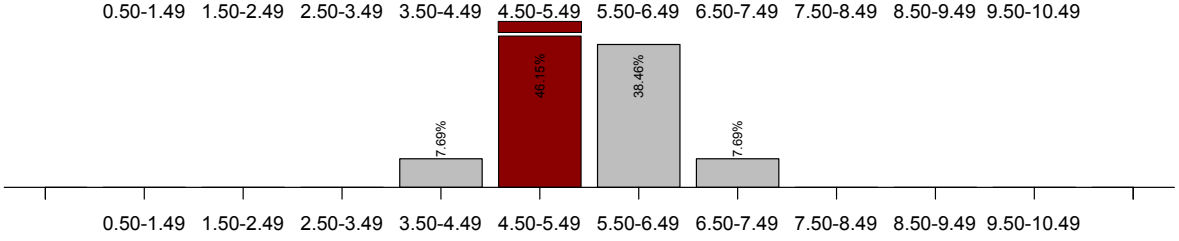


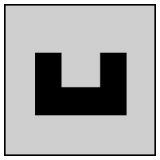
Num. obs.=35



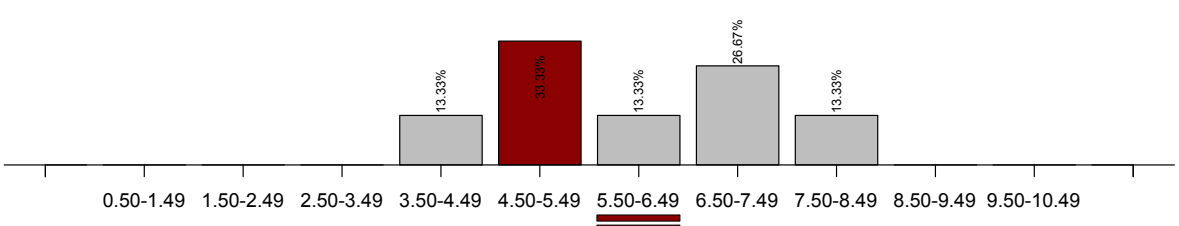


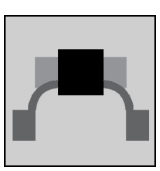
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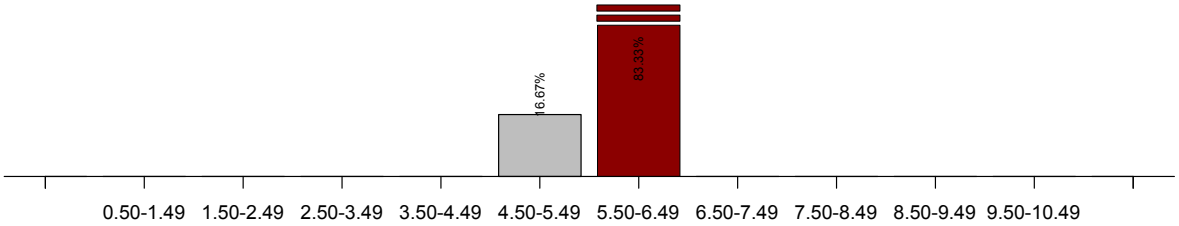


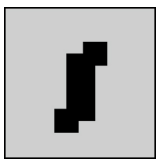
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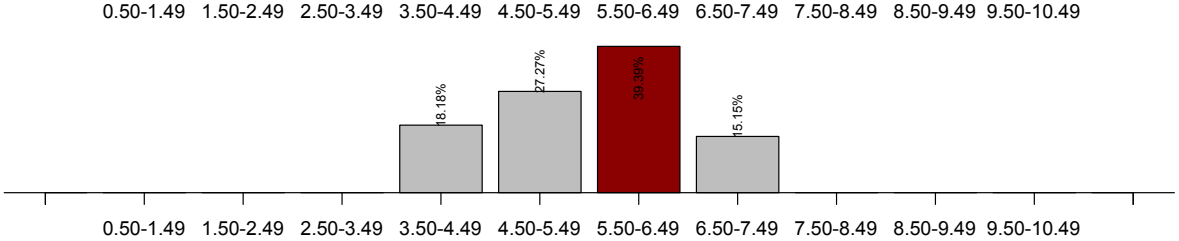


Num. obs.=6

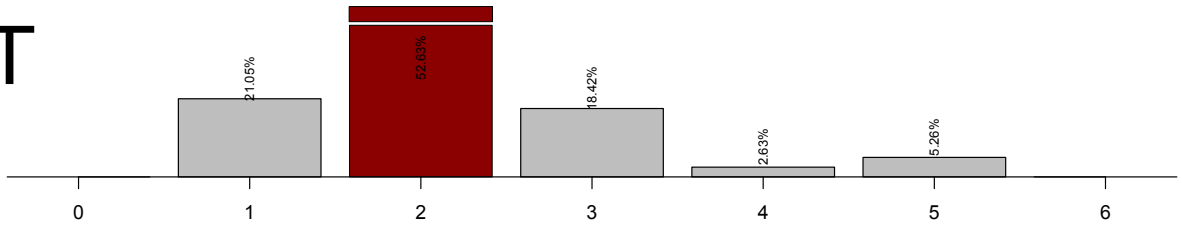


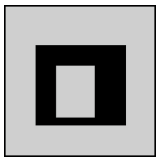


Num. obs.=33

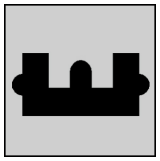


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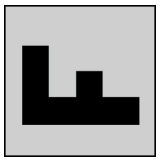




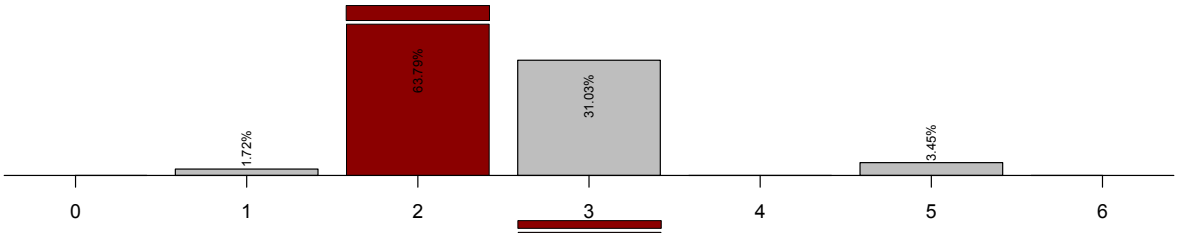
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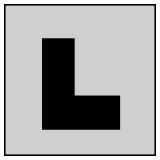


Num.obs. = 0

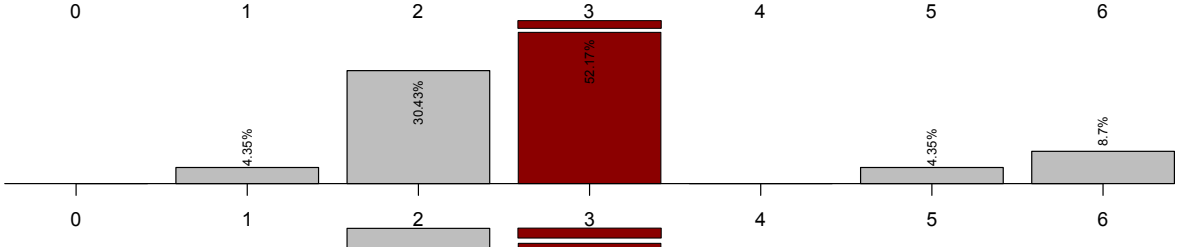


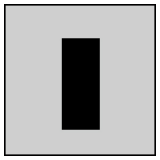
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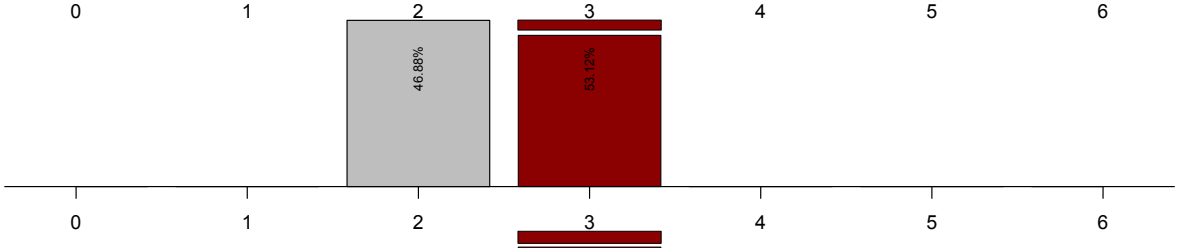


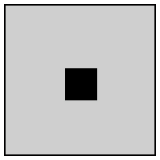
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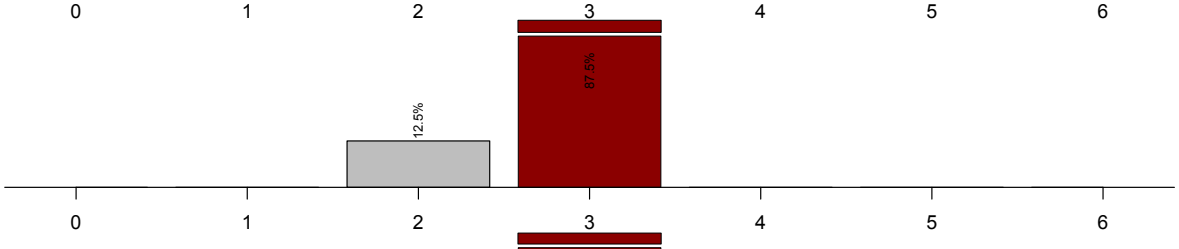


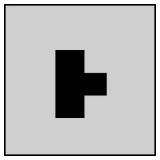
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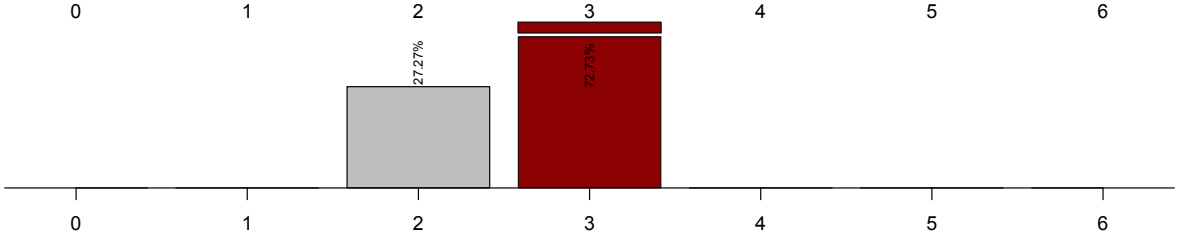


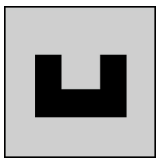
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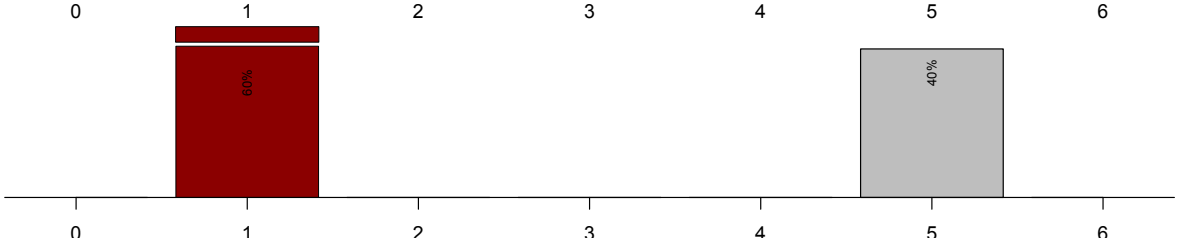


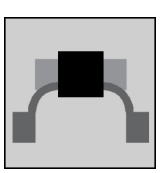
Num. obs.=8



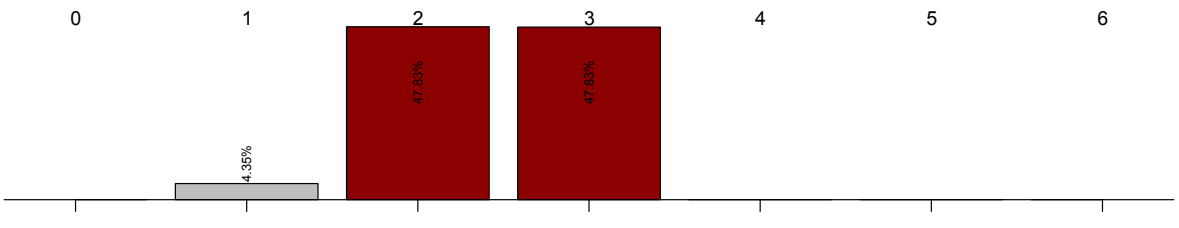


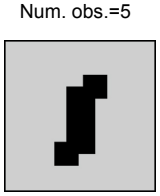
Num. obs.=11





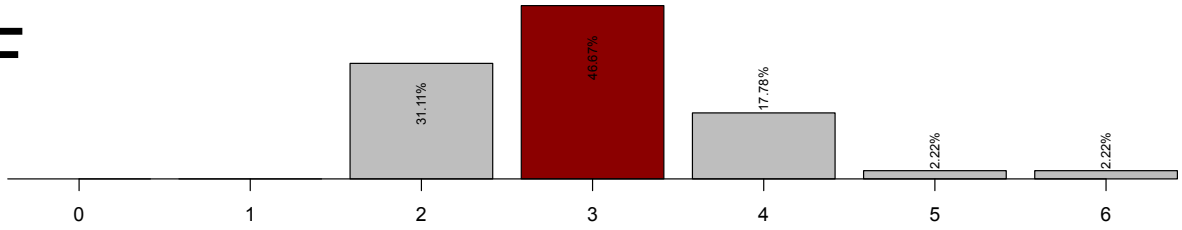
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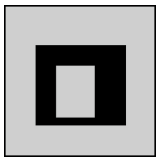




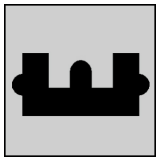
Num. obs.=23

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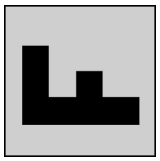




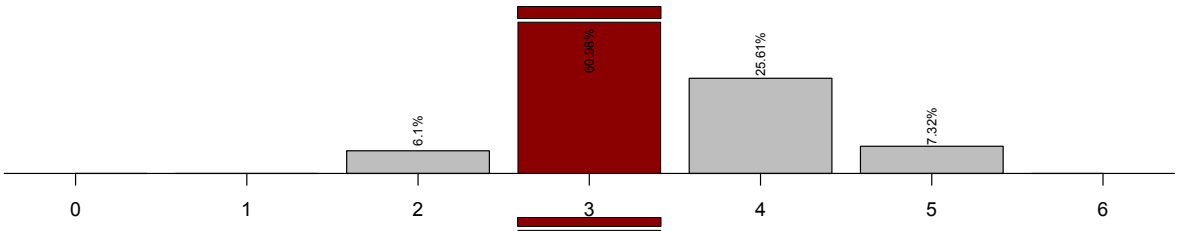
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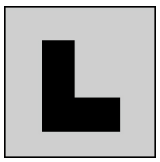


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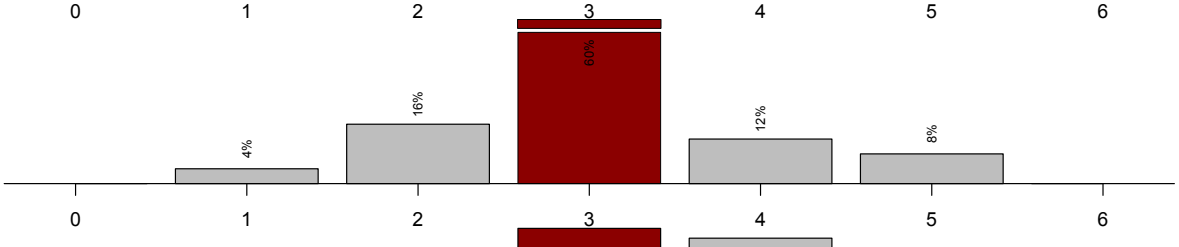


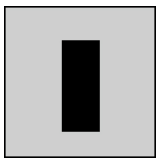
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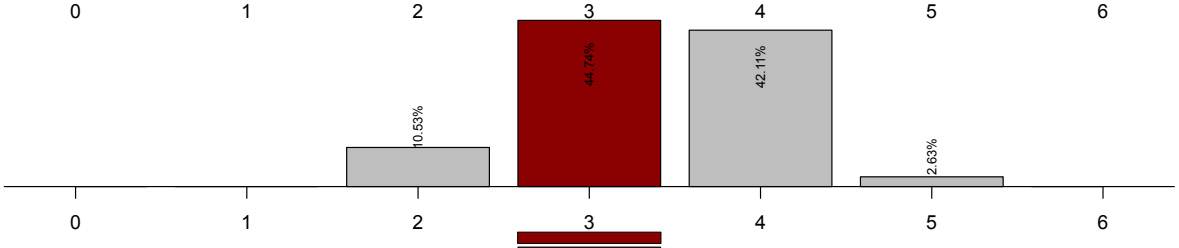


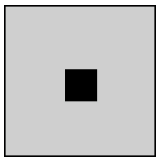
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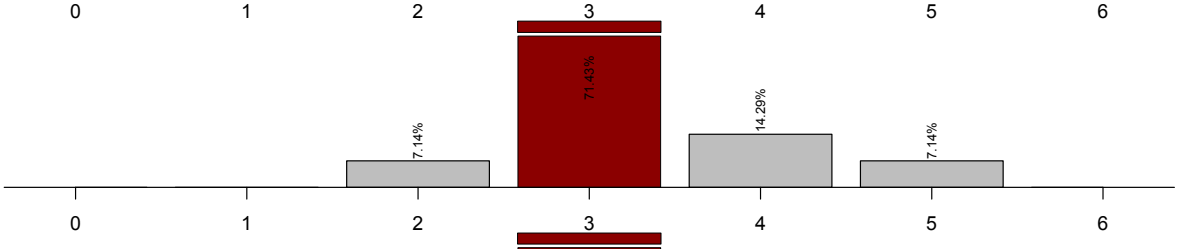


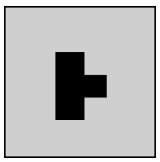
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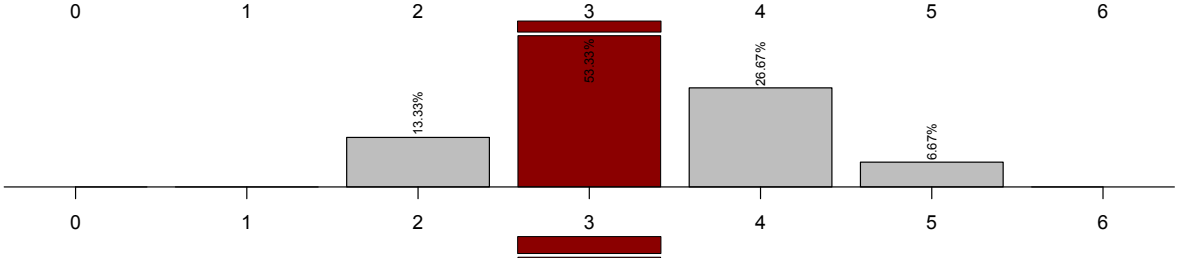


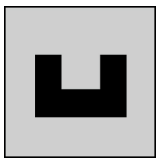
Num. obs.=38



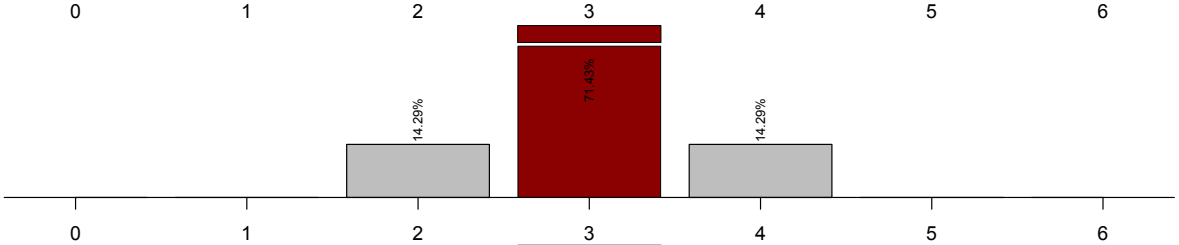


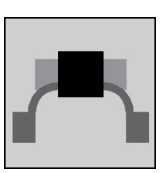
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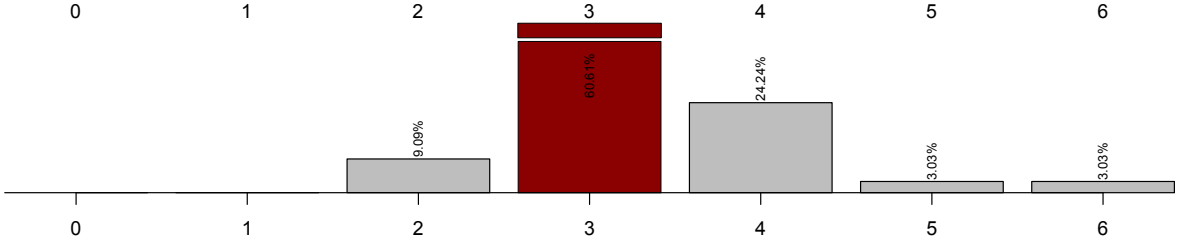


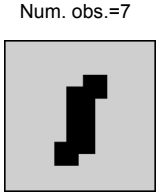
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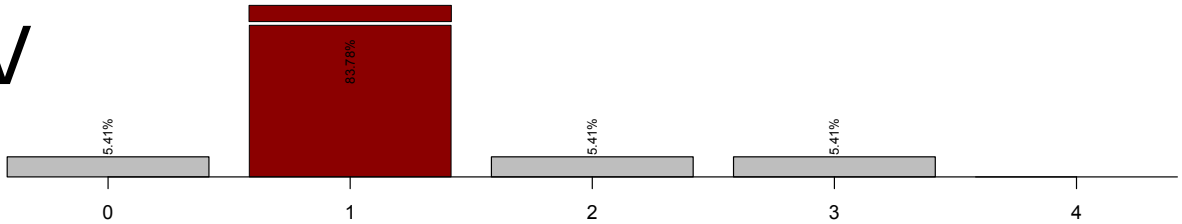
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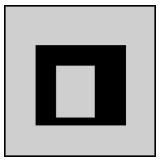




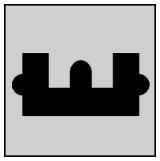
Num. obs.=33

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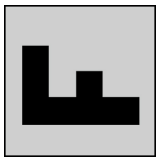


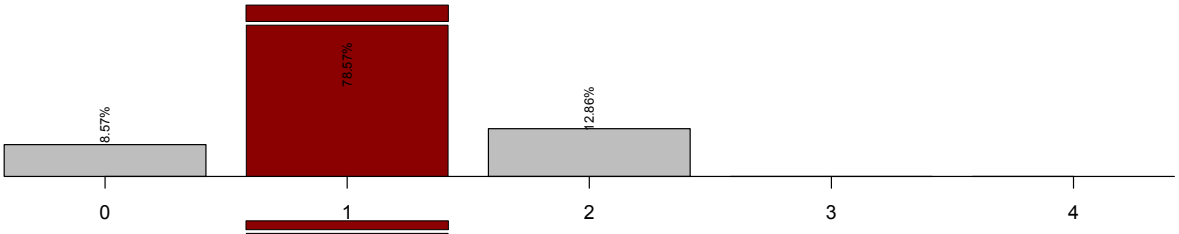


Num. obs.=37

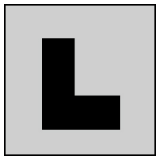


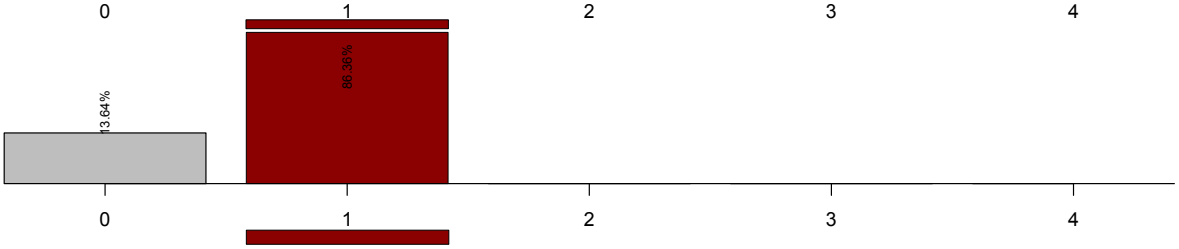
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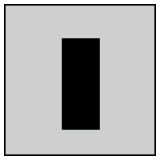


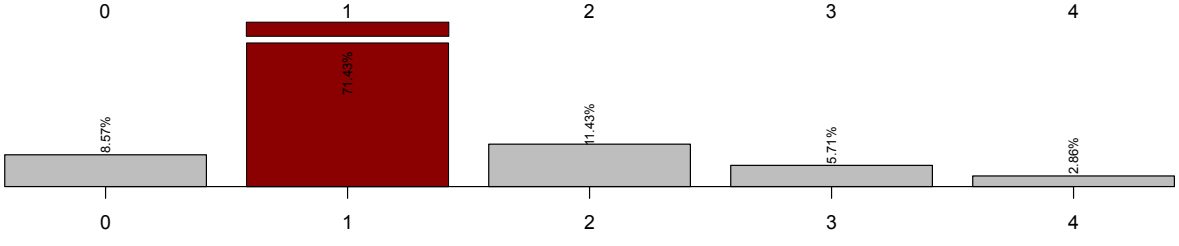
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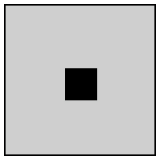


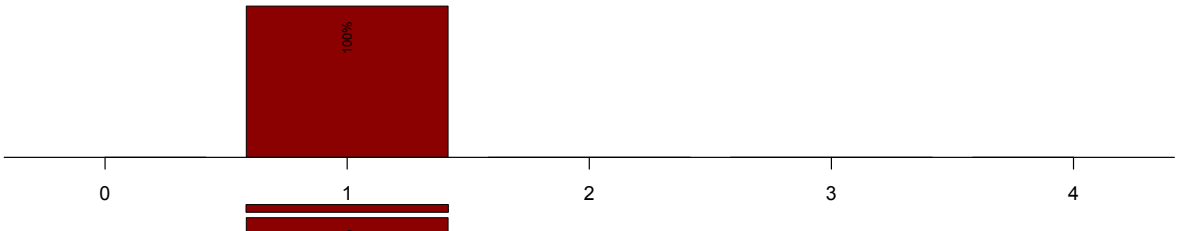
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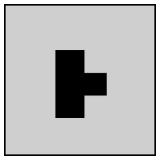


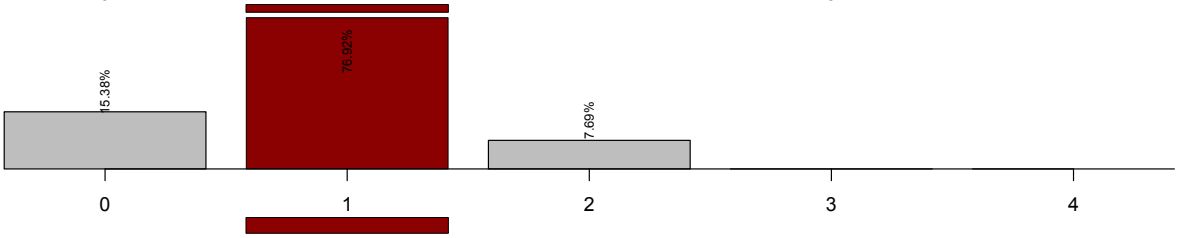
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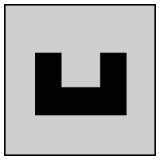


Num. obs.=35



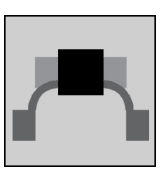


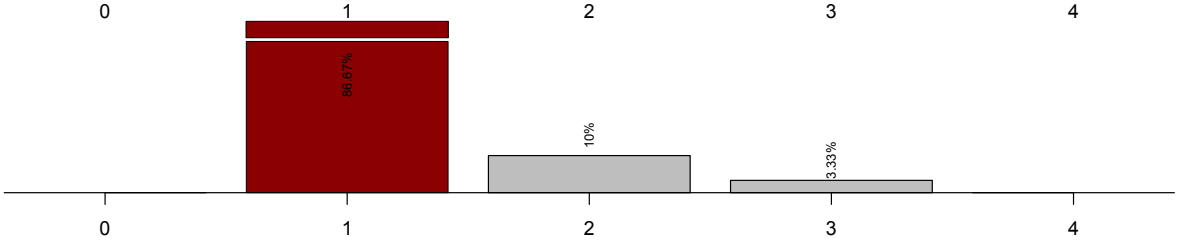
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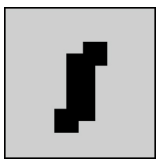


Num. obs.=13



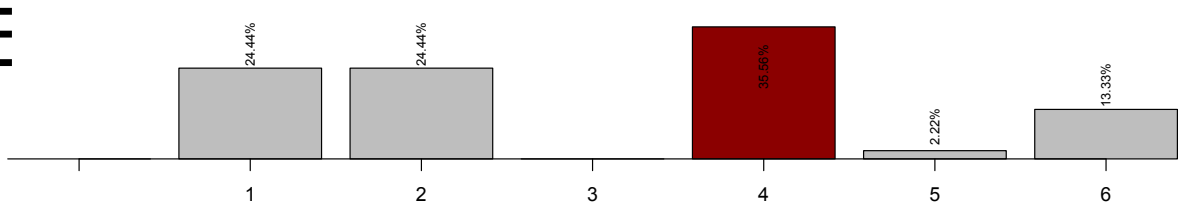


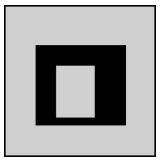
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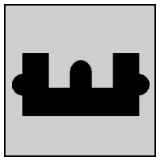
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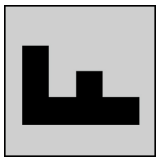




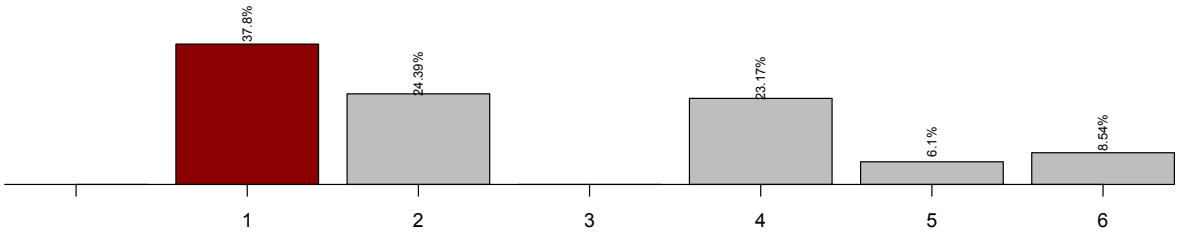
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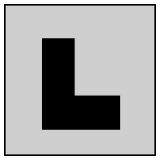


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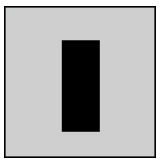


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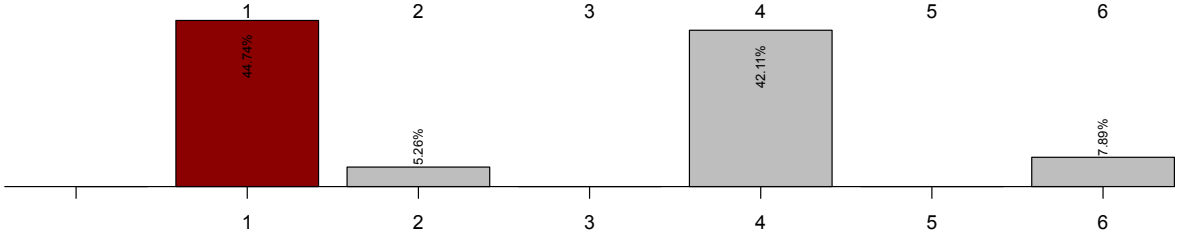


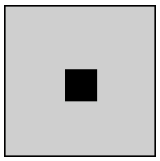


Num.obs.=82

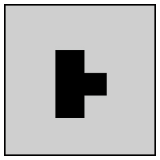


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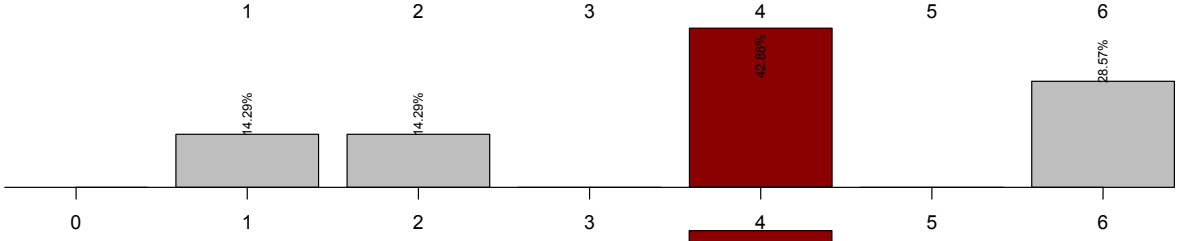


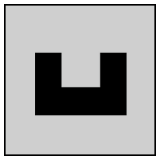


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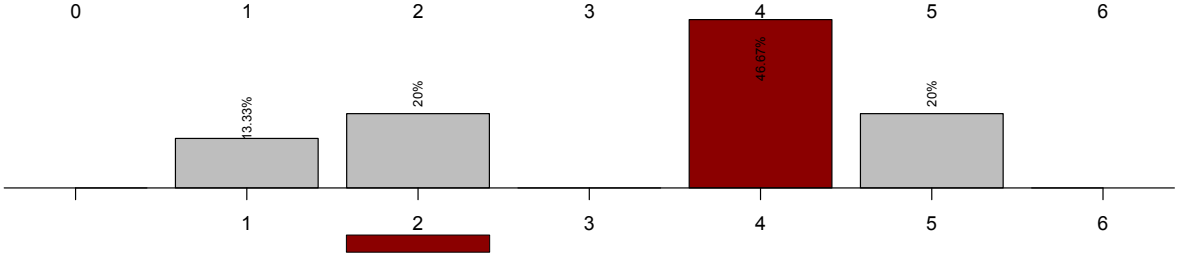


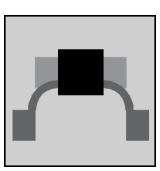
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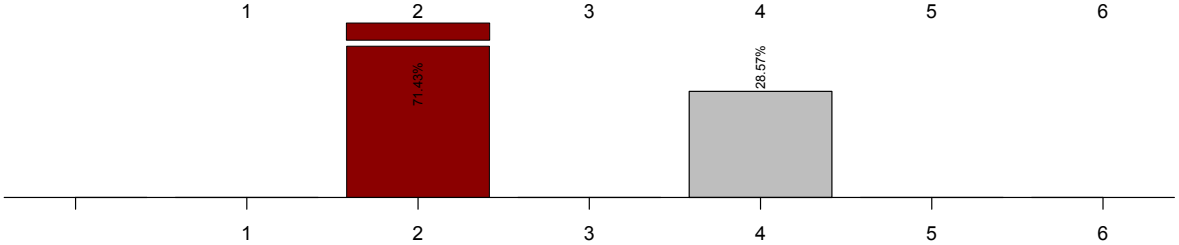


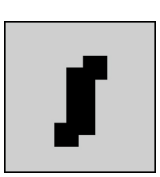
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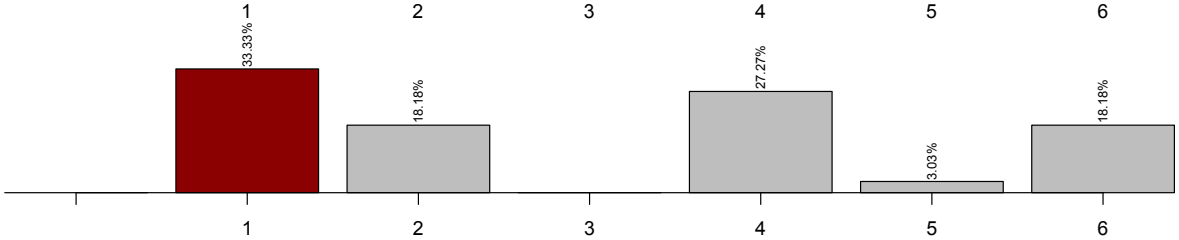


Num. obs.=7

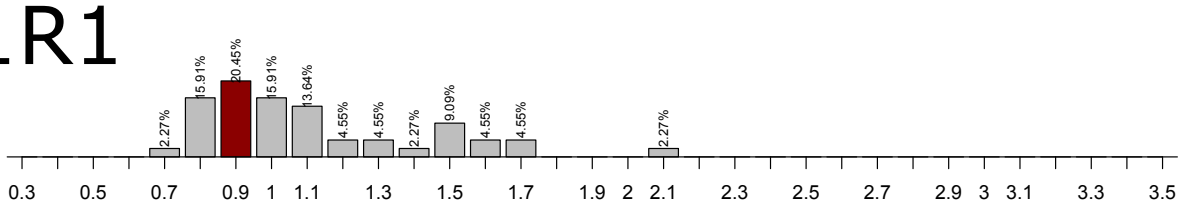


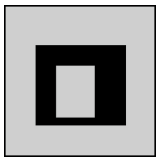


Num. obs.=33

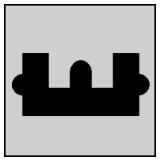


T1R1

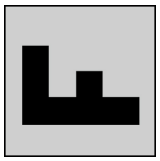




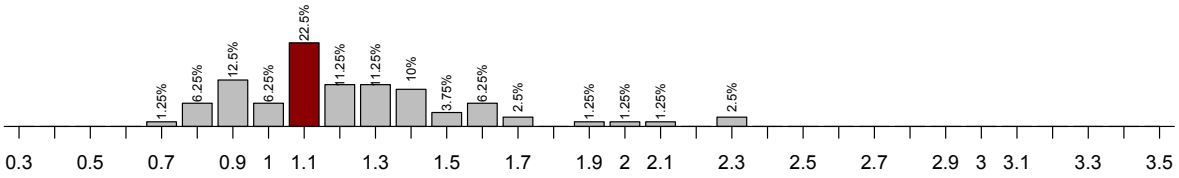
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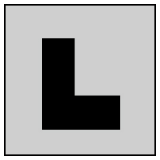


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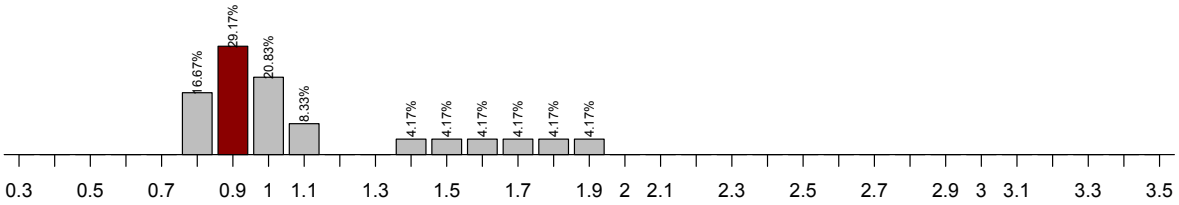


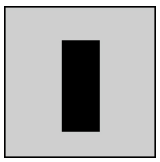
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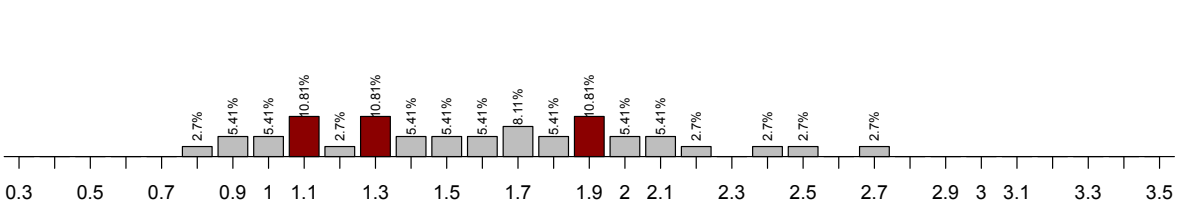


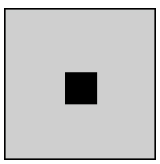
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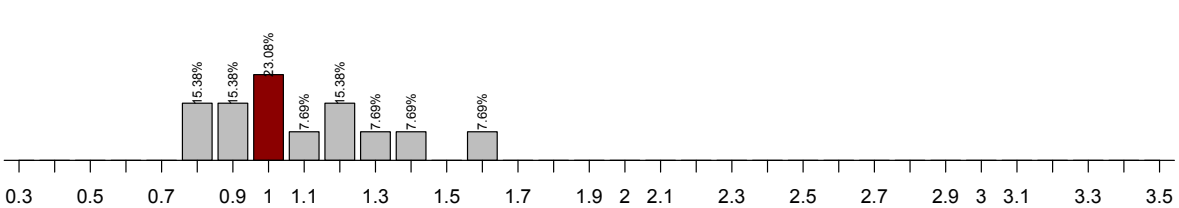


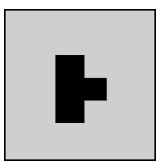
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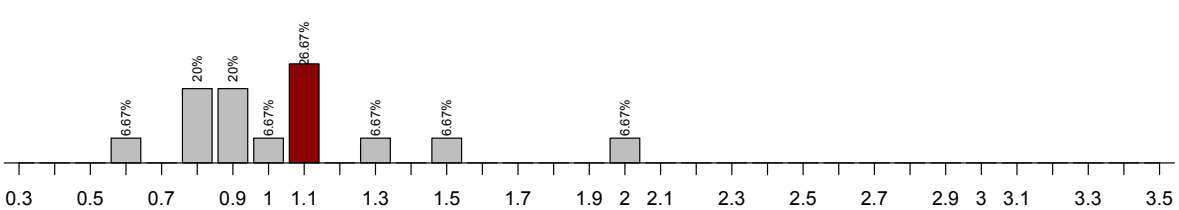


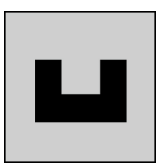
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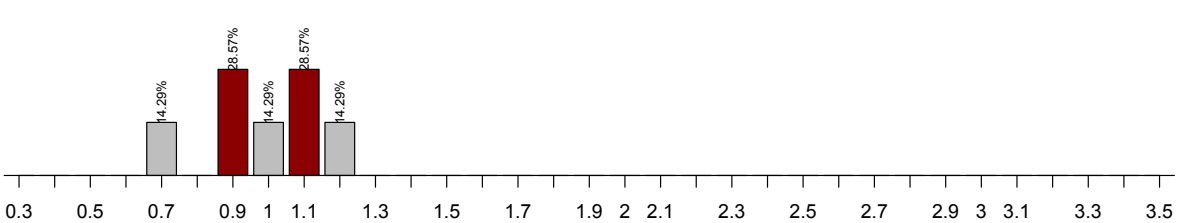


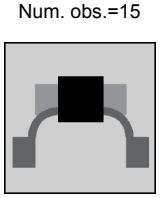
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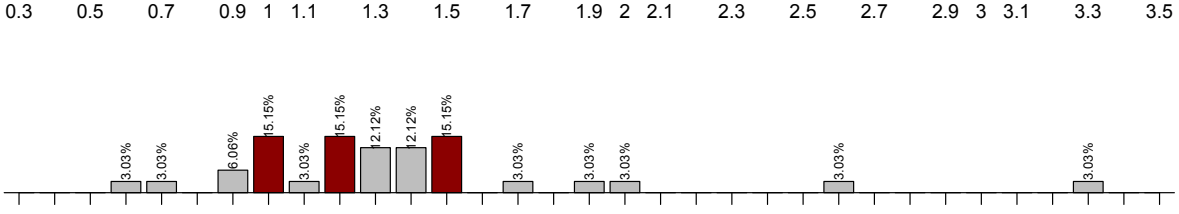


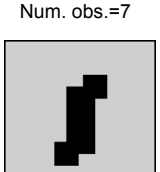
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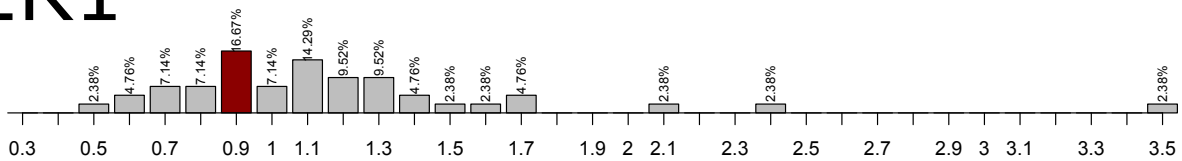
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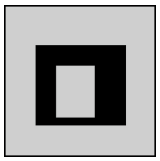




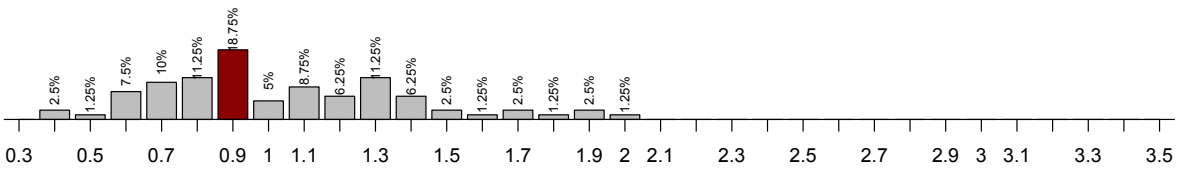
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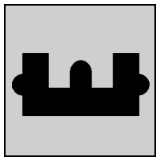
T2R1



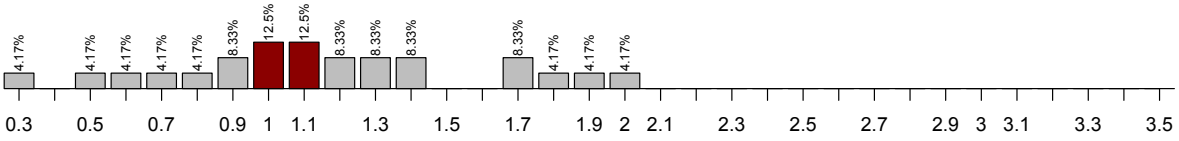


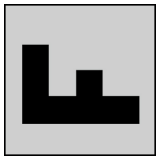
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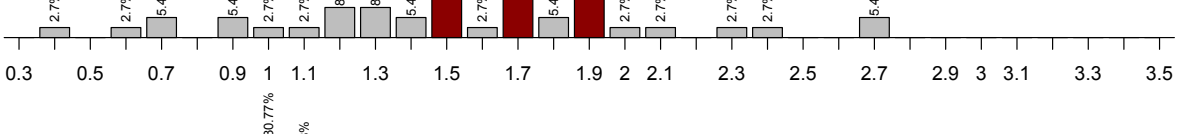


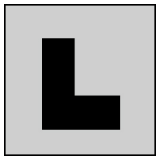
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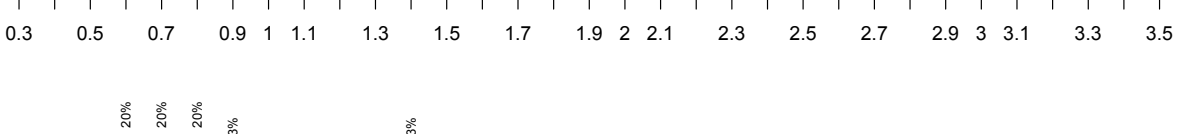


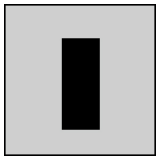
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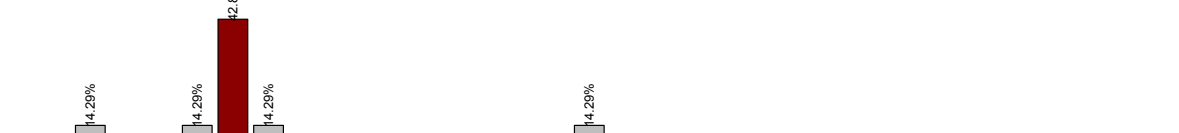


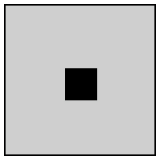
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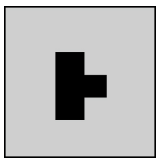
Num. obs. =24



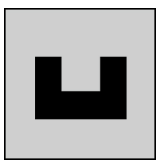


Num. obs.=37

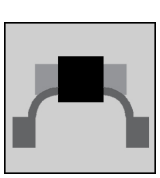




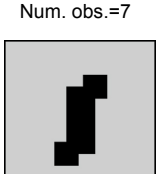
Num. obs.=13



Num. obs.=15



Num. obs.=7

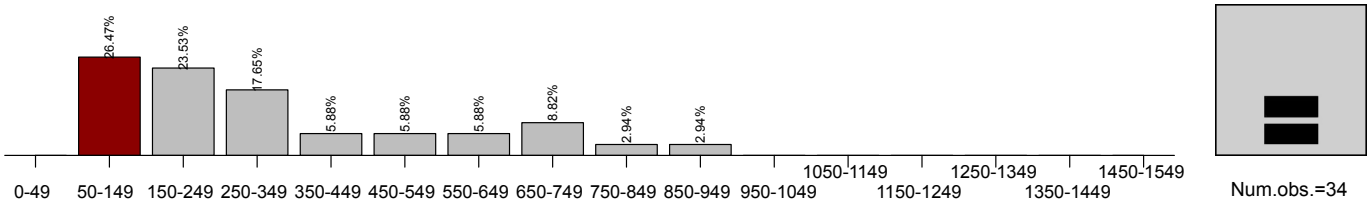


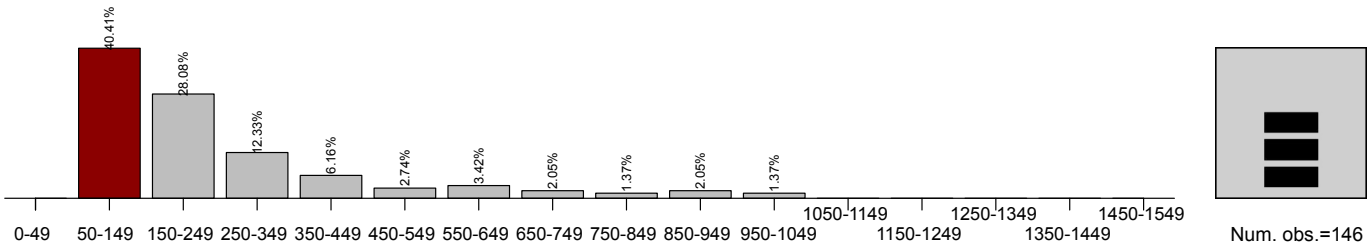
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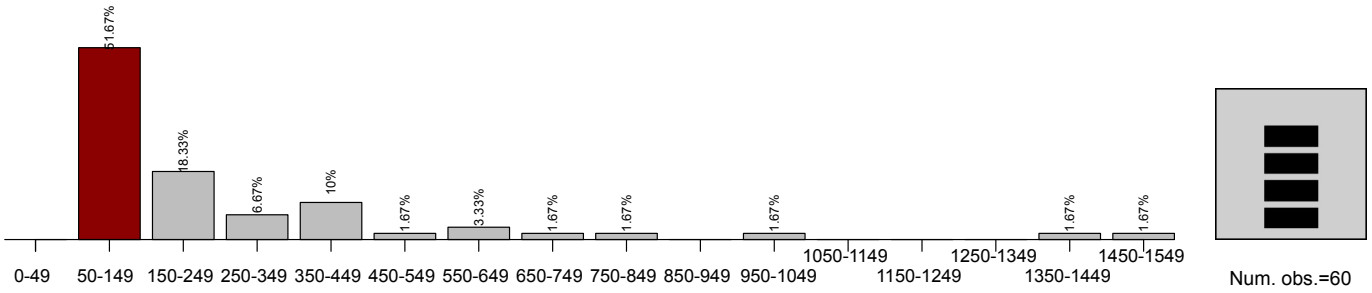
3.1.6 RESULTS REFERRED TO THE PARAMETER NF

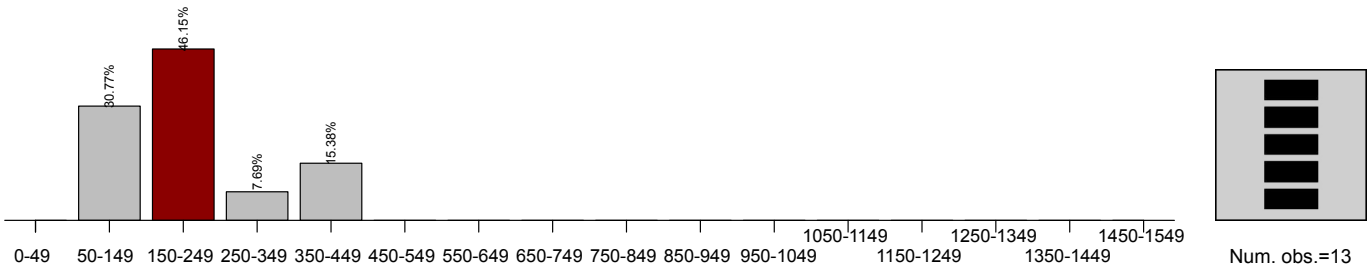
AAR

(*) NF=1 and 6 have 1 observation



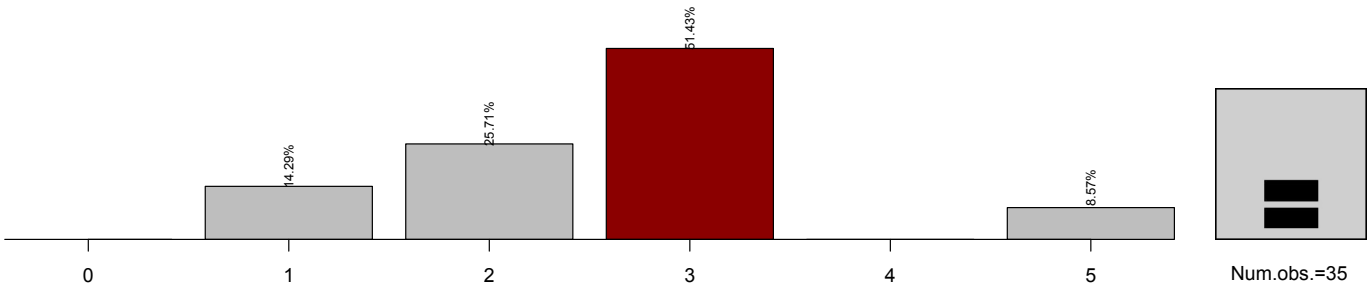


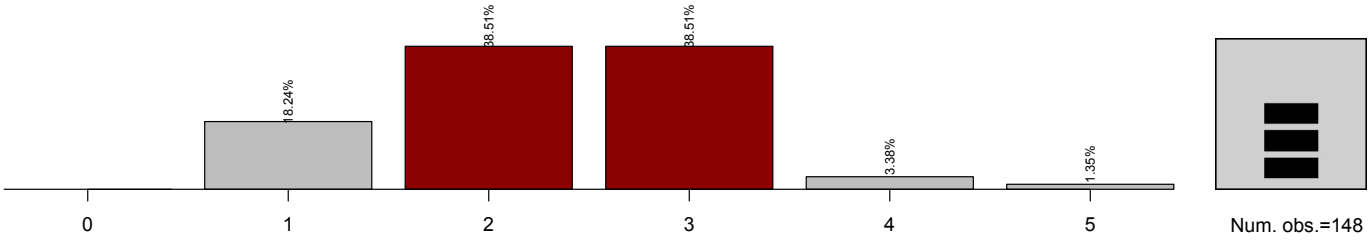


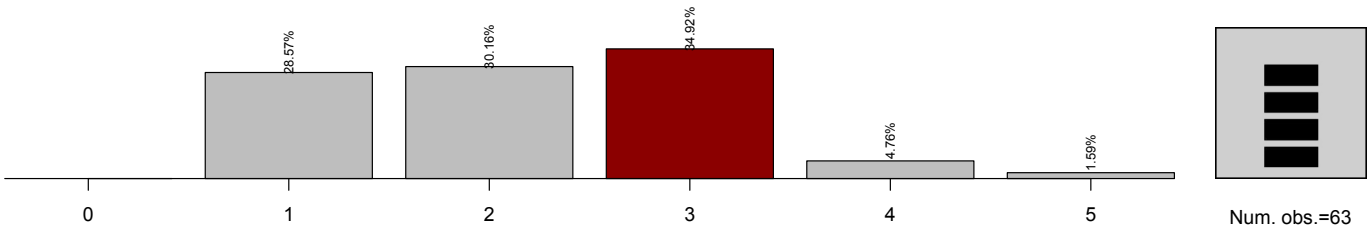


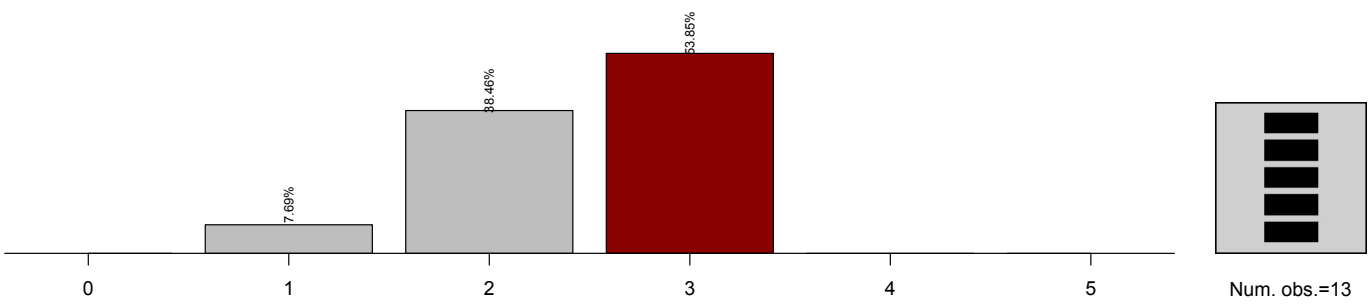
LOR

(*) NF=1 has 1 observation; NF=6 has 2 observations



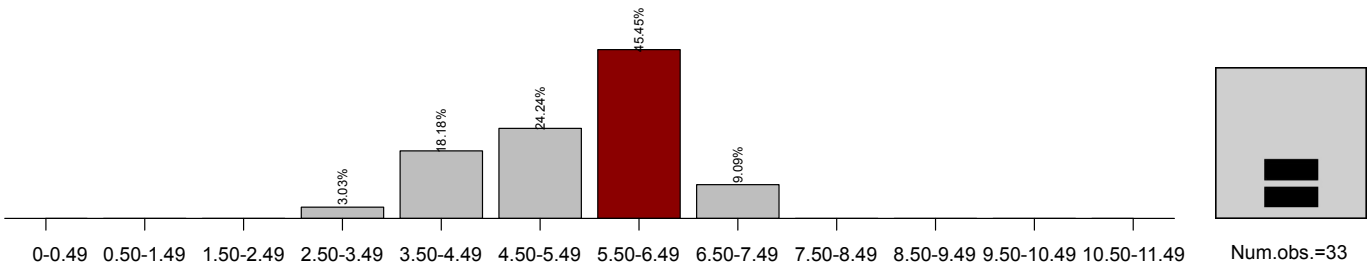


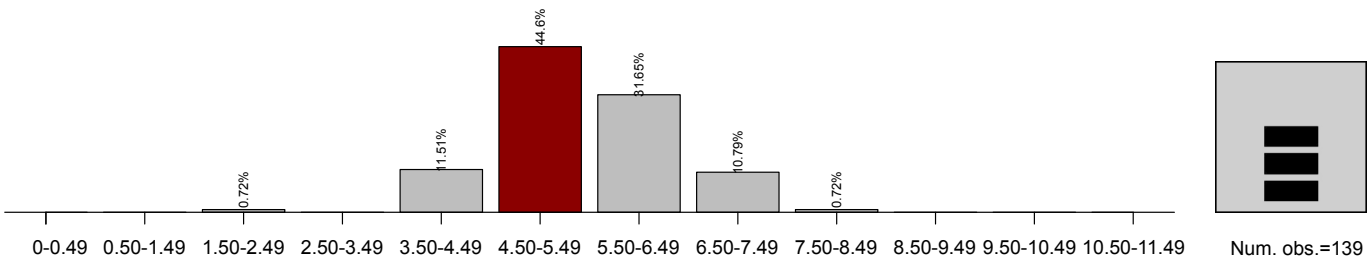


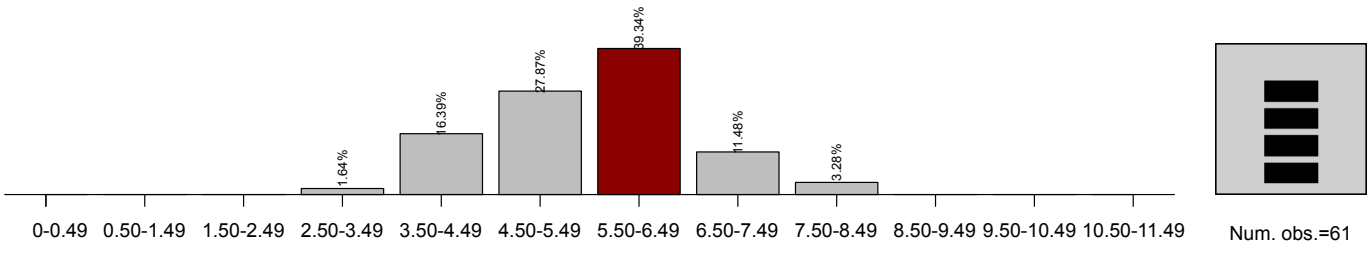


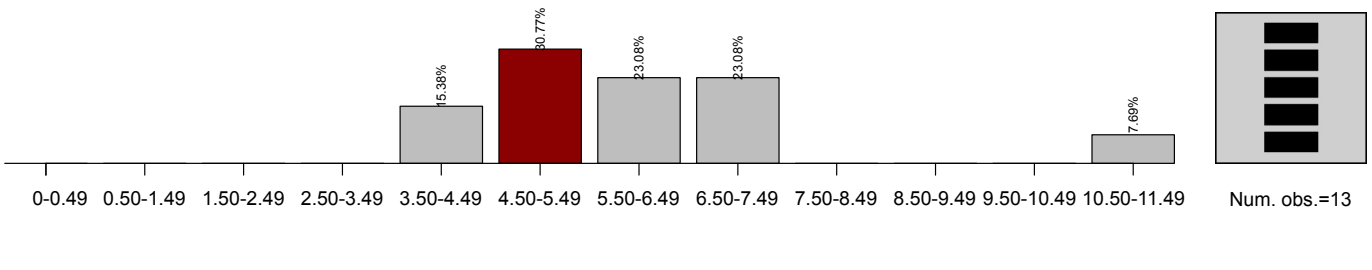
MSR

(*) NF=1 has 1 observation; NF=6 has 2 observations



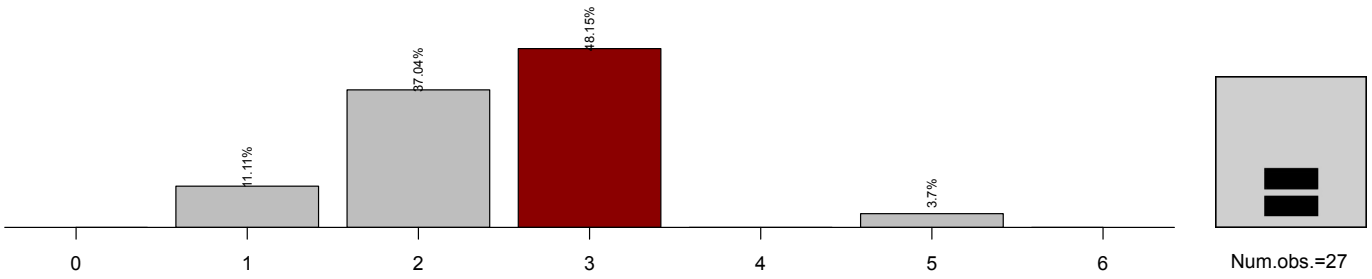


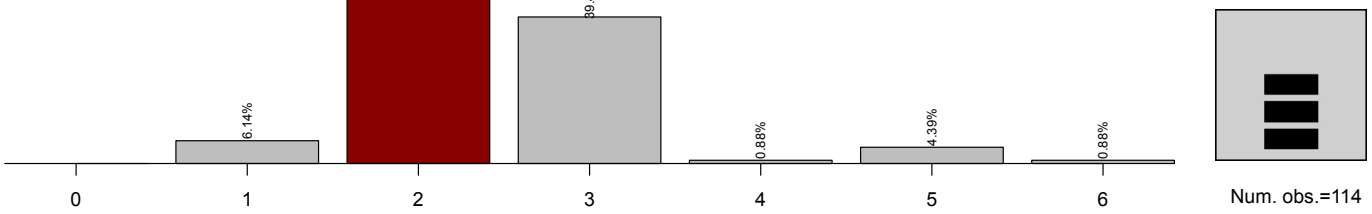


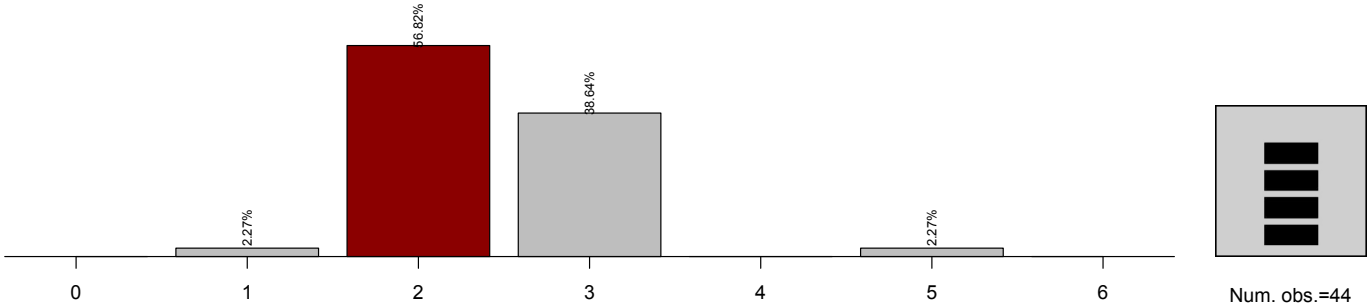


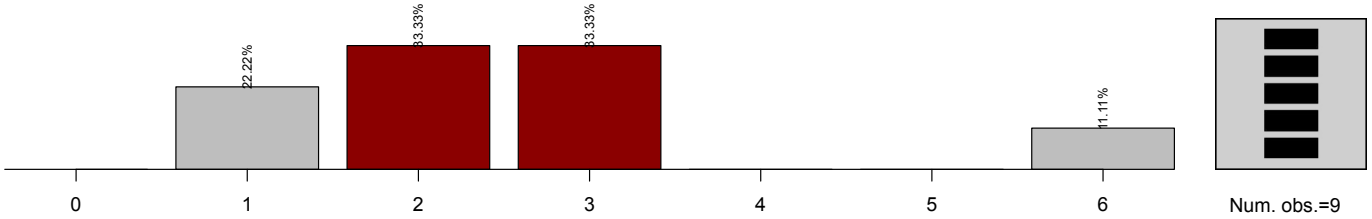
MT

(*) NF=1 has 1 observation; NF=6 has 2 observations



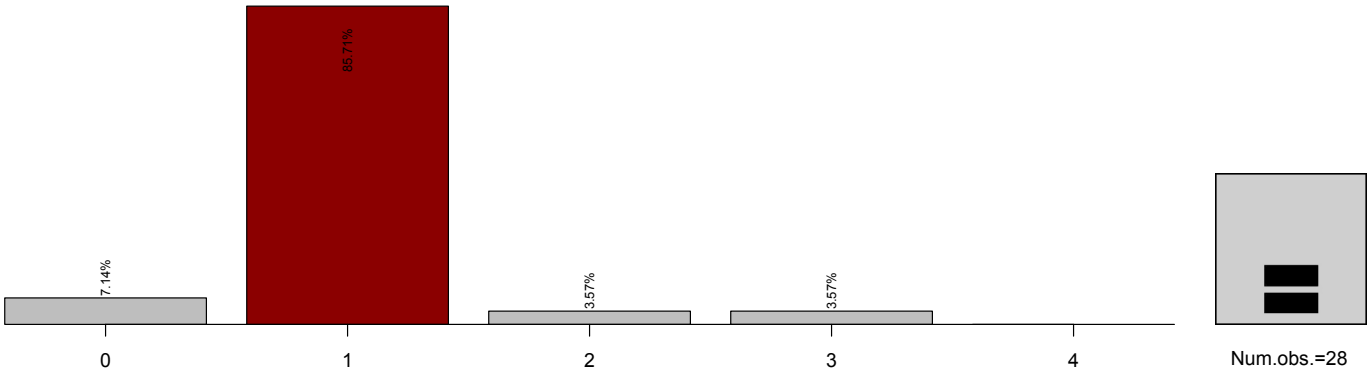


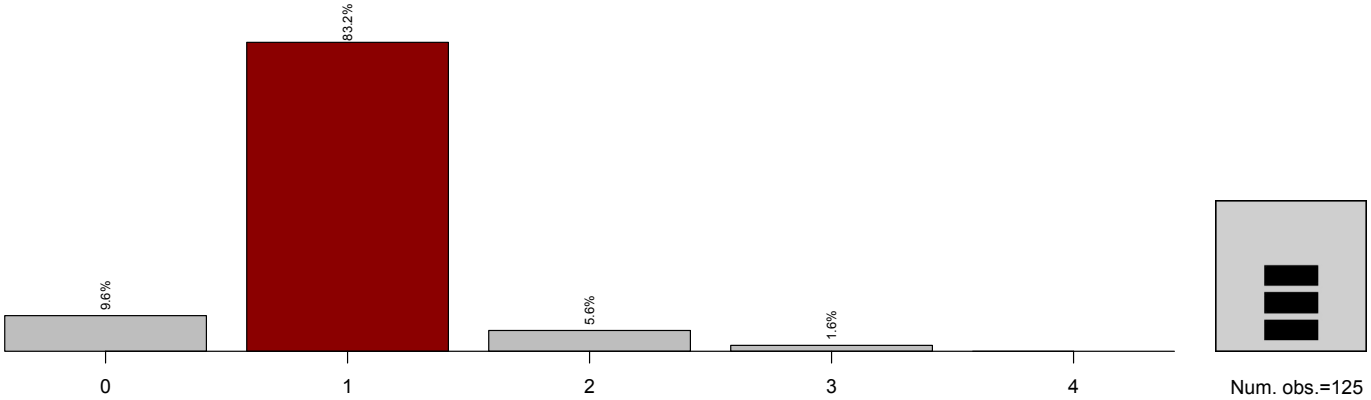


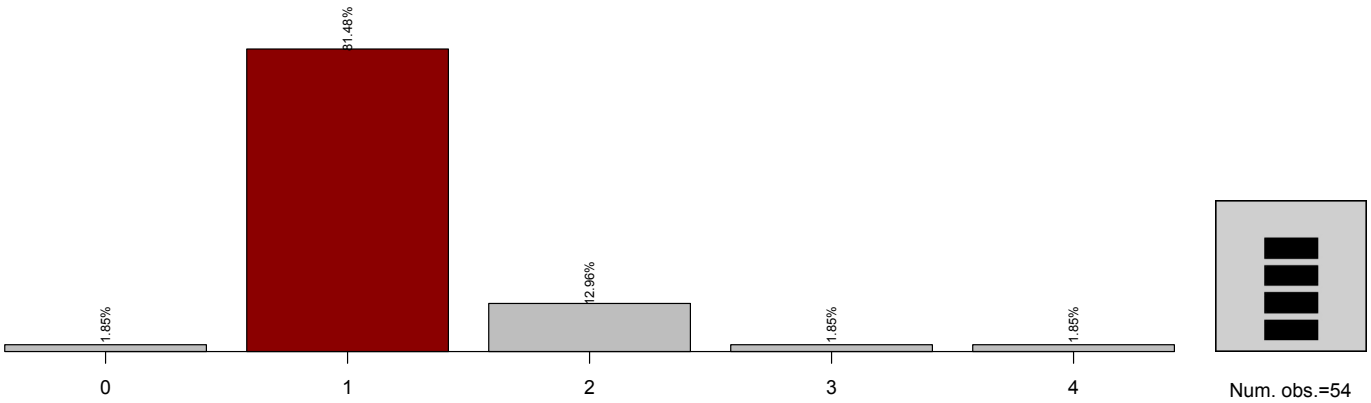


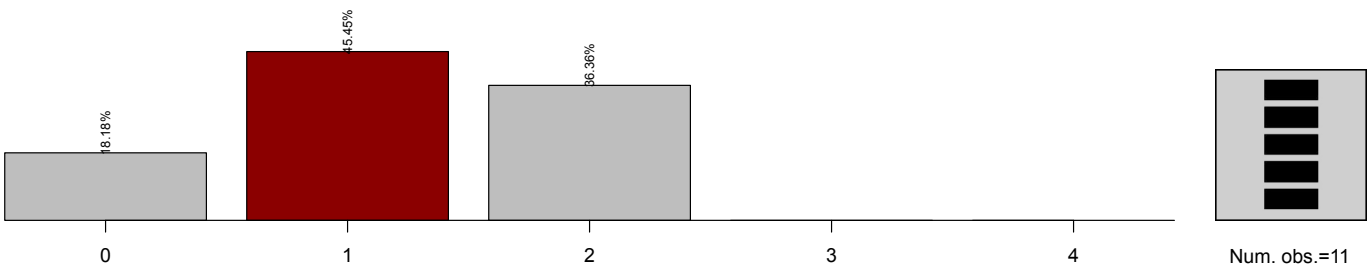
NV

(*) NF=1 has 1 observation; NF=6 has 2 observations



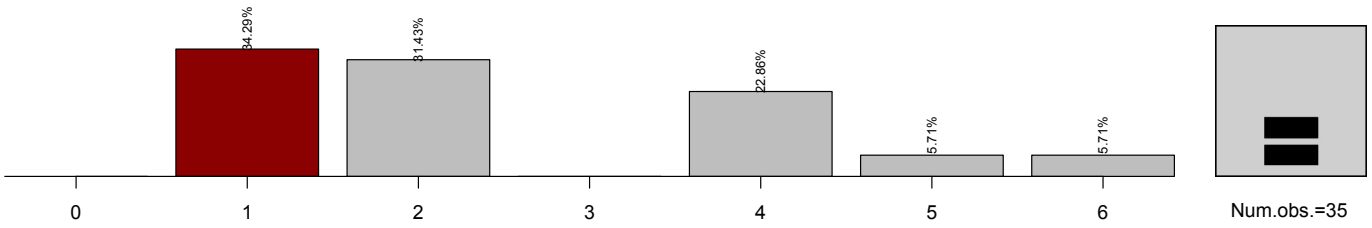


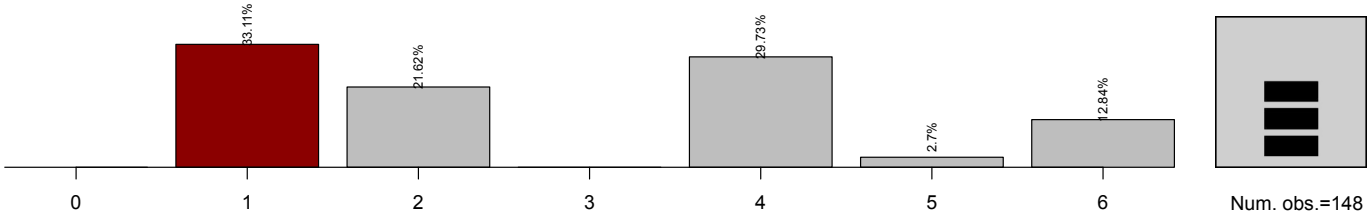


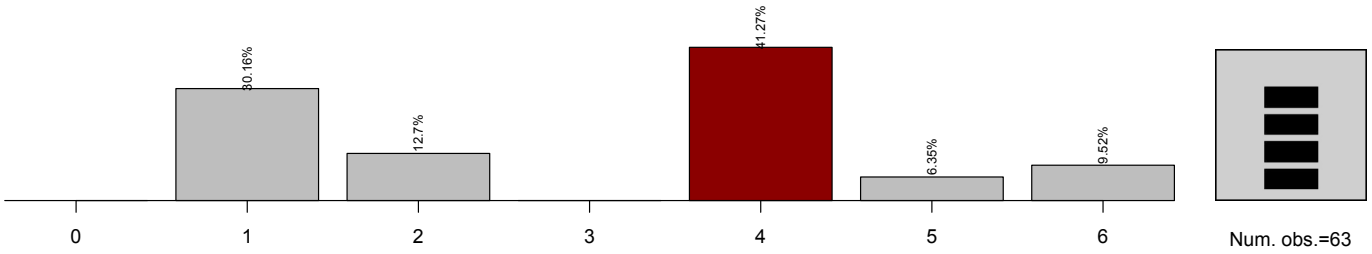


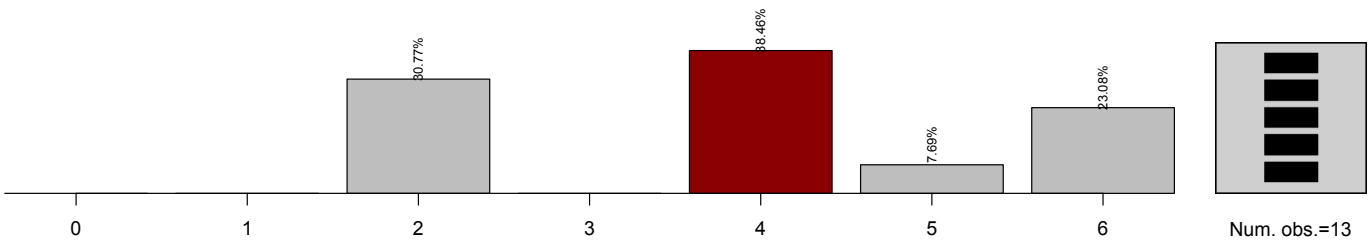
PE

(*) NF=1 has 1 observation; NF=6 has 2 observations



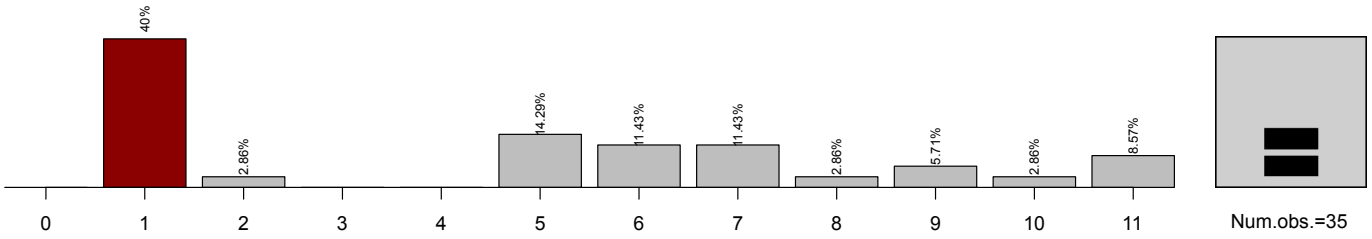


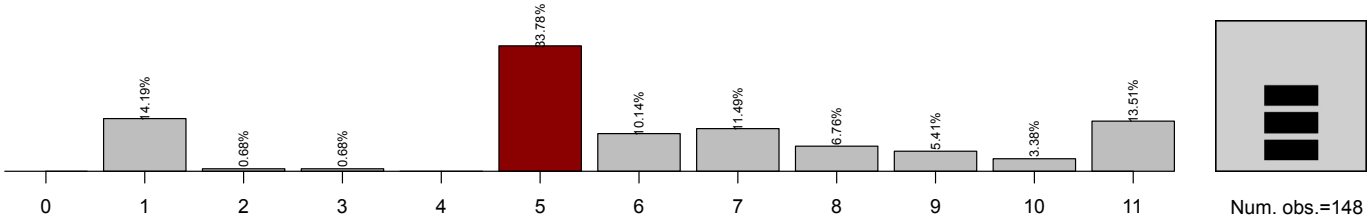


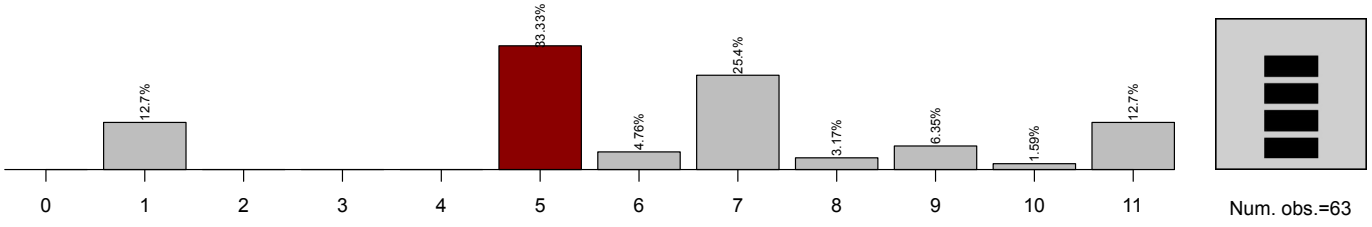


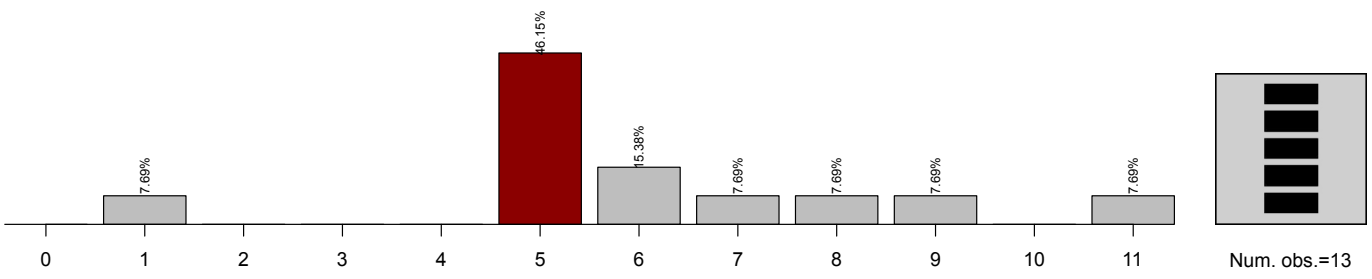
PL

(*) NF=1 has 1 observation; NF=6 has 2 observations



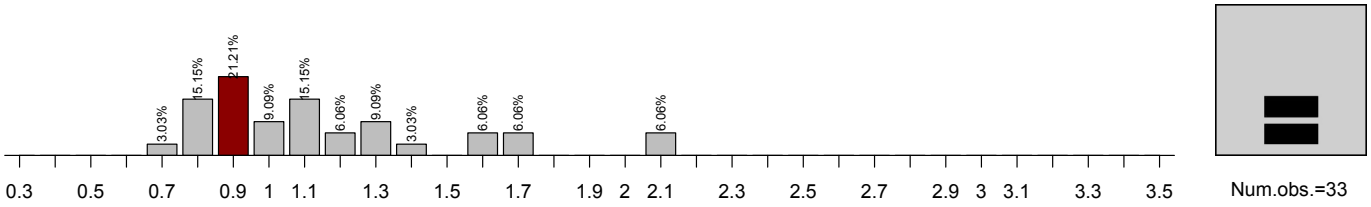


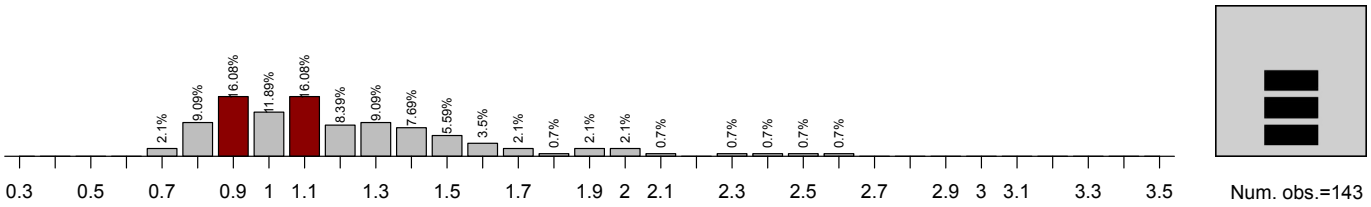


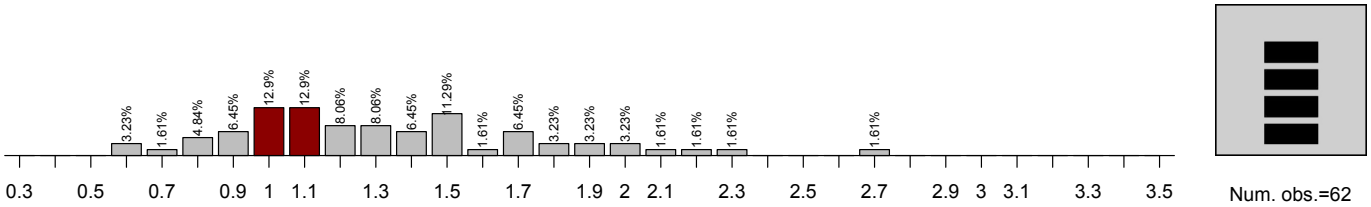


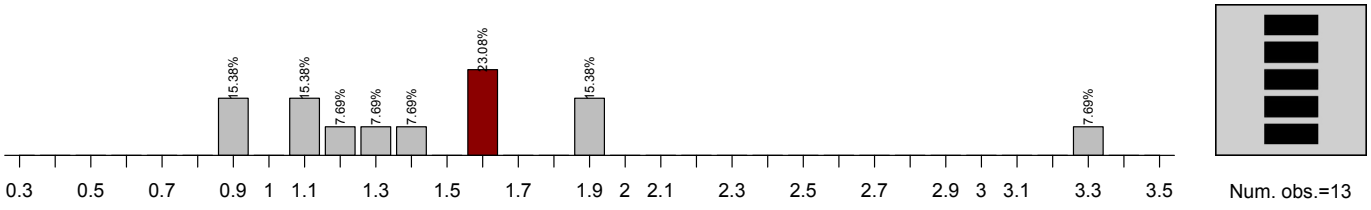
T1R1

(*) NF=1 has 1 observation; NF=6 has 2 observations



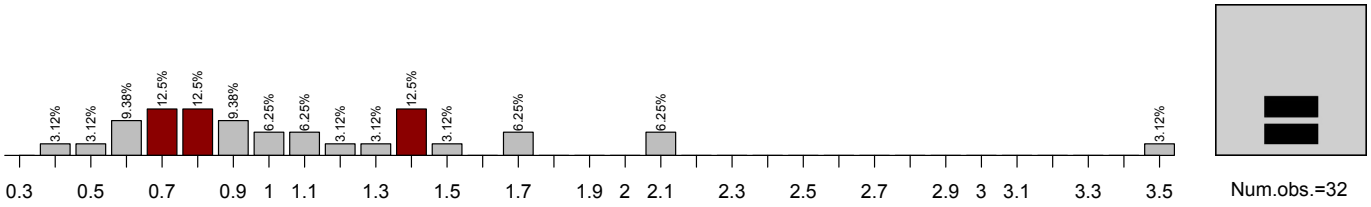


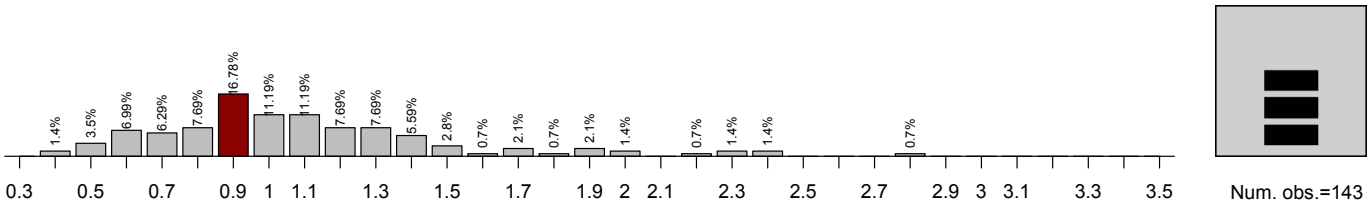


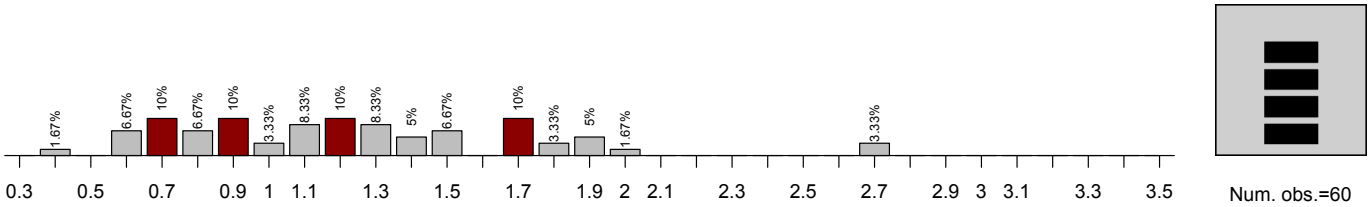


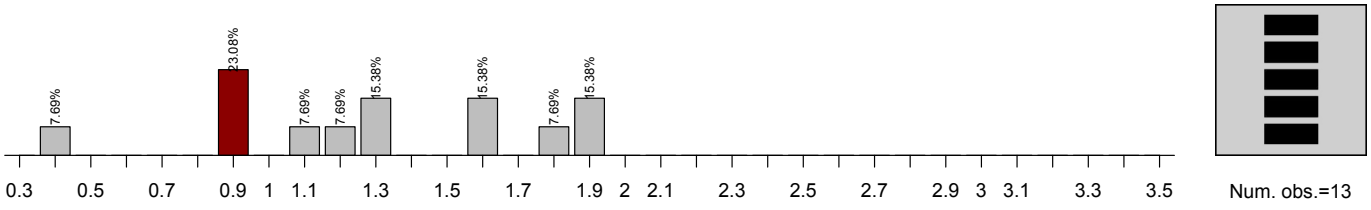
T2R1

(*) NF=1 has 1 observation; NF=6 has 2 observations



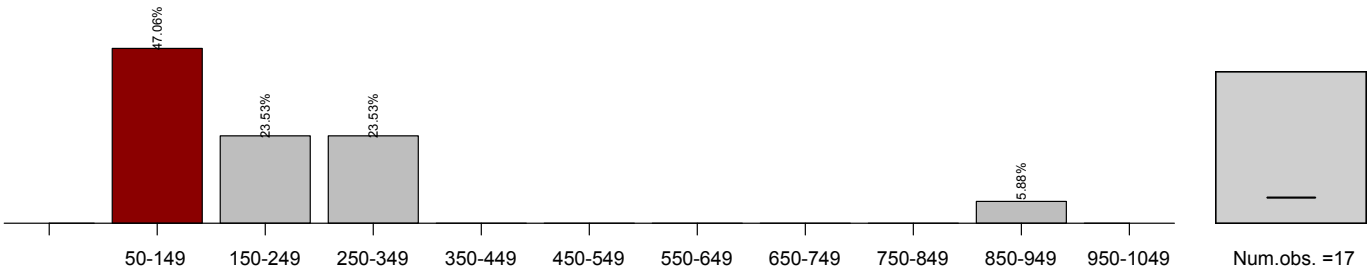


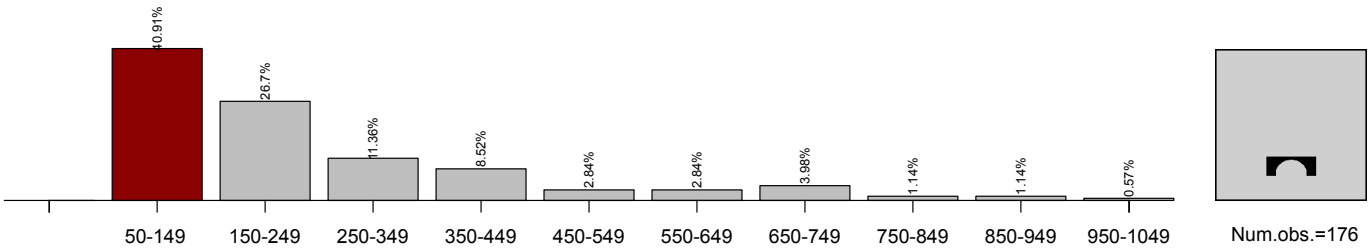


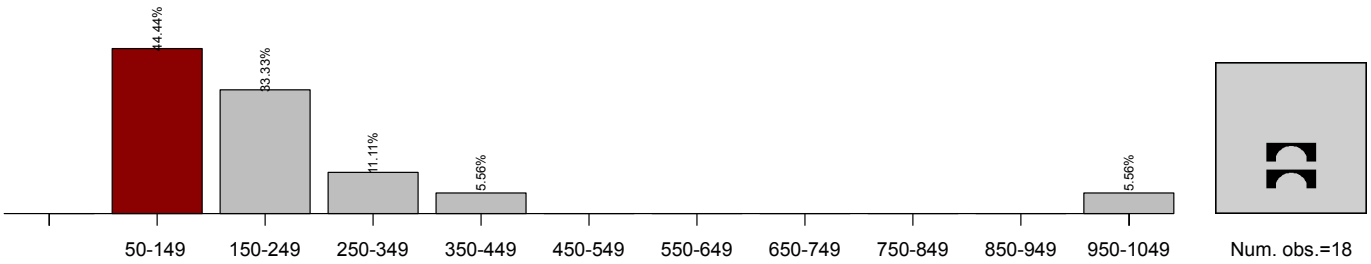


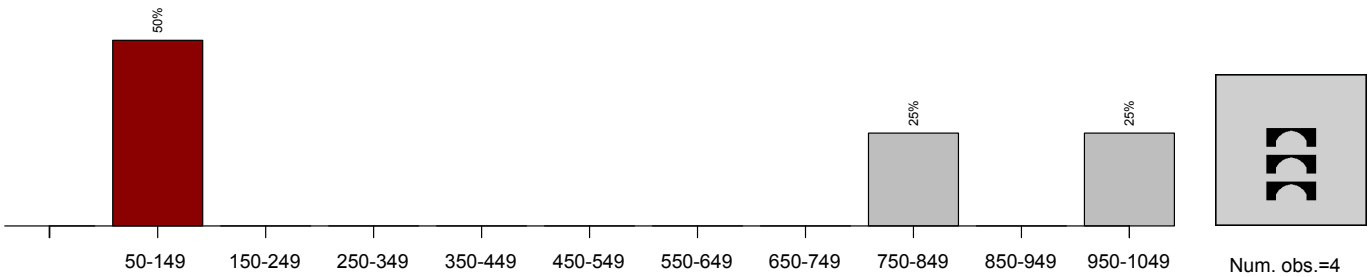
3.1.7 RESULTS REFERRED TO THE PARAMETER NV

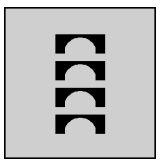
AAR


47.06%
23.53%
23.53%
5.88%
50-149
150-249
250-349
350-449
450-549
550-649
650-749
750-849
850-949
950-1049
Num.obs. =17


40.91%
26.7%
11.36%
8.52%
2.84%
2.84%
3.98%
1.14%
1.14%
0.57%
50-149
150-249
250-349
350-449
450-549
550-649
650-749
750-849
850-949
950-1049
Num.obs.=176

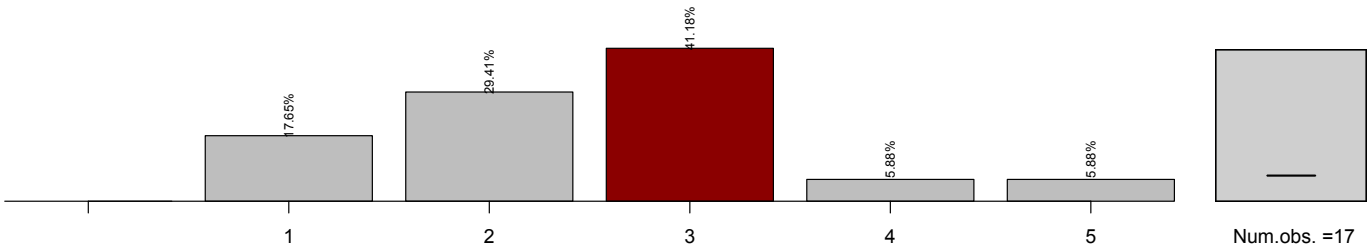

44.44%
33.33%
11.11%
5.56%
5.56%
50-149
150-249
250-349
350-449
450-549
550-649
650-749
750-849
850-949
950-1049
Num. obs.=18


50%
25%
25%
50-149
150-249
250-349
350-449
450-549
550-649
650-749
750-849
850-949
950-1049
Num. obs.=4

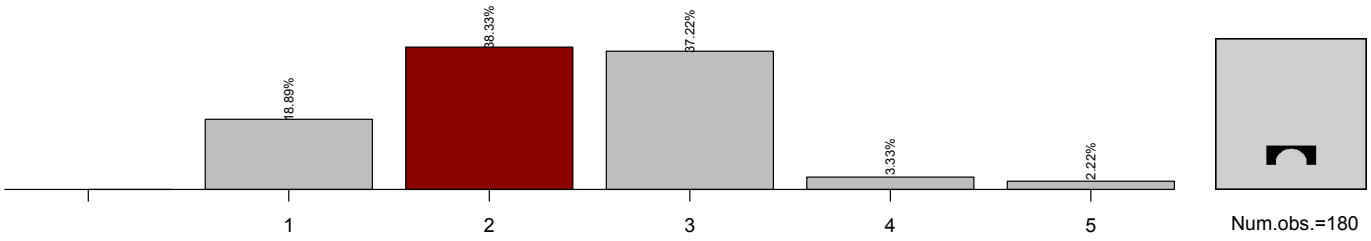


Num. obs.=1

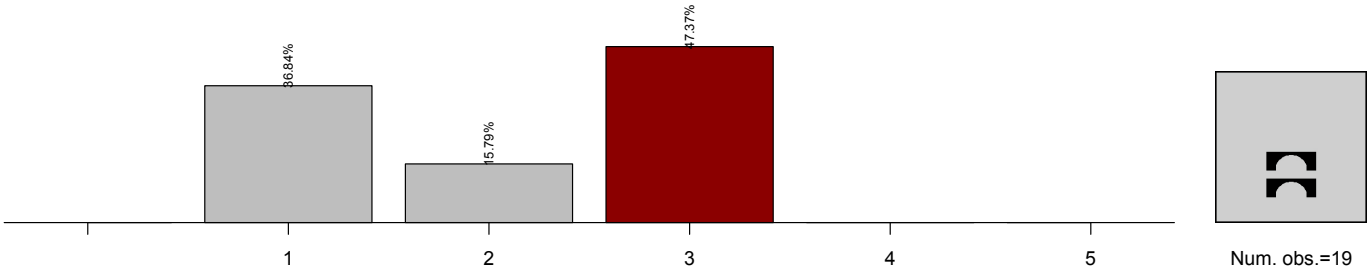
LOR



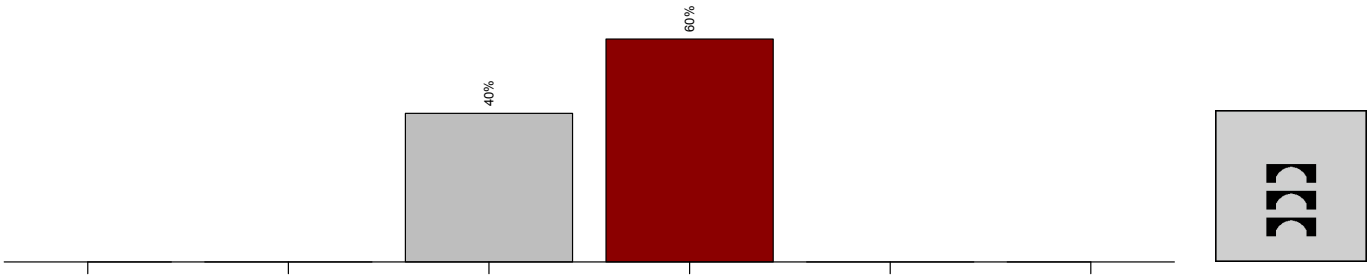
Num.obs. =17



Num.obs.=180



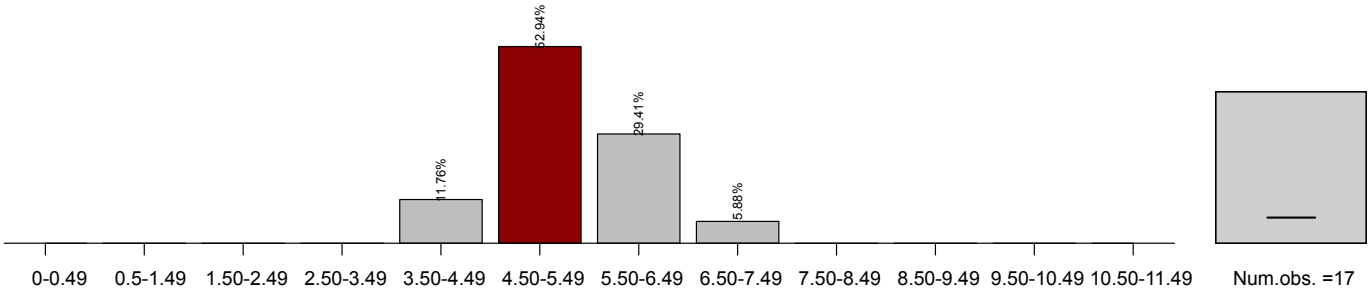
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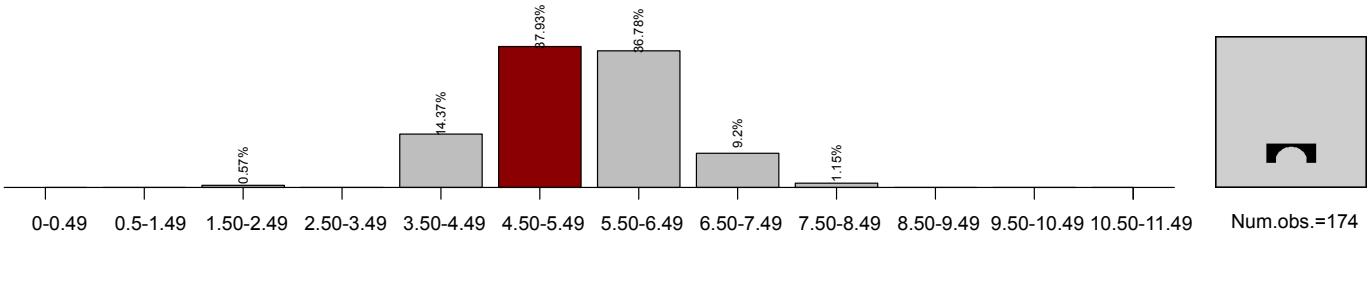
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Num. obs.=1

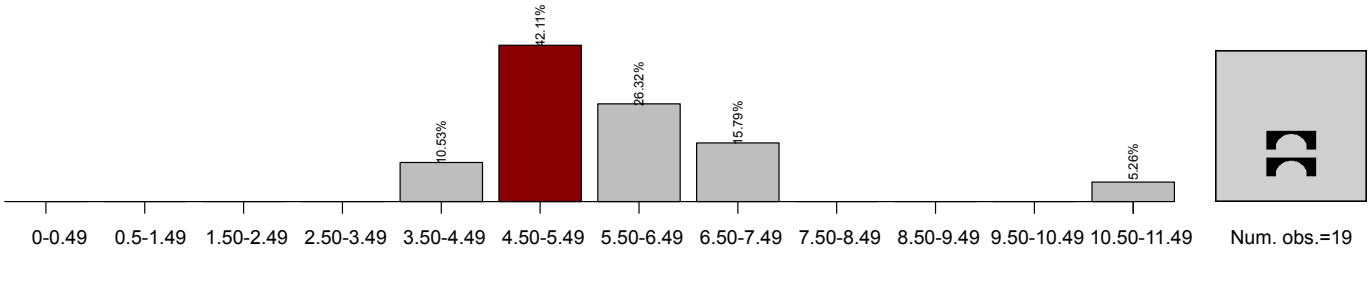
MSR



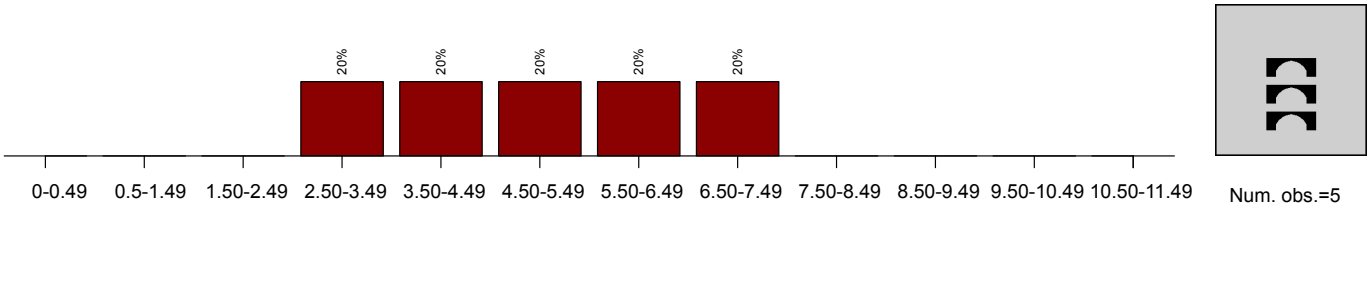
Num.obs. =17



Num.obs.=174



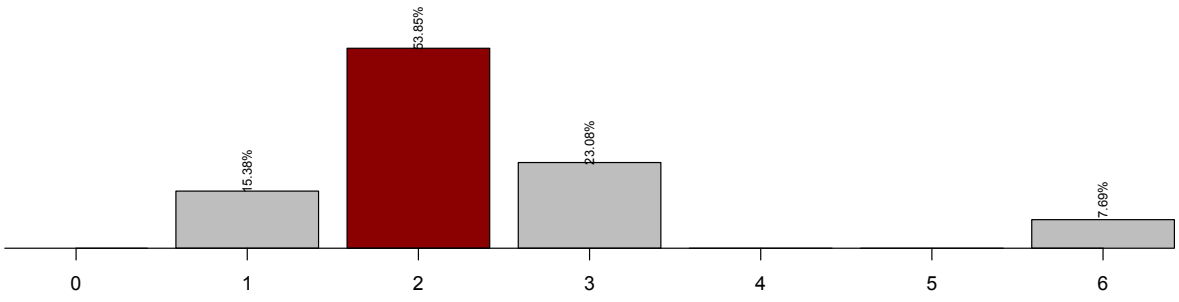
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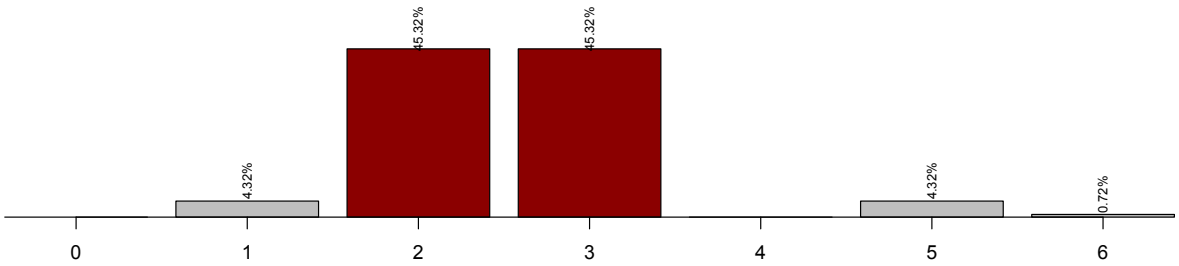
Num. obs.=5

Num. obs.=1

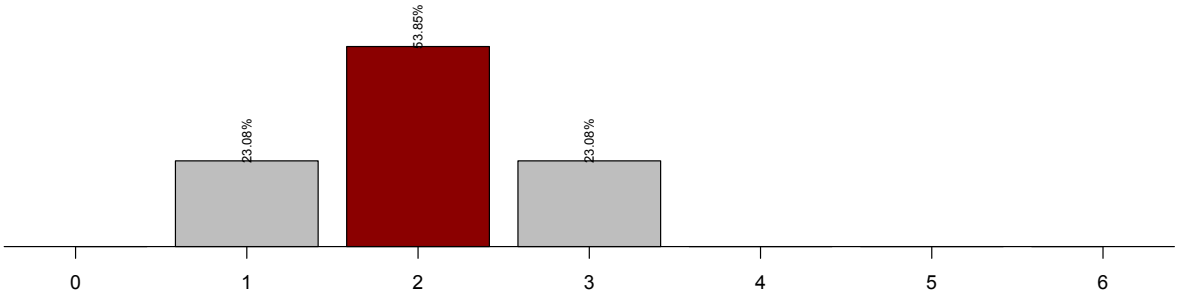
MT



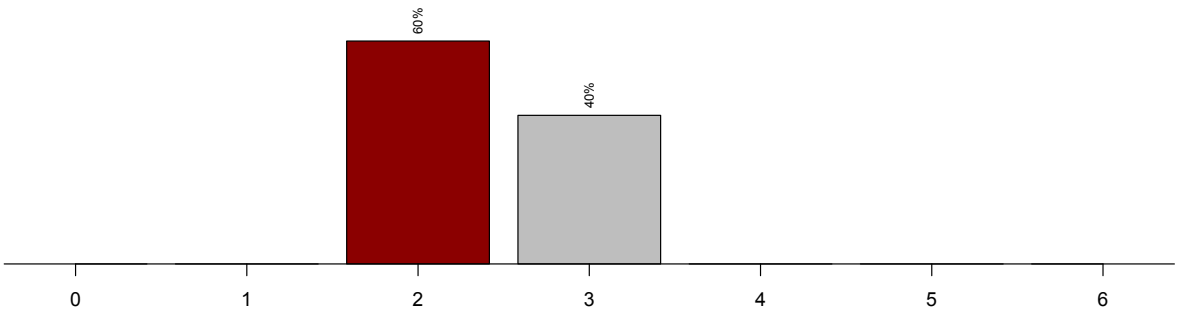
Num.obs. =13



Num.obs.=139



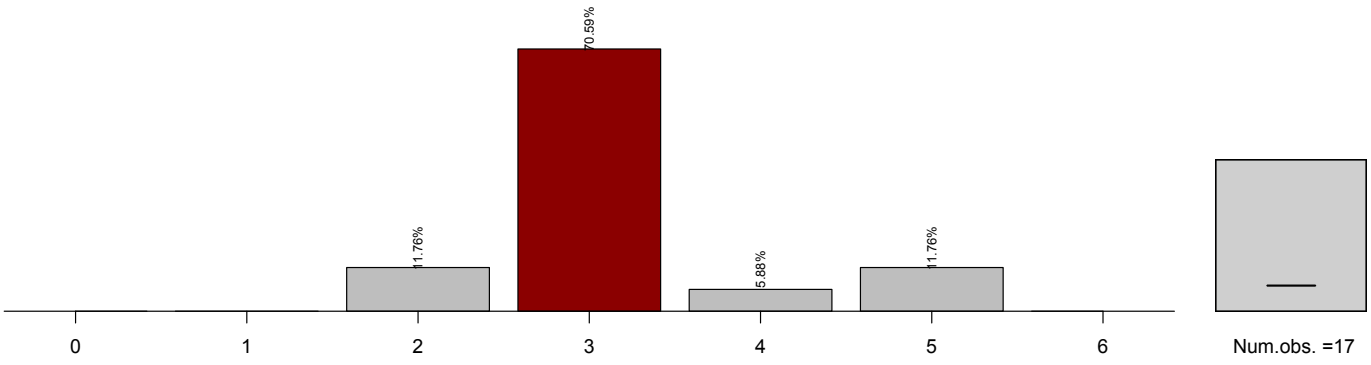
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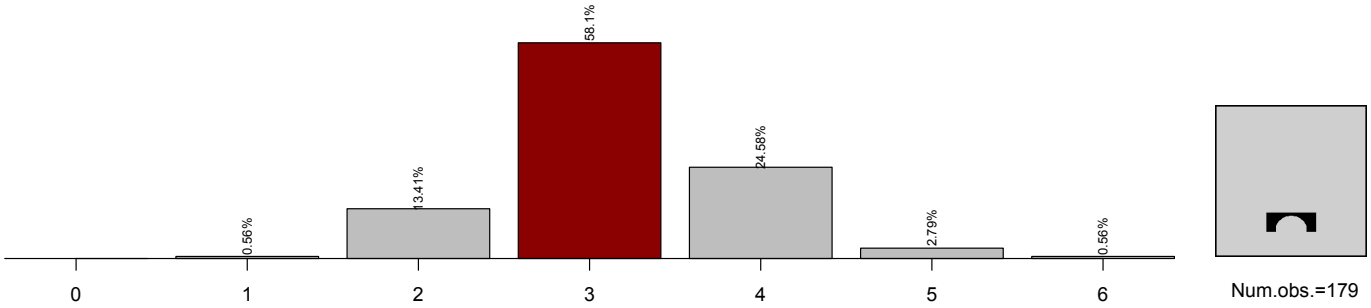
Num. obs.=5

Num. obs.=1

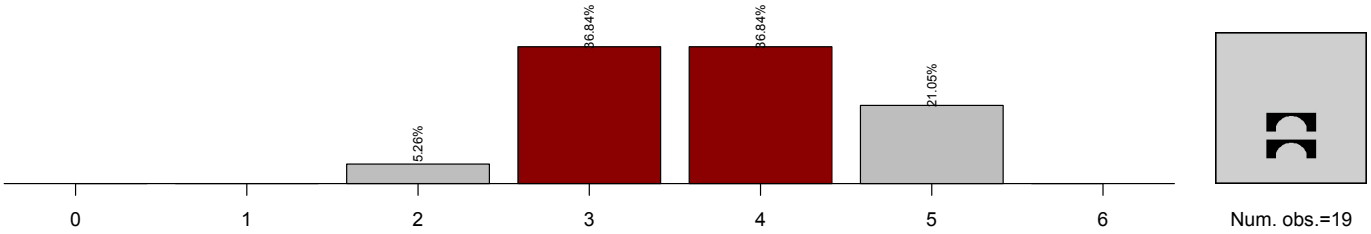
NF



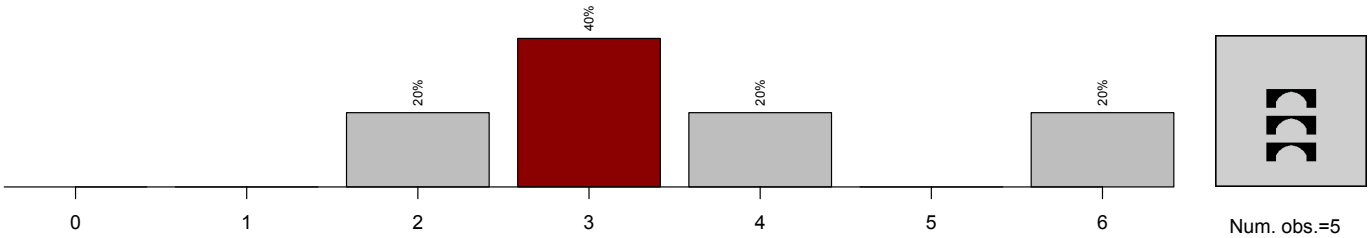
Num.obs. =17



Num.obs.=179



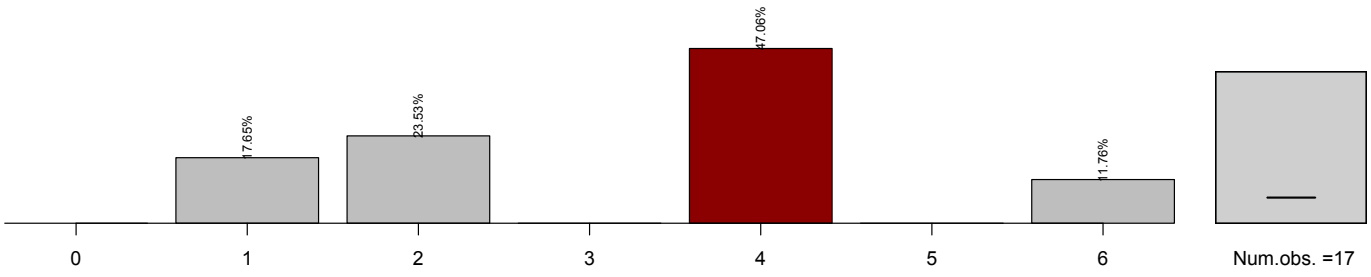
Num. obs.=19



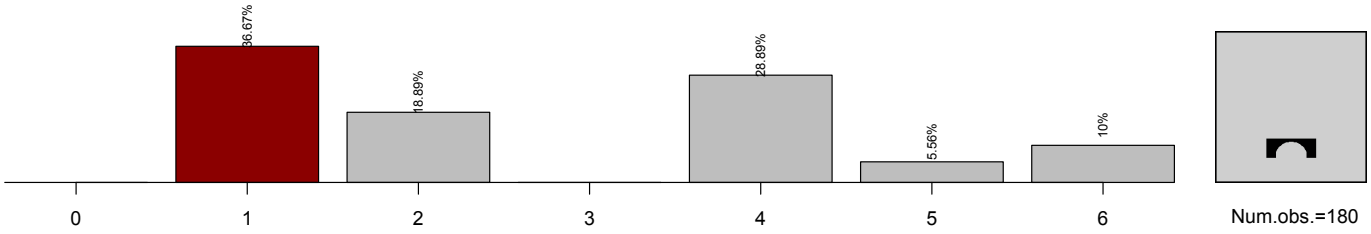
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Num. obs.=1

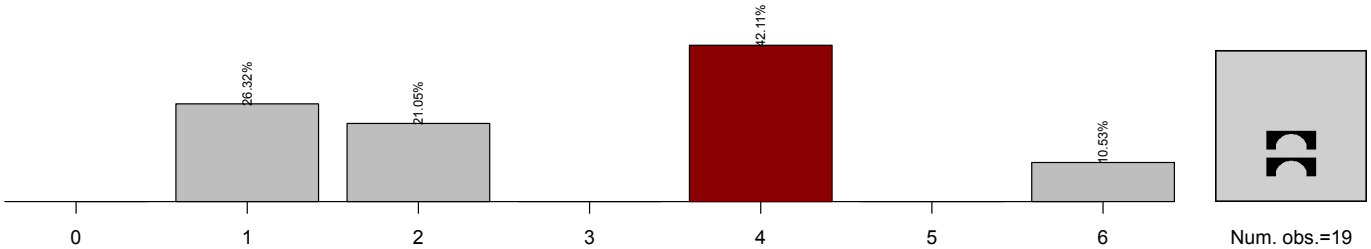
PE



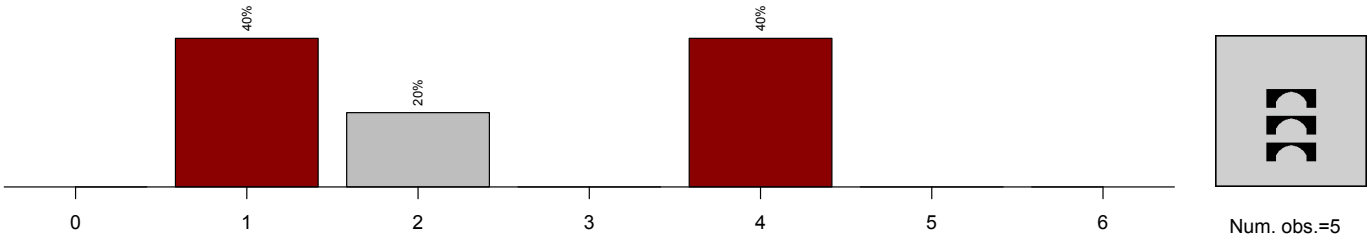
Num.obs. =17



Num.obs.=180



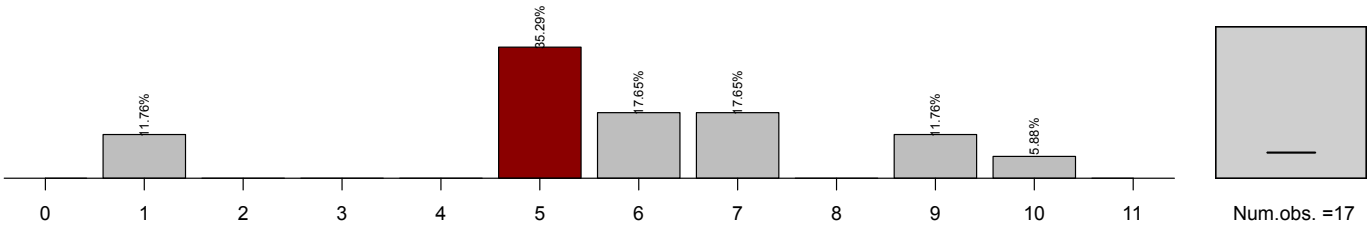
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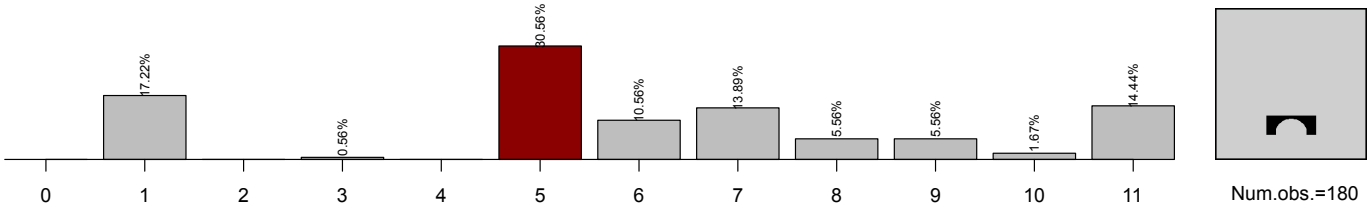
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Num. obs.=1

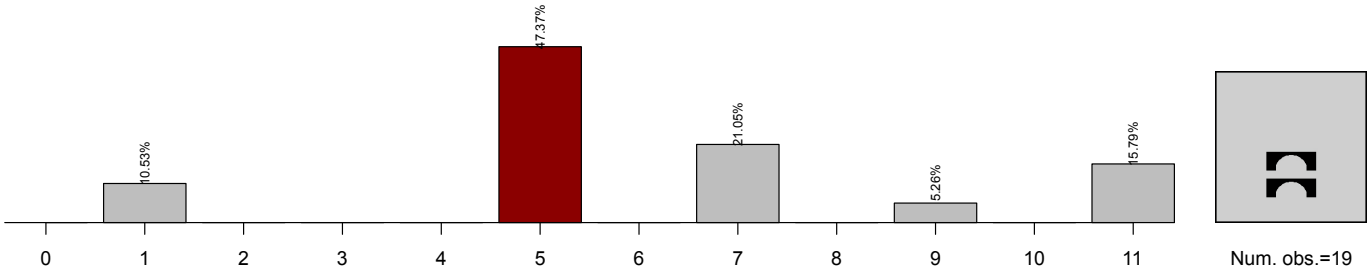
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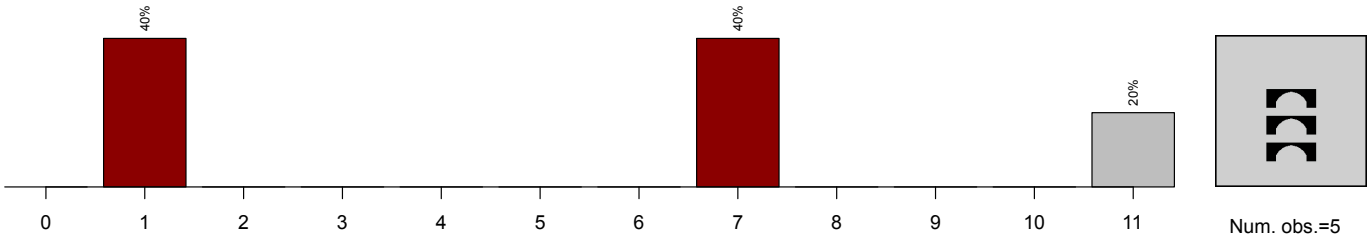
Num.obs. =17



Num.obs.=180



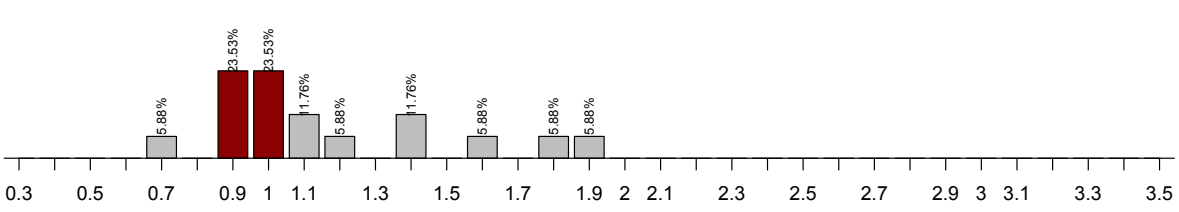
Num. obs.=19

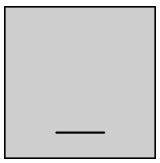


Num. obs.=5

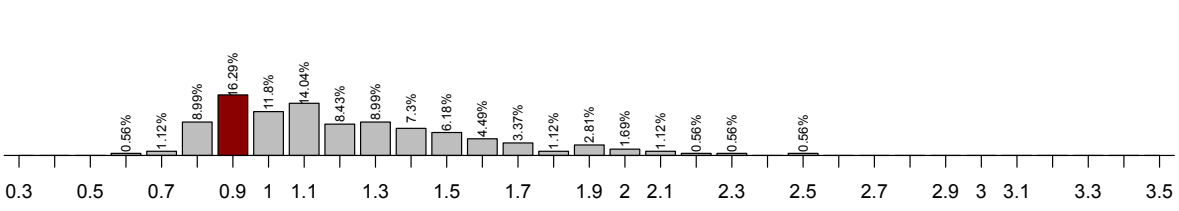
Num. obs.=1

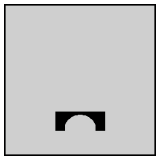
T1R1



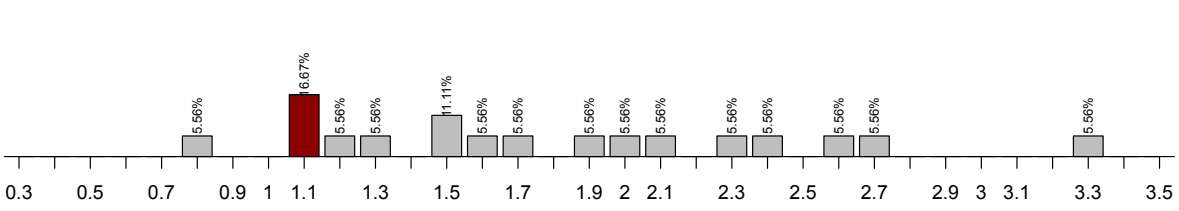


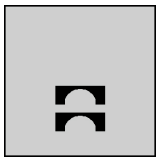
Num.obs. =17



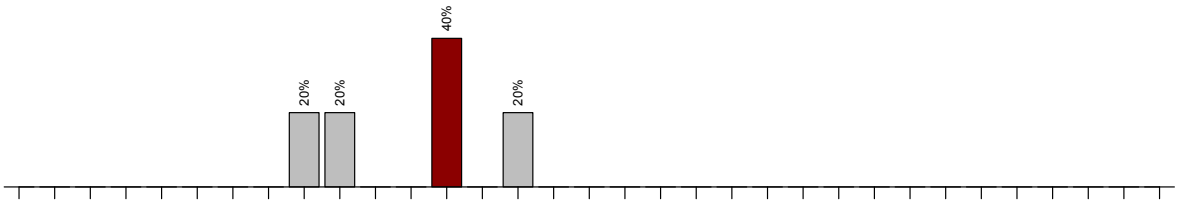


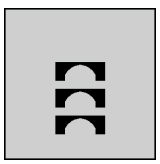
Num.obs.=178



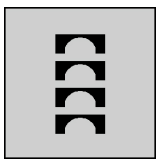


Num. obs.=18



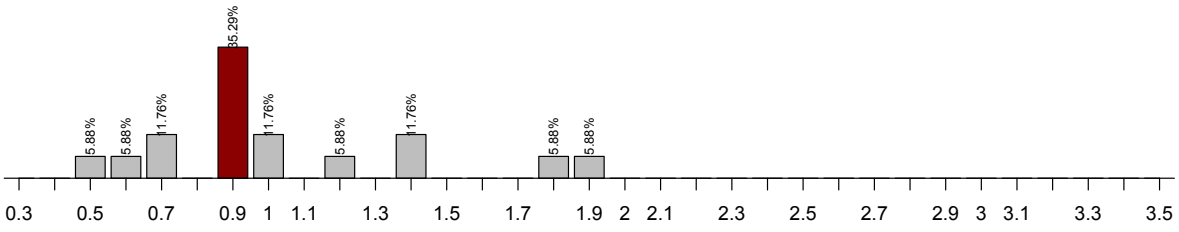


Num. obs.=5

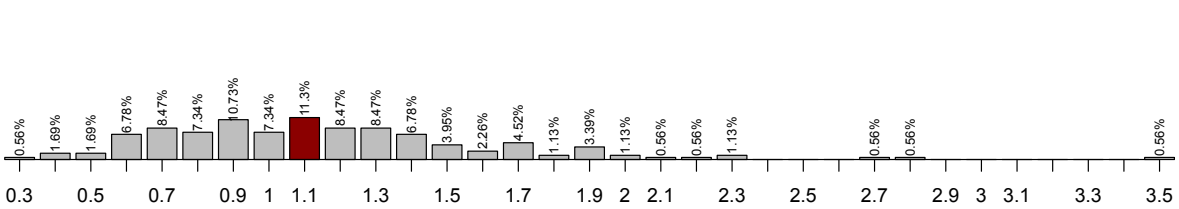


Num. obs.=1

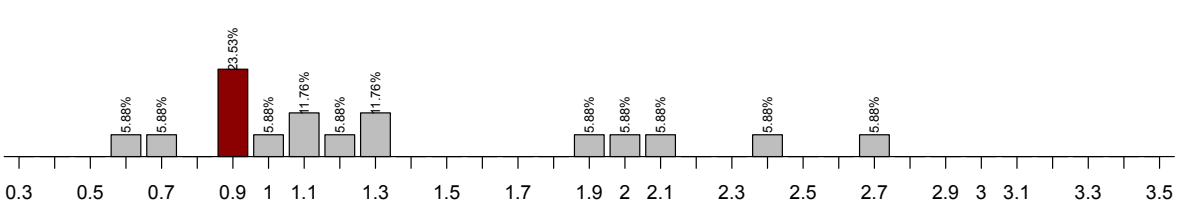
T2R1



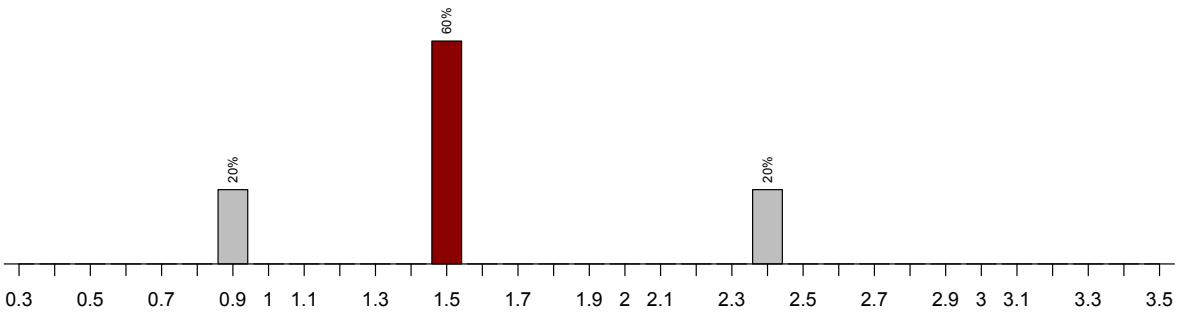
Num.obs. =17



Num.obs.=177



Num. obs.=17

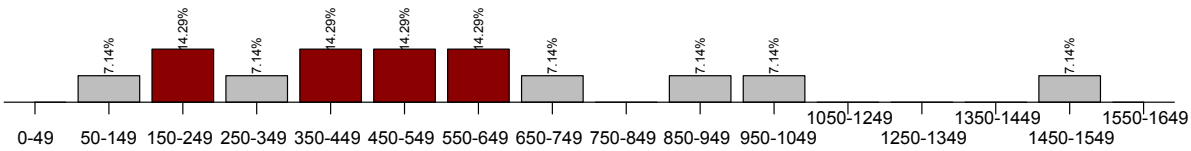


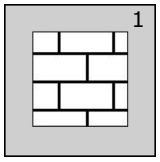
Num. obs.=5

Num. obs.=1

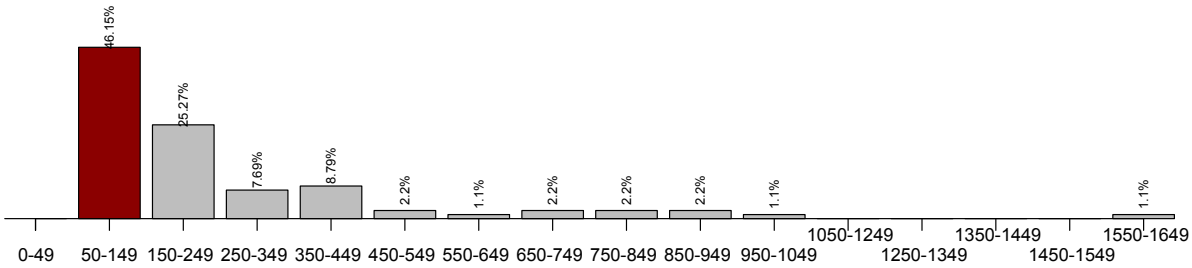
3.1.8 RESULTS REFERRED TO THE PARAMETER MT

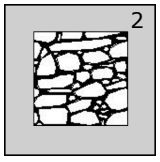
AAR



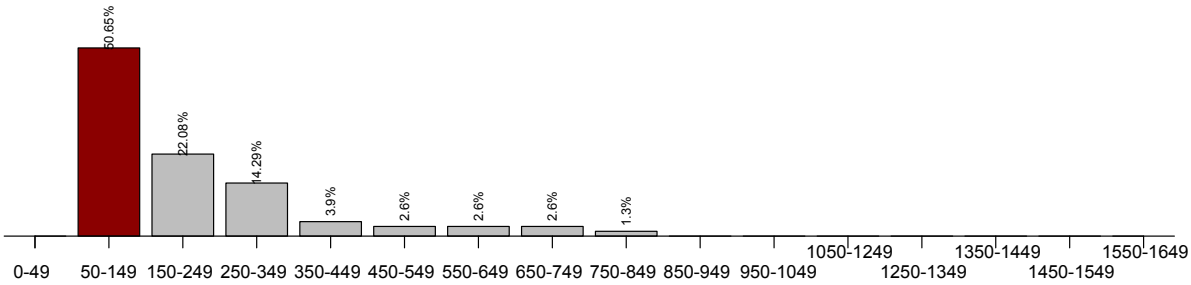


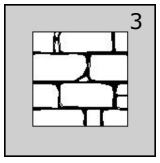
Num. obs. =14



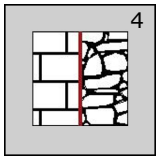


Num. obs. = 91

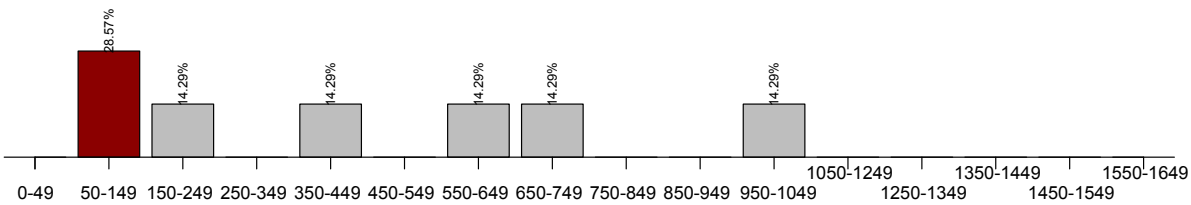


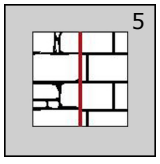


Num. obs. =77

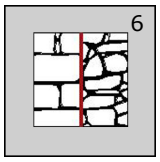


Num. obs. = 1



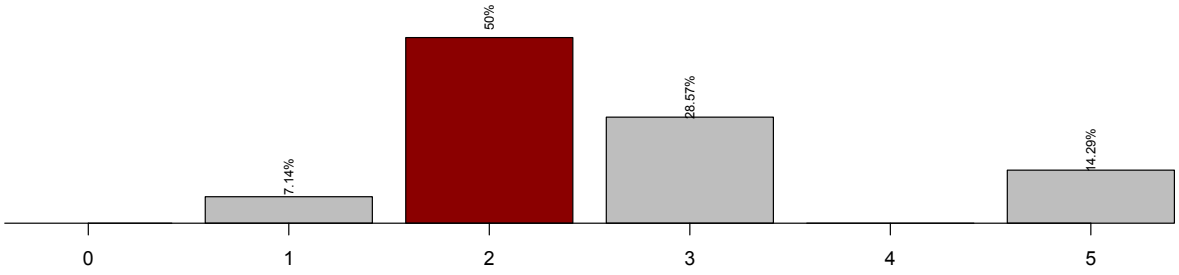


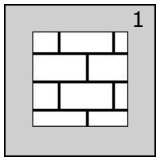
Num. obs. = 7



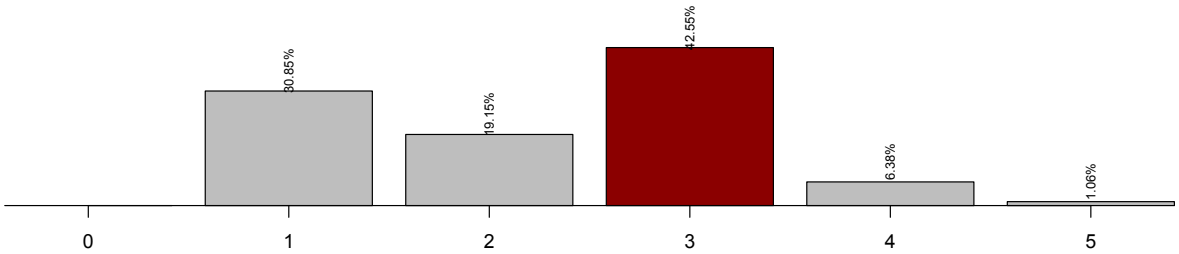
Num. obs. = 2

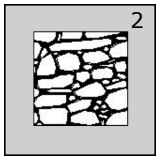
LOR



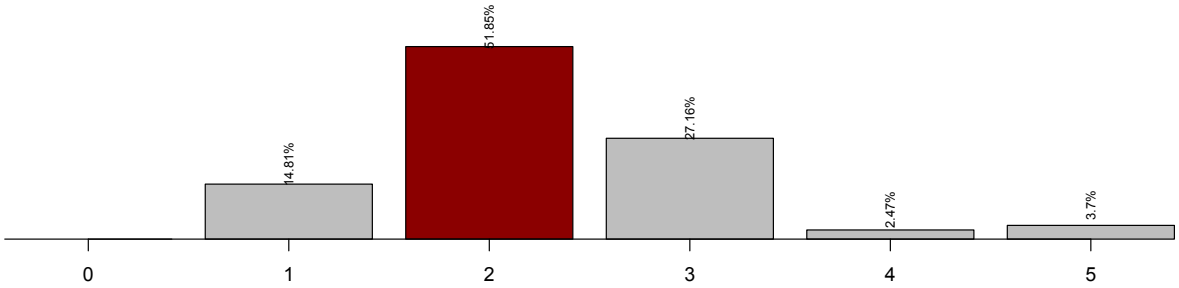


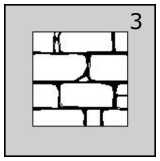
Num. obs. =14



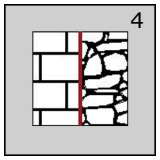


Num. obs. = 94

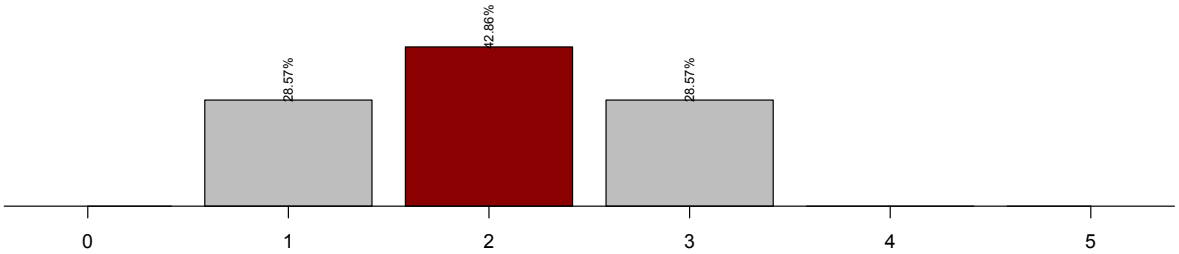


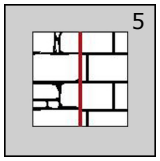


Num. obs. =81

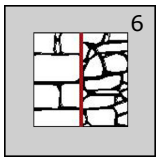


Num. obs. = 1



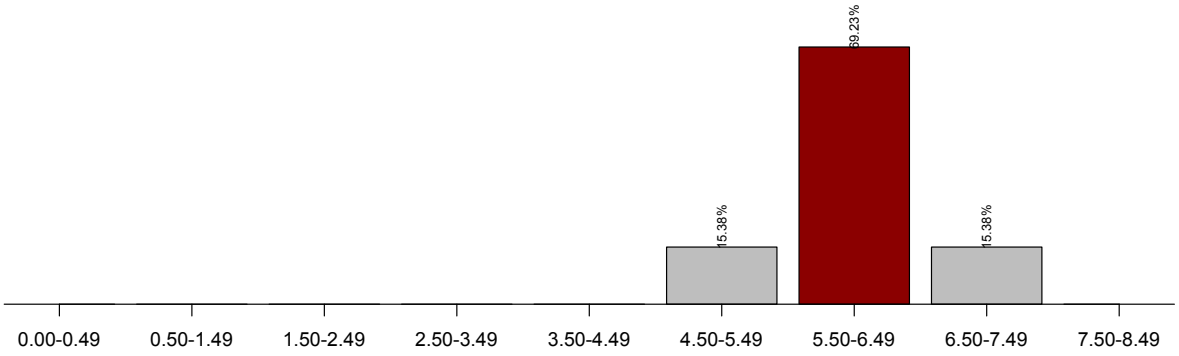


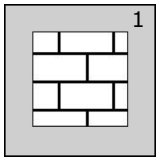
Num. obs. = 7



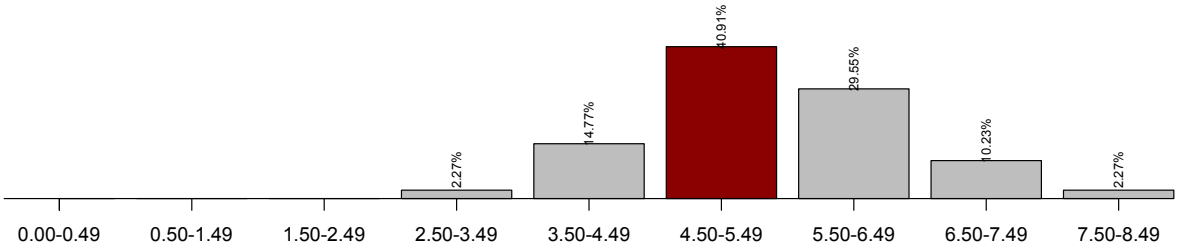
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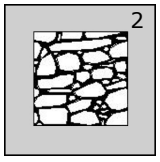
MSR



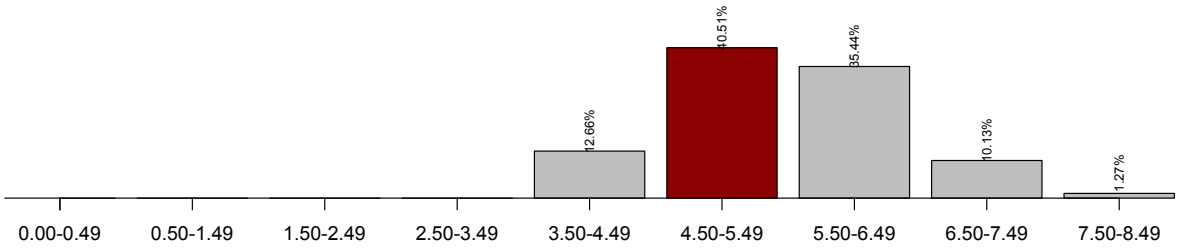


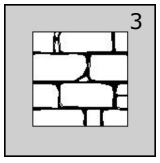
Num. obs. =13



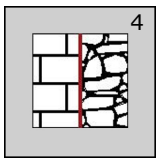


Num. obs. = 88

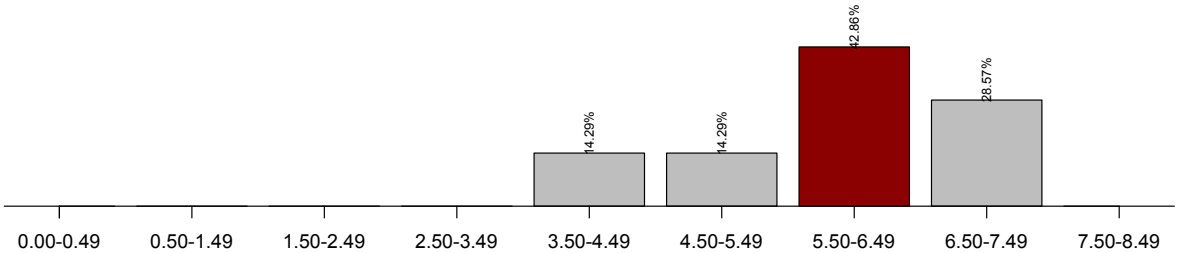


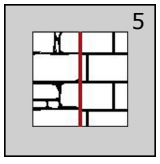


Num. obs. =79

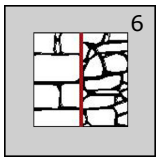


Num. obs. = 1



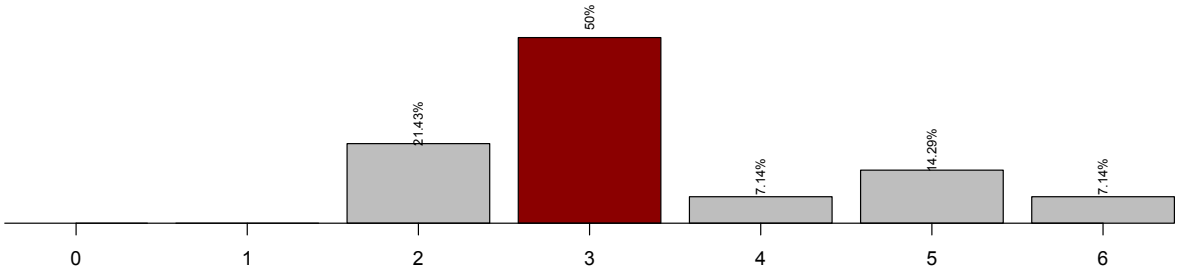


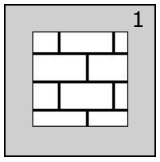
Num. obs. = 7



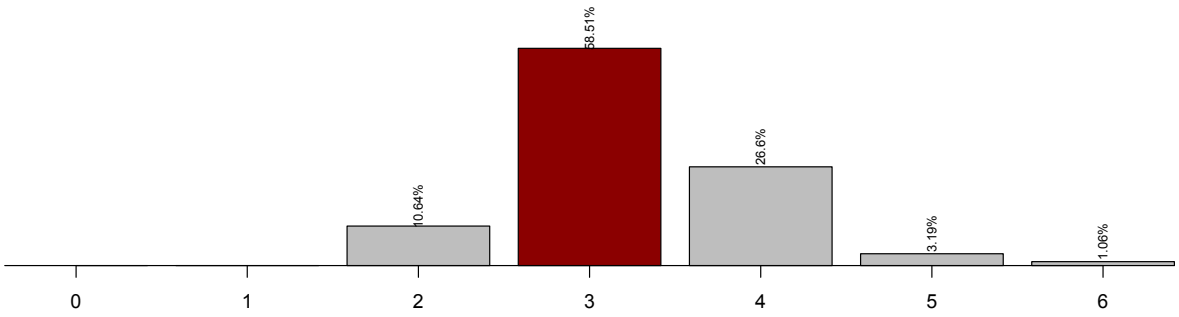
Num. obs. = 2

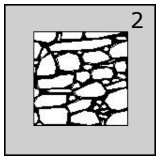
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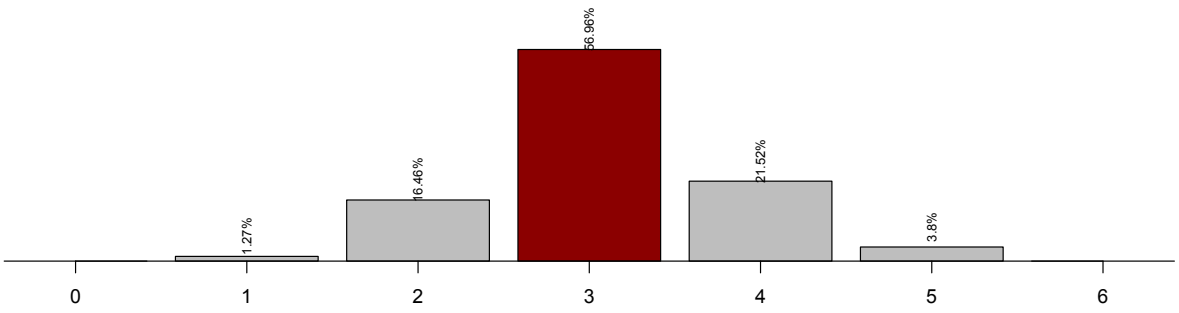


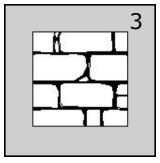
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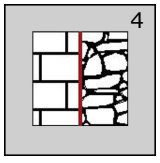


Num. obs. = 94

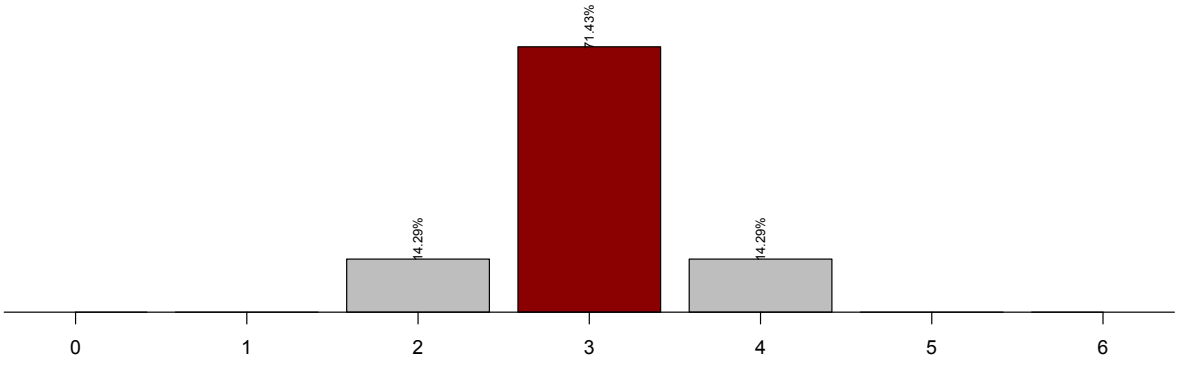


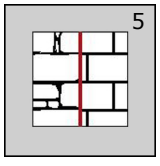


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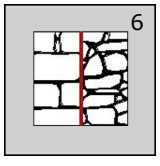


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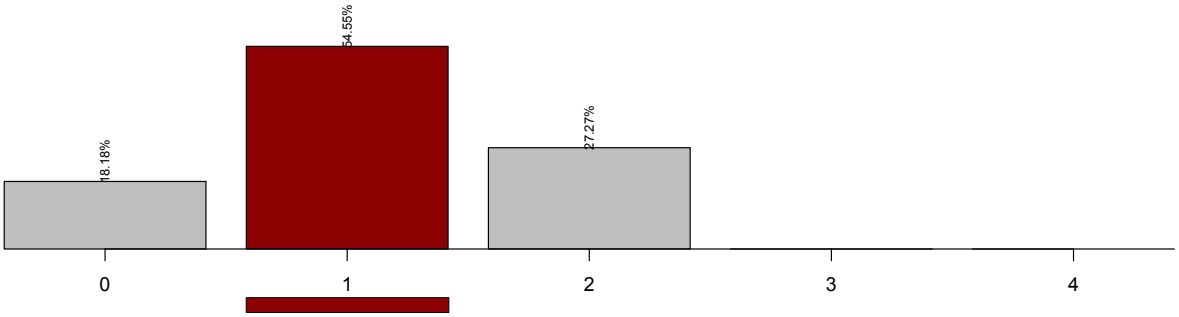


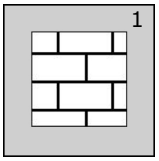
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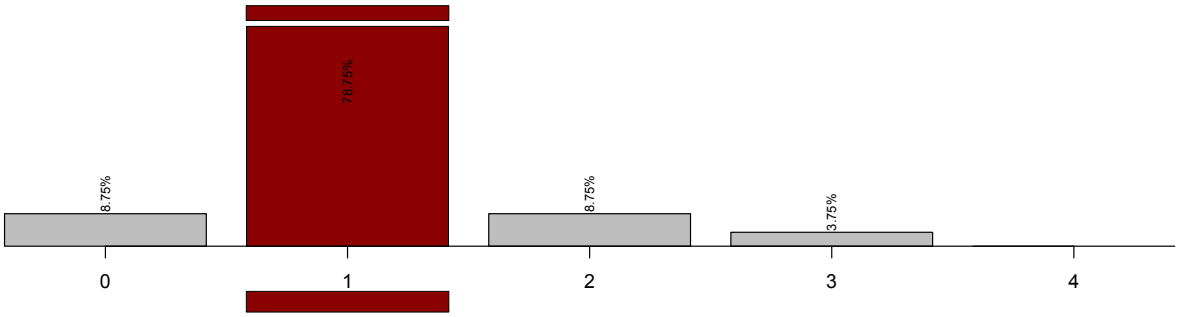
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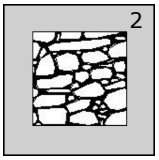
NV



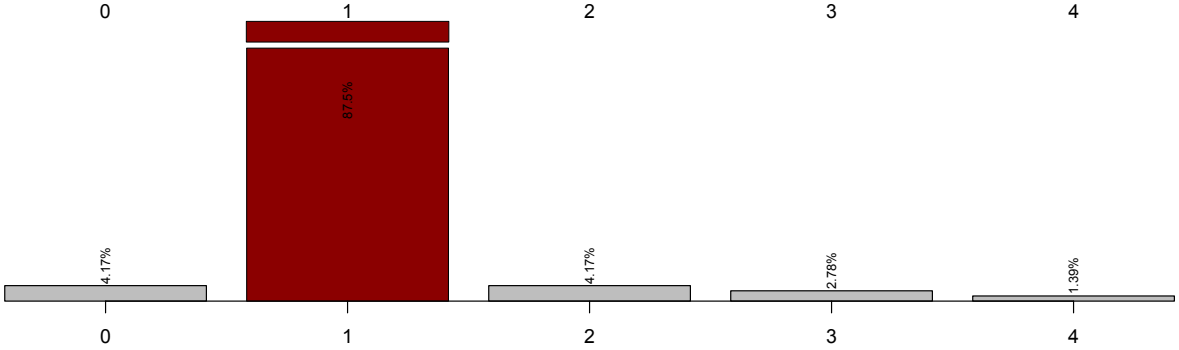


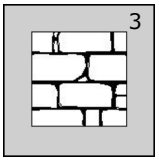
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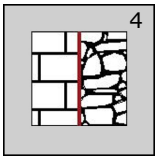


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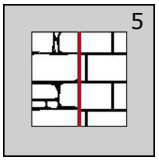


Num. obs. =72

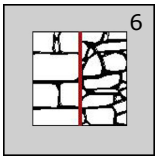


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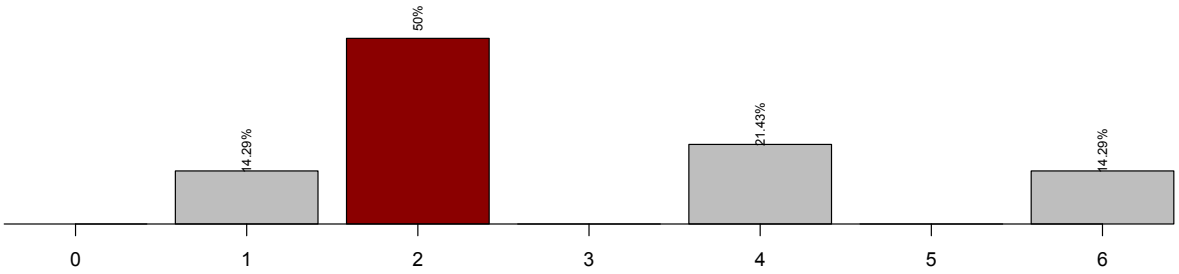


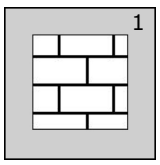
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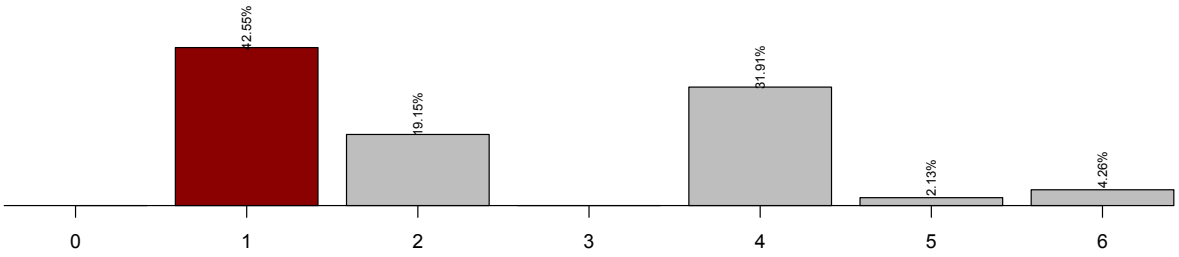
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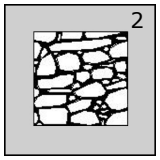
PE



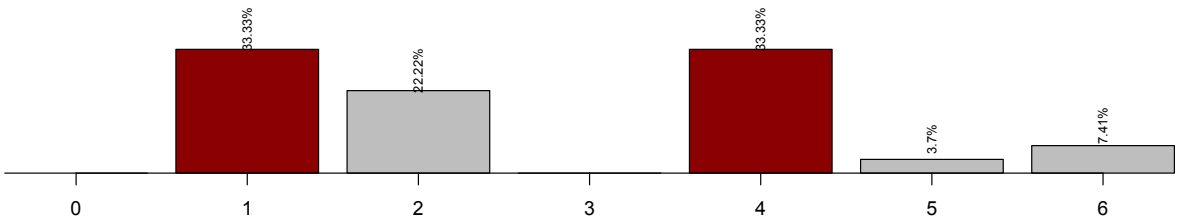


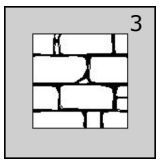
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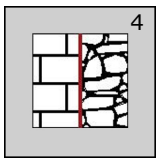


Num. obs. = 94

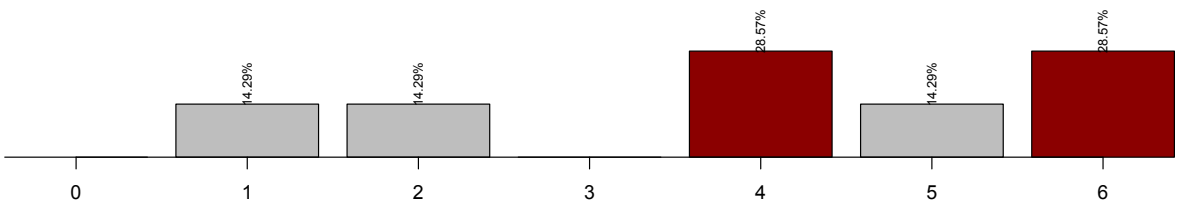


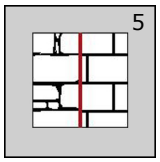


Num. obs. =81

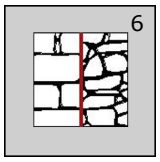


Num. obs. = 1



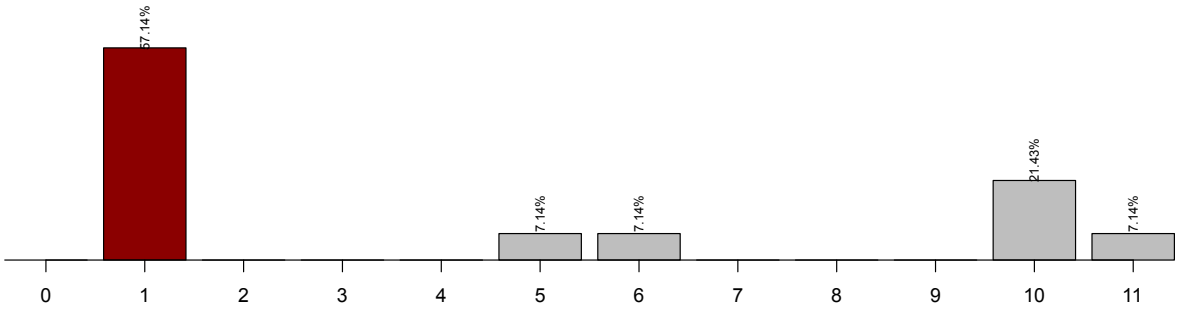


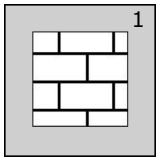
Num. obs. = 7



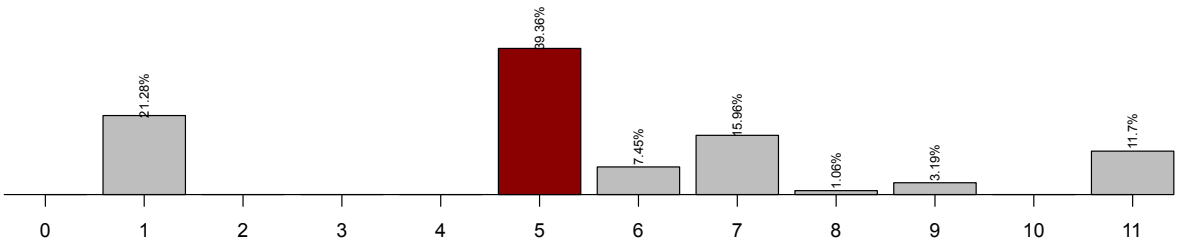
Num. obs. = 2

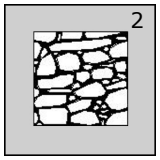
PL



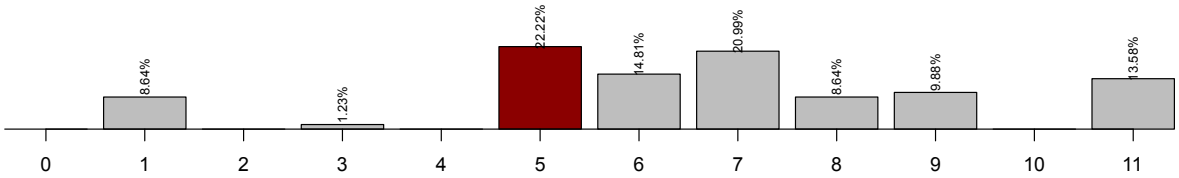


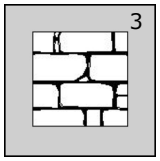
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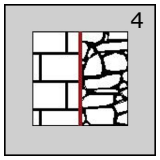


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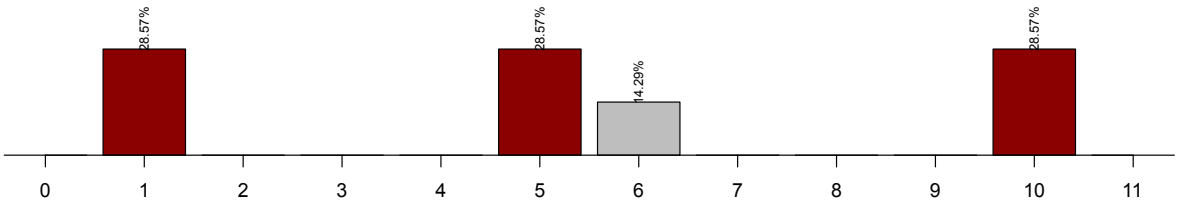


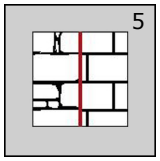


Num. obs. =81

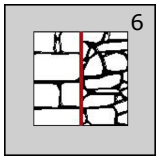


Num. obs. = 1



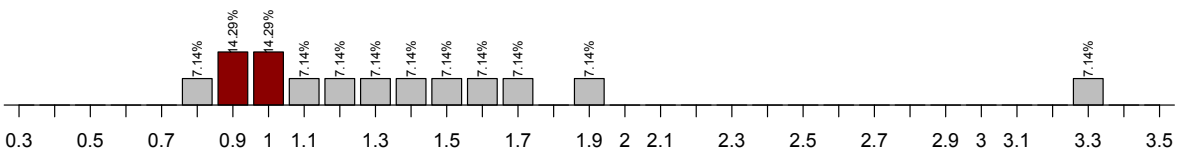


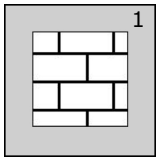
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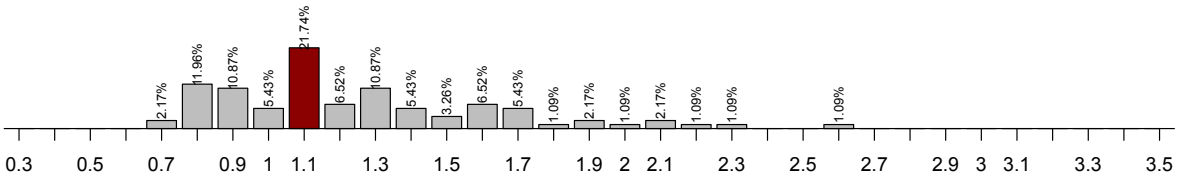
Num. obs. = 2

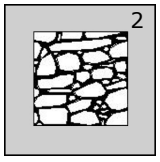
T1R1



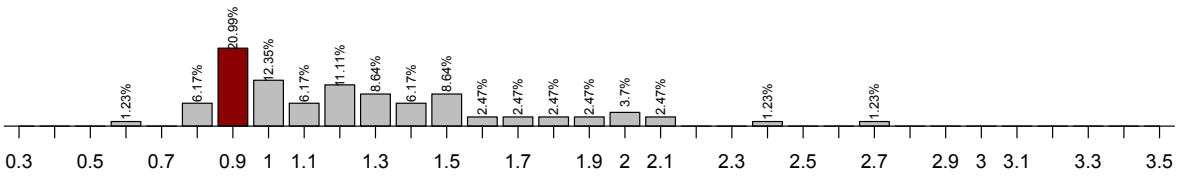


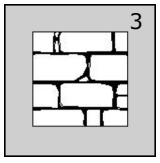
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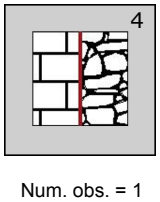


Num. obs. = 92

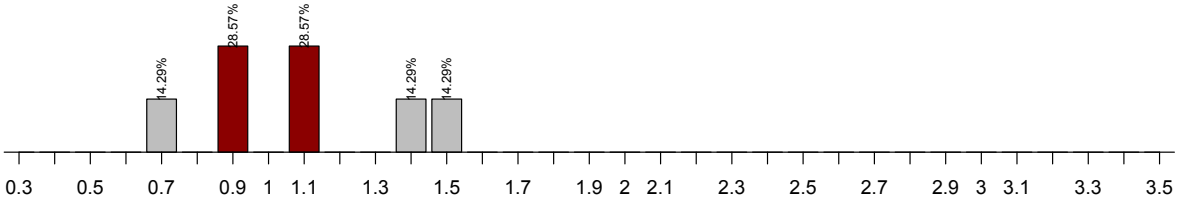


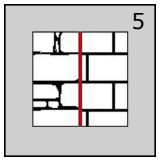


Num. obs. =81

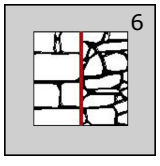


Num. obs. = 1



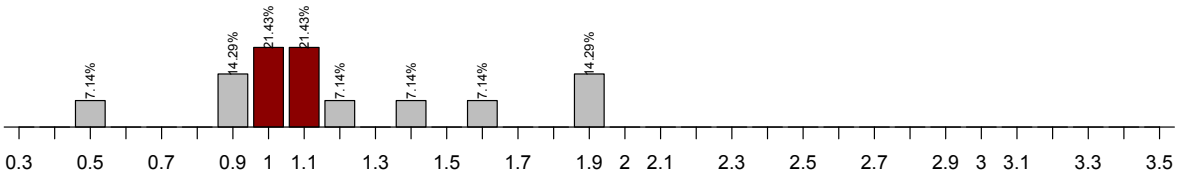


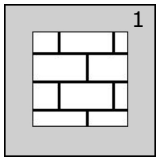
Num. obs. = 7



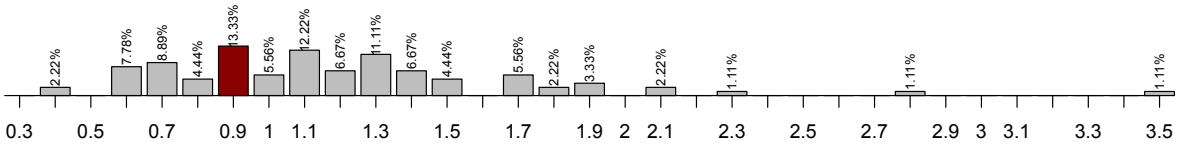
Num. obs. = 2

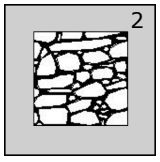
T2R1



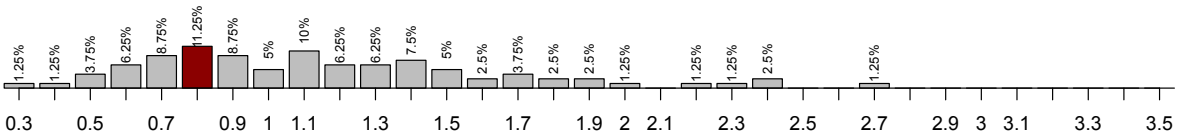


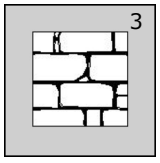
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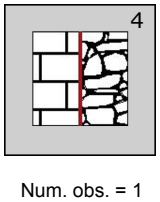


Num. obs. = 90

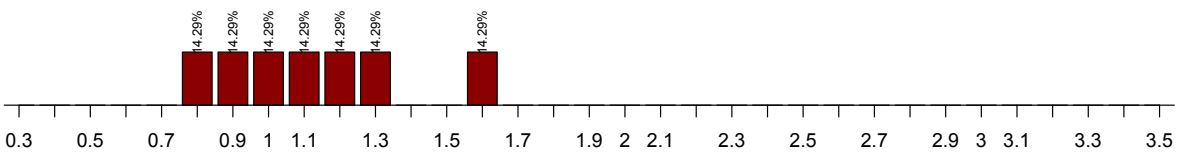


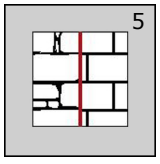


Num. obs. =80

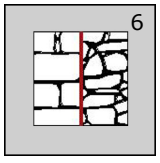


Num. obs. = 1





Num. obs. = 7

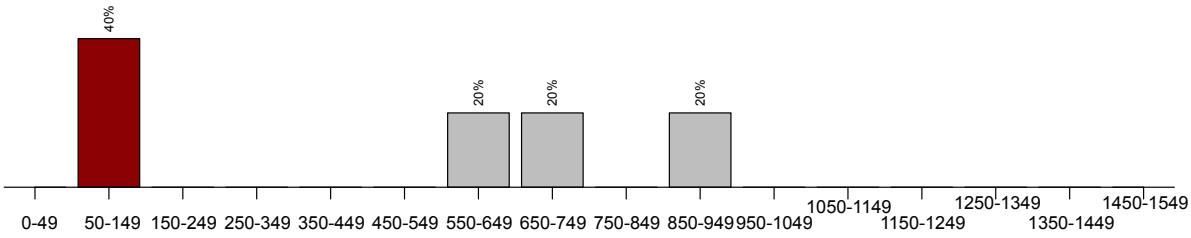


Num. obs. = 2

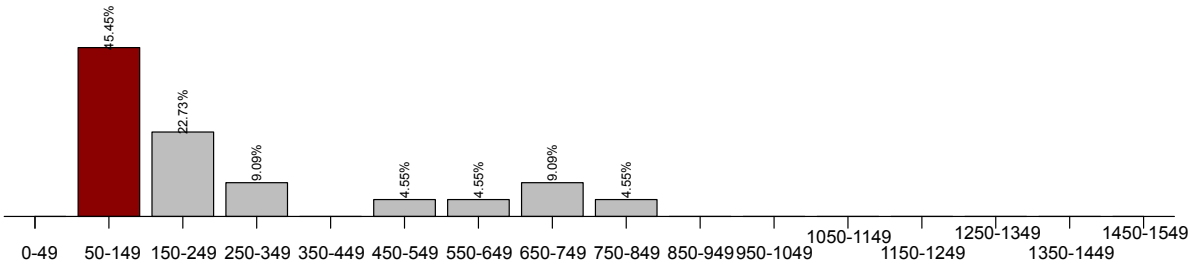
3.1.9 RESULTS REFERRED TO THE PARAMETER T1R1

$AAR_{(1)}$

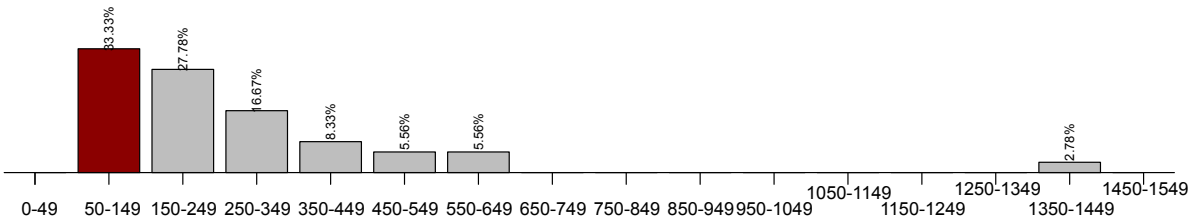
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



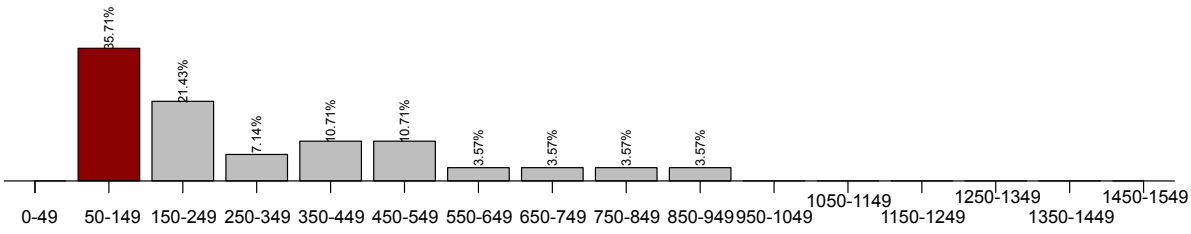
0.7
(0.65-0.74)
Num.obs. =5



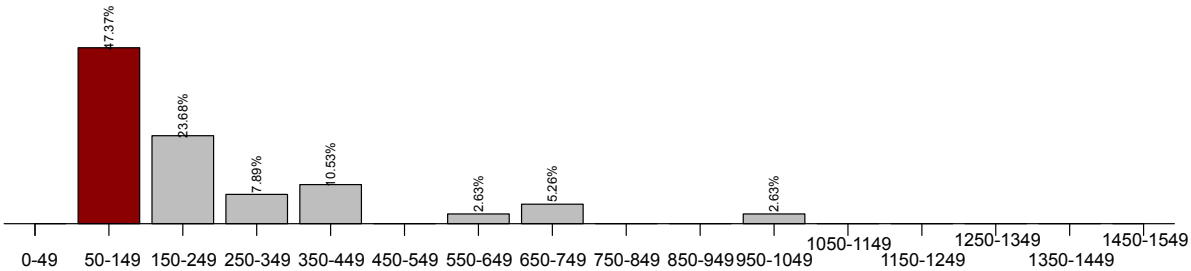
0.8
(0.75-0.84)
Num.obs.=22



0.9
(0.85-0.94)
Num. obs.=36



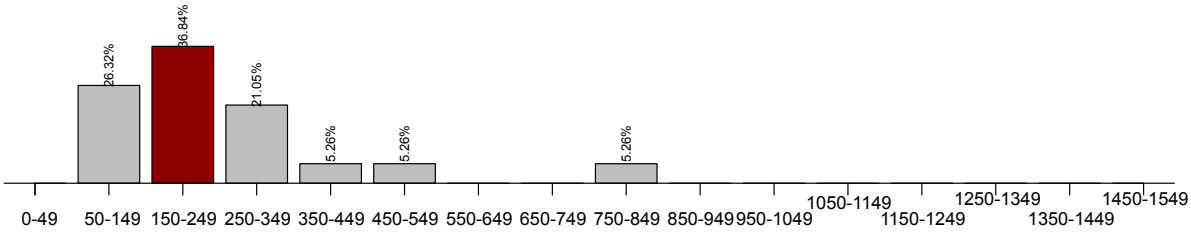
1.0
(0.95-1.04)
Num. obs.=28



1.1
(1.05-1.14)
Num. obs.=38

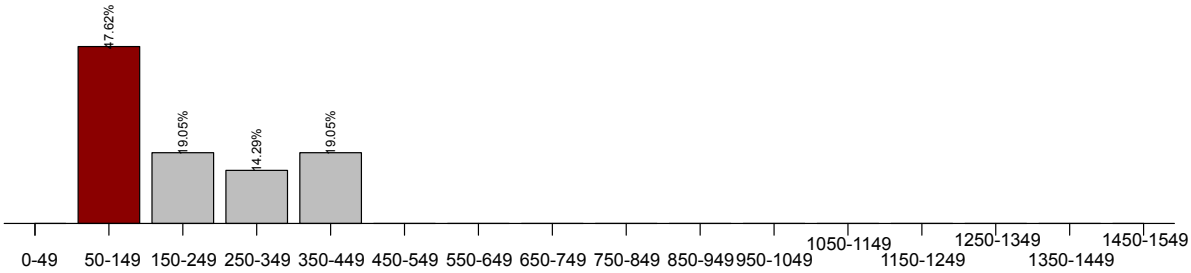
AAR(2)

(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



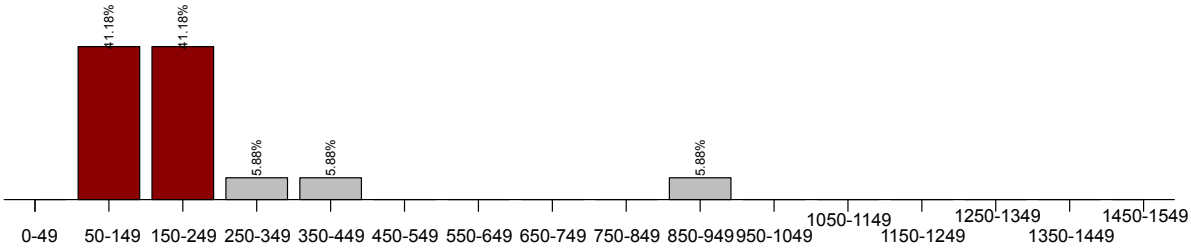
1.2
(1.15-1.24)

Num.obs. =19



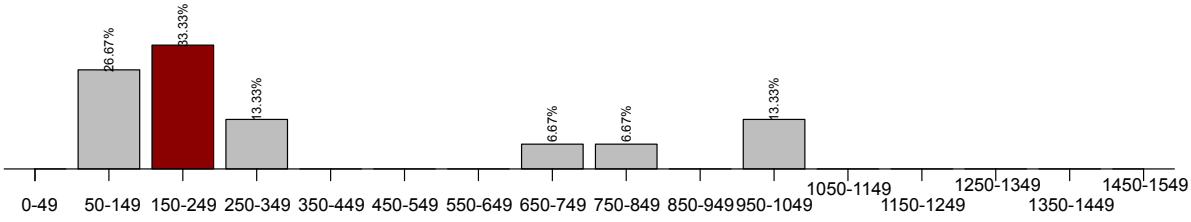
1.3
(1.25-1.34)

Num.obs.=21



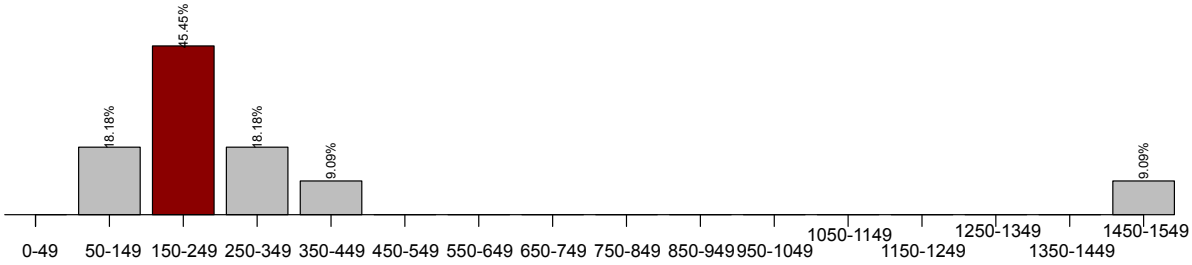
1.4
(1.35-1.44)

Num. obs.=17



1.5
(1.45-1.54)

Num. obs.=15

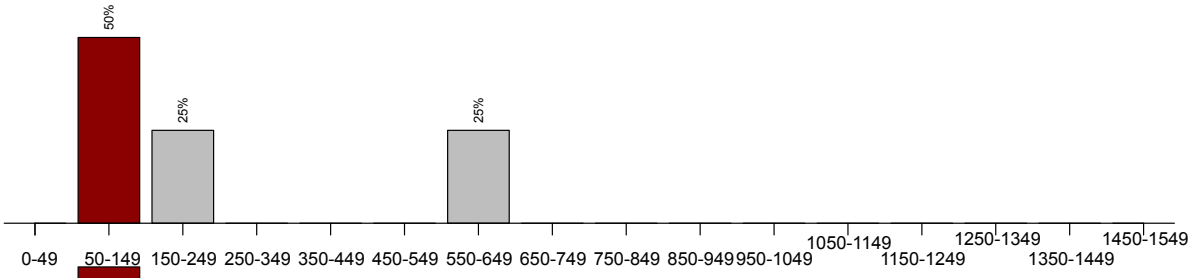


1.6
(1.55-1.64)

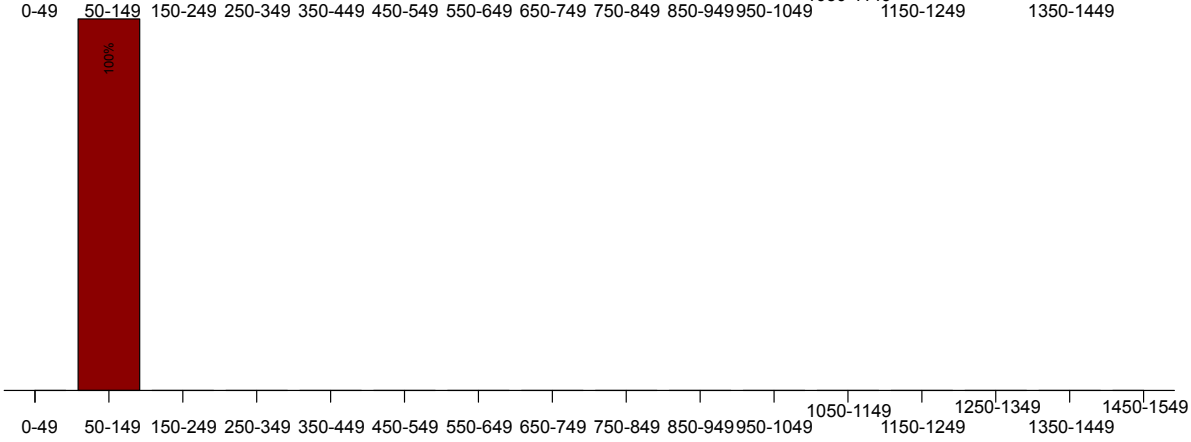
Num. obs.=11

AAR(3)

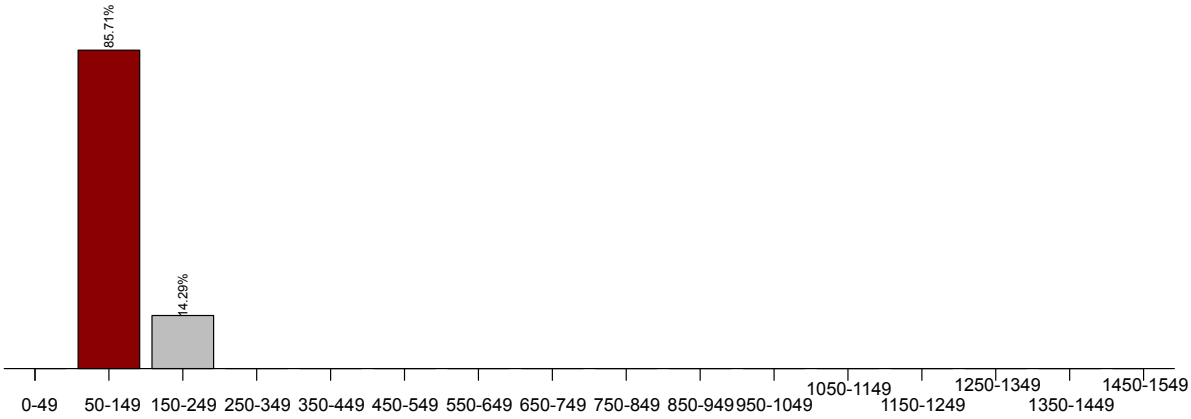
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



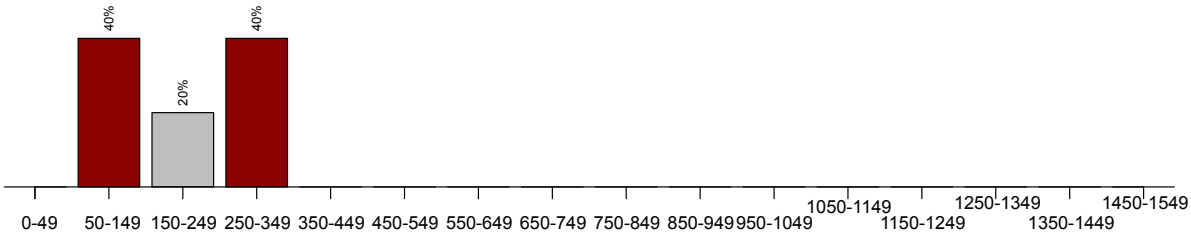
1.7
(1.65-1.74)
Num.obs. =8



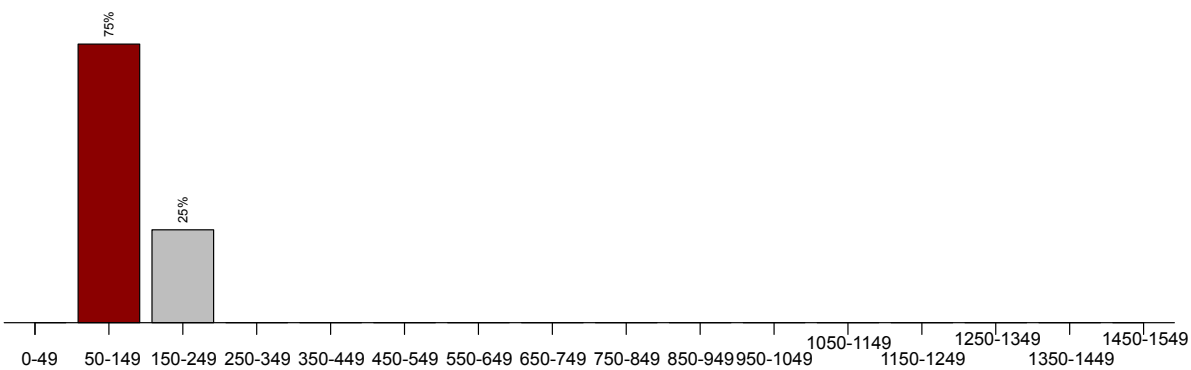
1.8
(1.75-1.84)
Num.obs.=3



1.9
(1.85-1.94)
Num. obs.=7



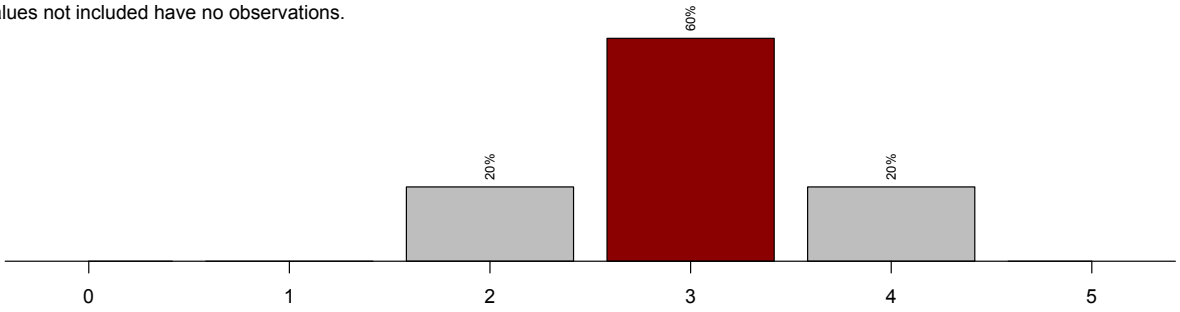
2.0
(1.95-2.04)
Num. obs.=5



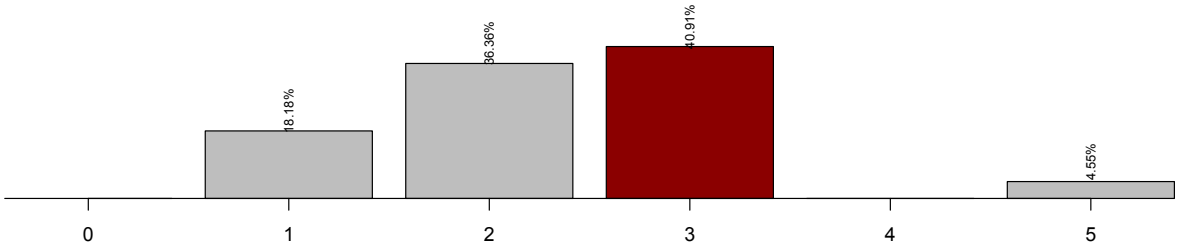
2.1
(2.05-1.14)
Num. obs.=4

LOR(1)

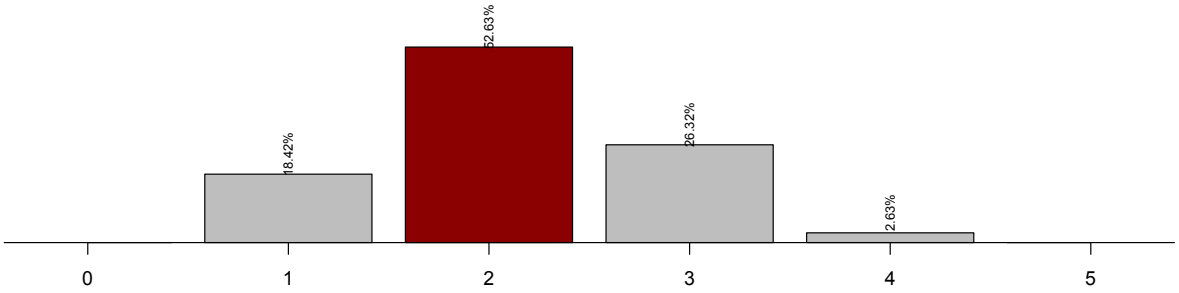
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



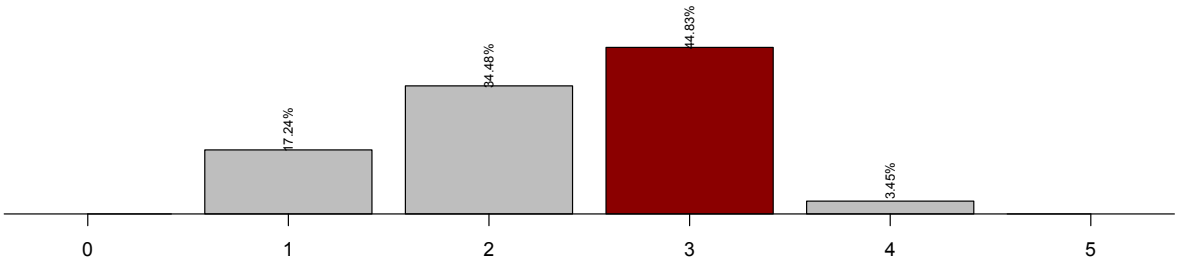
0.7
(0.65-0.74)
Num.obs. =5



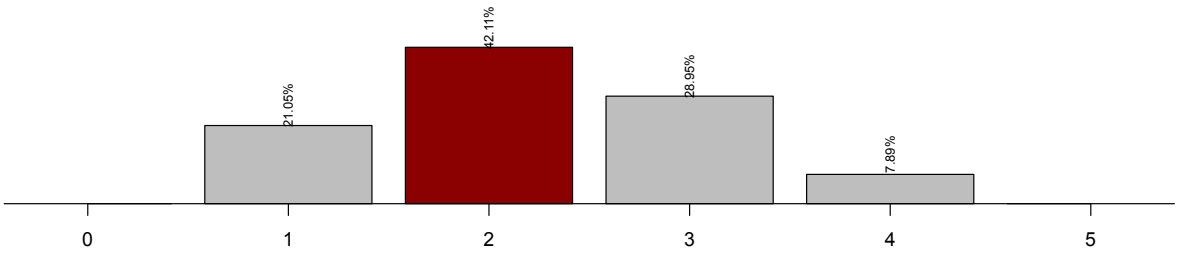
0.8
(0.75-0.84)
Num.obs.=22



0.9
(0.85-0.94)
Num. obs.=38



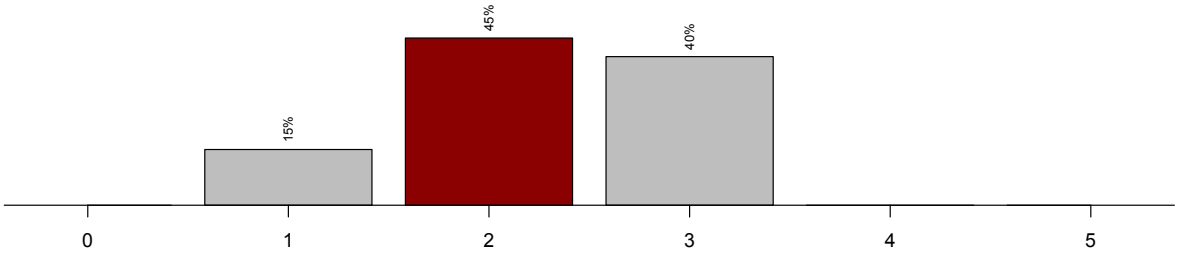
1.0
(0.95-1.04)
Num. obs.=29



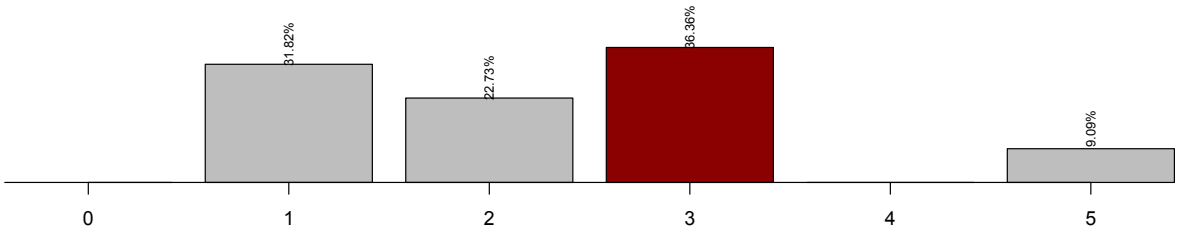
1.1
(1.05-1.14)
Num. obs.=38

LOR(2)

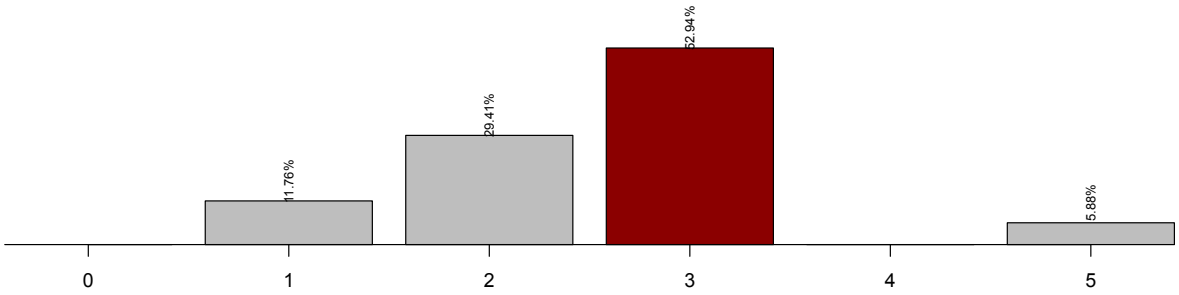
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



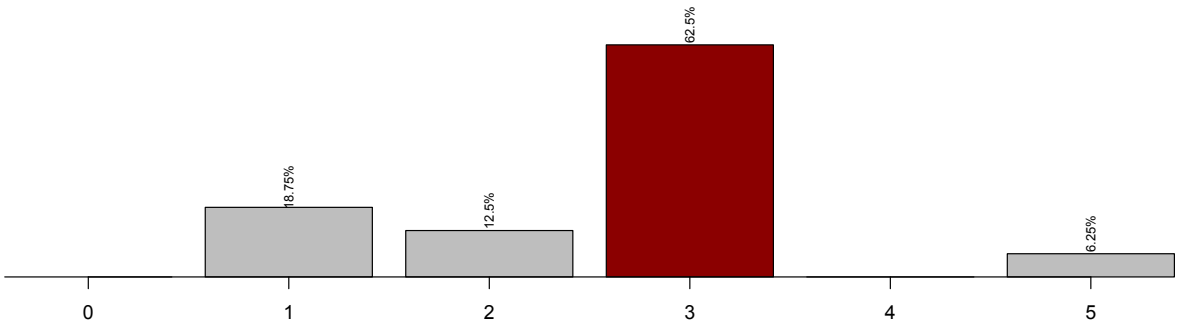
1.2
(1.15-1.24)
Num.obs. =20



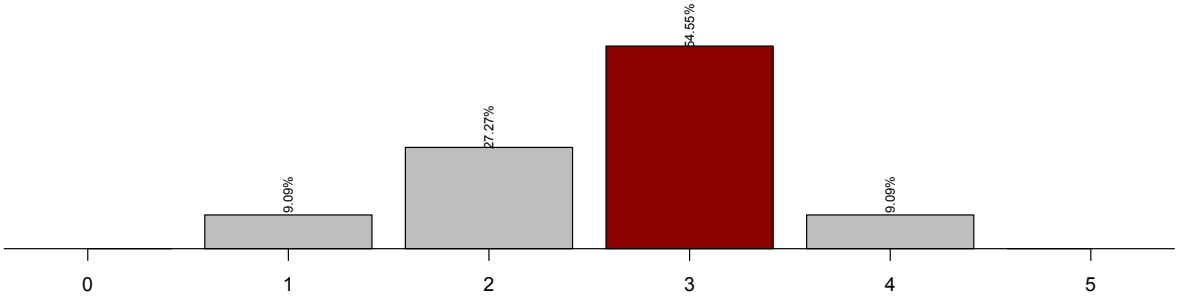
1.3
(1.25-1.34)
Num.obs.=22



1.4
(1.35-1.44)
Num. obs.=17



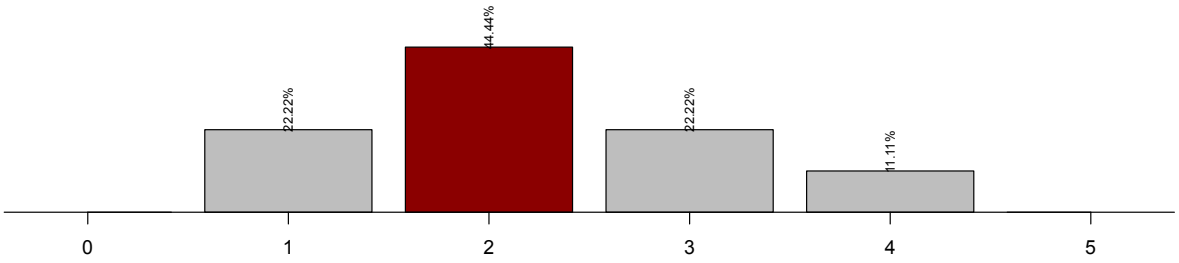
1.5
(1.45-1.54)
Num. obs.=16



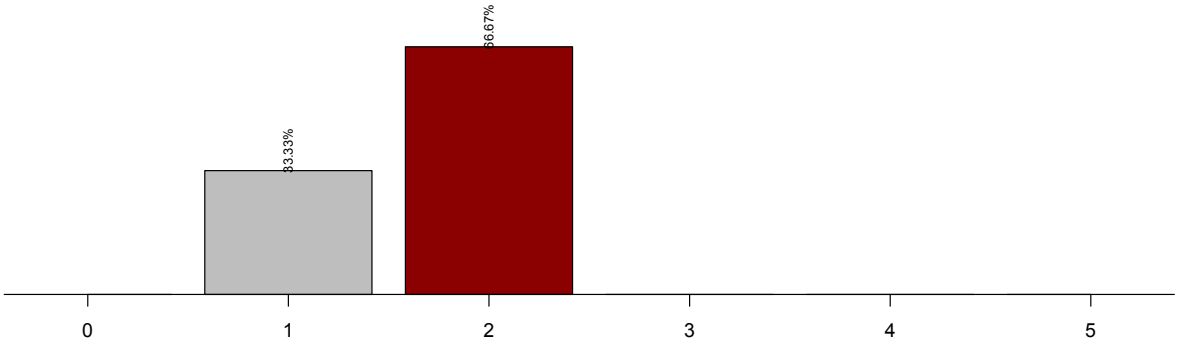
1.6
(1.55-1.64)
Num. obs.=11

LOR(3)

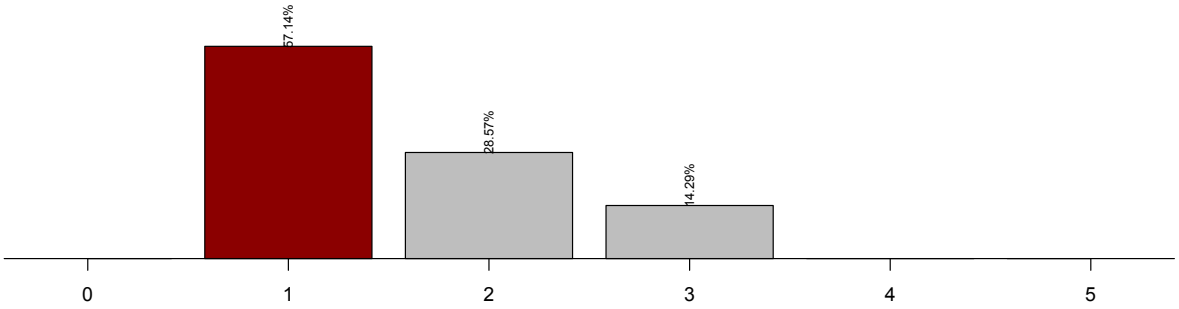
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



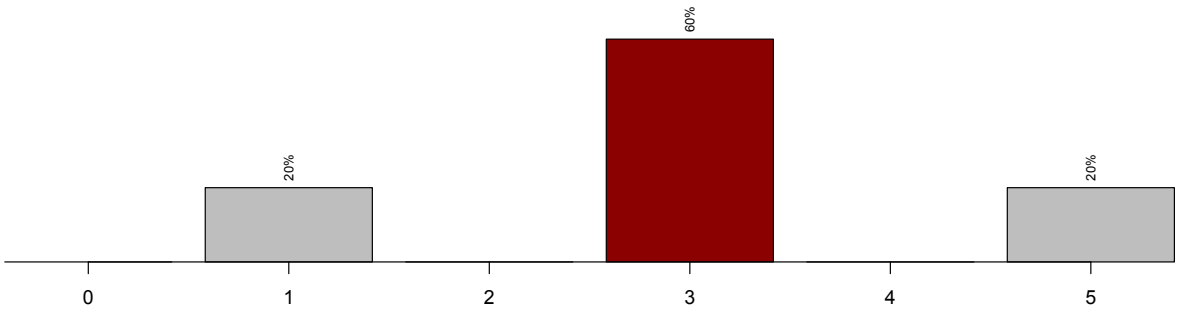
1.7
(1.65-1.74)
Num.obs. =9



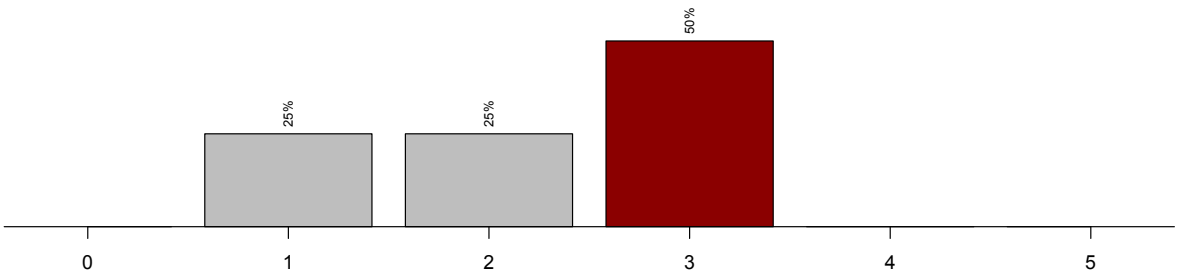
1.8
(1.75-1.84)
Num.obs.=3



1.9
(1.85-1.94)
Num. obs.=7



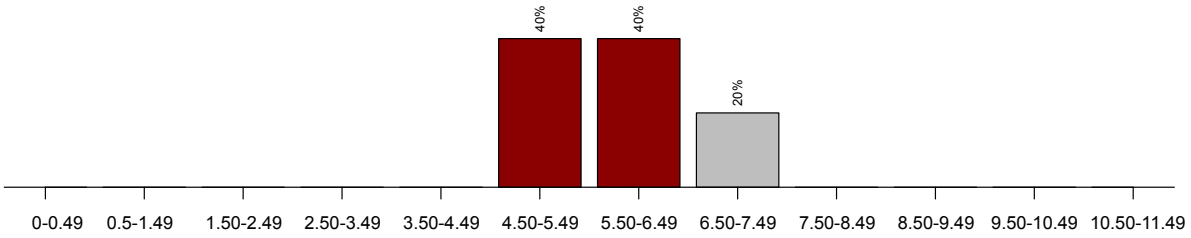
2.0
(1.95-2.04)
Num. obs.=5



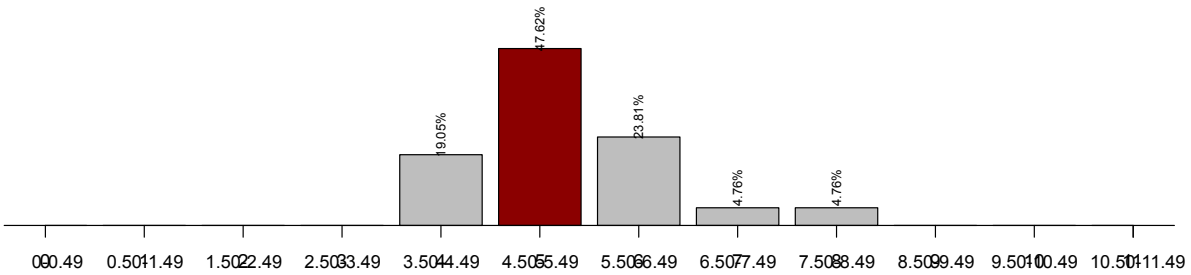
2.1
(2.05-1.14)
Num. obs.=4

MSR(1)

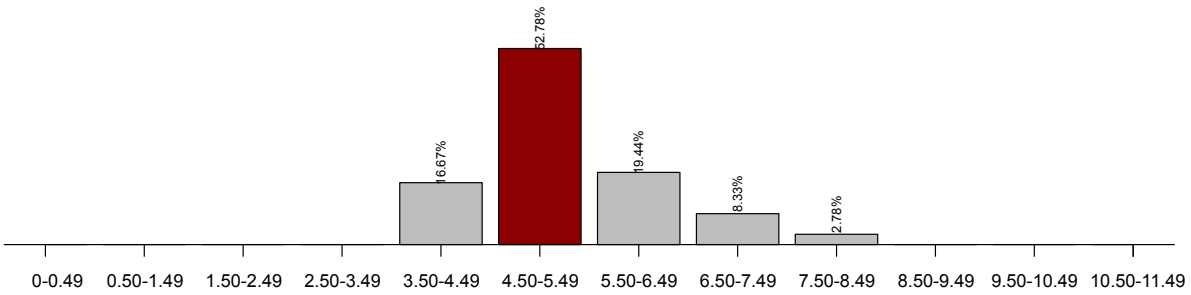
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



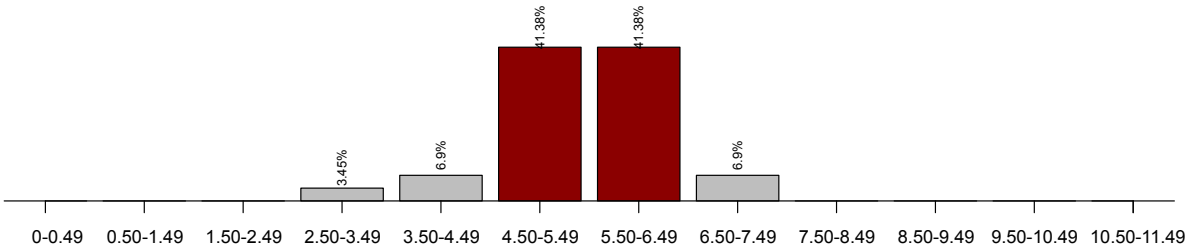
0.7
(0.65-0.74)
Num.obs. =5



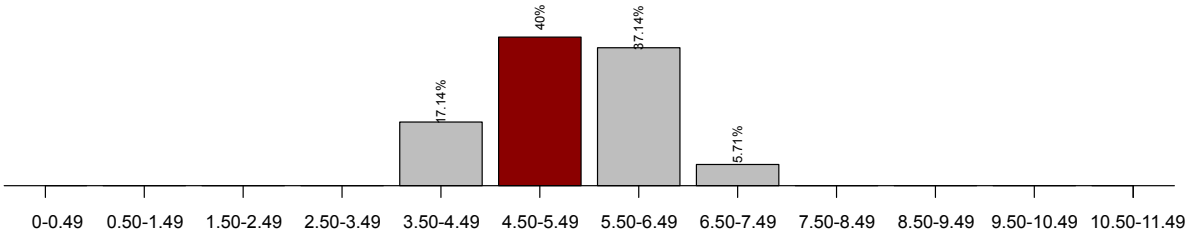
0.8
(0.75-0.84)
Num.obs.=22



0.9
(0.85-0.94)
Num. obs.=36



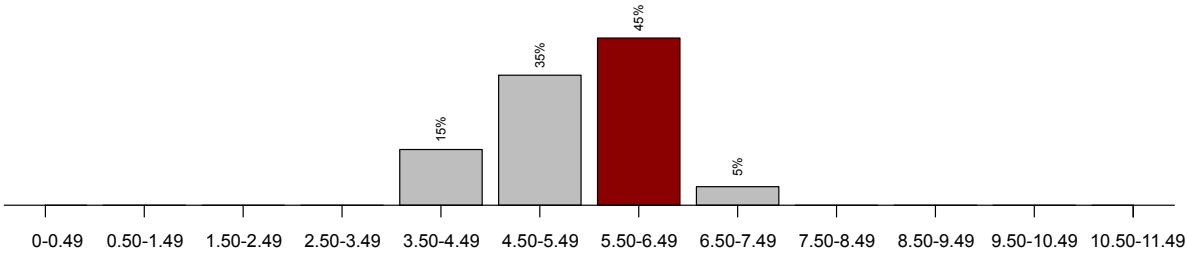
1.0
(0.95-1.04)
Num. obs.=29



1.1
(1.05-1.14)
Num. obs.=35

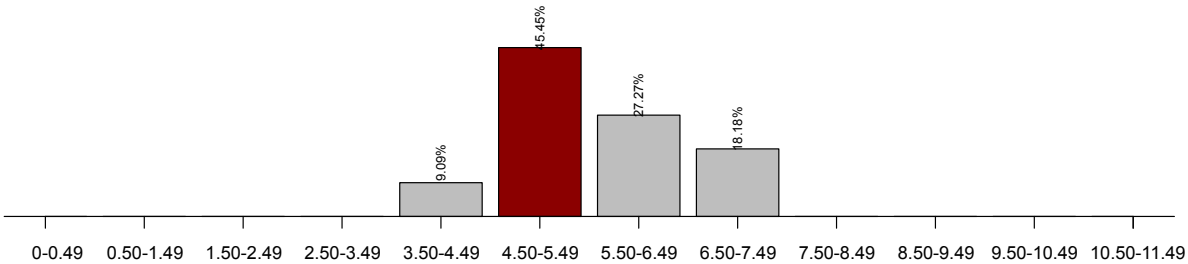
MSR(2)

(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



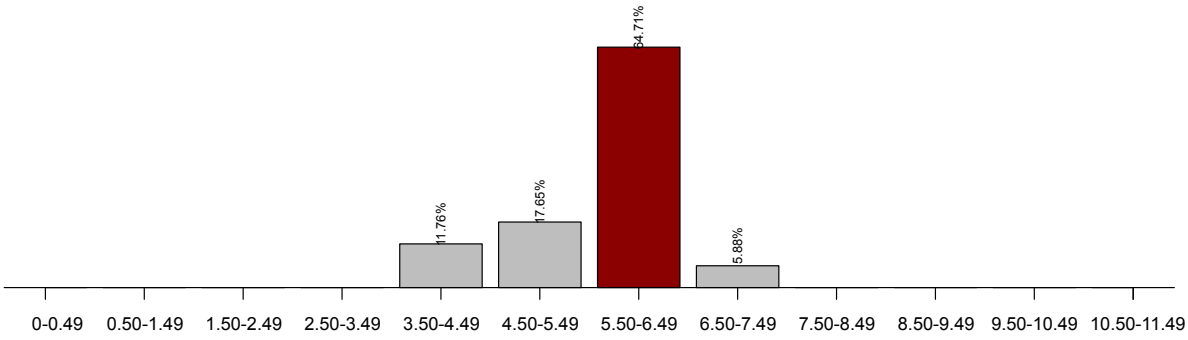
1.2
(1.15-1.24)

Num.obs. =20



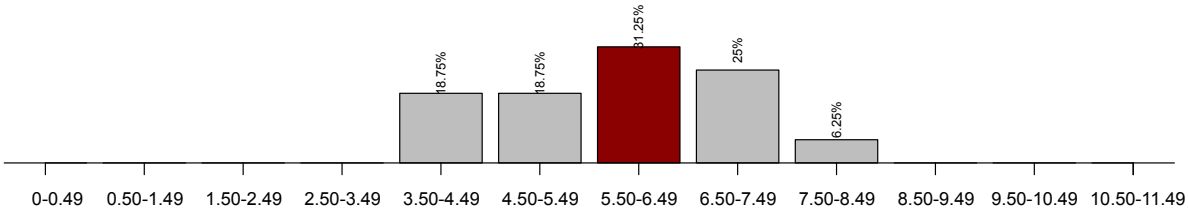
1.3
(1.25-1.34)

Num.obs.=22



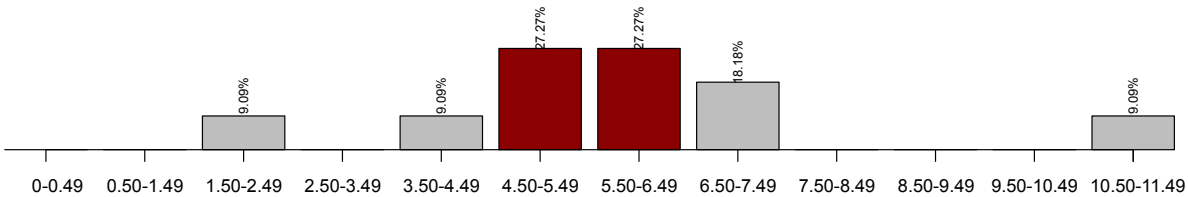
1.4
(1.35-1.44)

Num. obs.=17



1.5
(1.45-1.54)

Num. obs.=16

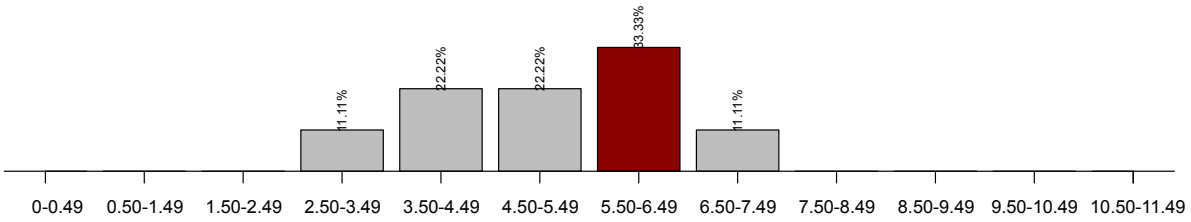


1.6
(1.55-1.64)

Num. obs.=11

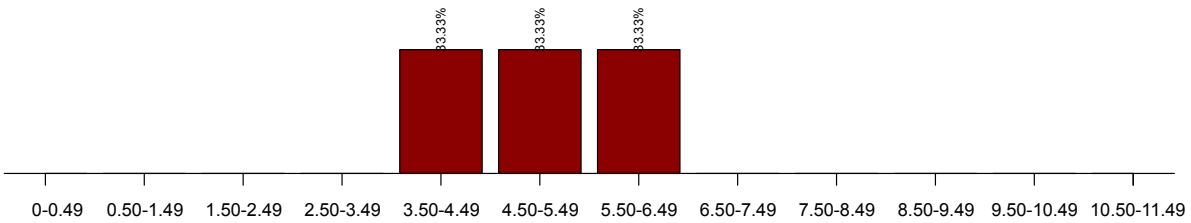
MSR(3)

(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



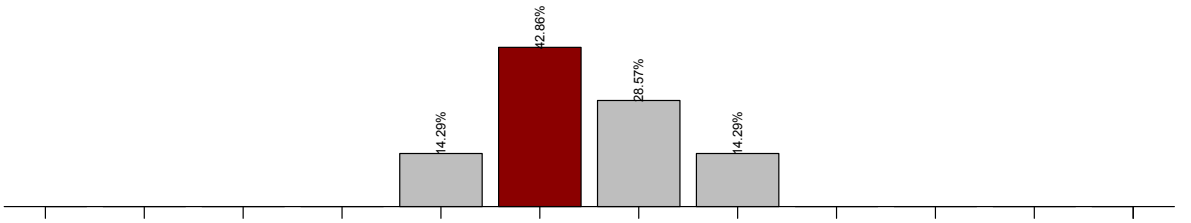
1.7
(1.65-1.74)

Num.obs. =9



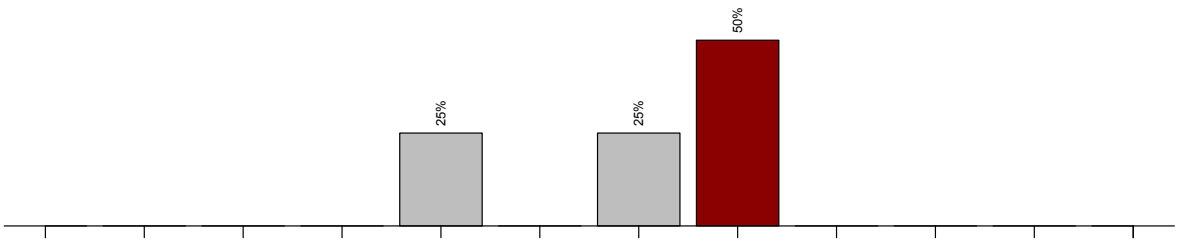
1.8
(1.75-1.84)

Num.obs.=3



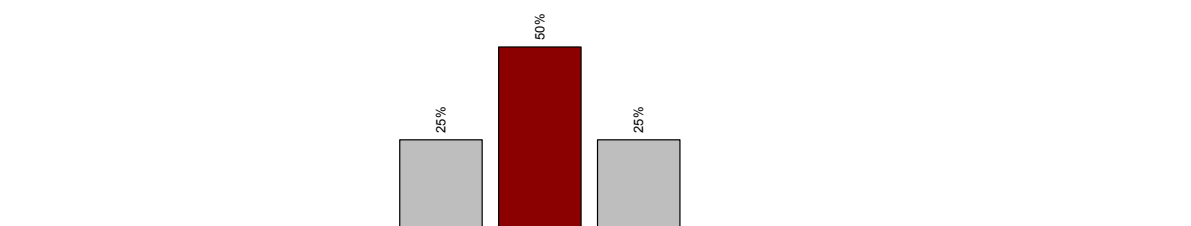
1.9
(1.85-1.94)

Num. obs.=7



2.0
(1.95-2.04)

Num. obs.=4

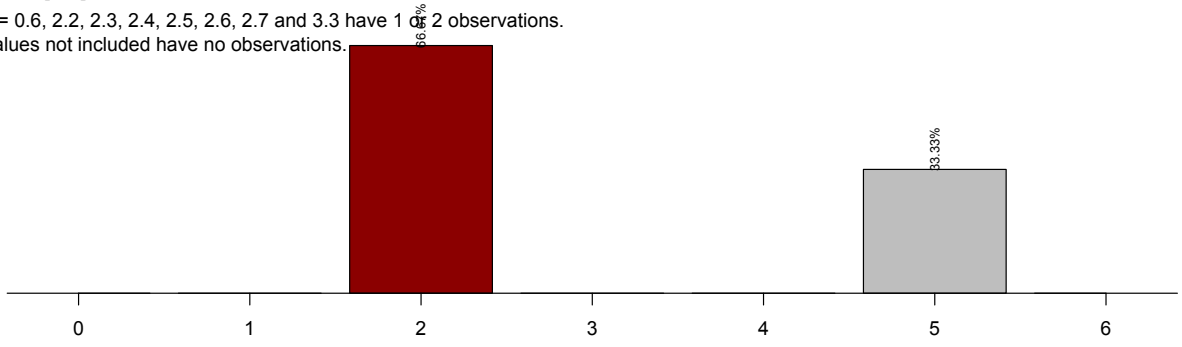


2.1
(2.05-1.14)

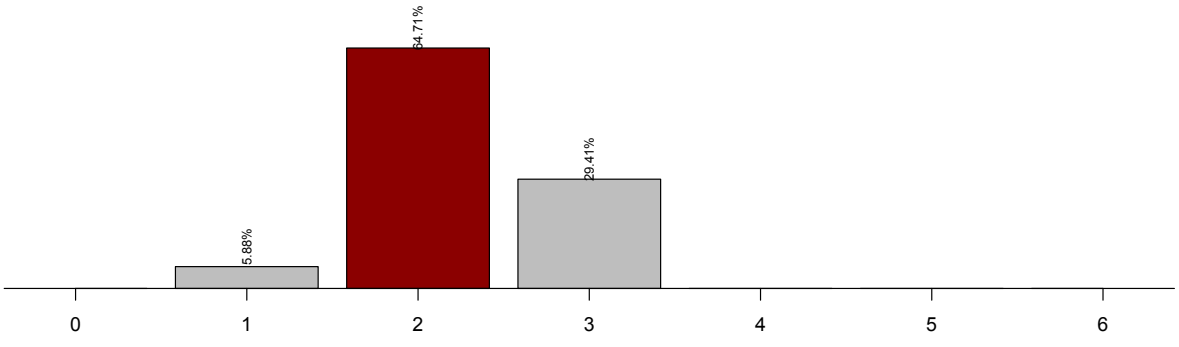
Num. obs.=4

$MT_{(1)}$

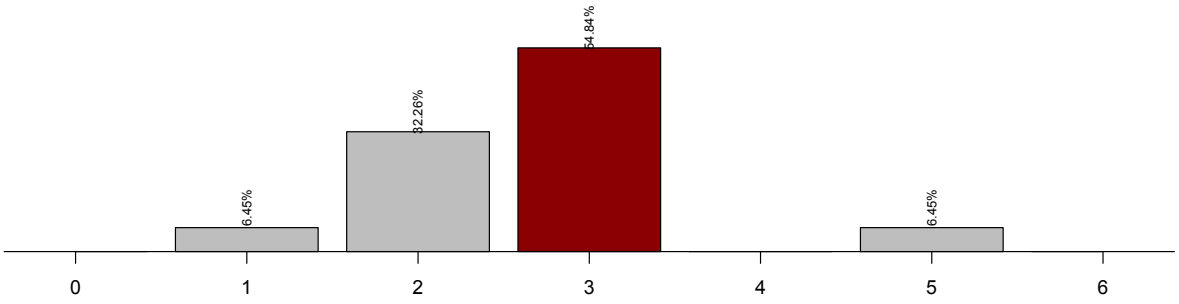
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



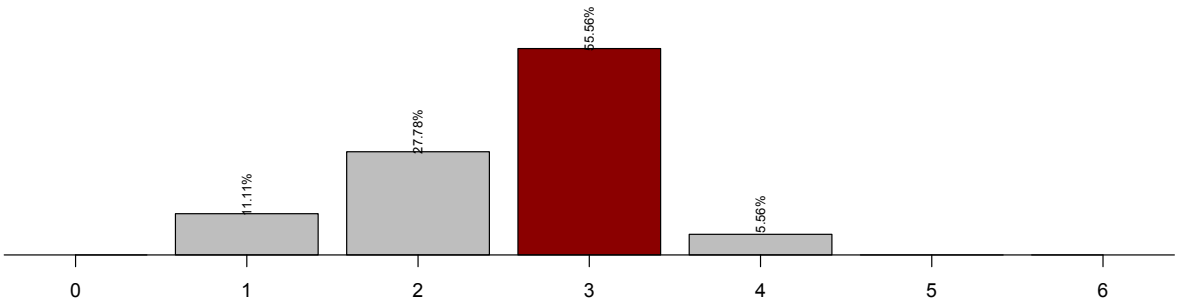
0.7
(0.65-0.74)
Num.obs. =3



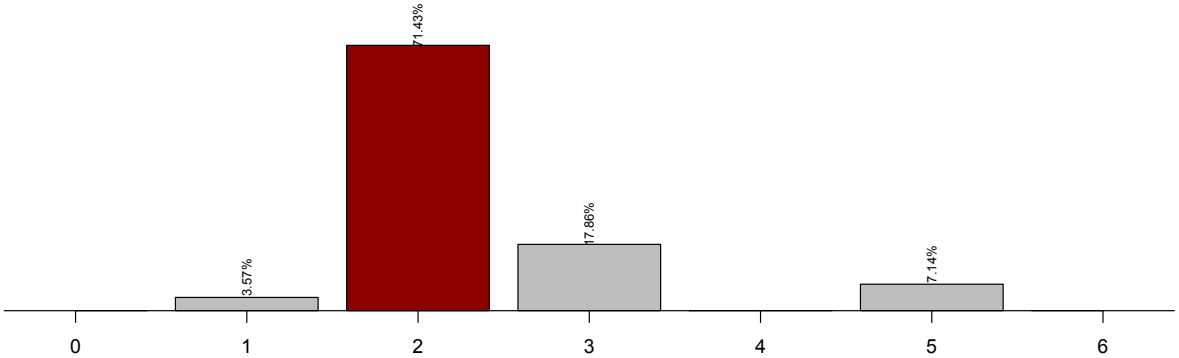
0.8
(0.75-0.84)
Num.obs.=17



0.9
(0.85-0.94)
Num. obs.=31



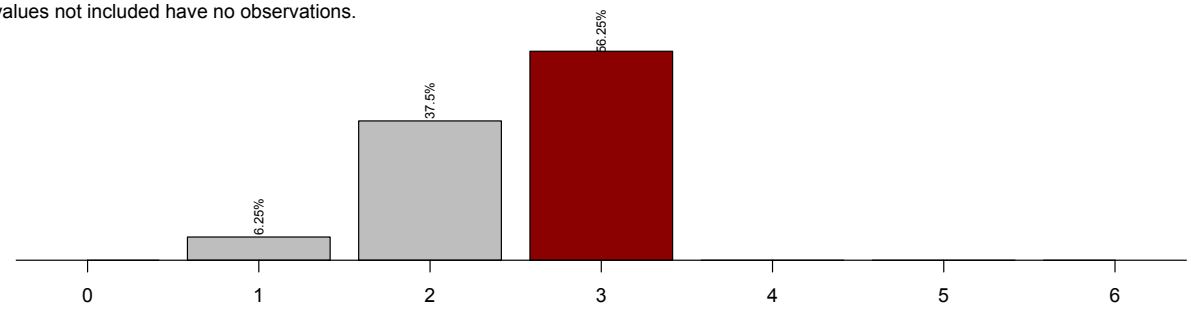
1.0
(0.95-1.04)
Num. obs.=18



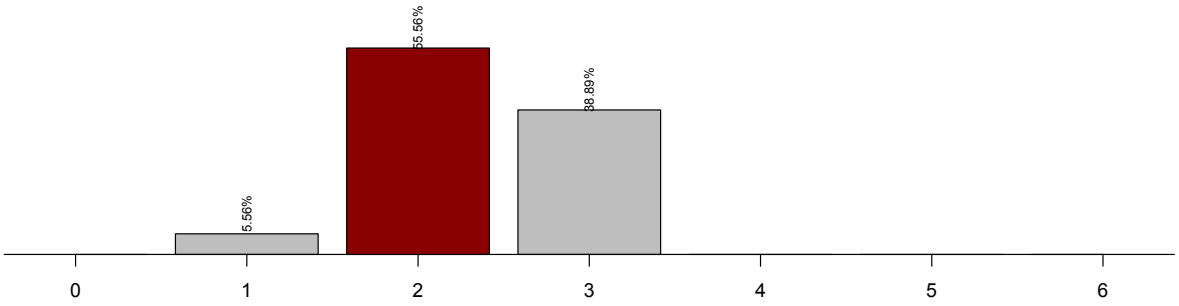
1.1
(1.05-1.14)
Num. obs.=28

MT(2)

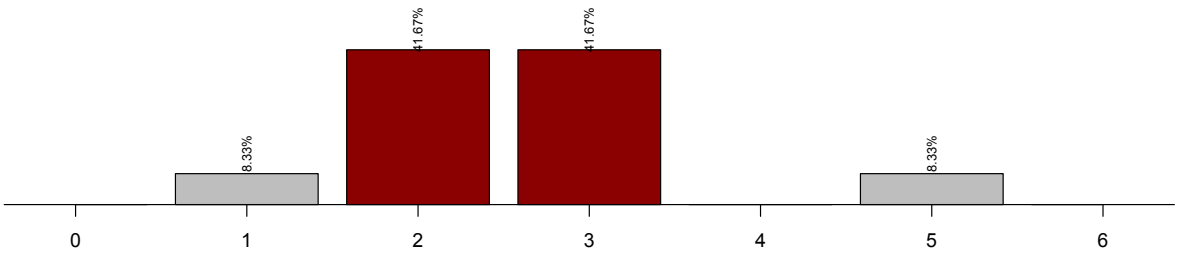
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



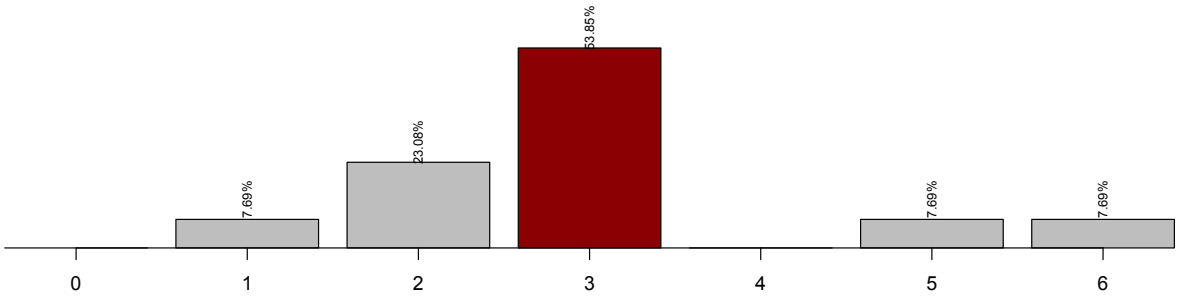
1.2
(1.15-1.24)
Num.obs. =16



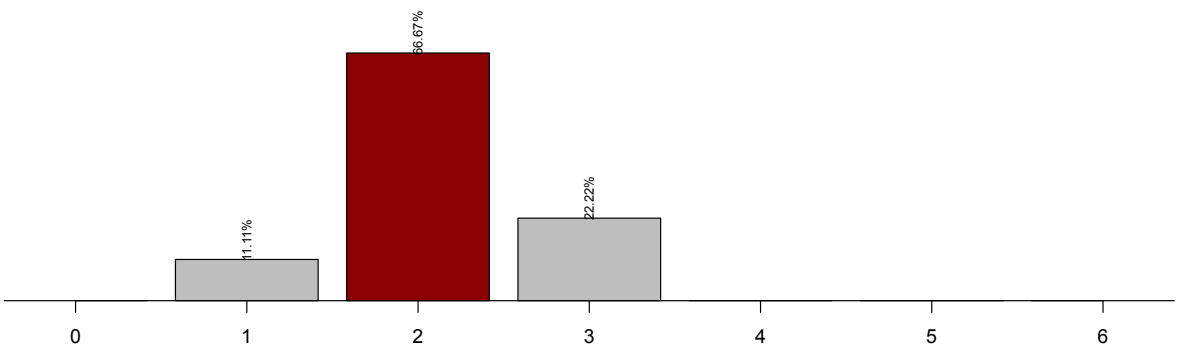
1.3
(1.25-1.34)
Num.obs.=18



1.4
(1.35-1.44)
Num. obs.=12



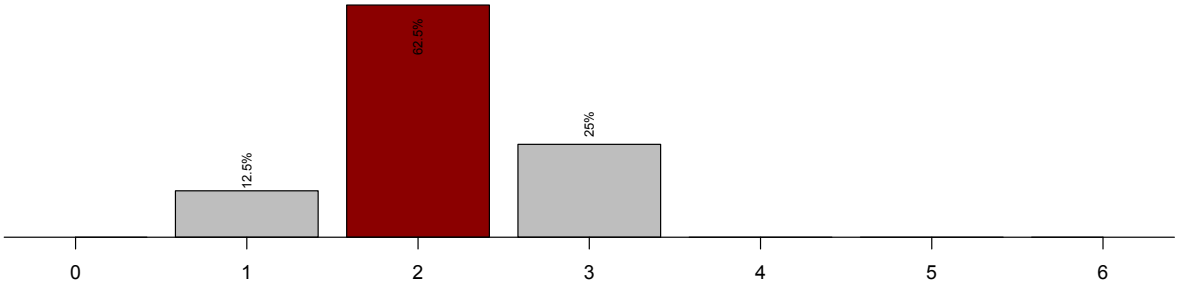
1.5
(1.45-1.54)
Num. obs.=13



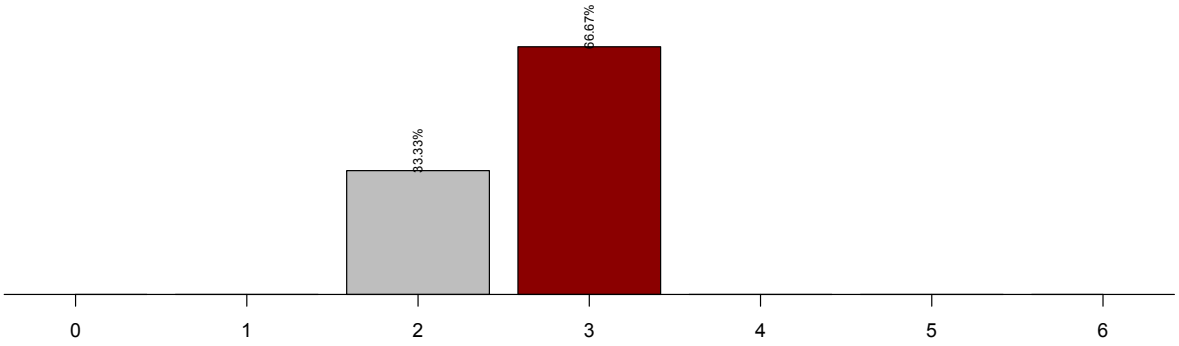
1.6
(1.55-1.64)
Num. obs.=09

MT(3)

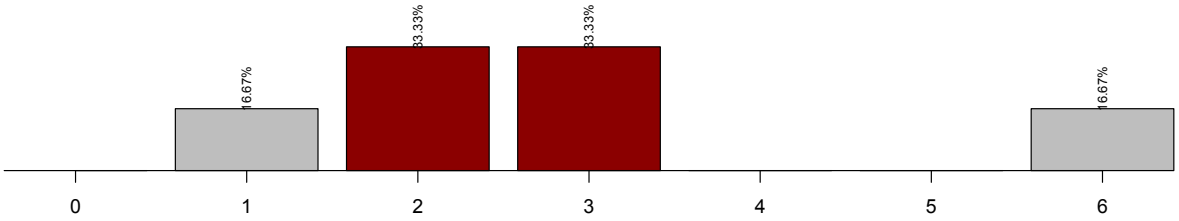
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



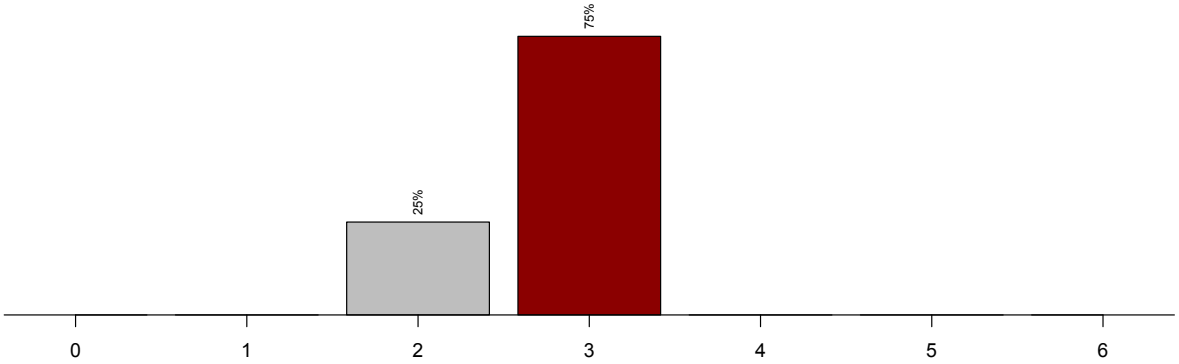
1.7
(1.65-1.74)
Num.obs. =8



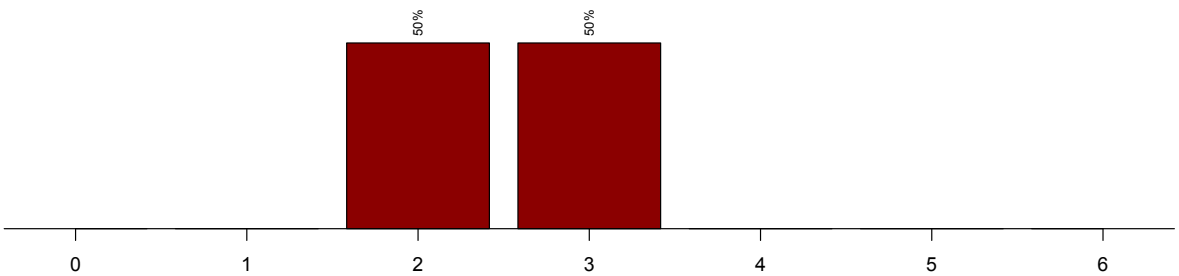
1.8
(1.75-1.84)
Num.obs.=3



1.9
(1.85-1.94)
Num. obs.=6



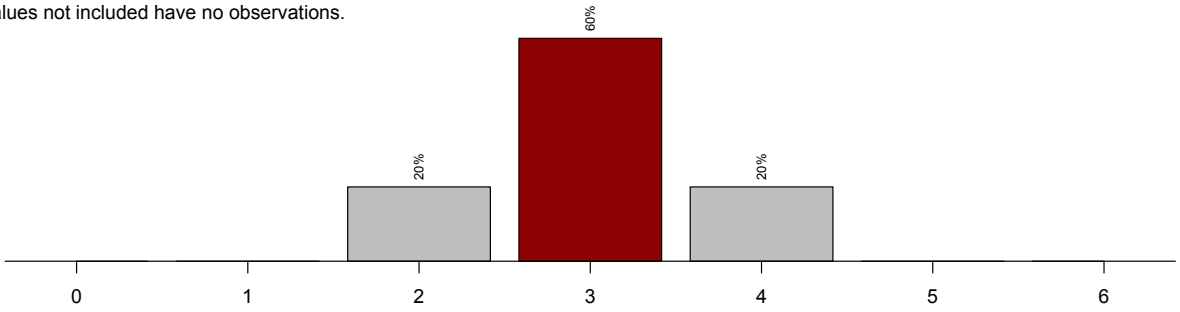
2.0
(1.95-2.04)
Num. obs.=4



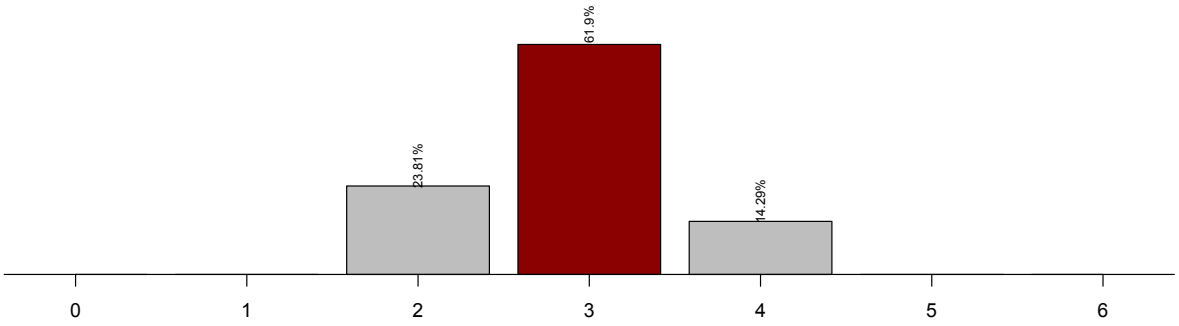
2.1
(2.05-1.14)
Num. obs.=4

$NF_{(1)}$

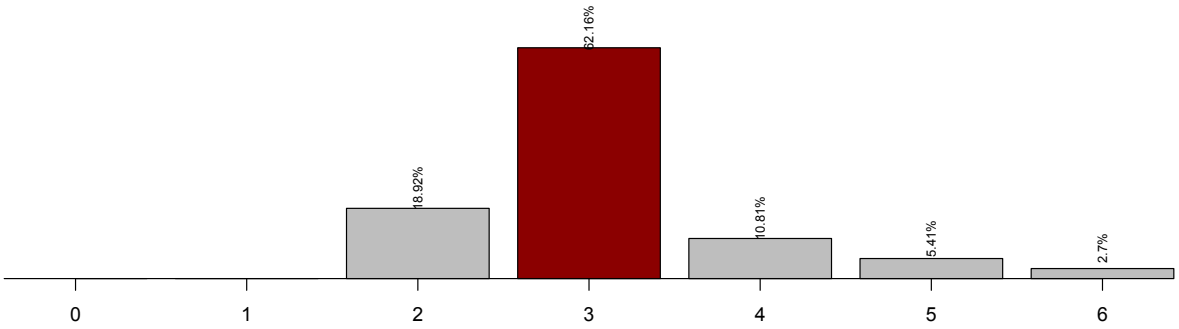
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



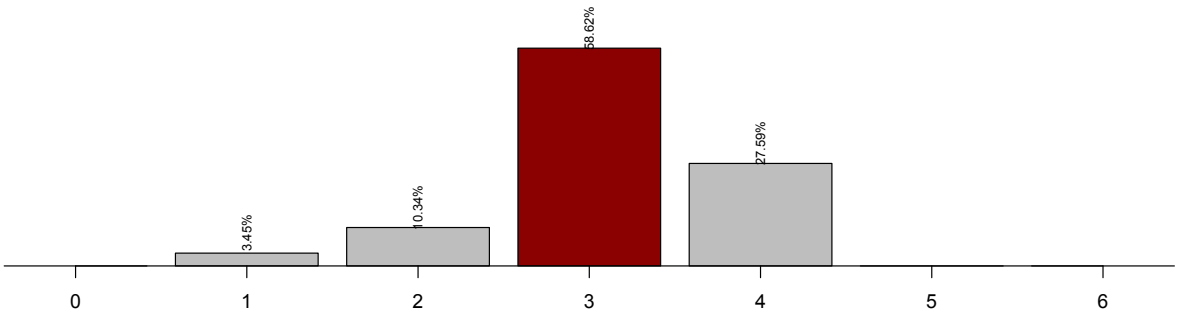
0.7
(0.65-0.74)
Num.obs. =5



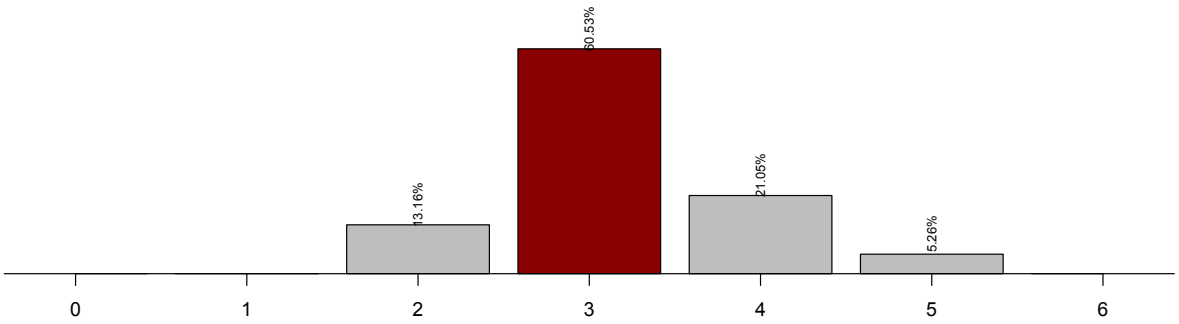
0.8
(0.75-0.84)
Num.obs.=21



0.9
(0.85-0.94)
Num. obs.=37



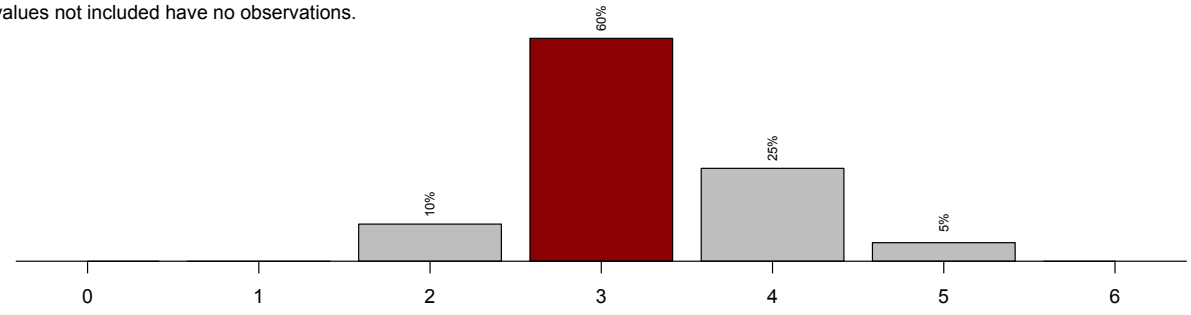
1.0
(0.95-1.04)
Num. obs.=29



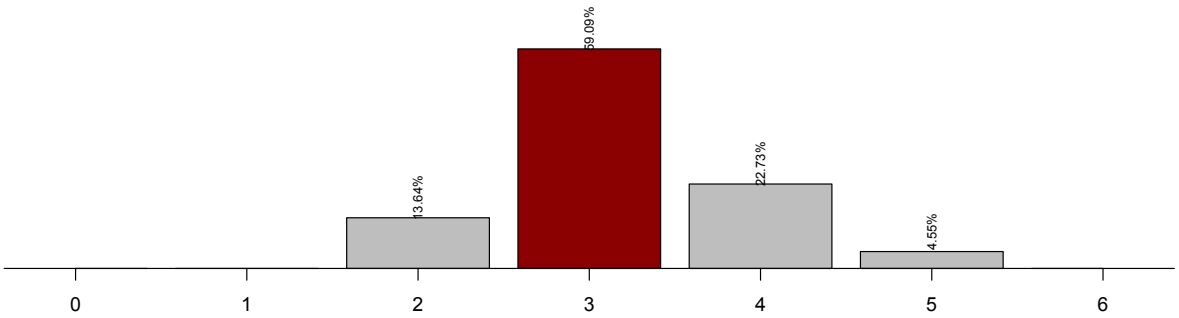
1.1
(1.05-1.14)
Num. obs.=38

$NF_{(2)}$

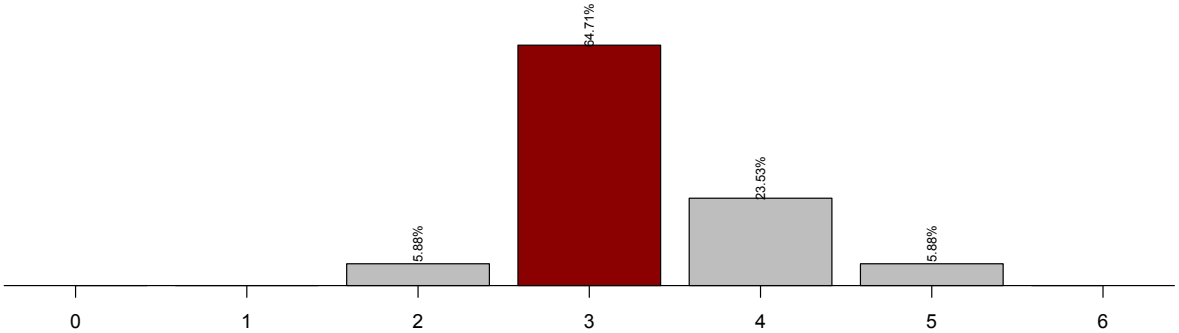
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



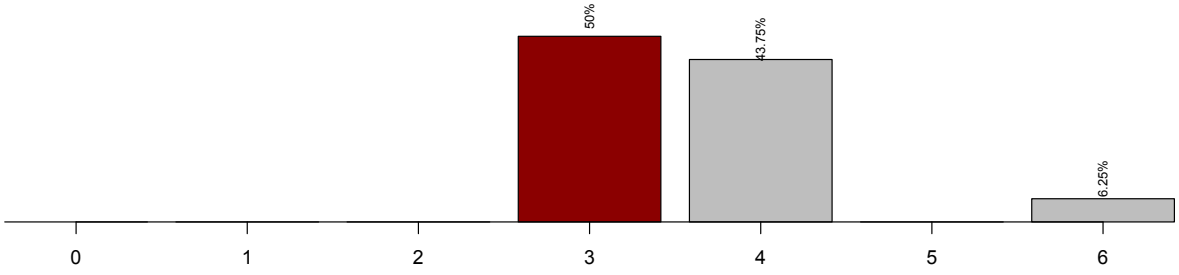
1.2
(1.15-1.24)
Num.obs. =20



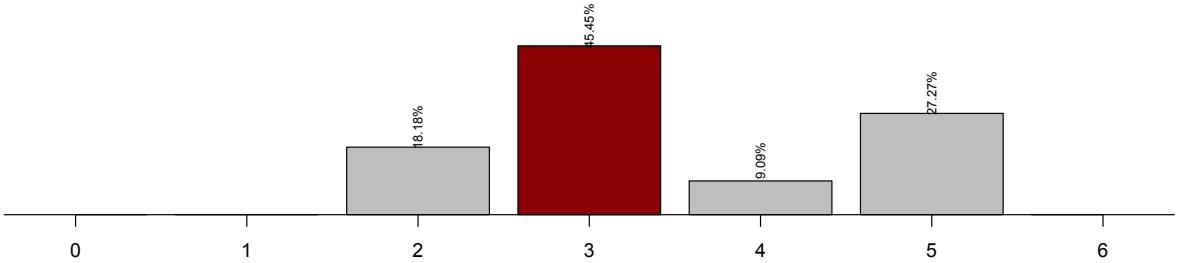
1.3
(1.25-1.34)
Num.obs.=22



1.4
(1.35-1.44)
Num. obs.=17



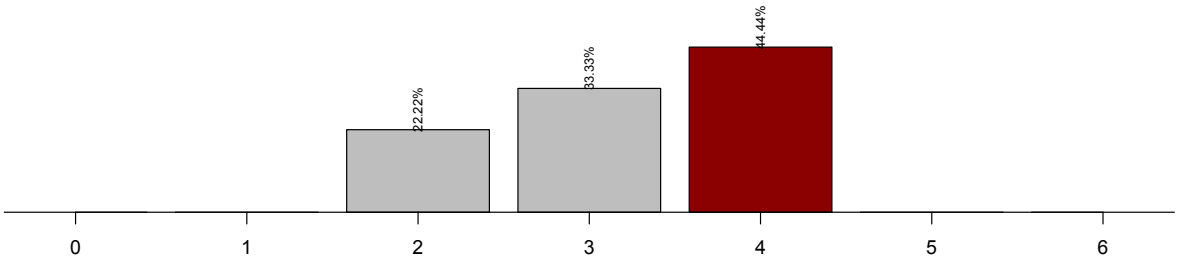
1.5
(1.45-1.54)
Num. obs.=16



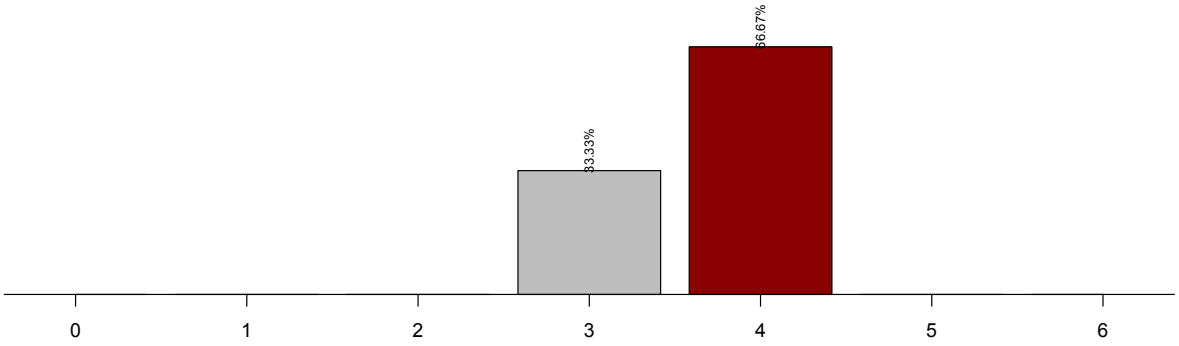
1.6
(1.55-1.64)
Num. obs.=11

$NF_{(3)}$

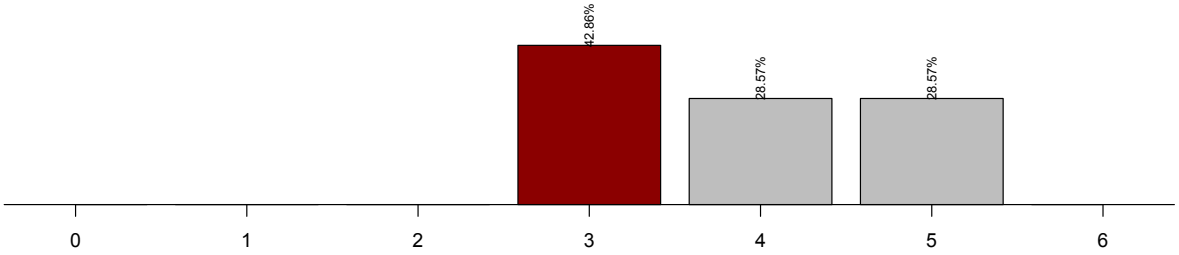
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



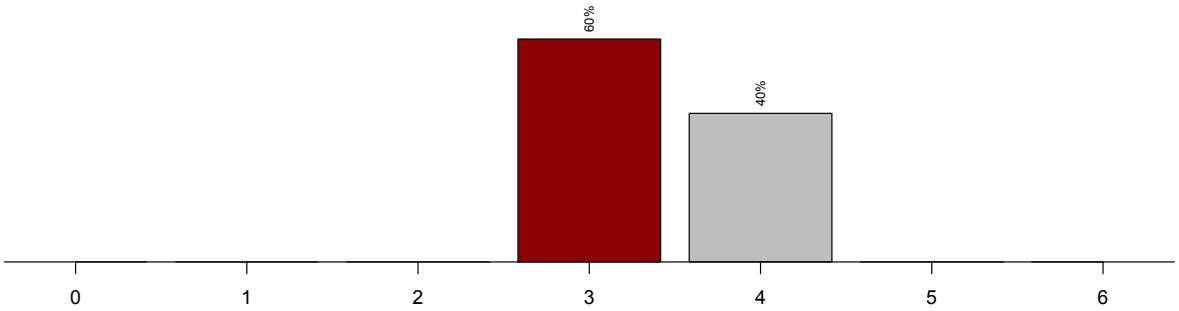
1.7
(1.65-1.74)
Num.obs. =9



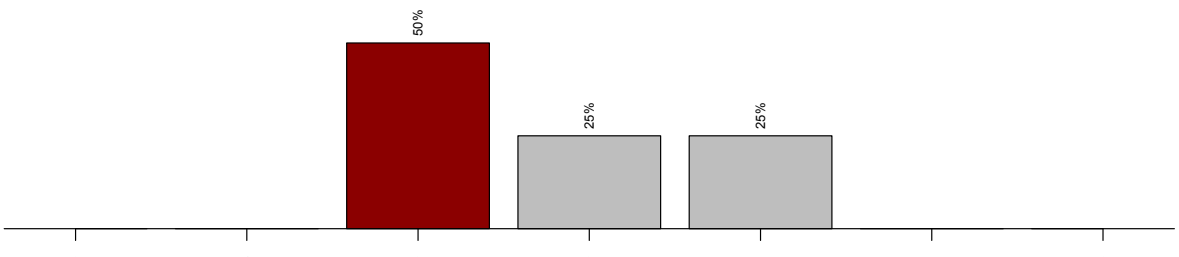
1.8
(1.75-1.84)
Num.obs.=3



1.9
(1.85-1.94)
Num. obs.=7



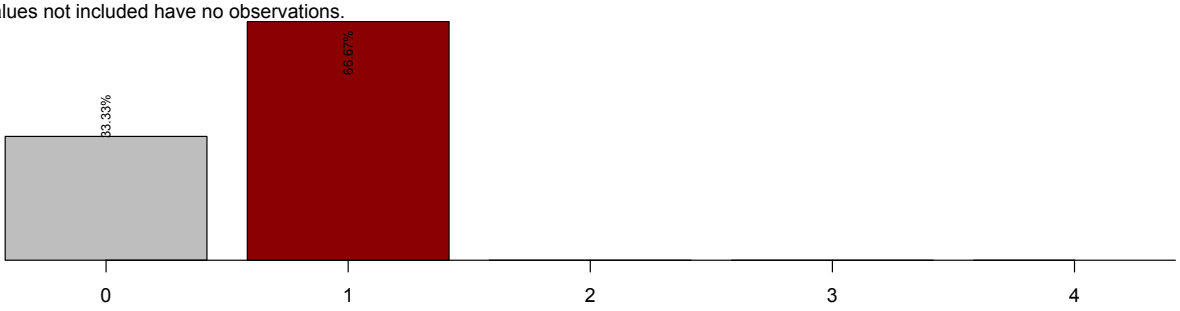
2.0
(1.95-2.04)
Num. obs.=5



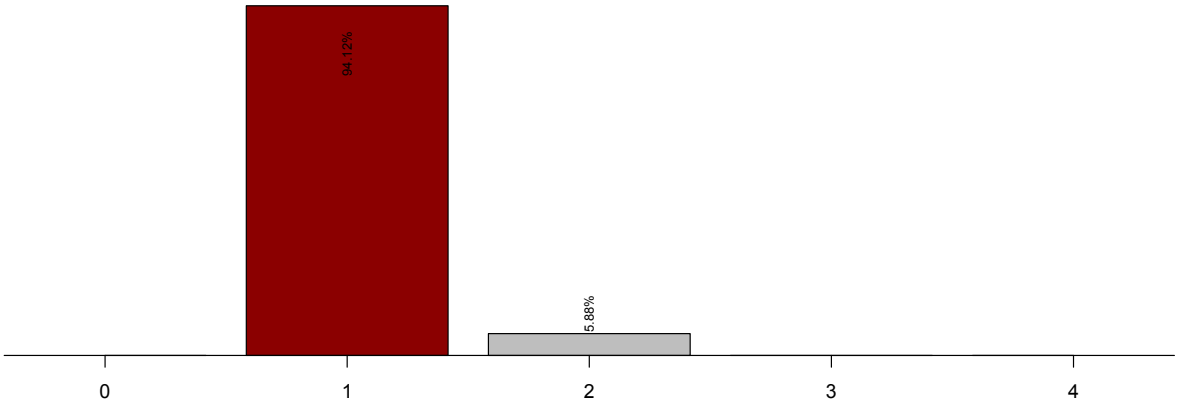
2.1
(2.05-1.14)
Num. obs.=4

$NV_{(1)}$

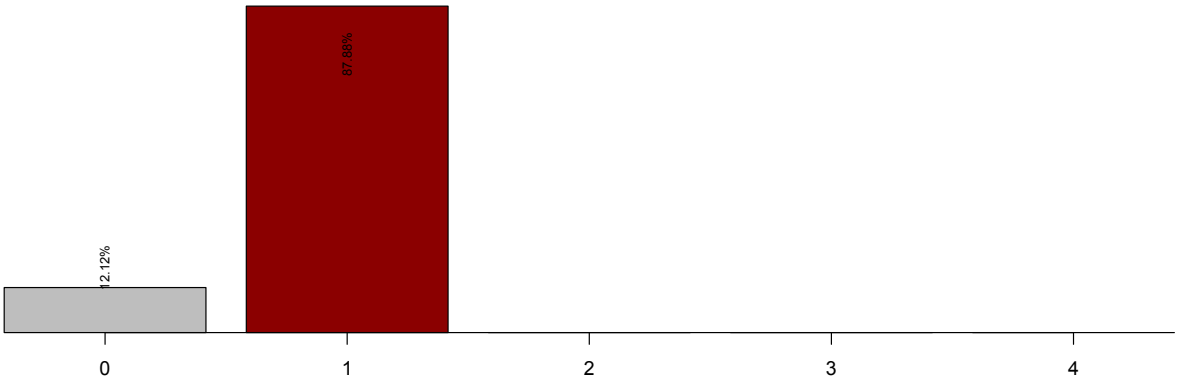
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



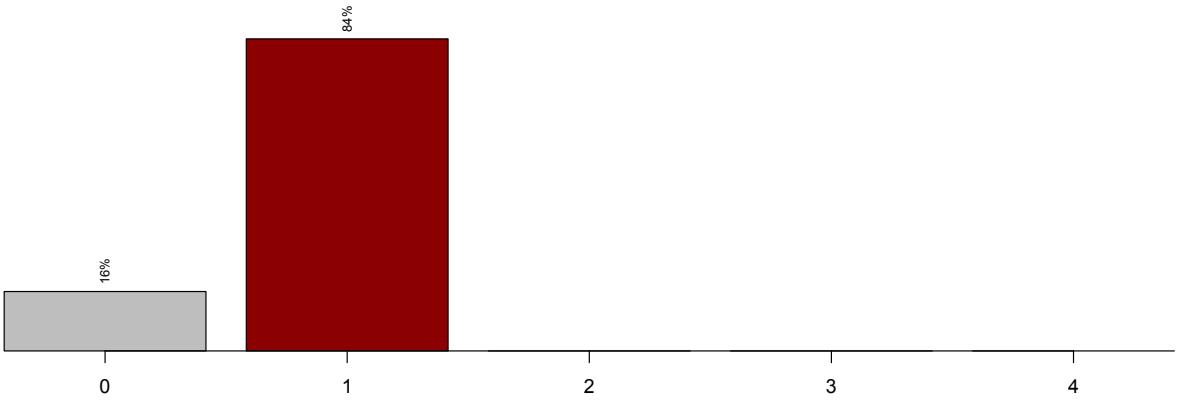
0.7
(0.65-0.74)
Num.obs. =3



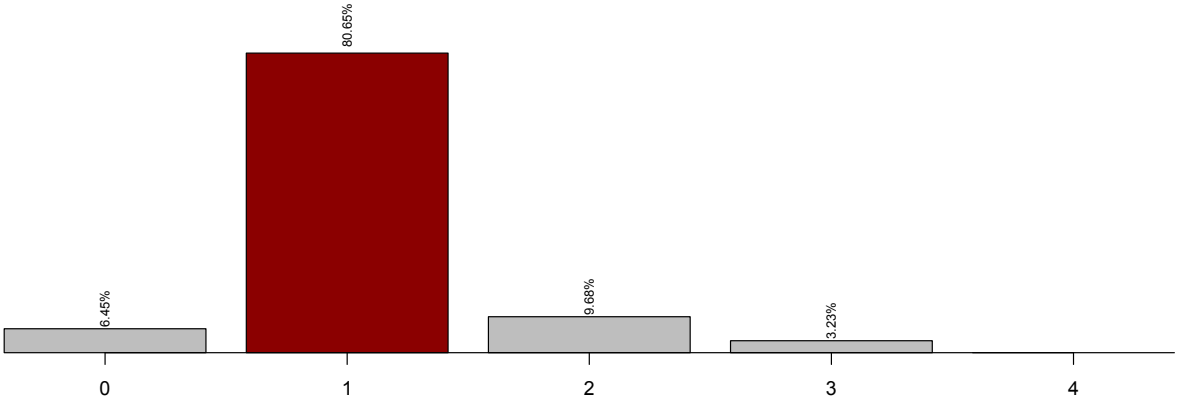
0.8
(0.75-0.84)
Num.obs.=17



0.9
(0.85-0.94)
Num. obs.=33



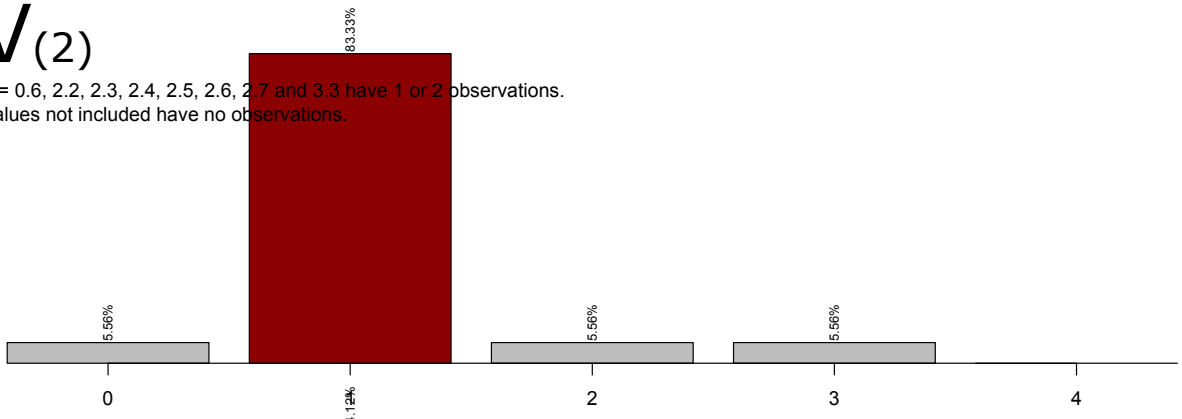
1.0
(0.95-1.04)
Num. obs.=25



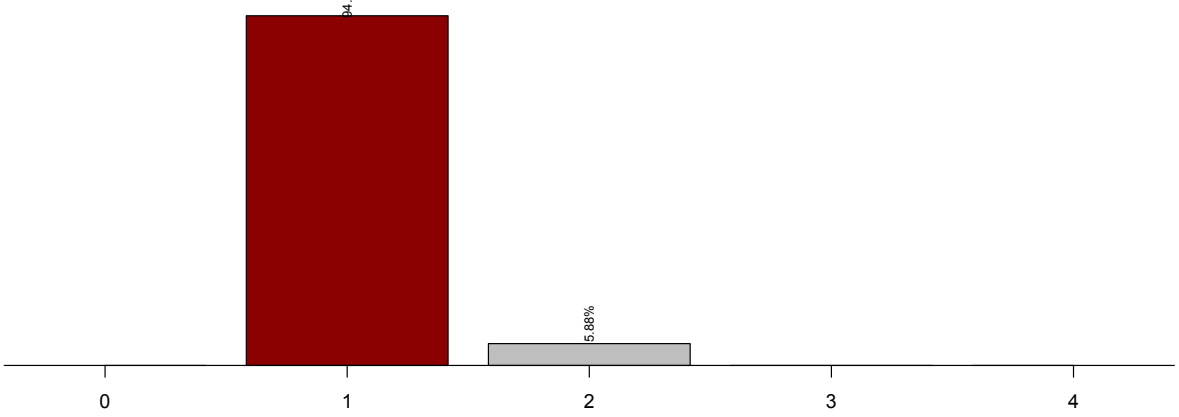
1.1
(1.05-1.14)
Num. obs.=31

$NV_{(2)}$

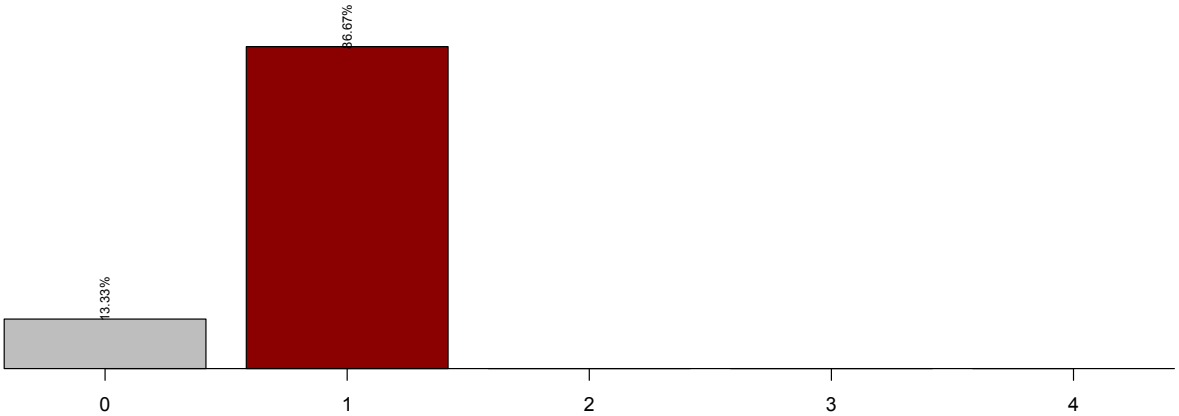
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



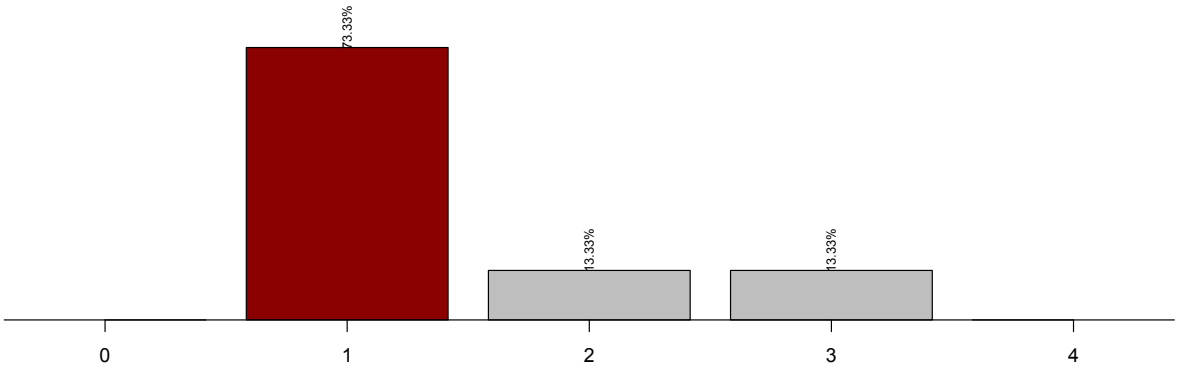
1.2
(1.15-1.24)
Num.obs. =18



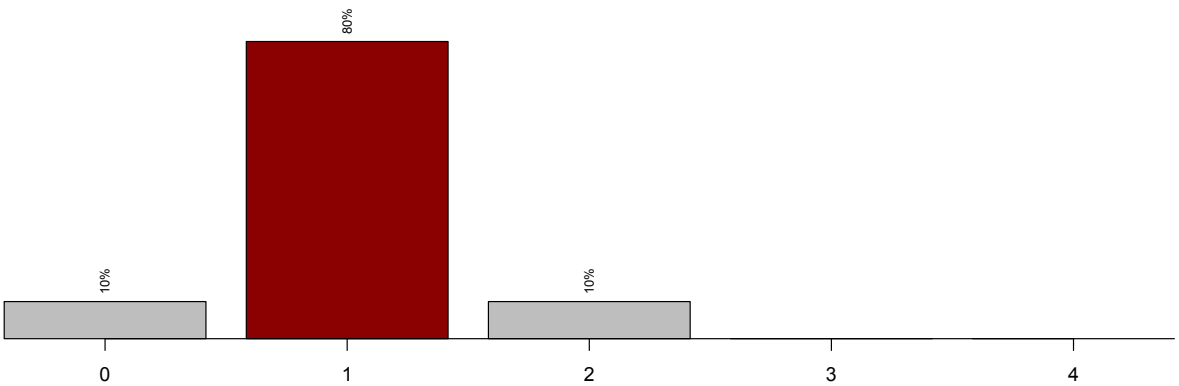
1.3
(1.25-1.34)
Num.obs.=17



1.4
(1.35-1.44)
Num. obs.=15



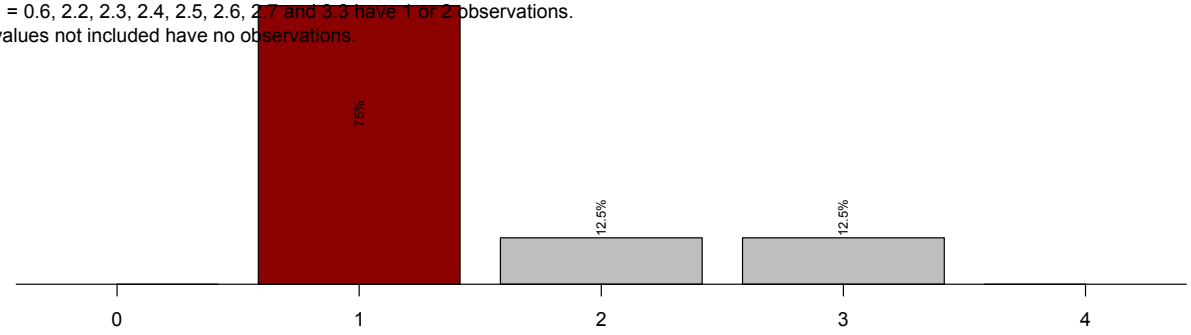
1.5
(1.45-1.54)
Num. obs.=15



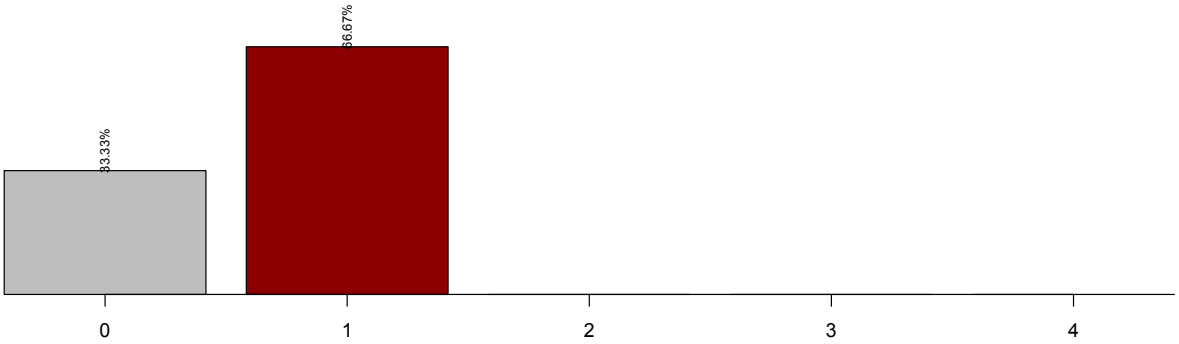
1.6
(1.55-1.64)
Num. obs.=10

$NV_{(3)}$

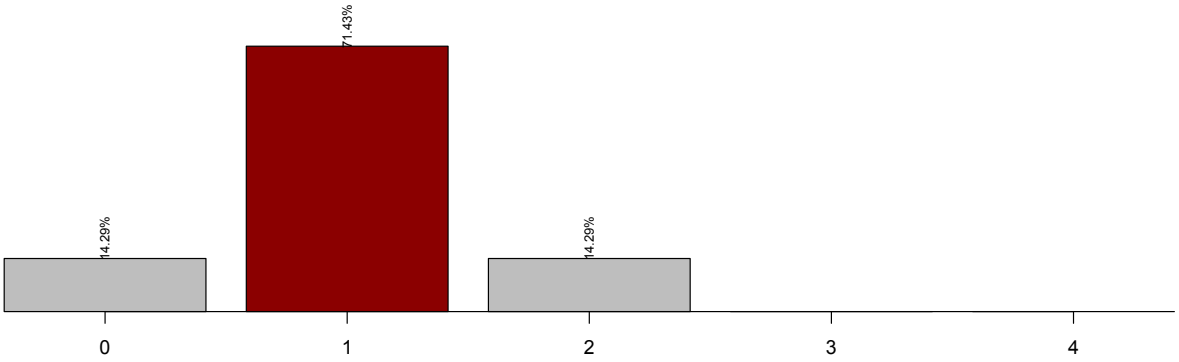
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



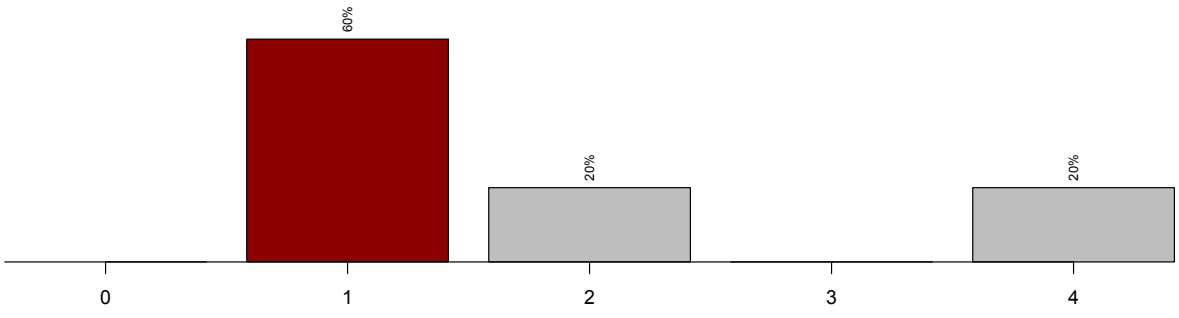
1.7
(1.65-1.74)
Num.obs. =8



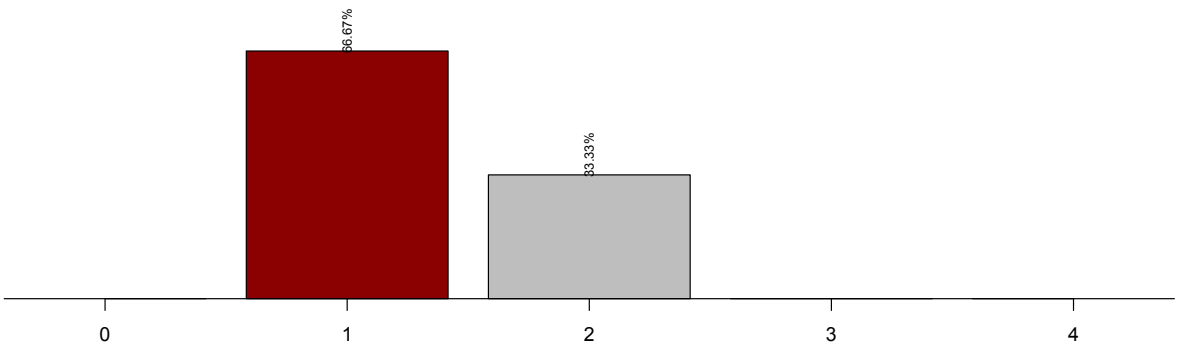
1.8
(1.75-1.84)
Num.obs.=3



1.9
(1.85-1.94)
Num. obs.=7



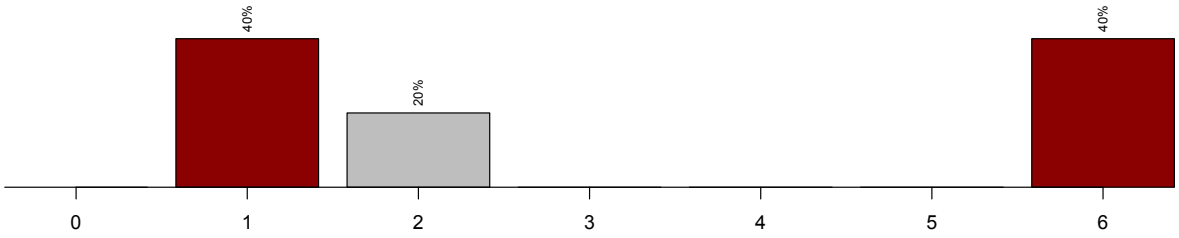
2.0
(1.95-2.04)
Num. obs.=5



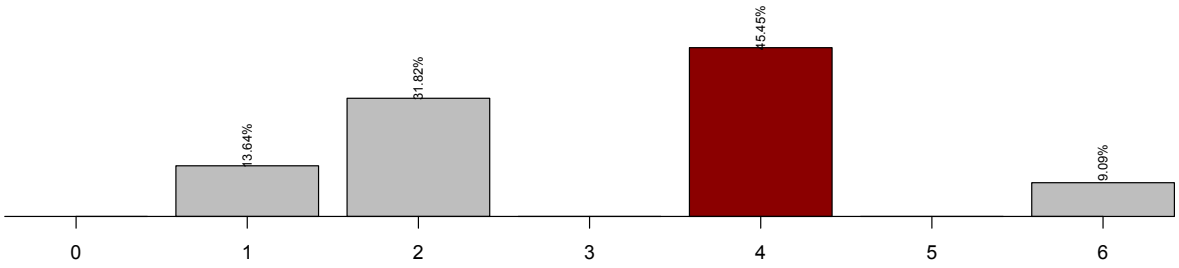
2.1
(2.05-1.14)
Num. obs.=3

$PE_{(1)}$

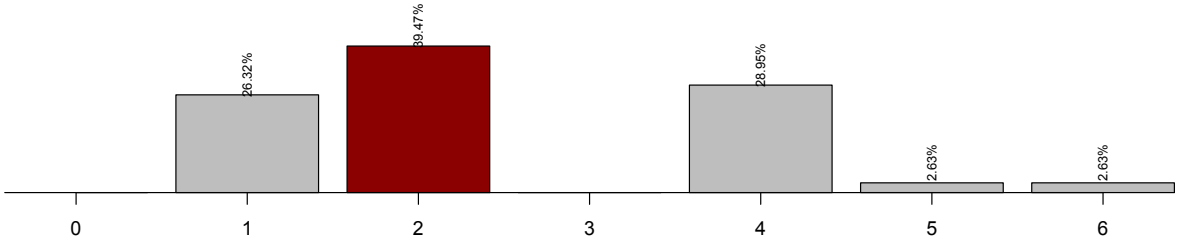
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



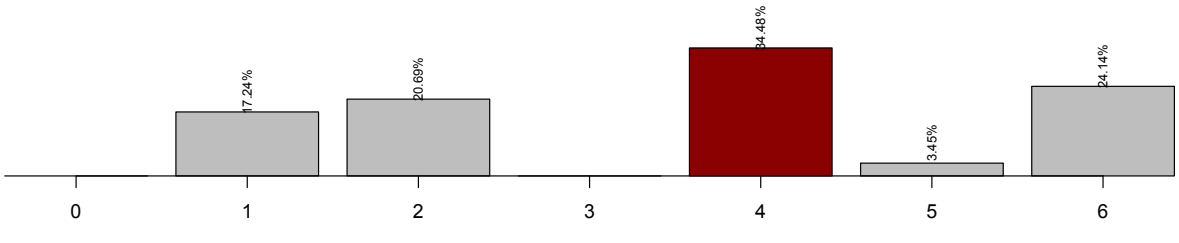
0.7
(0.65-0.74)
Num.obs. =5



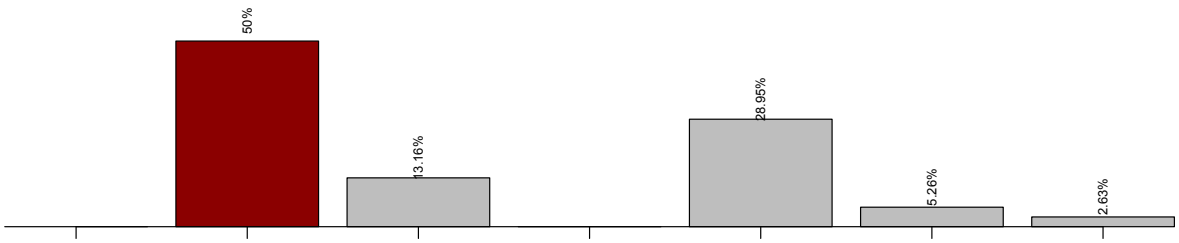
0.8
(0.75-0.84)
Num.obs.=22



0.9
(0.85-0.94)
Num. obs.=38



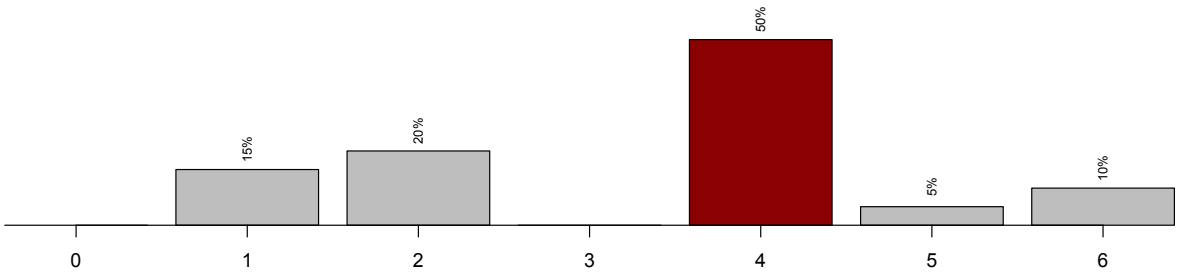
1.0
(0.95-1.04)
Num. obs.=29



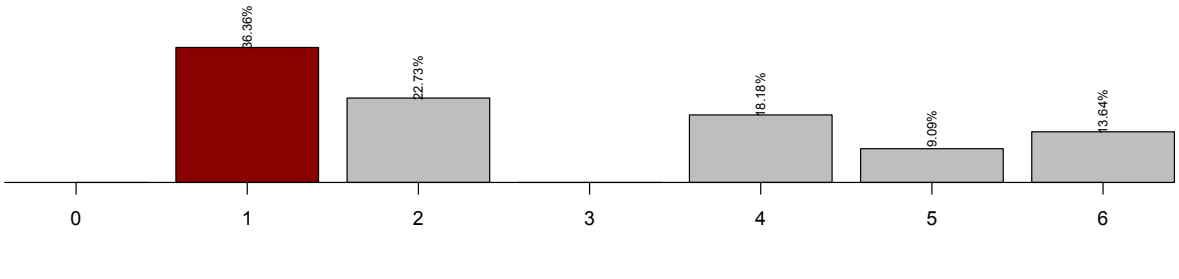
1.1
(1.05-1.14)
Num. obs.=38

PE(2)

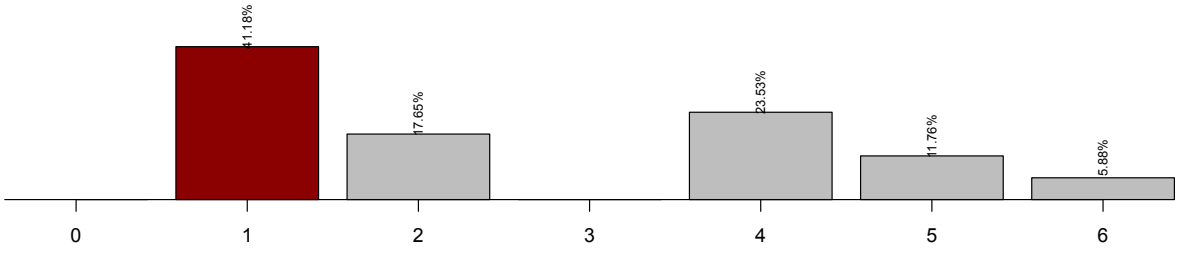
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



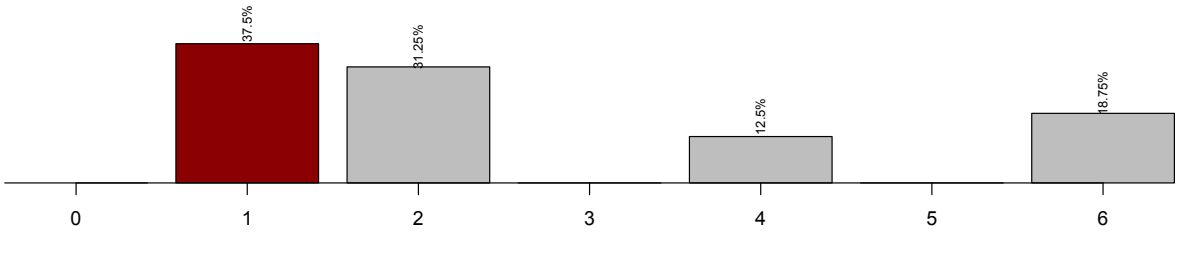
1.2
(1.15-1.24)
Num.obs. =20



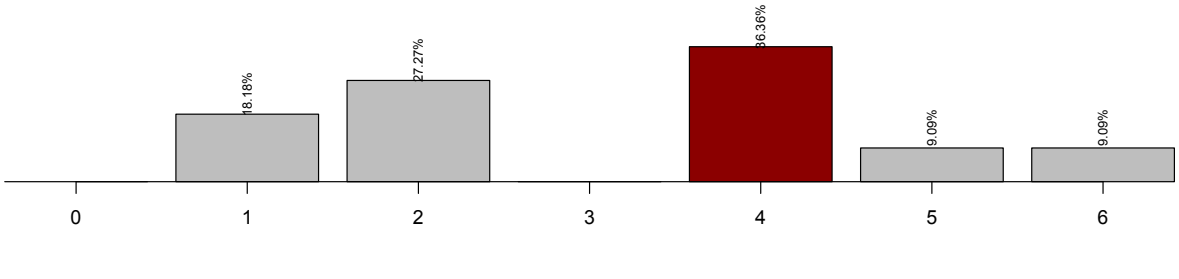
1.3
(1.25-1.34)
Num.obs.=22



1.4
(1.35-1.44)
Num. obs.=17



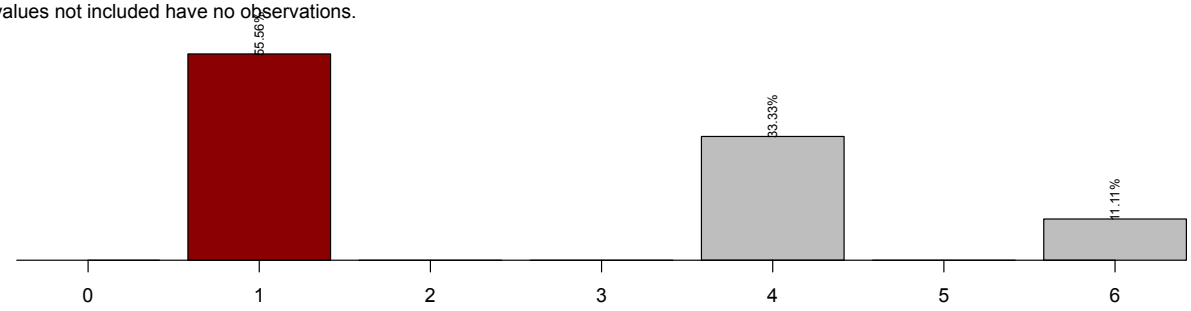
1.5
(1.45-1.54)
Num. obs.=16



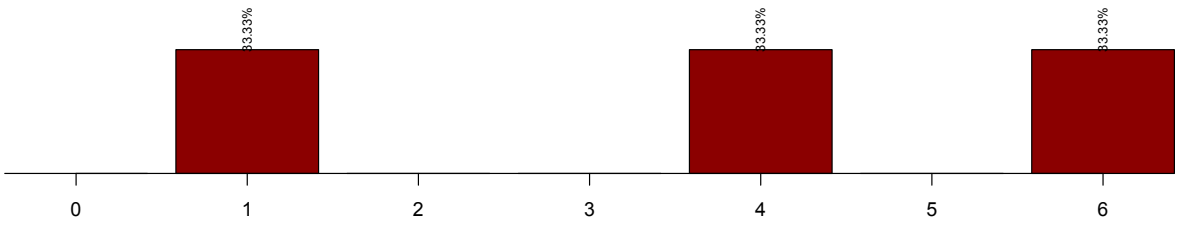
1.6
(1.55-1.64)
Num. obs.=11

$PE_{(3)}$

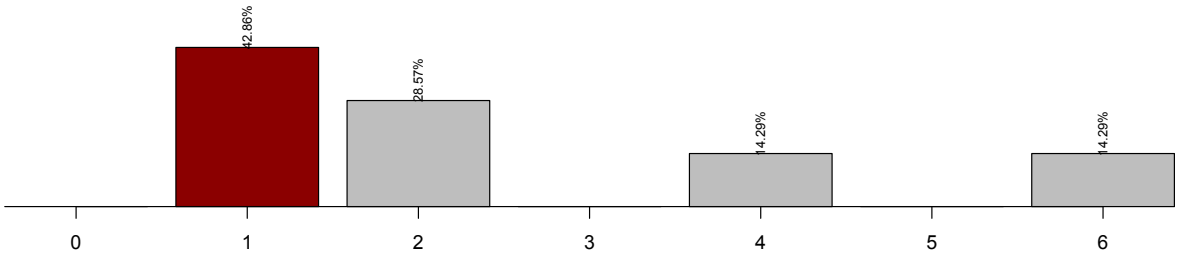
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



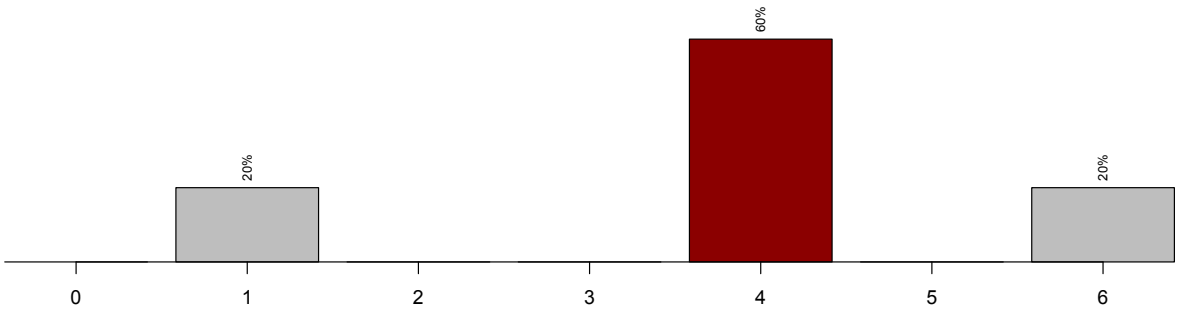
1.7
(1.65-1.74)
Num.obs. =9



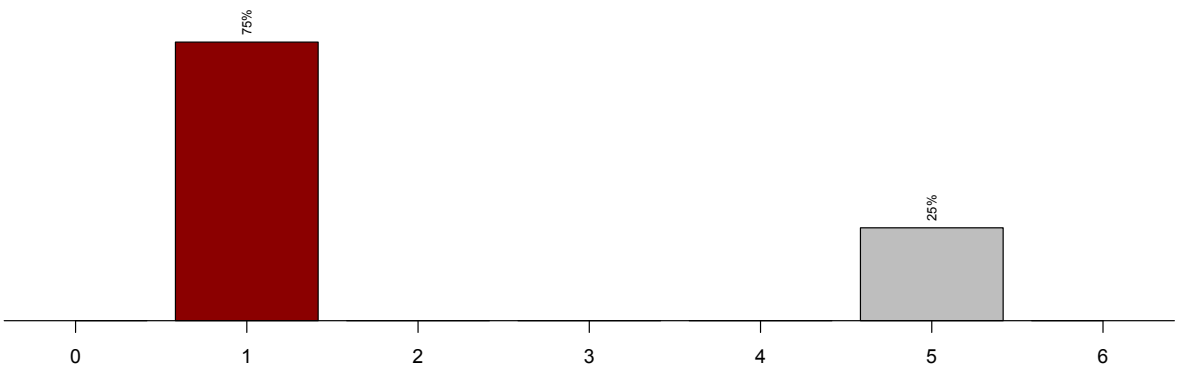
1.8
(1.75-1.84)
Num.obs.=3



1.9
(1.85-1.94)
Num. obs.=7



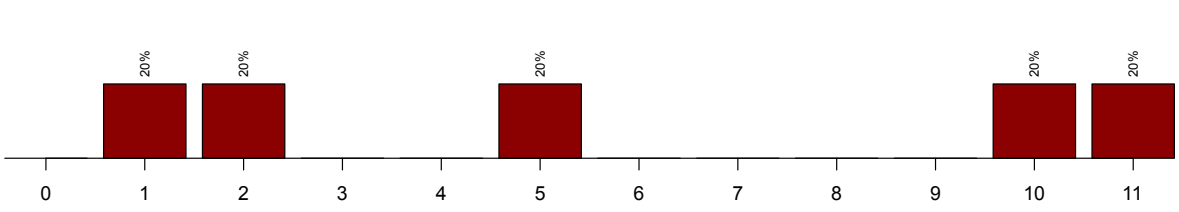
2.0
(1.95-2.04)
Num. obs.=5



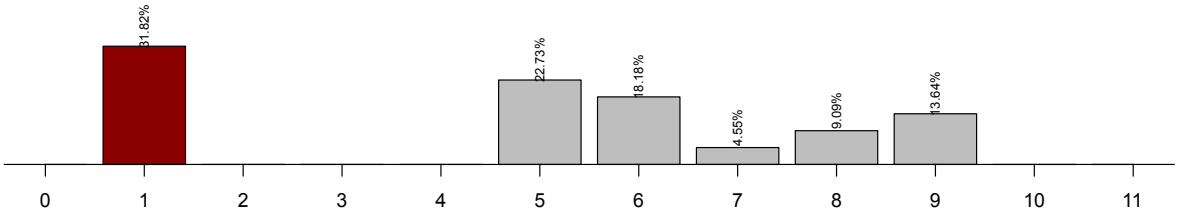
2.1
(2.05-1.14)
Num. obs.=4

PL(1)

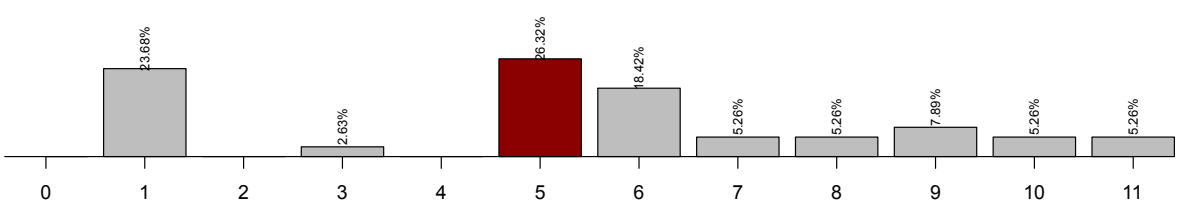
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



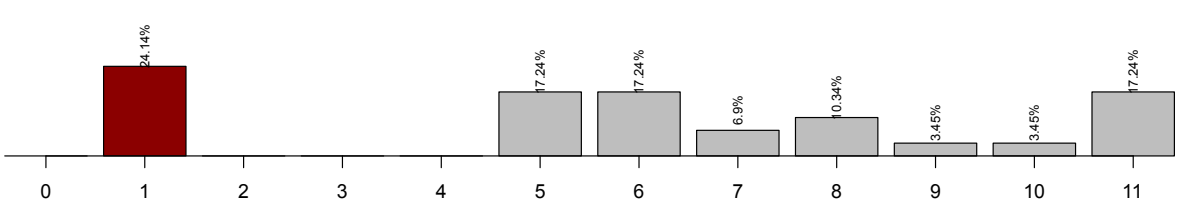
0.7
(0.65-0.74)
Num.obs. =5



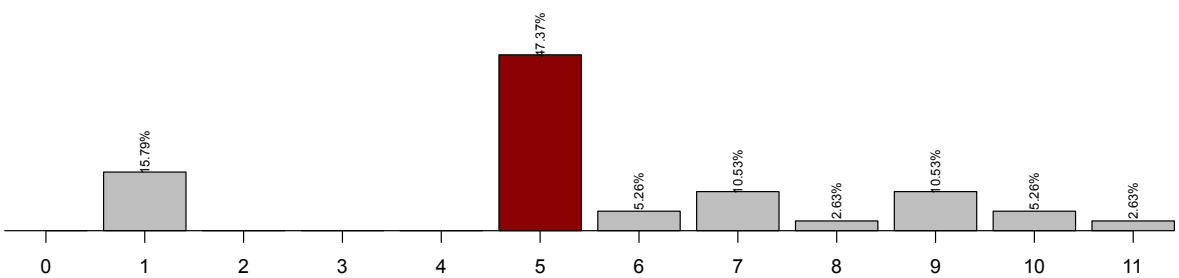
0.8
(0.75-0.84)
Num.obs.=22



0.9
(0.85-0.94)
Num. obs.=38



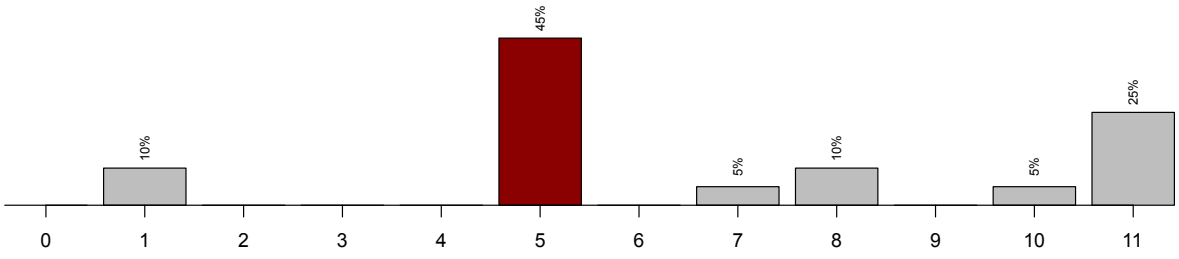
1.0
(0.95-1.04)
Num. obs.=29



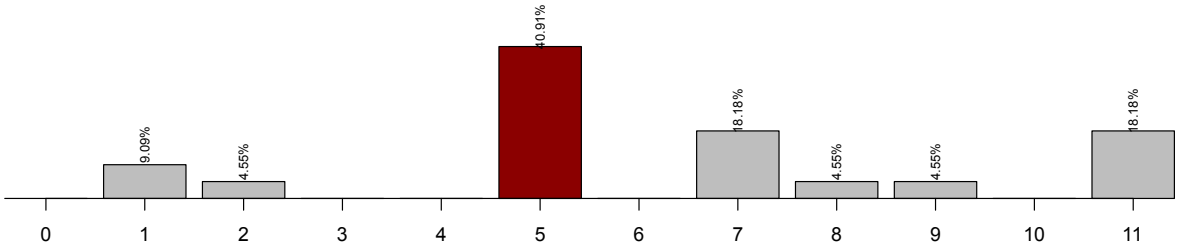
1.1
(1.05-1.14)
Num. obs.=38

PL(2)

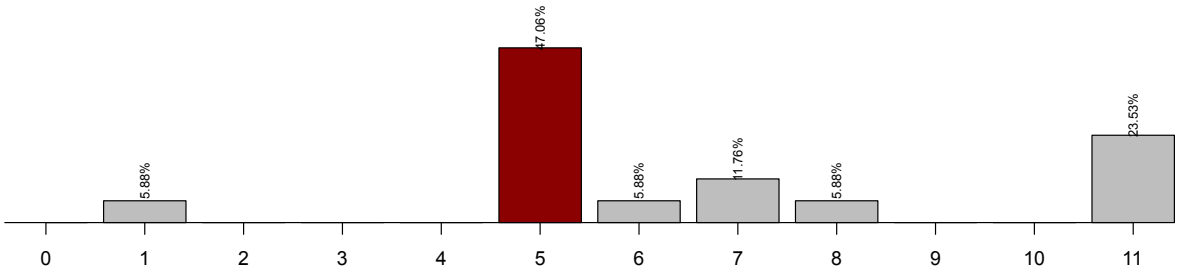
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



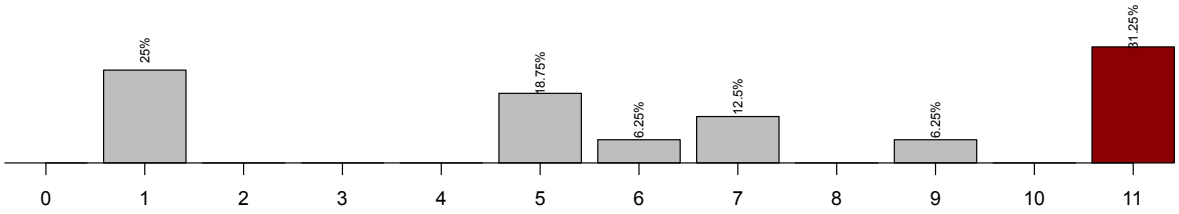
1.2
(1.15-1.24)
Num.obs. =20



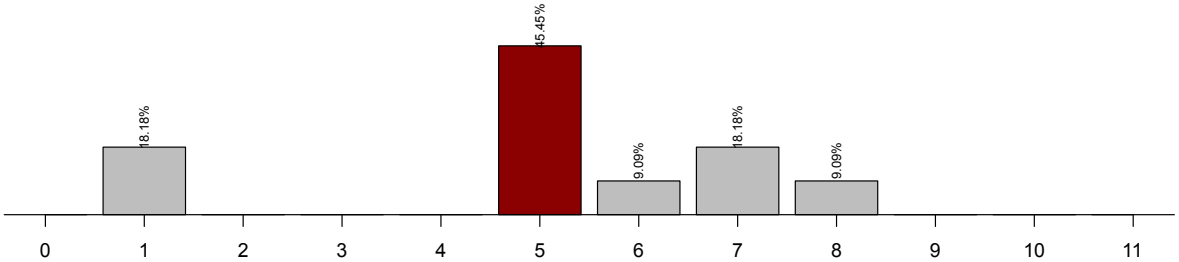
1.3
(1.25-1.34)
Num.obs.=22



1.4
(1.35-1.44)
Num. obs.=17



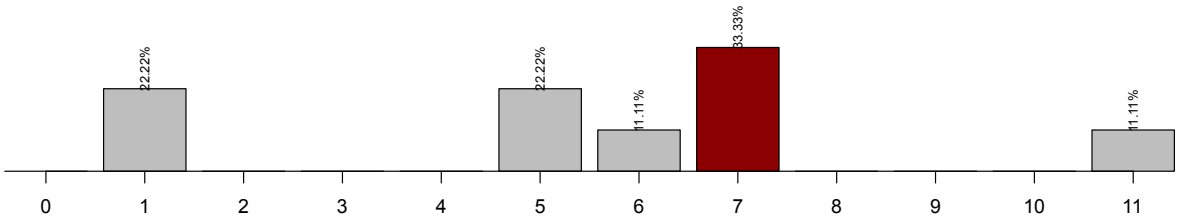
1.5
(1.45-1.54)
Num. obs.=16



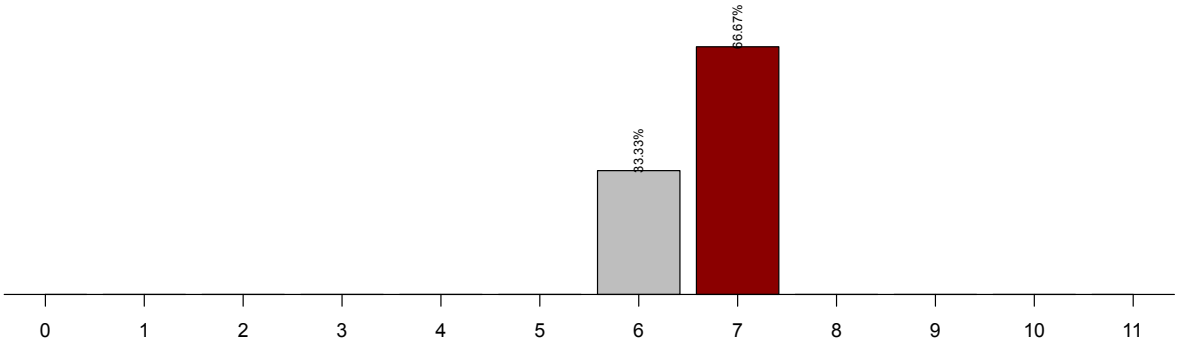
1.6
(1.55-1.64)
Num. obs.=11

PL(3)

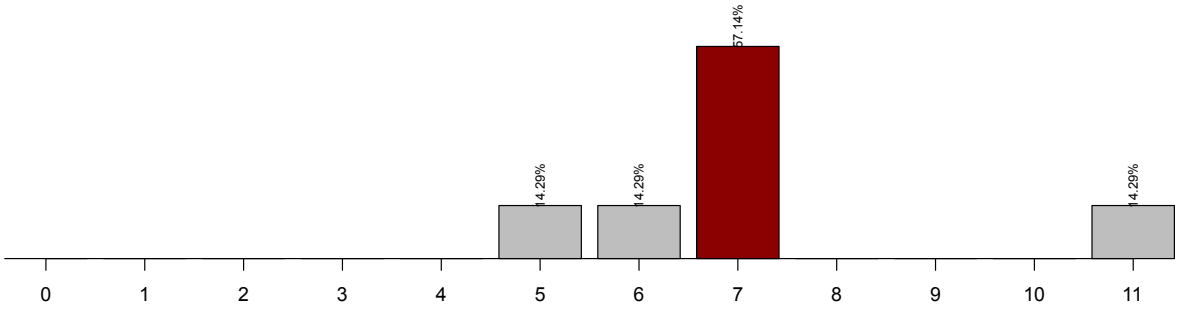
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



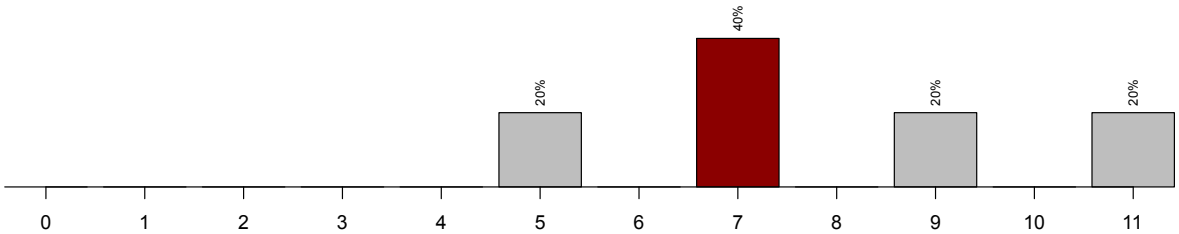
1.7
(1.65-1.74)
Num.obs. =9



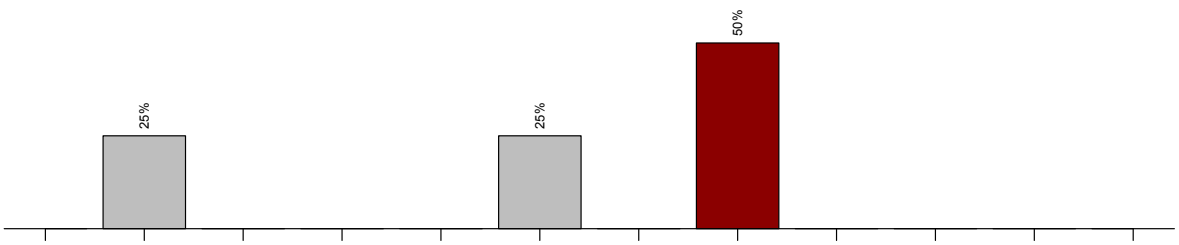
1.8
(1.75-1.84)
Num.obs.=3



1.9
(1.85-1.94)
Num. obs.=7



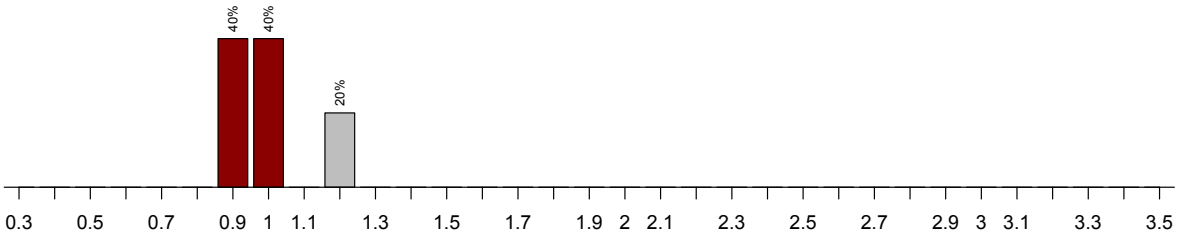
2.0
(1.95-2.04)
Num. obs.=5



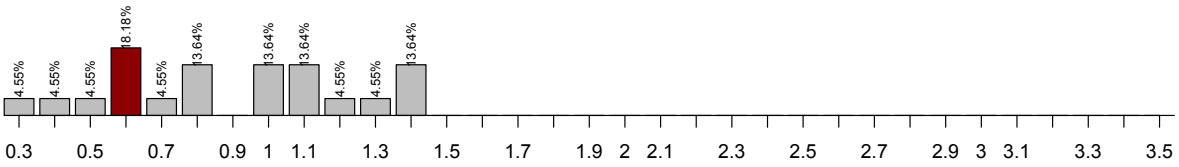
2.1
(2.05-1.14)
Num. obs.=4

T2R1(1)

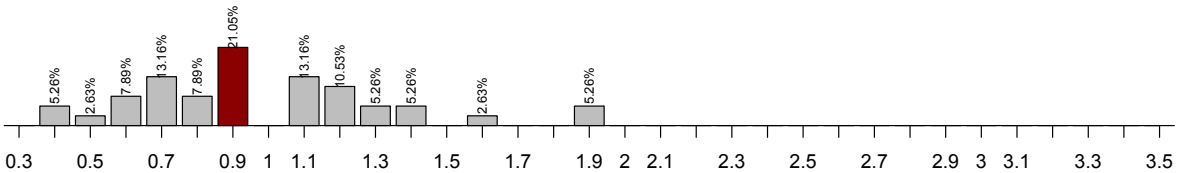
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



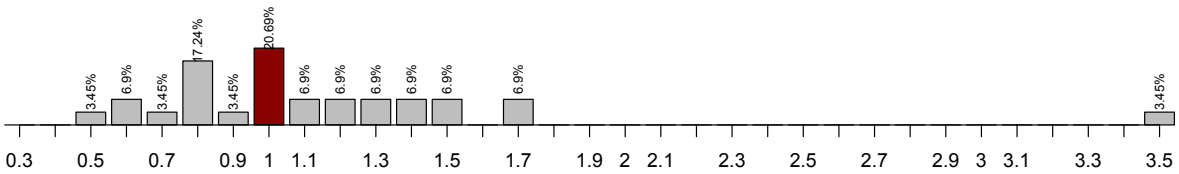
0.7
(0.65-0.74)
Num.obs. =5



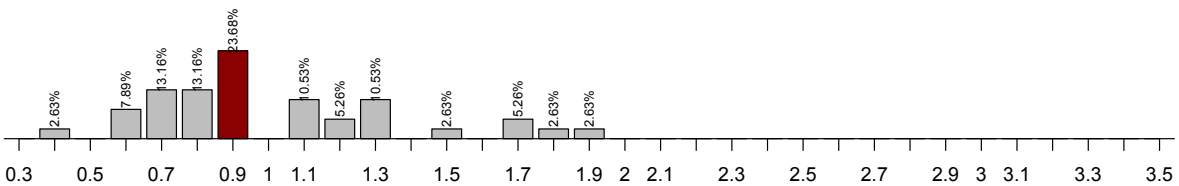
0.8
(0.75-0.84)
Num.obs.=22



0.9
(0.85-0.94)
Num. obs.=38



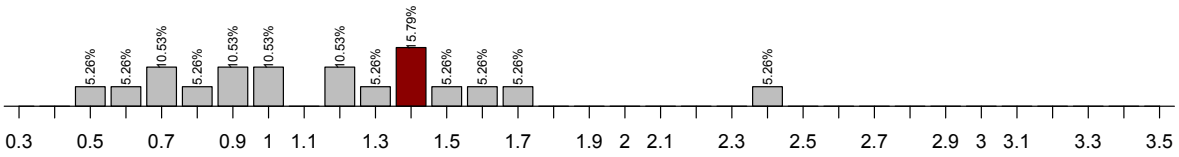
1.0
(0.95-1.04)
Num. obs.=29



1.1
(1.05-1.14)
Num. obs.=38

T2R1(2)

(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



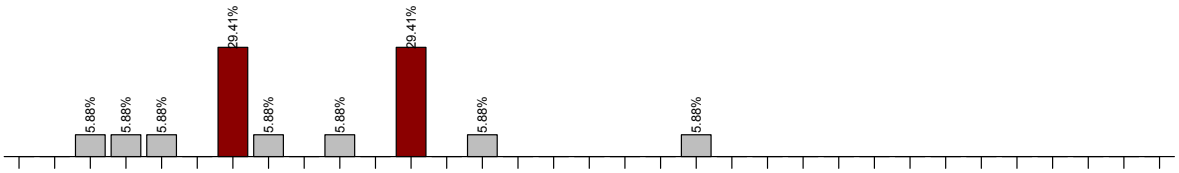
1.2
(1.15-1.24)

Num.obs. =19



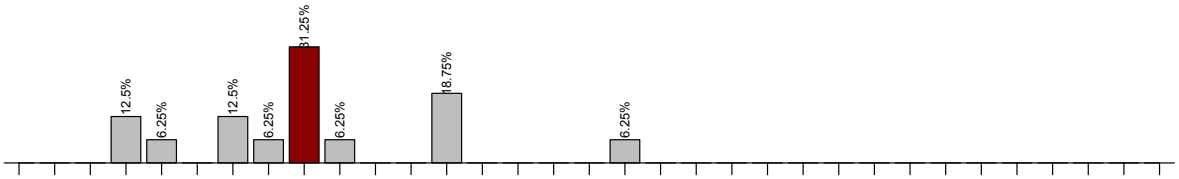
1.3
(1.25-1.34)

Num.obs.=22



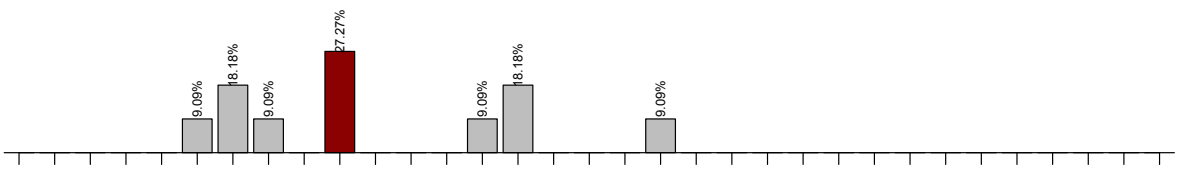
1.4
(1.35-1.44)

Num. obs.=17



1.5
(1.45-1.54)

Num. obs.=16

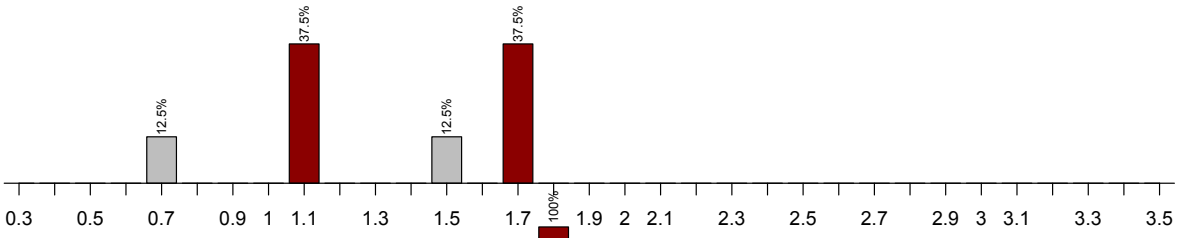


1.6
(1.55-1.64)

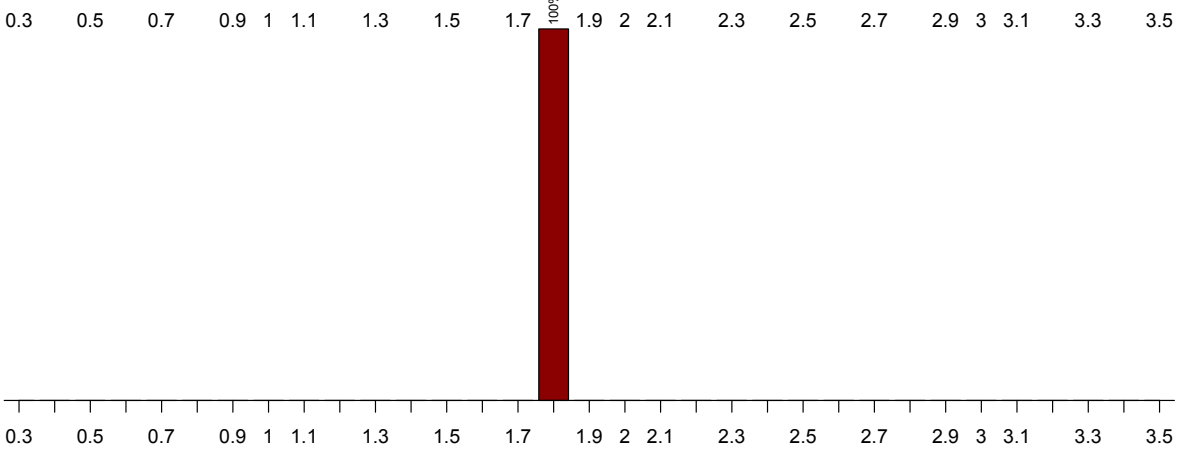
Num. obs.=11

T2R1 3)

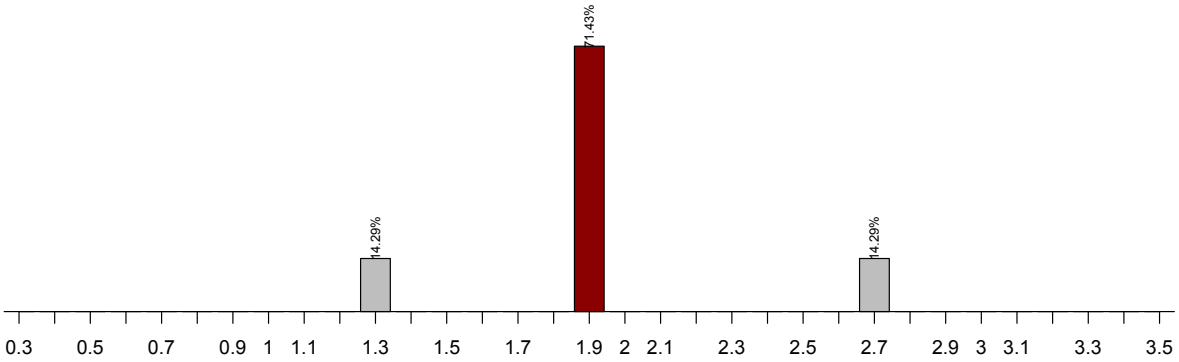
(*) T1R1 = 0.6, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 3.3 have 1 or 2 observations.
(*) The values not included have no observations.



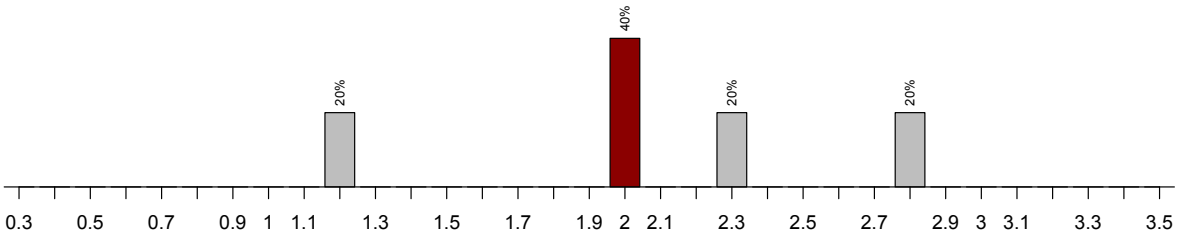
1.7
(1.65-1.74)
Num.obs. =8



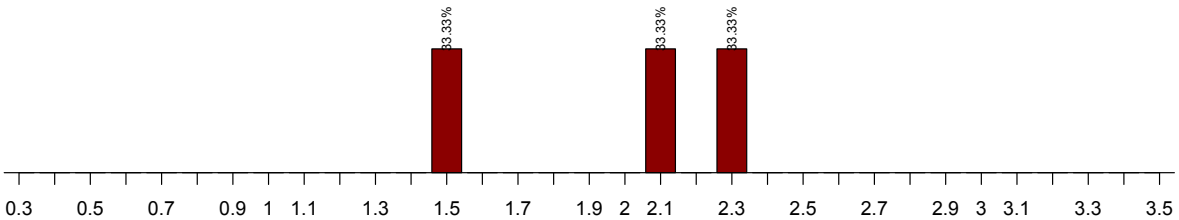
1.8
(1.75-1.84)
Num.obs.=3



1.9
(1.85-1.94)
Num. obs.=7



2.0
(1.95-2.04)
Num. obs.=5

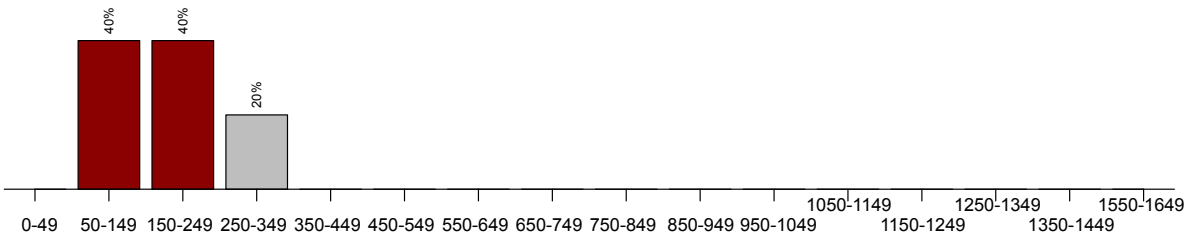


2.1
(2.05-1.14)
Num. obs.=3

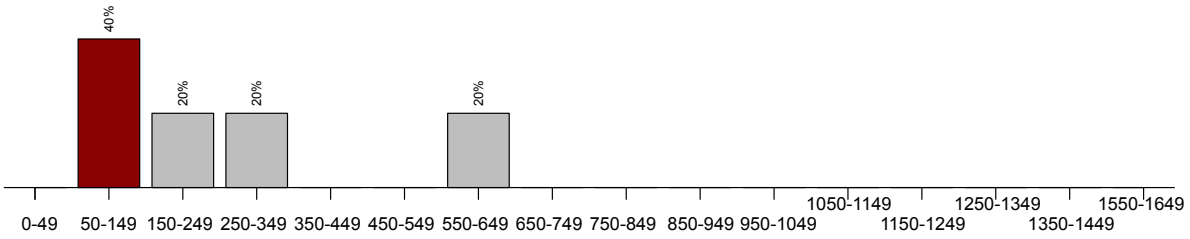
3.1.10 RESULTS REFERRED TO THE PARAMETER T2R1

$AAR_{(1)}$

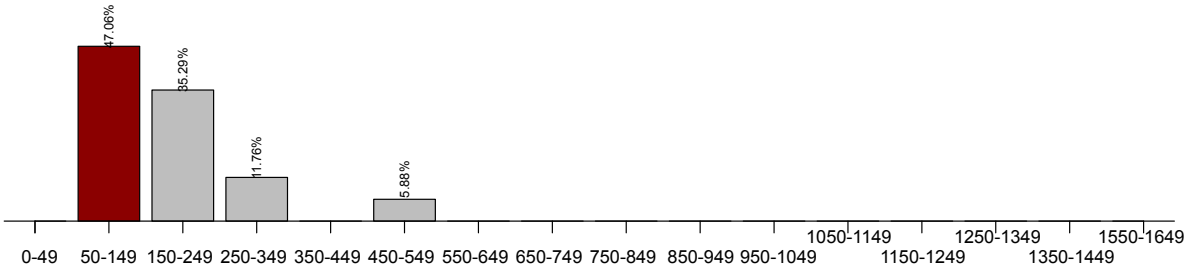
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



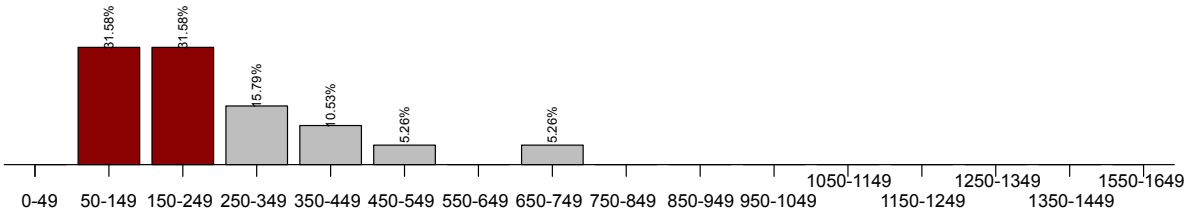
0.4
(0.35-0.44)
Num. obs. =5



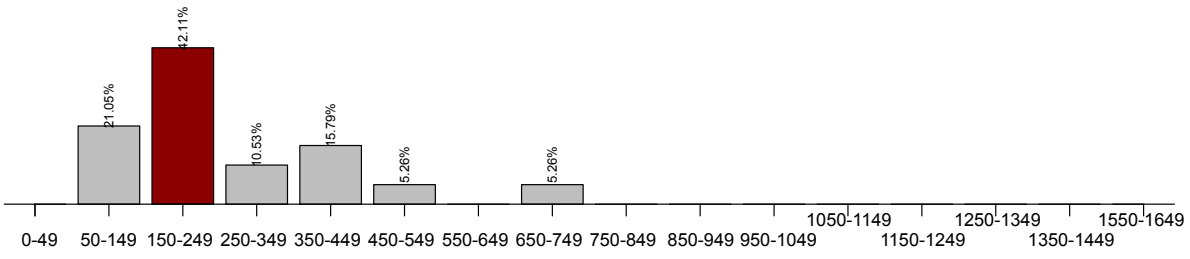
0.5
(0.45-0.54)
Num. obs. =5



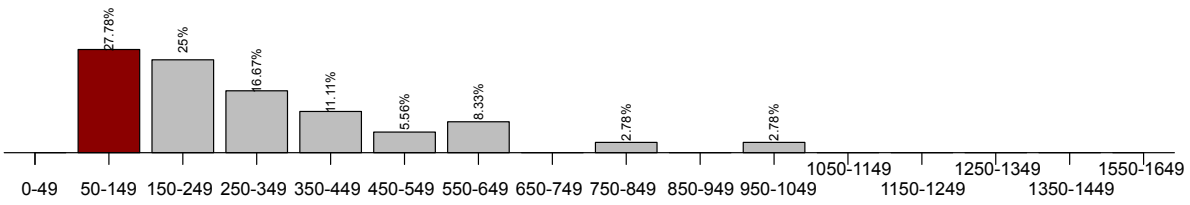
0.6
(0.55-0.64)
Num. obs.=17



0.7
(0.65-0.74)
Num. obs. =19



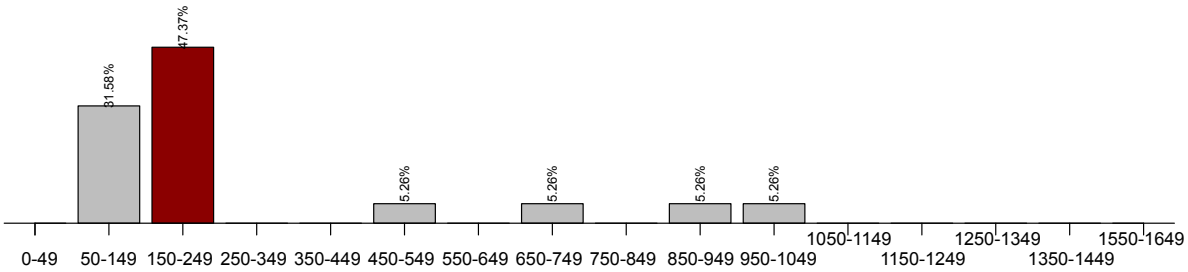
0.8
(0.75-0.84)
Num. obs. =19



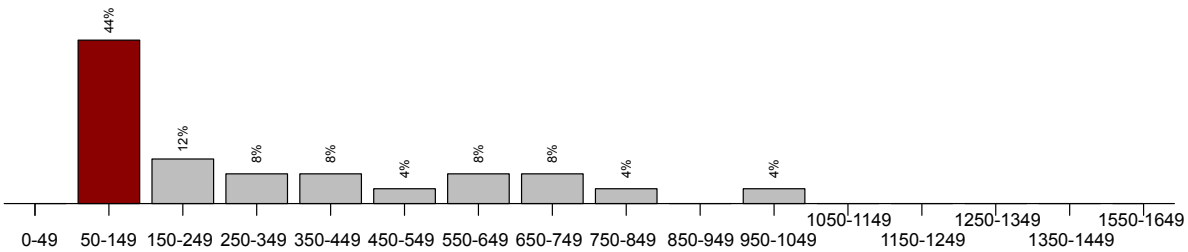
0.9
(0.85-0.94)
Num. obs. =36

AAR(2)

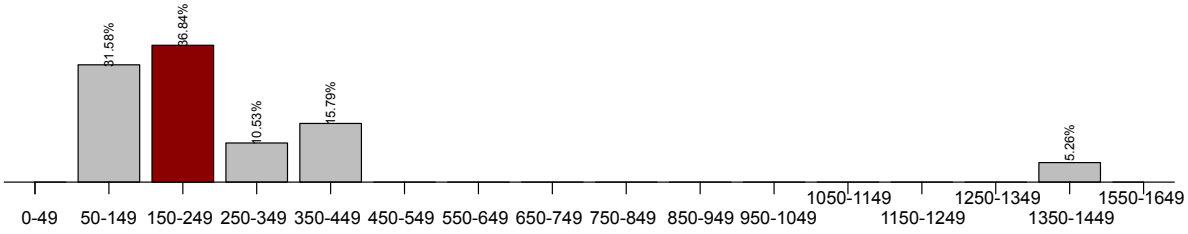
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



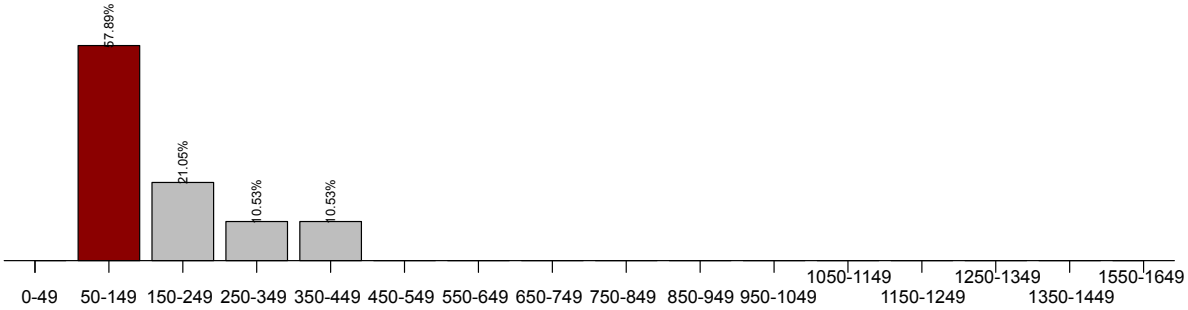
1.0
(0.95-1.04)
Num. obs. =19



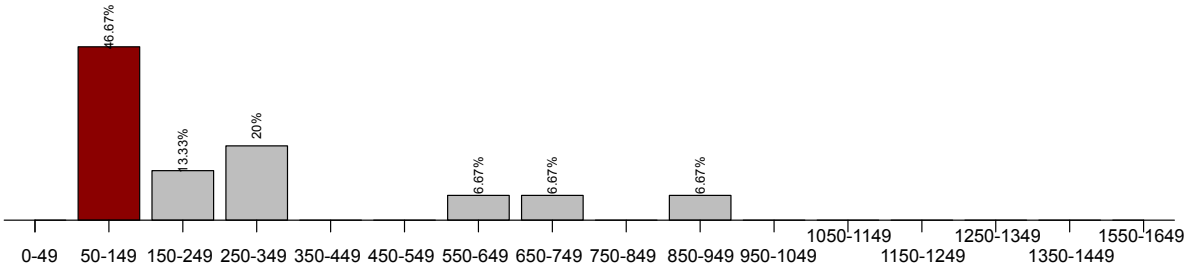
1.1
(1.05-1.14)
Num. obs. =25



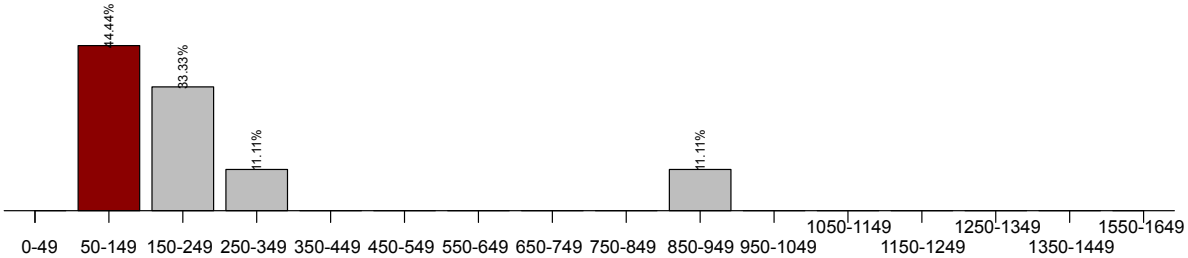
1.2
(1.15-1.24)
Num. obs.=19



1.3
(1.25-1.34)
Num. obs. =19



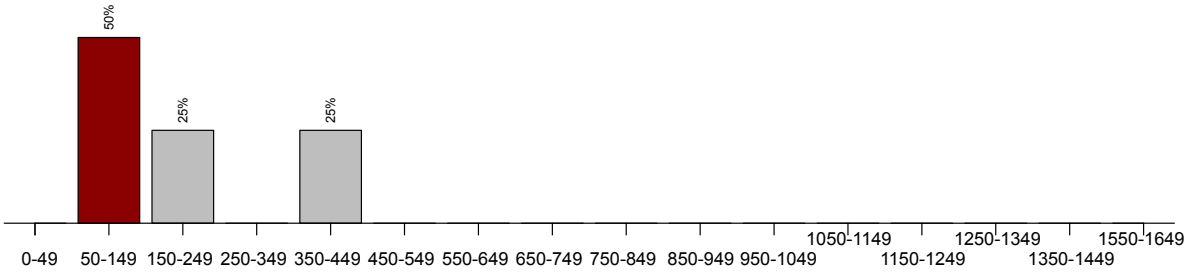
1.4
(1.35-1.44)
Num. obs. =15



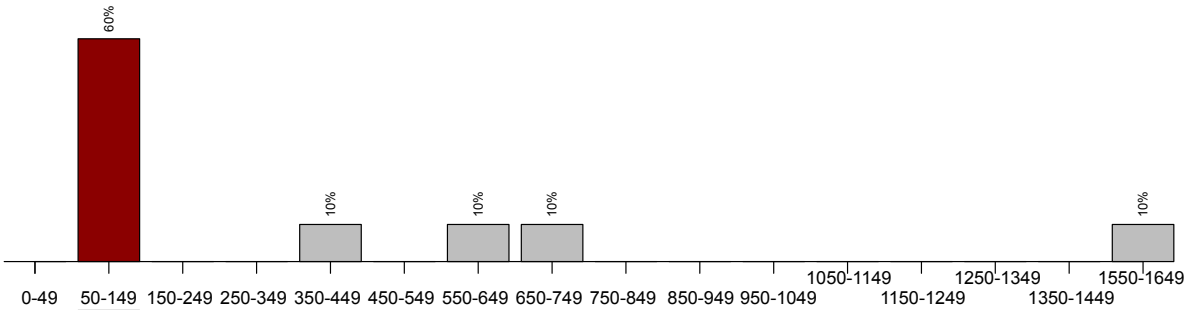
1.5
(1.45-1.54)
Num. obs. =9

AAR(3)

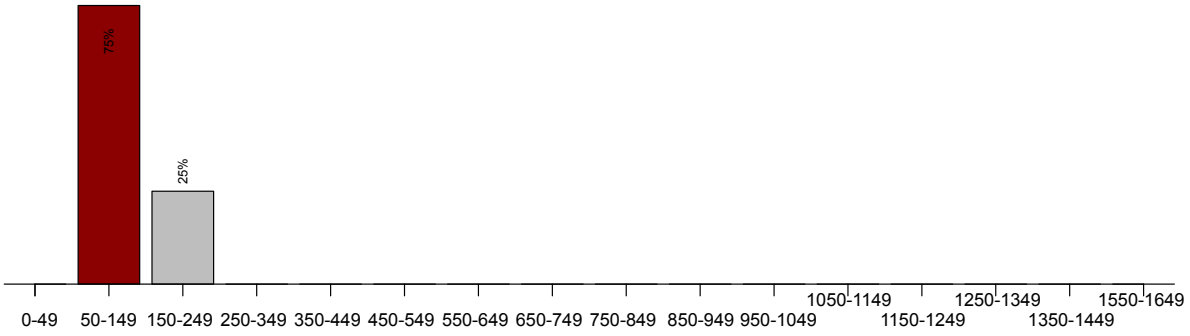
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



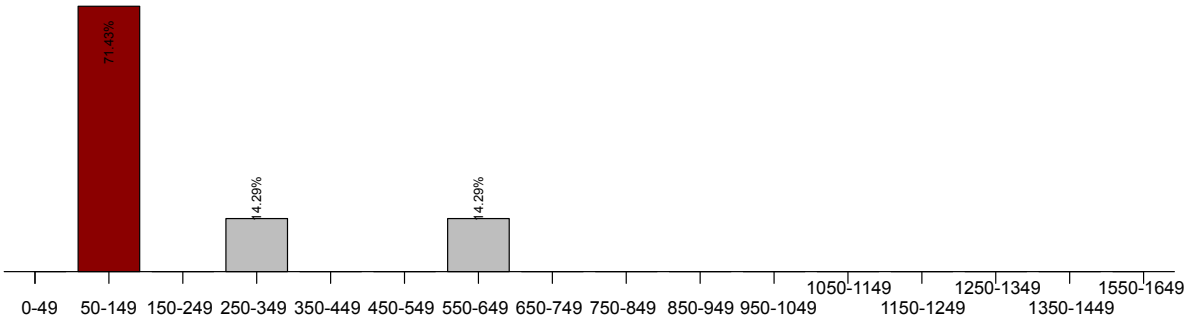
1.6
(0.95-1.04)
Num. obs. =4



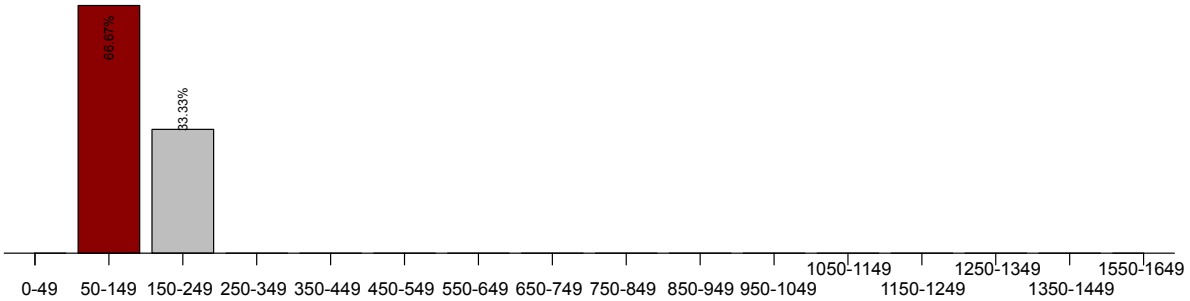
1.7
(1.05-1.14)
Num. obs. =10



1.8
(1.15-1.24)
Num. obs.=4



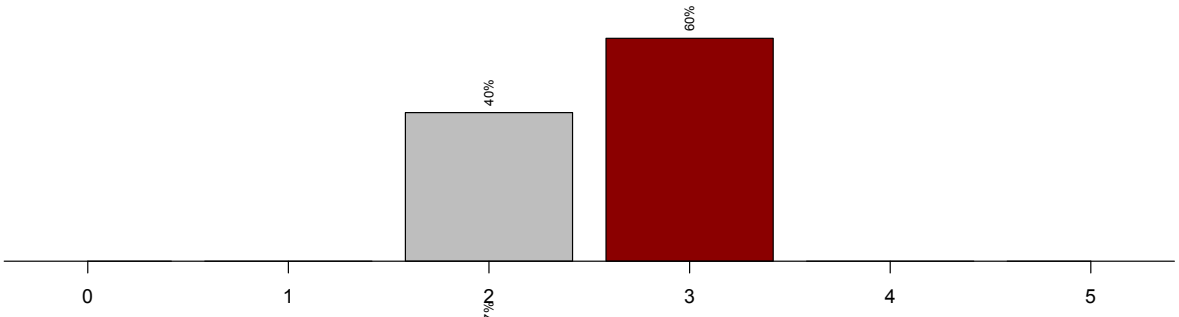
1.9
(1.25-1.34)
Num. obs. =7



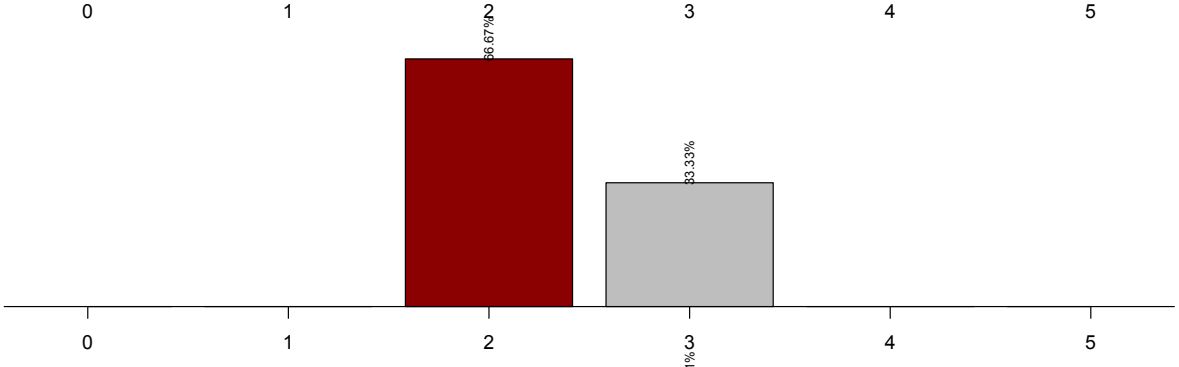
2.0
(1.35-1.44)
Num. obs. =3

LOR(1)

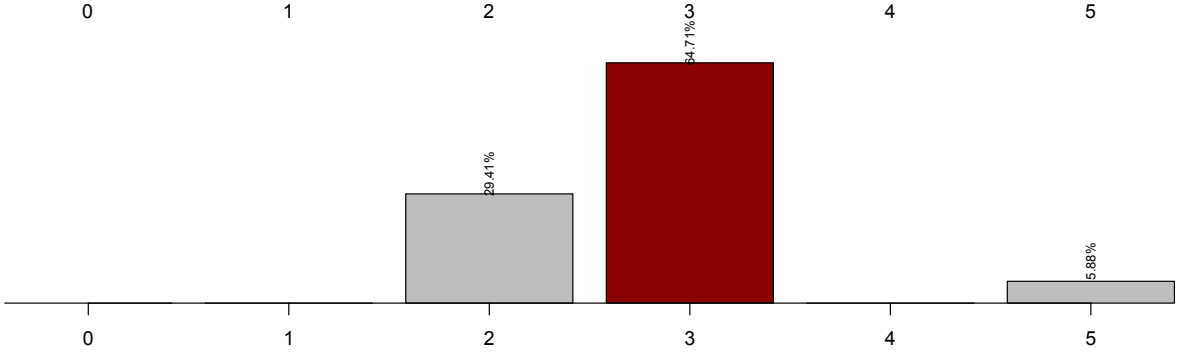
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



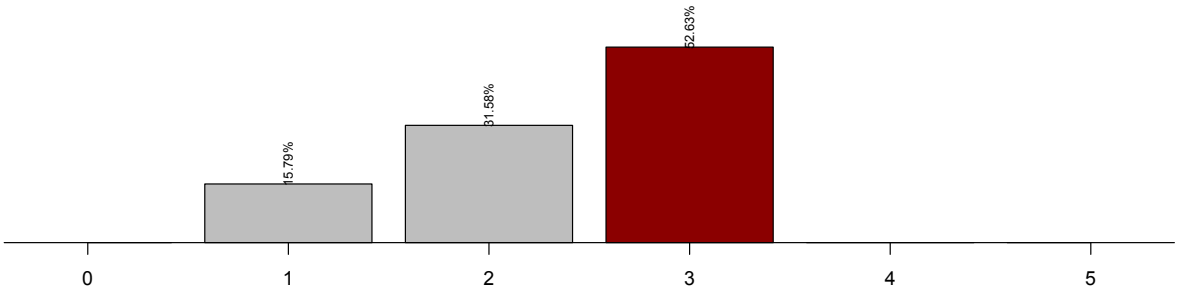
0.4
(0.35-0.44)
Num. obs. =5



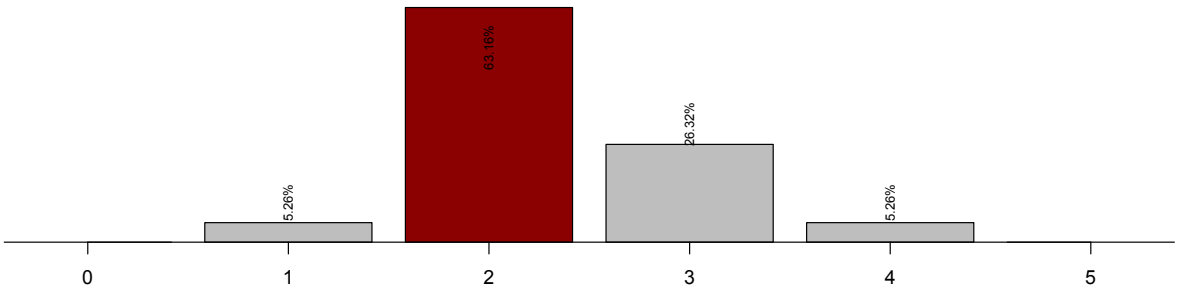
0.5
(0.45-0.54)
Num. obs. =6



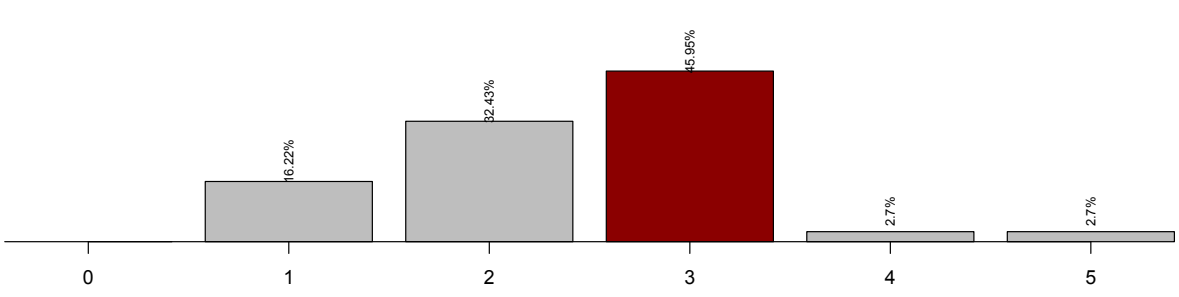
0.6
(0.55-0.64)
Num. obs.=17



0.7
(0.65-0.74)
Num. obs. =19



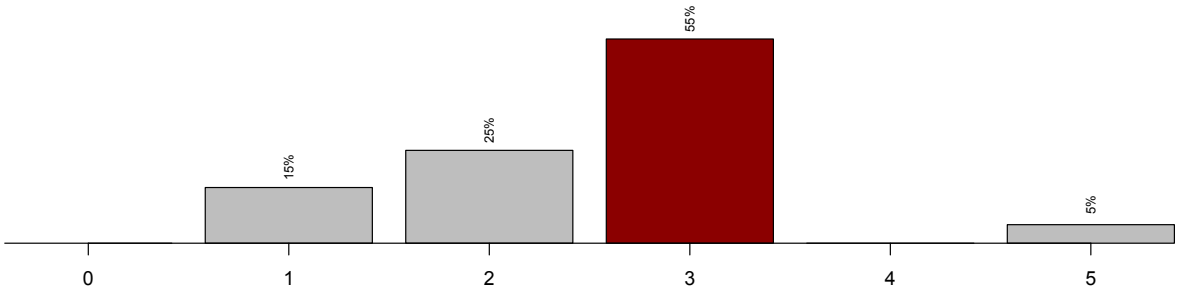
0.8
(0.75-0.84)
Num. obs. =19



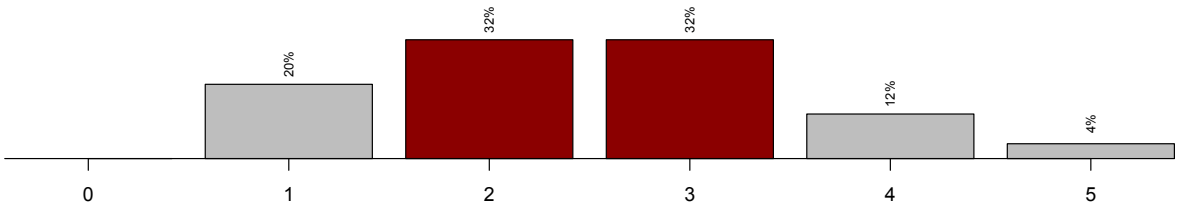
0.9
(0.85-0.94)
Num. obs. =37

LOR(2)

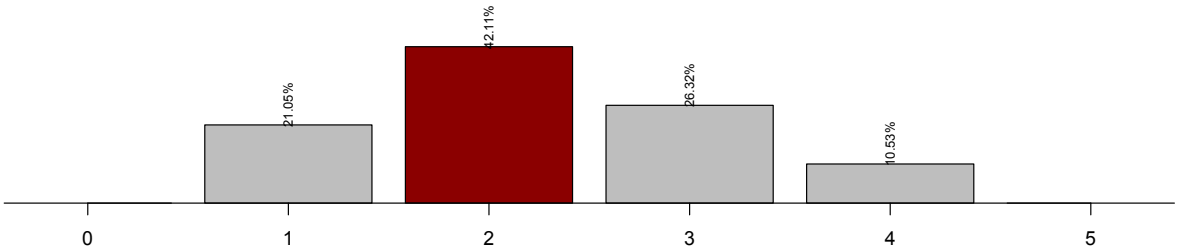
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



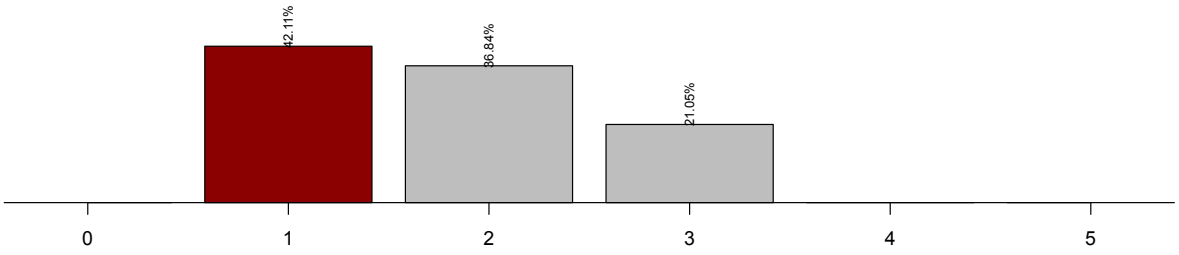
1.0
(0.95-1.04)
Num. obs. =20



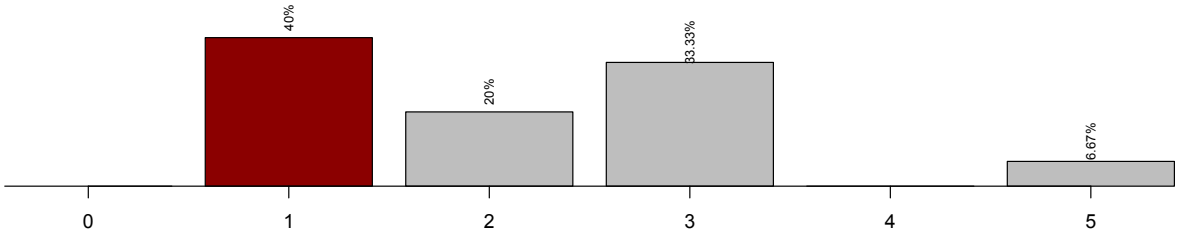
1.1
(1.05-1.14)
Num. obs. =25



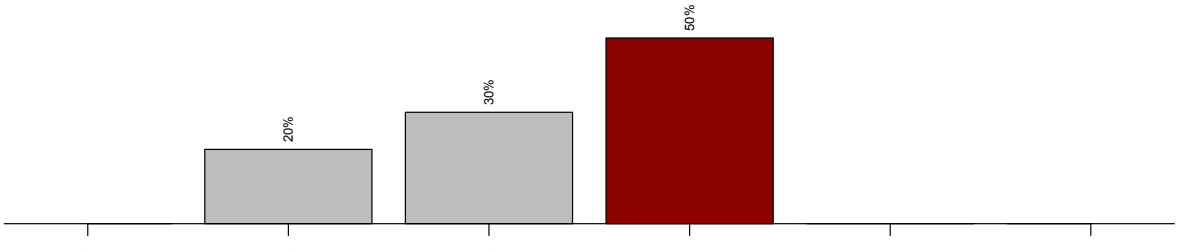
1.2
(1.15-1.24)
Num. obs.=19



1.3
(1.25-1.34)
Num. obs. =19



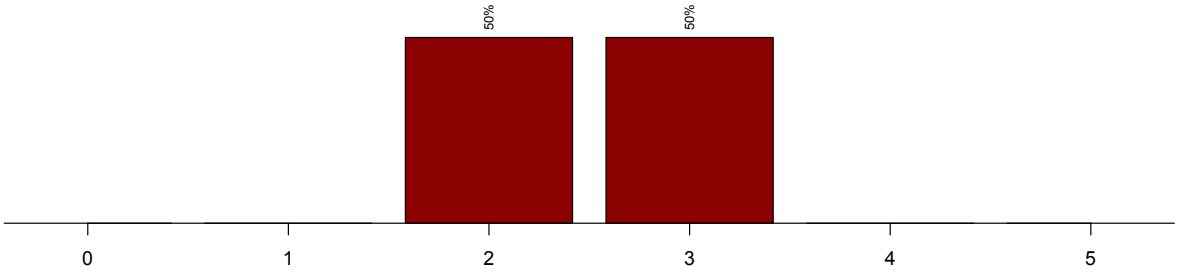
1.4
(1.35-1.44)
Num. obs. =15



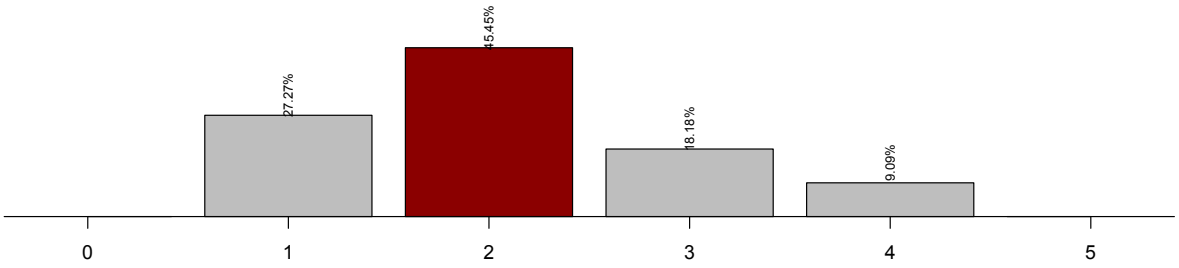
1.5
(1.45-1.54)
Num. obs. =10

LOR(3)

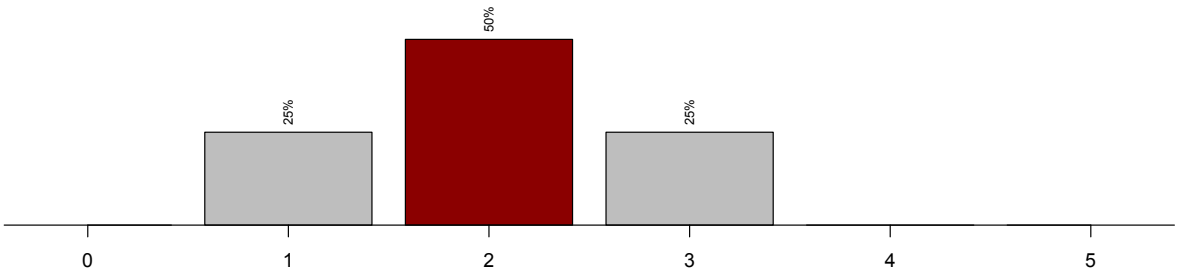
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



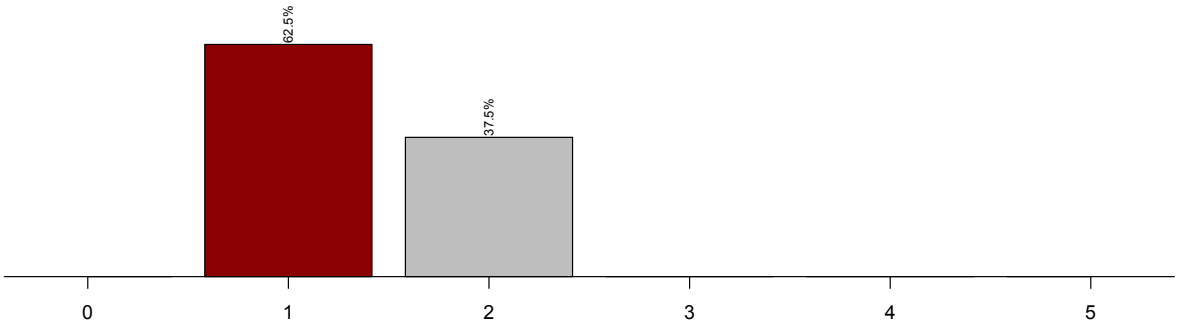
1.6
(0.95-1.04)
Num. obs. =4



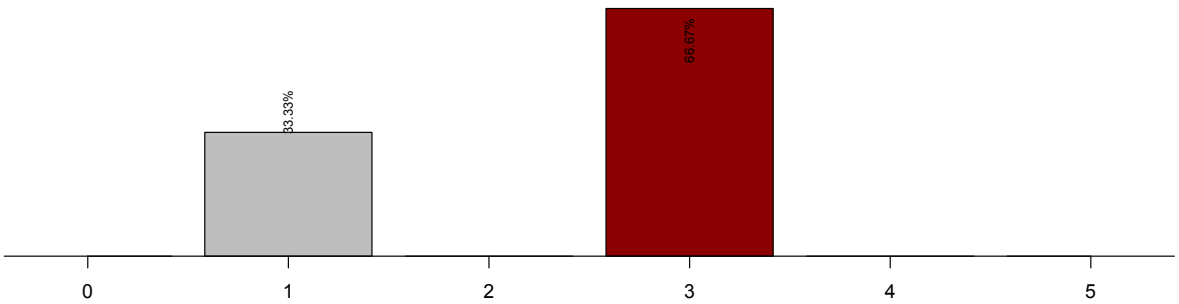
1.7
(1.05-1.14)
Num. obs. =11



1.8
(1.15-1.24)
Num. obs.=4



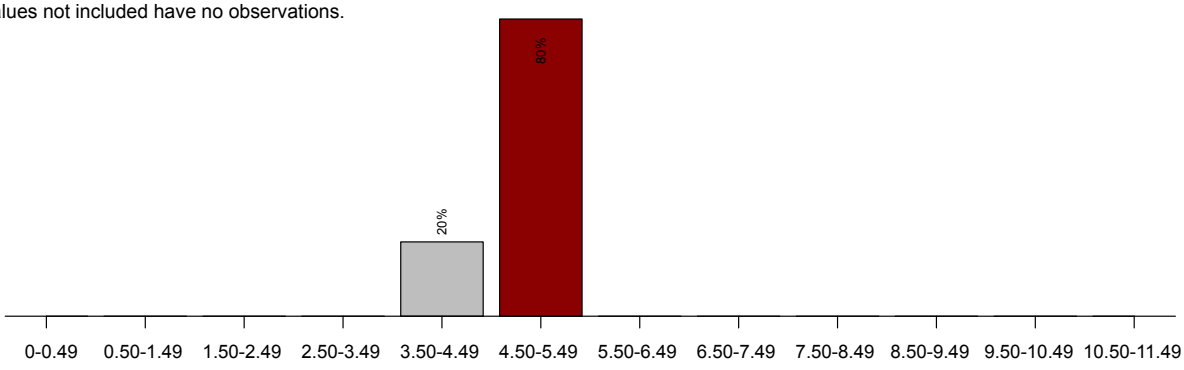
1.9
(1.25-1.34)
Num. obs. =8



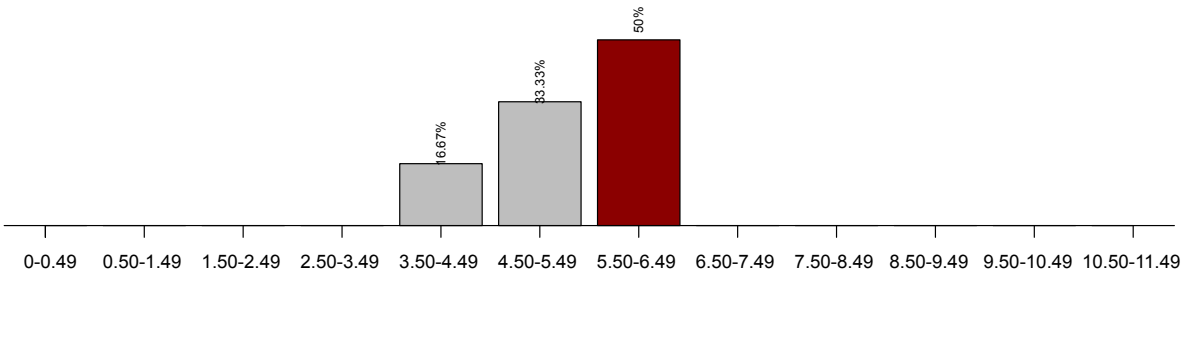
2.0
(1.35-1.44)
Num. obs. =3

$MSR_{(1)}$

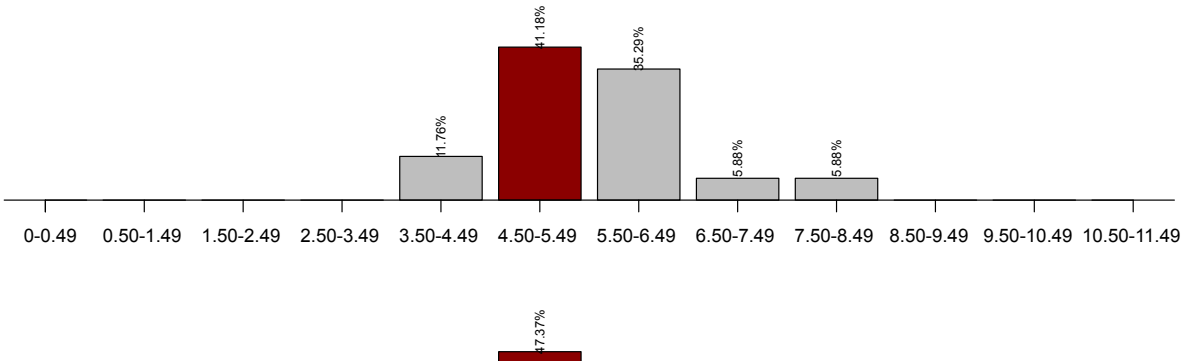
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



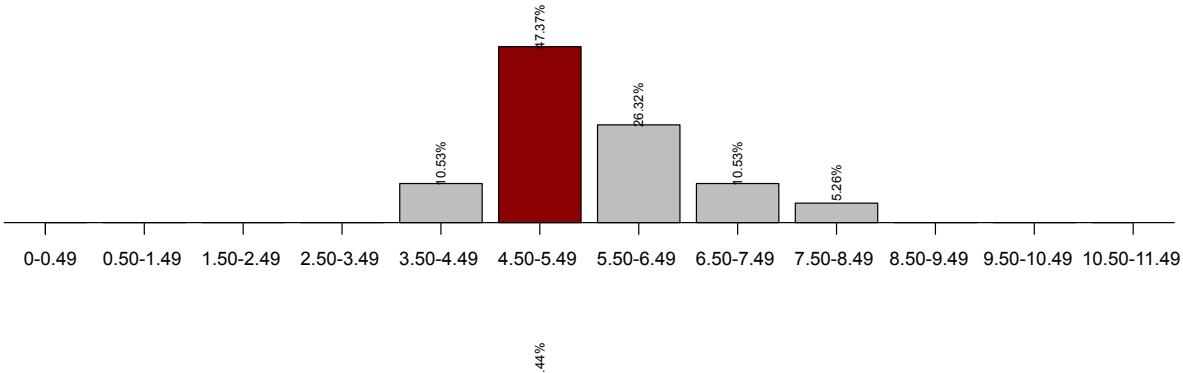
0.4
(0.35-0.44)
Num. obs. =5



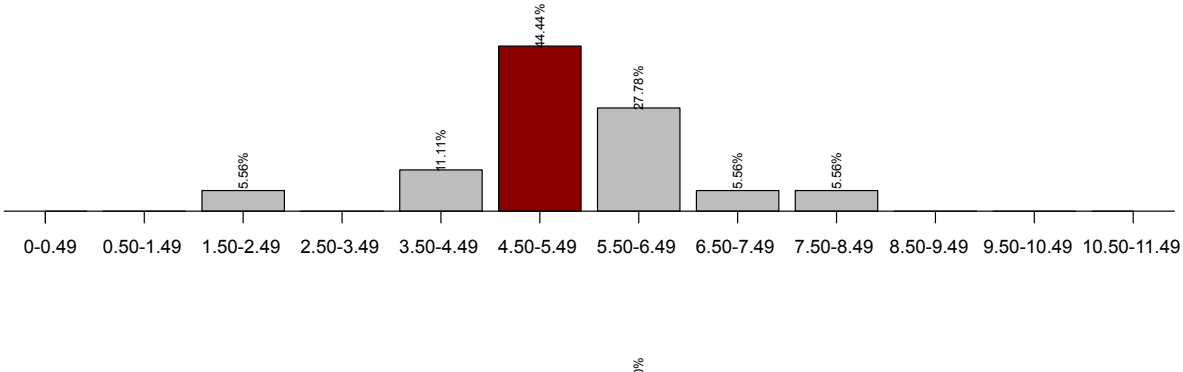
0.5
(0.45-0.54)
Num. obs. =6



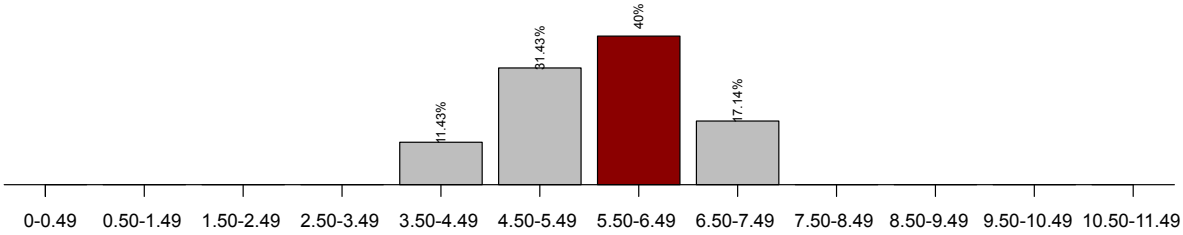
0.6
(0.55-0.64)
Num. obs.=17



0.7
(0.65-0.74)
Num. obs. =19



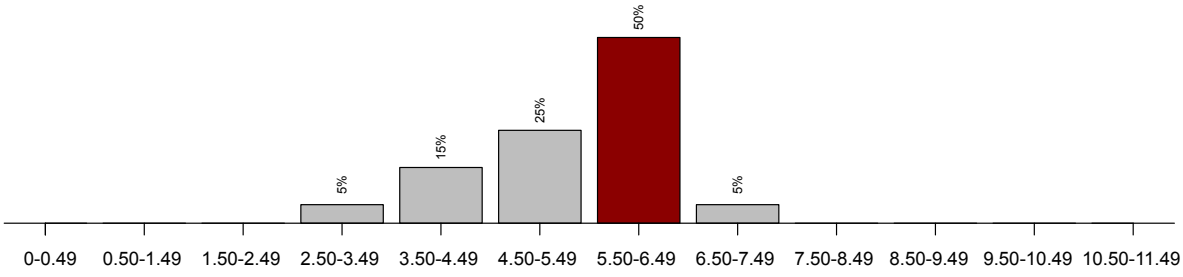
0.8
(0.75-0.84)
Num. obs. =18



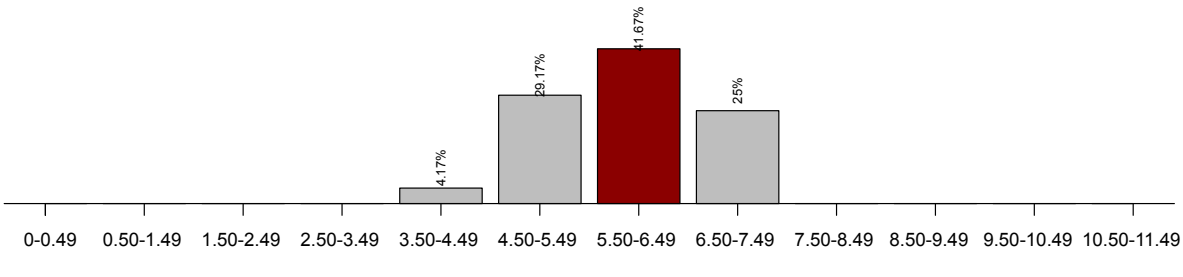
0.9
(0.85-0.94)
Num. obs. =35

MSR(2)

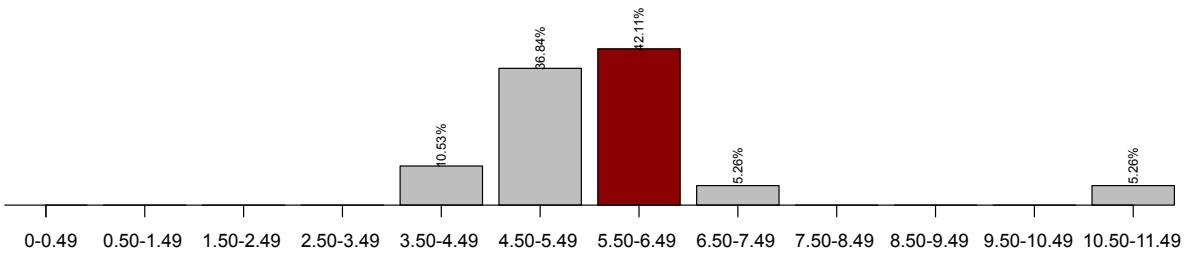
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



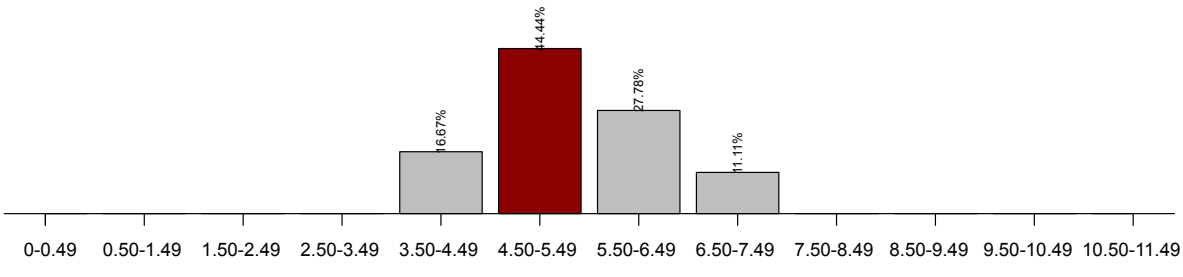
1.0
(0.95-1.04)
Num. obs. =20



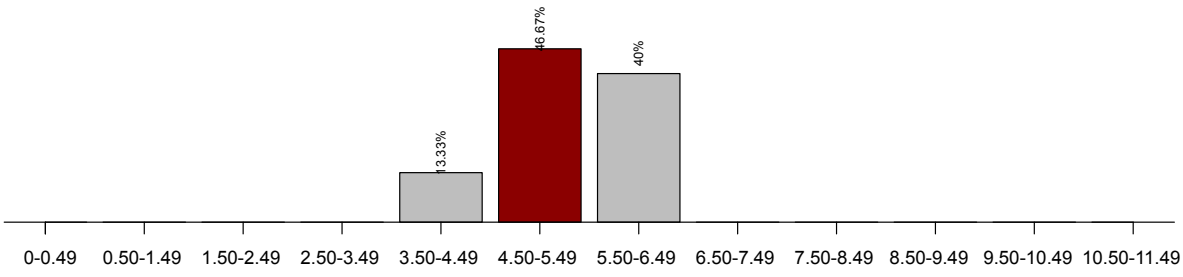
1.1
(1.05-1.14)
Num. obs. =24



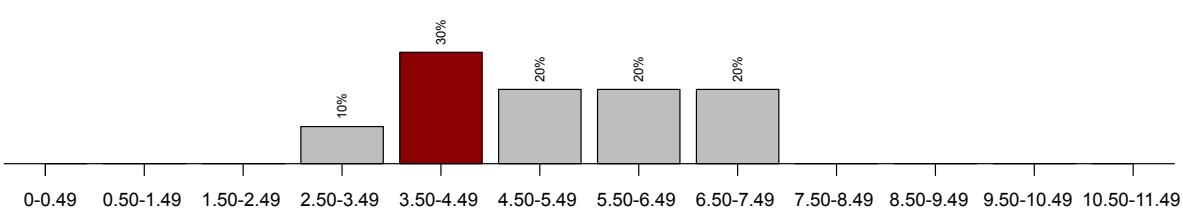
1.2
(1.15-1.24)
Num. obs.=19



1.3
(1.25-1.34)
Num. obs. =18



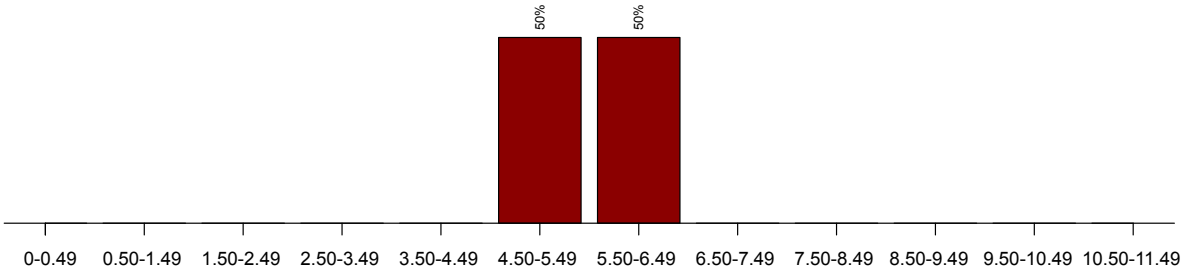
1.4
(1.35-1.44)
Num. obs. =15



1.5
(1.45-1.54)
Num. obs. =10

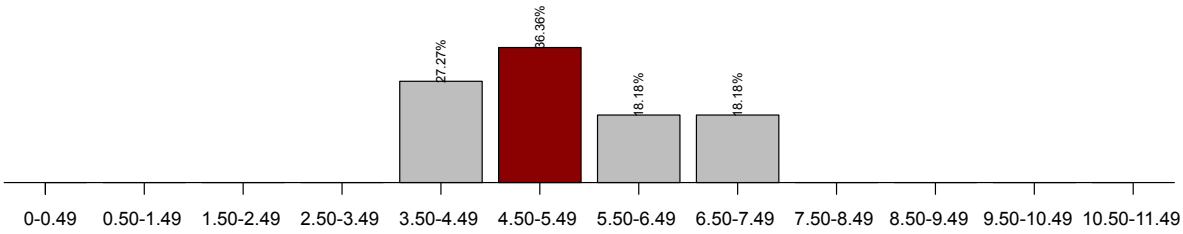
MSR(3)

(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



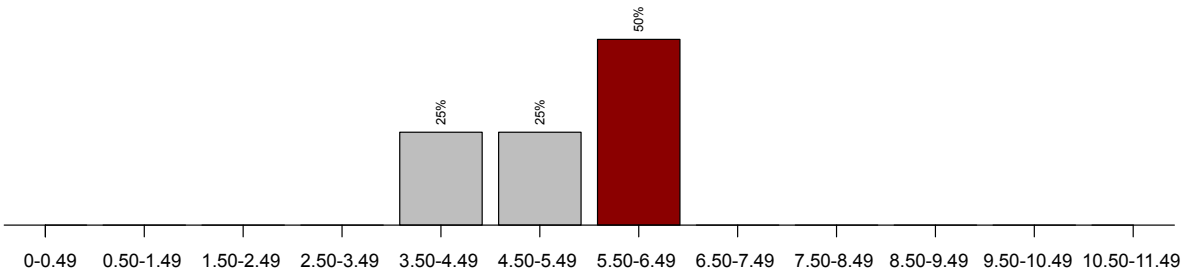
1.6
(0.95-1.04)

Num. obs. =4



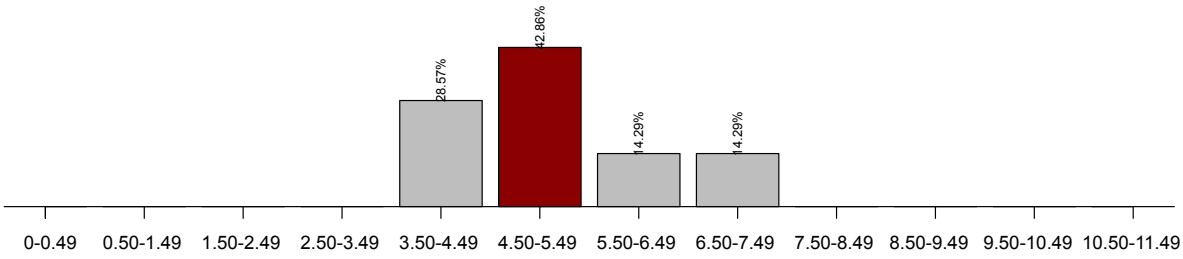
1.7
(1.05-1.14)

Num. obs. =11



1.8
(1.15-1.24)

Num. obs.=4



1.9
(1.25-1.34)

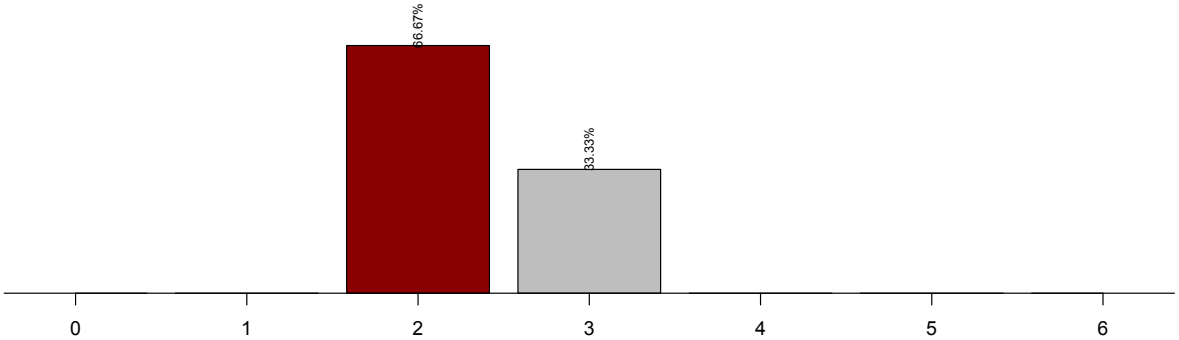
Num. obs. =7

2.0
(1.35-1.44)

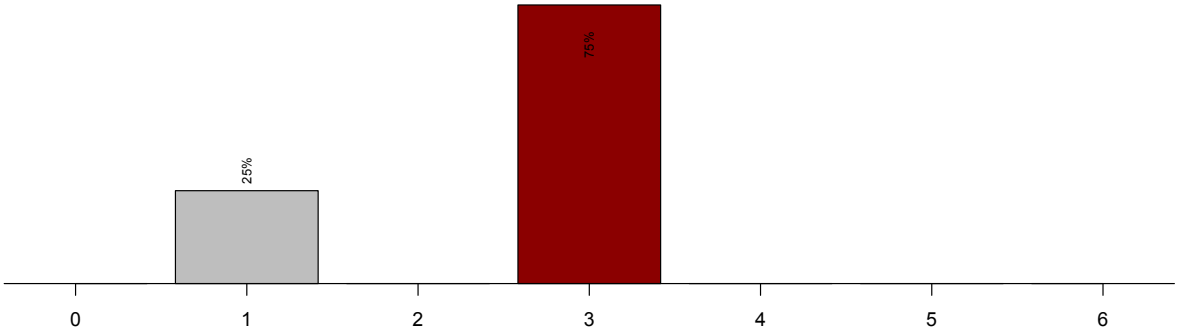
Num. obs. =2

$MT_{(1)}$

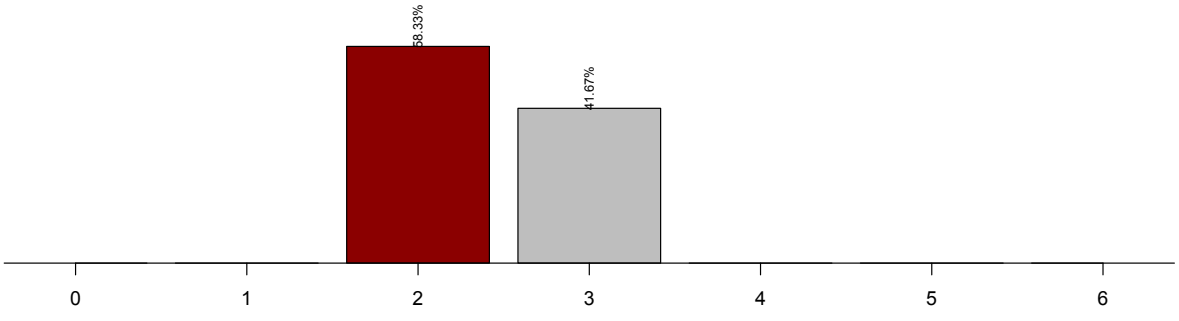
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



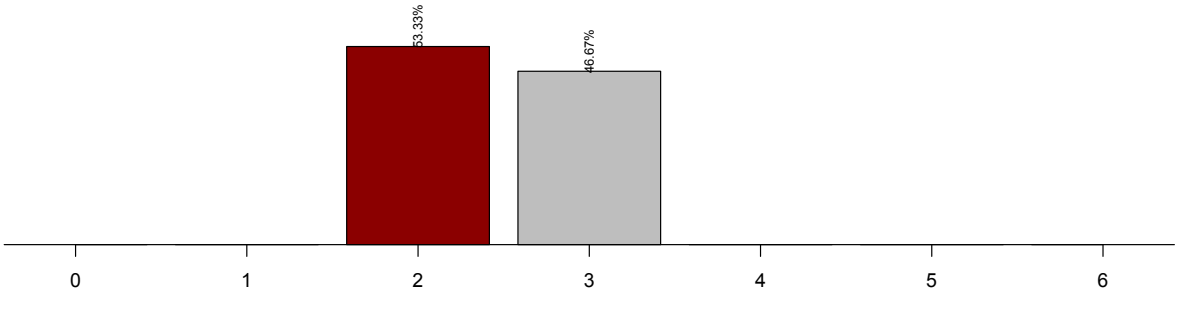
0.4
(0.35-0.44)
Num. obs. =3



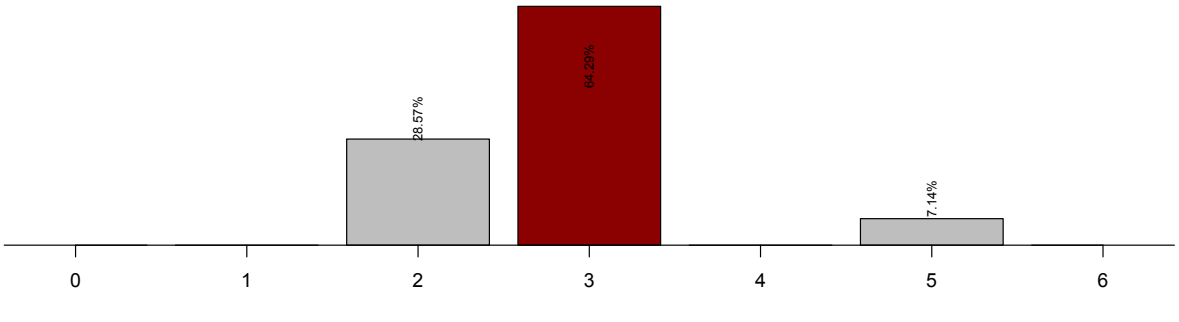
0.5
(0.45-0.54)
Num. obs. =4



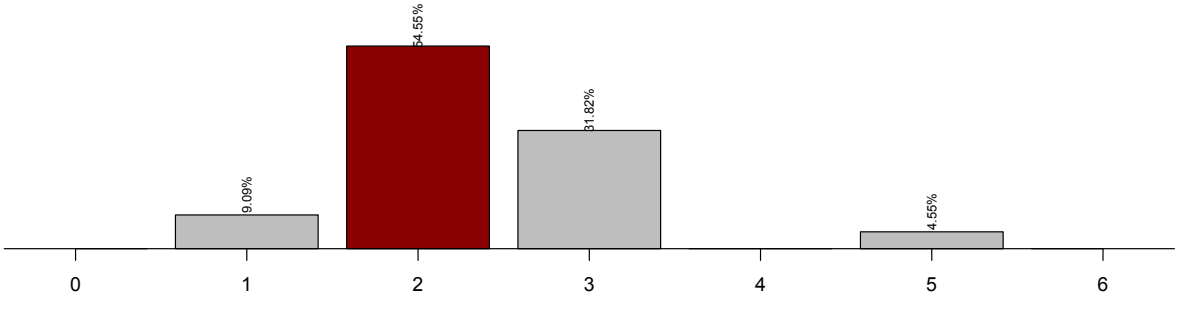
0.6
(0.55-0.64)
Num. obs.=12



0.7
(0.65-0.74)
Num. obs. =15



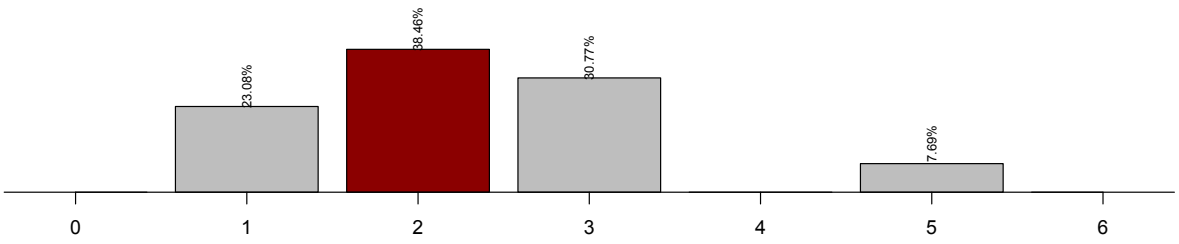
0.8
(0.75-0.84)
Num. obs. =14



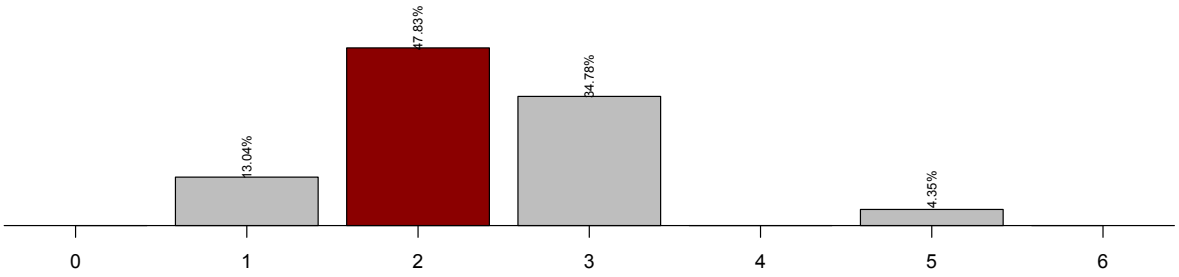
0.9
(0.85-0.94)
Num. obs. =22

$MT_{(2)}$

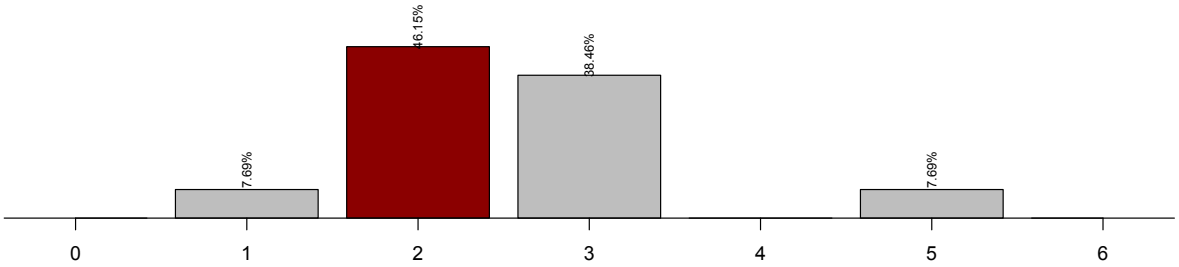
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



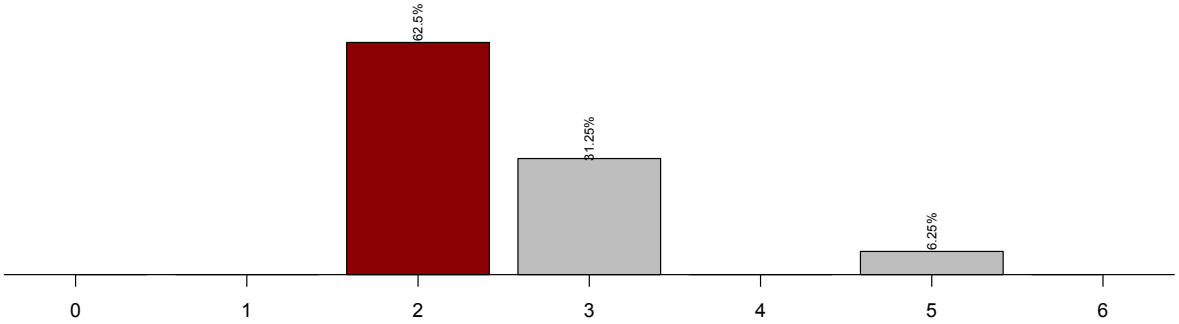
1.0
(0.95-1.04)
Num. obs. =13



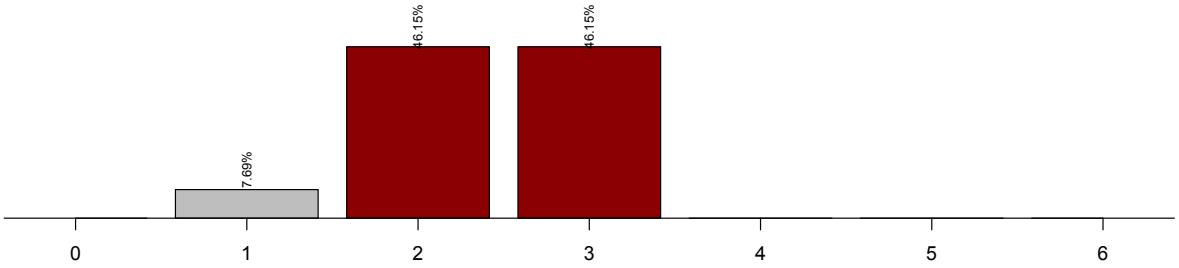
1.1
(1.05-1.14)
Num. obs. =23



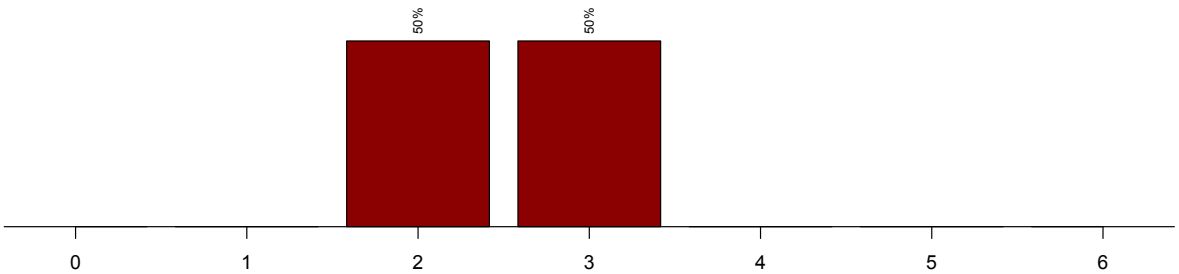
1.2
(1.15-1.24)
Num. obs.=19



1.3
(1.25-1.34)
Num. obs. =16



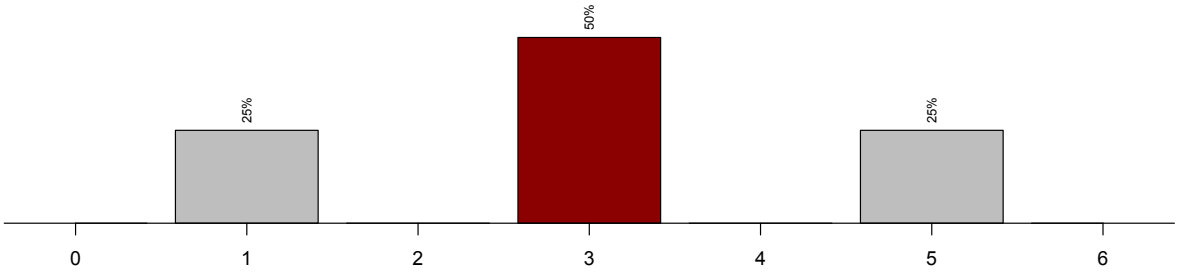
1.4
(1.35-1.44)
Num. obs. =13



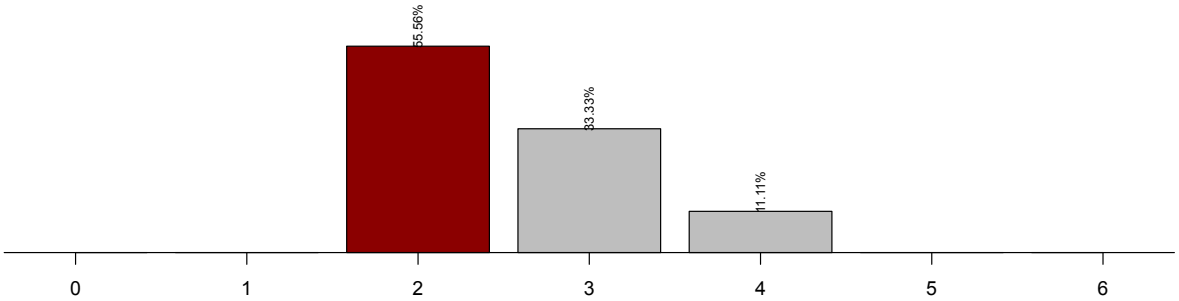
1.5
(1.45-1.54)
Num. obs. =8

$MT_{(3)}$

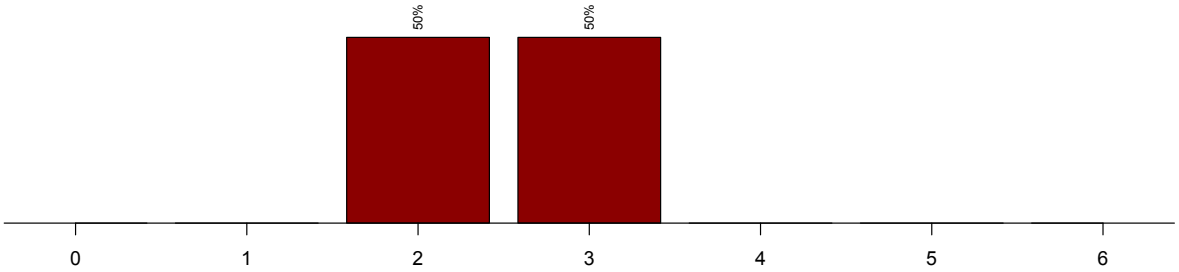
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



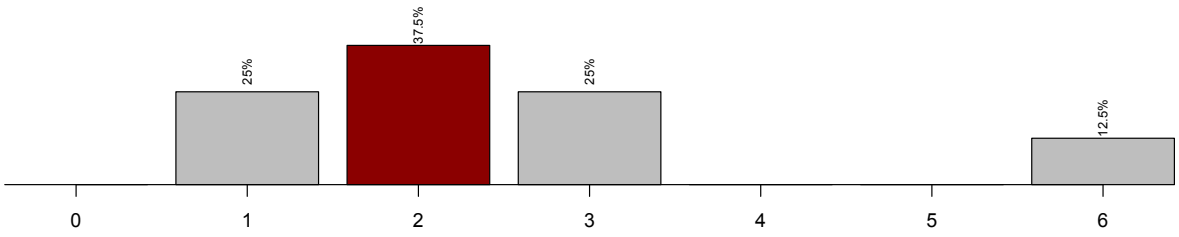
1.6
(0.95-1.04)
Num. obs. =4



1.7
(1.05-1.14)
Num. obs. =9



1.8
(1.15-1.24)
Num. obs.=4

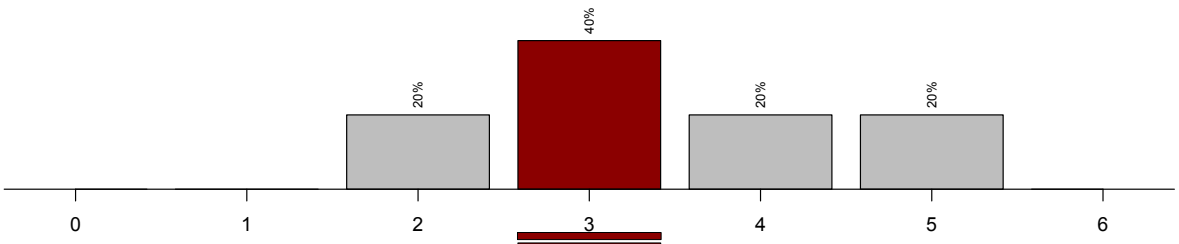


1.9
(1.25-1.34)
Num. obs. =8

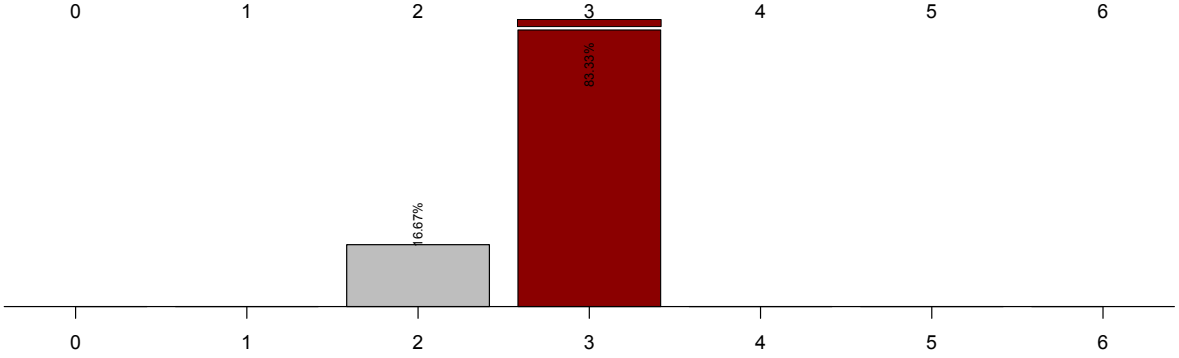
2.0
(1.35-1.44)
Num. obs. =2

$NF_{(1)}$

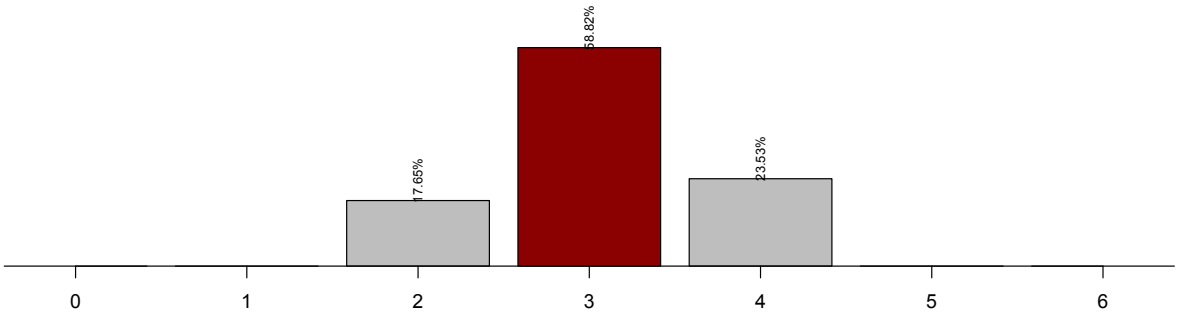
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



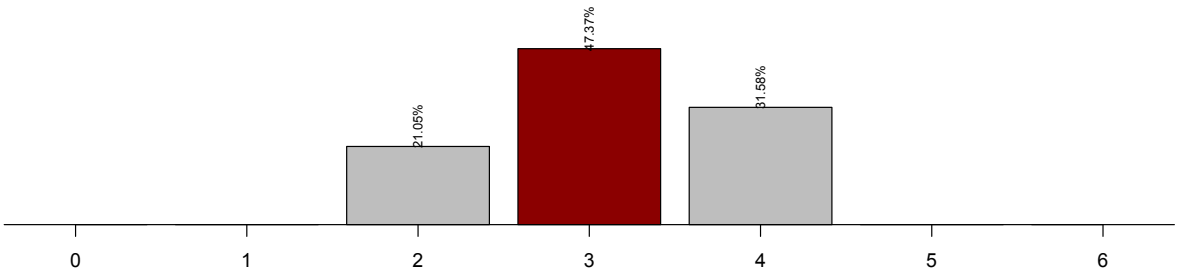
0.4
(0.35-0.44)
Num. obs. =5



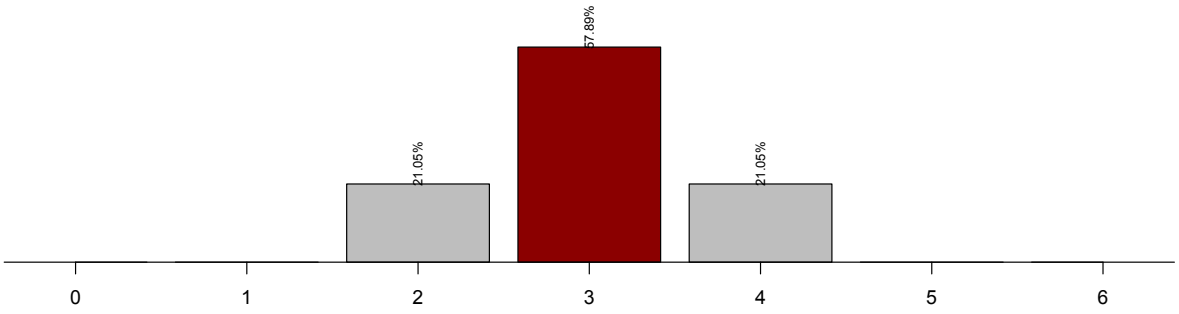
0.5
(0.45-0.54)
Num. obs. =6



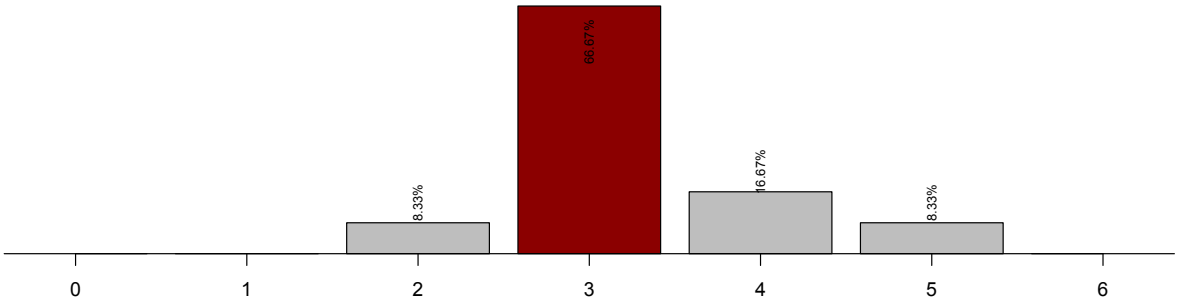
0.6
(0.55-0.64)
Num. obs.=17



0.7
(0.65-0.74)
Num. obs. =19



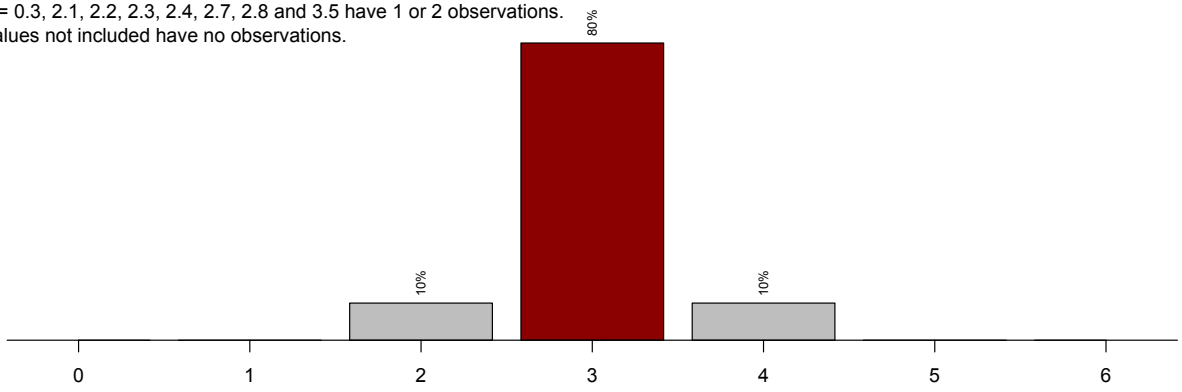
0.8
(0.75-0.84)
Num. obs. =19



0.9
(0.85-0.94)
Num. obs. =36

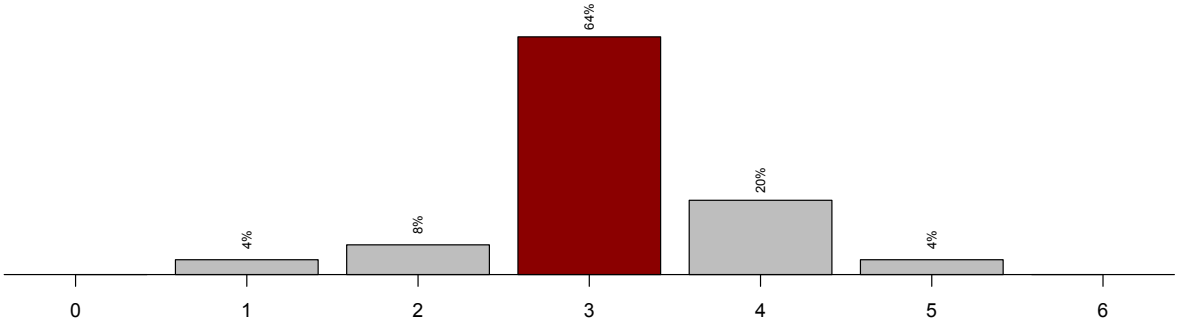
$NF_{(2)}$

(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



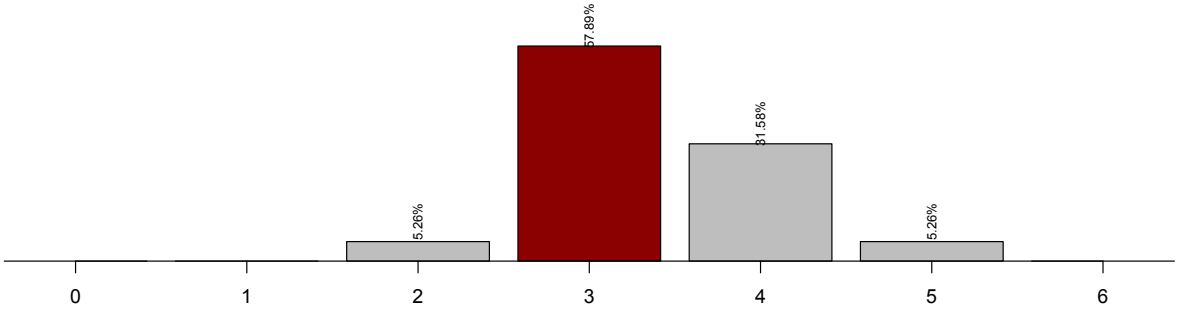
1.0 (0.95-1.04)

Num. obs. =20



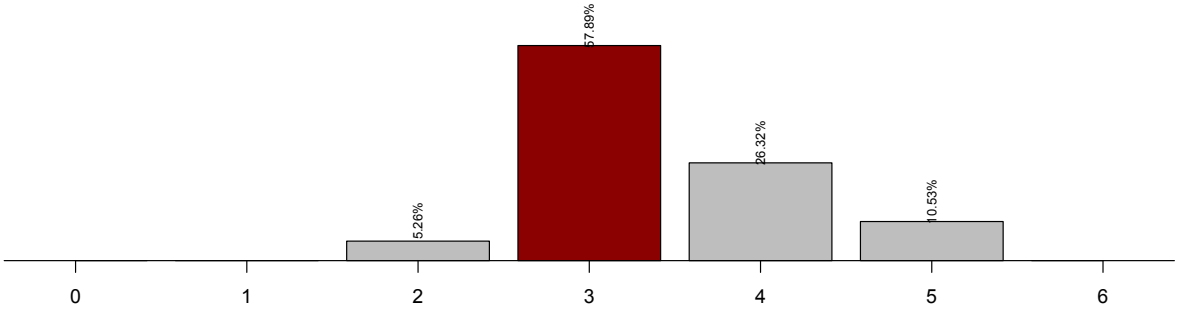
1.1 (1.05-1.14)

Num. obs. =25



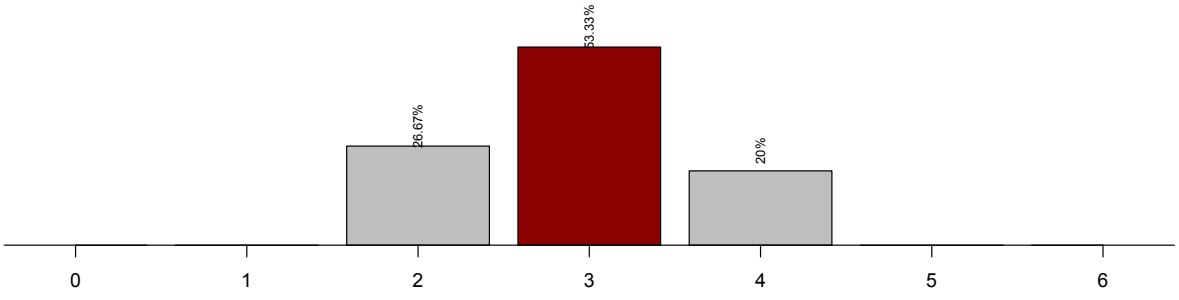
1.2 (1.15-1.24)

Num. obs.=19



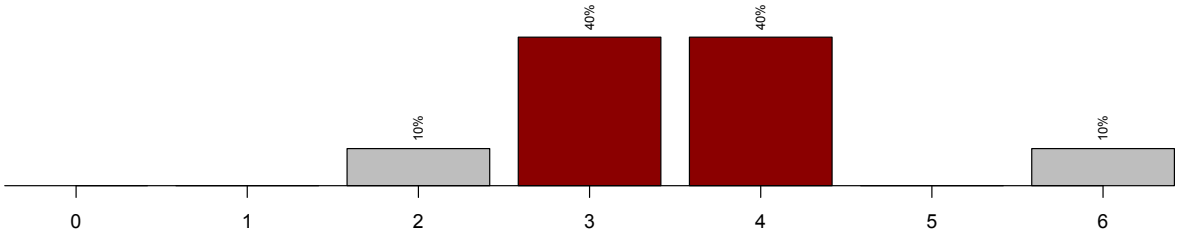
1.3 (1.25-1.34)

Num. obs. =19



1.4 (1.35-1.44)

Num. obs. =15

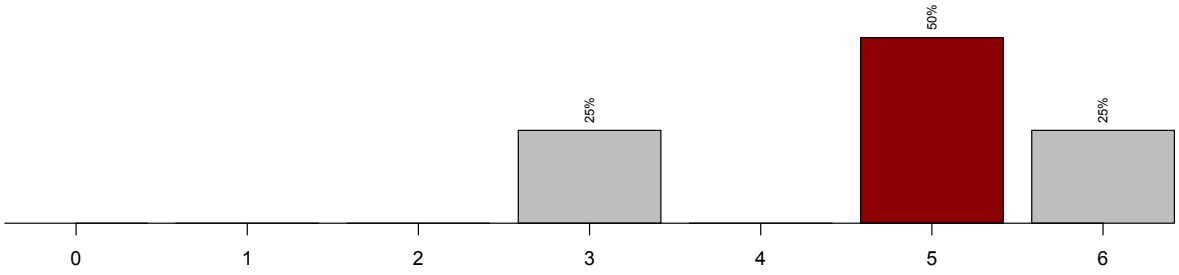


1.5 (1.45-1.54)

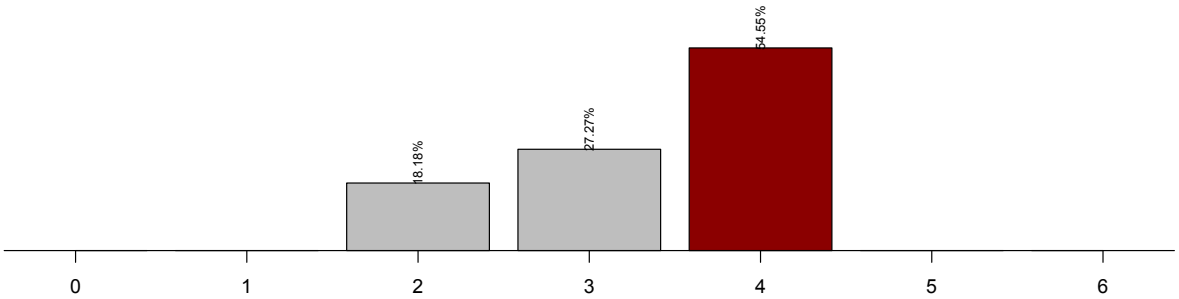
Num. obs. =10

$NF_{(3)}$

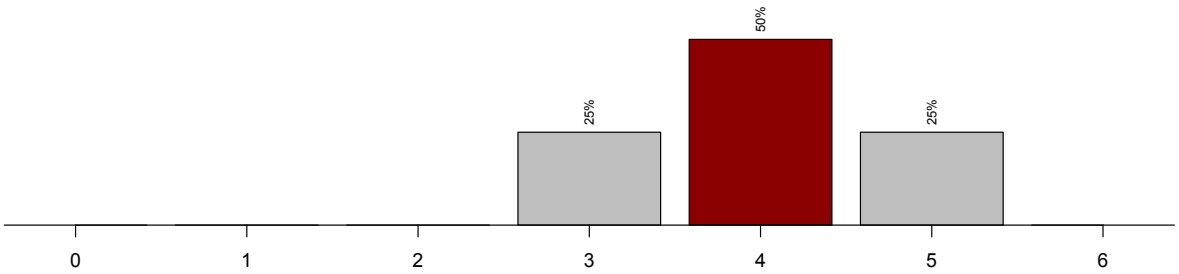
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



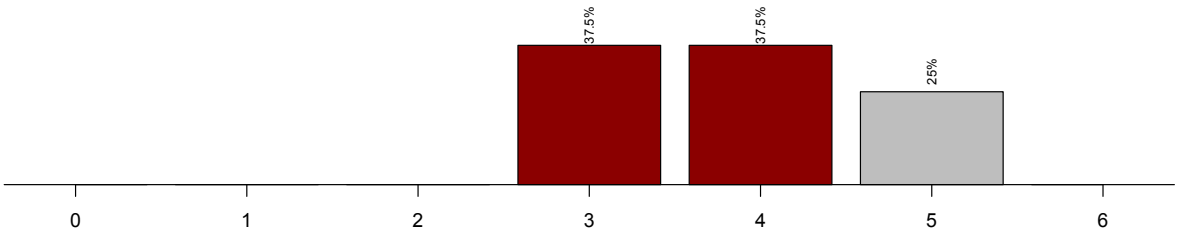
1.6
(0.95-1.04)
Num. obs. =4



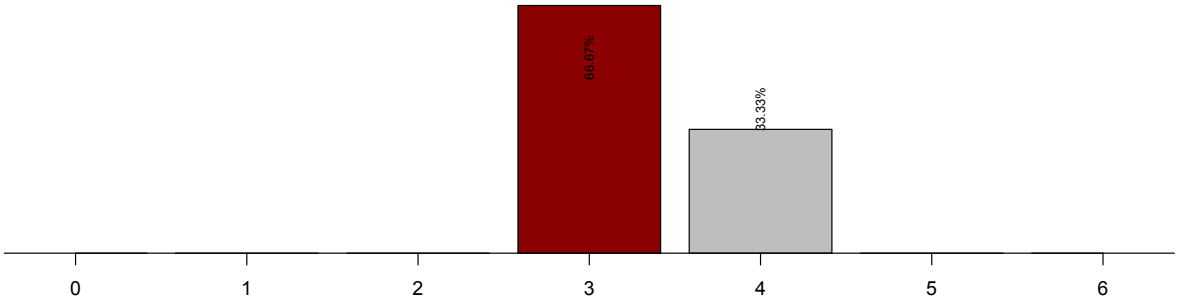
1.7
(1.05-1.14)
Num. obs. =11



1.8
(1.15-1.24)
Num. obs.=4



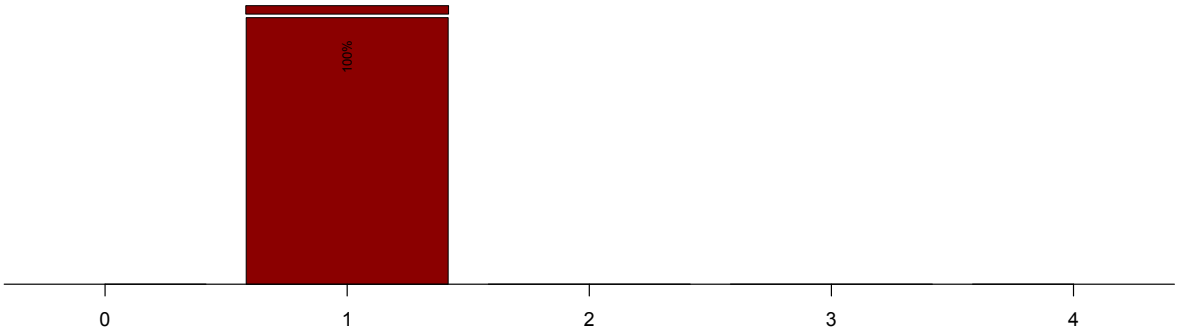
1.9
(1.25-1.34)
Num. obs. =8



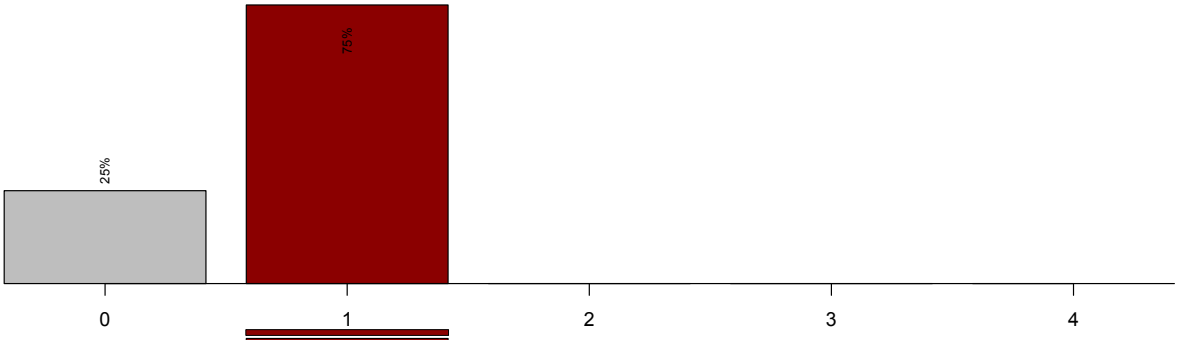
2.0
(1.35-1.44)
Num. obs. =3

$NV_{(1)}$

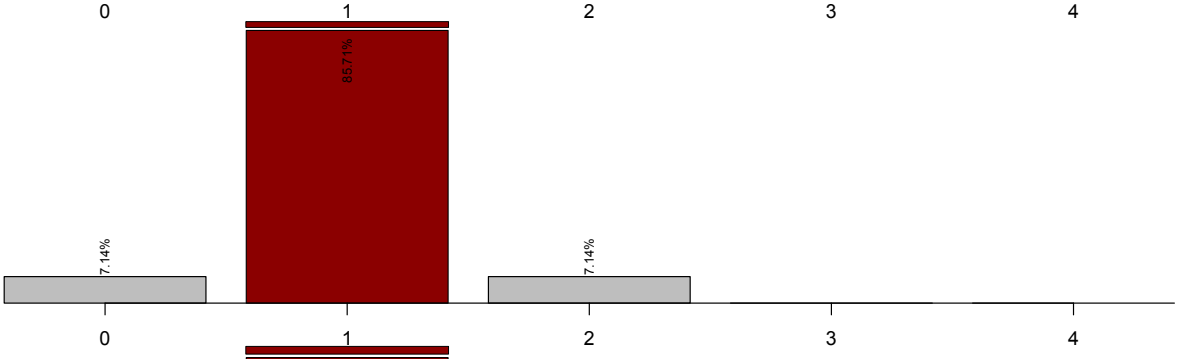
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



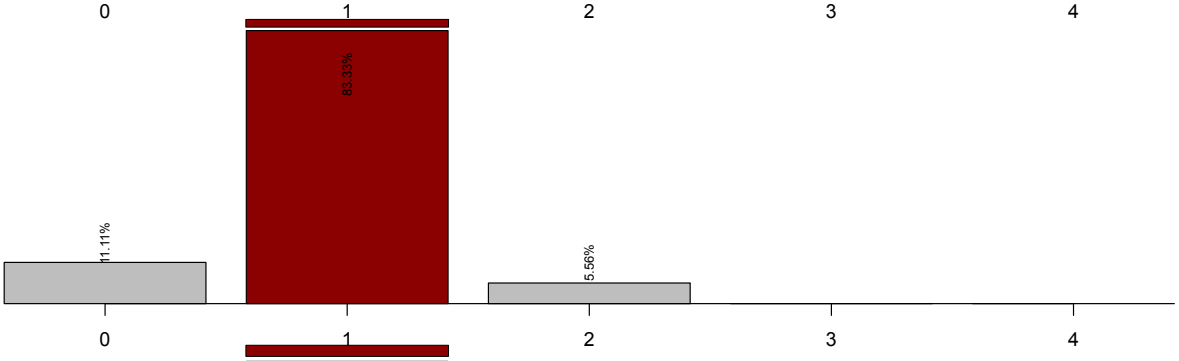
0.4
(0.35-0.44)
Num. obs. =3



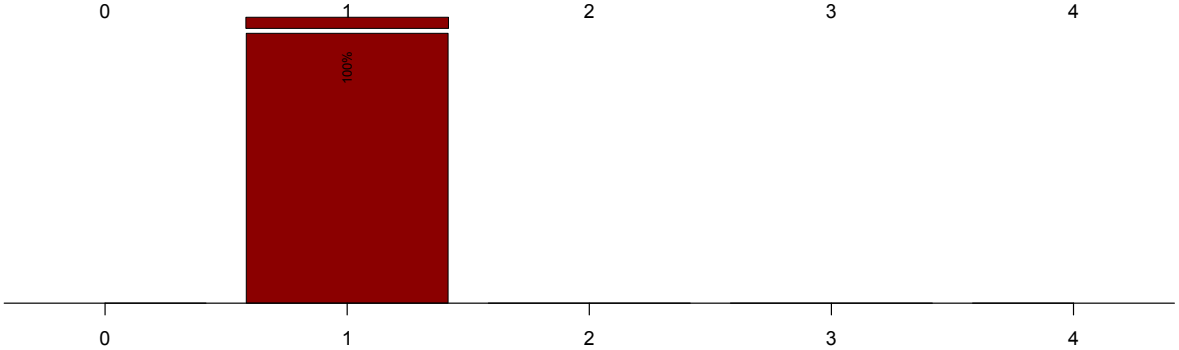
0.5
(0.45-0.54)
Num. obs. =4



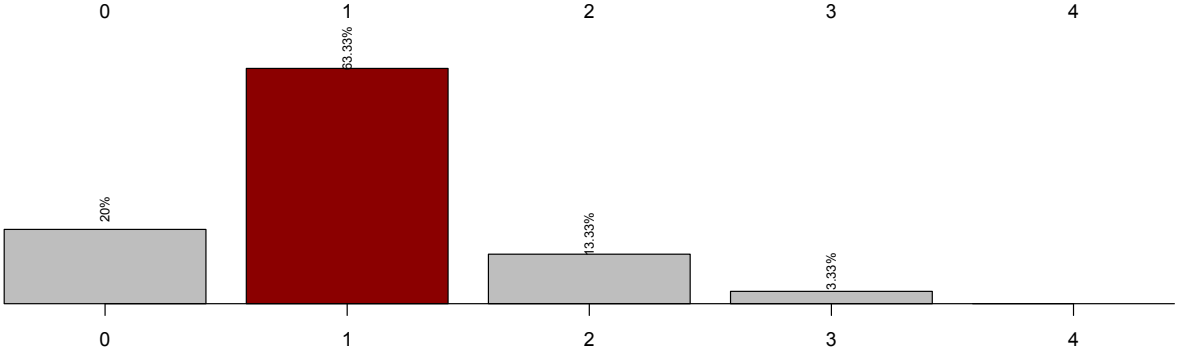
0.6
(0.55-0.64)
Num. obs.=14



0.7
(0.65-0.74)
Num. obs. =18



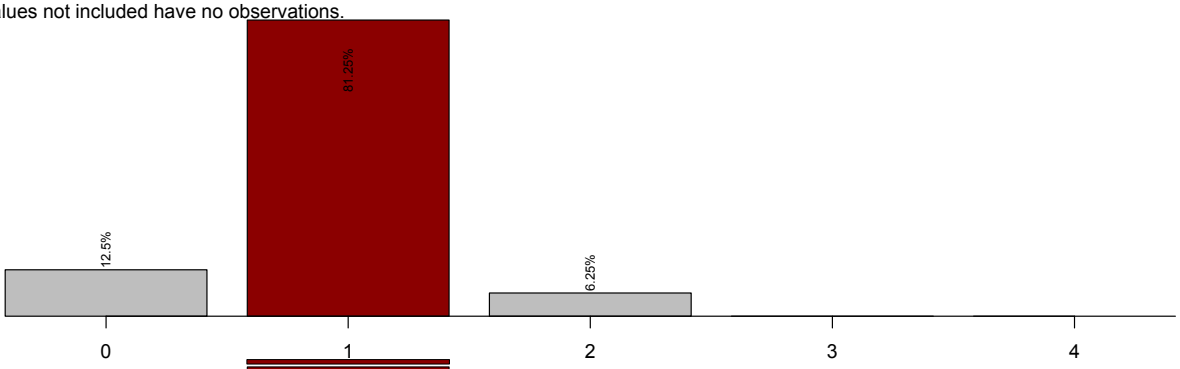
0.8
(0.75-0.84)
Num. obs. =13



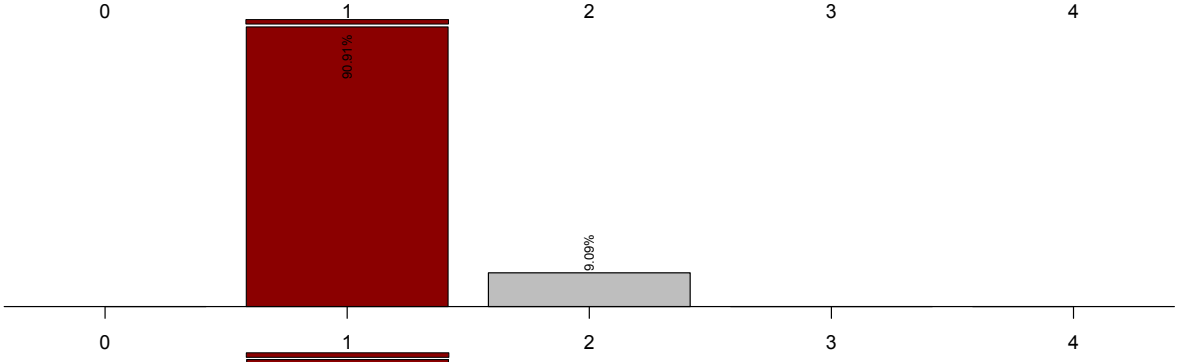
0.9
(0.85-0.94)
Num. obs. =30

$NV_{(2)}$

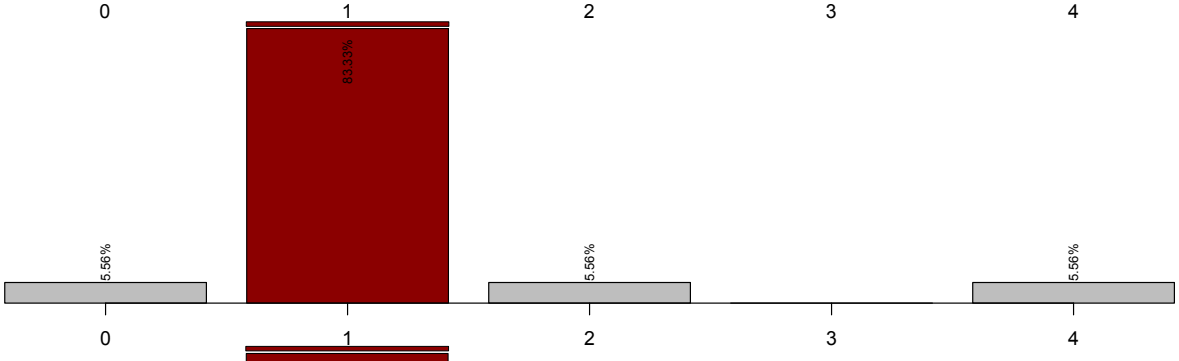
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



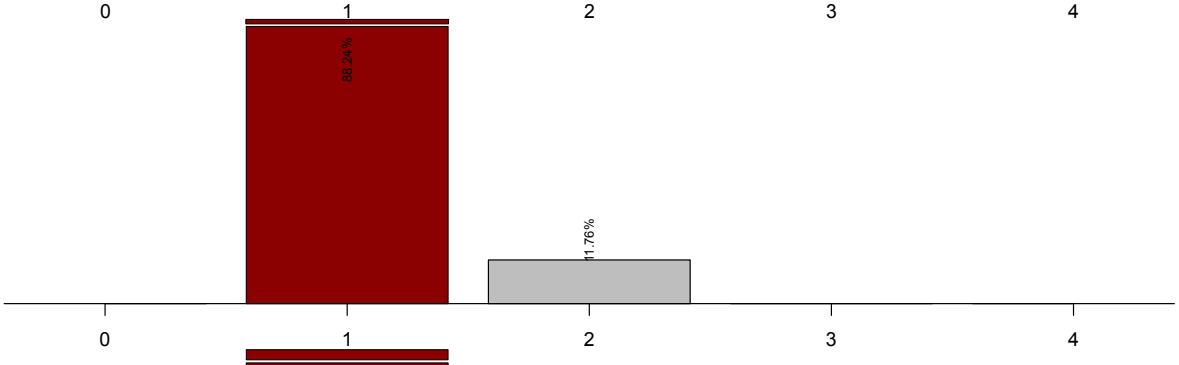
1.0
(0.95-1.04)
Num. obs. =16



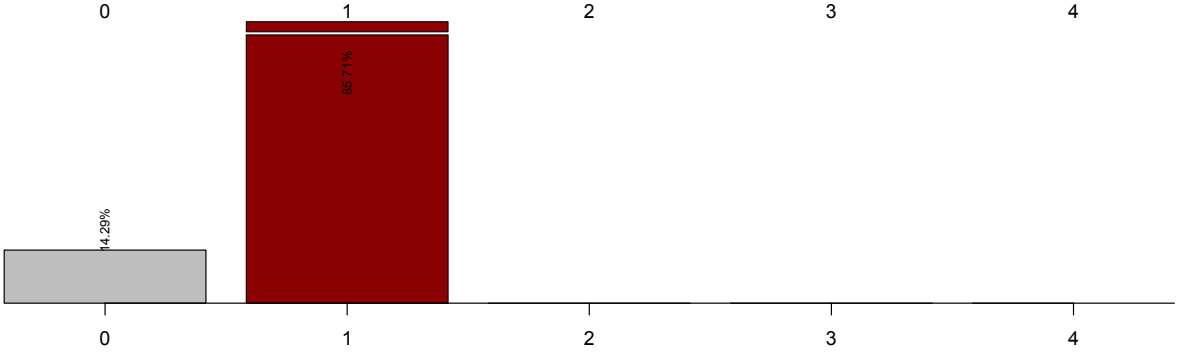
1.1
(1.05-1.14)
Num. obs. =22



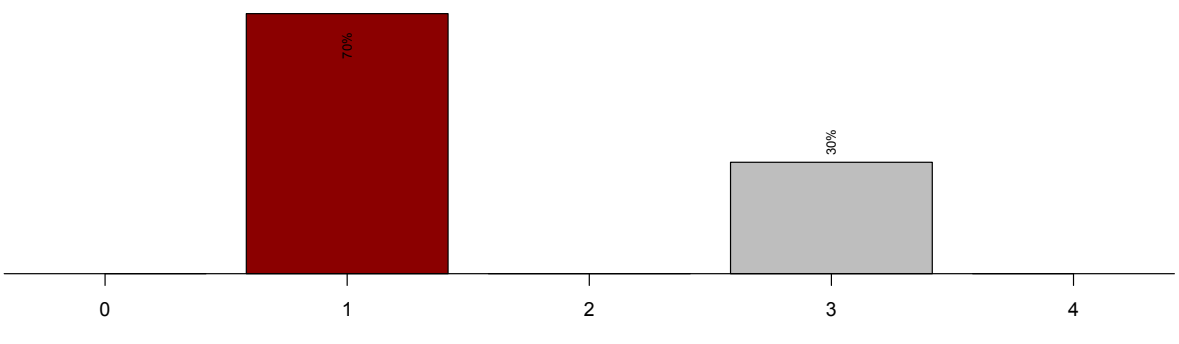
1.2
(1.15-1.24)
Num. obs.=18



1.3
(1.25-1.34)
Num. obs. =17



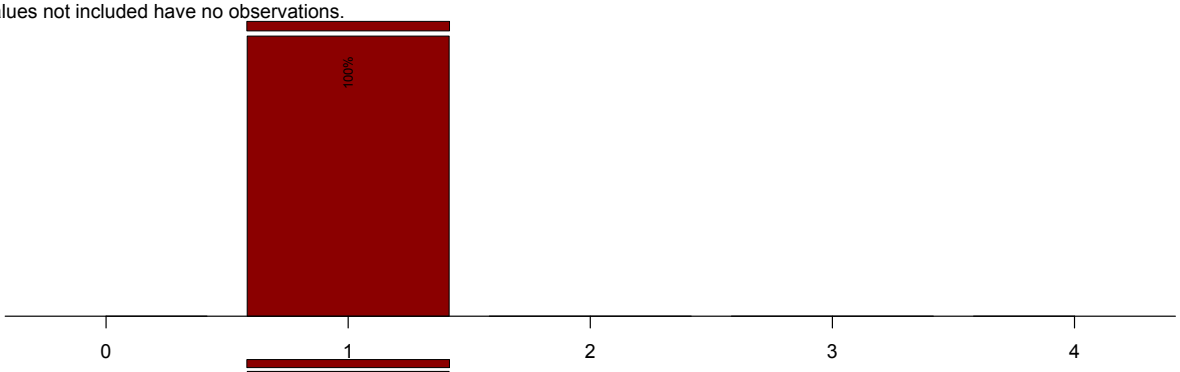
1.4
(1.35-1.44)
Num. obs. =14



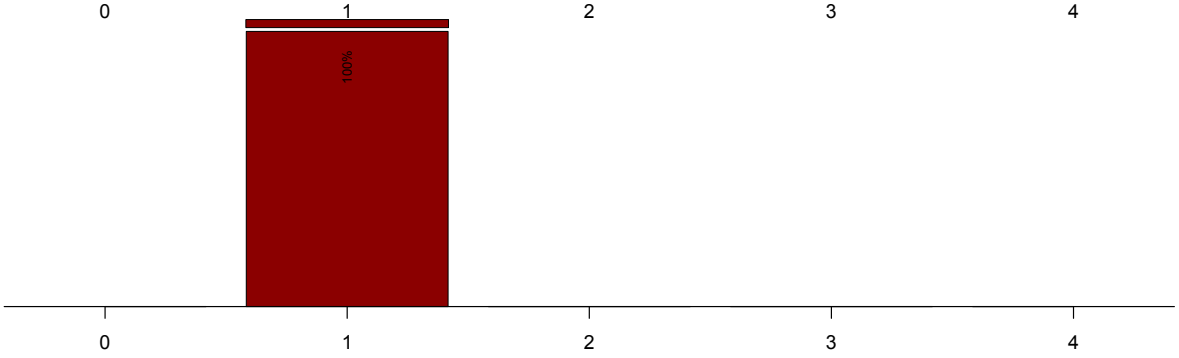
1.5
(1.45-1.54)
Num. obs. =10

$NV_{(3)}$

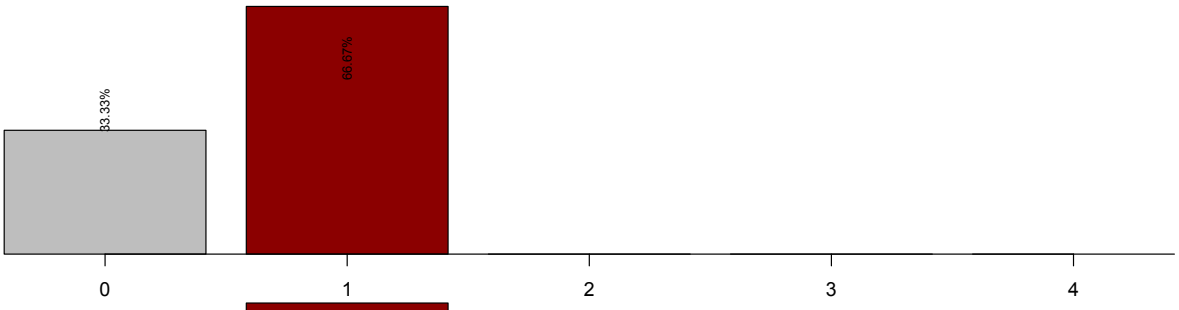
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



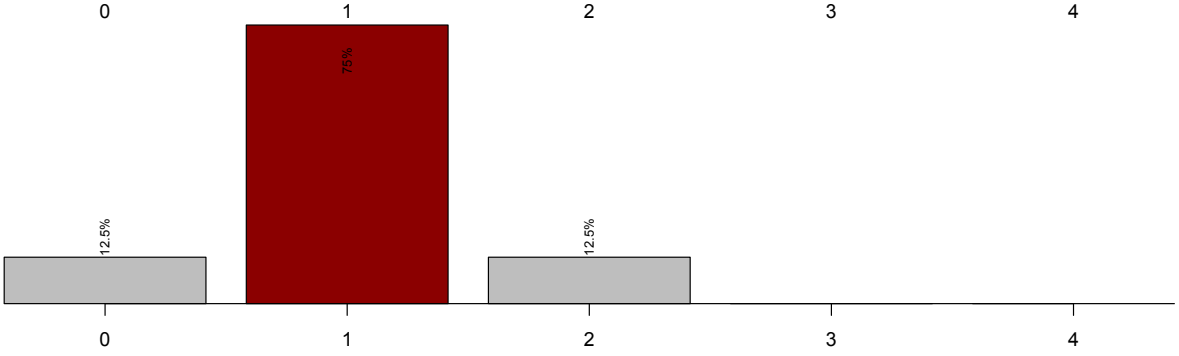
1.6
(0.95-1.04)
Num. obs. =4



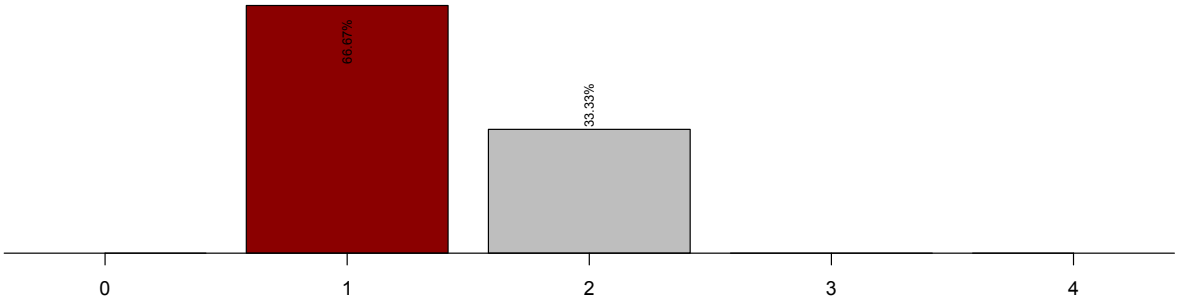
1.7
(1.05-1.14)
Num. obs. =8



1.8
(1.15-1.24)
Num. obs.=3



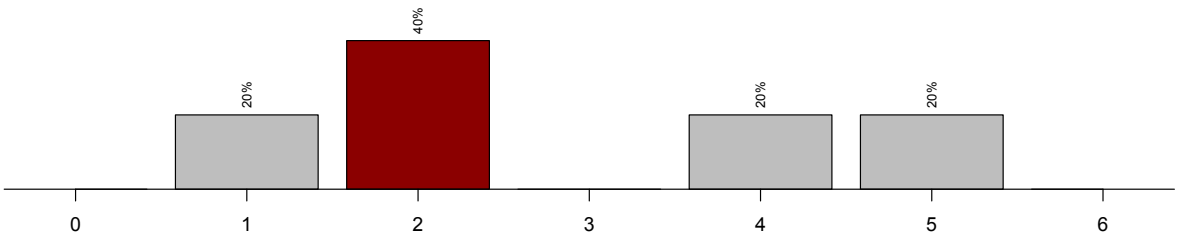
1.9
(1.25-1.34)
Num. obs. =8



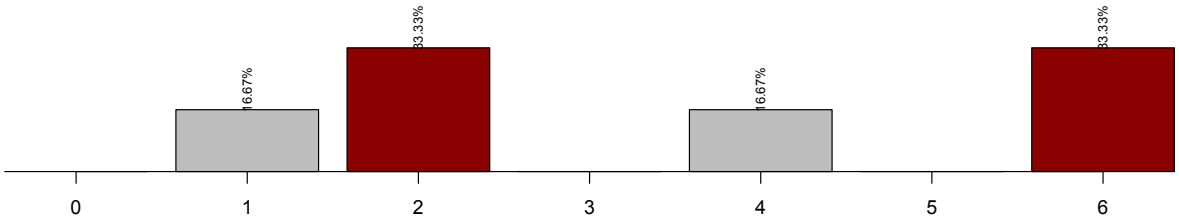
2.0
(1.35-1.44)
Num. obs. =3

$PE_{(1)}$

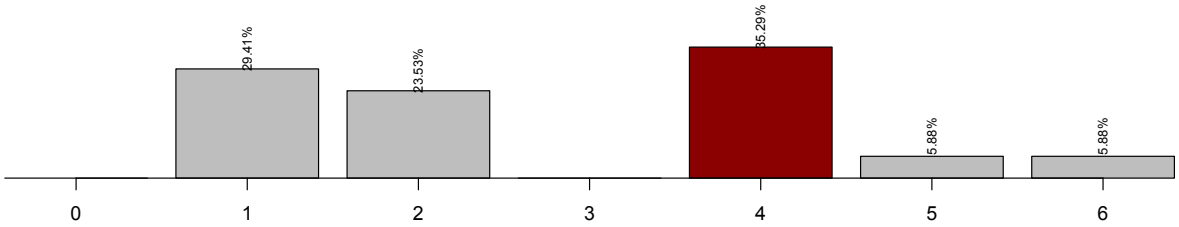
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



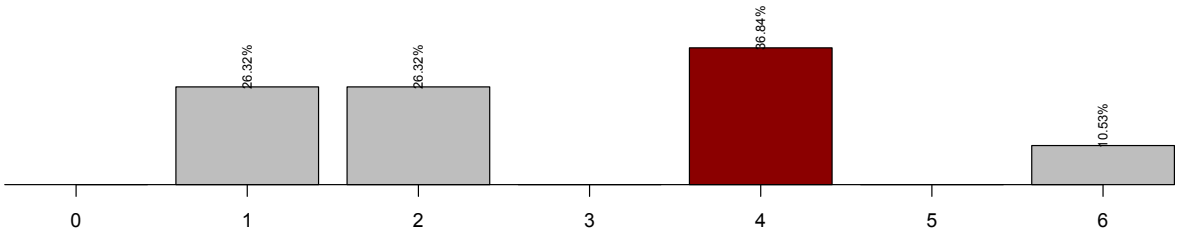
0.4
(0.35-0.44)
Num. obs. =5



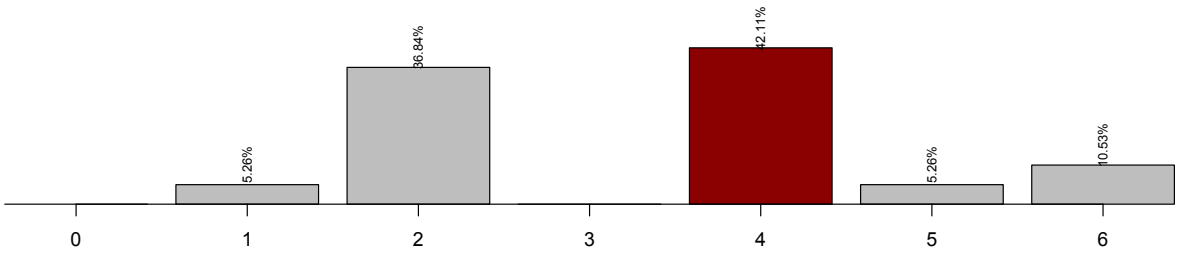
0.5
(0.45-0.54)
Num. obs. =6



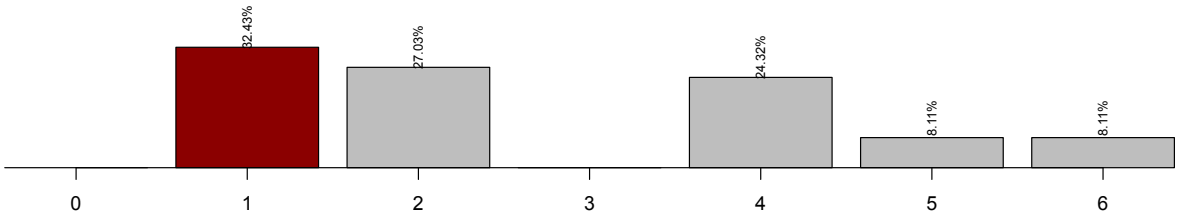
0.6
(0.55-0.64)
Num. obs.=17



0.7
(0.65-0.74)
Num. obs. =19



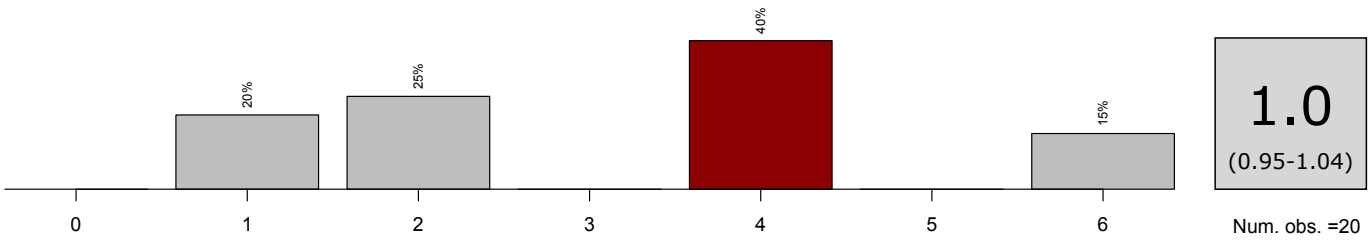
0.8
(0.75-0.84)
Num. obs. =19

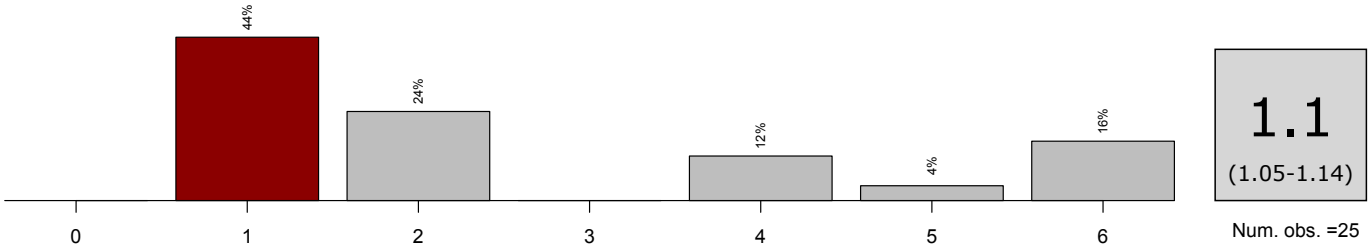


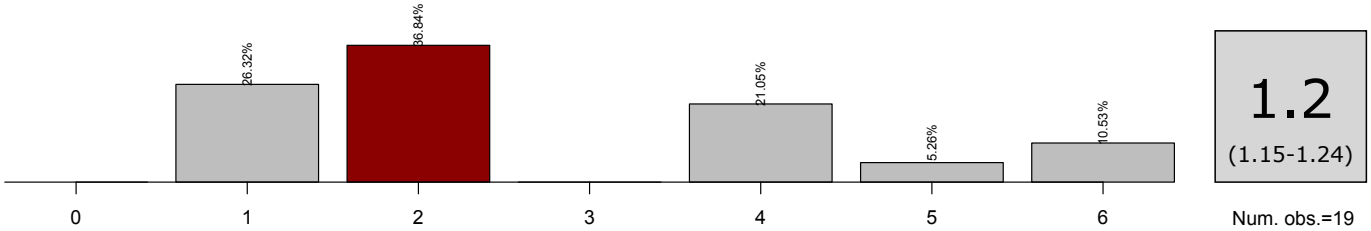
0.9
(0.85-0.94)
Num. obs. =37

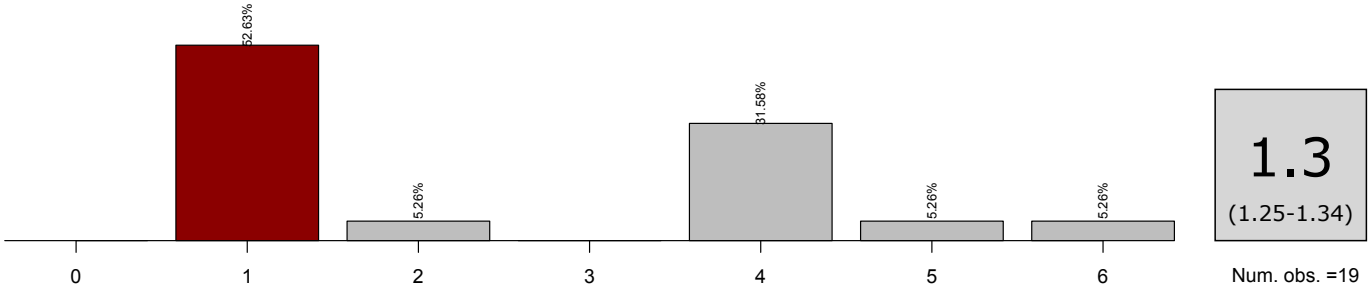
$PE_{(2)}$

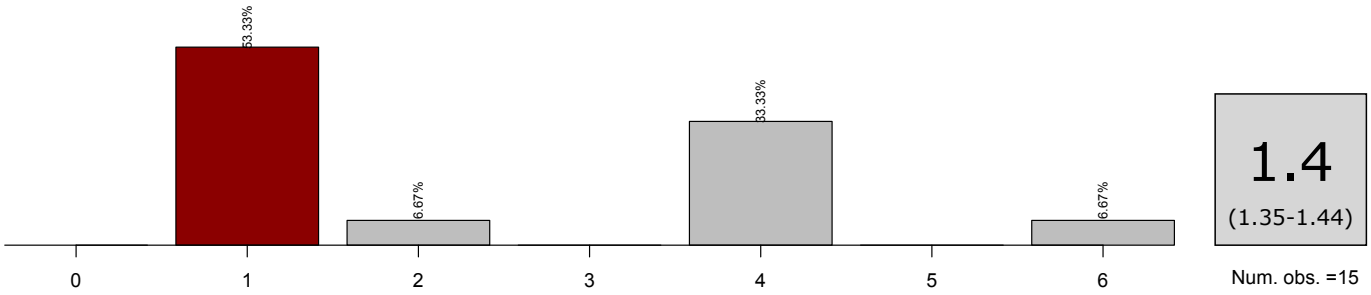
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.

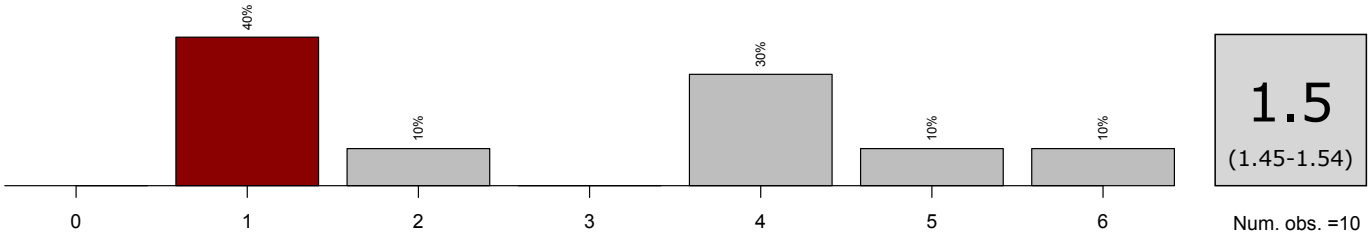






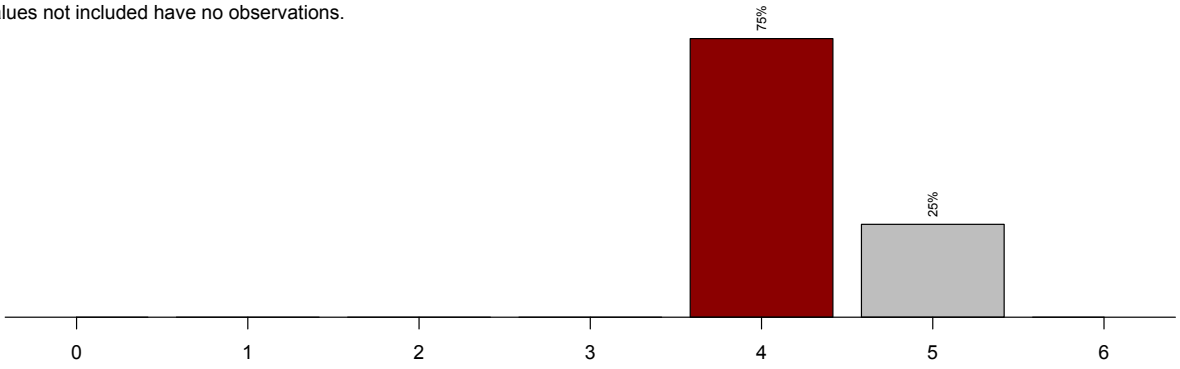




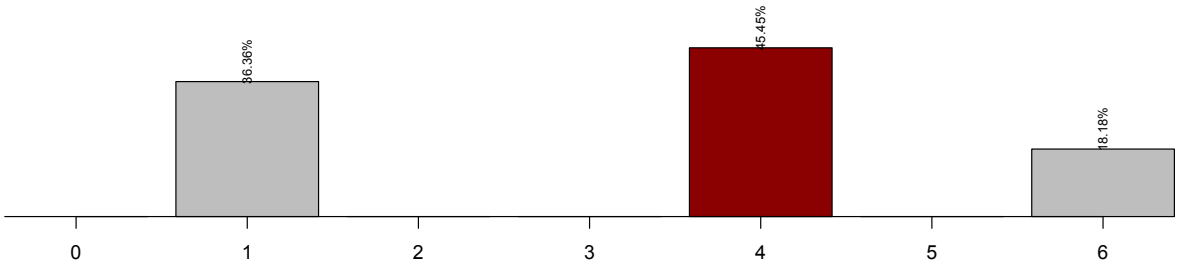


$PE_{(3)}$

(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



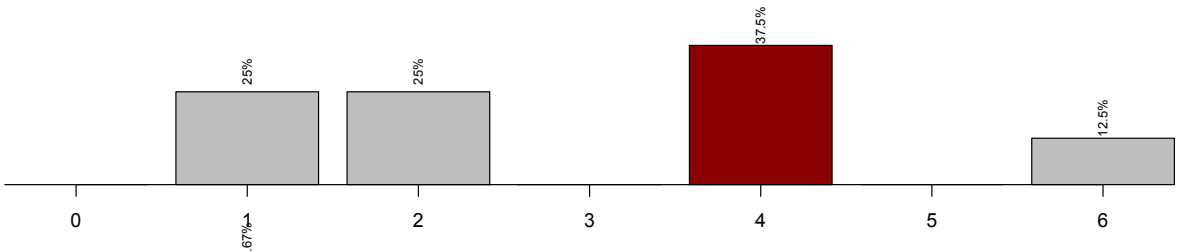
1.6
(0.95-1.04)
Num. obs. =4



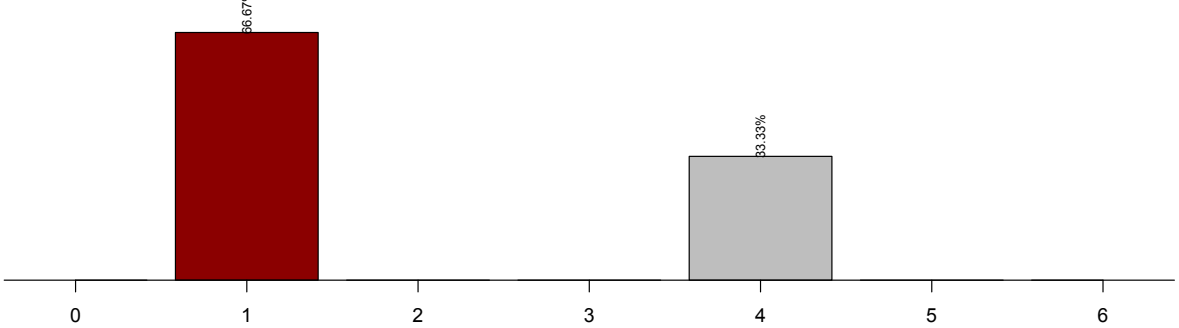
1.7
(1.05-1.14)
Num. obs. =11



1.8
(1.15-1.24)
Num. obs.=4



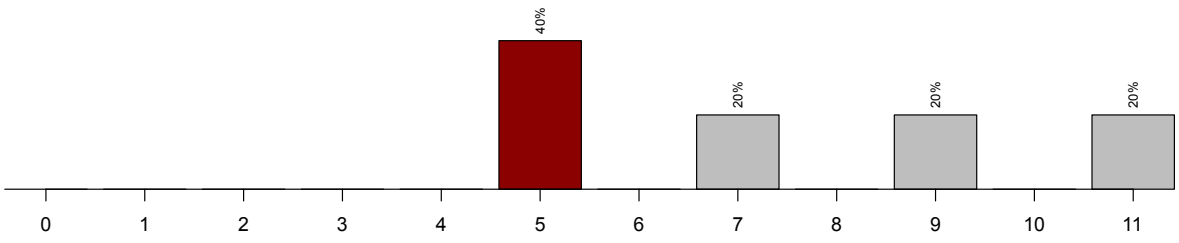
1.9
(1.25-1.34)
Num. obs. =8



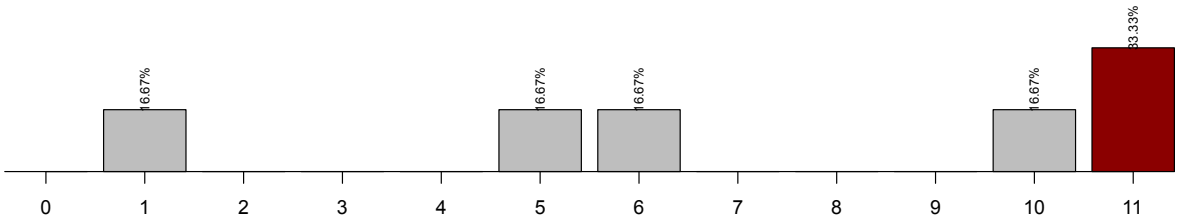
2.0
(1.35-1.44)
Num. obs. =3

$PL_{(1)}$

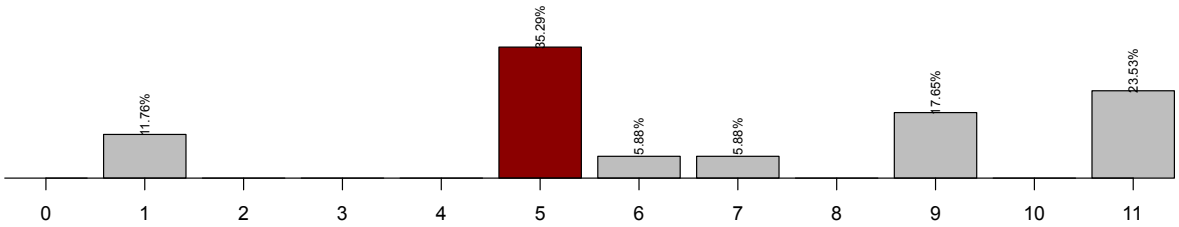
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



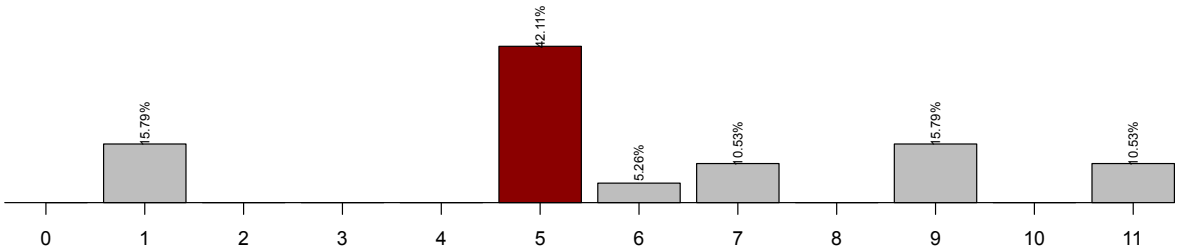
0.4
(0.35-0.44)
Num. obs. =5



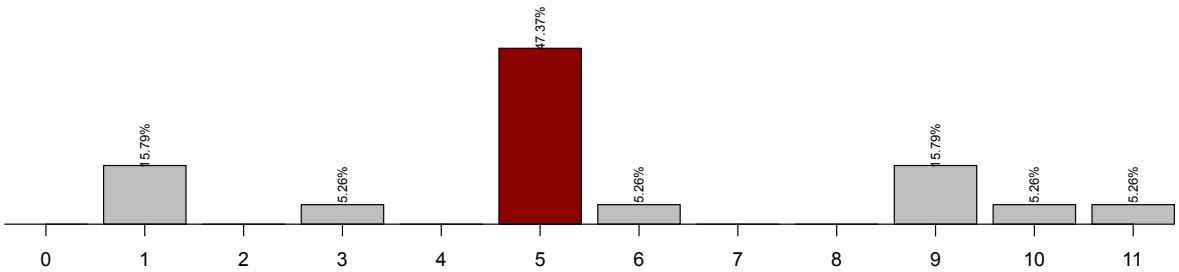
0.5
(0.45-0.54)
Num. obs. =6



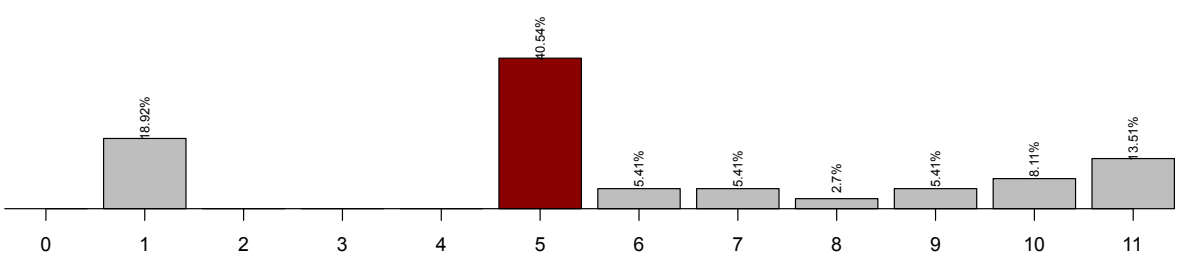
0.6
(0.55-0.64)
Num. obs.=17



0.7
(0.65-0.74)
Num. obs. =19



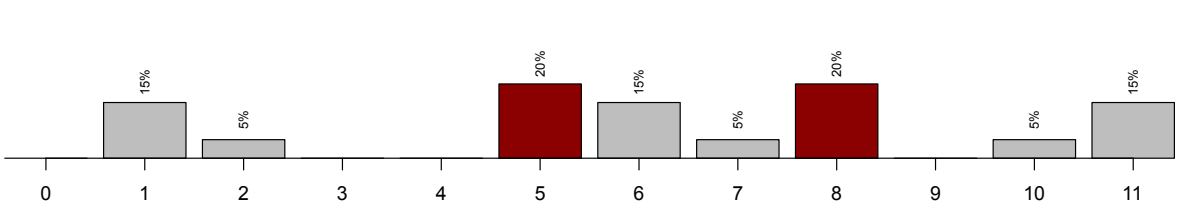
0.8
(0.75-0.84)
Num. obs. =19



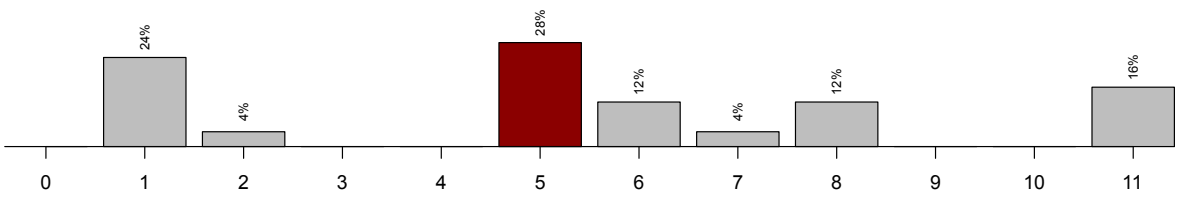
0.9
(0.85-0.94)
Num. obs. =37

PL(2)

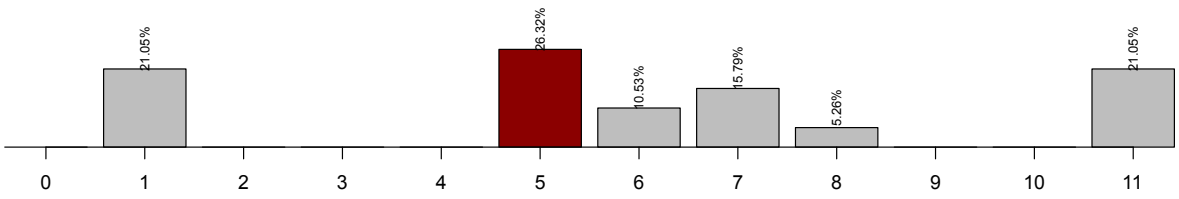
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



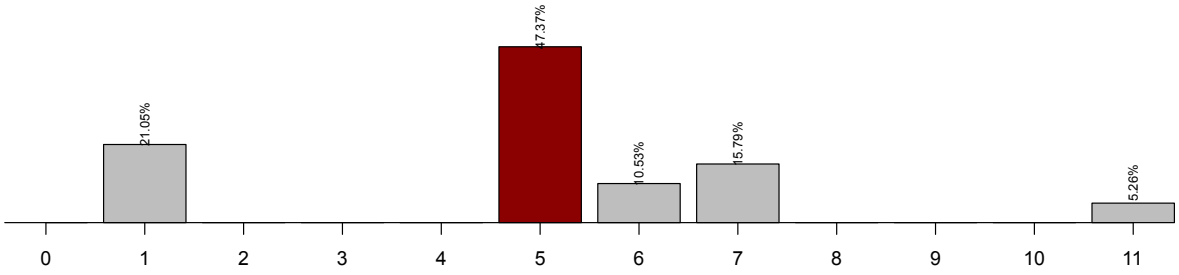
1.0
(0.95-1.04)
Num. obs. =20



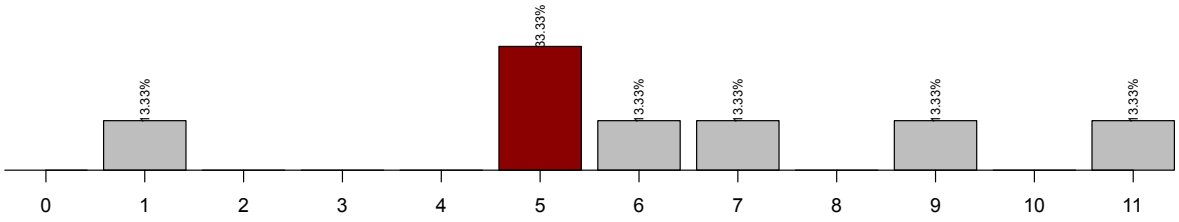
1.1
(1.05-1.14)
Num. obs. =25



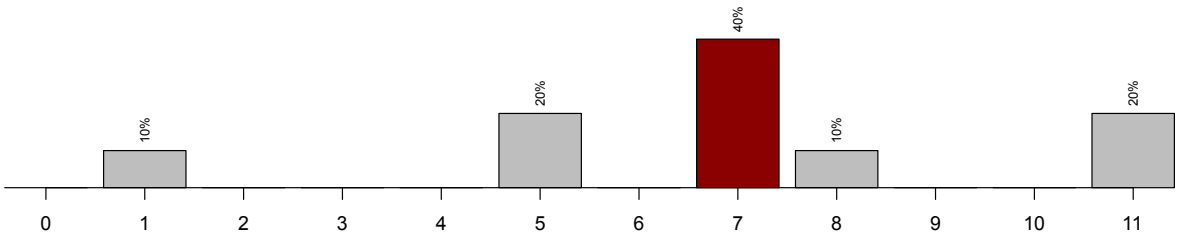
1.2
(1.15-1.24)
Num. obs.=19



1.3
(1.25-1.34)
Num. obs. =19



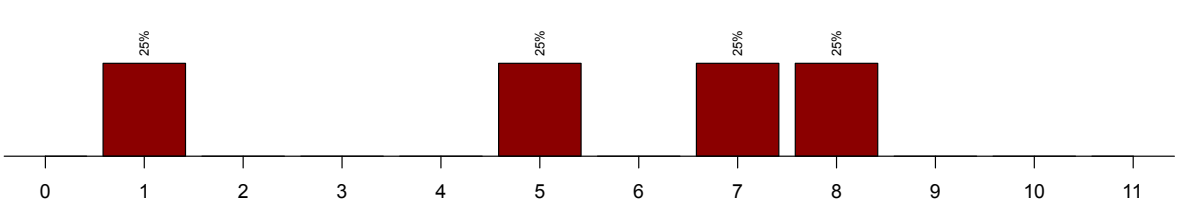
1.4
(1.35-1.44)
Num. obs. =15



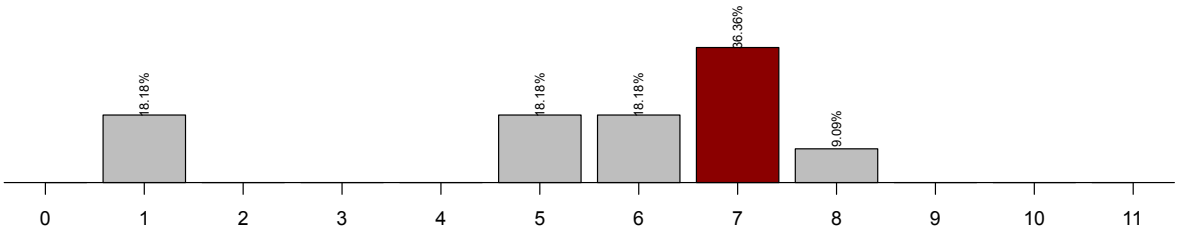
1.5
(1.45-1.54)
Num. obs. =10

PL(3)

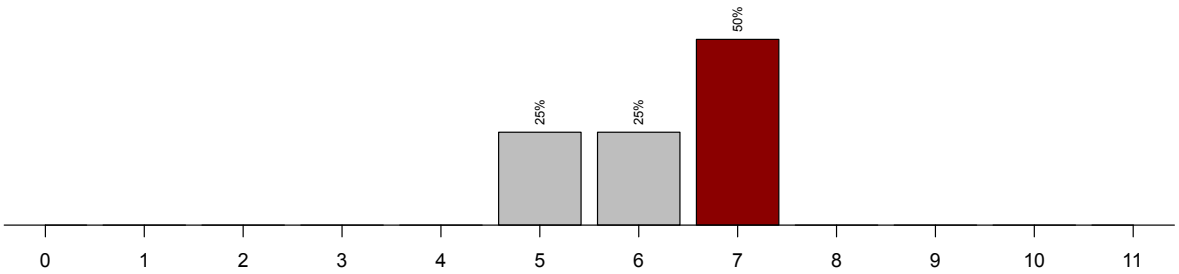
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



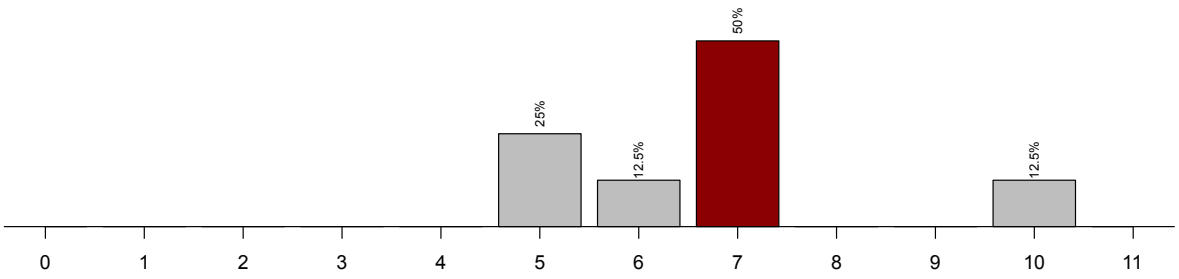
1.6
(0.95-1.04)
Num. obs. =4



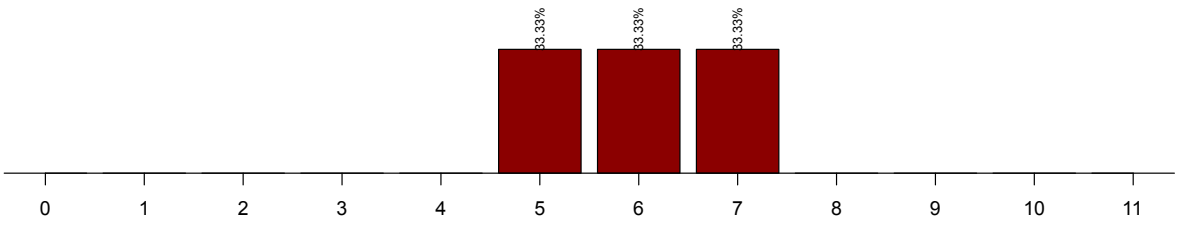
1.7
(1.05-1.14)
Num. obs. =11



1.8
(1.15-1.24)
Num. obs.=4



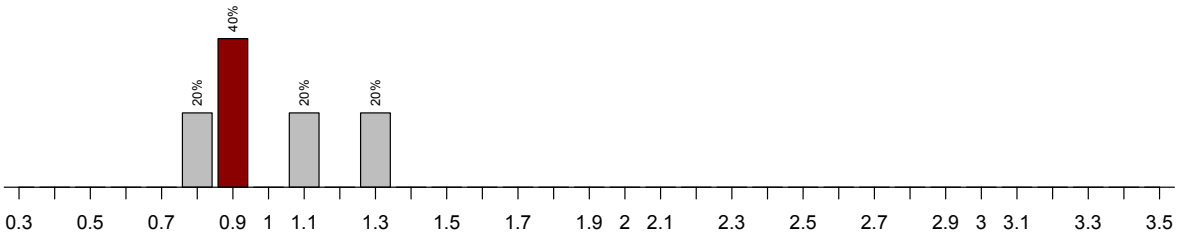
1.9
(1.25-1.34)
Num. obs. =8



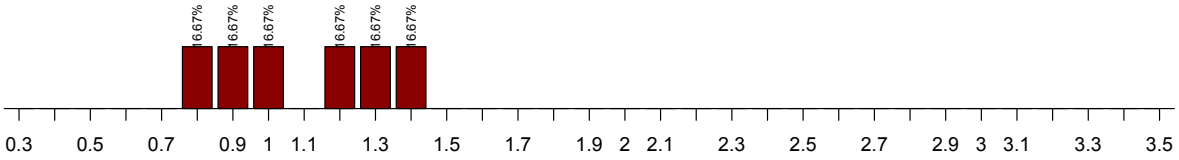
2.0
(1.35-1.44)
Num. obs. =3

T1R1(1)

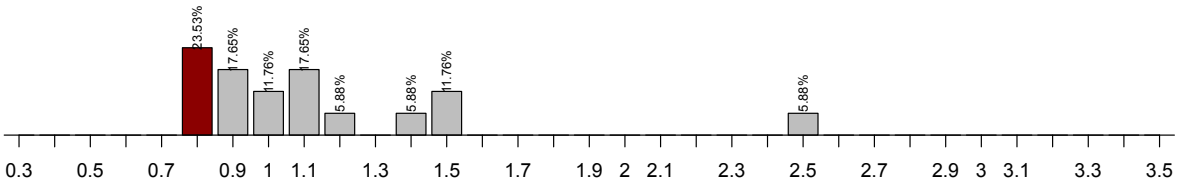
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



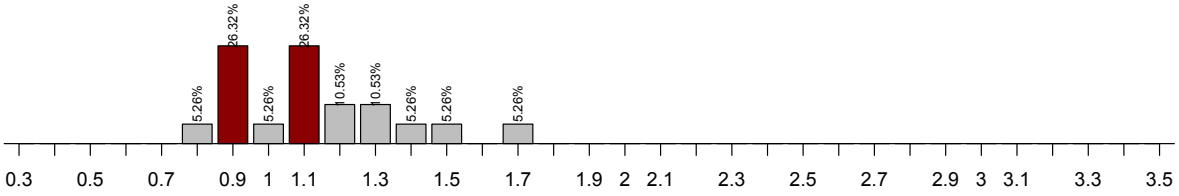
0.4
(0.35-0.44)
Num. obs. =5



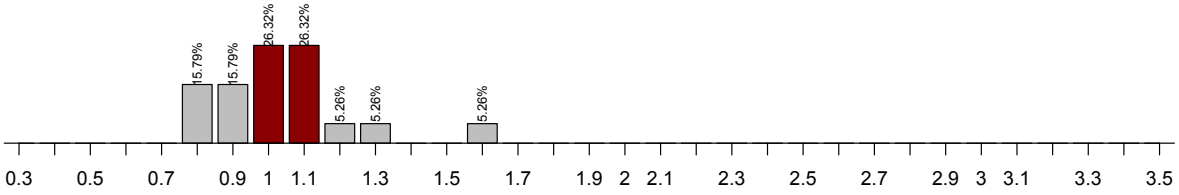
0.5
(0.45-0.54)
Num. obs. =6



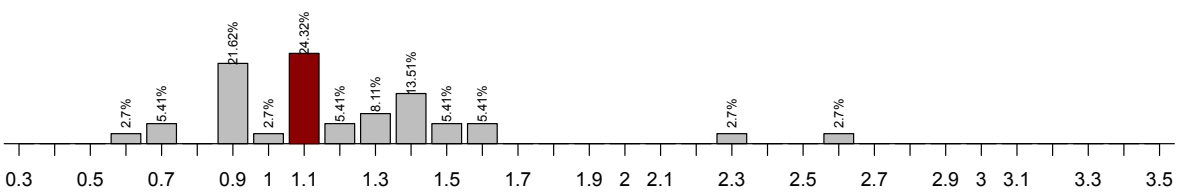
0.6
(0.55-0.64)
Num. obs.=17



0.7
(0.65-0.74)
Num. obs. =19



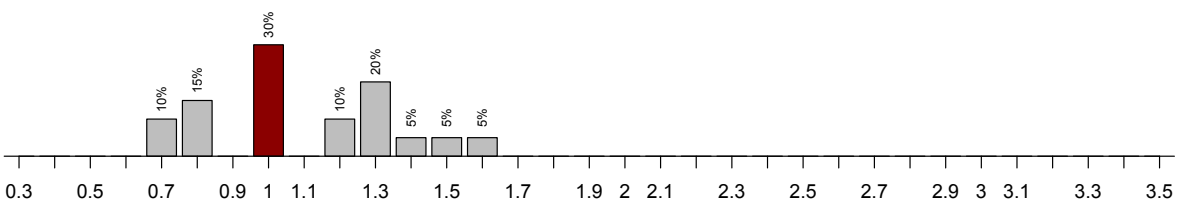
0.8
(0.75-0.84)
Num. obs. =19



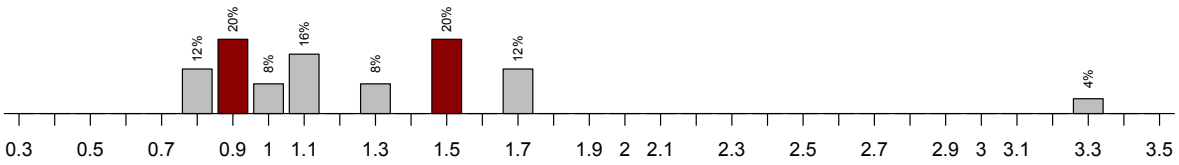
0.9
(0.85-0.94)
Num. obs. =37

T1R1(2)

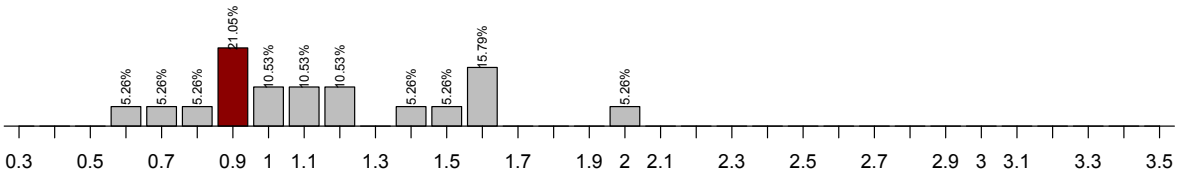
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



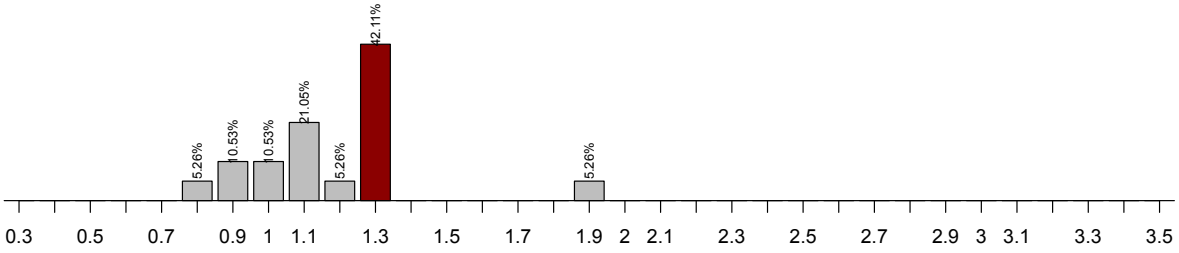
1.0
(0.95-1.04)
Num. obs. =20



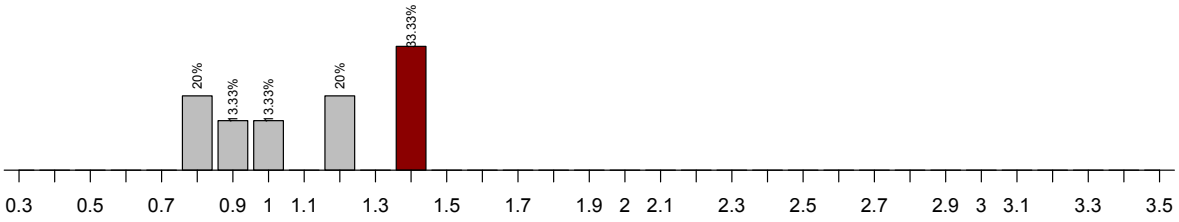
1.1
(1.05-1.14)
Num. obs. =25



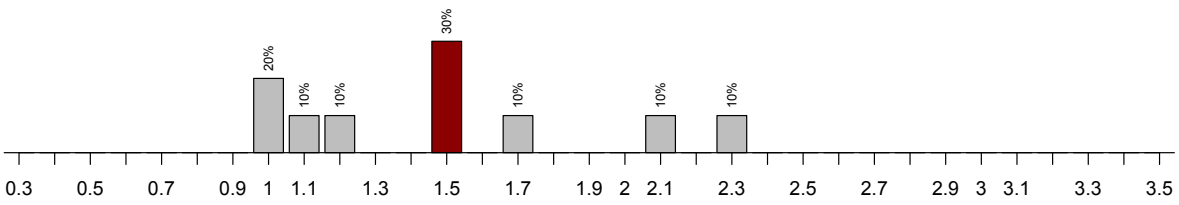
1.2
(1.15-1.24)
Num. obs.=19



1.3
(1.25-1.34)
Num. obs. =19



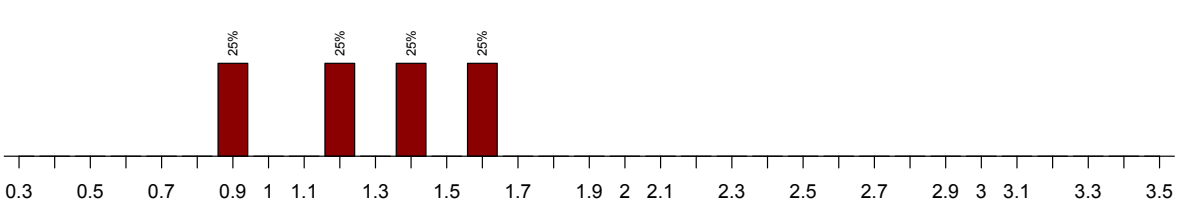
1.4
(1.35-1.44)
Num. obs. =15



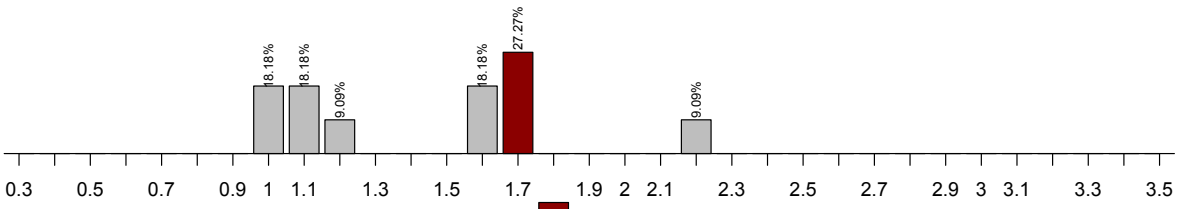
1.5
(1.45-1.54)
Num. obs. =10

T1R1(3)

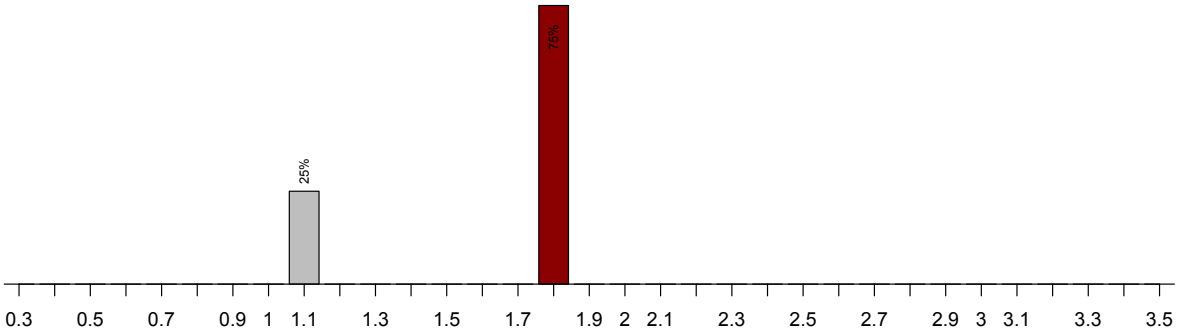
(*) T2R1 = 0.3, 2.1, 2.2, 2.3, 2.4, 2.7, 2.8 and 3.5 have 1 or 2 observations.
(*) The values not included have no observations.



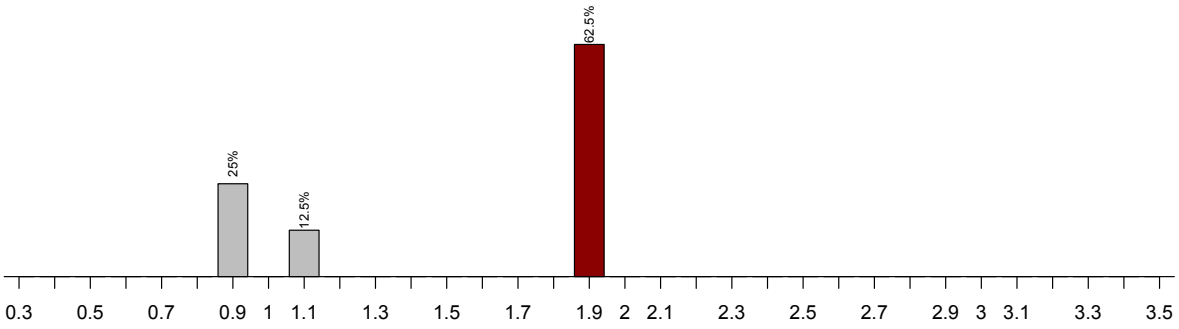
1.6
(0.95-1.04)
Num. obs. =4



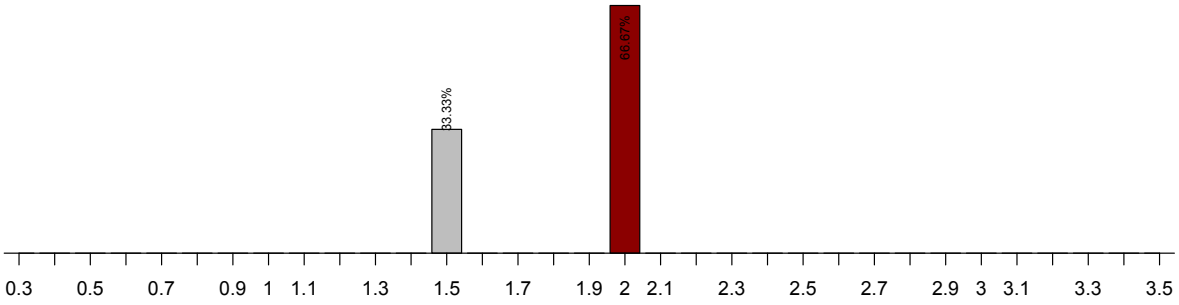
1.7
(1.05-1.14)
Num. obs. =11



1.8
(1.15-1.24)
Num. obs.=4



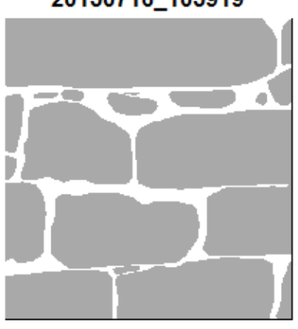
1.9
(1.25-1.34)
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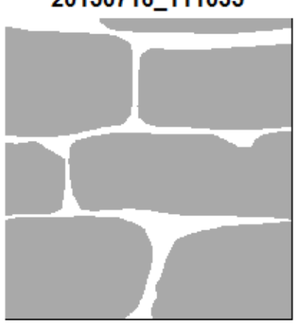


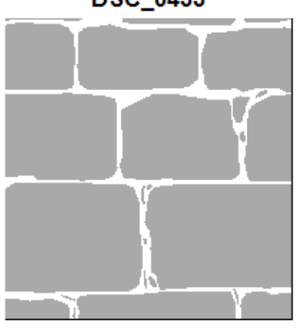
2.0
(1.35-1.44)
Num. obs. =3

3.2 PATTERNS CLASSIFICATION RESULTS

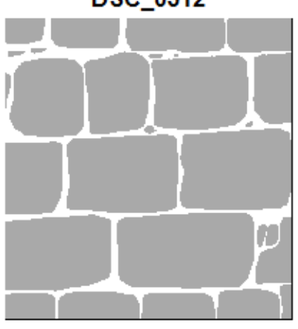
CLUSTER 1

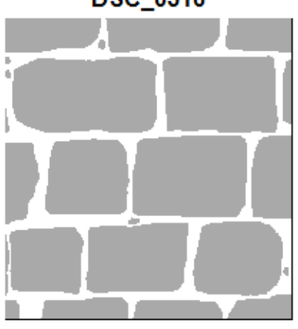
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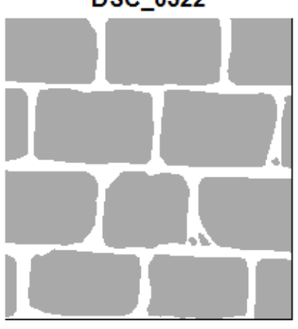
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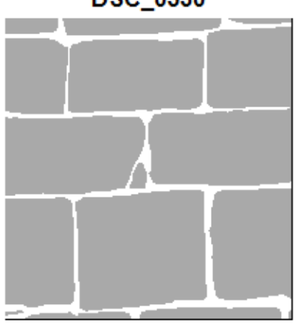
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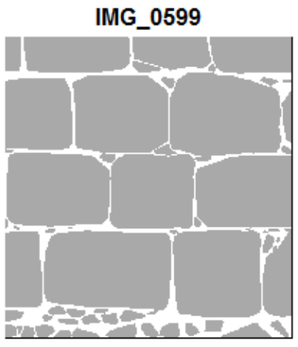
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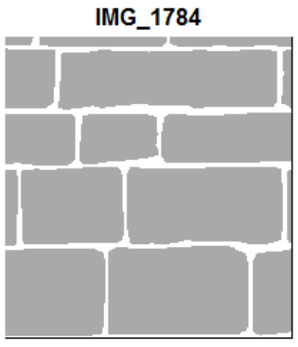
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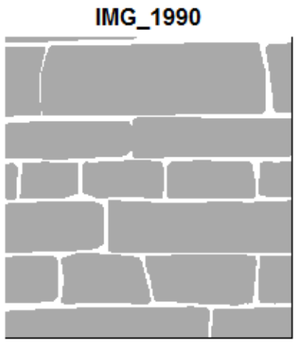
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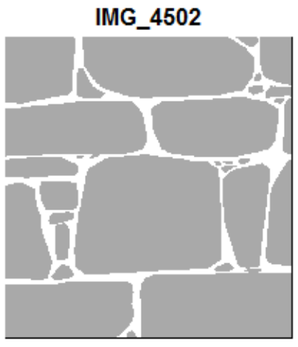
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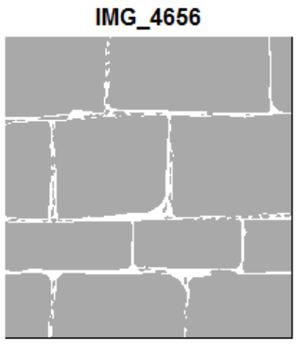
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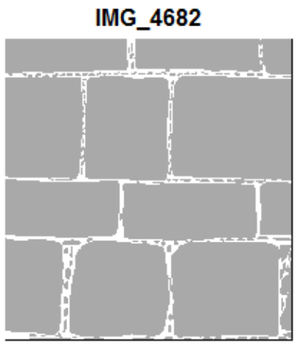
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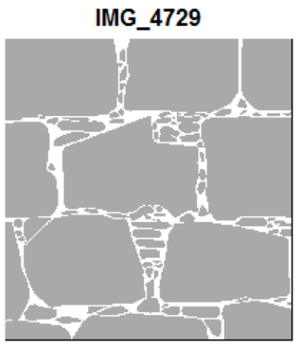
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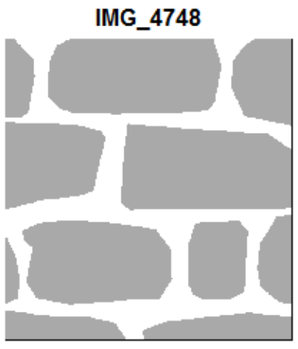
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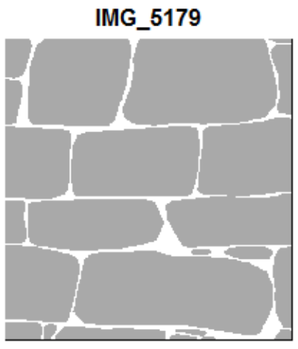
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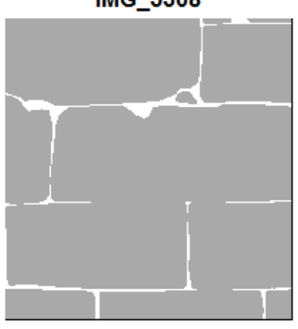
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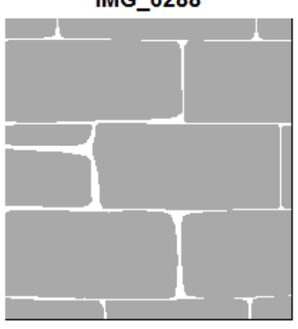
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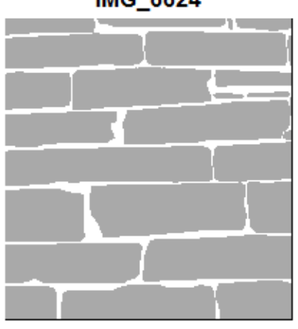
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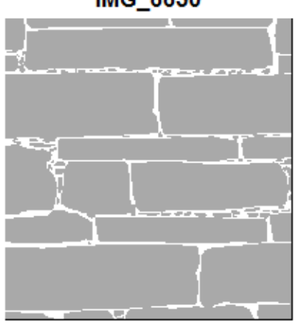
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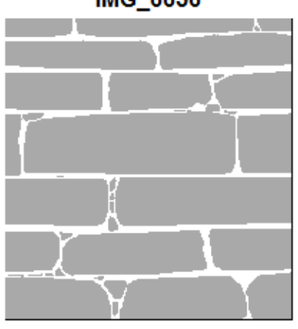
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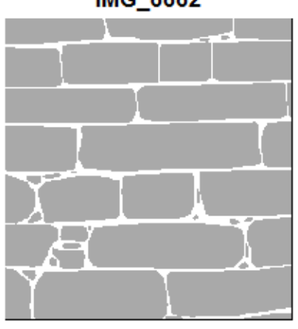
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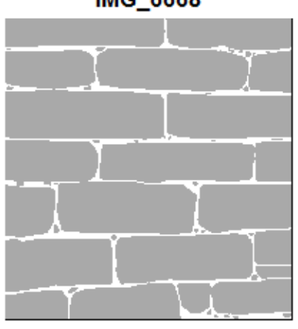
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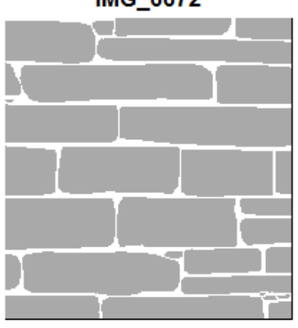
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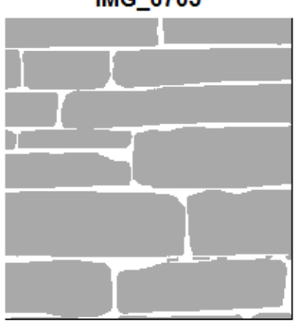
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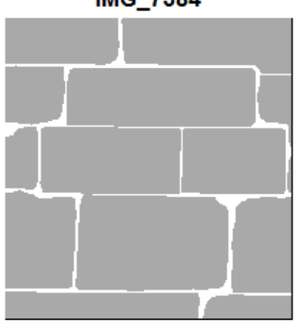
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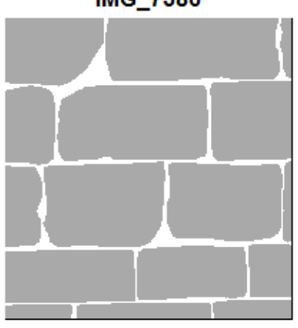
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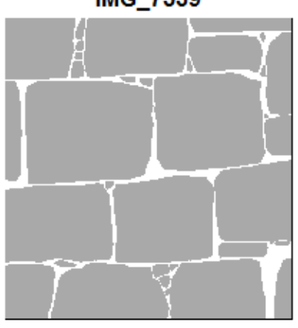
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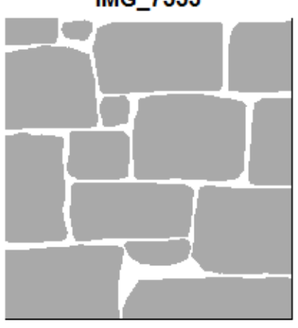
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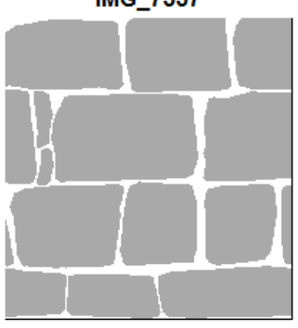
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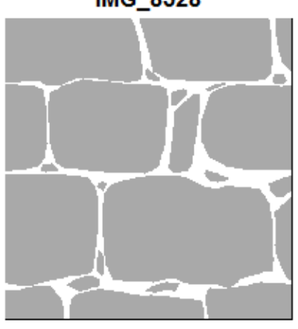
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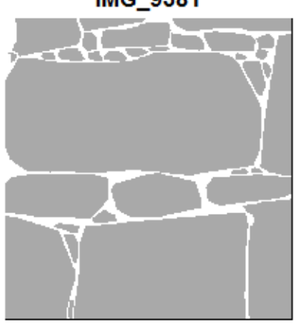
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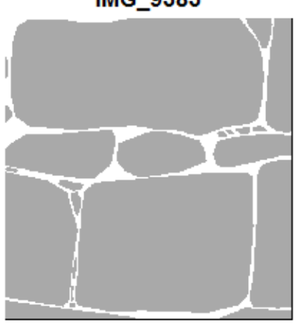
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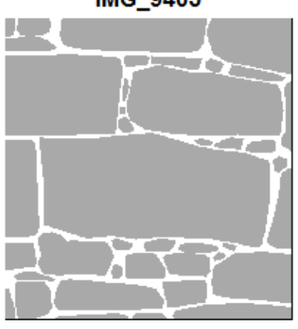
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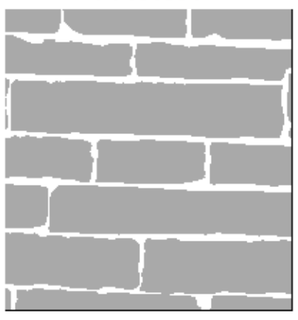
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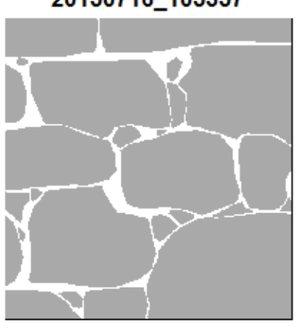
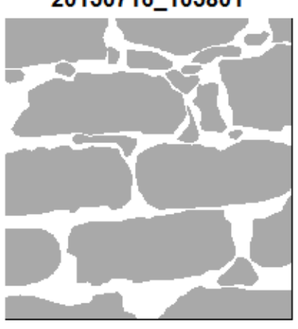
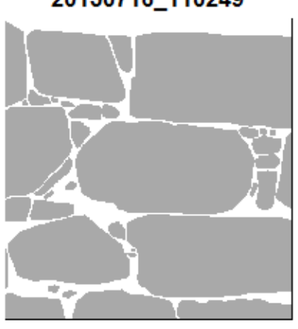
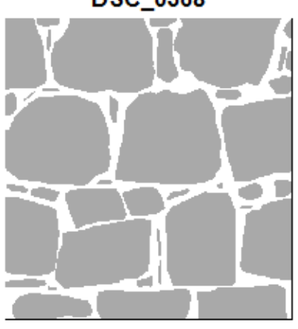
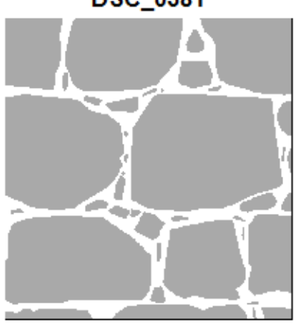
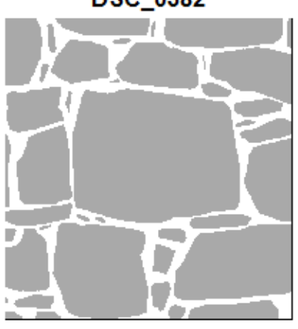
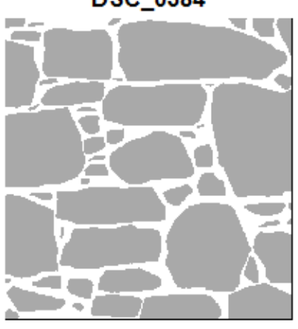
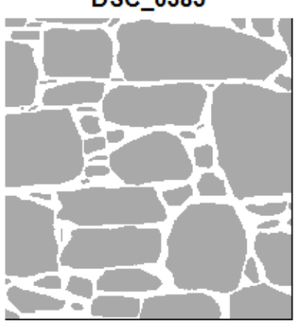
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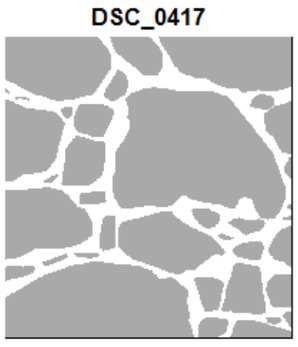
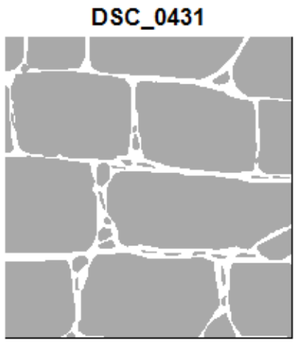
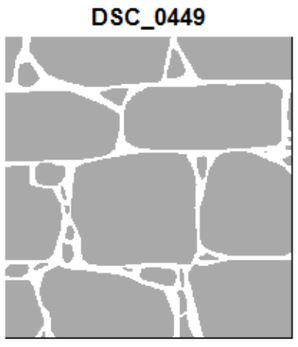


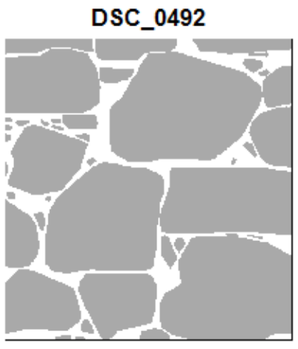
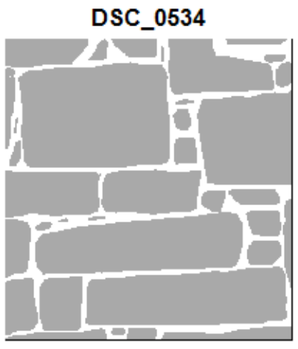
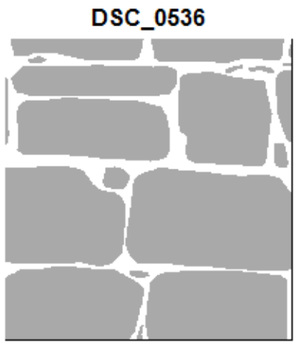
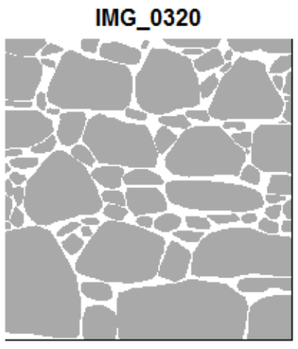
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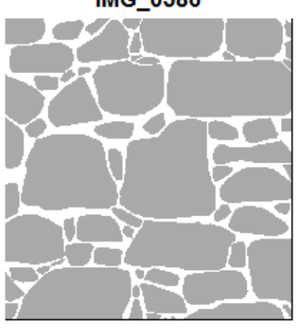
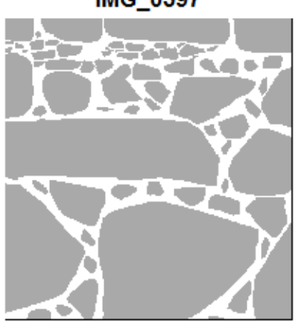
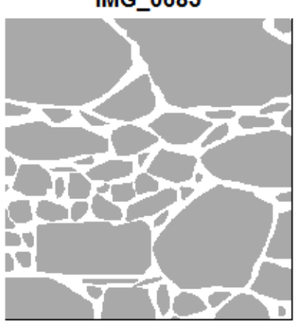
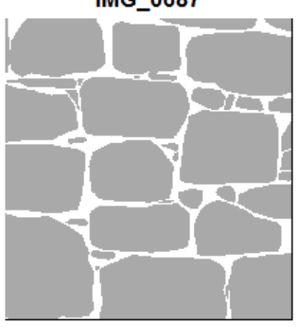
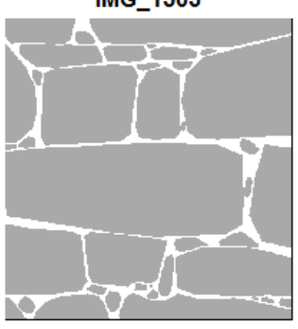


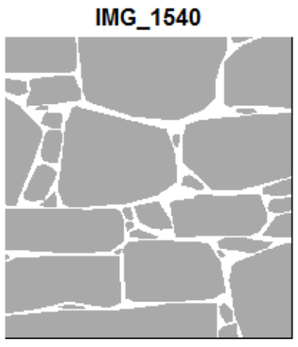
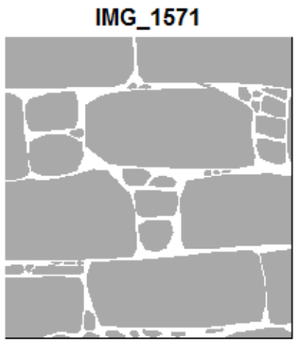
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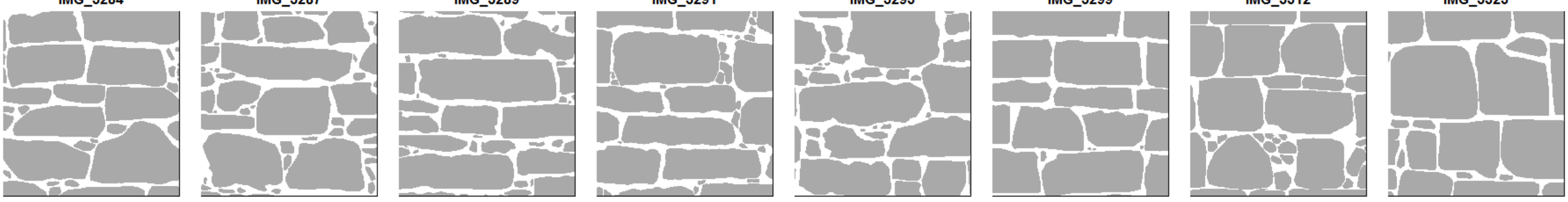
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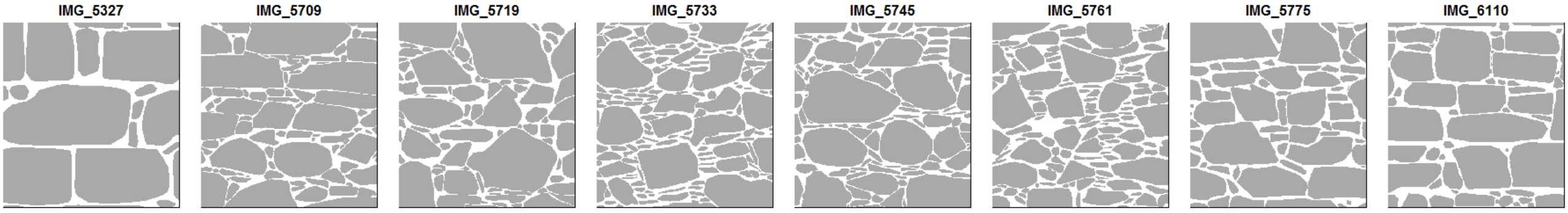
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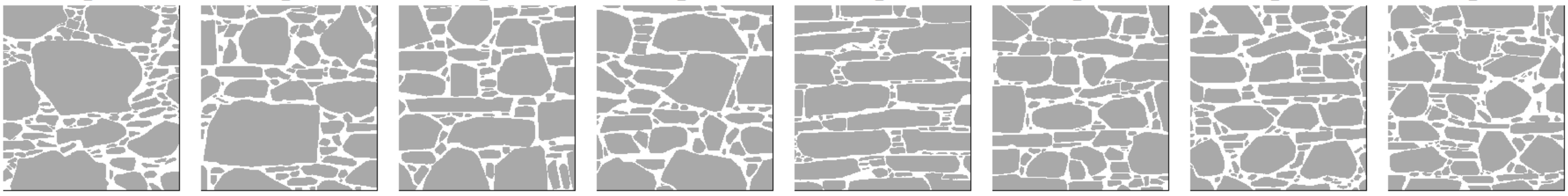
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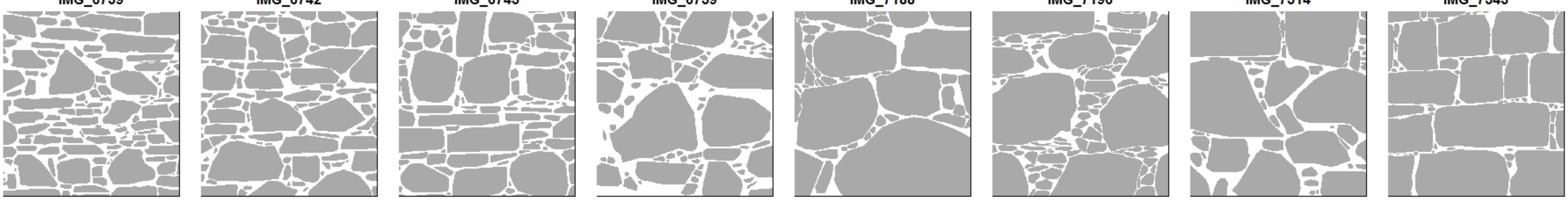
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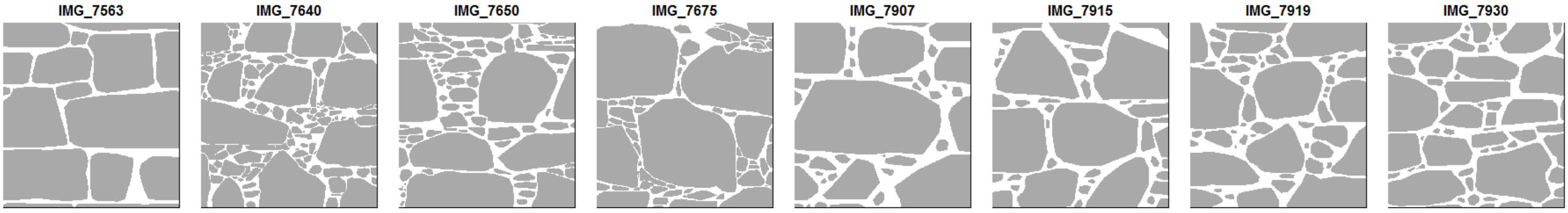
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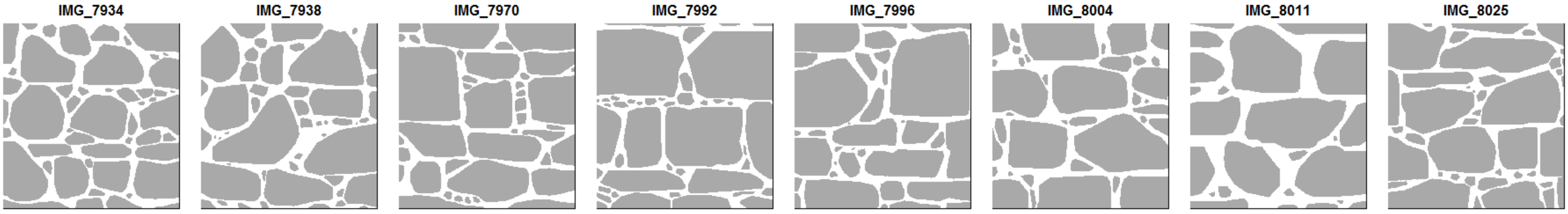
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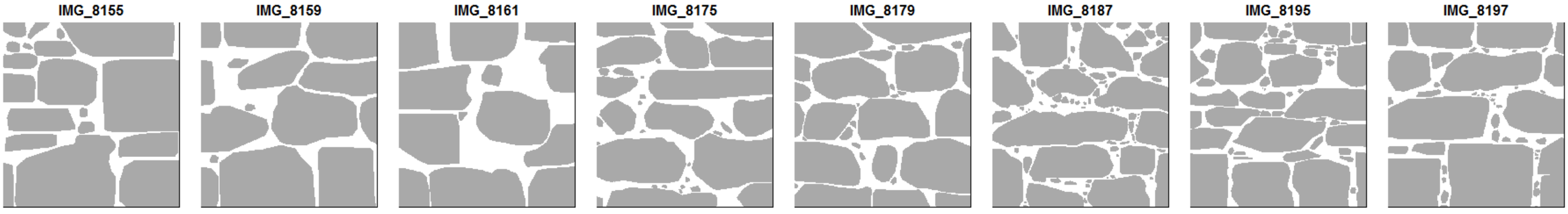
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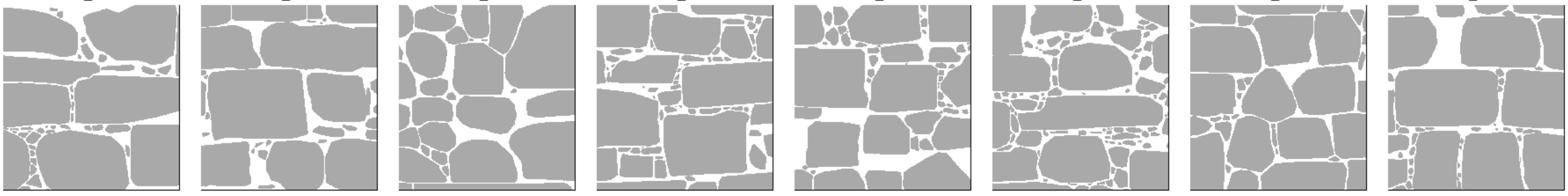
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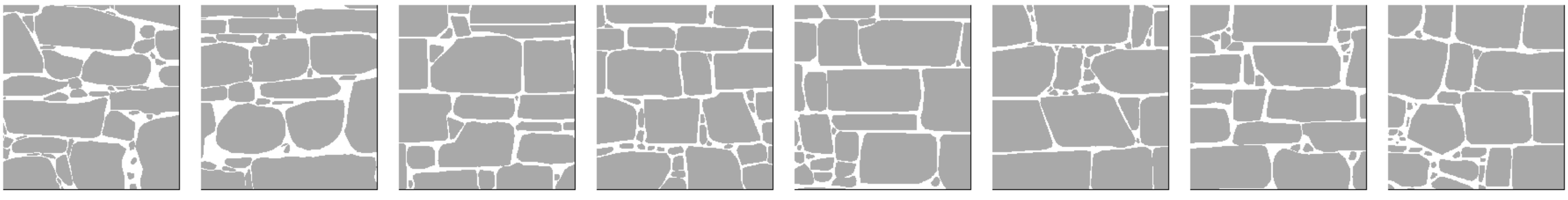
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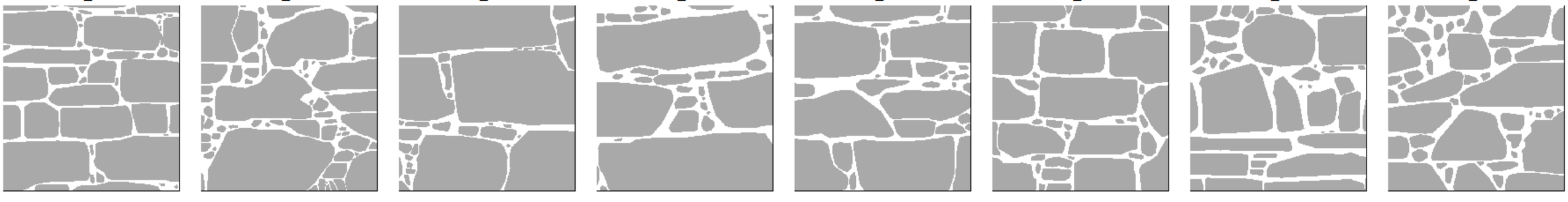
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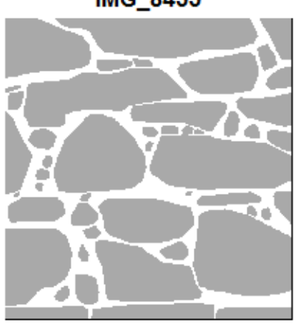


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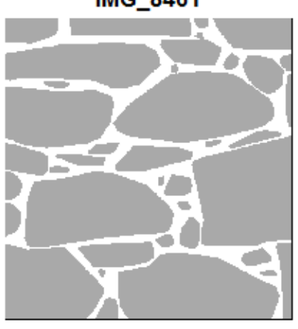


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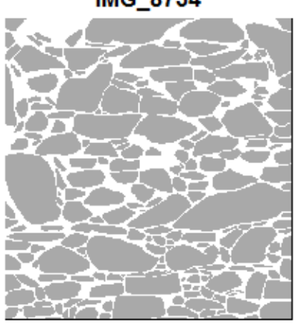
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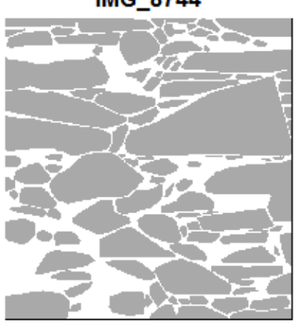
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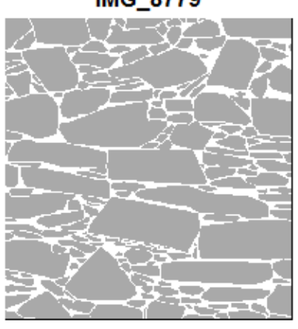
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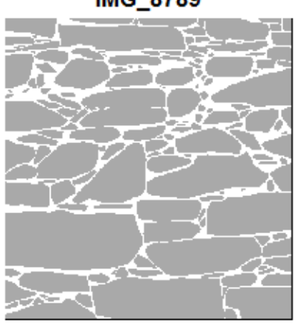
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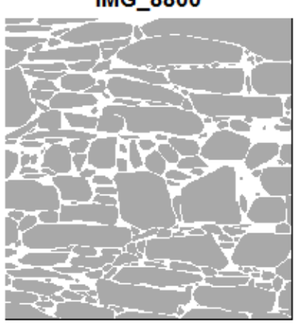
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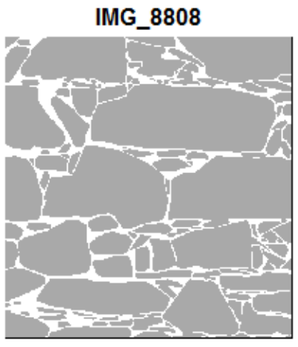
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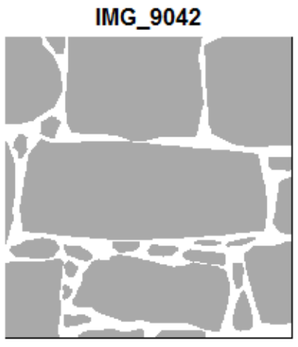
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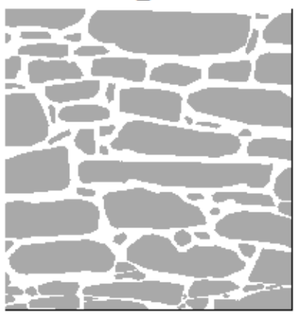
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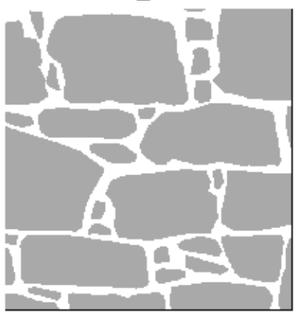
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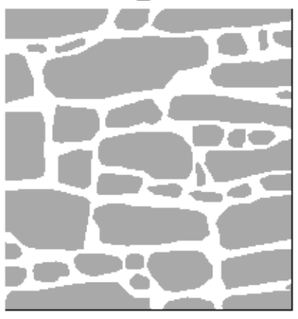
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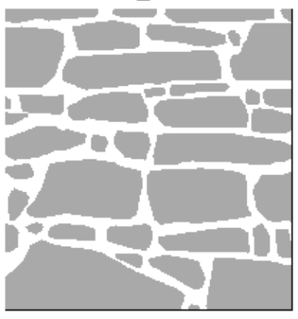
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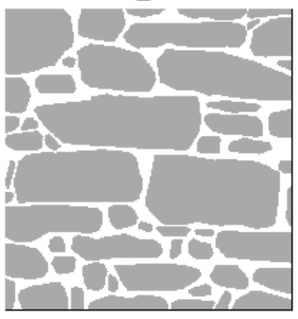
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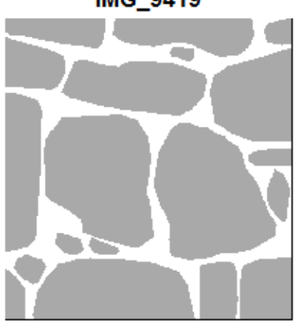
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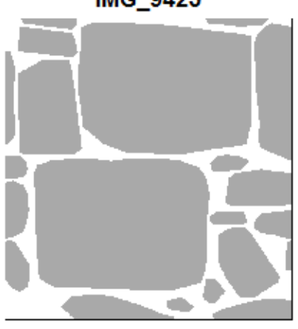
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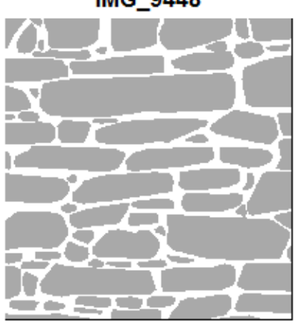
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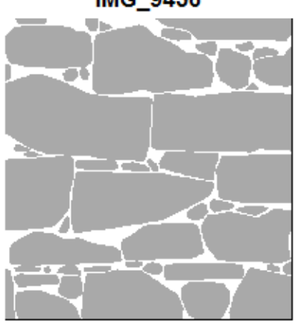
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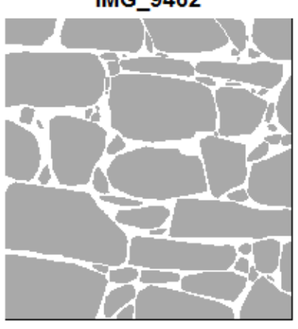
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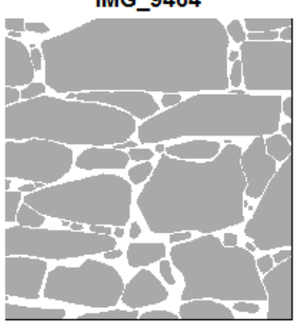
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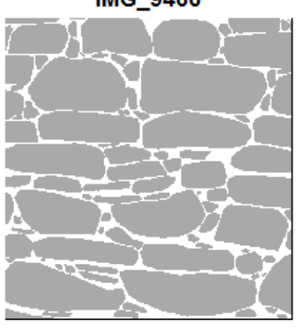
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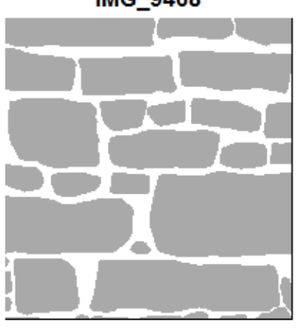
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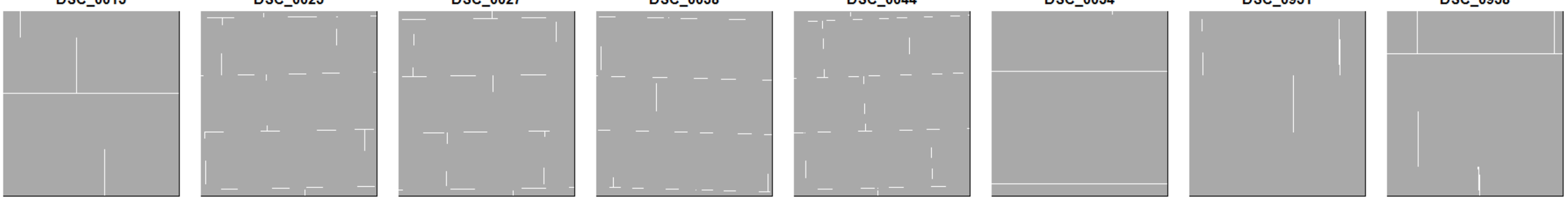


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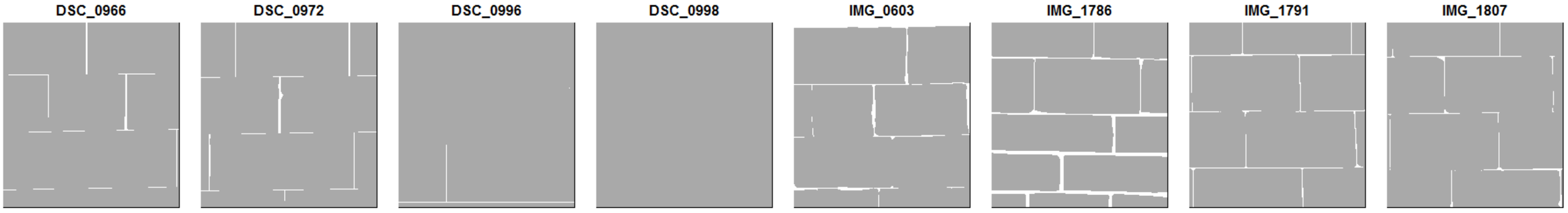


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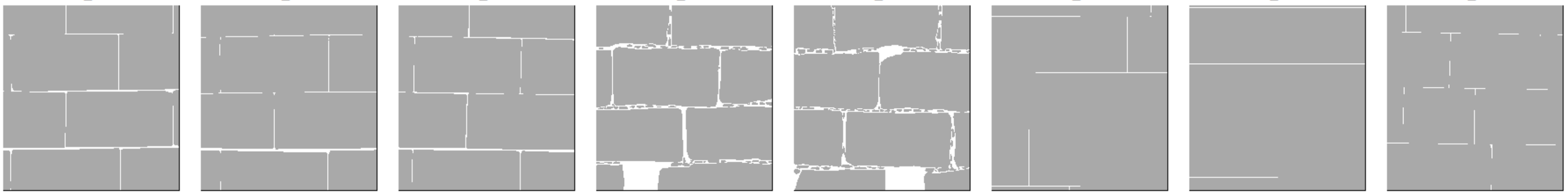
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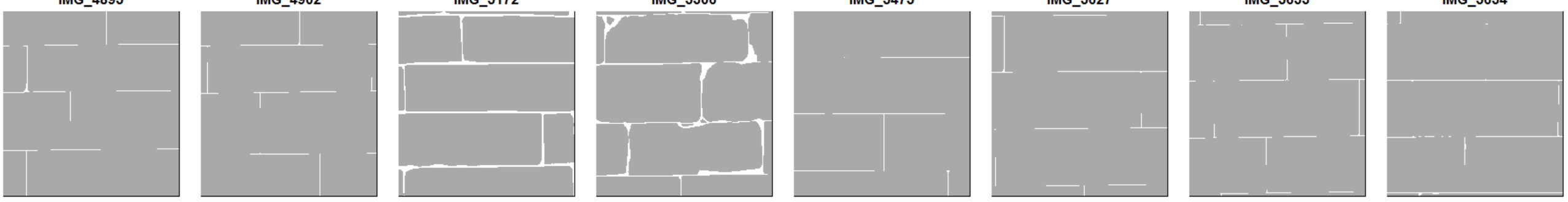
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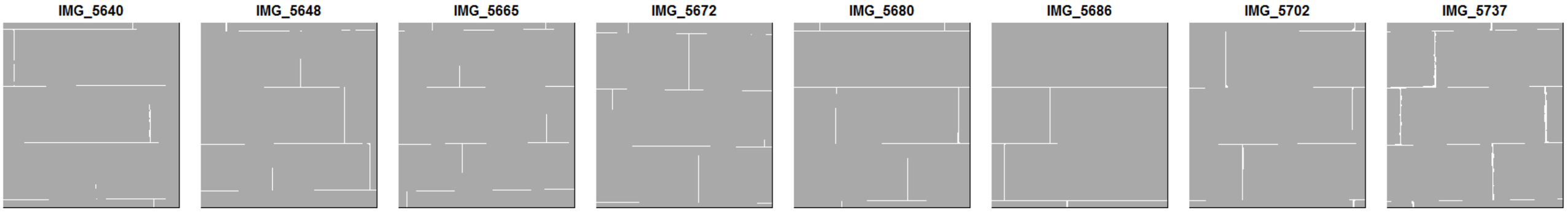
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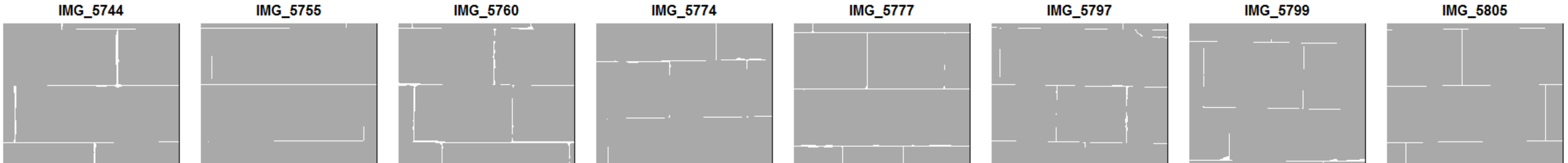
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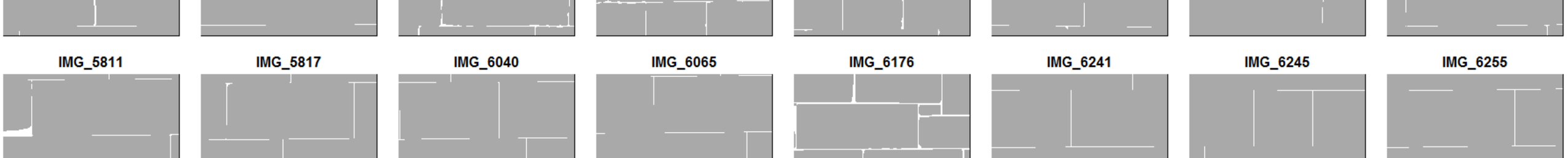
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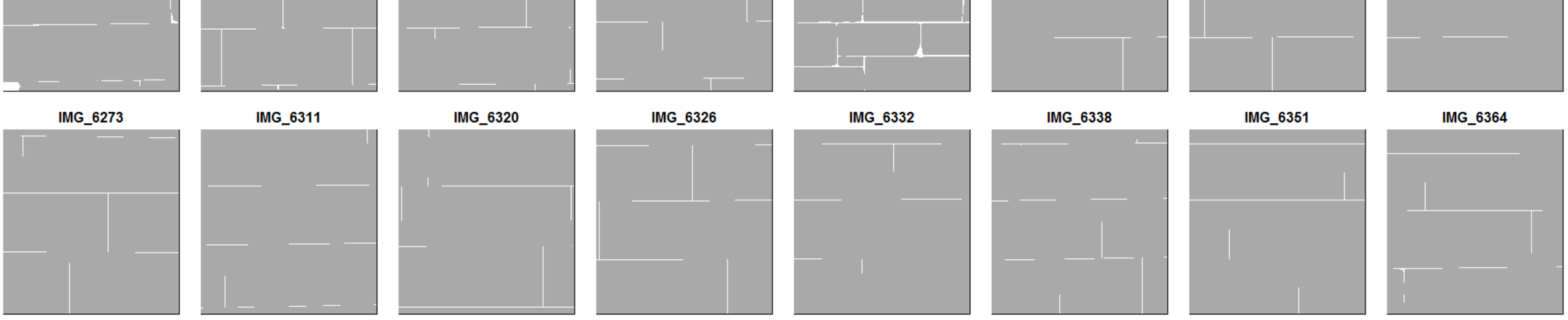
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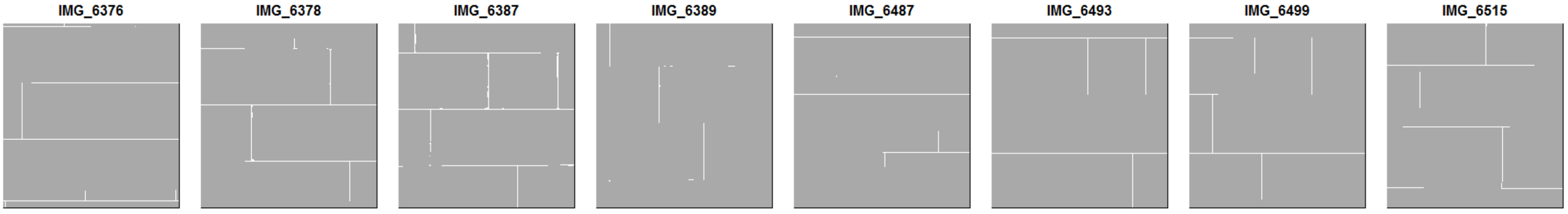
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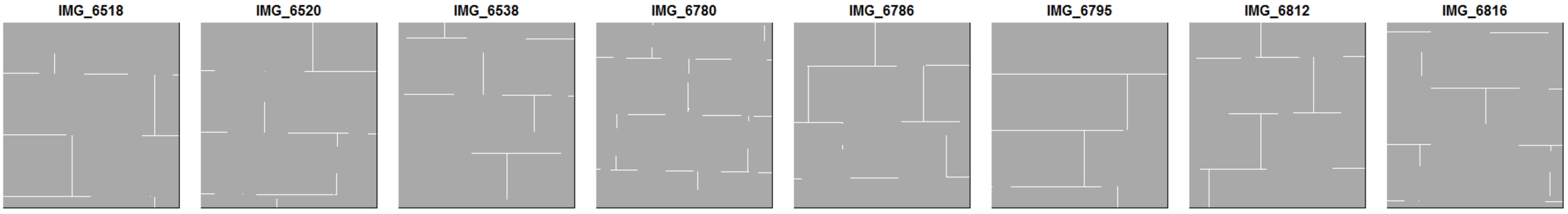
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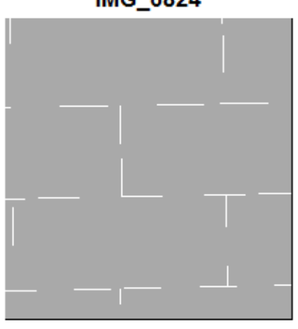
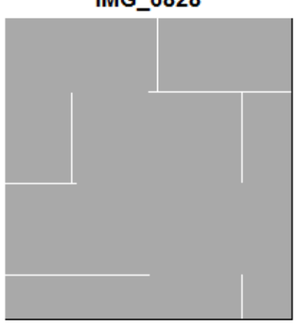
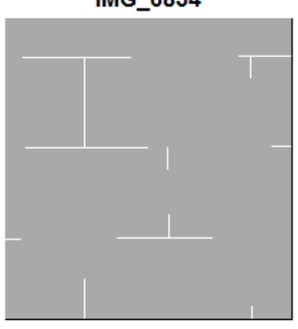
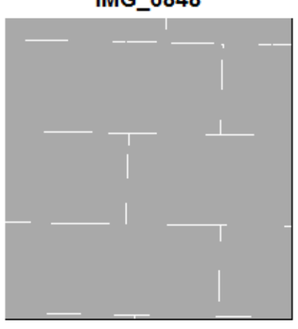
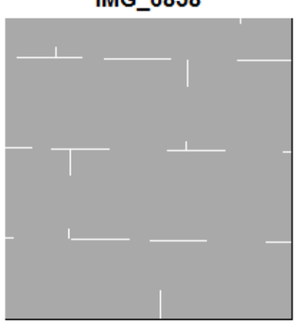
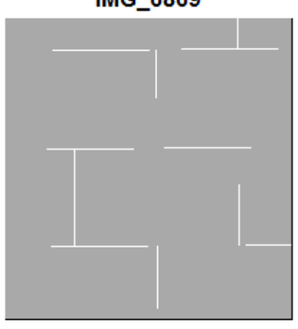
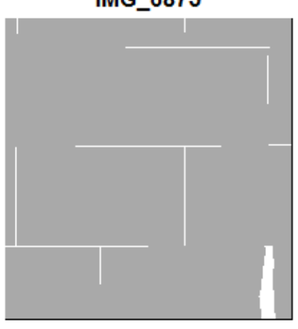
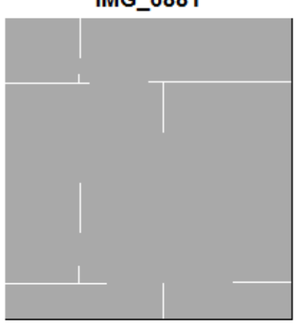
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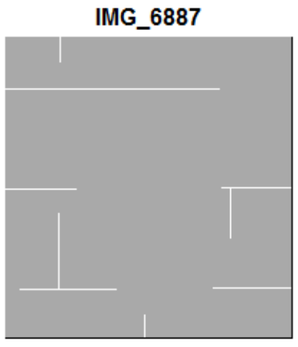
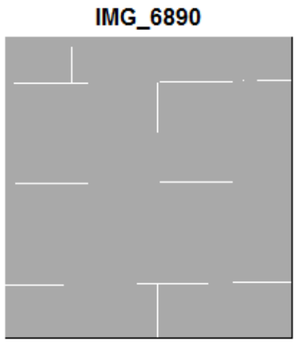
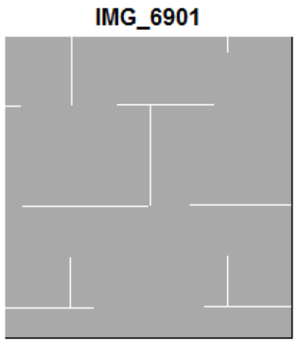
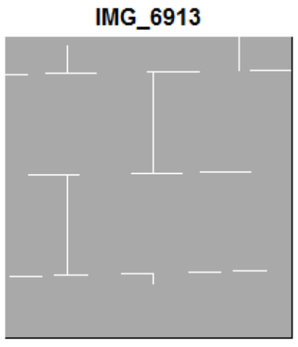
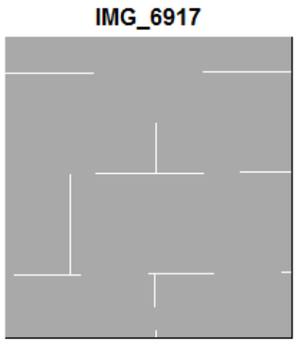
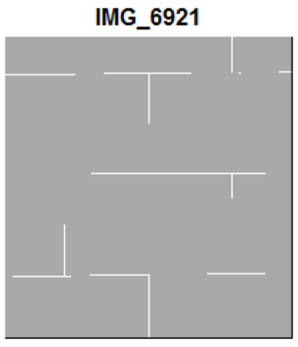
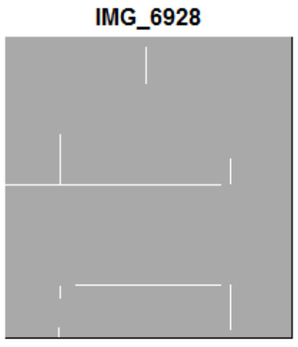
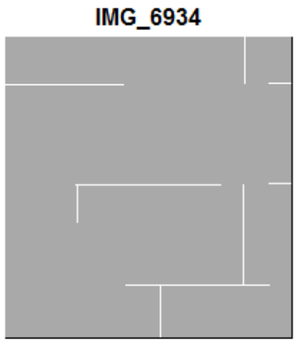


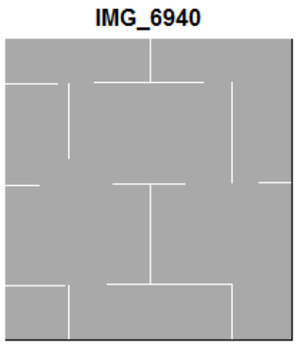
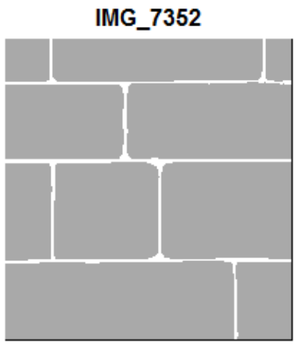
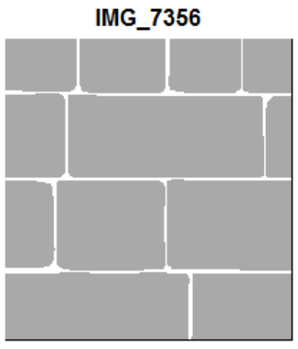
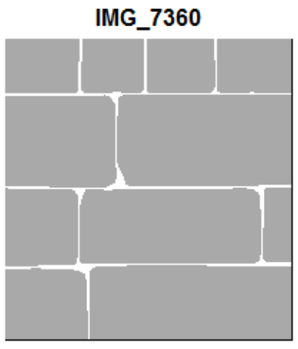
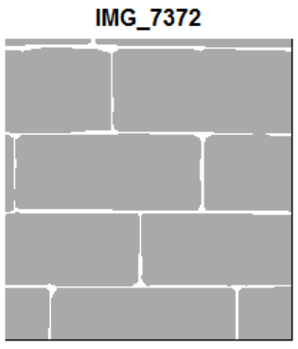
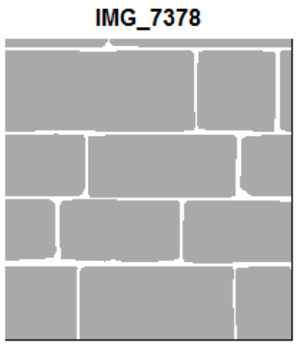
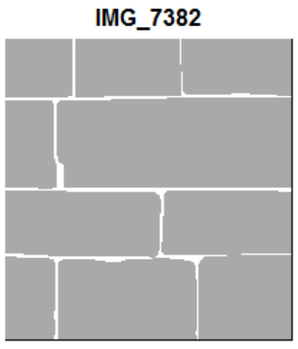
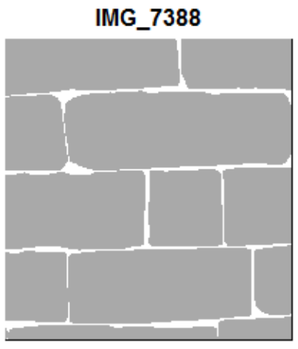
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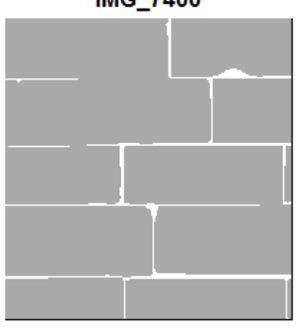
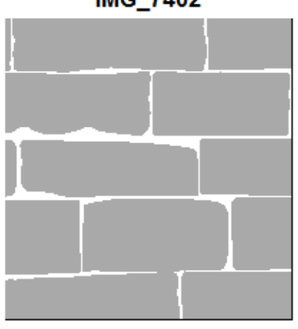
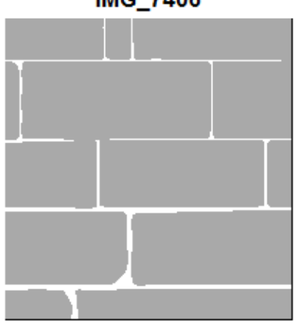
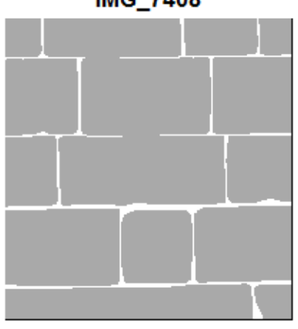
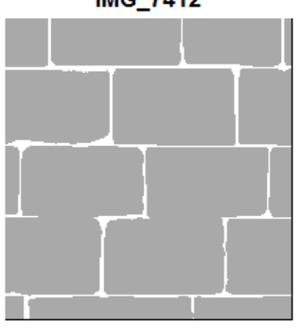
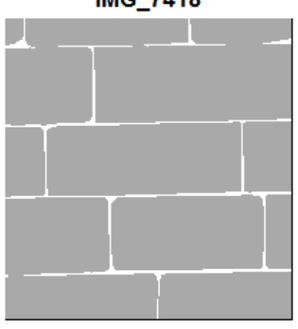
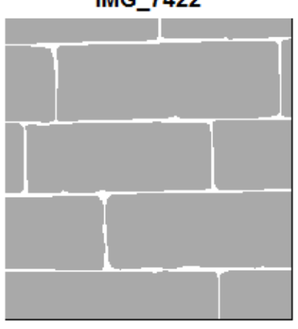
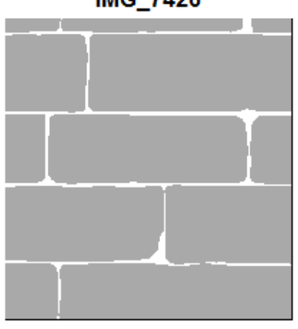


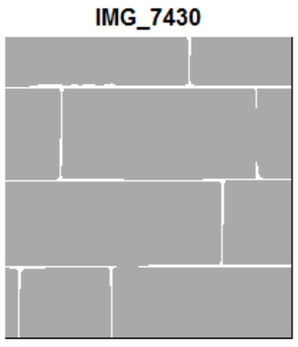
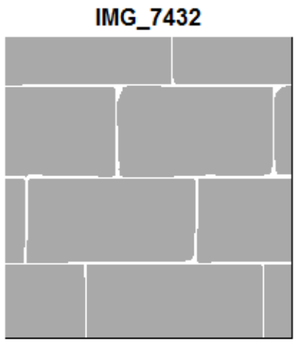
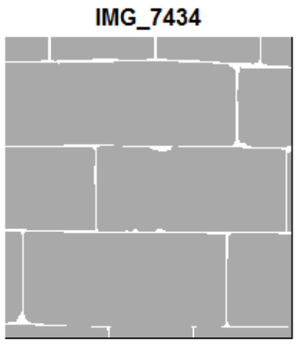
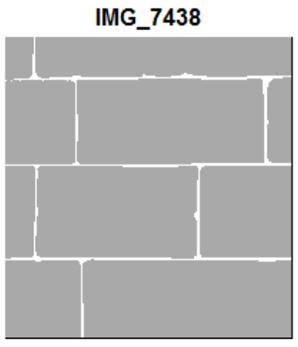
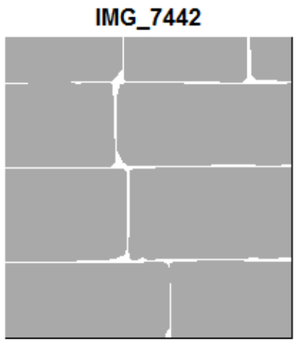
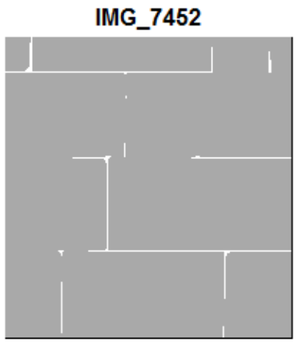
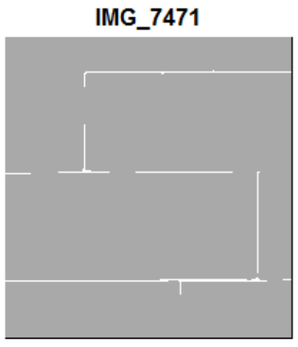
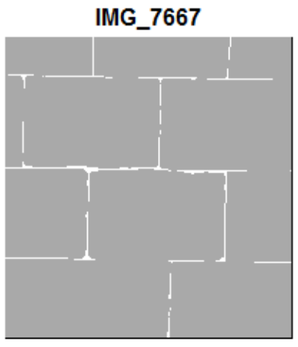
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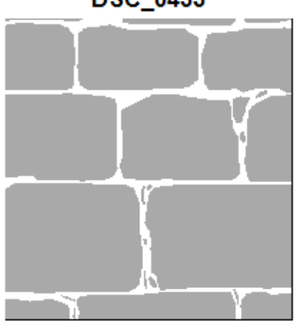
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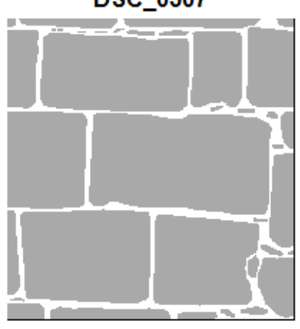
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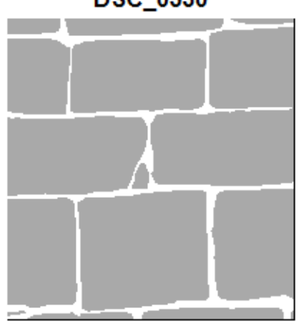
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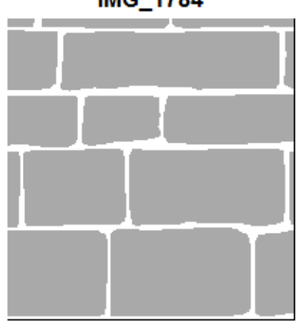
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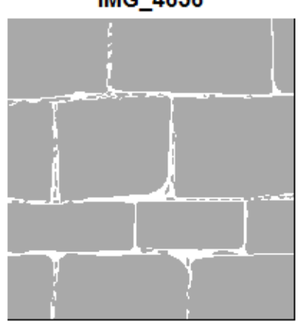
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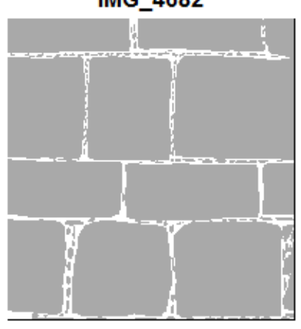
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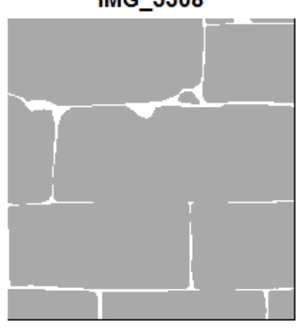
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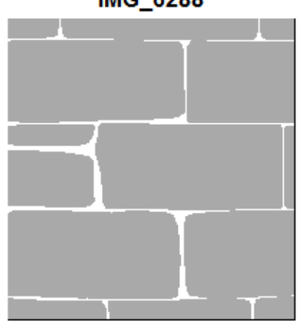
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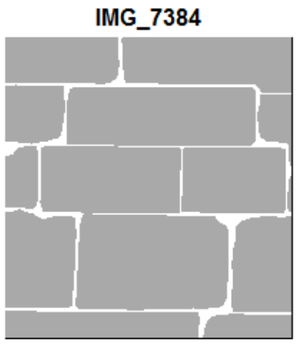
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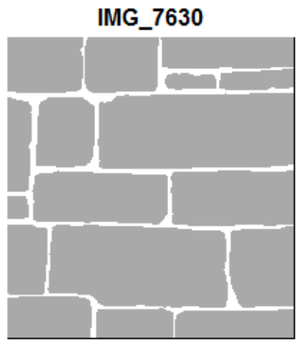
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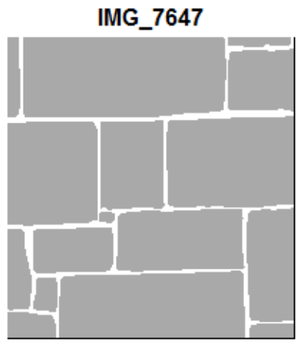
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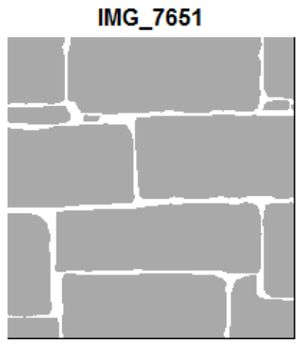
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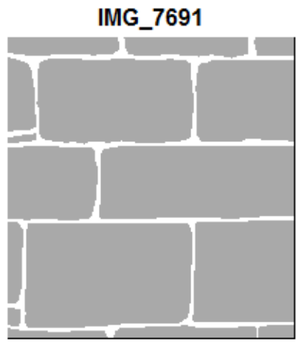
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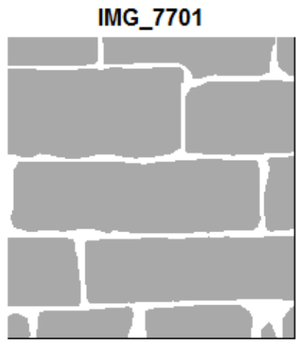
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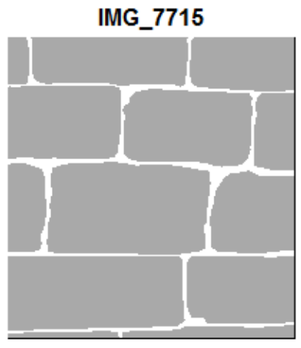
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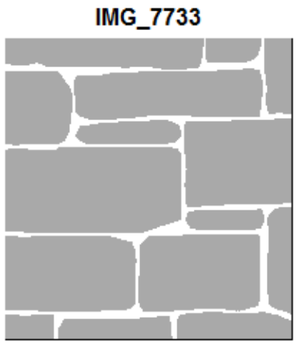
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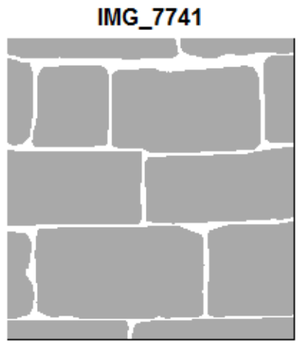
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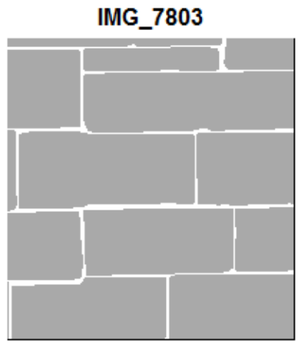
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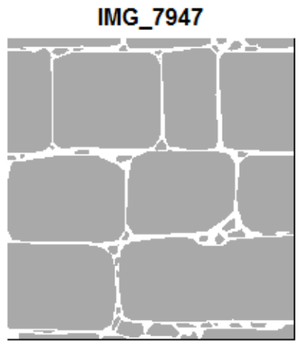
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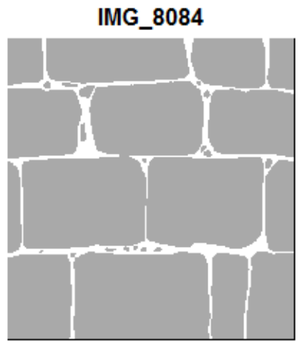
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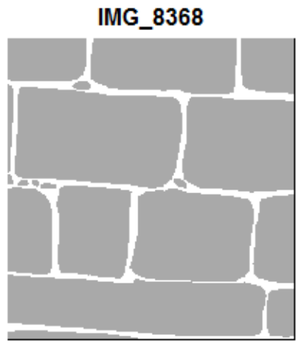
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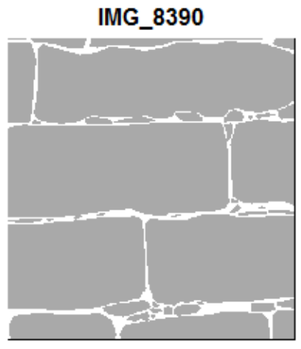
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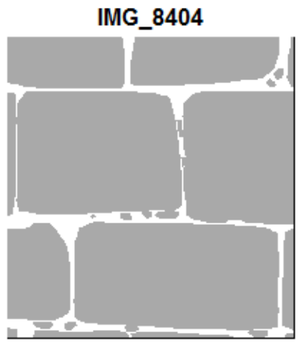
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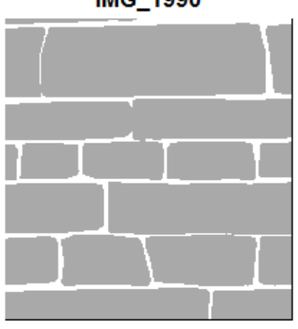


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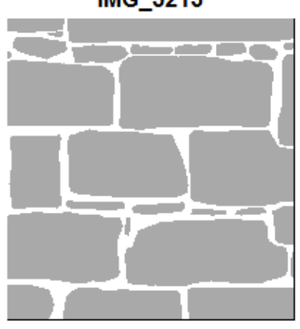


SUBCLUSTER 1.2

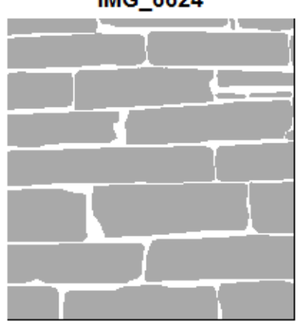
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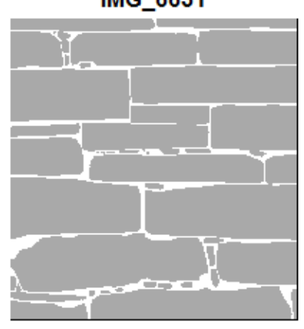
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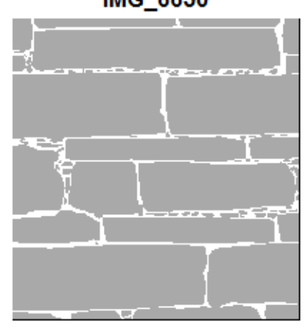
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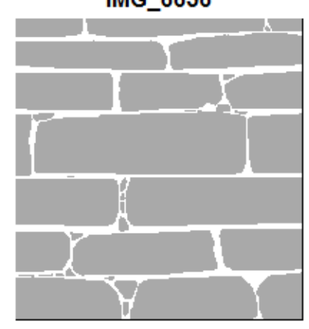
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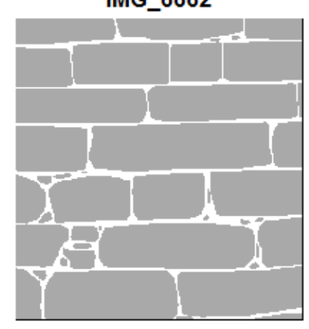
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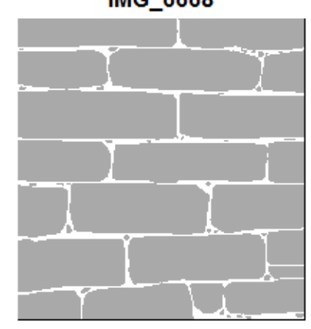
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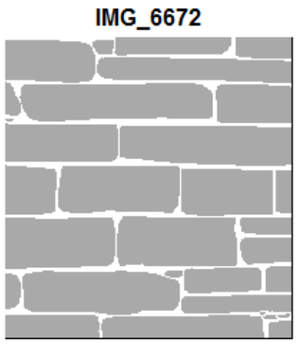
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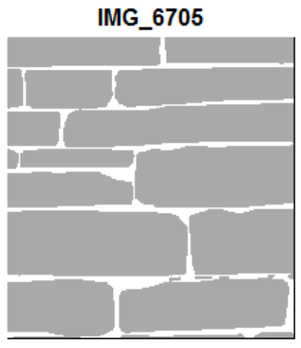
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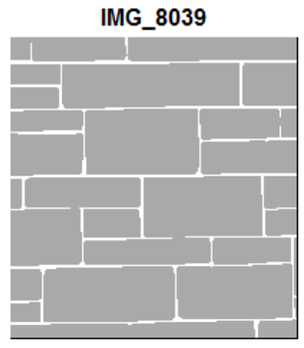
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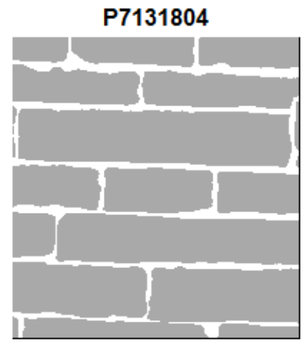
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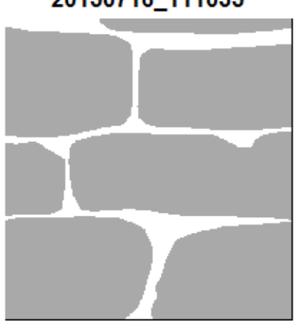


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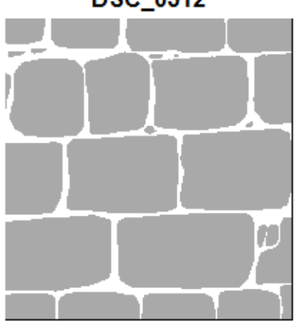


SUBCLUSTER 1.3

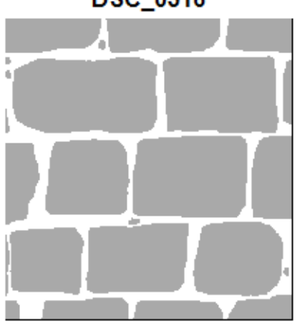
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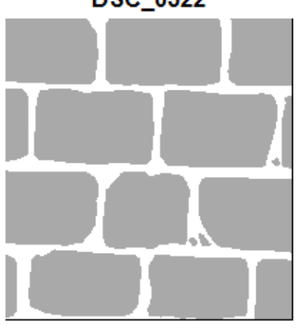
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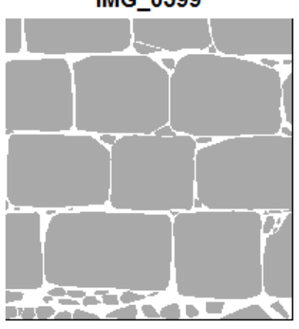
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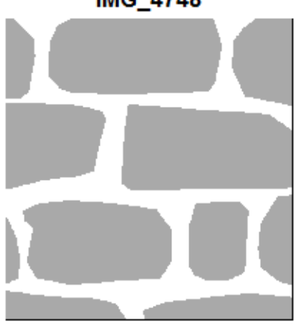
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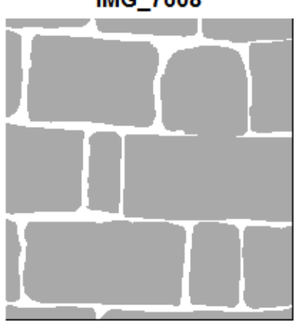
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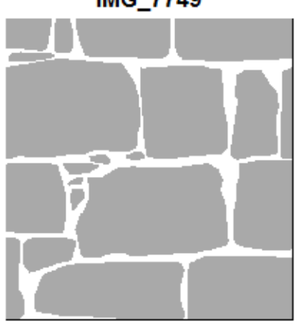
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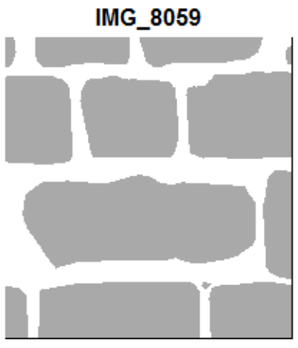
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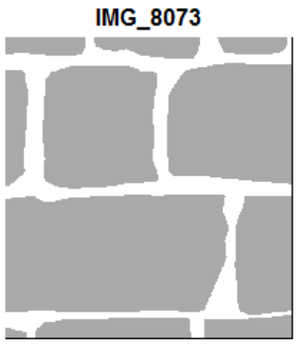
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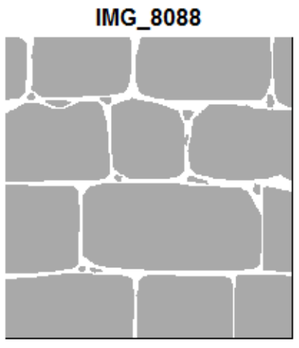
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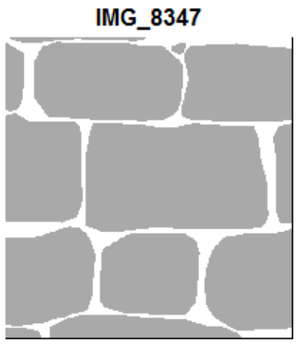
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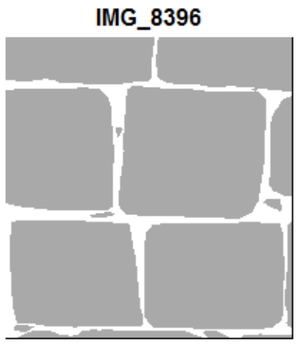
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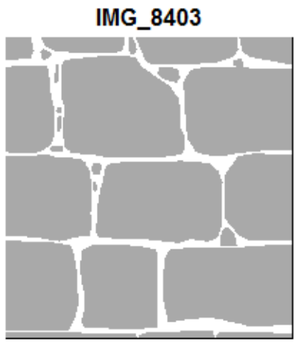
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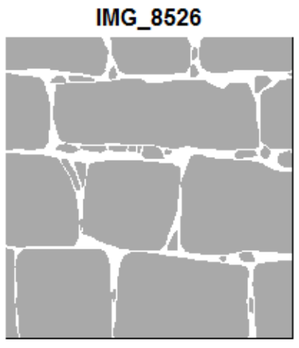
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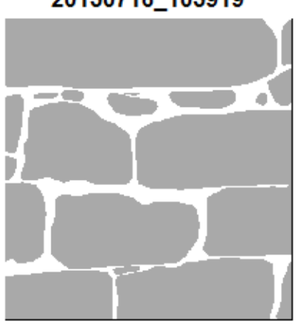


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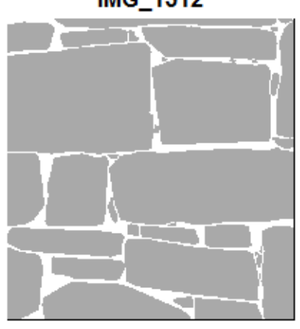


SUBCLUSTER 1.4

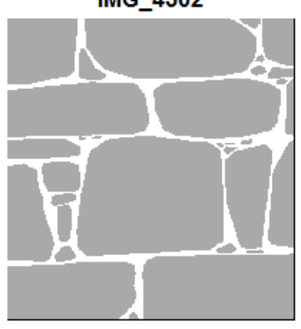
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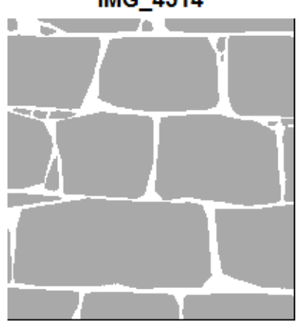
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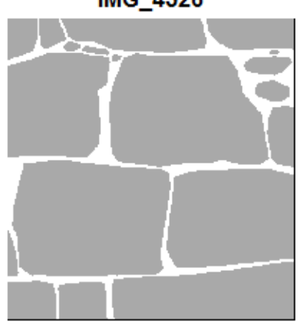
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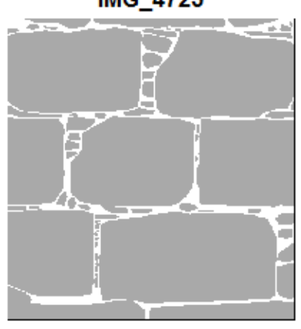
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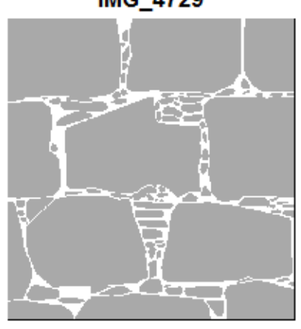
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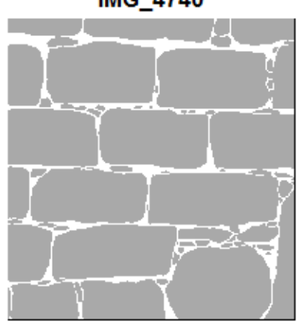
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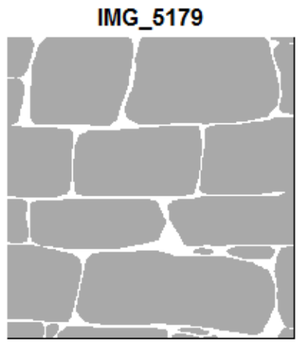
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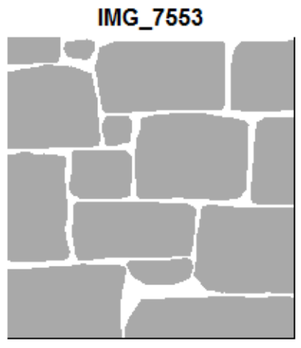
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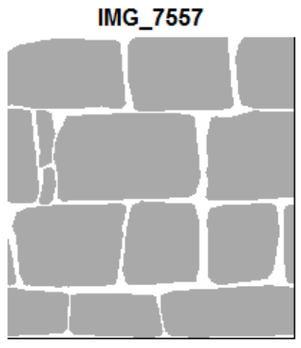
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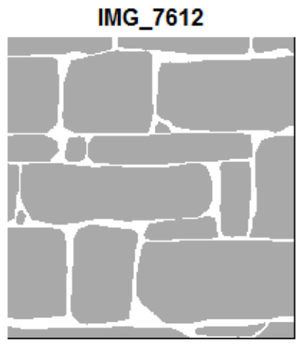
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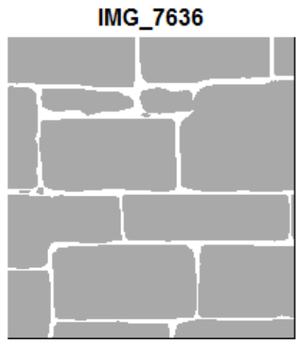
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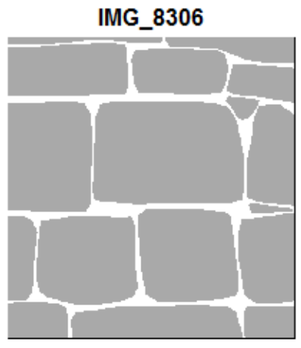
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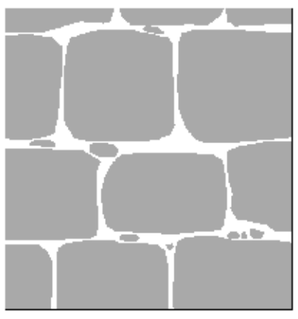
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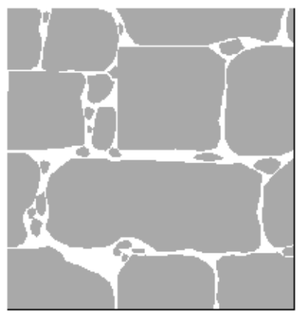
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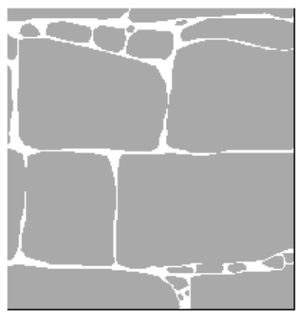
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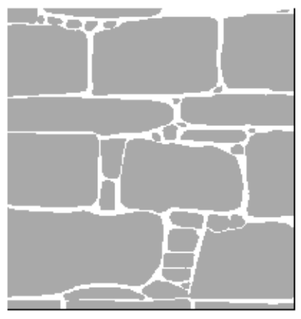
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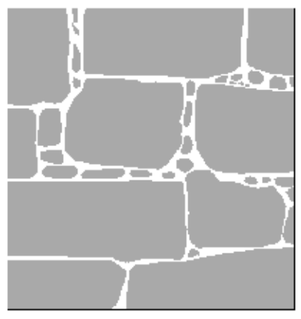
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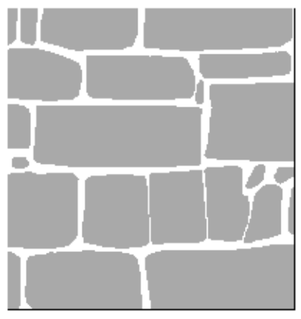
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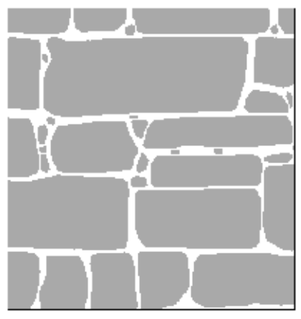
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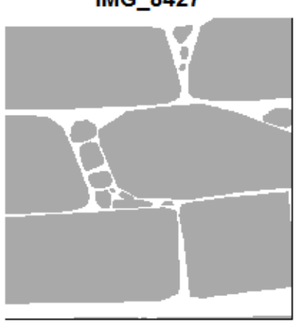
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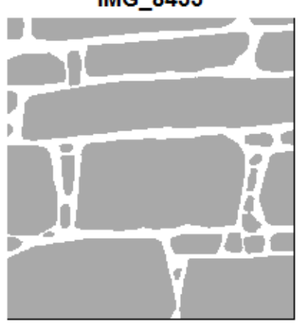
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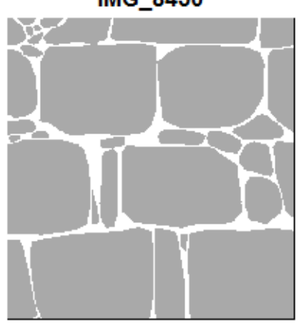
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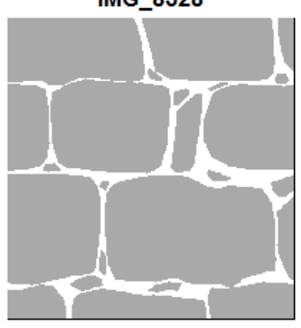
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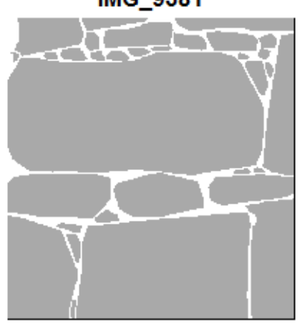
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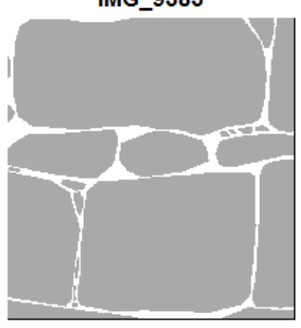
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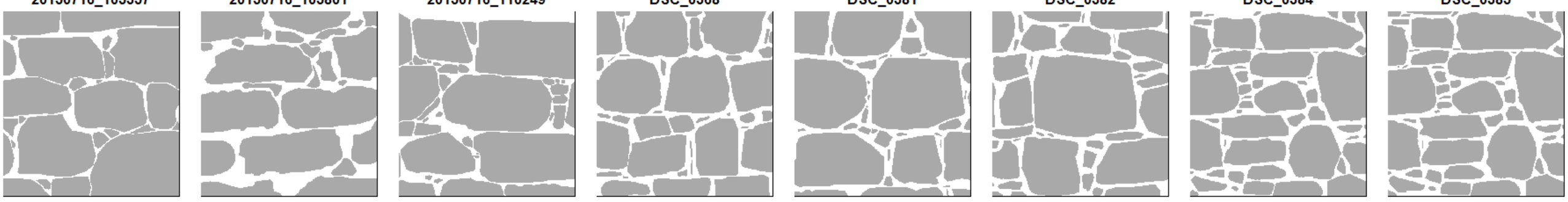


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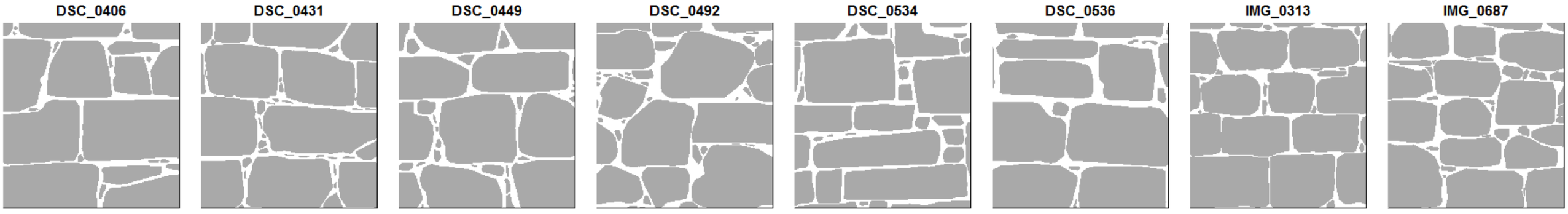


SUBCLUSTER 2.1

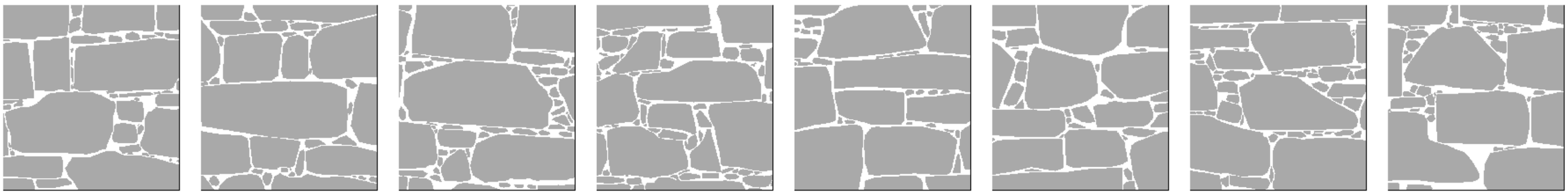
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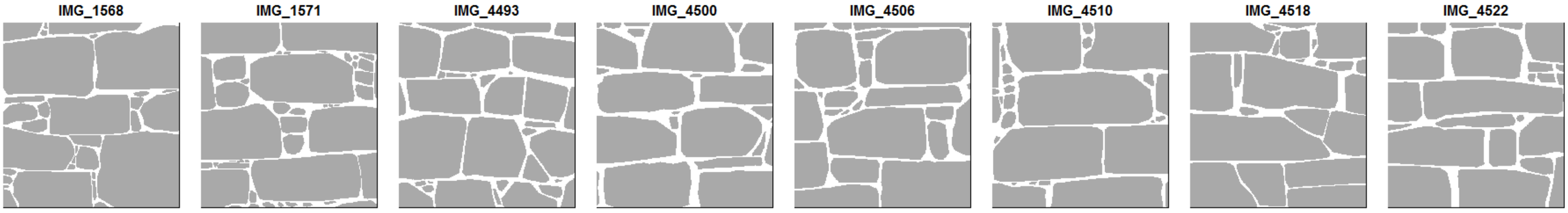
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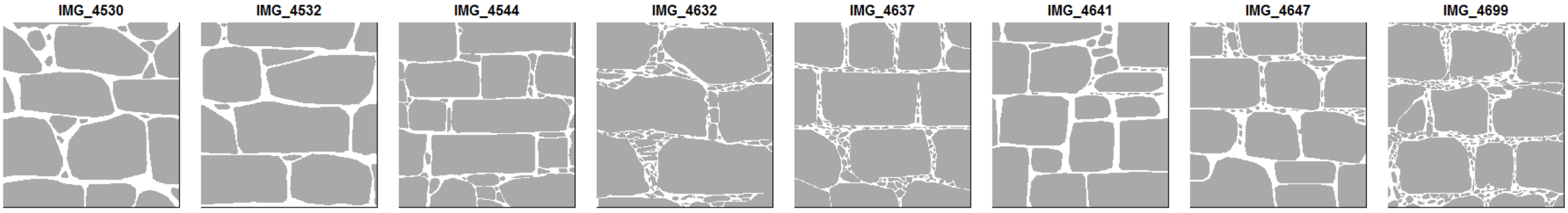
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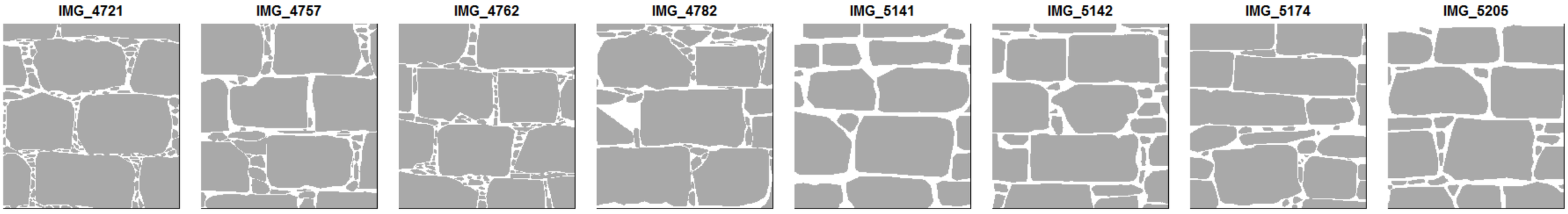
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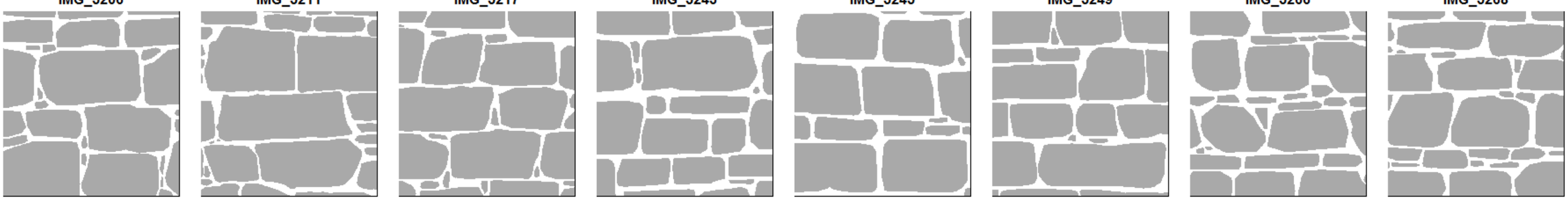
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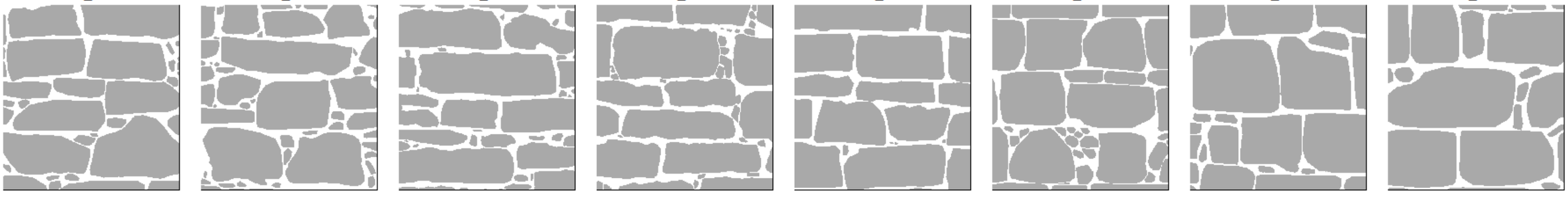
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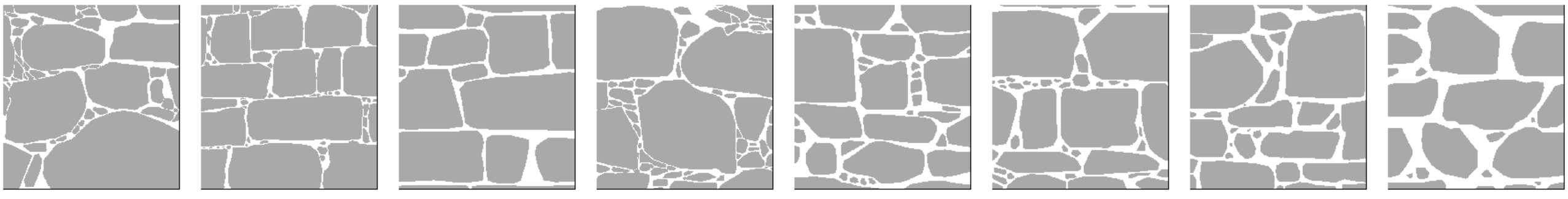
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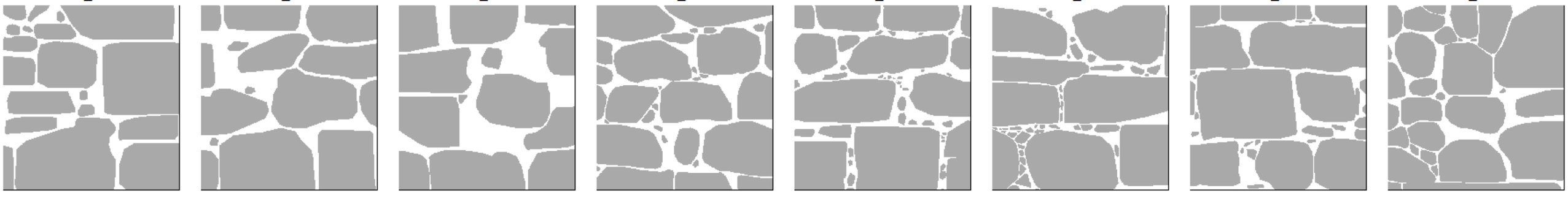
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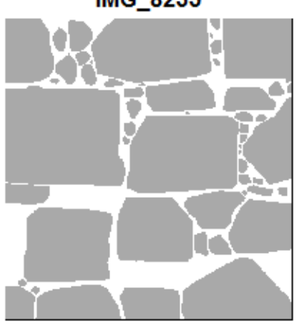


SUBCLUSTER 2.1

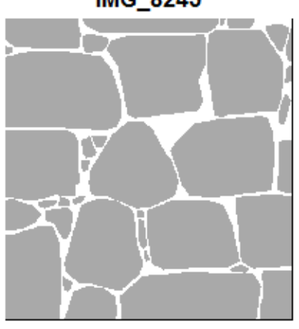
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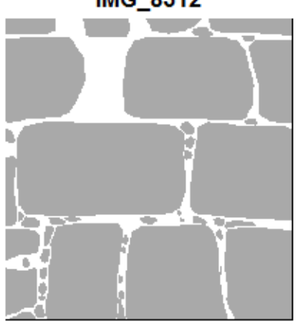
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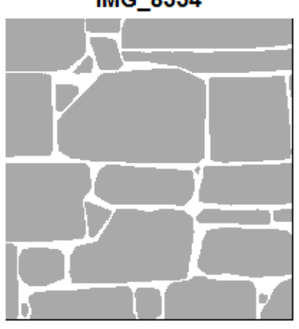
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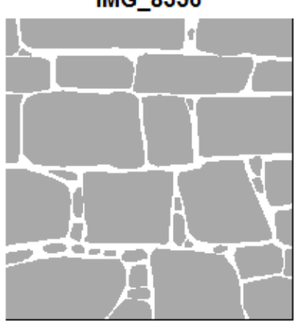
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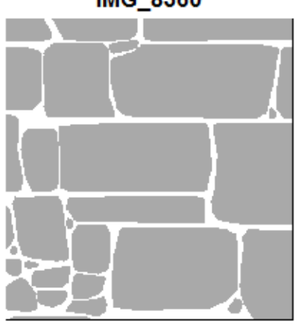
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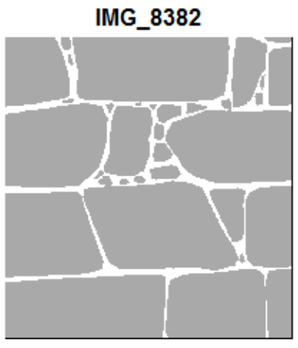
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IMG_8360



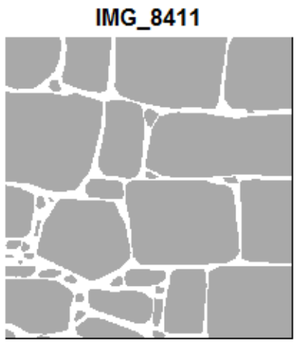
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IMG_8411



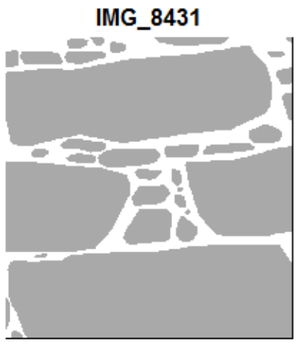
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IMG_8443



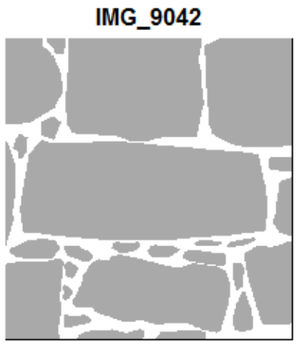
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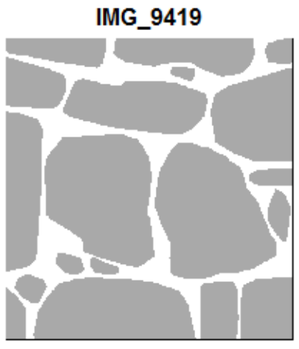
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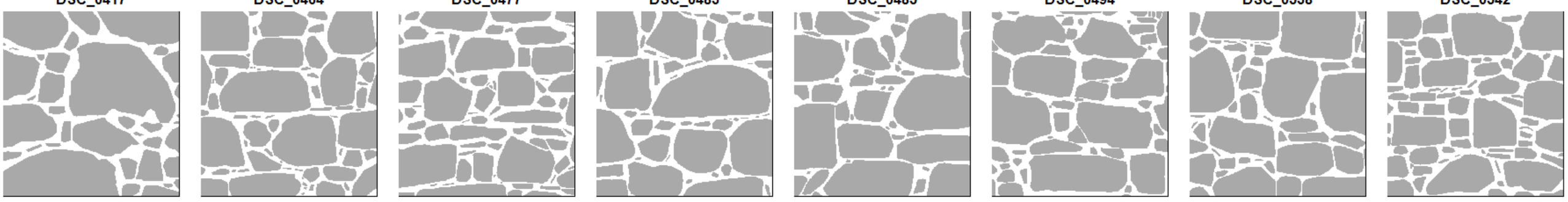


IMG_9468

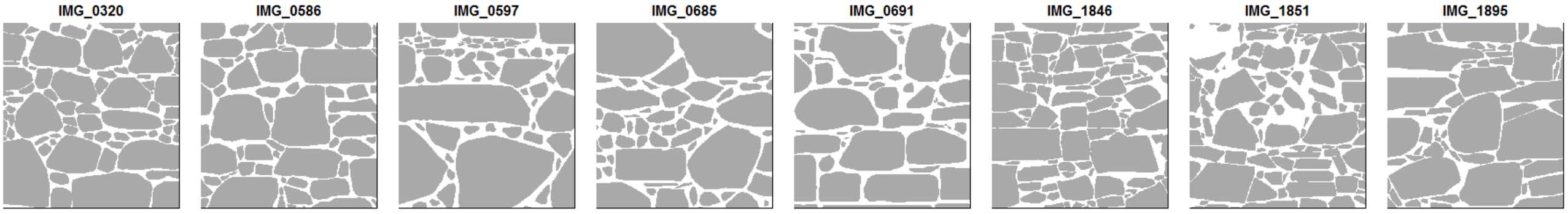


SUBCLUSTER 2.2

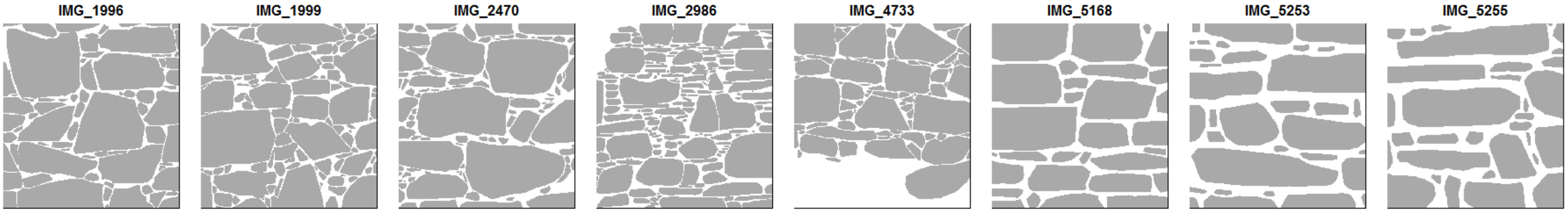
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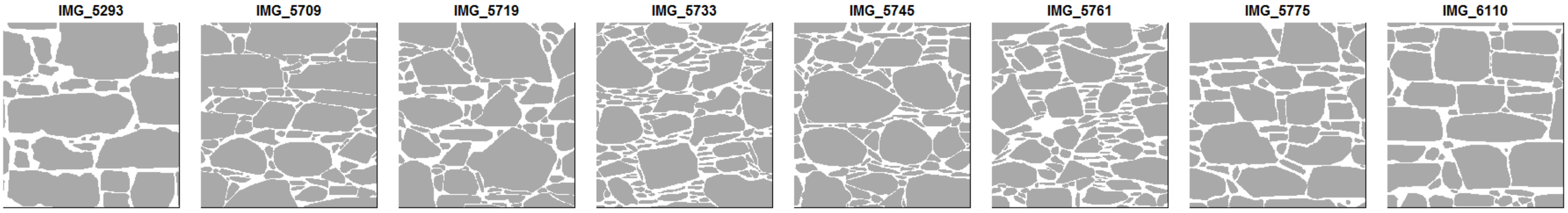
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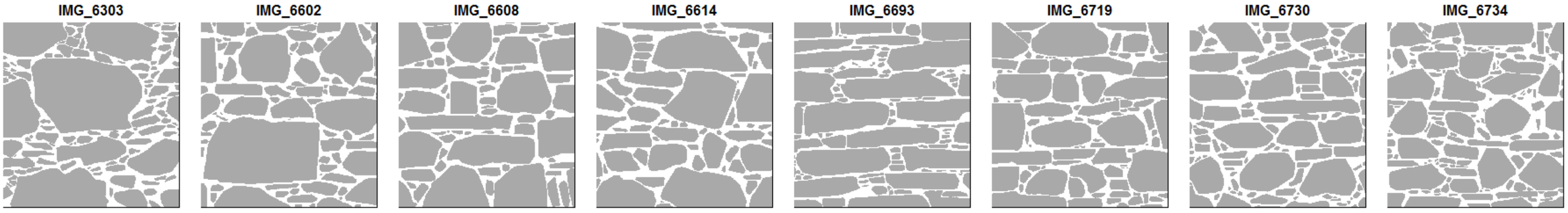
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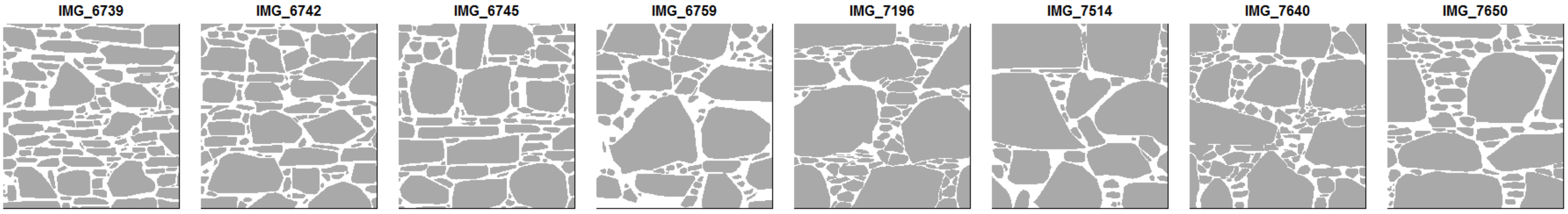
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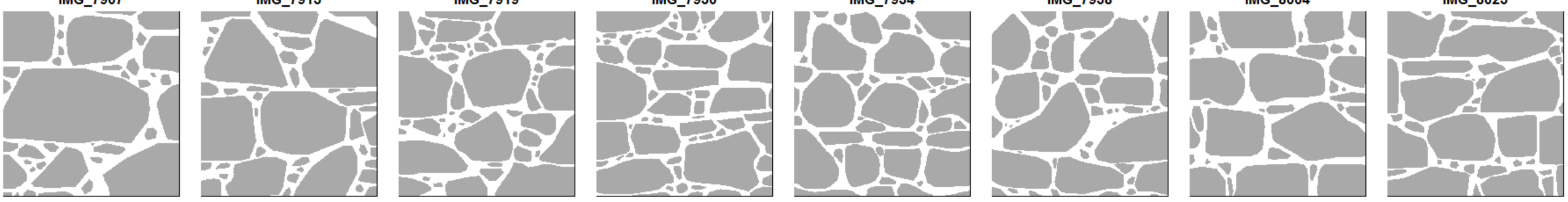
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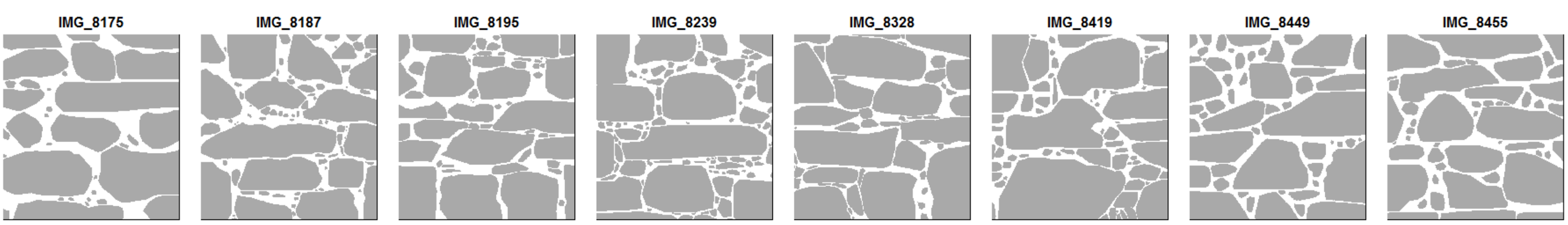
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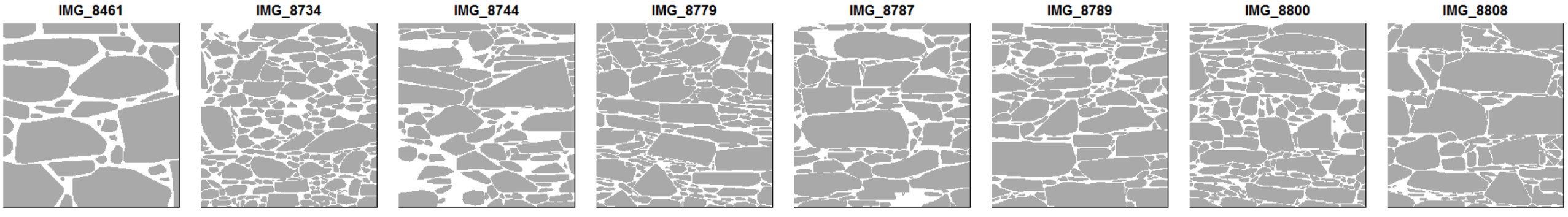
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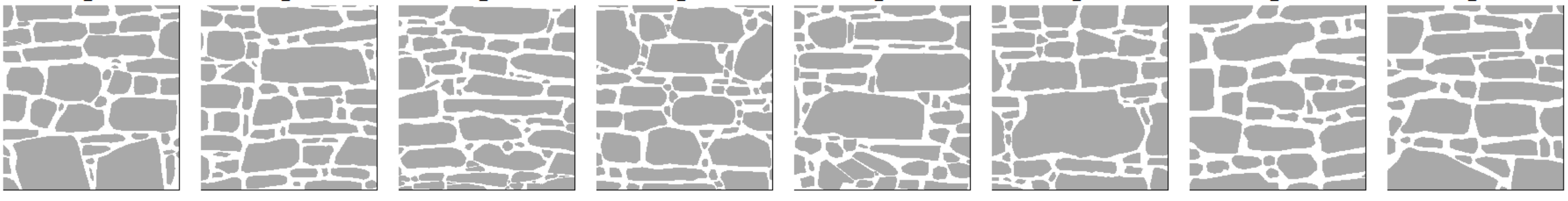
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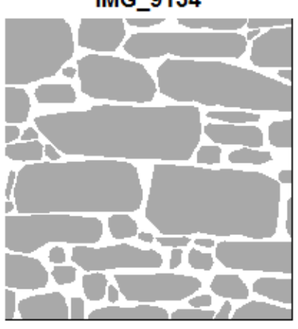


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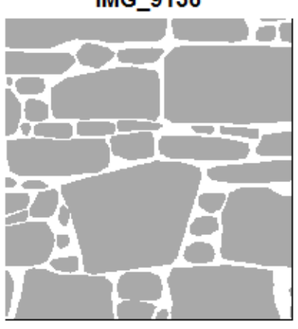


SUBCLUSTER 2.2

IMG_9134



IMG_9136



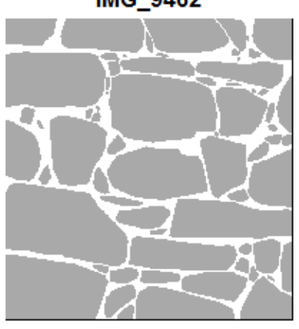
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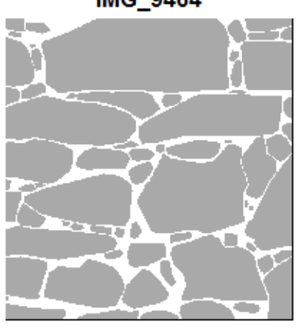
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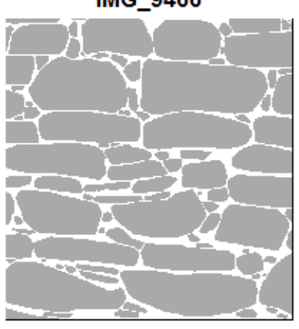
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IMG_9464

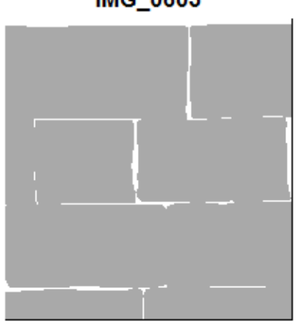


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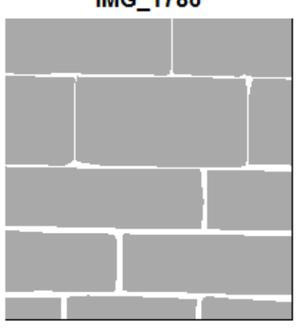


SUBCLUSTER 3.1

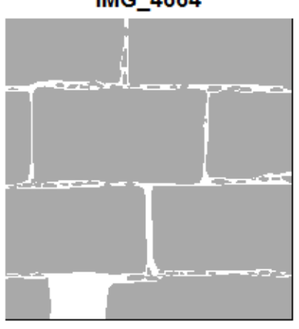
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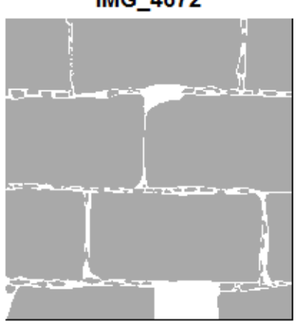
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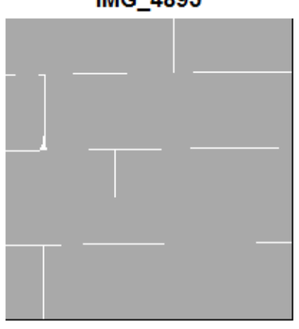
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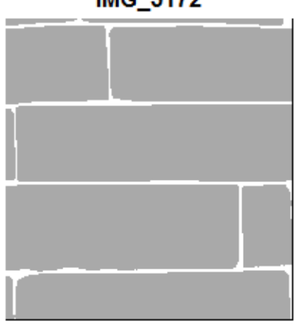
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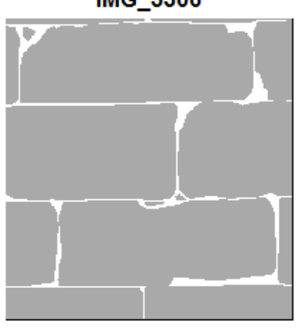
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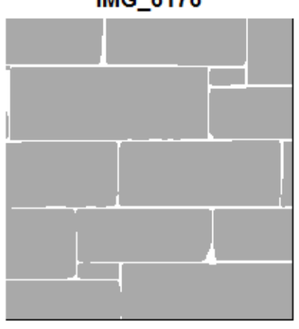
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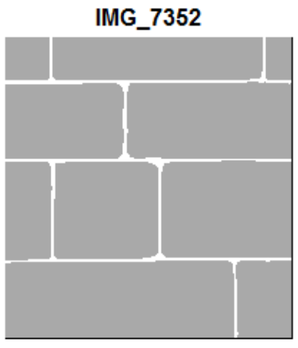
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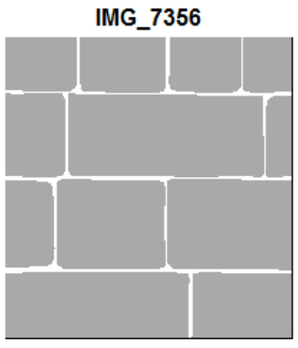
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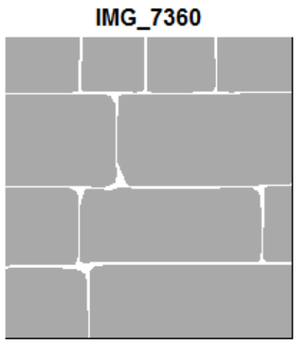
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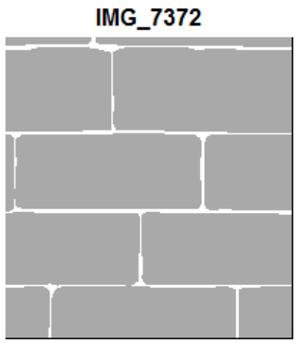
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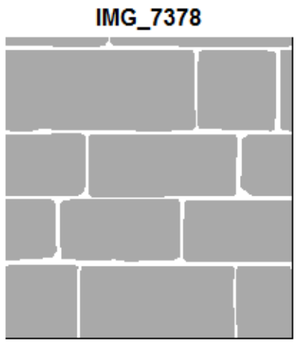
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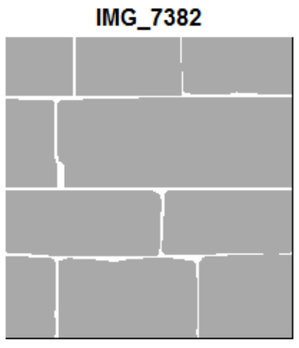
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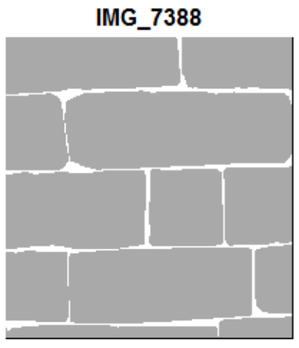
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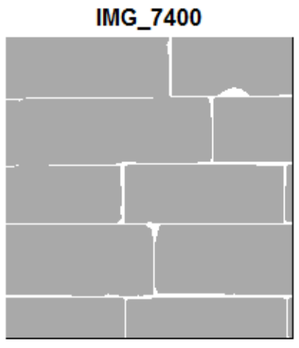
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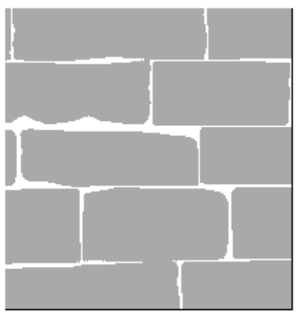
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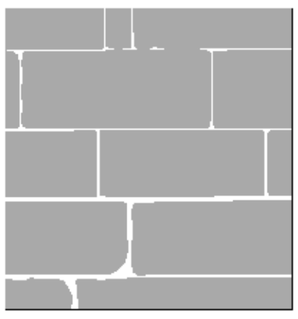
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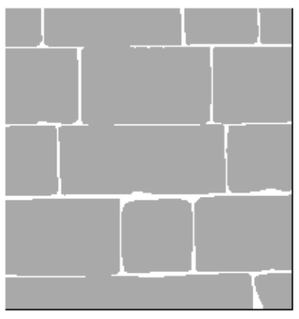
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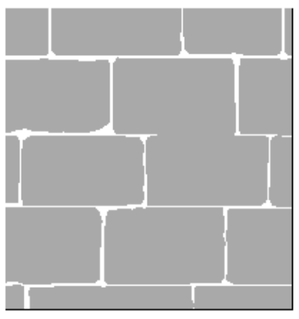
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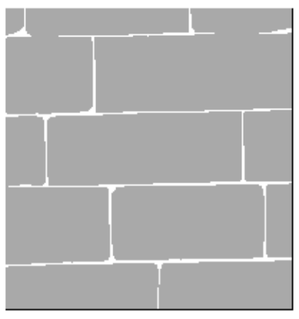
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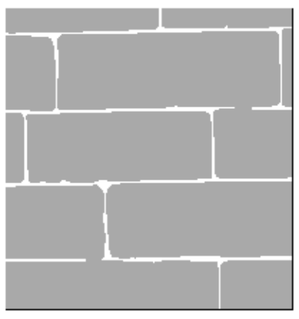
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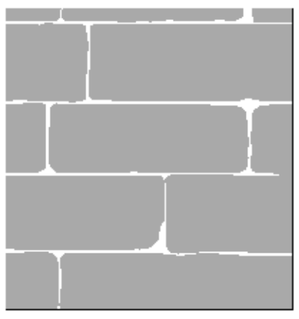
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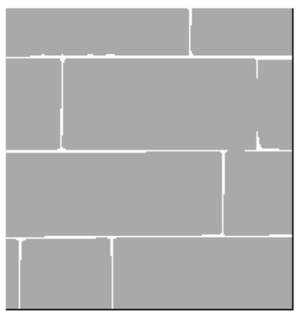
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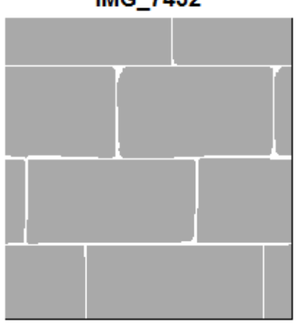
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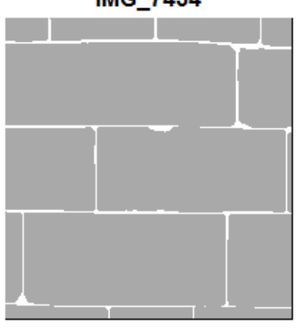
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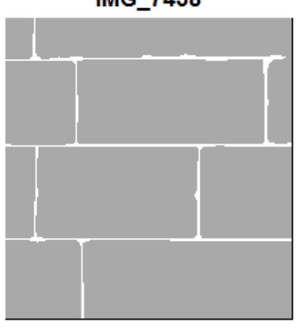
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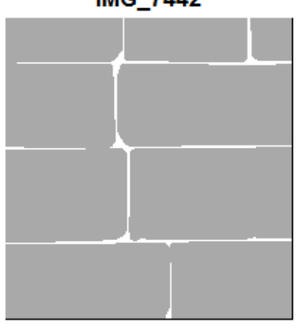
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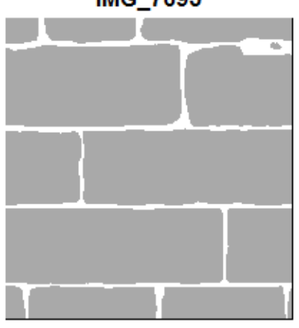
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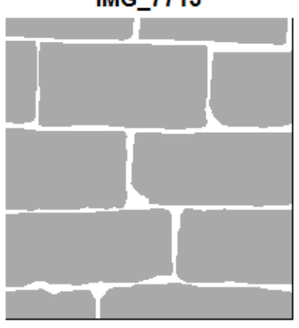
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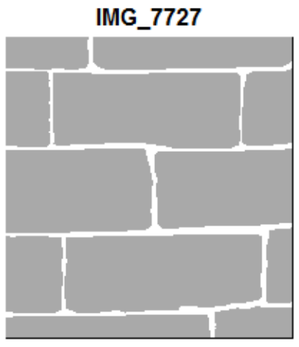
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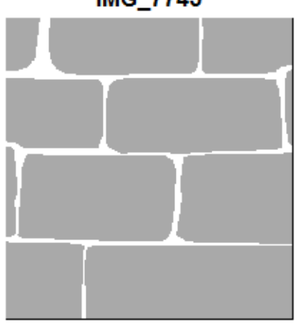
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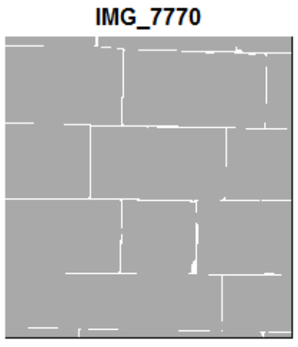
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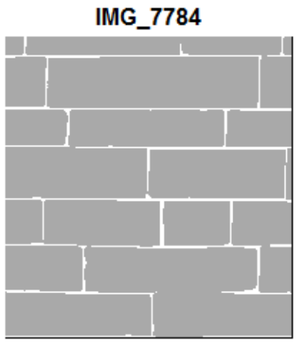
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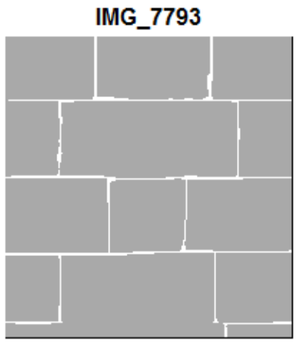
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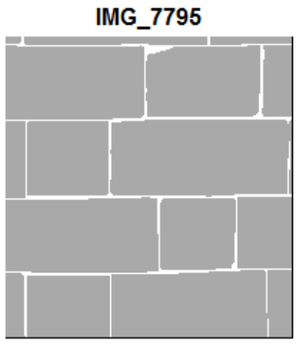
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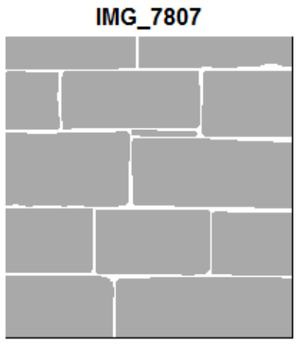
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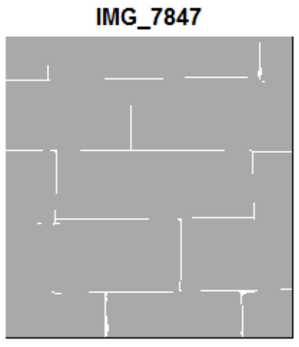
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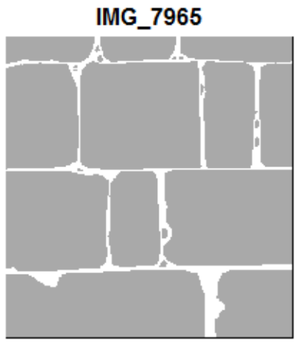
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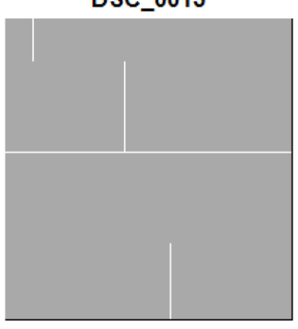
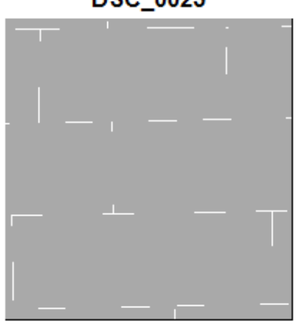
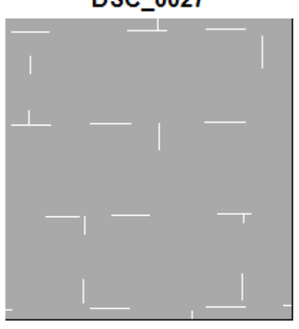
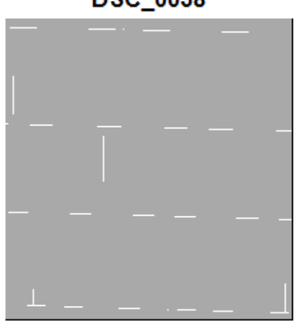
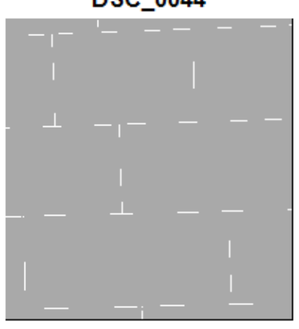
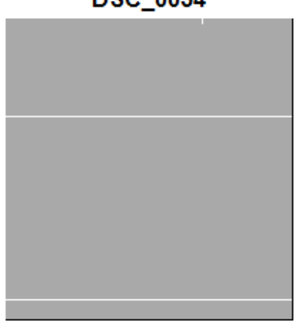
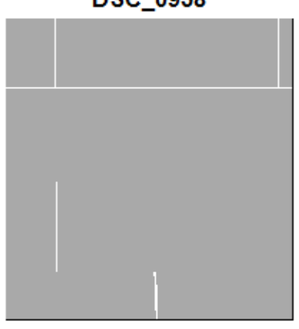
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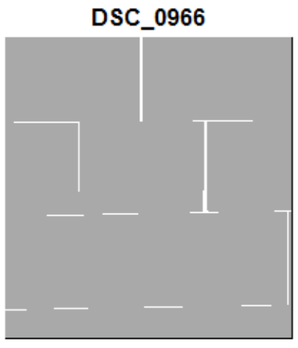
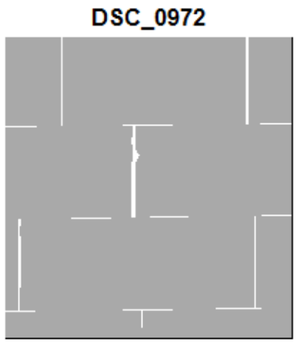
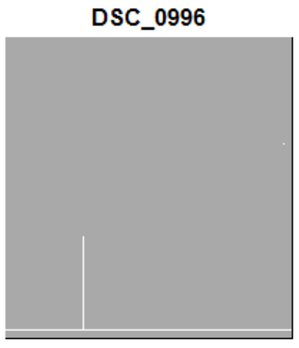
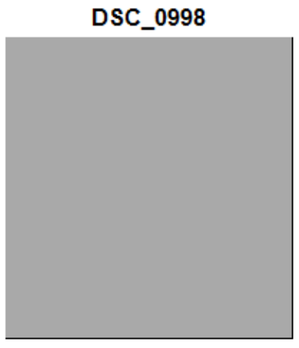
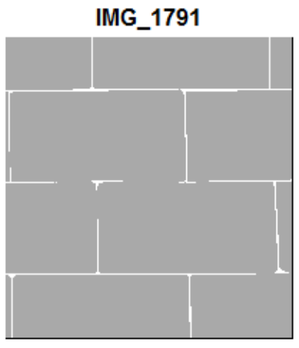
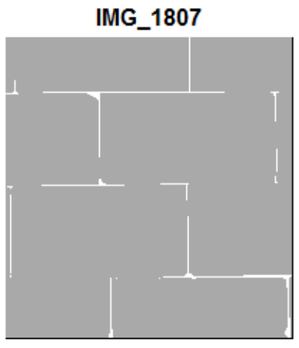
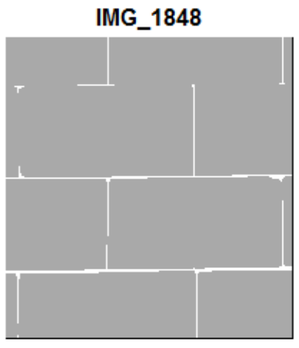
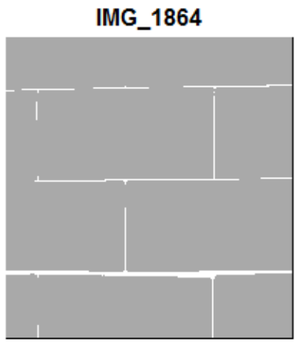


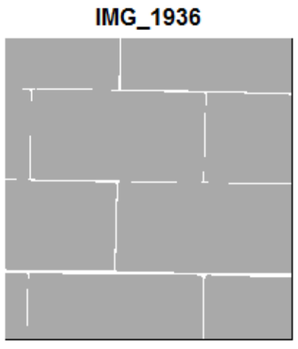
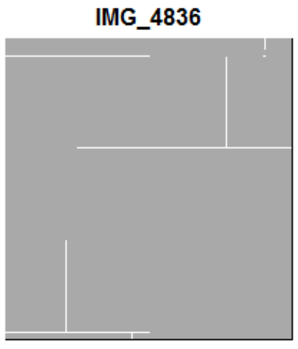
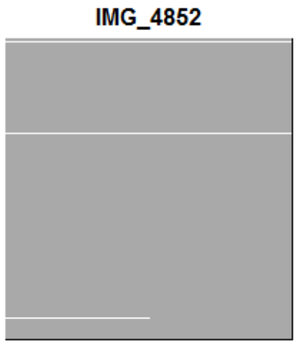
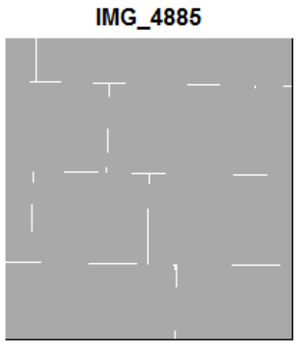
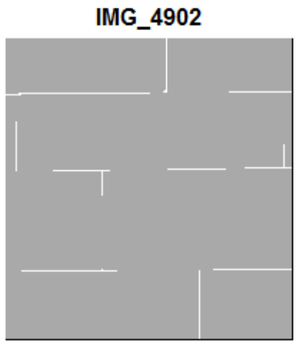
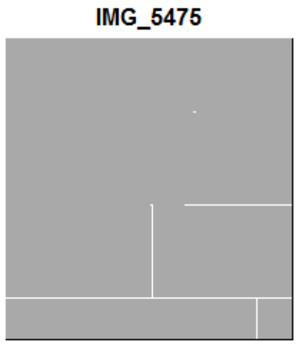
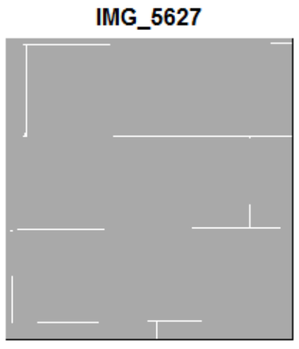
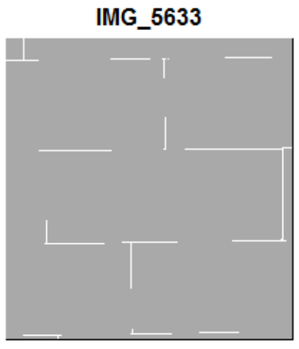
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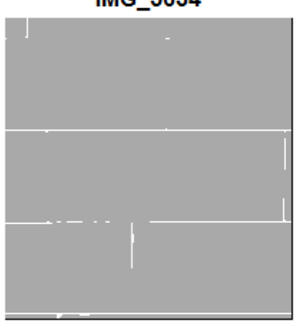
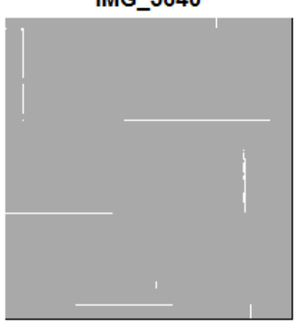
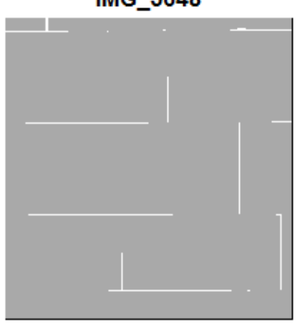
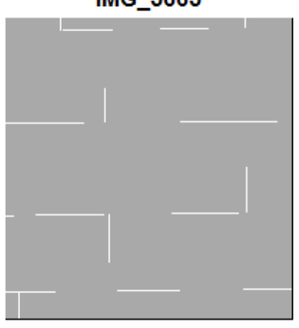
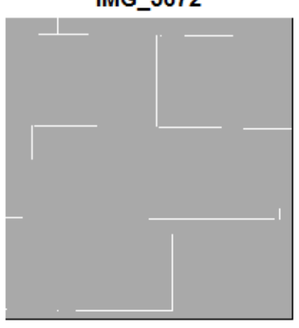
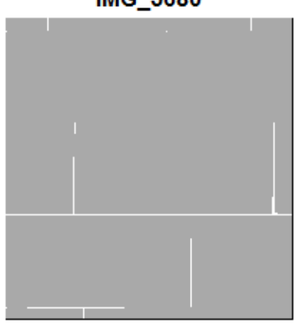
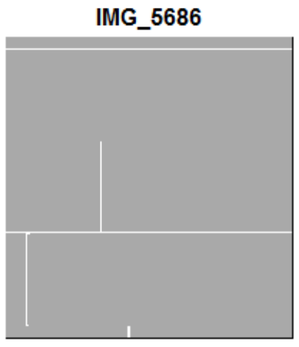
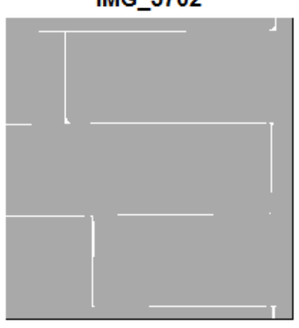
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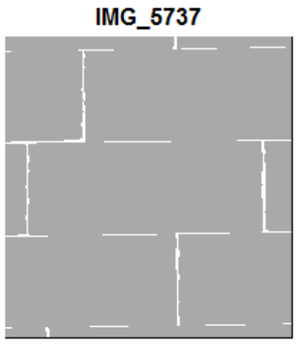
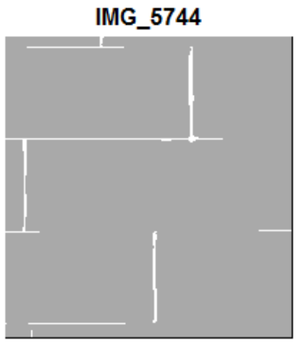
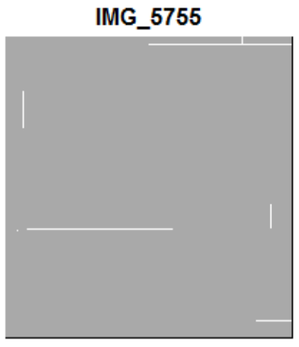
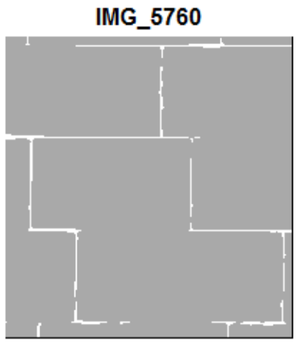
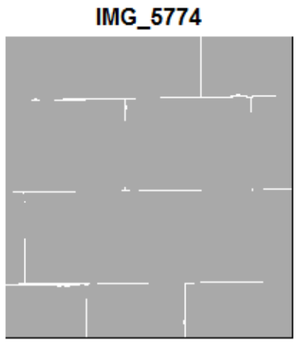
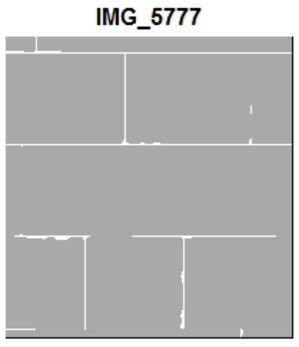
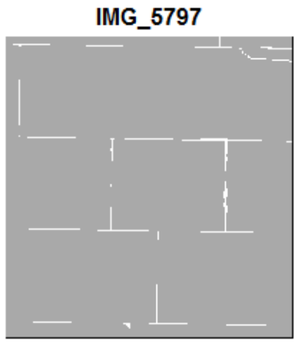
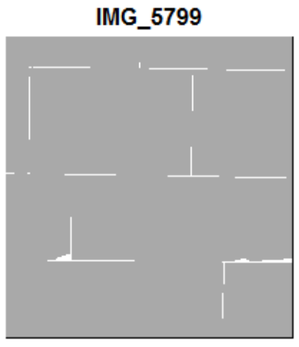
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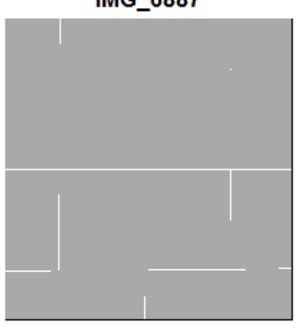
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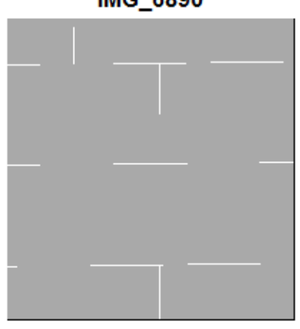
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SUBCLUSTER 3.2

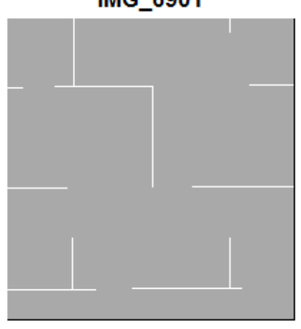
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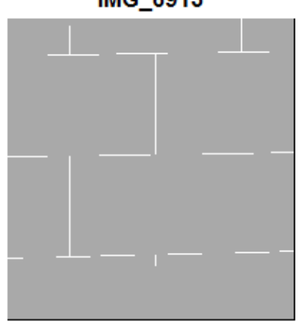
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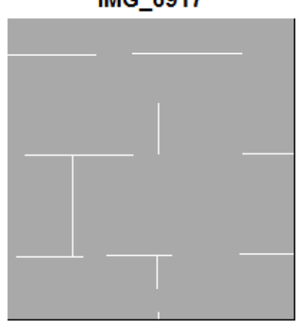
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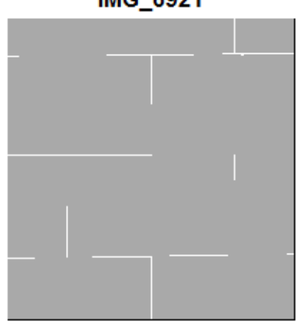
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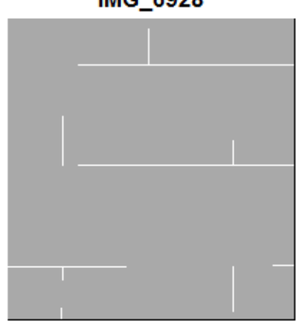
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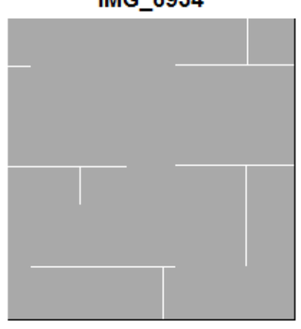
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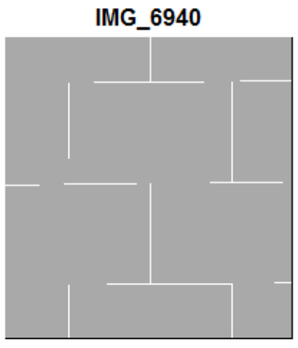
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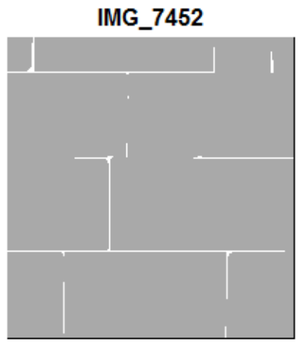
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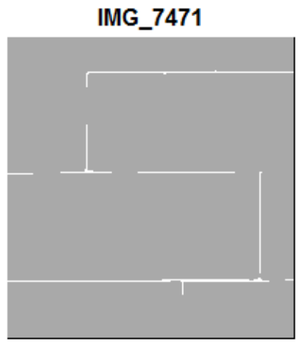
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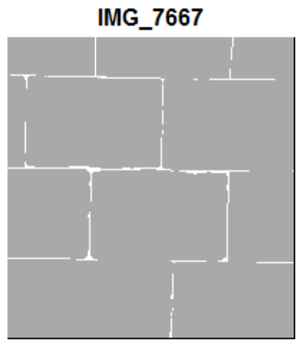
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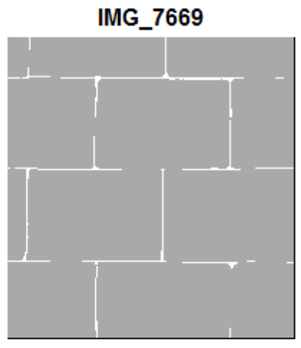
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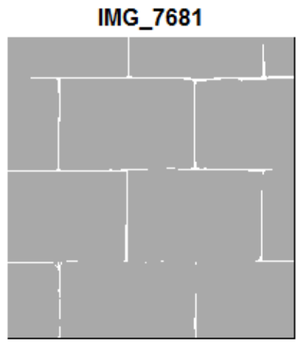
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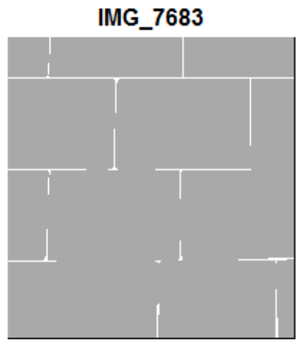
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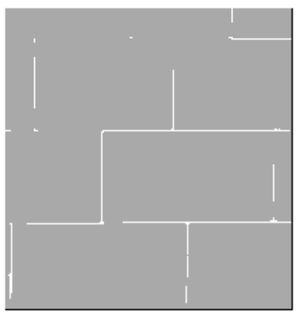
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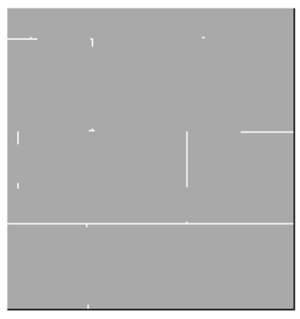
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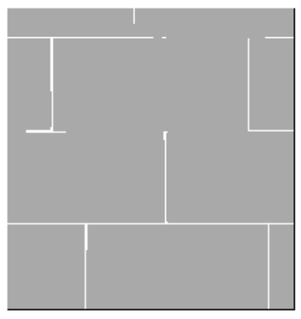
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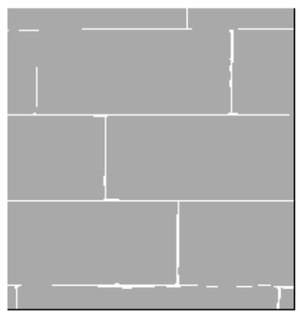
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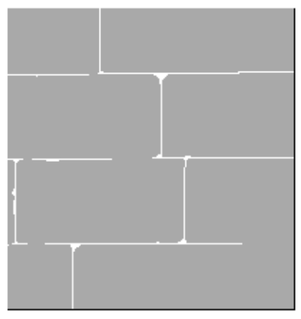
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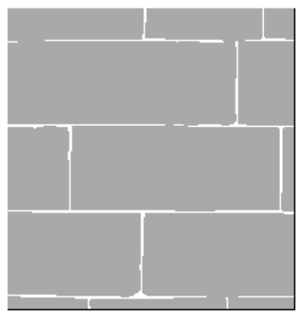
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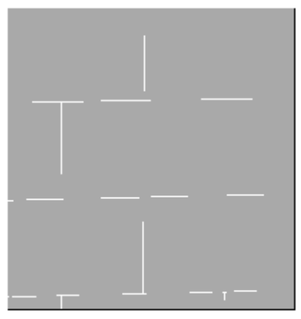
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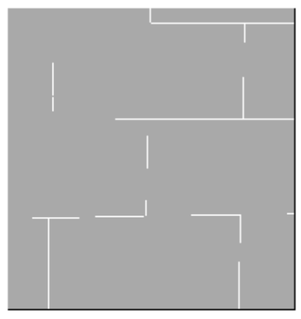
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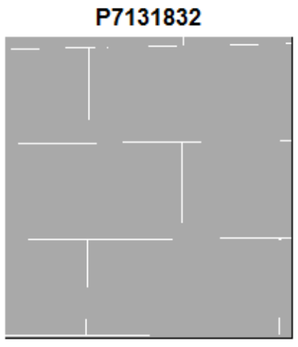
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3.3 FORMS SUMMARISING THE DATA RELATED WITH THE MORPHOLOGY OF THE MASONRIES OF EACH CASE STUDY

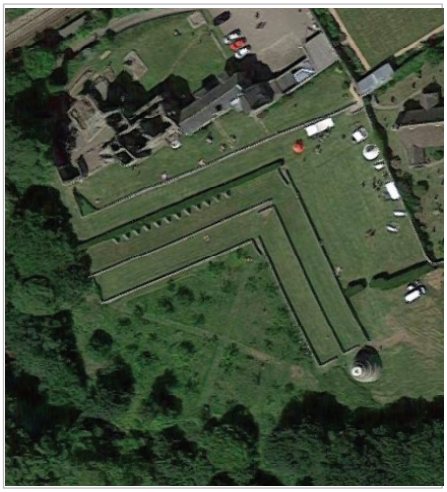
ABEDOUR CASTLE _ FIFE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

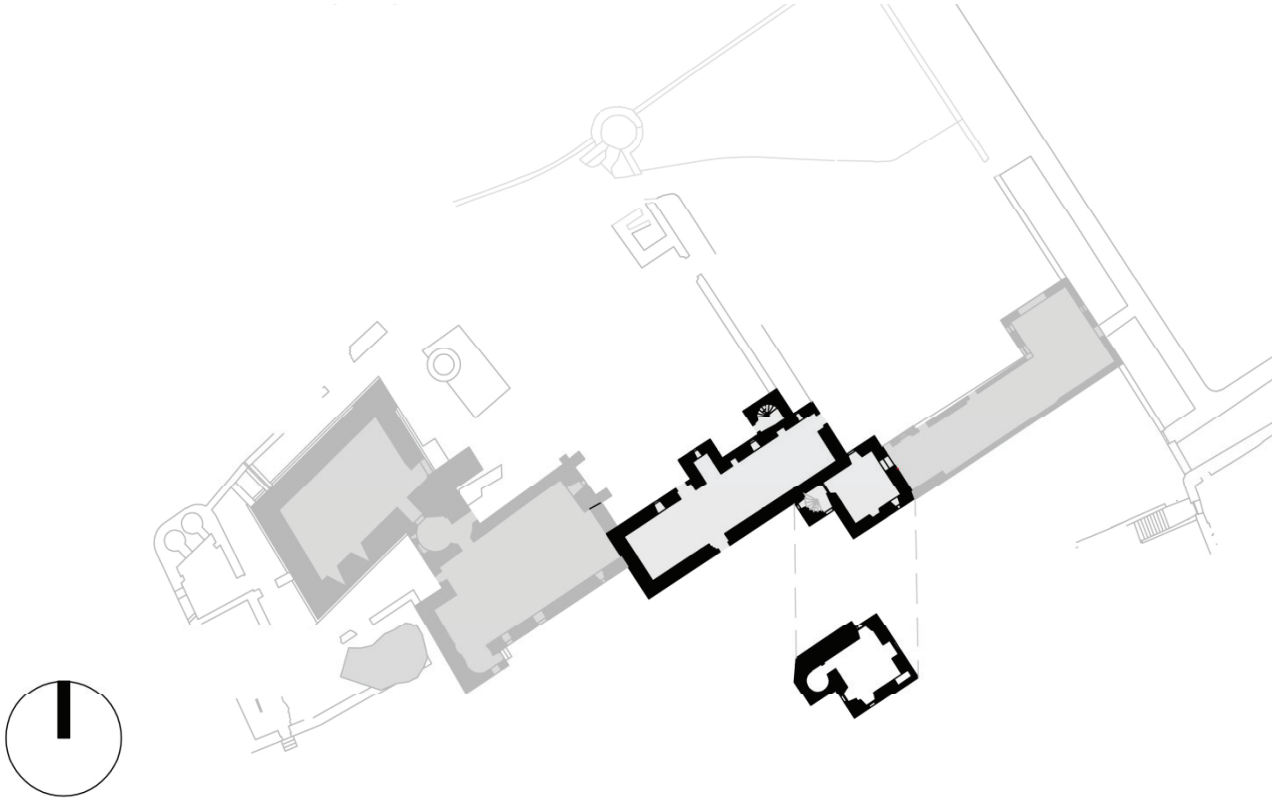


GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



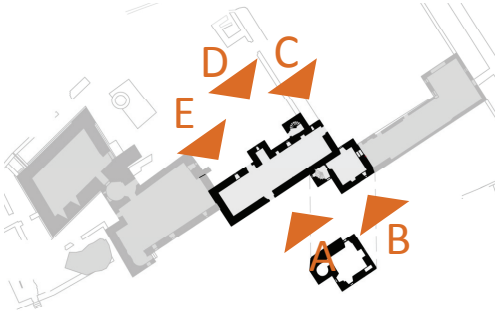
Area included in the research

Area not included in the research

Walls inspected

ABEDOUR CASTLE _ FIFE

IMAGES OF THE BUILDING



A



B



C



D

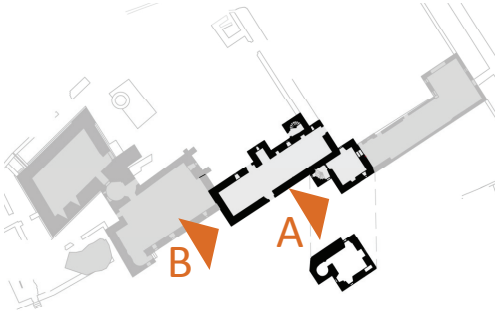


E



ABEDOUR CASTLE _ FIFE

IMAGES OF THE BUILDING



A



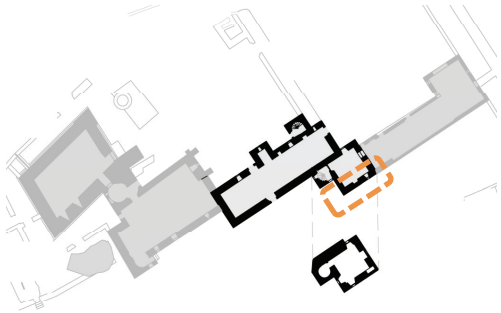
B



ABEDOUR CASTLE _ FIFE

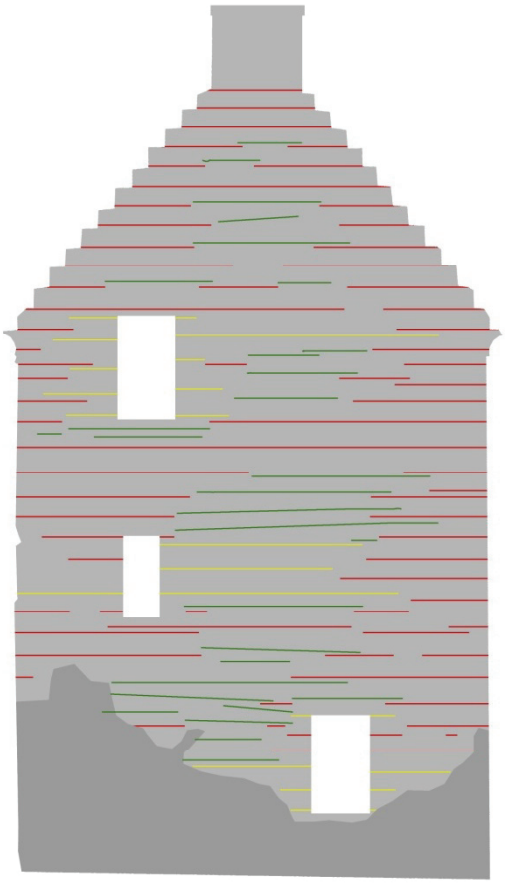
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

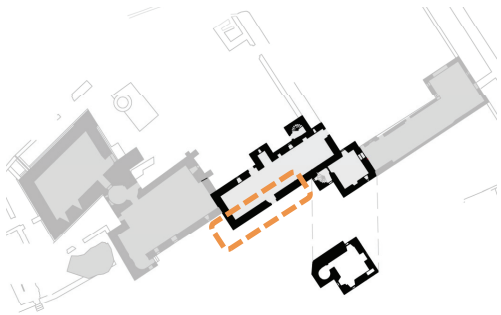


Courses determined by quoins
Courses determined by jambs
Other courses

ABEDOUR CASTLE _ FIFE

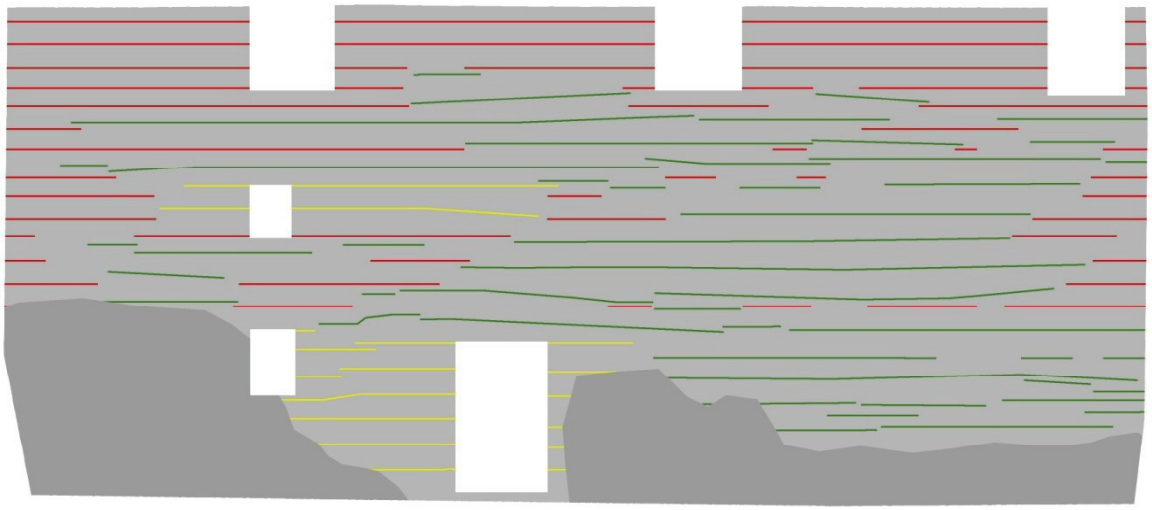
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

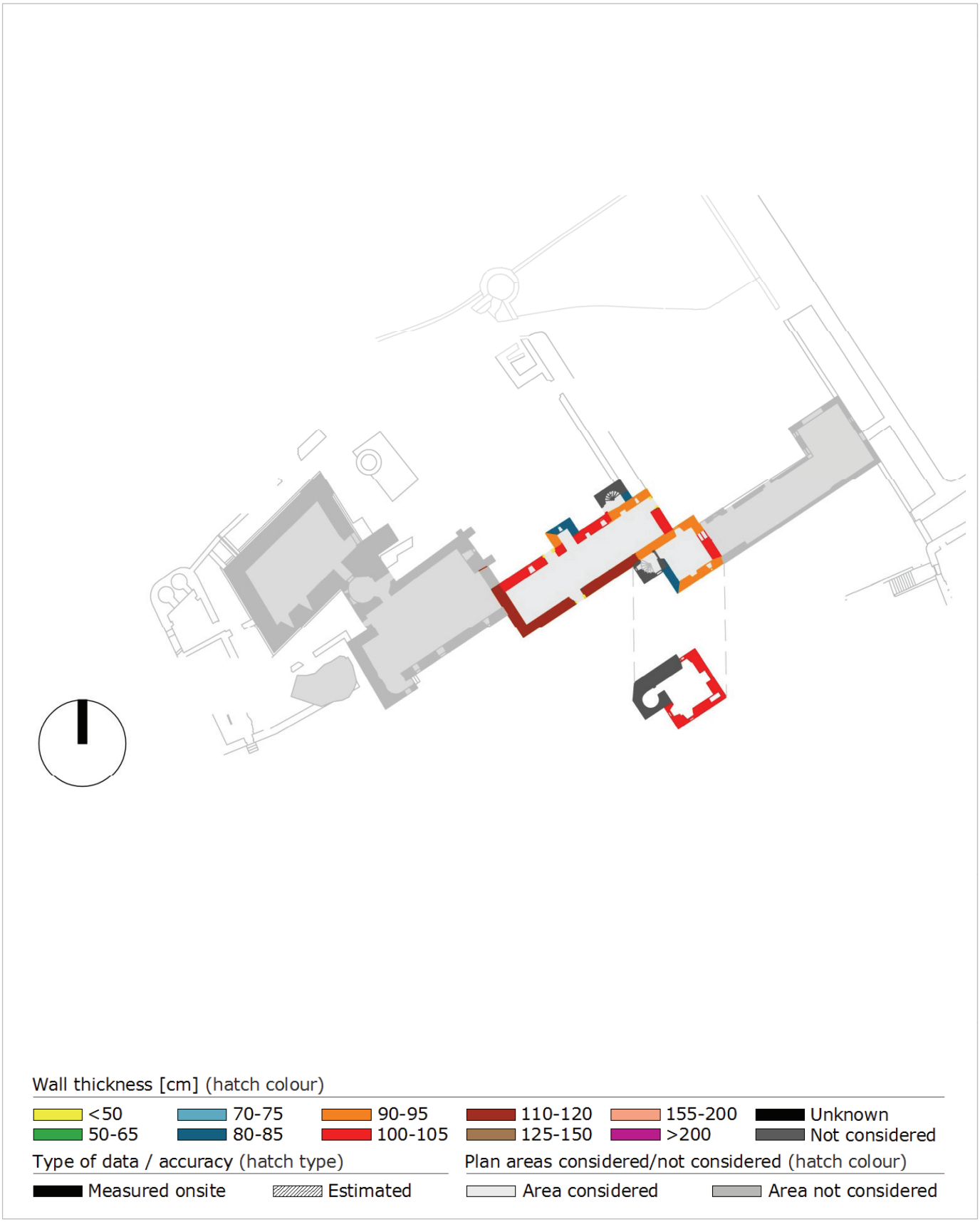


Courses determined by quoins
Courses determined by jambs
Other courses

ABEDOUR CASTLE _ FIFE

WALL THICKNESSES

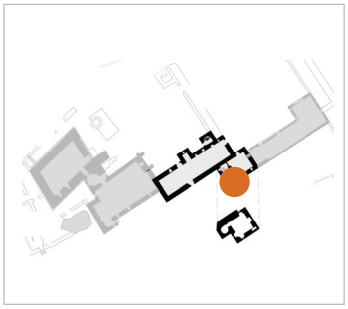
WALL THICKNESSES: GROUND FLOOR



ABEDOUR CASTLE _ FIFE

CORNERS

LOCATION



CORNER

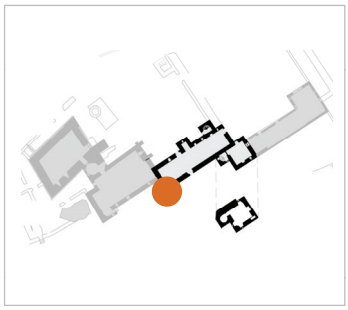


CORNER -SIDE 1



CORNER –SIDE 2

LOCATION



CORNER



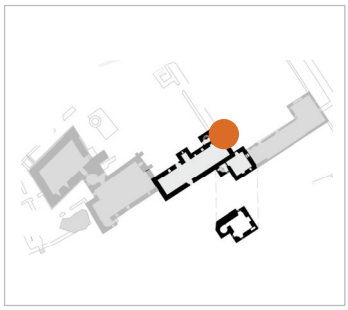
CORNER -SIDE 1



CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1

CORNER –SIDE 2



ABEDOUR CASTLE _ FIFE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


DSC_0368_corrected_silhouette


DSC_0381_corrected_silhouette


DSC_0406_corrected_silhouette


DSC_0417_corrected_silhouette


DSC_0431_corrected_silhouette


DSC_0433_corrected_silhouette


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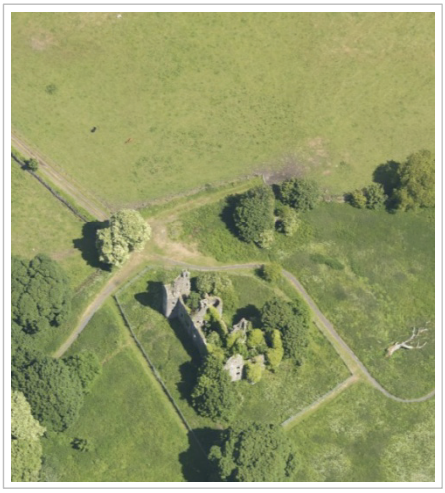
AUCHANS CASTLE_SOUTH AYRSHIRE

GENERAL INFORMATION

LOCATION



BUILDING PLAN



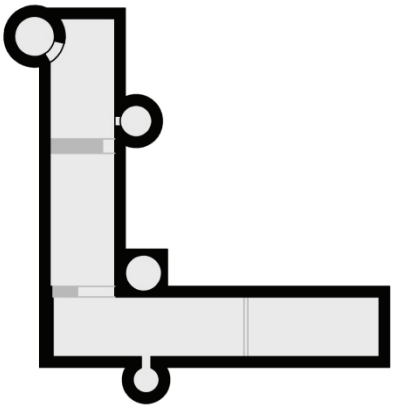
GENERAL IMAGE



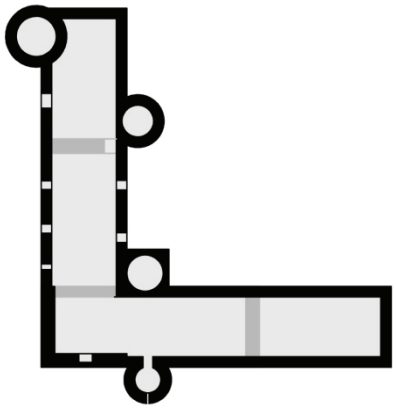
Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH

BASEMENT



MAIN FLOOR





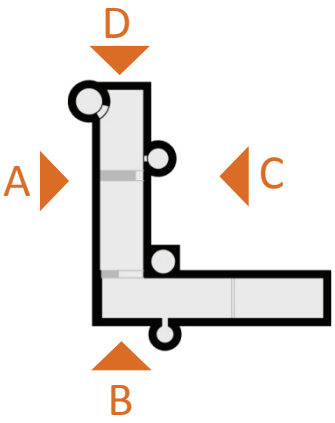
Area included in the research

Area not included in the research

Walls inspected

AUCHANS CASTLE_SOUTH AYRSHIRE

IMAGES OF THE BUILDING



A



B



C



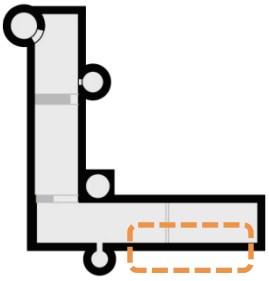
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AUCHANS CASTLE_SOUTH AYRSHIRE

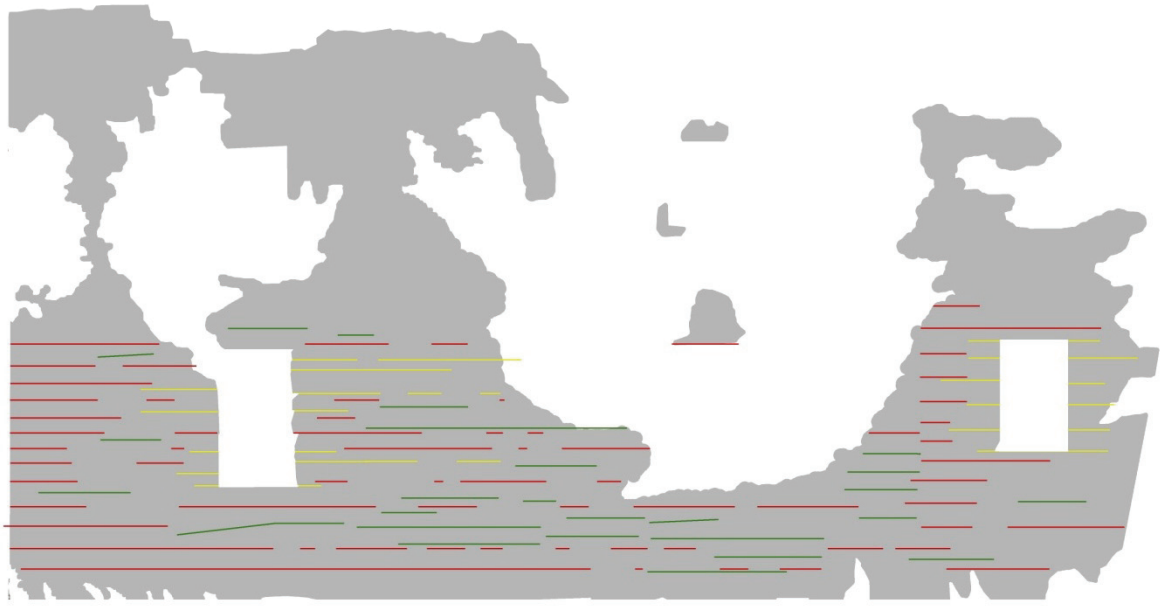
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES



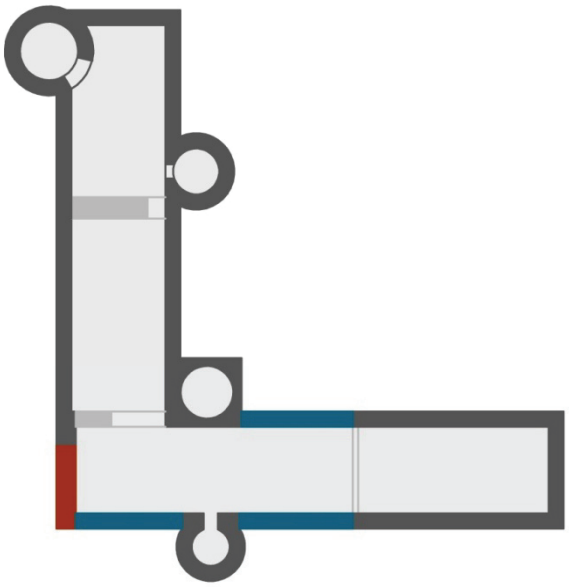
Courses determined by quoins
Courses determined by jambs
Other courses

AUCHANS CASTLE_SOUTH AYRSHIRE

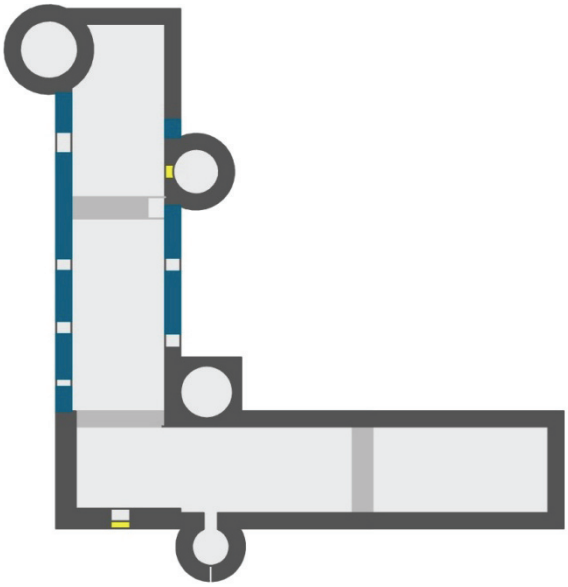
WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR

BASEMENT



MAIN FLOOR





Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

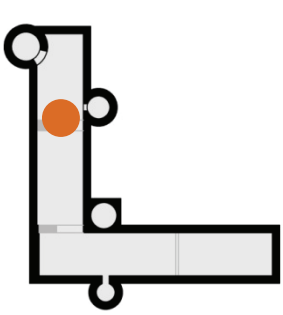
Measured onsite | Estimated

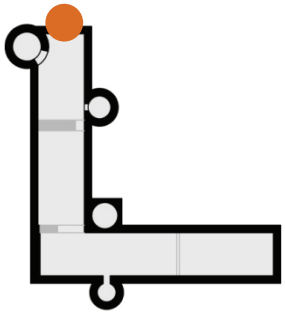
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

AUCHANS CASTLE_SOUTH AYRSHIRE

WALL SECTIONS



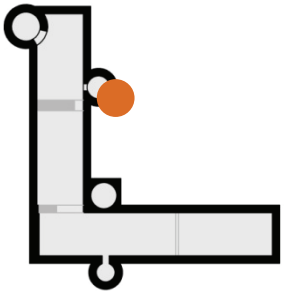


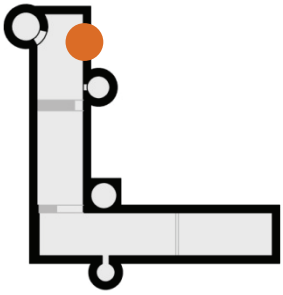




AUCHANS CASTLE_SOUTH AYRSHIRE

WALL SECTIONS



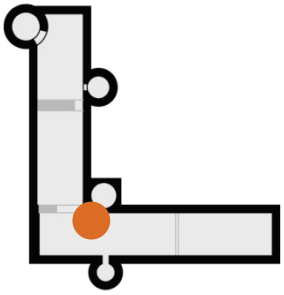






AUCHANS CASTLE_SOUTH AYRSHIRE

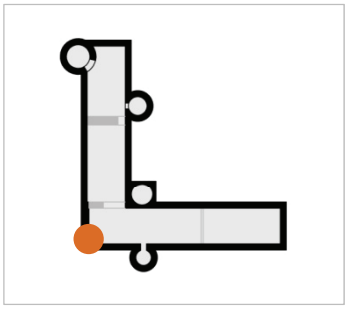
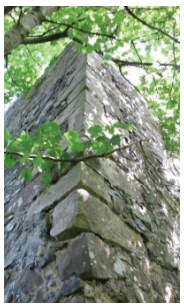
WALL SECTIONS

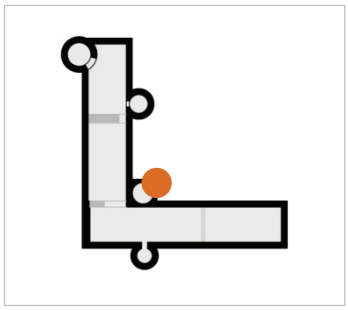
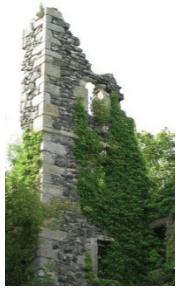


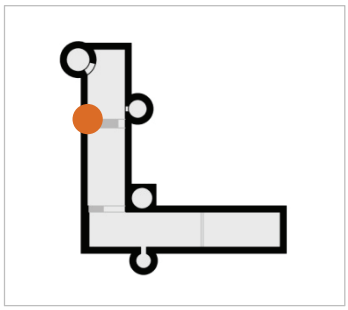
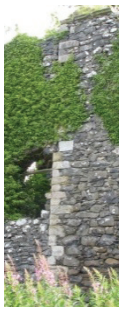


AUCHANS CASTLE_SOUTH AYRSHIRE

CORNERS

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
	 		

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			

AUCHANS CASTLE_SOUTH AYRSHIRE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


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IMG_1851_corrected_silhouette


IMG_1895_corrected_silhouette

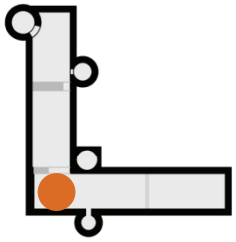

IMG_1996_corrected_silhouette


IMG_1999_corrected_silhouette

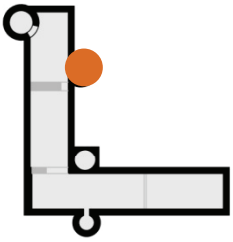
AUCHANS CASTLE_SOUTH AYRSHIRE

OTHER FEATURES

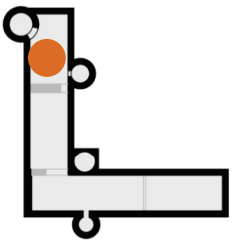
FLOORS



GROUND FLOOR:
Stone vault



GROUND FLOOR:
Stair remains



GROUND FLOOR:
Light floor marks



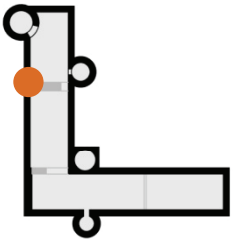


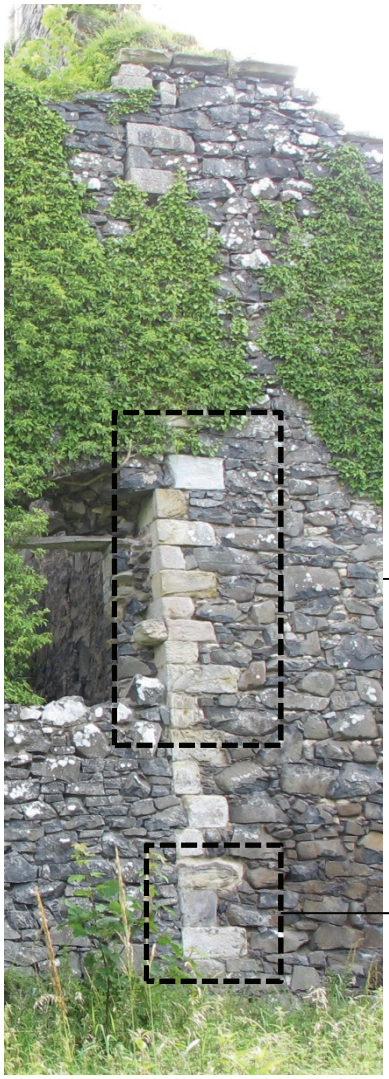


AUCHANS CASTLE_SOUTH AYRSHIRE

OTHER FEATURES

LINKS BETWEEN ADDITIONS





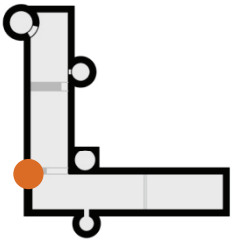




AUCHANS CASTLE_SOUTH AYRSHIRE

OTHER FEATURES

LINKS BETWEEN ADDITIONS





AUCHINDINNY HOUSE _ MIDLOTHIAN

GENERAL INFORMATION

LOCATION



BUILDING PLAN

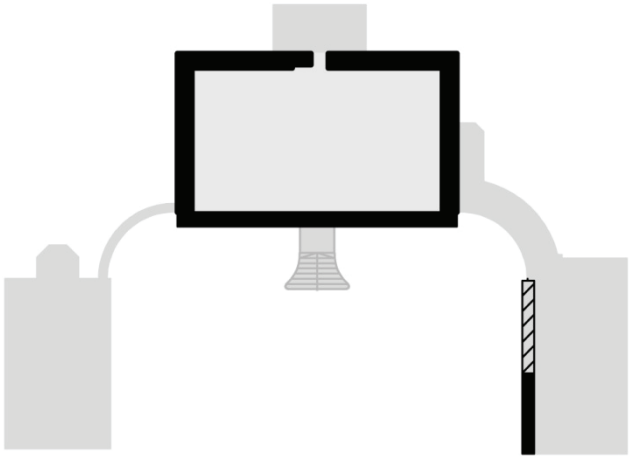


GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





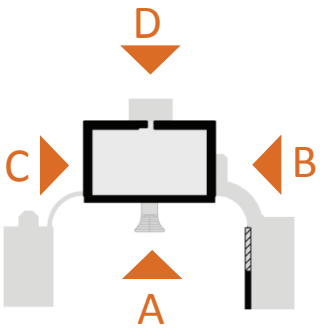
Area included in the research

Area not included in the research

Walls inspected

AUCHINDINNY HOUSE _ MIDLOTHIAN

IMAGES OF THE BUILDING



A



B



C



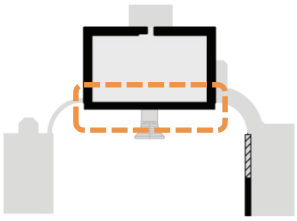
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AUCHINDINNY HOUSE _ MIDLOTHIAN

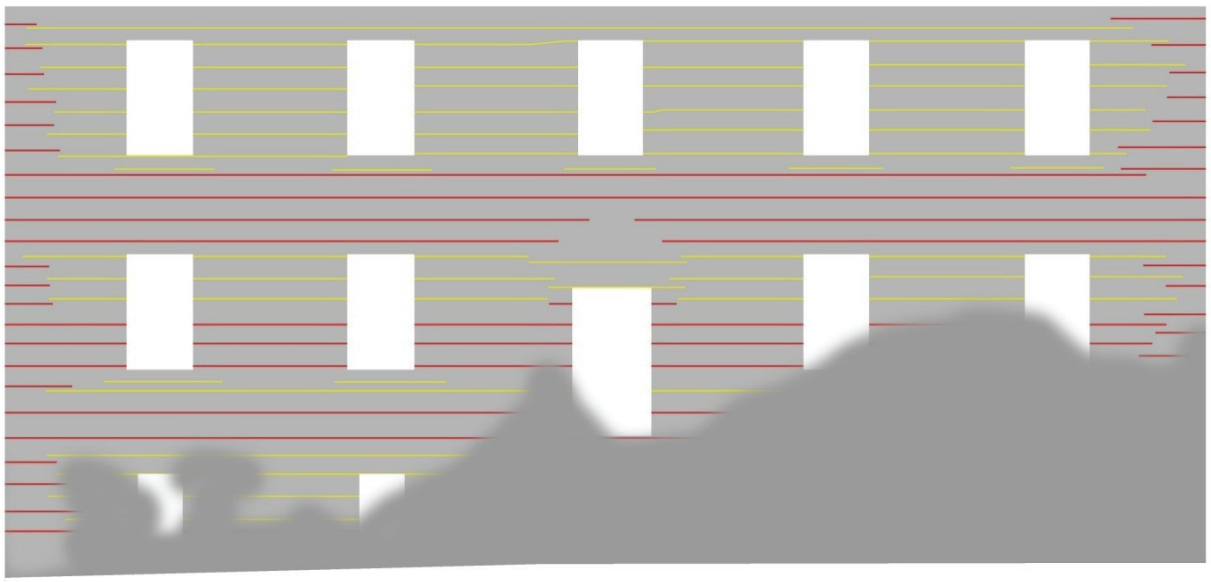
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

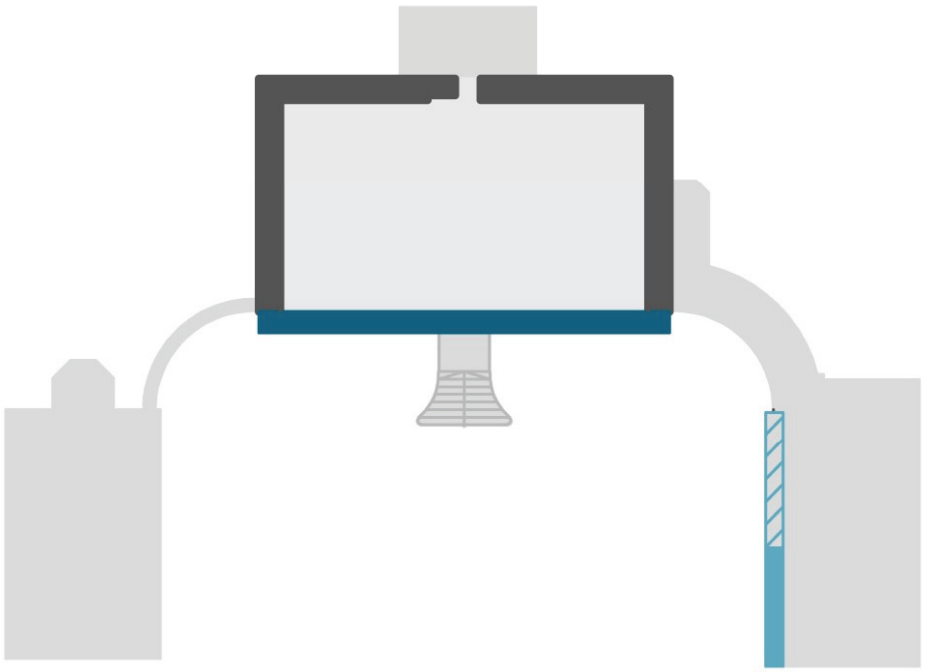


Courses determined by quoins
Courses determined by jambs
Other courses

AUCHINDINNY HOUSE _ MIDLOTHIAN

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
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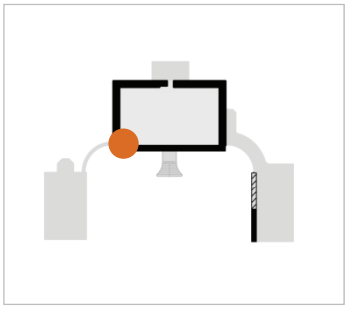
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

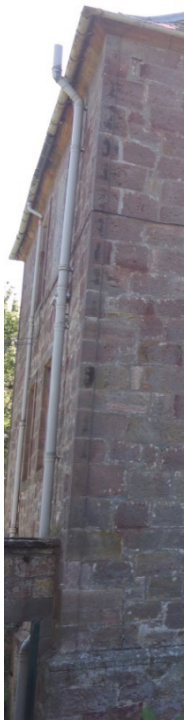
AUCHINDINNY HOUSE _ MIDLOTHIAN

CORNERS

LOCATION



CORNER



CORNER -SIDE 1

CORNER –SIDE 2



CORNER -SIDE 1

CORNER –SIDE 2



AUCHINDINNY HOUSE _ MIDLOTHIAN

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



IMG_7553_corrected_silhouette



IMG_7557_corrected_silhouette



IMG_7563_corrected_silhouette

AUCHINDINNY HOUSE _ MIDLOTHIAN

OTHER FEATURES



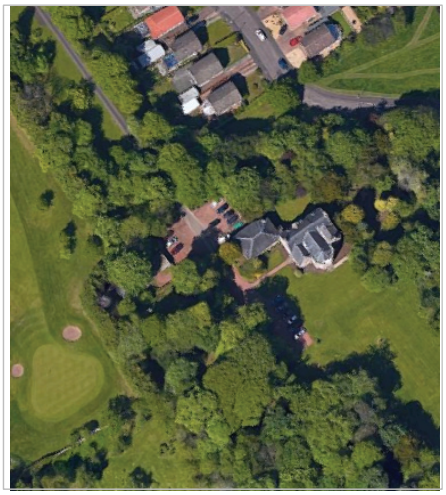
BABERTON HOUSE _ EDINBURGH, CITY OF

GENERAL INFORMATION

LOCATION



BUILDING PLAN

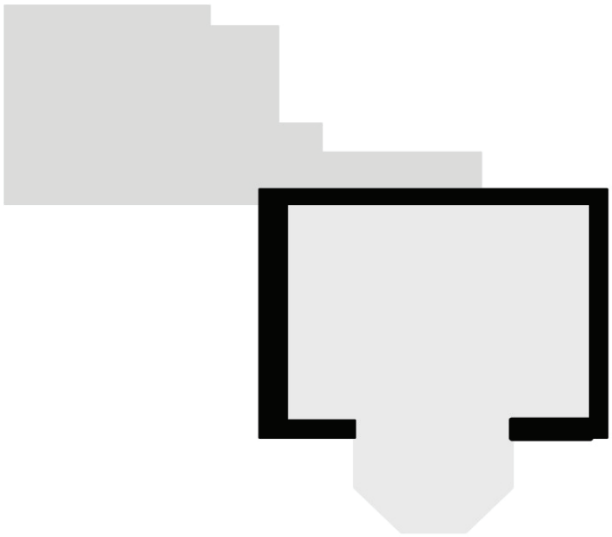


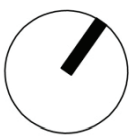
GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





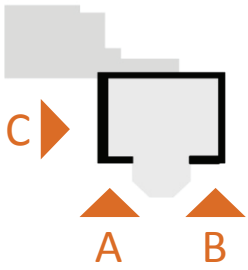
Area included in the research

Area not included in the research

Walls inspected

BABERTON HOUSE _ EDINBURGH, CITY OF

IMAGES OF THE BUILDING



A



B

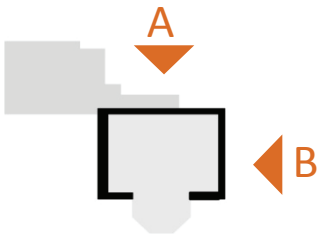


C



BABERTON HOUSE _ EDINBURGH, CITY OF

IMAGES OF THE BUILDING



A



B



BABERTON HOUSE _ EDINBURGH, CITY OF

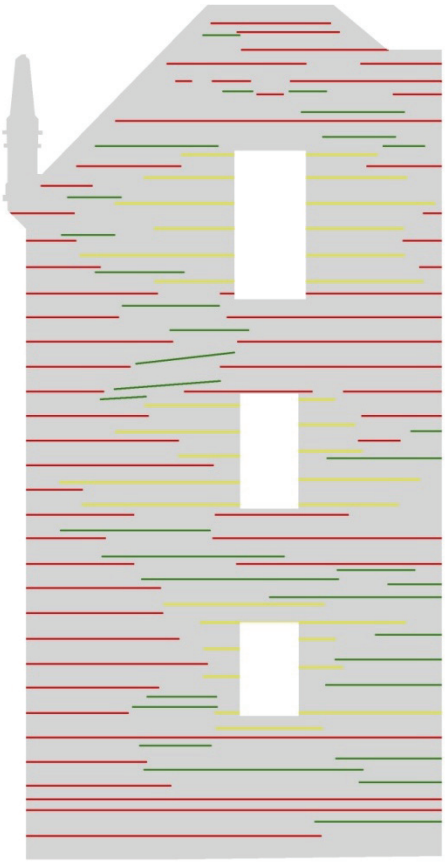
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

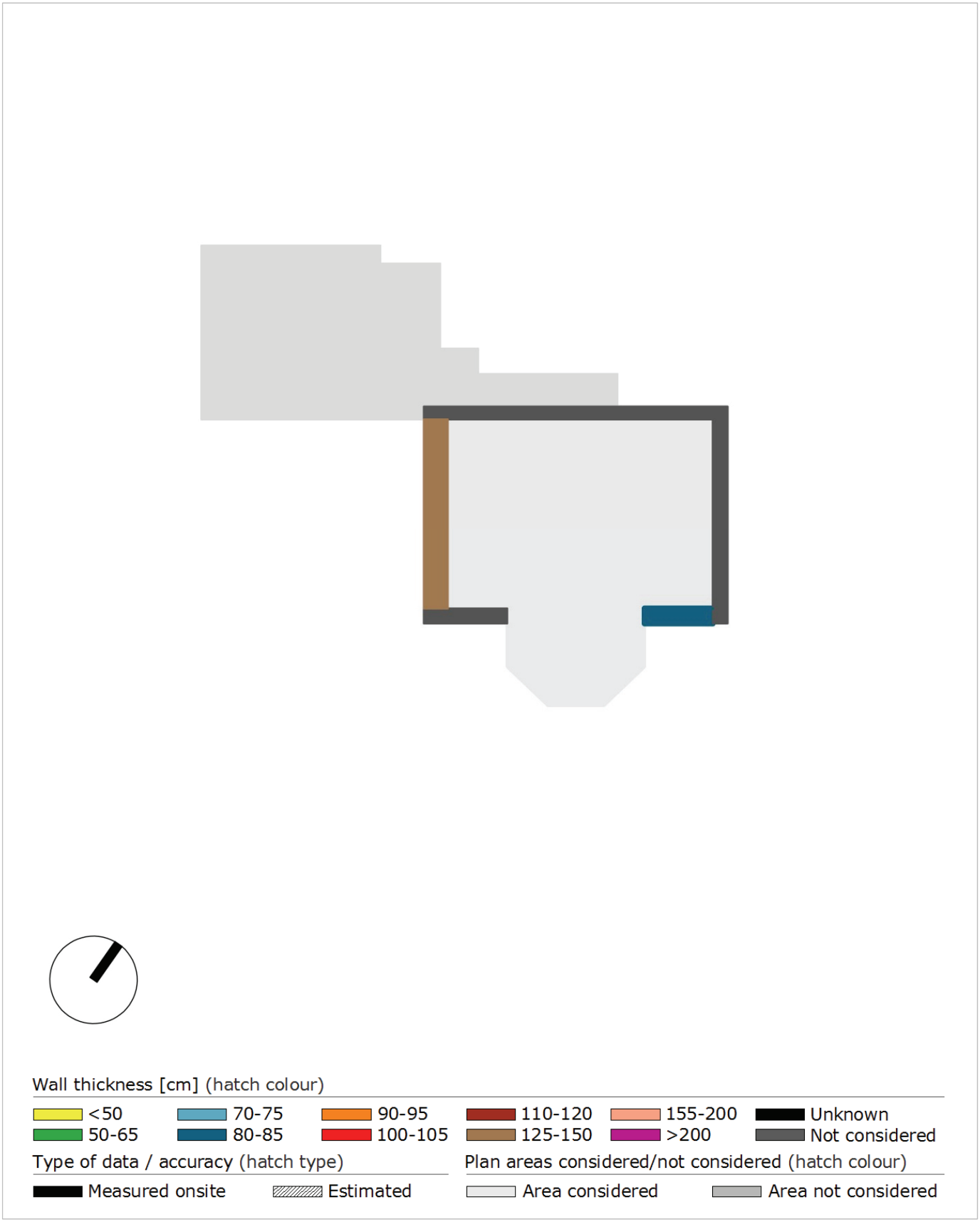


Courses determined by quoins
Courses determined by jambs
Other courses

BABERTON HOUSE _ EDINBURGH, CITY OF

WALL THICKNESSES

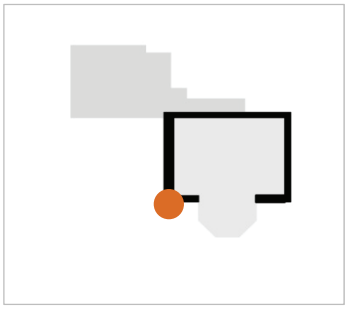
WALL THICKNESSES: GROUND FLOOR



BABERTON HOUSE _ EDINBURGH, CITY OF

CORNERS

LOCATION



CORNER

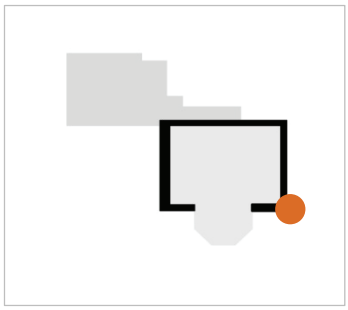


CORNER -SIDE 1

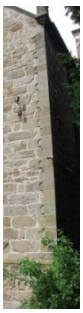
CORNER –SIDE 2



LOCATION



CORNER



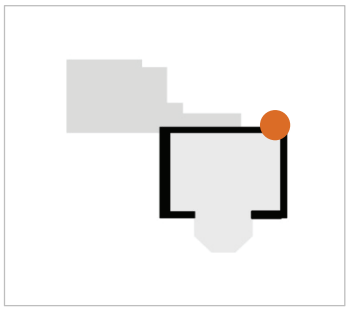
CORNER -SIDE 1



CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



BABERTON HOUSE _ EDINBURGH, CITY OF

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


IMG_4493_corrected_silhouette


IMG_4500_corrected_silhouette


IMG_4502_corrected_silhouette


IMG_4506_corrected_silhouette


IMG_4510_corrected_silhouette


IMG_4514_corrected_silhouette


IMG_4518_corrected_silhouette


IMG_4522_corrected_silhouette


IMG_4526_corrected_silhouette


IMG_4530_corrected_silhouette


IMG_4532_corrected_silhouette


IMG_4544_corrected_silhouette

BALGONIE CASTLE_FIFE

GENERAL INFORMATION

LOCATION



BUILDING PLAN



GENERAL IMAGE

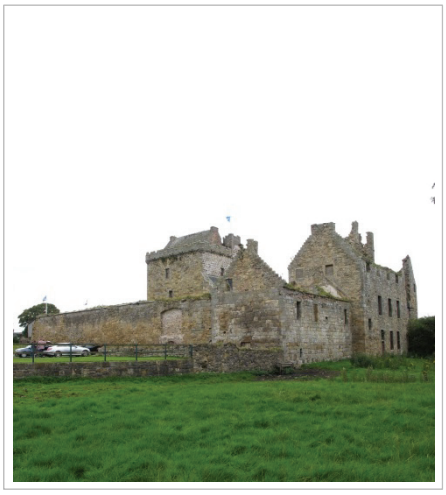
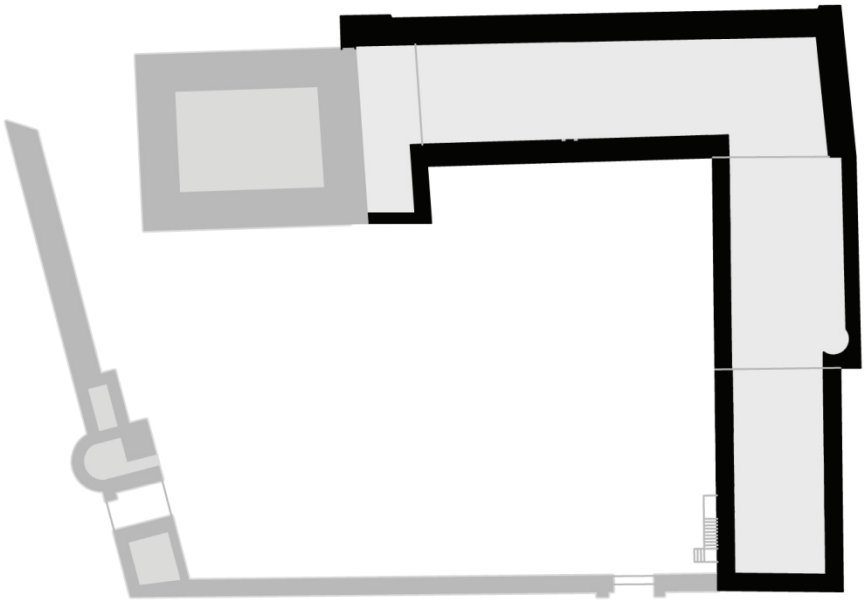


Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



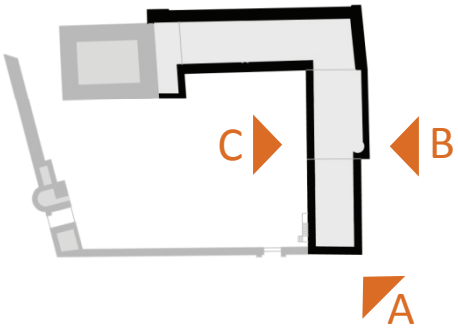
Area included in the research

Area not included in the research

Walls inspected

BALGONIE CASTLE_FIFE

IMAGES OF THE BUILDING



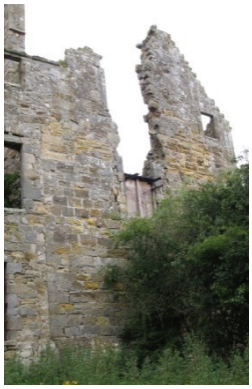
A



B





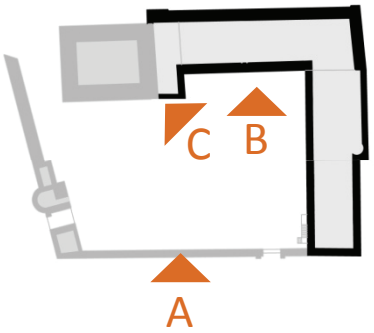


C



BALGONIE CASTLE_FIFE

IMAGES OF THE BUILDING



A



B



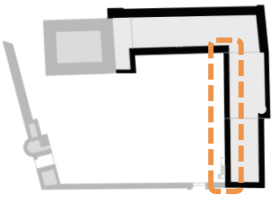
C



BALGONIE CASTLE_FIFE

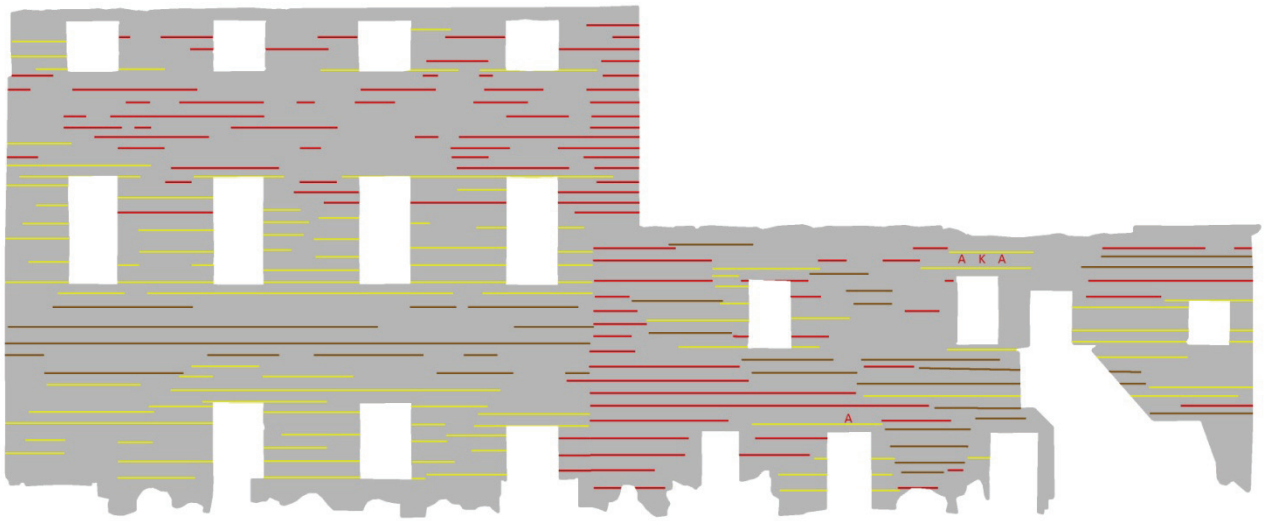
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

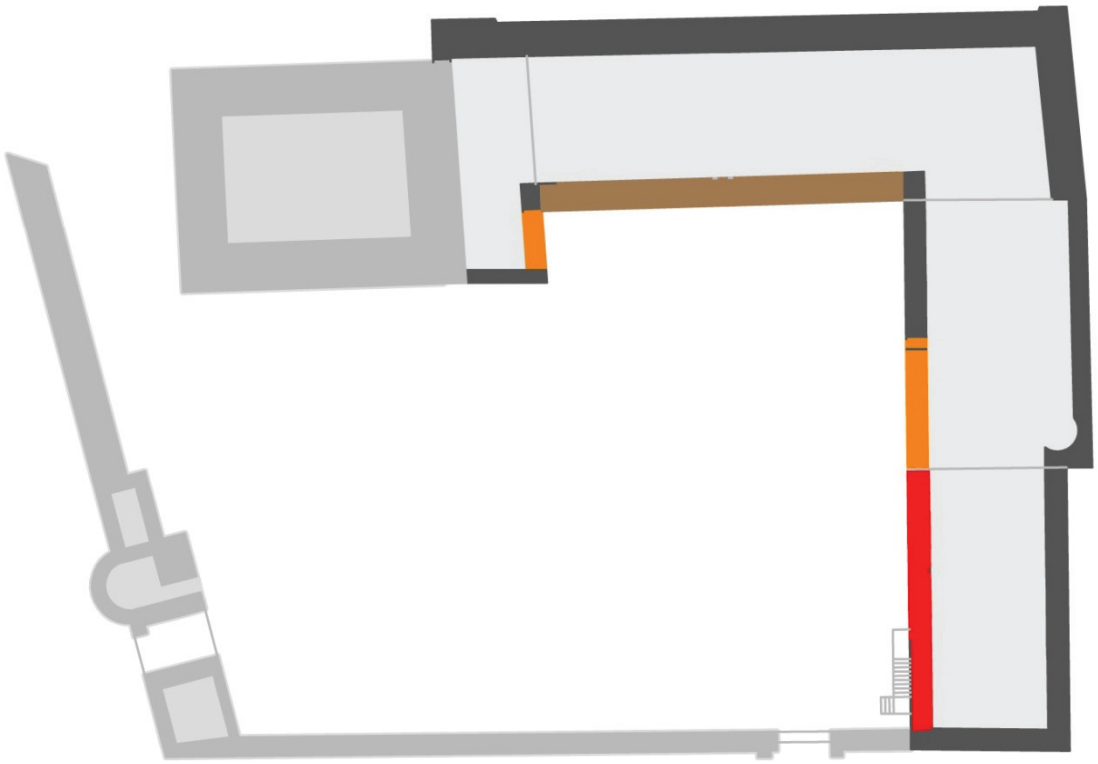


Courses determined by quoins
Courses determined by jambs
Other courses

BALGONIE CASTLE_FIFE

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

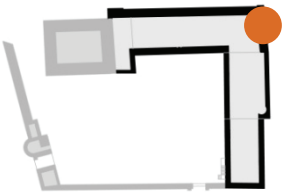
Measured onsite | Estimated

Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

BALGONIE CASTLE_FIFE

WALL SECTIONS

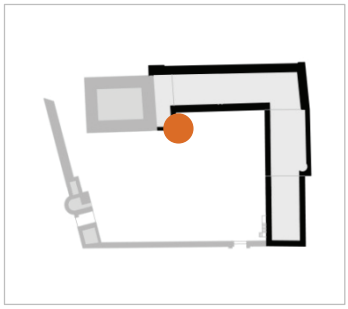




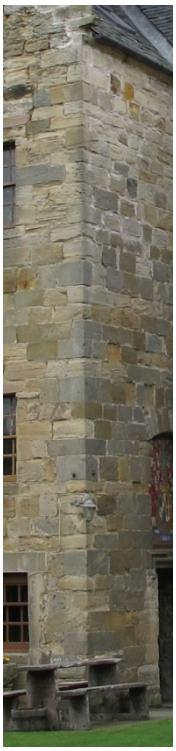
BALGONIE CASTLE_FIFE

CORNERS

LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



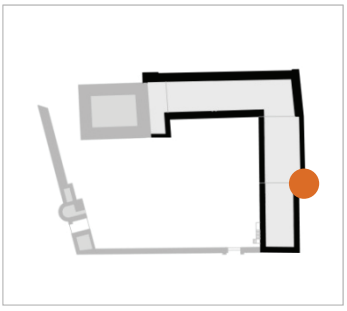
CORNER -SIDE 1



CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1

CORNER –SIDE 2



BALGONIE CASTLE_FIFE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


IMG_8306_corrected_silhouette


IMG_8312_corrected_silhouette


IMG_8320_corrected_silhouette


IMG_8324_corrected_silhouette


IMG_8328_corrected_silhouette


IMG_8341_corrected_silhouette


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IMG_8376_corrected_silhouette


IMG_8450_corrected_silhouette

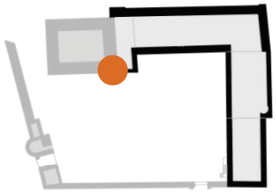

IMG_8526_corrected_silhouette


IMG_8528_corrected_silhouette

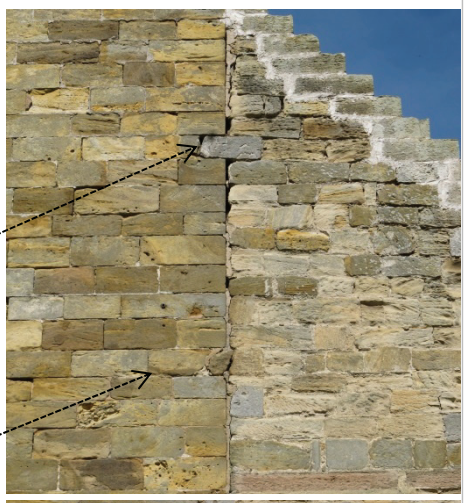
BALGONIE CASTLE_FIFE

OTHER FEATURES

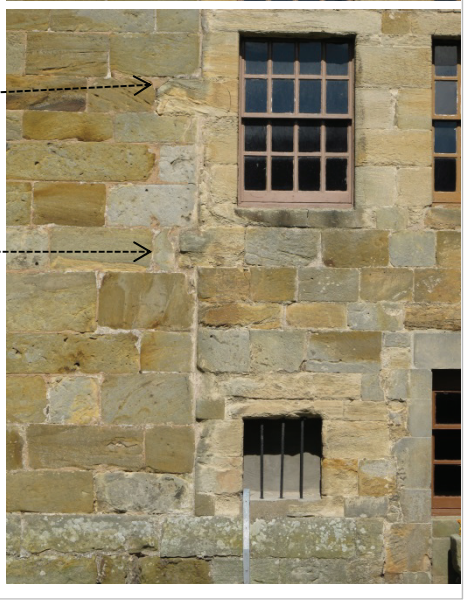
LINKS BETWEEN ADDITIONS







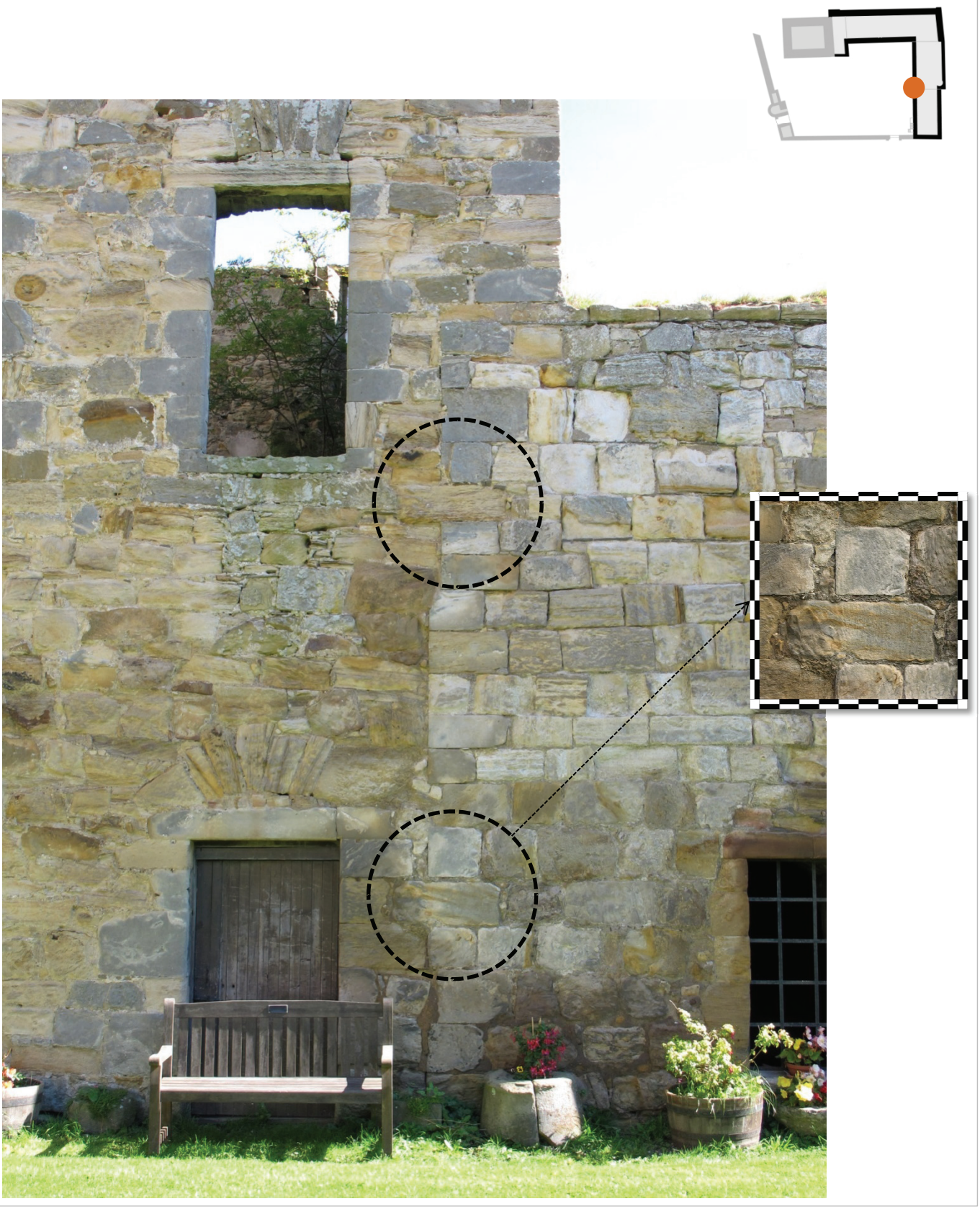




BALGONIE CASTLE_FIFE

OTHER FEATURES

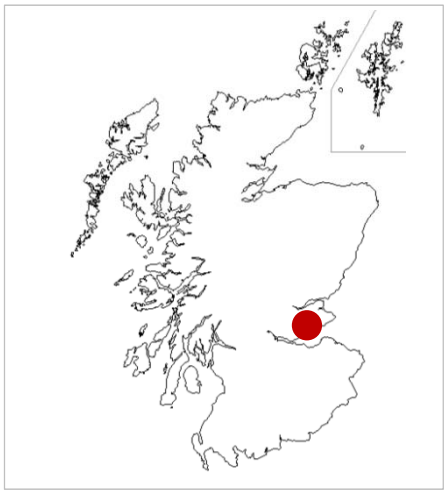
LINKS BETWEEN ADDITIONS



BALGONIE TOWER_FIFE

GENERAL INFORMATION

LOCATION

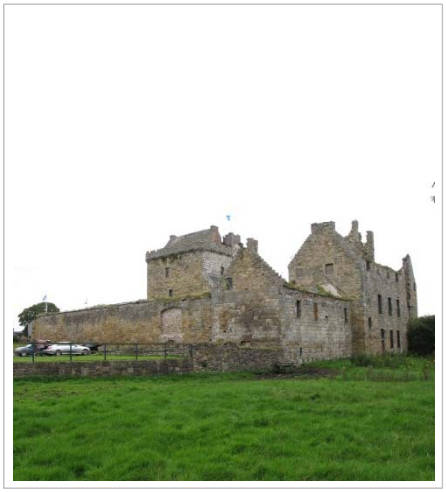


BUILDING PLAN

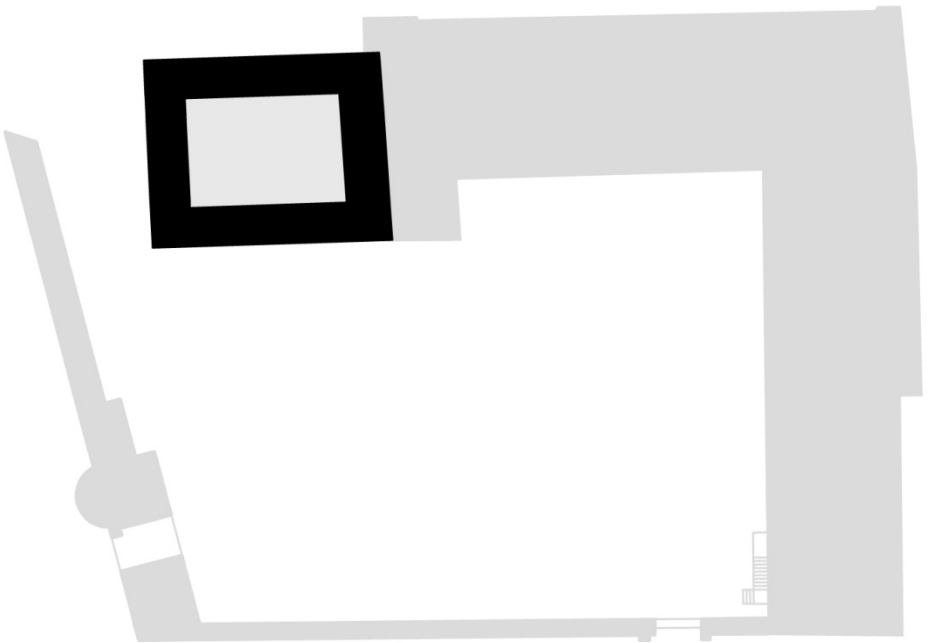


Image form Google maps 2017

GENERAL IMAGE



IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



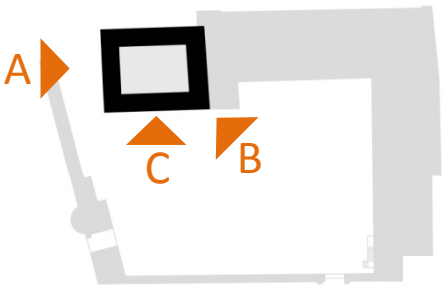
Area included in the research

Area not included in the research

Walls inspected

BALGONIE TOWER_FIFE

IMAGES OF THE BUILDING



A



B

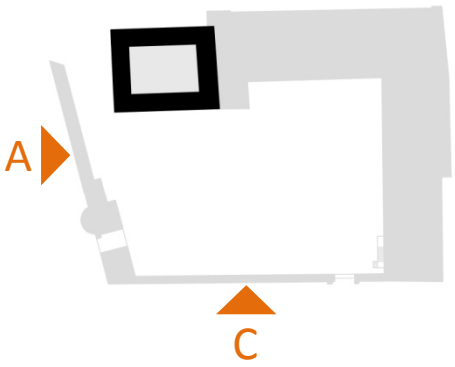


C



BALGONIE TOWER_FIFE

IMAGES OF THE BUILDING



A



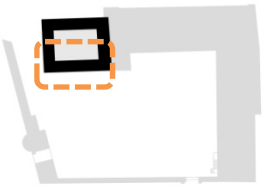
B

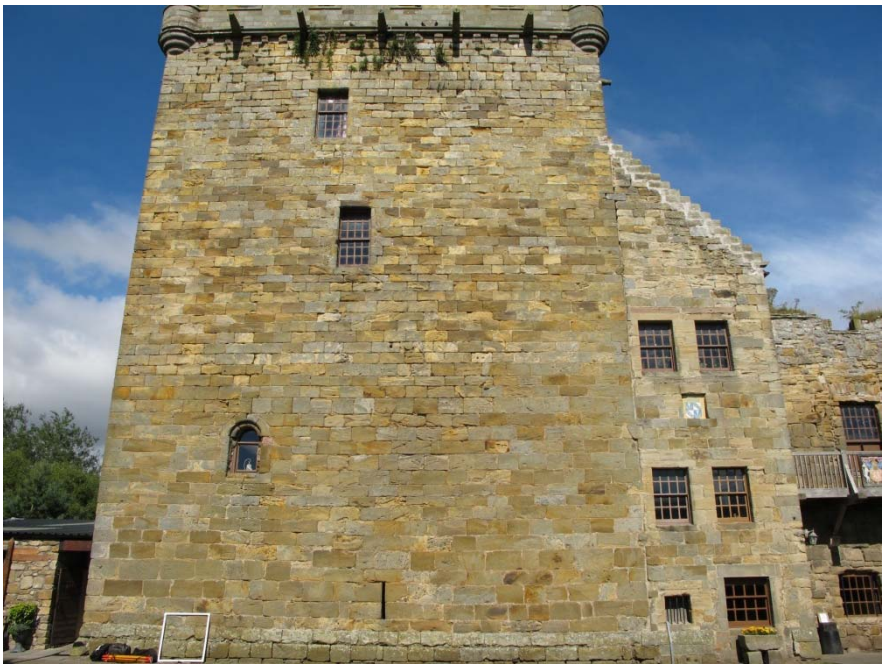


BALGONIE TOWER_FIFE

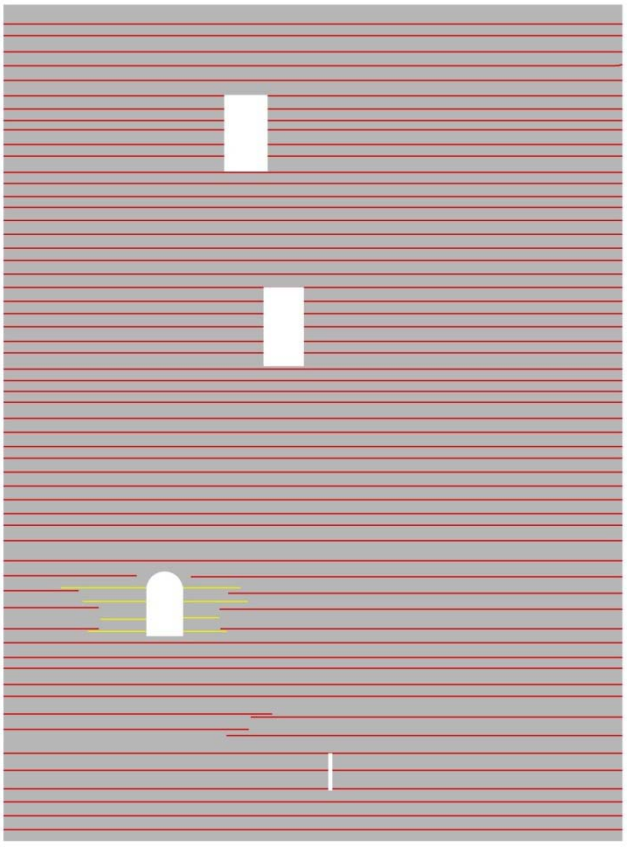
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

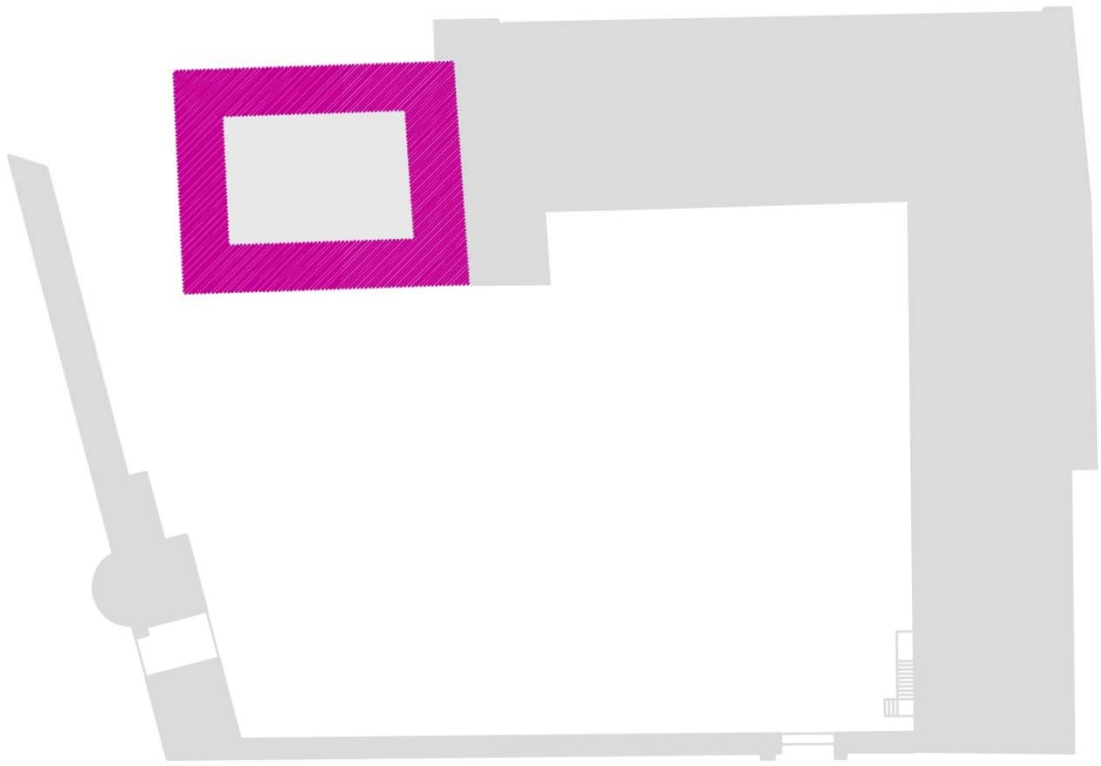


Courses determined by quoins
Courses determined by jambs
Other courses

BALGONIE TOWER_FIFE

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

Measured onsite | Estimated

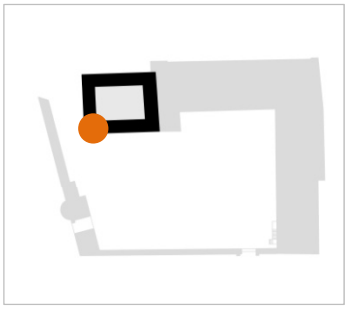
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

BALGONIE TOWER_FIFE

CORNERS

LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



CORNER -SIDE 1



CORNER –SIDE 2



BALGONIE TOWER_FIFE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


IMG_8390_corrected_silhouette


IMG_8392_corrected_silhouette


IMG_8394_corrected_silhouette


IMG_8396_corrected_silhouette


IMG_8400_corrected_silhouette


IMG_8404_corrected_silhouette

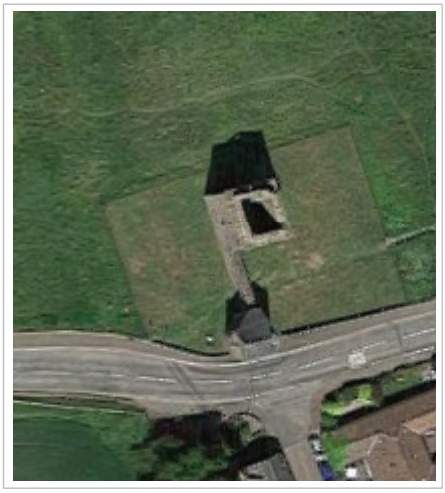
BURLEIGH CASTLE_PERTH AND KINROSS

GENERAL INFORMATION

LOCATION



BUILDING PLAN



GENERAL IMAGE

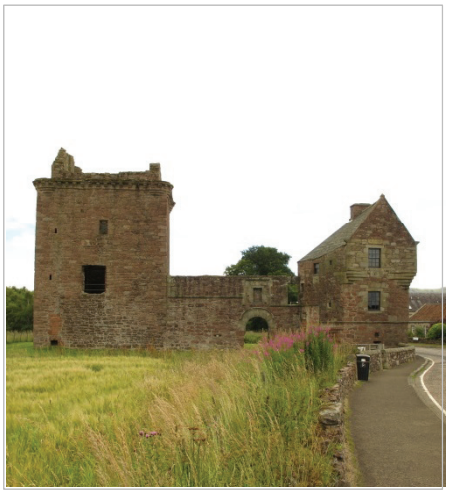
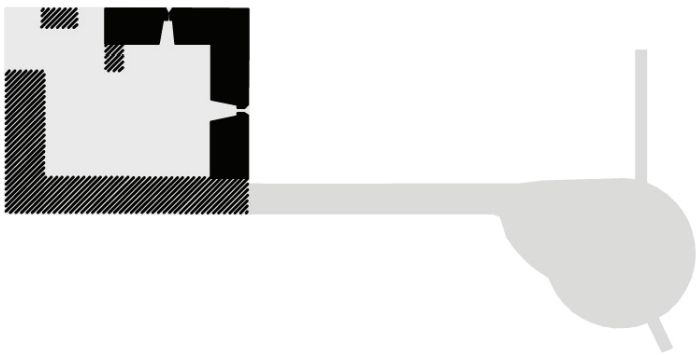
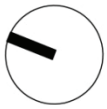


Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





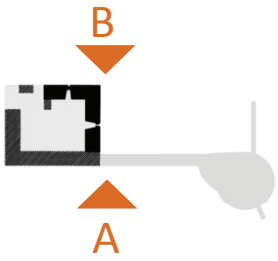
Area included in the research

Area not included in the research

Walls inspected

BURLEIGH CASTLE_PERTH AND KINROSS

IMAGES OF THE BUILDING



A

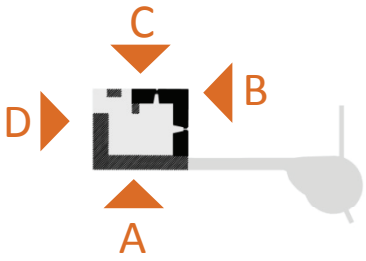


B



BURLEIGH CASTLE_PERTH AND KINROSS

IMAGES OF THE BUILDING



A



B



C



D



BURLEIGH CASTLE_PERTH AND KINROSS

ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES



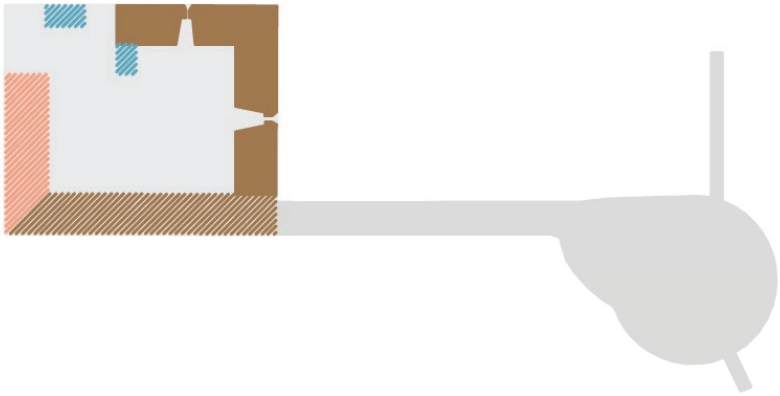
Courses determined by quoins
Courses determined by jambs
Other courses

BURLEIGH CASTLE_PERTH AND KINROSS

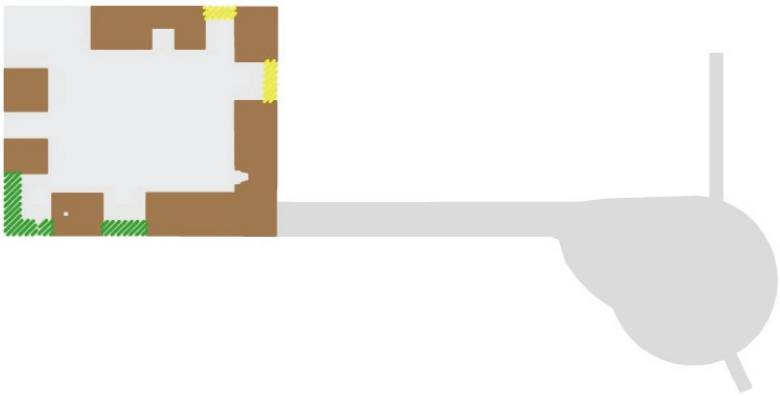
WALL THICKNESSES

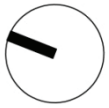
WALL THICKNESSES: GROUND FLOOR

BASEMENT



FIRST FLOOR





Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

Measured onsite | Estimated

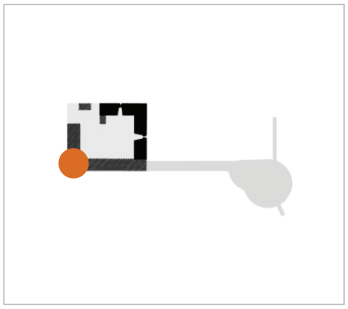
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

BURLEIGH CASTLE_PERTH AND KINROSS

CORNERS

LOCATION



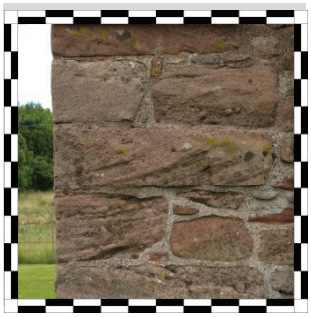
CORNER



CORNER -SIDE 1



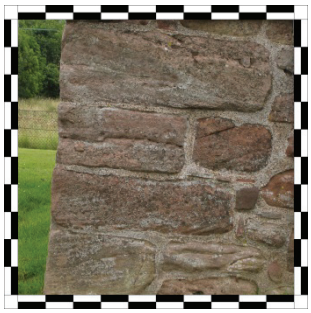
CORNER –SIDE 2



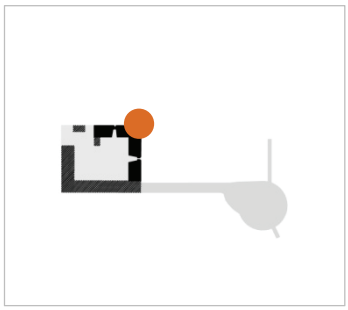
CORNER -SIDE 1



CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



CORNER -SIDE 1



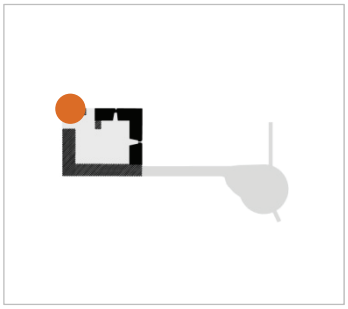
CORNER –SIDE 2



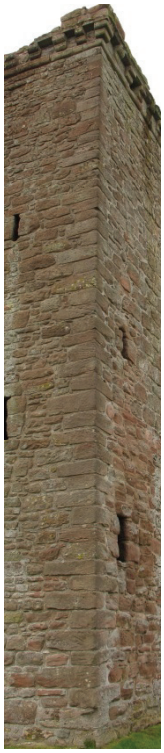
BURLEIGH CASTLE_PERTH AND KINROSS

CORNERS

LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2

CORNER -SIDE 1



CORNER –SIDE 2

BURLEIGH CASTLE_PERTH AND KINROSS

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



IMG_5141_corrected_silhouette



IMG_5168_corrected_silhouette



IMG_5206_corrected_silhouette



IMG_5302_corrected_silhouette

BURLEIGH CASTLE_PERTH AND KINROSS

OTHER FEATURES

FLOORS

GROUND FLOOR
Stone vault



1st FLOOR
Joist marks

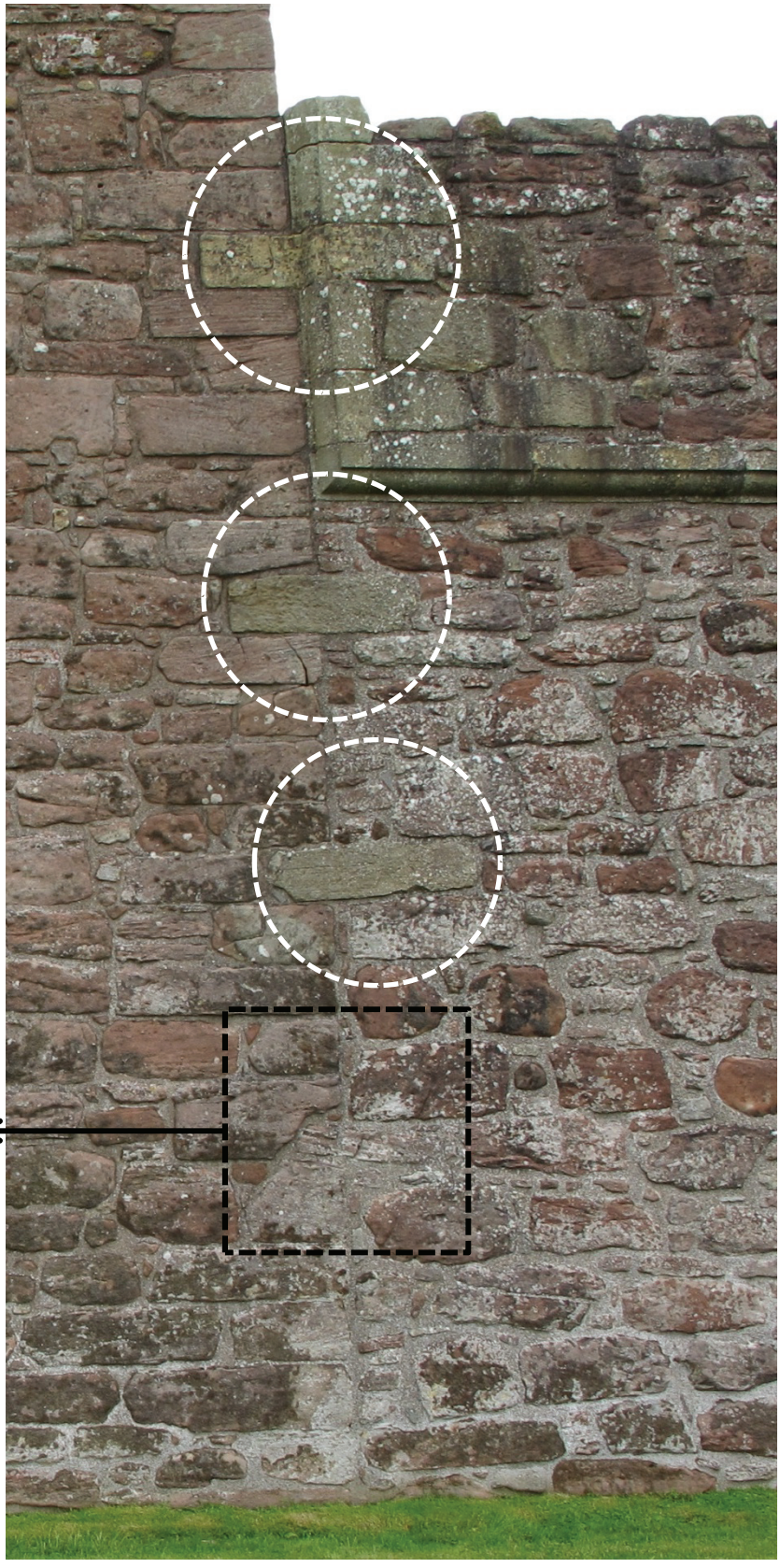


BURLEIGH CASTLE_PERTH AND KINROSS

OTHER FEATURES

LINKS BETWEEN ADDITIONS







CASTLE CAMPBELL TOWER_CLACKMANNAN

GENERAL INFORMATION

LOCATION



BUILDING PLAN



GENERAL IMAGE

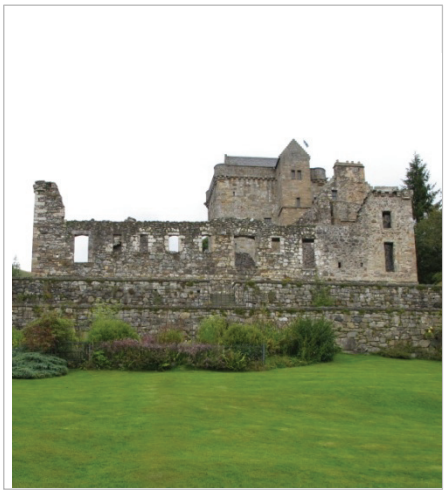
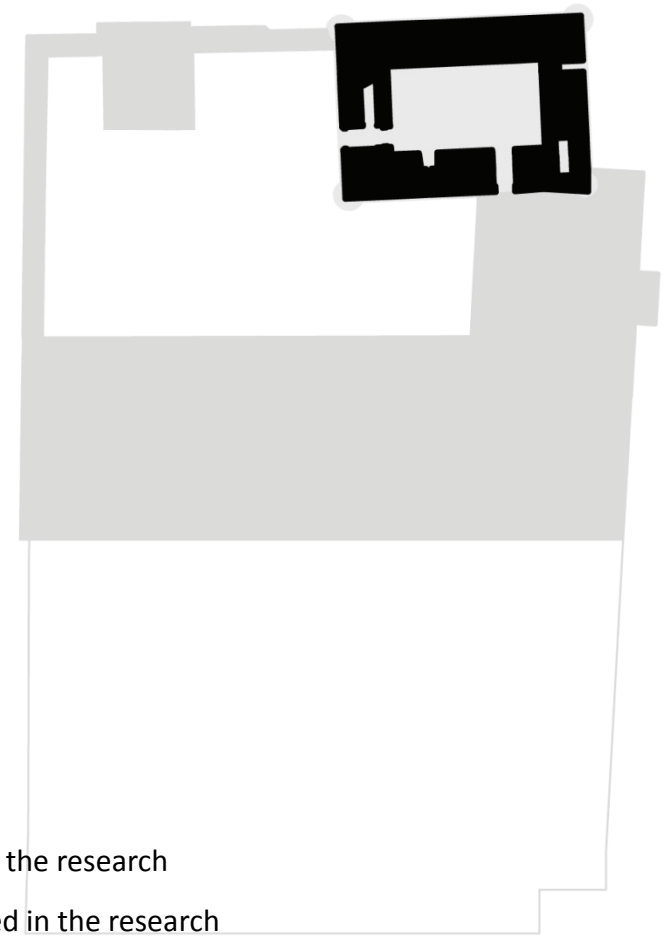


Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



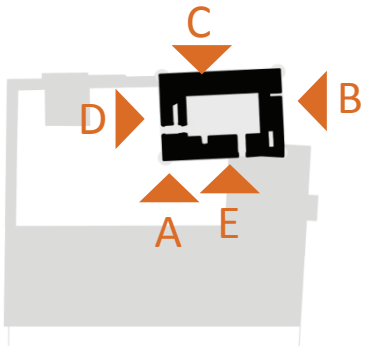
Area included in the research

Area not included in the research

Walls inspected

CASTLE CAMPBELL TOWER_CLACKMANNAN

IMAGES OF THE BUILDING



A



B



C



D



E



CASTLE CAMPBELL TOWER_CLACKMANNAN

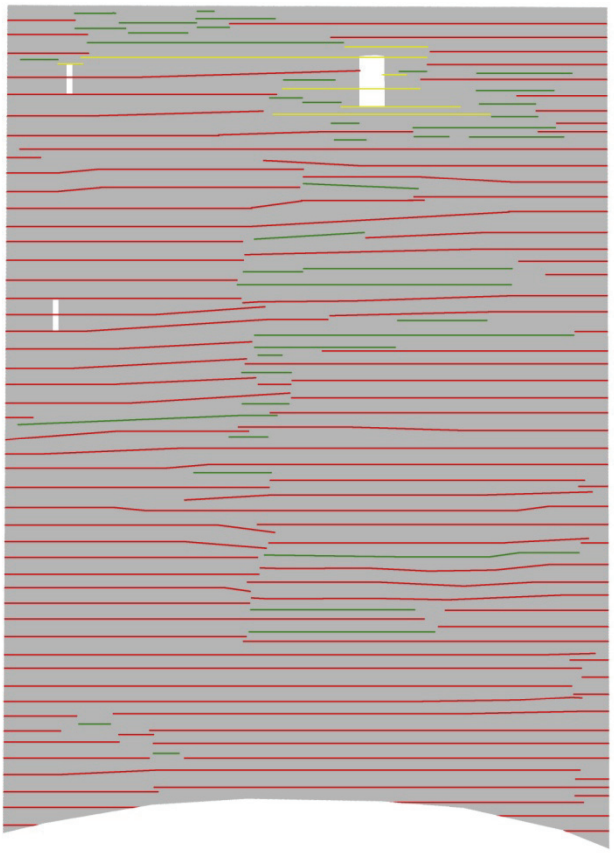
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

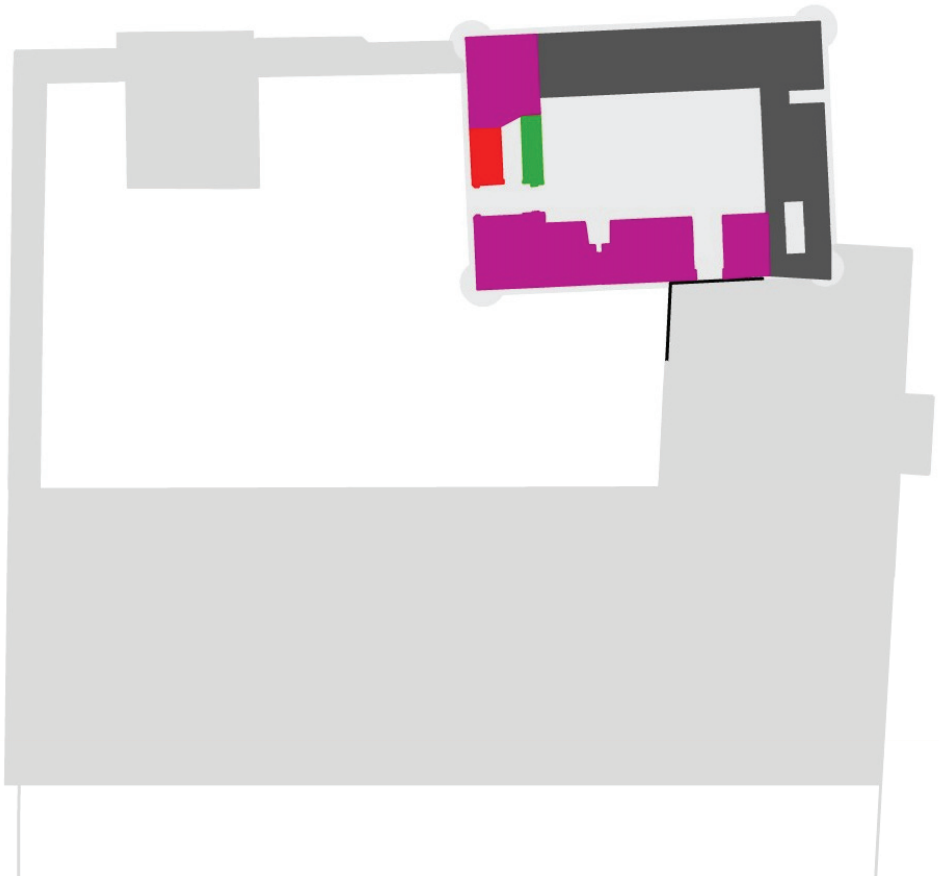


Courses determined by quoins
Courses determined by jambs
Other courses

CASTLE CAMPBELL TOWER_CLACKMANNAN

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

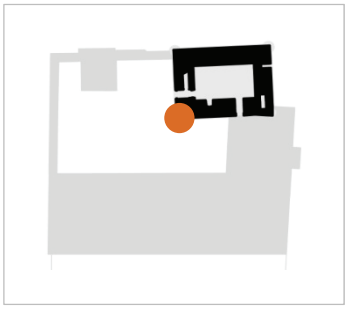
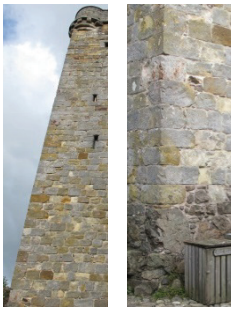
Measured onsite | Estimated

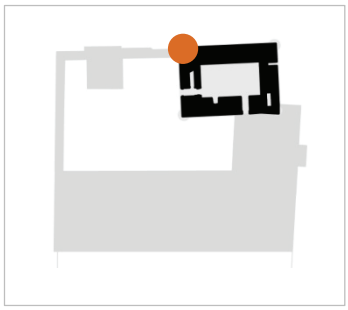
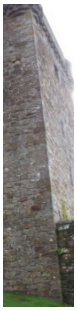
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

CASTLE CAMPBELL TOWER_CLACKMANNAN

CORNERS

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			

CASTLE CAMPBELL TOWER_CLACKMANNAN

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



IMG_0313_corrected_silhouette



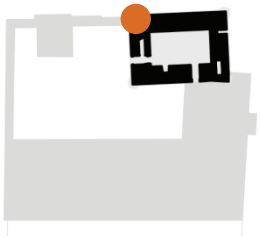
IMG_0597_corrected_silhouette



IMG_0599_corrected_silhouette

CASTLE CAMPBELL TOWER_CLACKMANNAN

OTHER FEATURES





CHATELHERAULT HUNTING LODGE _ SOUTH LANARKSHIRE

GENERAL INFORMATION

LOCATION



BUILDING PLAN



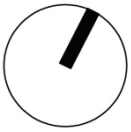
GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





Area included in the research

Area not included in the research

Walls inspected

CHATELHERAULT HUNTING LODGE _ SOUTH LANARKSHIRE

IMAGES OF THE BUILDING



A



B



C



CHATELHERAULT HUNTING LODGE _ SOUTH LANARKSHIRE

IMAGES OF THE BUILDING



A



B



CHATELHERAULT HUNTING LODGE _ SOUTH LANARKSHIRE

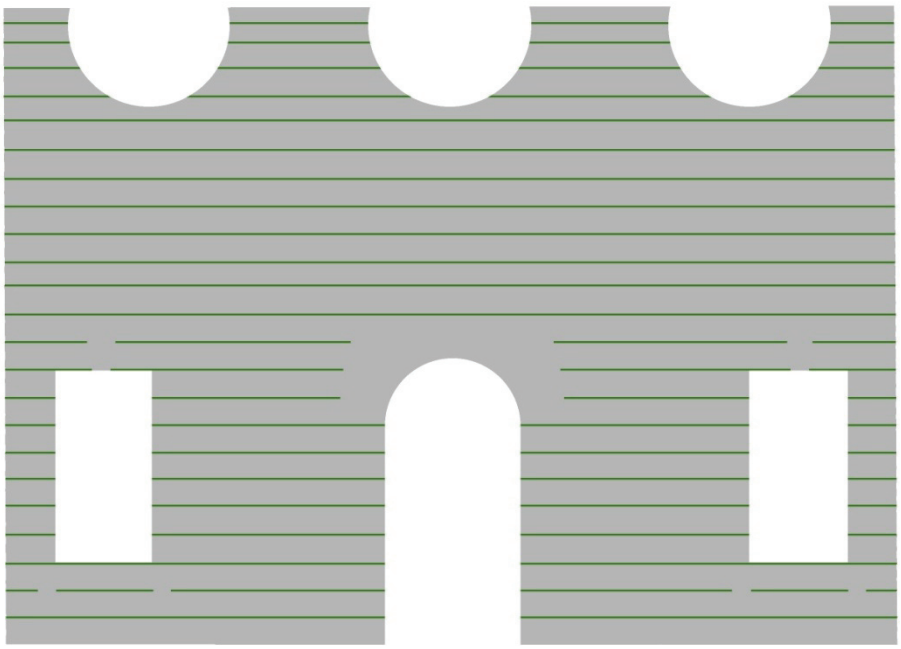
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

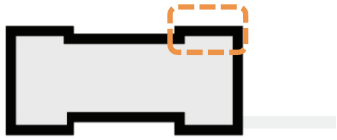


Courses determined by quoins
Courses determined by jambs
Other courses

CHATELHERAULT HUNTING LODGE _ SOUTH LANARKSHIRE

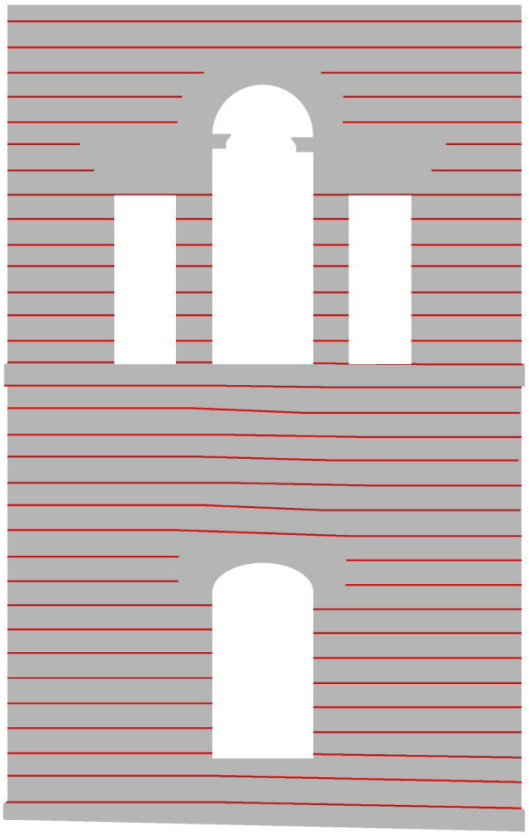
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES



Courses determined by quoins
Courses determined by jambs
Other courses

CHATELHERAULT HUNTING LODGE _ SOUTH LANARKSHIRE

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR





Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

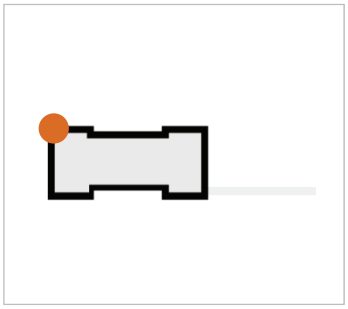
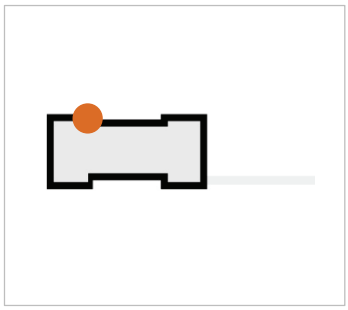
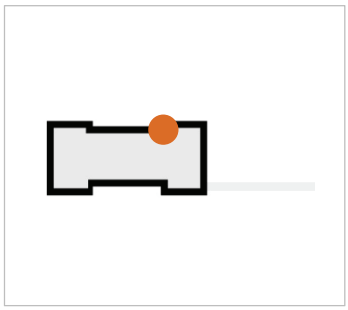
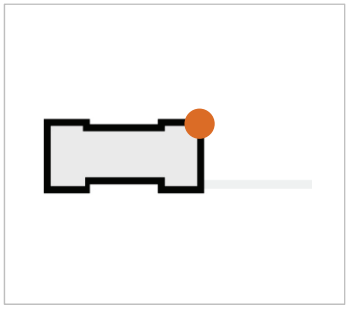
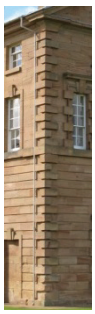
Measured onsite | Estimated

Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

CHATELHERAULT HUNTING LODGE _ SOUTH LANARKSHIRE

CORNERS

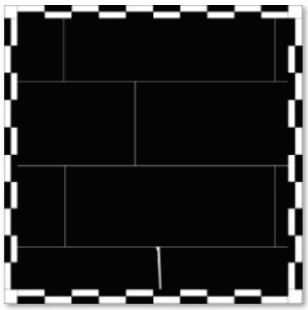
LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			

CHATELHERAULT HUNTING LODGE _ SOUTH LANARKSHIRE

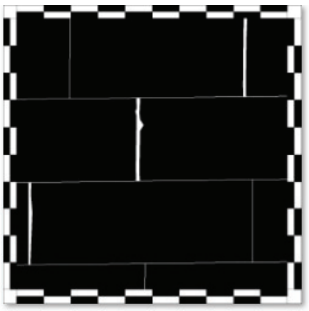
MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


DSC_0951_corrected_silhouette


DSC_0958_corrected_silhouette

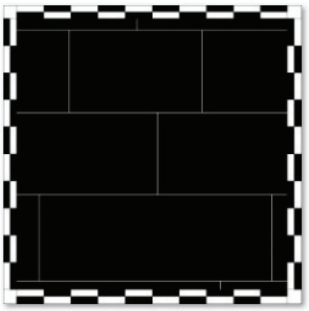

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DSC_0972_corrected_silhouette


DSC_0980_corrected_silhouette


DSC_0986_corrected_silhouette


DSC_0996_corrected_silhouette


DSC_0998_corrected_silhouette

CRAIGIEHALL HOUSE _ EDINBURGH, CITY OF

GENERAL INFORMATION

LOCATION



BUILDING PLAN

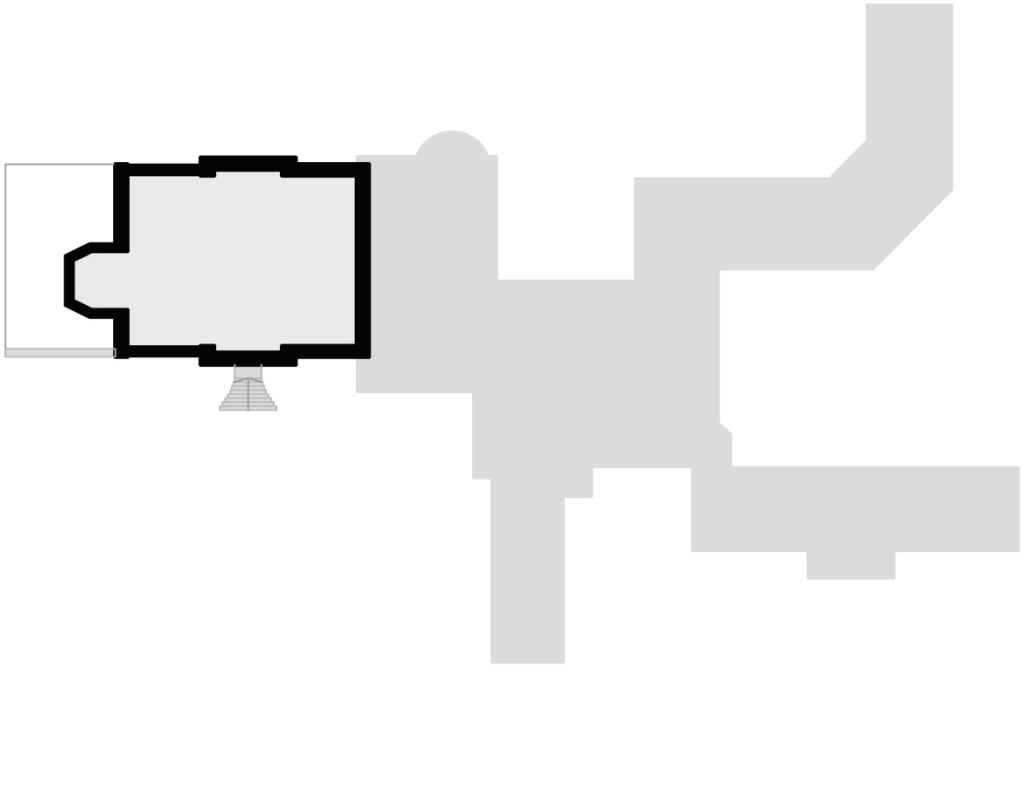


GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



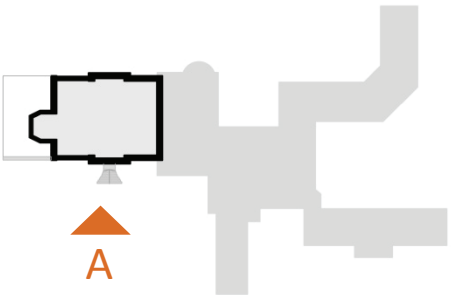
Area included in the research

Area not included in the research

Walls inspected

CRAIGIEHALL HOUSE _ EDINBURGH, CITY OF

IMAGES OF THE BUILDING

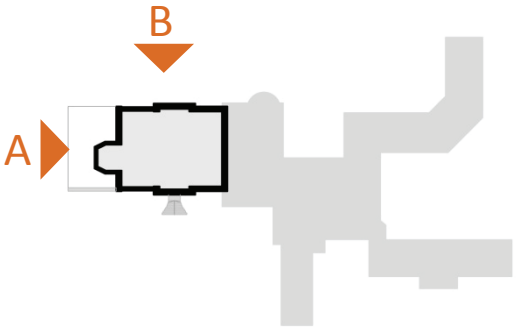


A



CRAIGIEHALL HOUSE _ EDINBURGH, CITY OF

IMAGES OF THE BUILDING



A



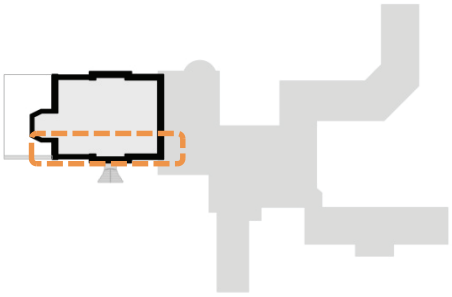
B



CRAIGIEHALL HOUSE _ EDINBURGH, CITY OF

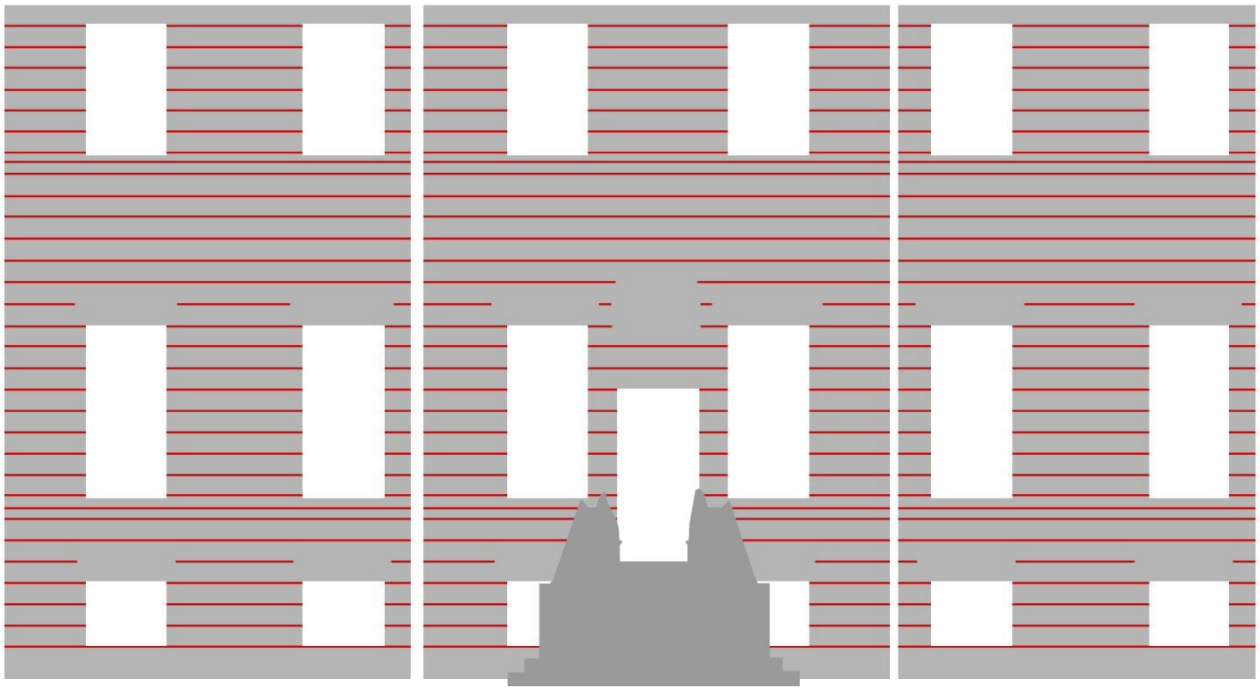
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

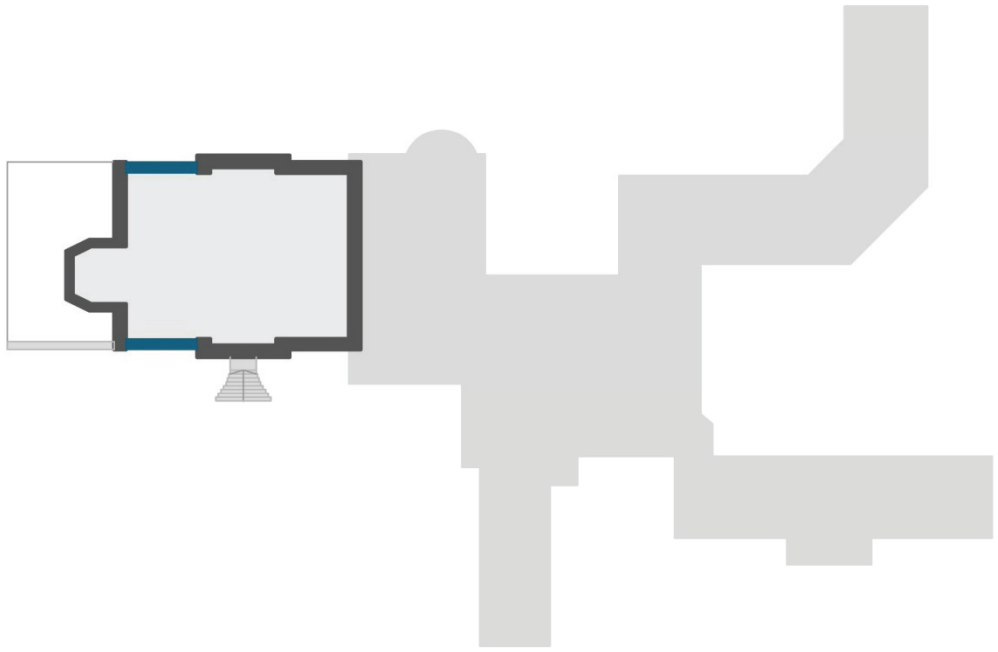


Courses determined by quoins
Courses determined by jambs
Other courses

CRAIGIEHALL HOUSE _ EDINBURGH, CITY OF

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

Measured onsite | Estimated

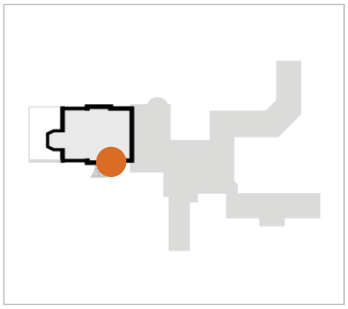
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

CRAIGIEHALL HOUSE _ EDINBURGH, CITY OF

CORNERS

LOCATION



CORNER



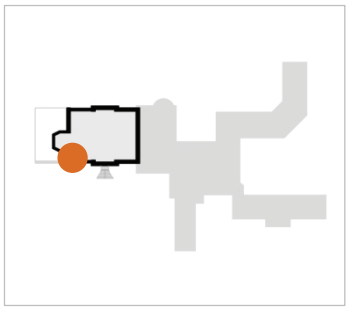
CORNER -SIDE 1



CORNER –SIDE 2



LOCATION



CORNER



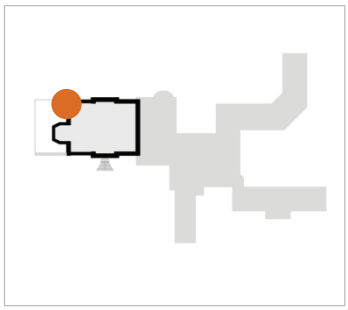
CORNER -SIDE 1



CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1

CORNER –SIDE 2

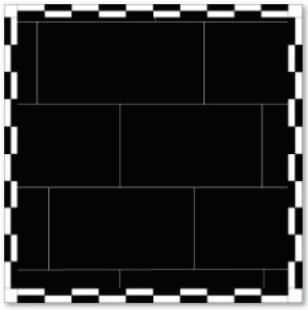


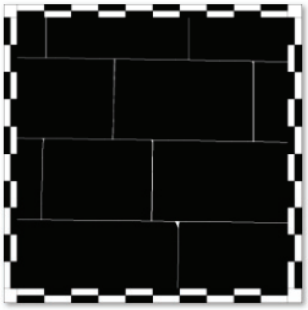
CRAIGIEHALL HOUSE _ EDINBURGH, CITY OF

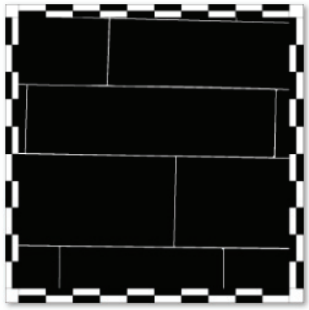
MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION

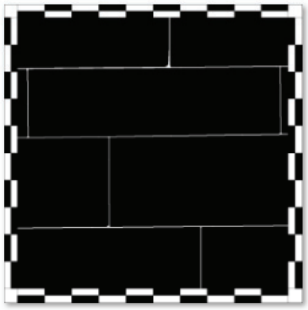

IMG_4836_corrected_silhouette


IMG_4852_corrected_silhouette


IMG_4885_corrected_silhouette


IMG_4887_corrected_silhouette


IMG_4895_corrected_silhouette


IMG_4902_corrected_silhouette

CRAIGMILLAR CASTLE _EDINBURGH, CITY OF

GENERAL INFORMATION

LOCATION

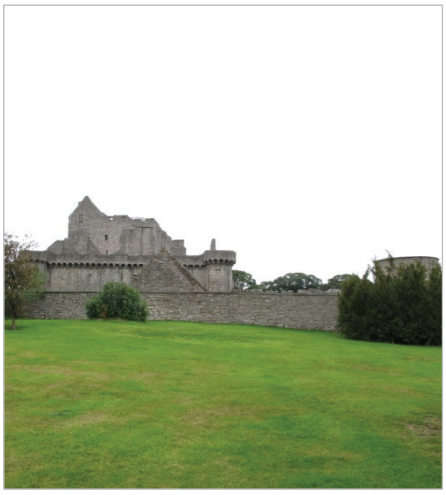


BUILDING PLAN

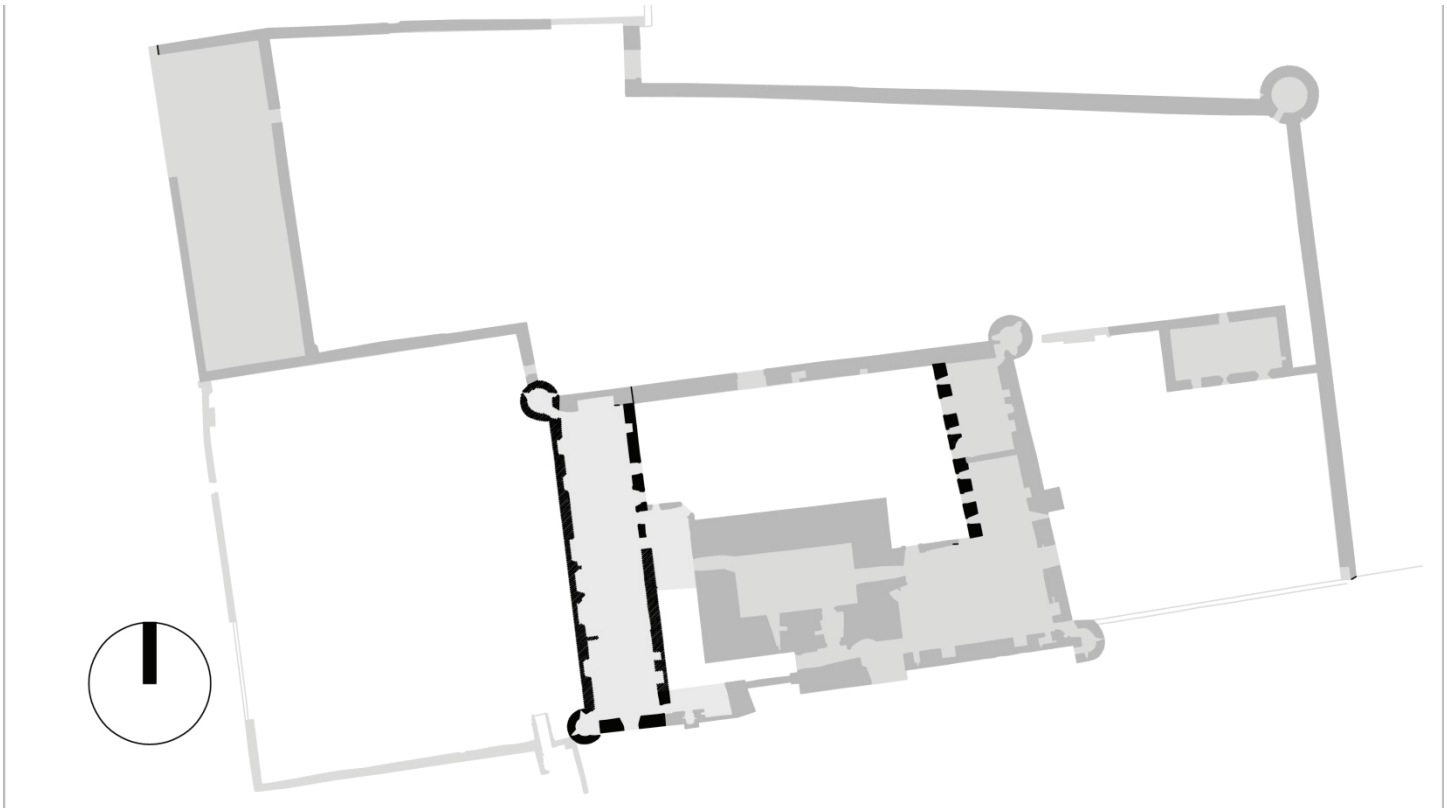


Image form Google maps 2017

GENERAL IMAGE



IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



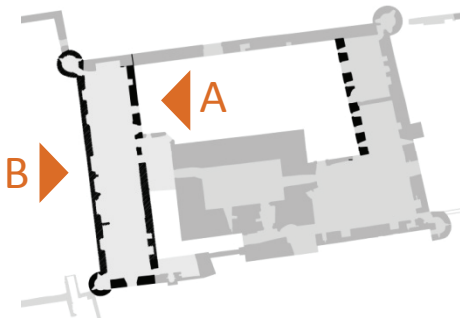
Area included in the research

Area not included in the research

Walls inspected

CRAIGMILLAR CASTLE _EDINBURGH, CITY OF

IMAGES OF THE BUILDING



A

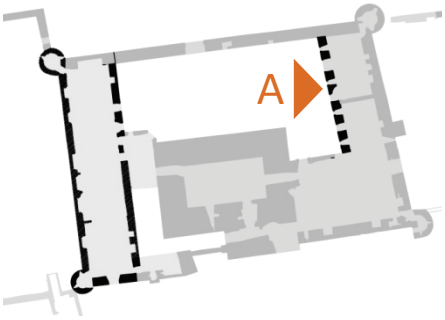


B



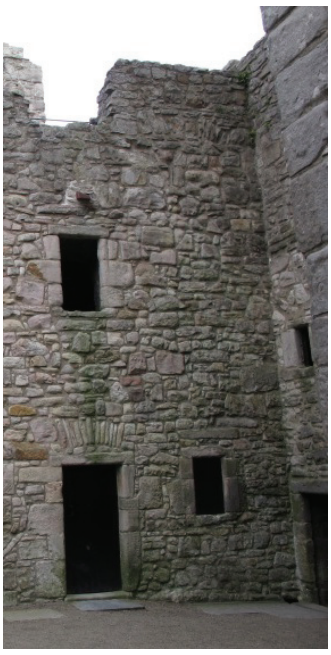
CRAIGMILLAR CASTLE _EDINBURGH, CITY OF

IMAGES OF THE BUILDING



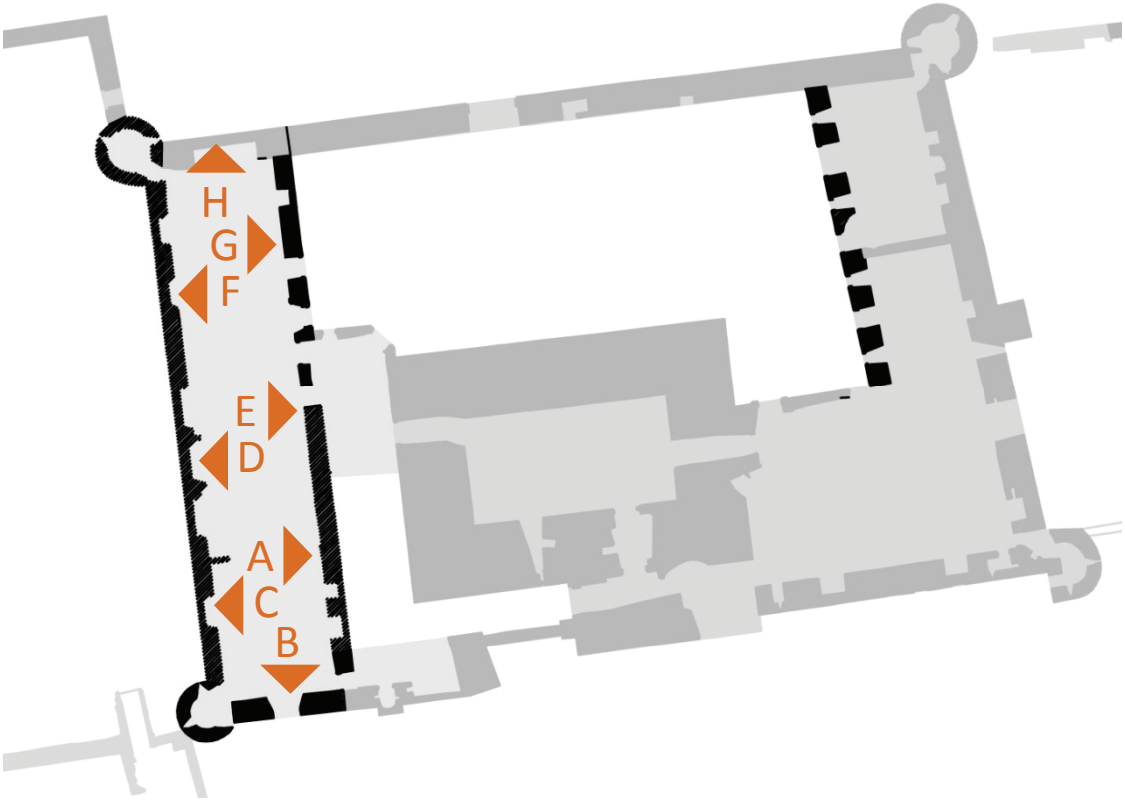
A





CRAIGMILLAR CASTLE _EDINBURGH, CITY OF

IMAGES OF THE BUILDING



A





B





C





CRAIGMILLAR CASTLE _EDINBURGH, CITY OF

IMAGES OF THE BUILDING

D





E





F





H





G

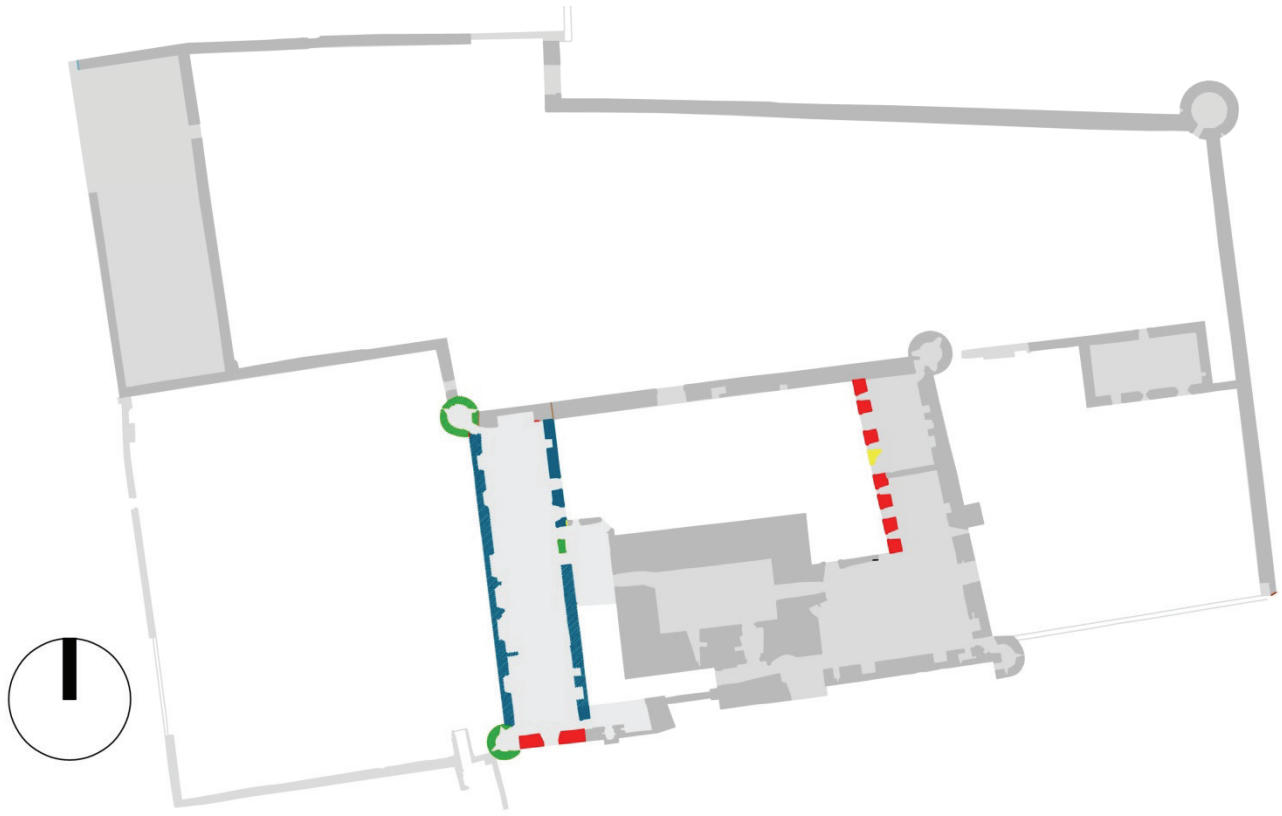




CRAIGMILLAR CASTLE _EDINBURGH, CITY OF

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

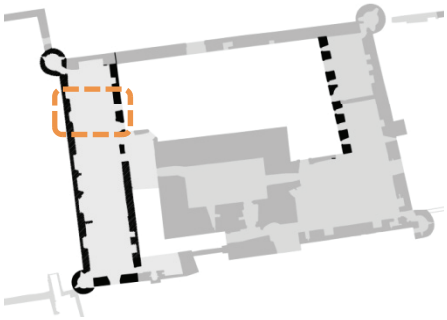
Measured onsite | Estimated

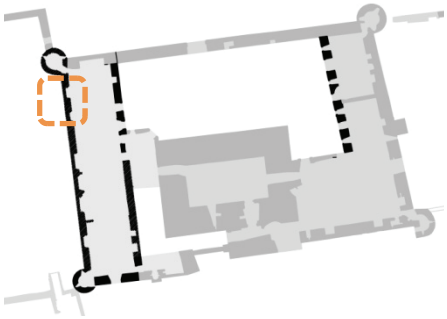
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

CRAIGMILLAR CASTLE _EDINBURGH, CITY OF

WALL SECTIONS



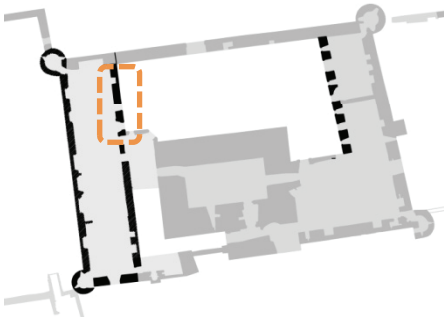


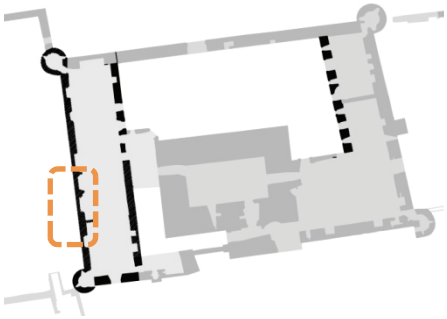




CRAIGMILLAR CASTLE _EDINBURGH, CITY OF

WALL SECTIONS









CRAIGMILLAR CASTLE _EDINBURGH, CITY OF

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


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IMG_9116_corrected_silhouette


IMG_9134_corrected_silhouette


IMG_9136_corrected_silhouette

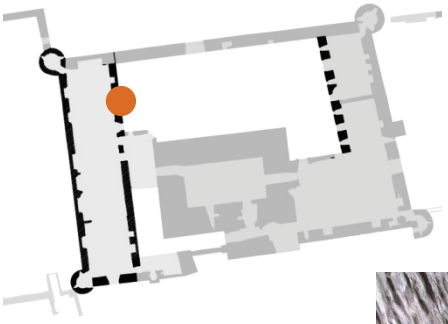

IMG_9183_corrected_silhouette


IMG_9231_corrected_silhouette


IMG_9448_corrected_silhouette

CRAIGMILLAR CASTLE _EDINBURGH, CITY OF

OTHER FEATURES







CRAIGMILLAR CASTLE TOWER_EDINBURGH, CITY OF

GENERAL INFORMATION

LOCATION

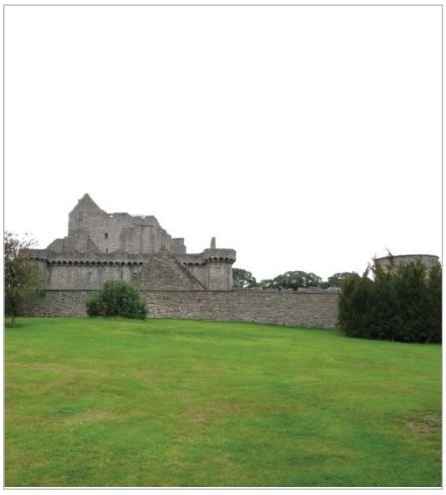


BUILDING PLAN

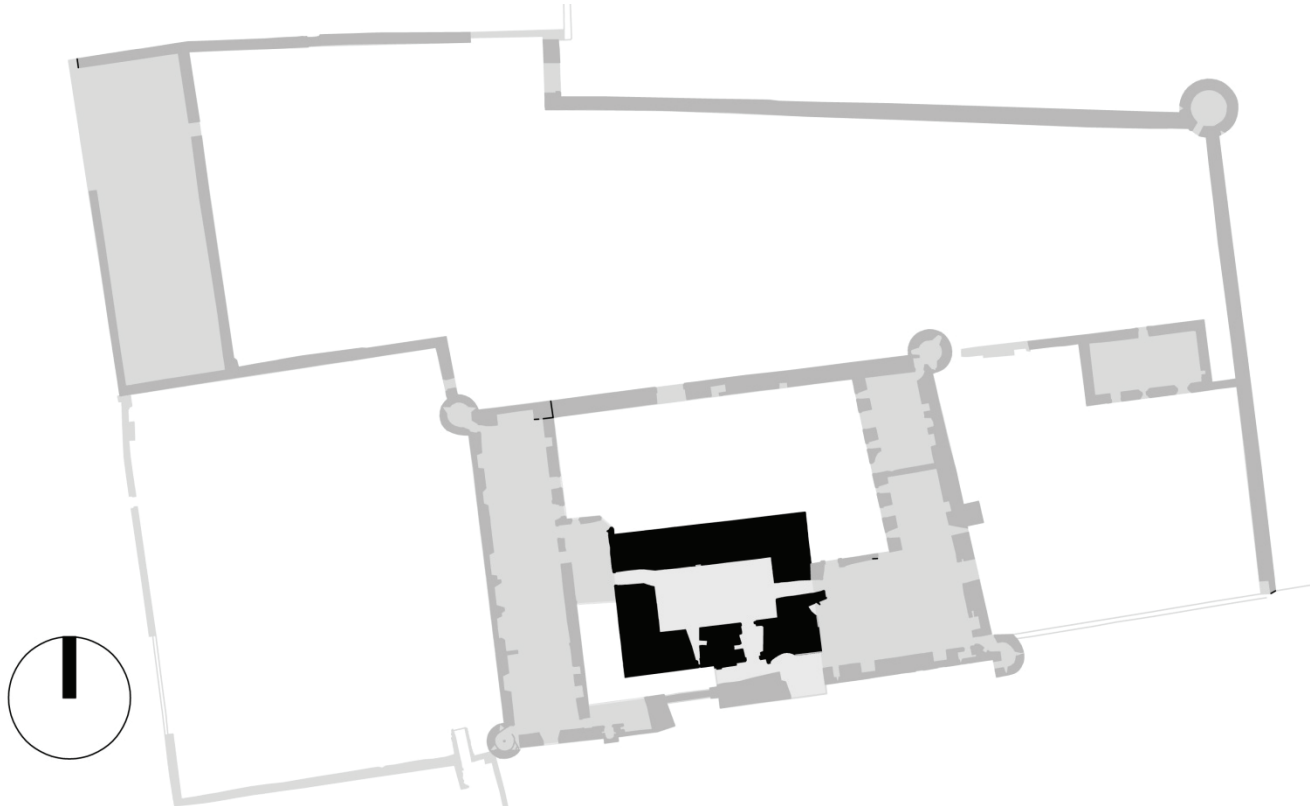


Image form Google maps 2017

GENERAL IMAGE



IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



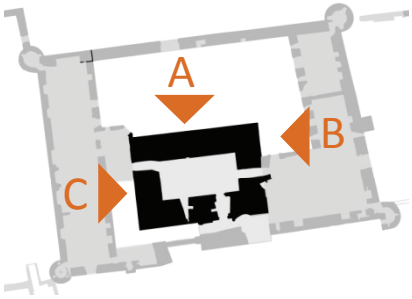
Area included in the research

Area not included in the research

Walls inspected

CRAIGMILLAR CASTLE TOWER_EDINBURGH, CITY OF

IMAGES OF THE BUILDING



A



B (up)



C



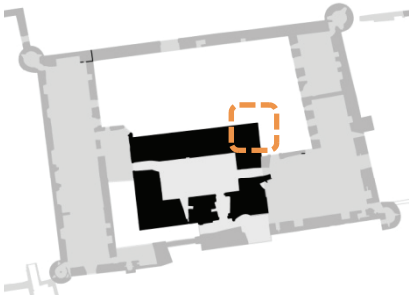
B (down)



CRAIGMILLAR CASTLE TOWER_EDINBURGH, CITY OF

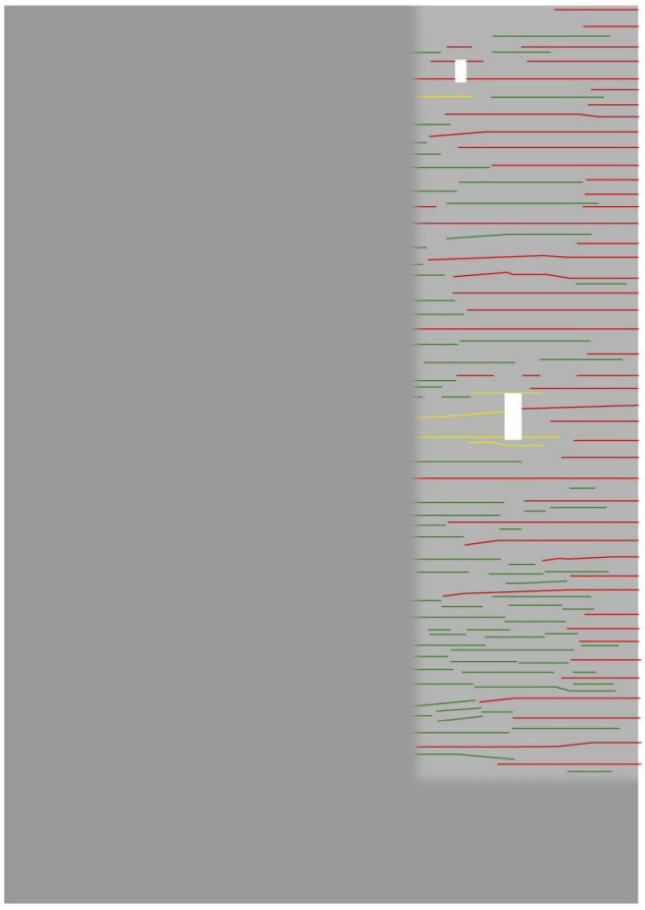
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

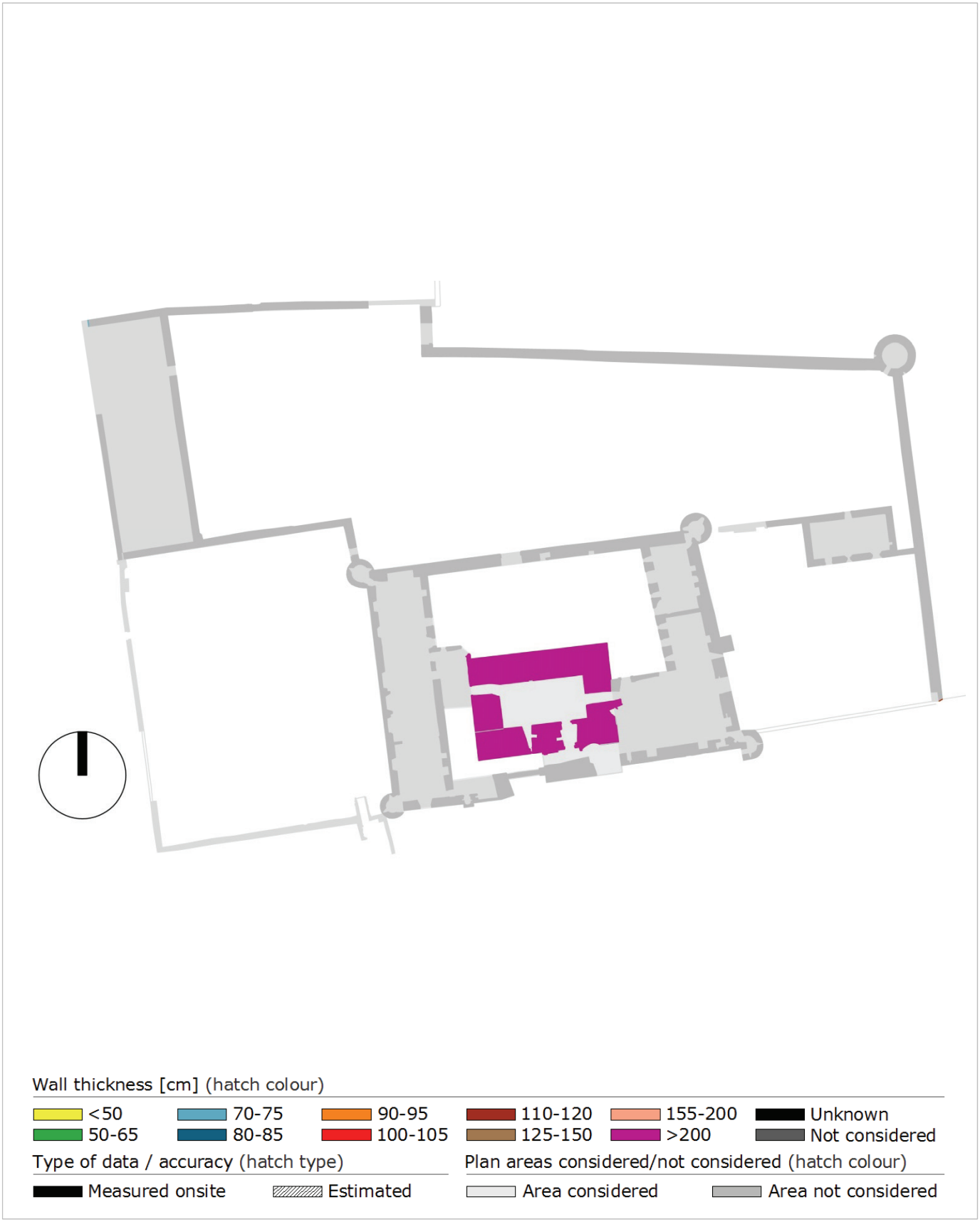


Courses determined by quoins
Courses determined by jambs
Other courses

CRAIGMILLAR CASTLE TOWER_EDINBURGH, CITY OF

WALL THICKNESSES

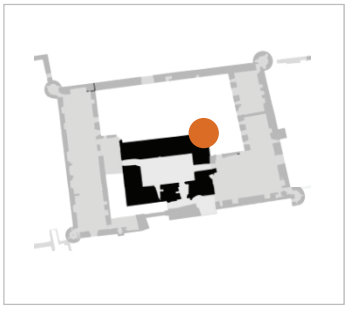
WALL THICKNESSES: GROUND FLOOR



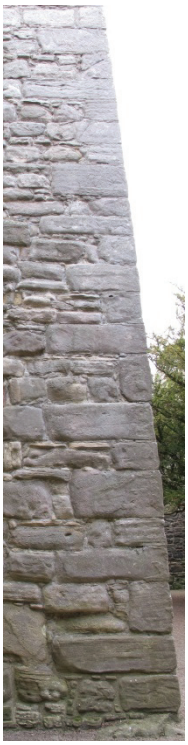
CRAIGMILLAR CASTLE TOWER_EDINBURGH, CITY OF

CORNERS

LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



CORNER -SIDE 1

CORNER –SIDE 2



CRAIGMILLAR CASTLE TOWER_EDINBURGH, CITY OF

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


IMG_9381_corrected_silhouette


IMG_9383_corrected_silhouette


IMG_9405_corrected_silhouette

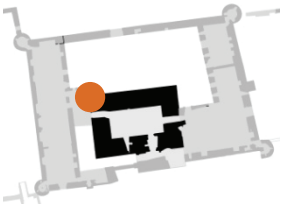

IMG_9417_corrected_silhouette


IMG_9419_corrected_silhouette


IMG_9425_corrected_silhouette

CRAIGMILLAR CASTLE TOWER_EDINBURGH, CITY OF

OTHER FEATURES







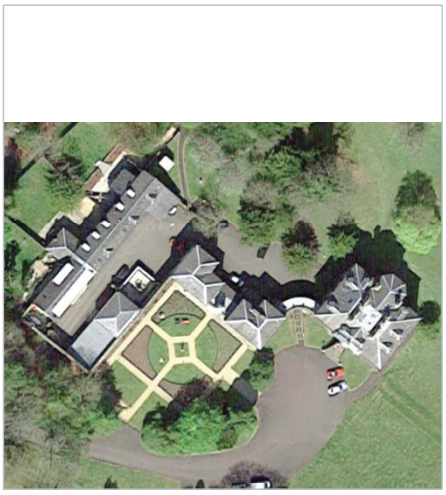
CUMBERNAULD HOUSE _ NORTH LANARKSHIRE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

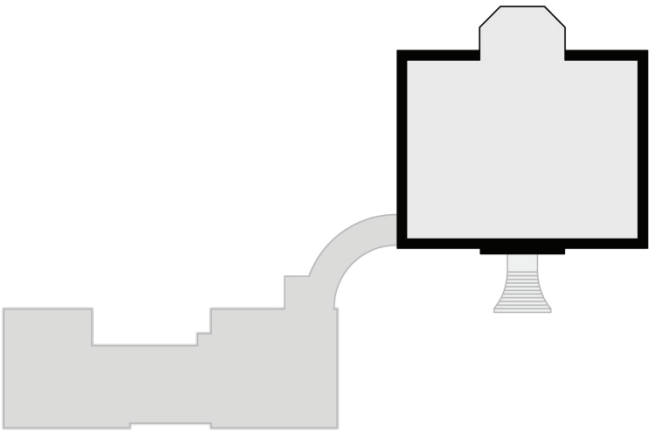


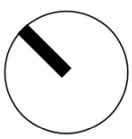
GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





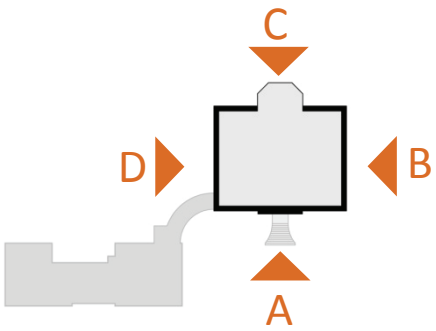
Area included in the research

Area not included in the research

Walls inspected

CUMBERNAULD HOUSE _ NORTH LANARKSHIRE

IMAGES OF THE BUILDING



A



B



C



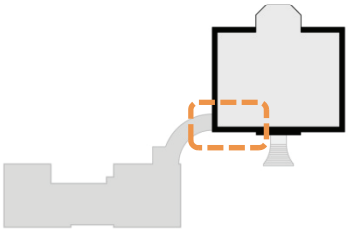
D



CUMBERNAULD HOUSE _ NORTH LANARKSHIRE

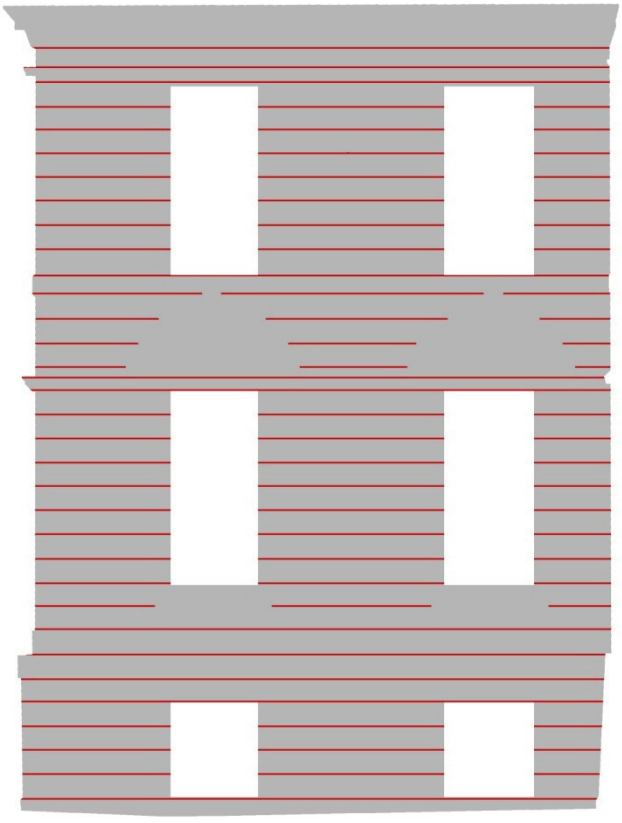
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

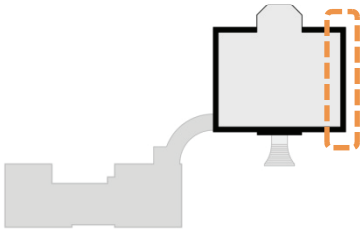


Courses determined by quoins
Courses determined by jambs
Other courses

CUMBERNAULD HOUSE _ NORTH LANARKSHIRE

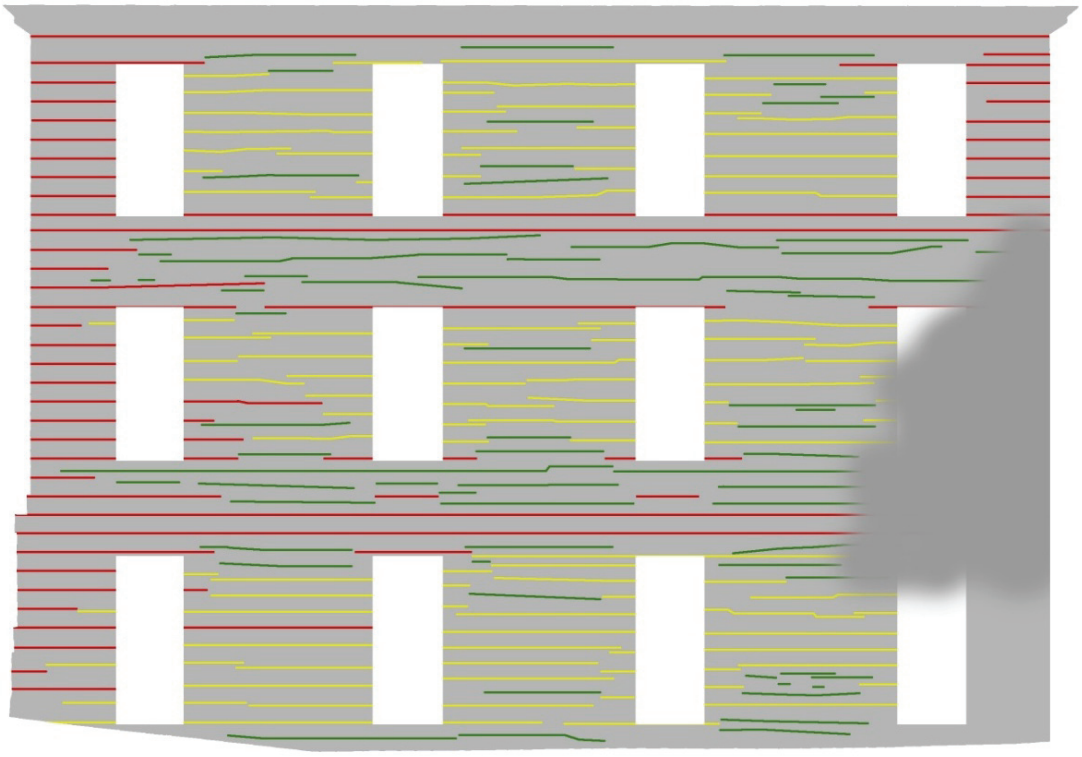
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

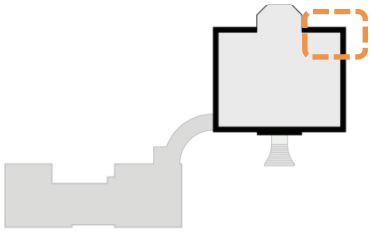


Courses determined by quoins
Courses determined by jambs
Other courses

CUMBERNAULD HOUSE _ NORTH LANARKSHIRE

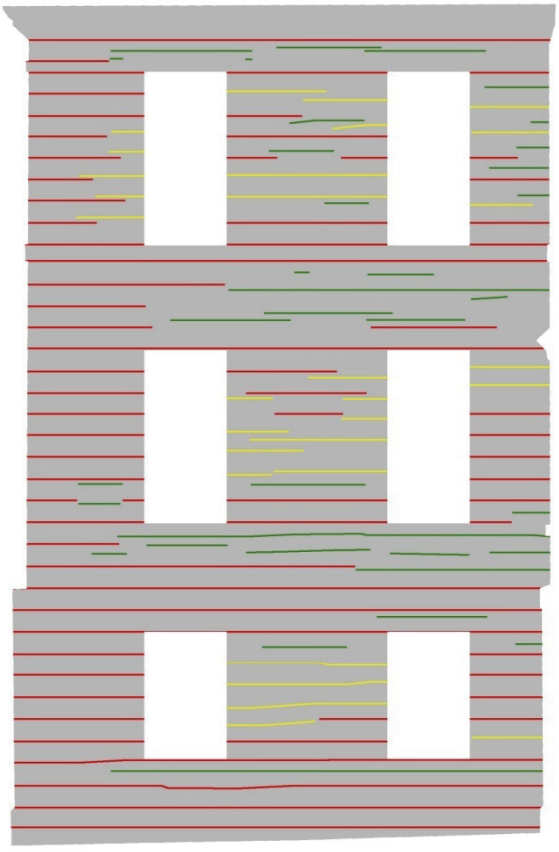
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

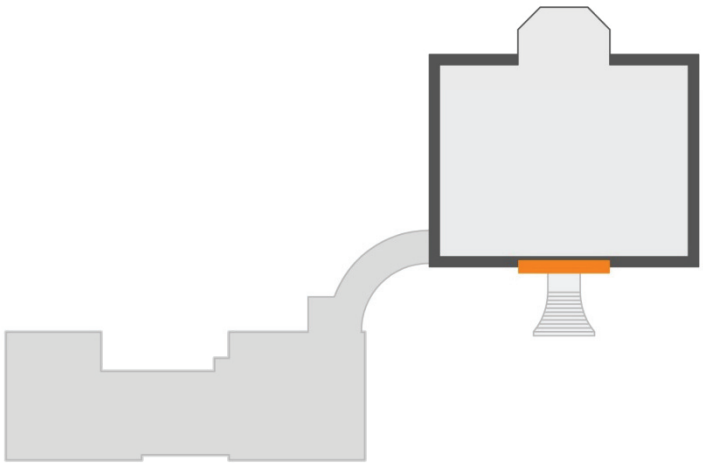


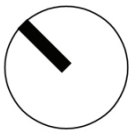
Courses determined by quoins
Courses determined by jambs
Other courses

CUMBERNAULD HOUSE _ NORTH LANARKSHIRE

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR





Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

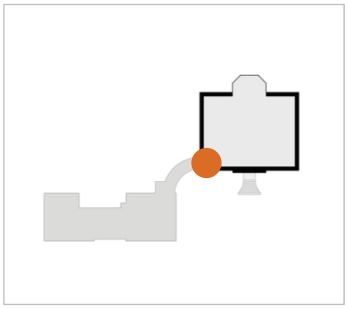
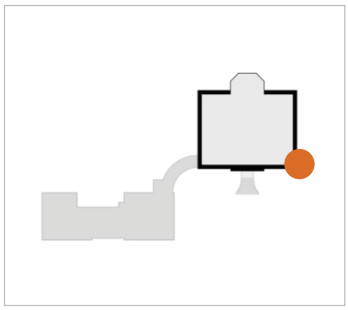
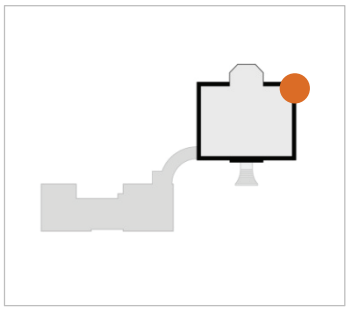
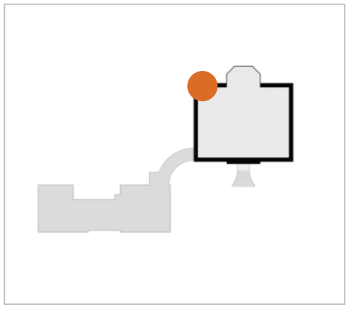
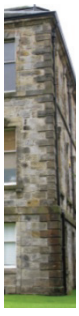
Measured onsite | Estimated

Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

CUMBERNAULD HOUSE _ NORTH LANARKSHIRE

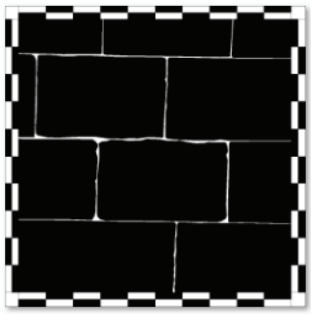
CORNERS

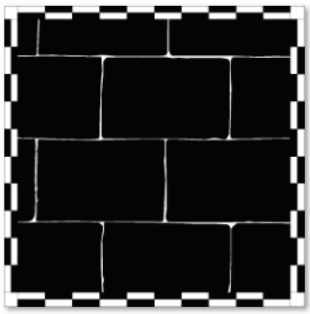
LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			

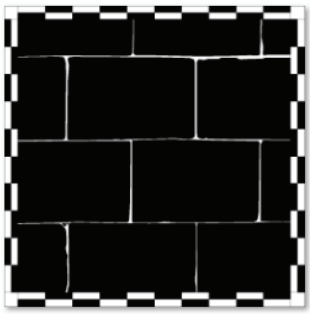
CUMBERNAULD HOUSE _ NORTH LANARKSHIRE

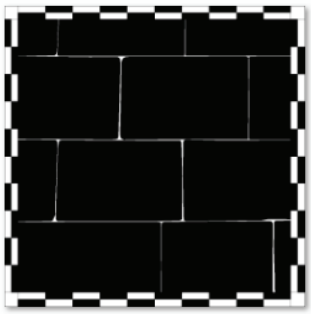
MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


IMG_7667_corrected_silhouette


IMG_7669_corrected_silhouette


IMG_7681_corrected_silhouette


IMG_7683_corrected_silhouette


IMG_7691_corrected_silhouette


IMG_7695_corrected_silhouette


IMG_7701_corrected_silhouette


IMG_7713_corrected_silhouette


IMG_7715_corrected_silhouette


IMG_7727_corrected_silhouette


IMG_7733_corrected_silhouette


IMG_7741_corrected_silhouette


IMG_7745_corrected_silhouette

DALKEITH PALACE _ MIDLOTHIAN

GENERAL INFORMATION

LOCATION



BUILDING PLAN

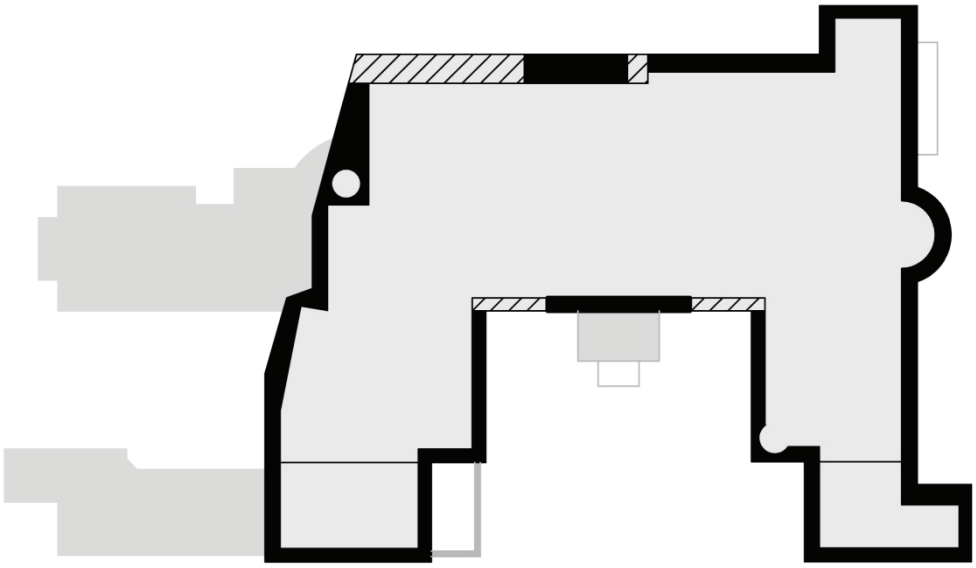


GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



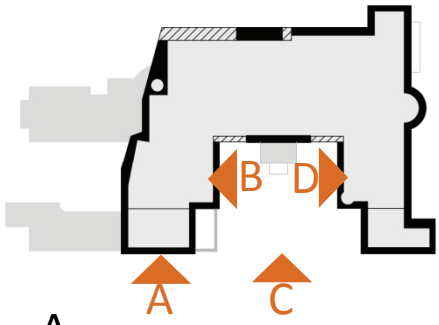
Area included in the research

Area not included in the research

Walls inspected

DALKEITH PALACE _ MIDLOTHIAN

IMAGES OF THE BUILDING



A



B



C

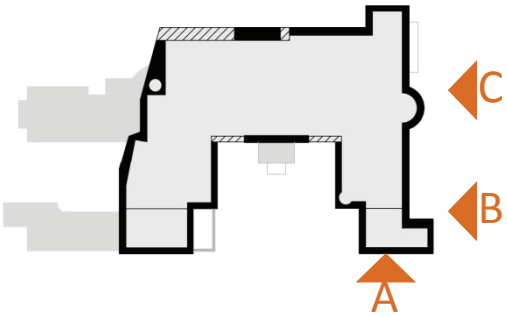


D



DALKEITH PALACE _ MIDLOTHIAN

IMAGES OF THE BUILDING



A



B

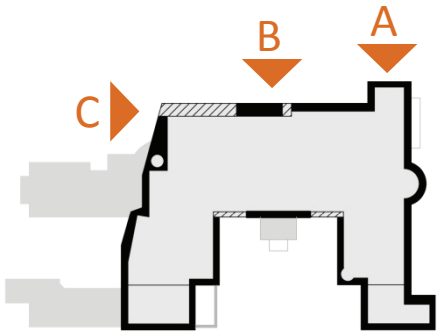


C



DALKEITH PALACE _ MIDLOTHIAN

IMAGES OF THE BUILDING



A



B



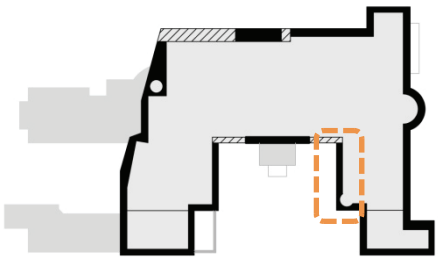
C



DALKEITH PALACE _ MIDLOTHIAN

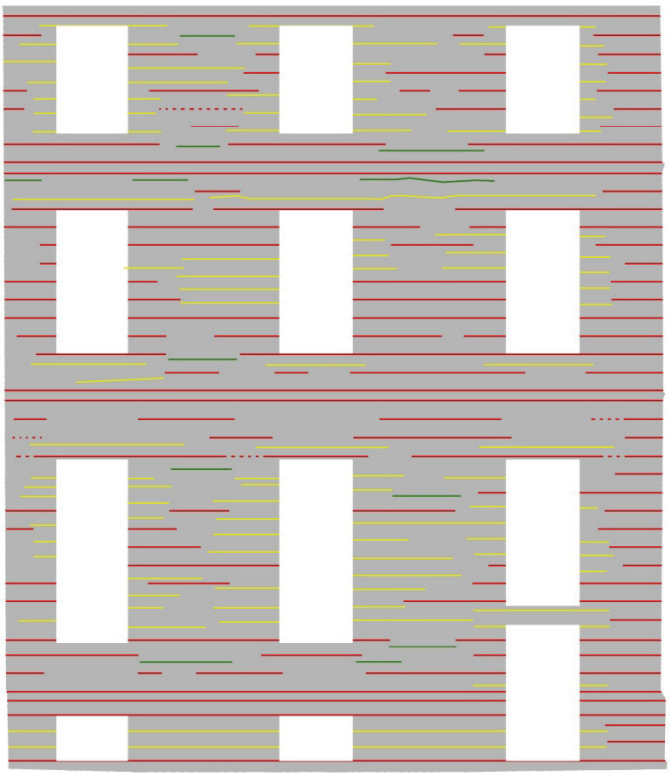
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

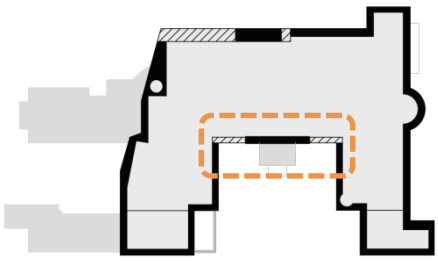


Courses determined by quoins
Courses determined by jambs
Other courses

DALKEITH PALACE _ MIDLOTHIAN

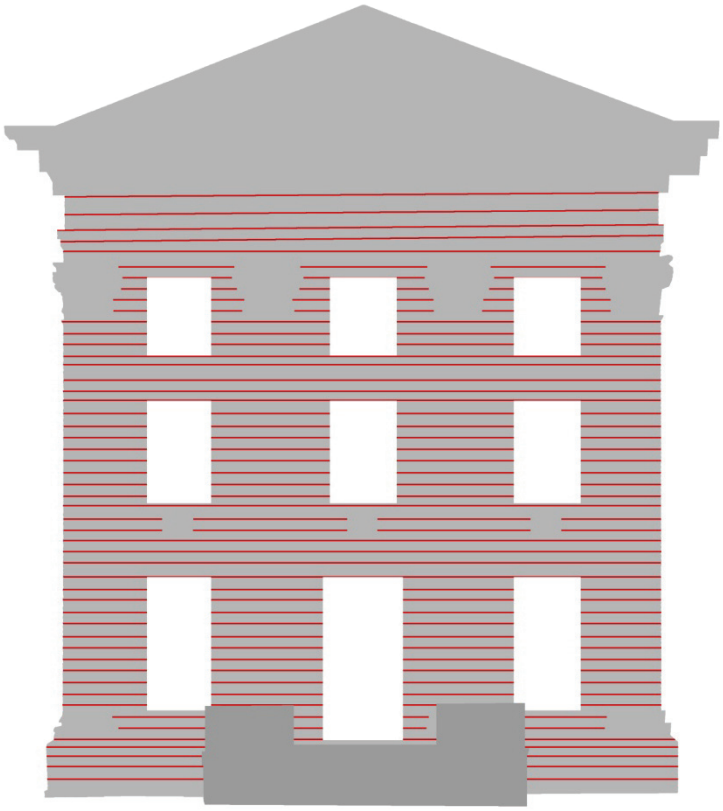
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

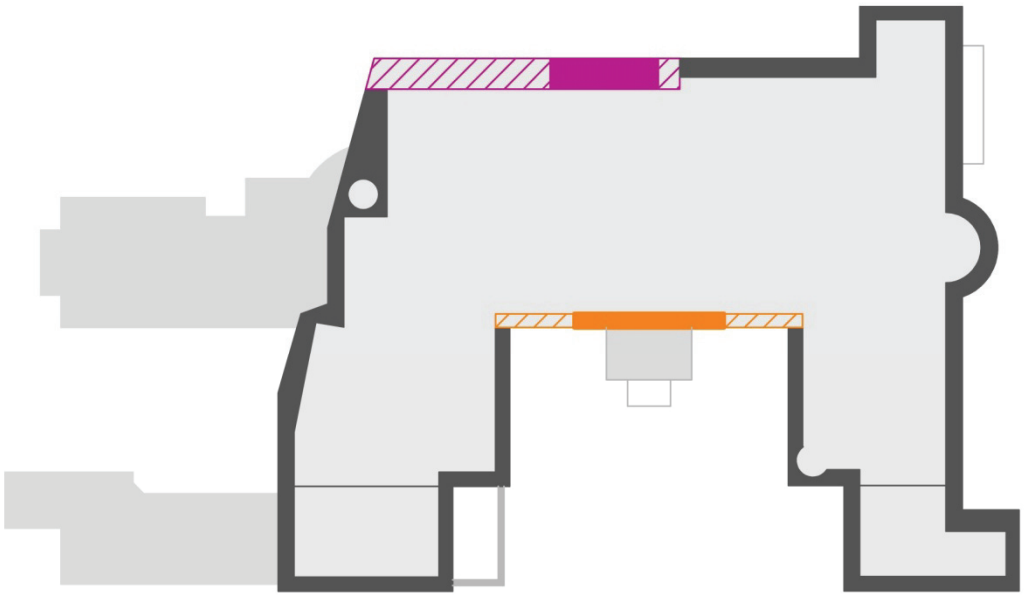


Courses determined by quoins
Courses determined by jambs
Other courses

DALKEITH PALACE _ MIDLOTHIAN

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

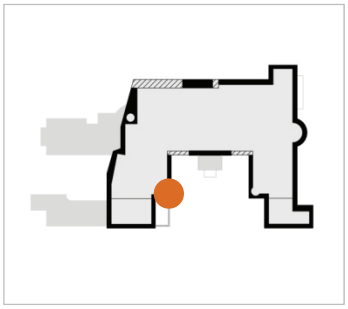
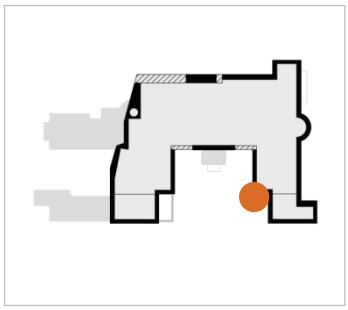
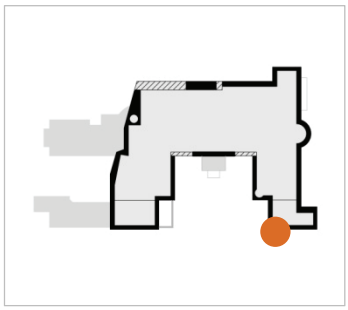
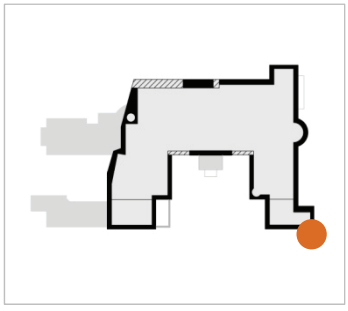
Measured onsite | Estimated

Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

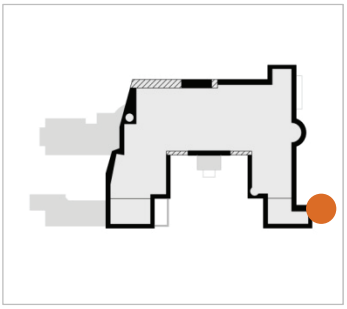
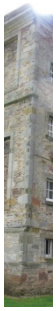
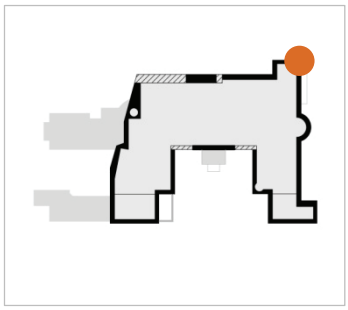
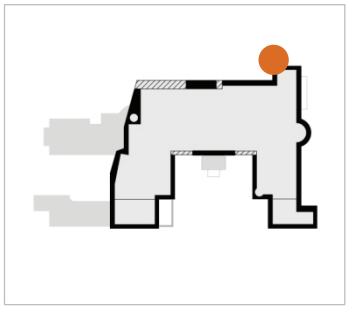
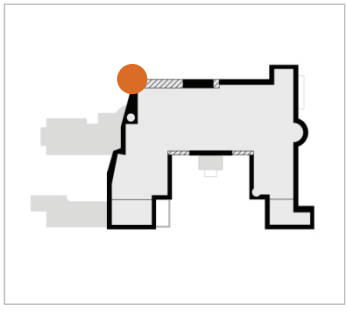
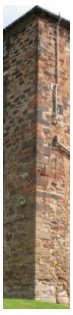
DALKEITH PALACE _ MIDLOTHIAN

CORNERS

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			

DALKEITH PALACE _ MIDLOTHIAN

CORNERS

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			

DALKEITH PALACE _ MIDLOTHIAN

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


IMG_8155_corrected_silhouette


IMG_8159_corrected_silhouette


IMG_8161_corrected_silhouette


IMG_8175_corrected_silhouette


IMG_8179_corrected_silhouette


IMG_8187_corrected_silhouette


IMG_8195_corrected_silhouette


IMG_8197_corrected_silhouette

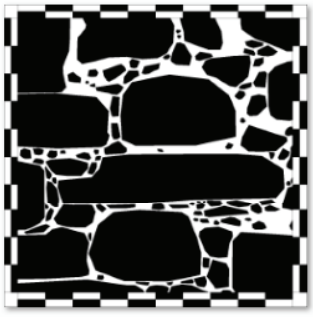

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IMG_8219_corrected_silhouette


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IMG_8235_corrected_silhouette


IMG_8239_corrected_silhouette


IMG_8245_corrected_silhouette

DALQUHARRAN CASTLE_SOUTH AYRSHIRE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

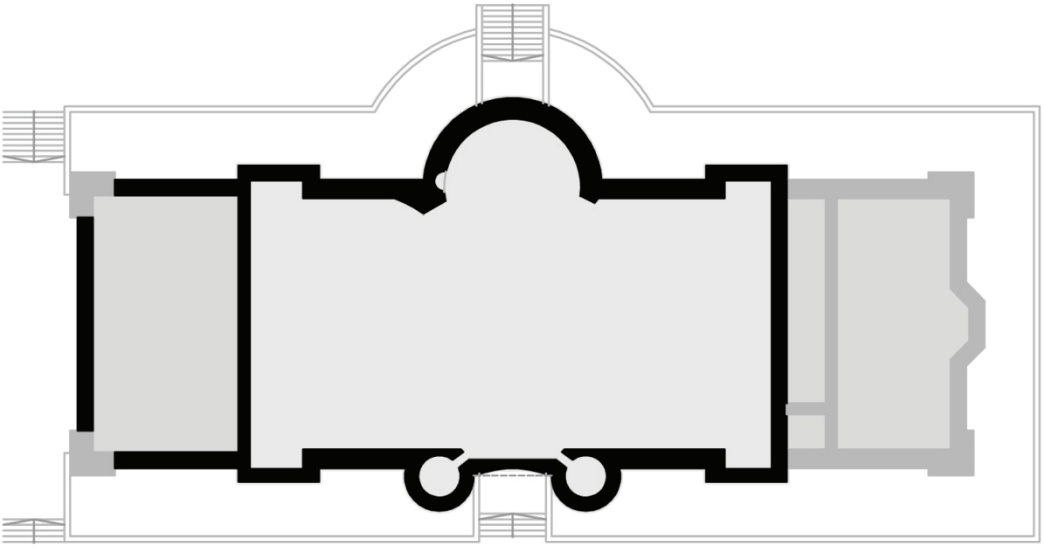


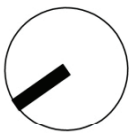
Image form Google maps 2017

GENERAL IMAGE



IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





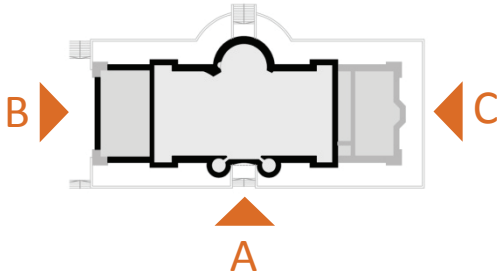
Area included in the research

Area not included in the research

Walls inspected

DALQUHARRAN CASTLE_SOUTH AYRSHIRE

IMAGES OF THE BUILDING



A



B



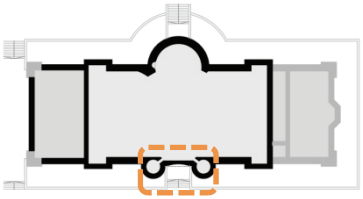
C



DALQUHARRAN CASTLE_SOUTH AYRSHIRE

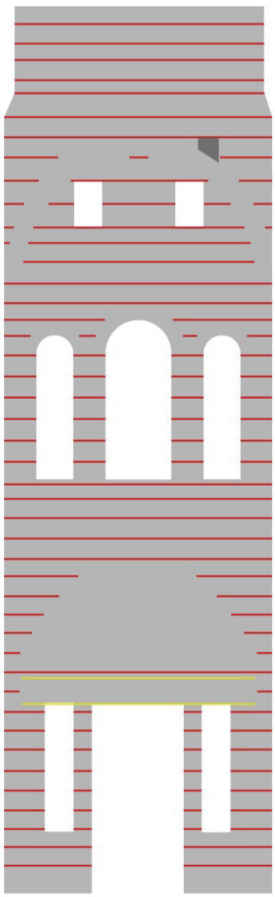
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

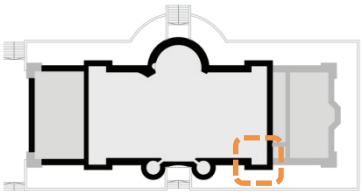


Courses determined by quoins
Courses determined by jambs
Other courses

DALQUHARRAN CASTLE_SOUTH AYRSHIRE

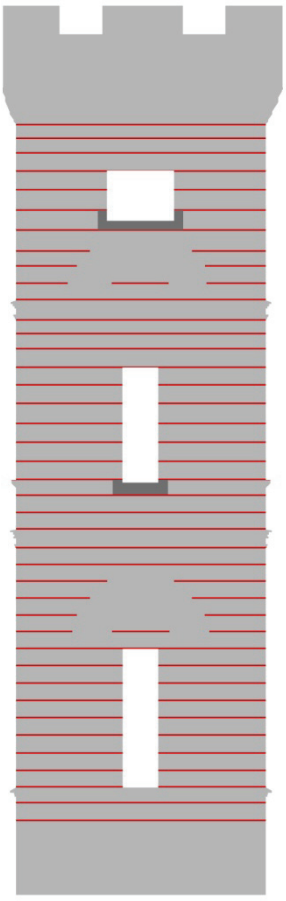
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

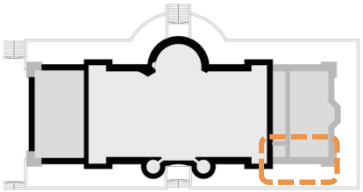


Courses determined by quoins
Courses determined by jambs
Other courses

DALQUHARRAN CASTLE_SOUTH AYRSHIRE

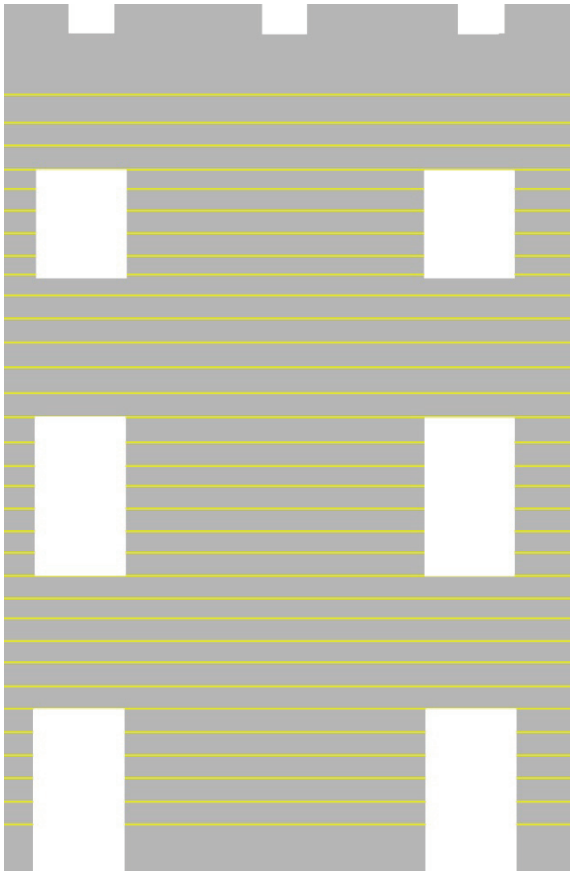
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

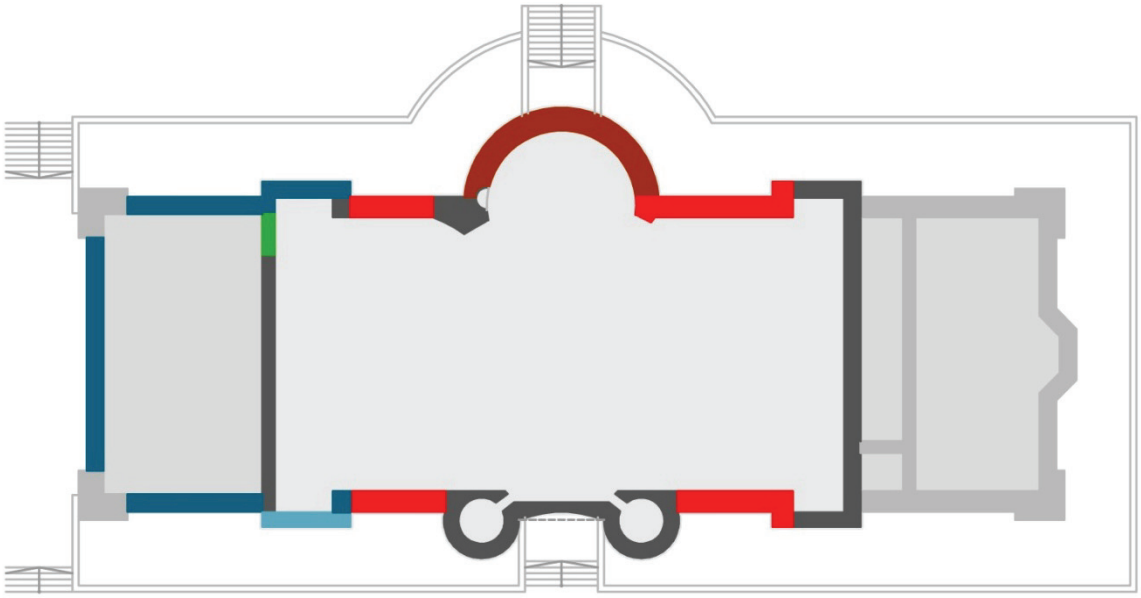


Courses determined by quoins
Courses determined by jambs
Other courses

DALQUHARRAN CASTLE_SOUTH AYRSHIRE

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

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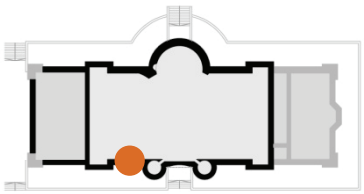
Measured onsite | Estimated

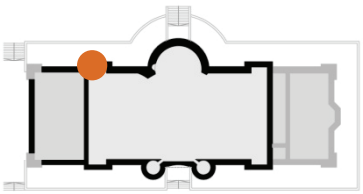
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

DALQUHARRAN CASTLE_SOUTH AYRSHIRE

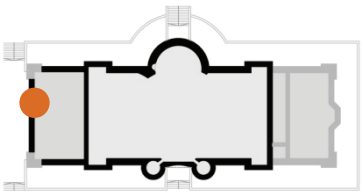
WALL SECTIONS









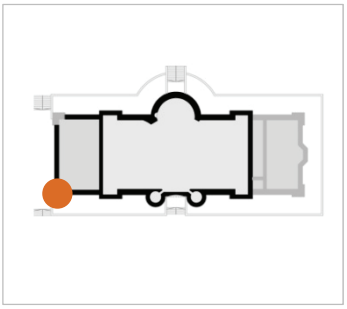




DALQUHARRAN CASTLE_SOUTH AYRSHIRE

CORNERS

LOCATION



CORNER

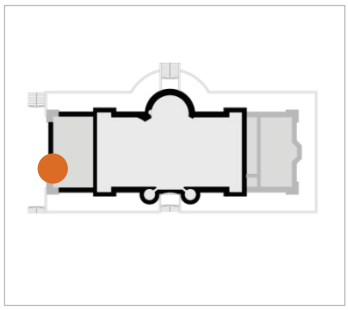


CORNER -SIDE 1



CORNER –SIDE 2

LOCATION



CORNER



CORNER -SIDE 1

CORNER –SIDE 2



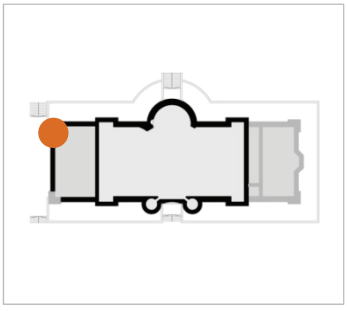
LOCATION

CORNER -SIDE 1

CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1

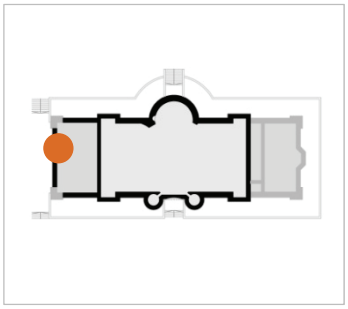
CORNER –SIDE 2



DALQUHARRAN CASTLE_SOUTH AYRSHIRE

CORNERS

LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2

CORNER -SIDE 1

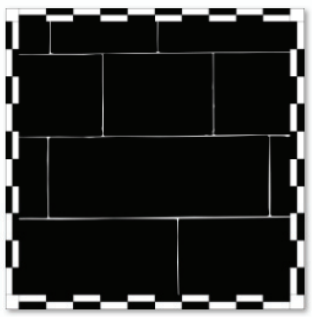


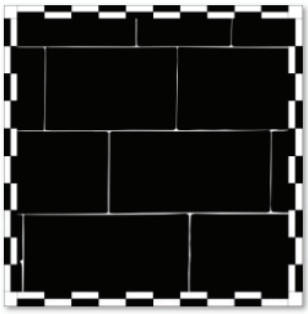
CORNER –SIDE 2

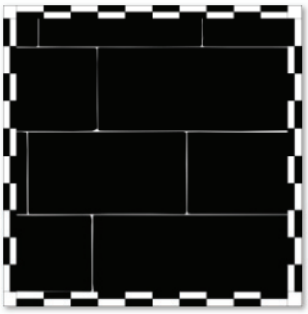
DALQUHARRAN CASTLE_SOUTH AYRSHIRE

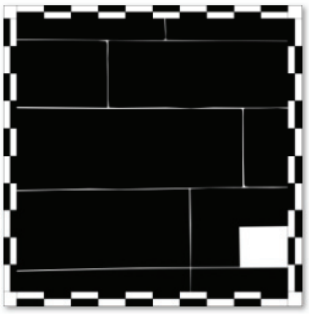
MASONRY PATERNS: 1x1 FRAMES

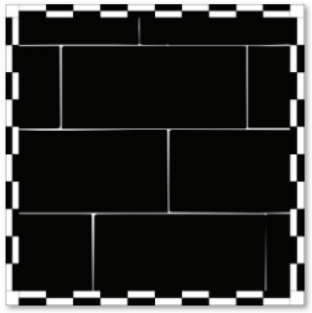
WALL CENTRAL PORTION

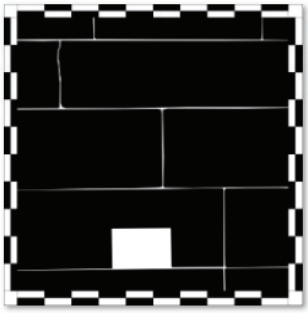

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IMG_7973_corrected_silhouette


IMG_7979_corrected_silhouette


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IMG_7990_corrected_silhouette


IMG_8012_corrected_silhouette


IMG_8016_corrected_silhouette


IMG_8019_corrected_silhouette


IMG_8021_corrected_silhouette


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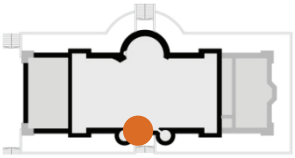

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IMG_8043_corrected_silhouette


IMG_8049_corrected_silhouette

DALQUHARRAN CASTLE_SOUTH AYRSHIRE

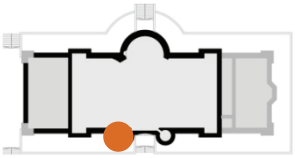
OTHER FEATURES





DALQUHARRAN CASTLE_SOUTH AYRSHIRE

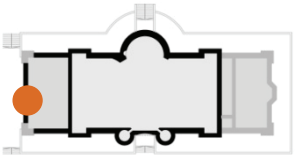
OTHER FEATURES





DALQUHARRAN CASTLE_SOUTH AYRSHIRE

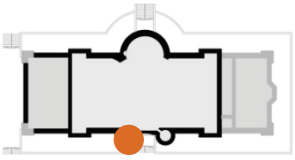
OTHER FEATURES





DALQUHARRAN CASTLE_SOUTH AYRSHIRE

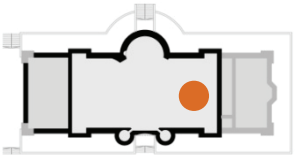
OTHER FEATURES





DALQUHARRAN CASTLE_SOUTH AYRSHIRE

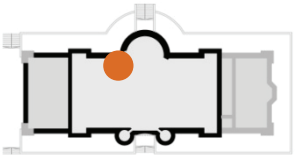
OTHER FEATURES





DALQUHARRAN CASTLE_SOUTH AYRSHIRE

OTHER FEATURES





DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

GENERAL INFORMATION

LOCATION



BUILDING PLAN

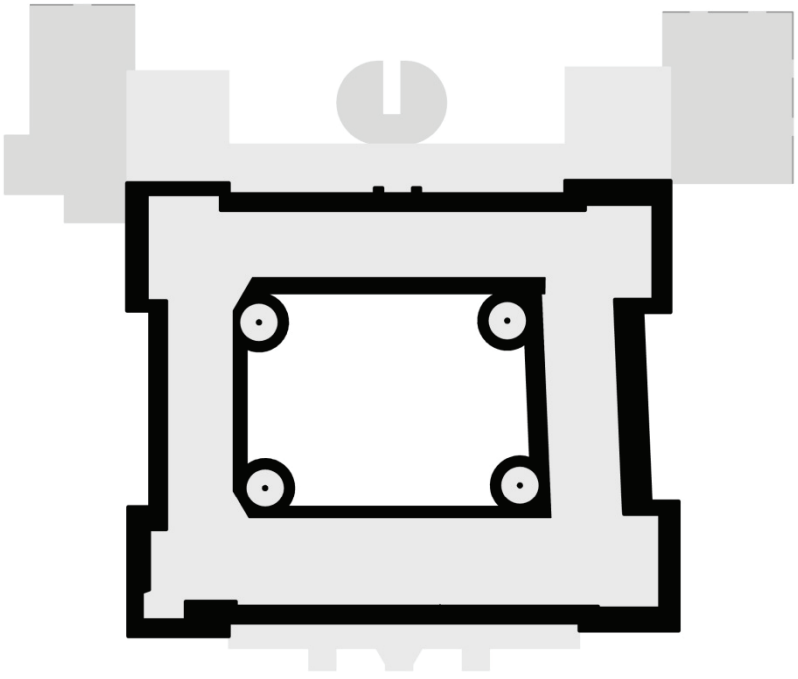


Image form Google maps 2017

GENERAL IMAGE



IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



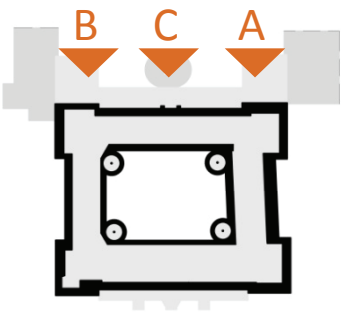
Area included in the research

Area not included in the research

Walls inspected

DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

IMAGES OF THE BUILDING



A



B

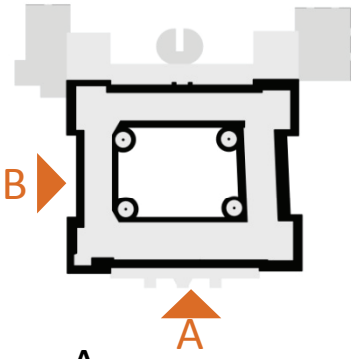


C



DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

IMAGES OF THE BUILDING



A

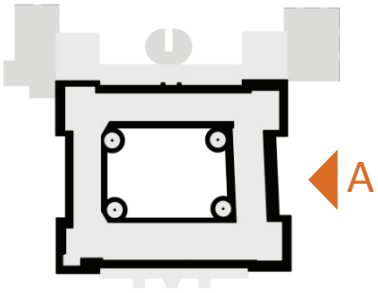


B



DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

IMAGES OF THE BUILDING

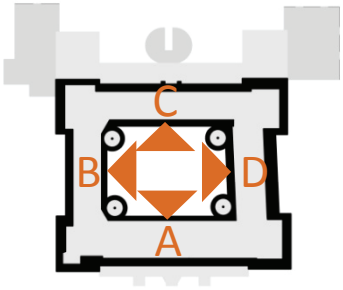


A



DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

IMAGES OF THE BUILDING



A



B



C



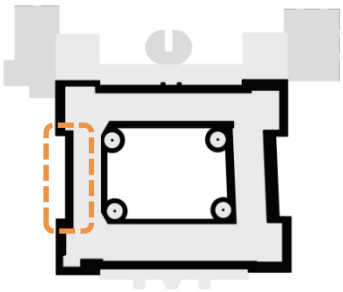
D



DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

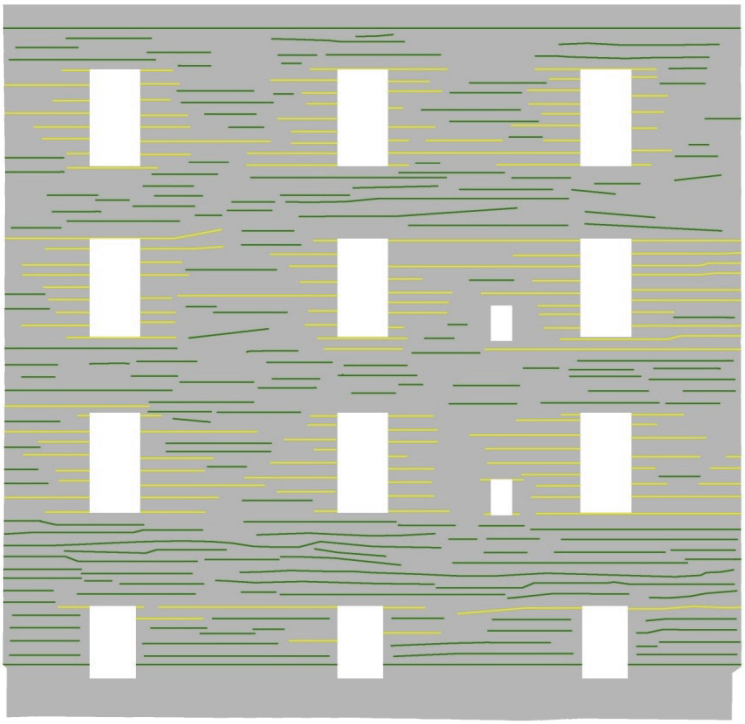
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

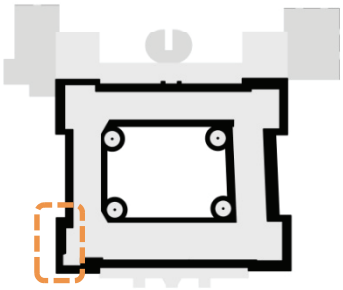


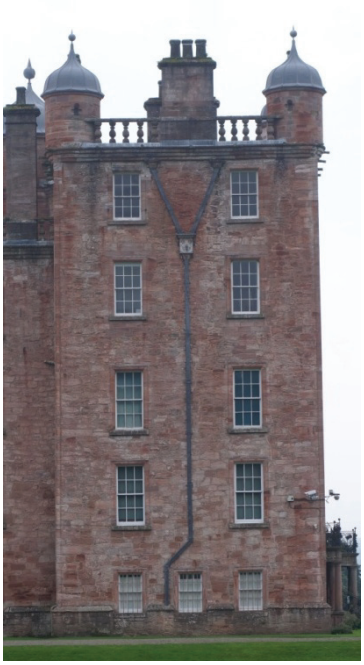
Courses determined by quoins
Courses determined by jambs
Other courses

DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

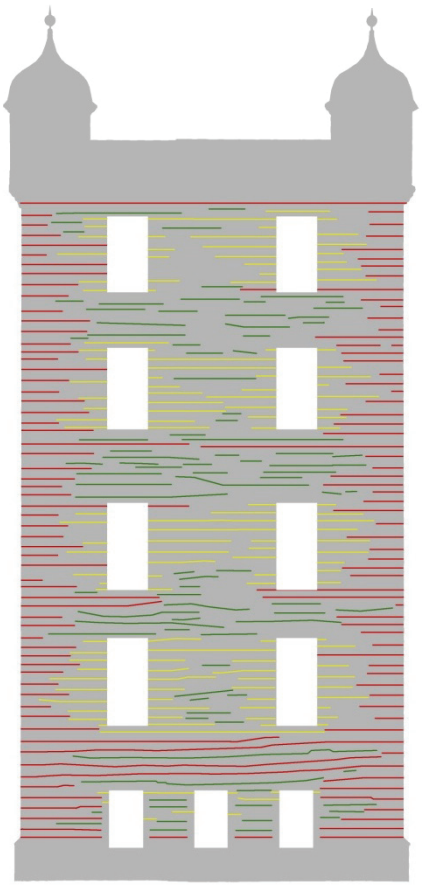
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

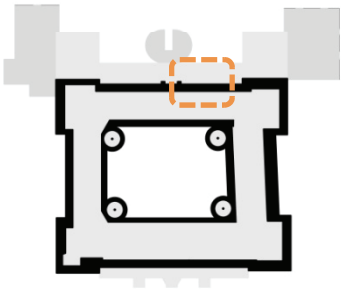


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Courses determined by jambs
Other courses

DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

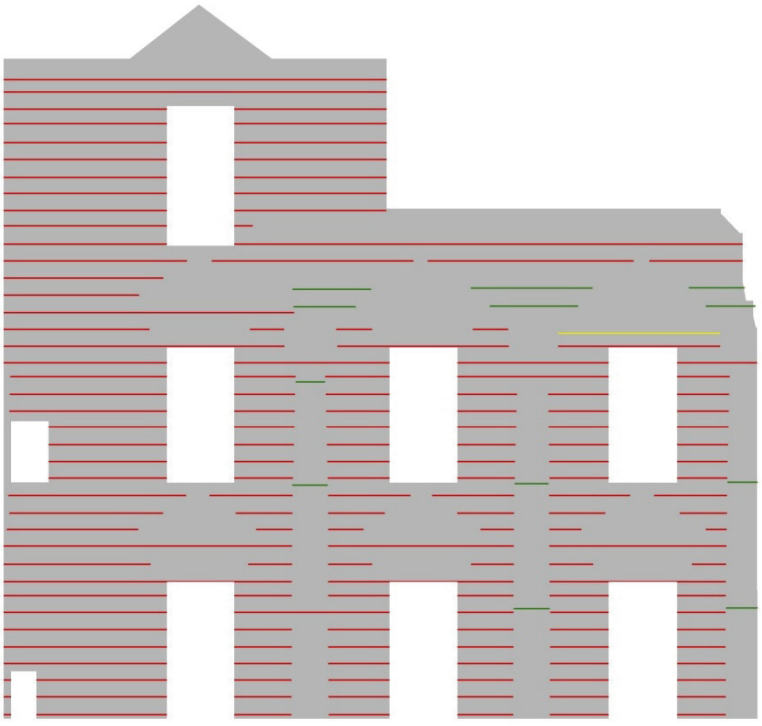
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

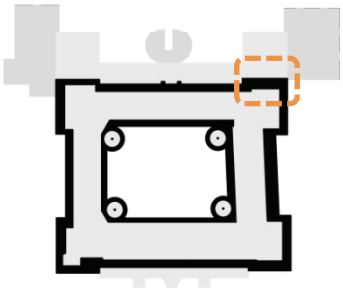


Courses determined by quoins
Courses determined by jambs
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DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

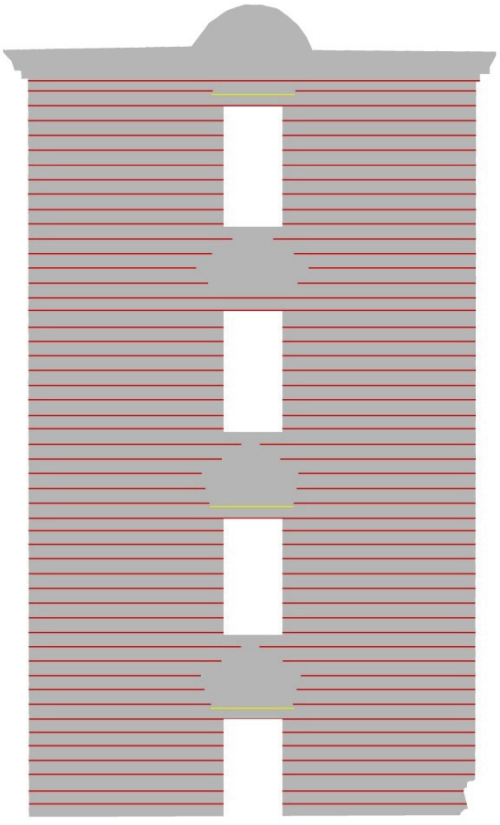
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

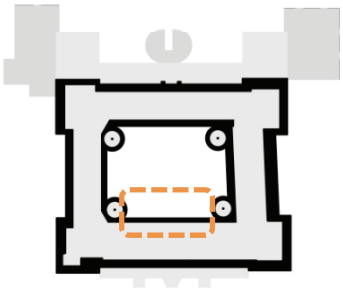


Courses determined by quoins
Courses determined by jambs
Other courses

DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

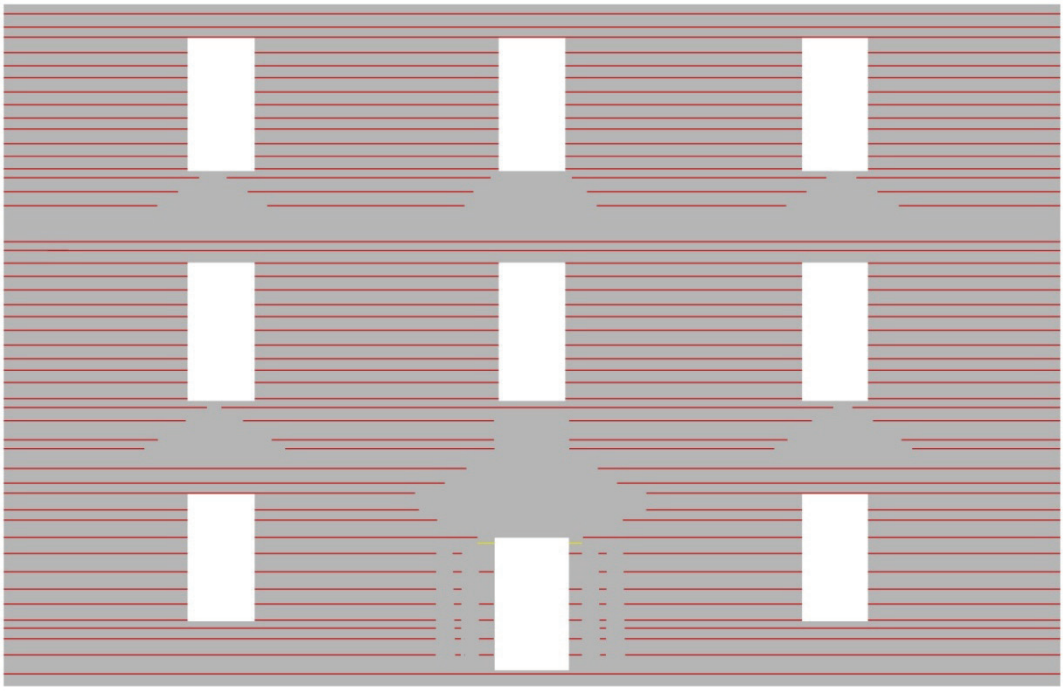
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

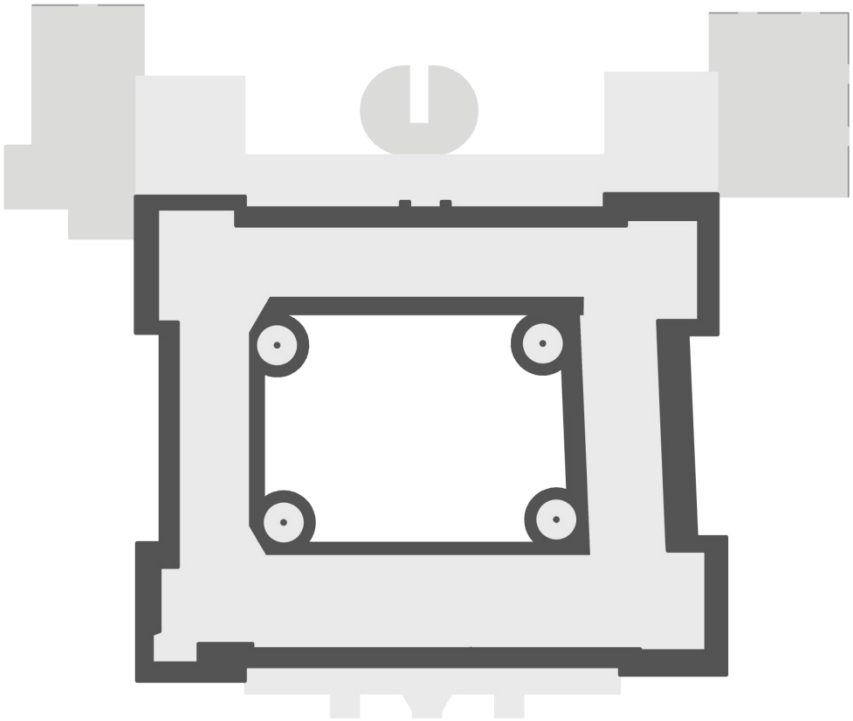


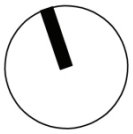
Courses determined by quoins
Courses determined by jambs
Other courses

DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR





Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

Measured onsite | Estimated

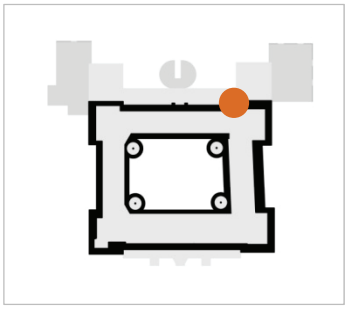
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

CORNERS

LOCATION



CORNER

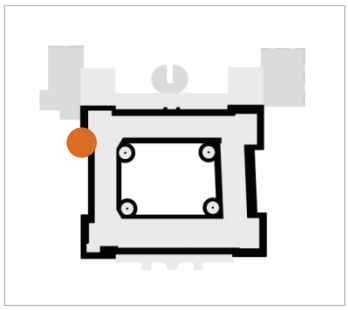


CORNER -SIDE 1



CORNER –SIDE 2

LOCATION



CORNER



CORNER -SIDE 1

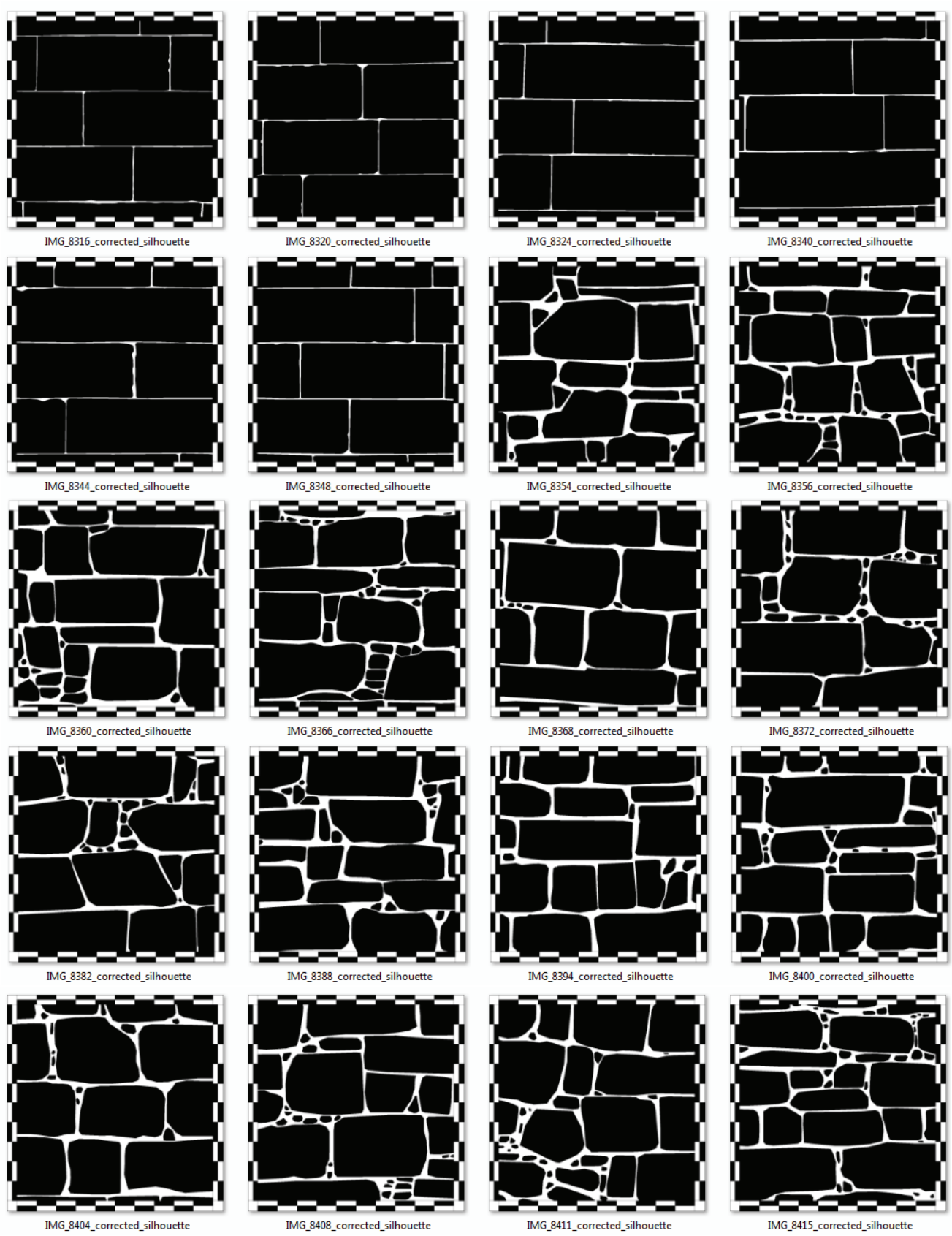
CORNER –SIDE 2



DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


IMG_8419_corrected_silhouette


IMG_8421_corrected_silhouette


IMG_8427_corrected_silhouette


IMG_8431_corrected_silhouette


IMG_8433_corrected_silhouette


IMG_8441_corrected_silhouette


IMG_8443_corrected_silhouette


IMG_8445_corrected_silhouette


IMG_8449_corrected_silhouette


IMG_8455_corrected_silhouette


IMG_8461_corrected_silhouette

DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

OTHER FEATURES





DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

OTHER FEATURES







DRUMLANRIG CASTLE _ DUMFRIES AND GALLOWAY

OTHER FEATURES





DUN HOUSE (HOUSE OF DUN) _ ANGUS

GENERAL INFORMATION

LOCATION



BUILDING PLAN

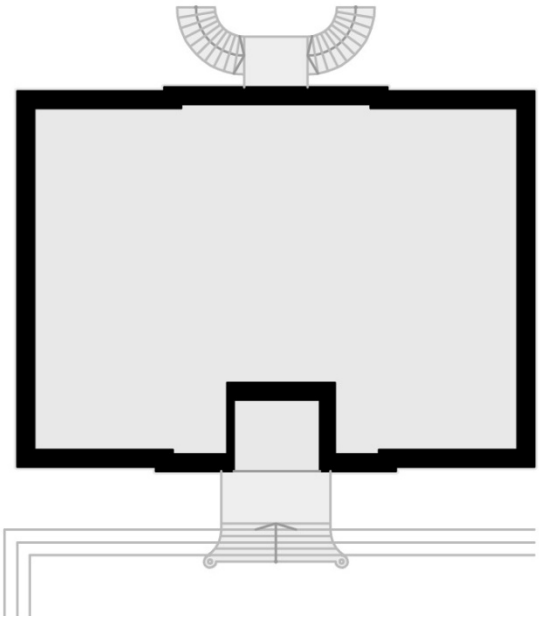


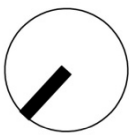
GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





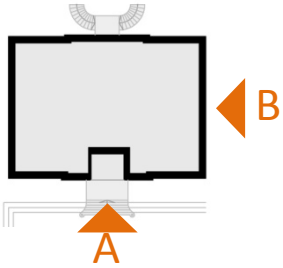
Area included in the research

Area not included in the research

Walls inspected

DUN HOUSE (HOUSE OF DUN) _ ANGUS

IMAGES OF THE BUILDING



A

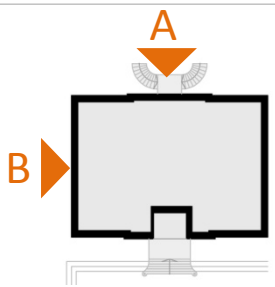


B



DUN HOUSE (HOUSE OF DUN) _ ANGUS

IMAGES OF THE BUILDING



A



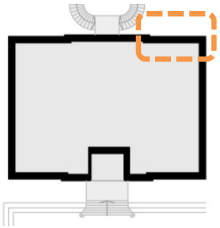
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DUN HOUSE (HOUSE OF DUN) _ ANGUS

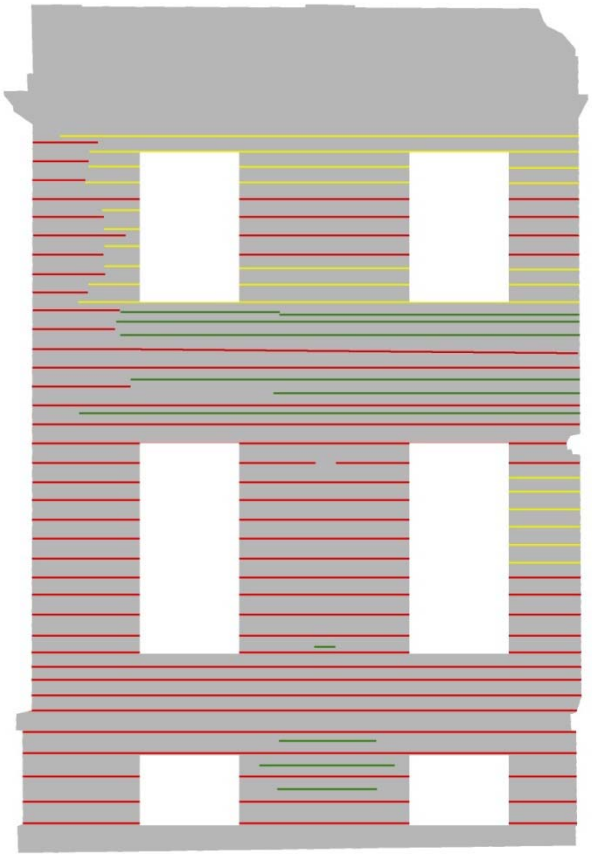
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

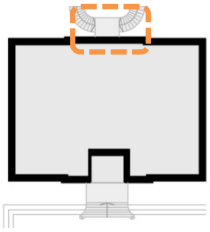


Courses determined by quoins
Courses determined by jambs
Other courses

DUN HOUSE (HOUSE OF DUN) _ ANGUS

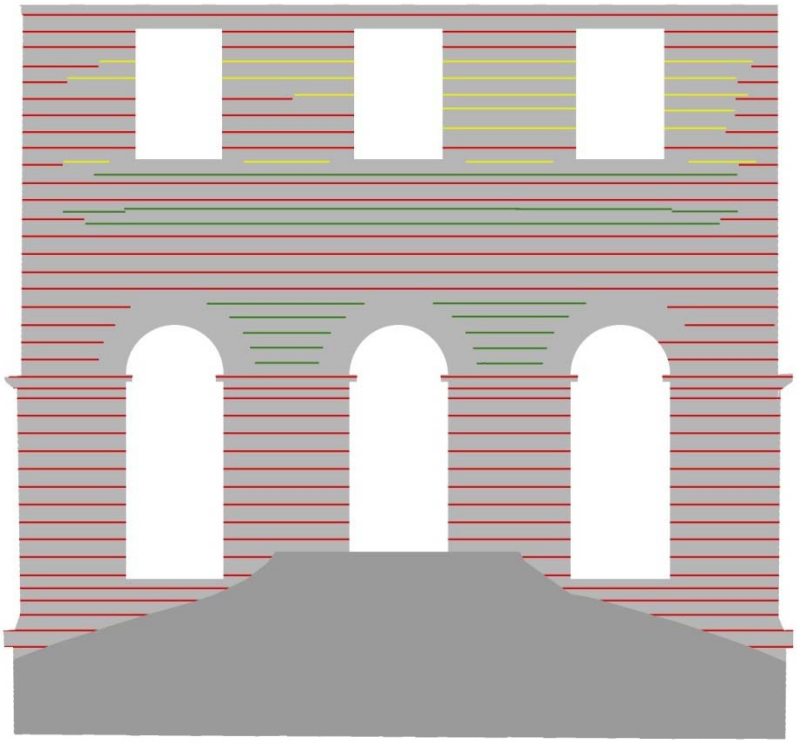
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





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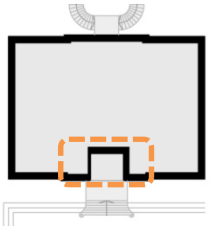


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DUN HOUSE (HOUSE OF DUN) _ ANGUS

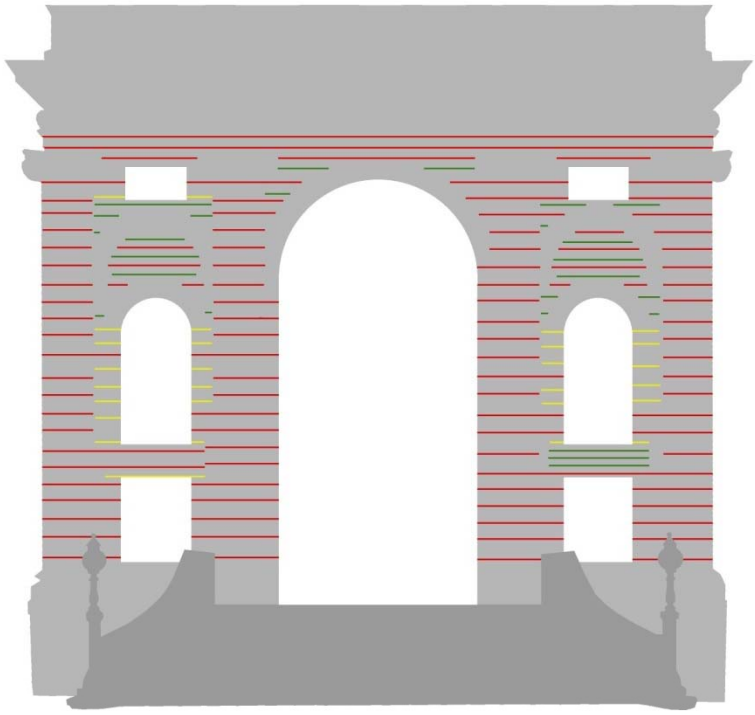
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

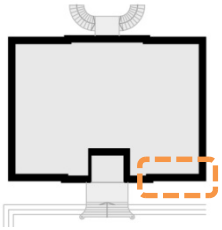


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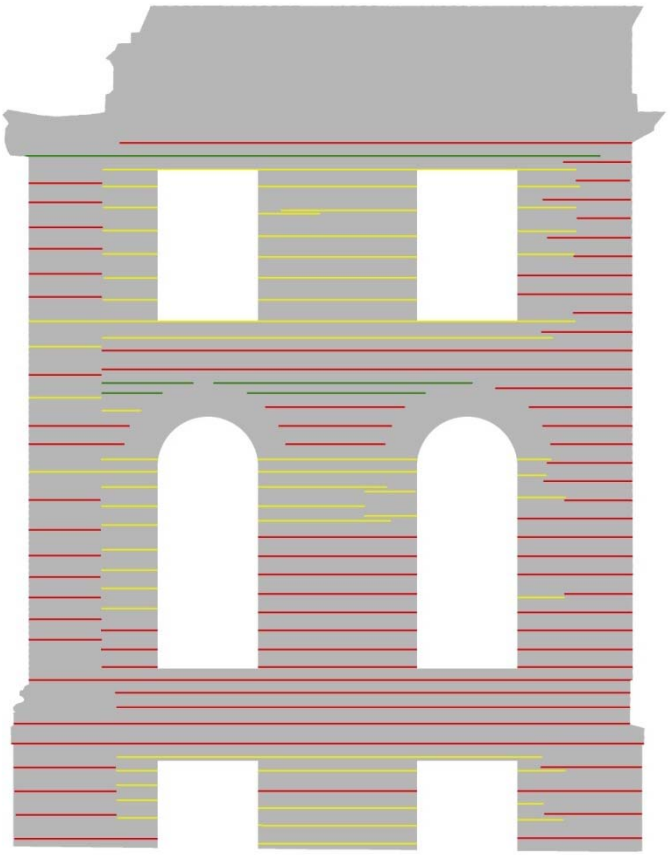
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

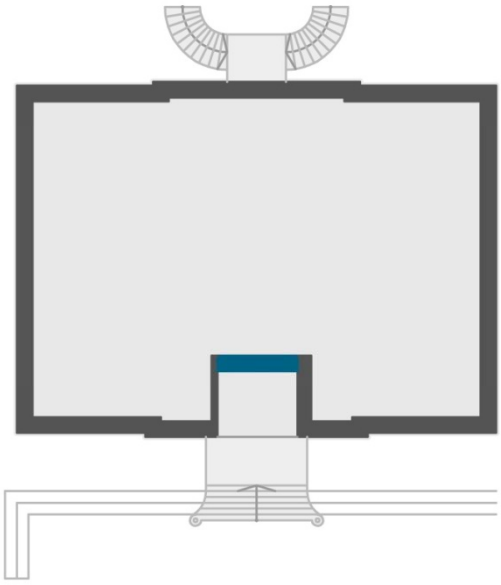


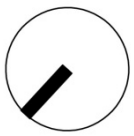
Courses determined by quoins
Courses determined by jambs
Other courses

DUN HOUSE (HOUSE OF DUN) _ ANGUS

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR





Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
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Type of data / accuracy (hatch type)

Measured onsite | Estimated

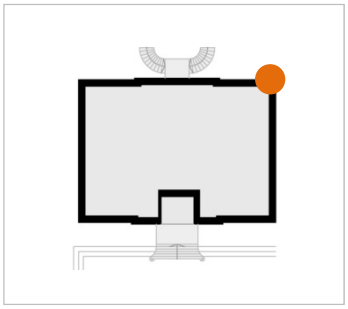
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

DUN HOUSE (HOUSE OF DUN) _ ANGUS

CORNERS

LOCATION



CORNER



CORNER -SIDE 1

CORNER –SIDE 2

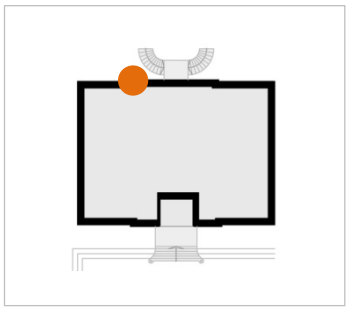


CORNER -SIDE 1

CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2

CORNER -SIDE 1

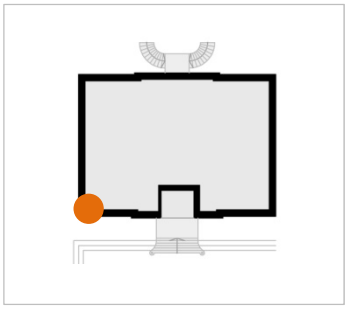


CORNER –SIDE 2

DUN HOUSE (HOUSE OF DUN) _ ANGUS

CORNERS

LOCATION



CORNER

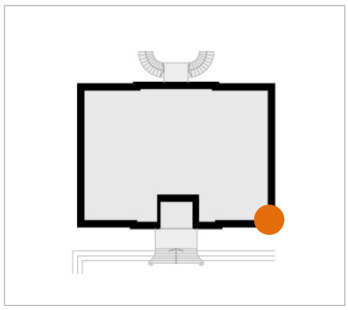


CORNER -SIDE 1

CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1

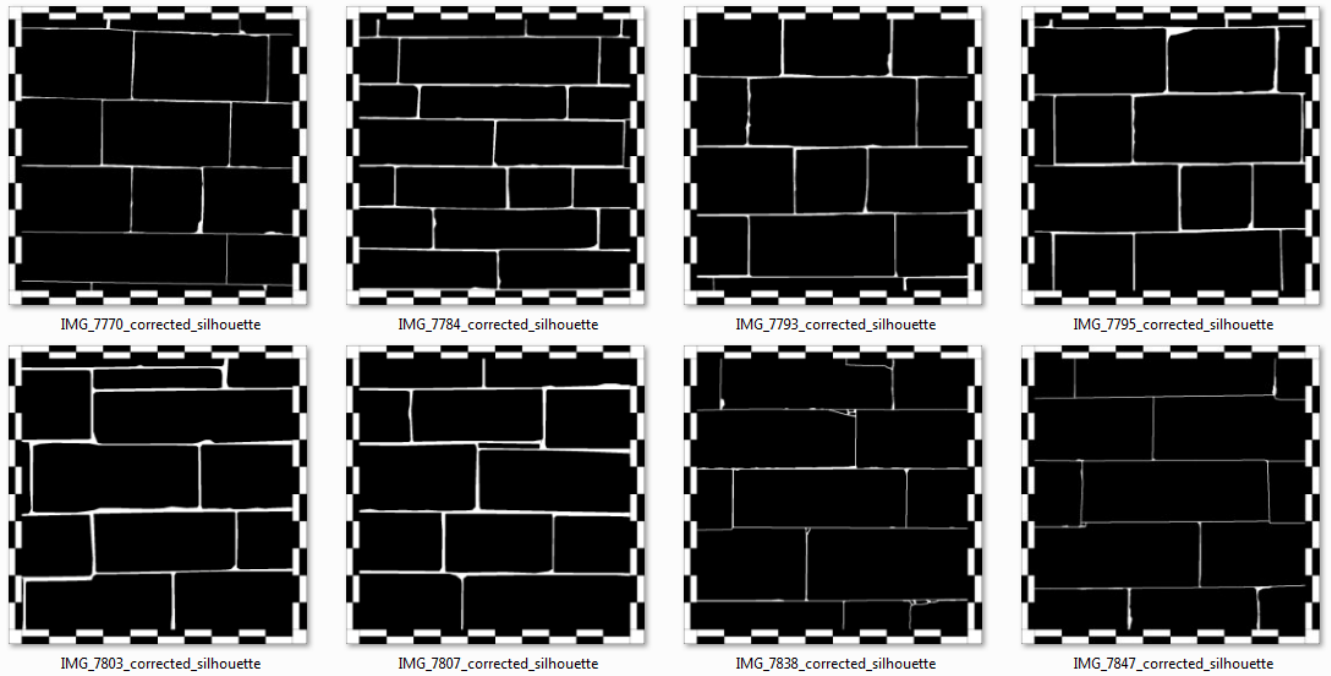


CORNER –SIDE 2

DUN HOUSE (HOUSE OF DUN) _ ANGUS

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



DUN HOUSE (HOUSE OF DUN) _ ANGUS

OTHER FEATURES



DUN HOUSE (HOUSE OF DUN) _ ANGUS

OTHER FEATURES



DUN HOUSE (HOUSE OF DUN) _ ANGUS

OTHER FEATURES



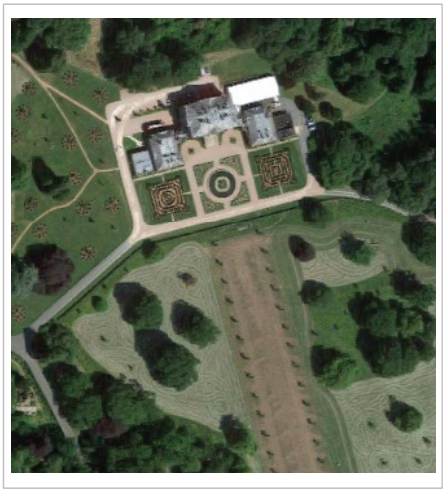
DUNFRIES HOUSE _ EAST AYRSHIRE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

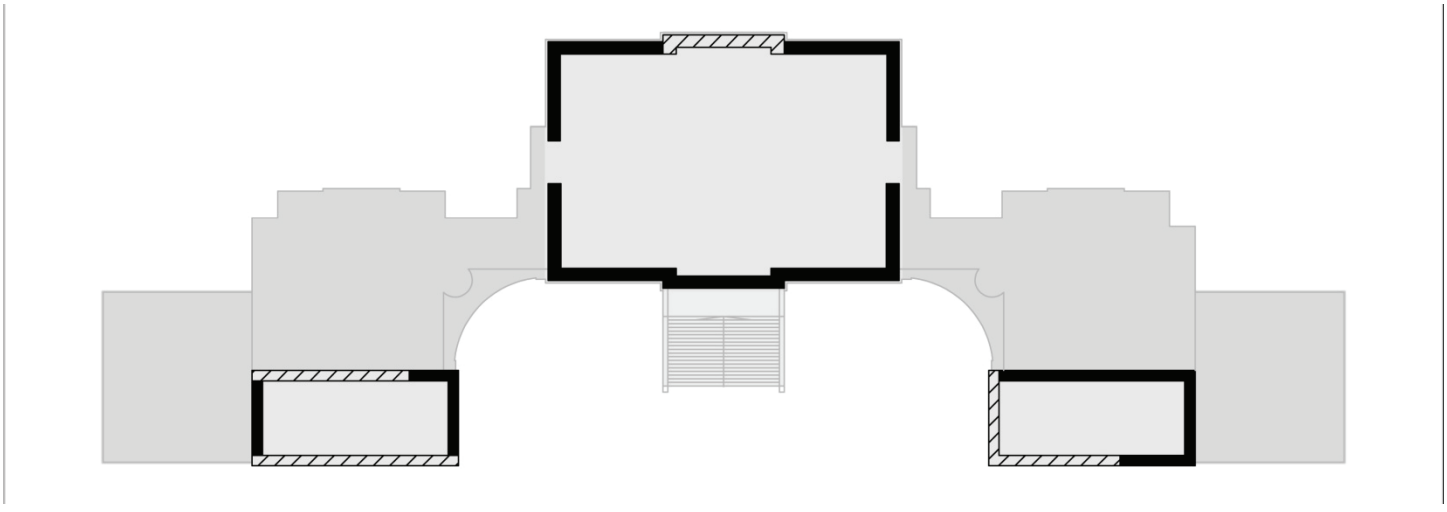


GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



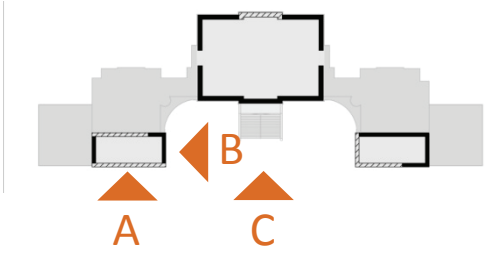
Area included in the research

Area not included in the research

Walls inspected

DUNFRIES HOUSE _ EAST AYRSHIRE

IMAGES OF THE BUILDING



A



B

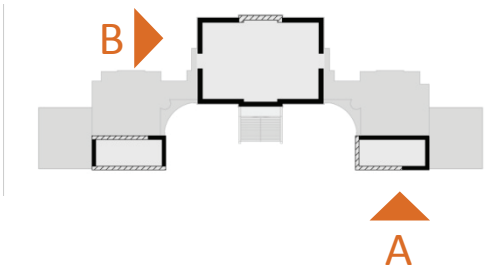


C



DUNFRIES HOUSE _ EAST AYRSHIRE

IMAGES OF THE BUILDING



A

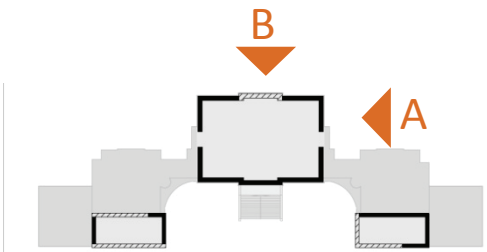


B



DUNFRIES HOUSE _ EAST AYRSHIRE

IMAGES OF THE BUILDING



A



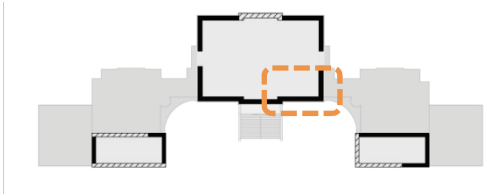
B



DUNFRIES HOUSE _ EAST AYRSHIRE

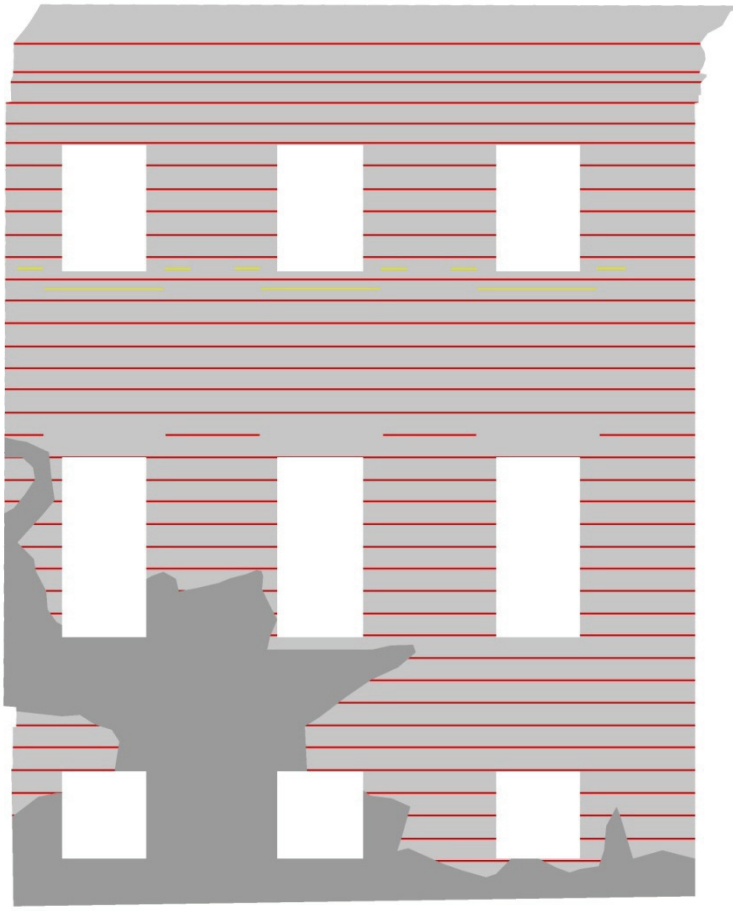
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

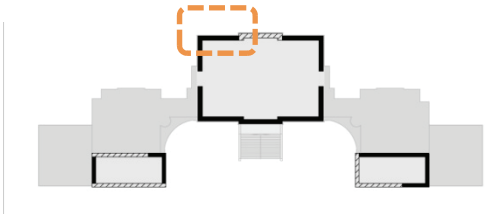


Courses determined by quoins
Courses determined by jambs
Other courses

DUNFRIES HOUSE _ EAST AYRSHIRE

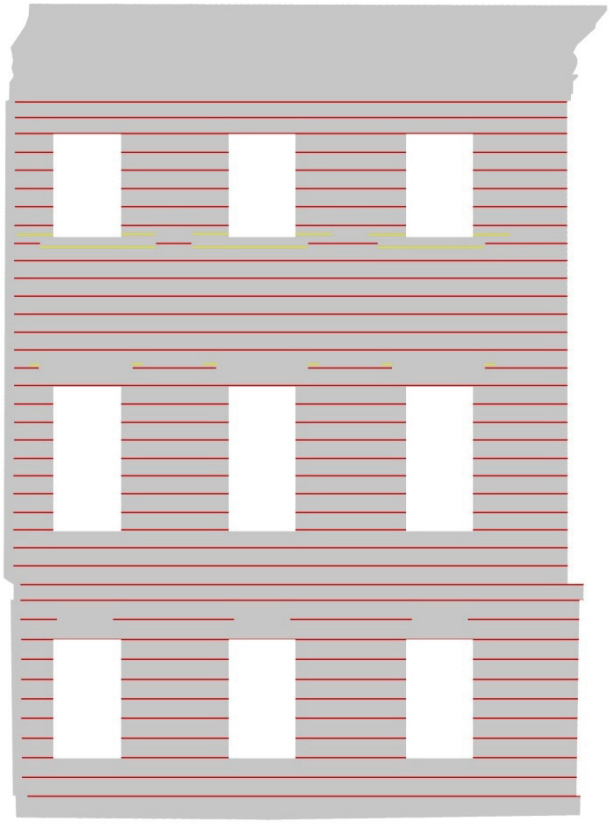
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

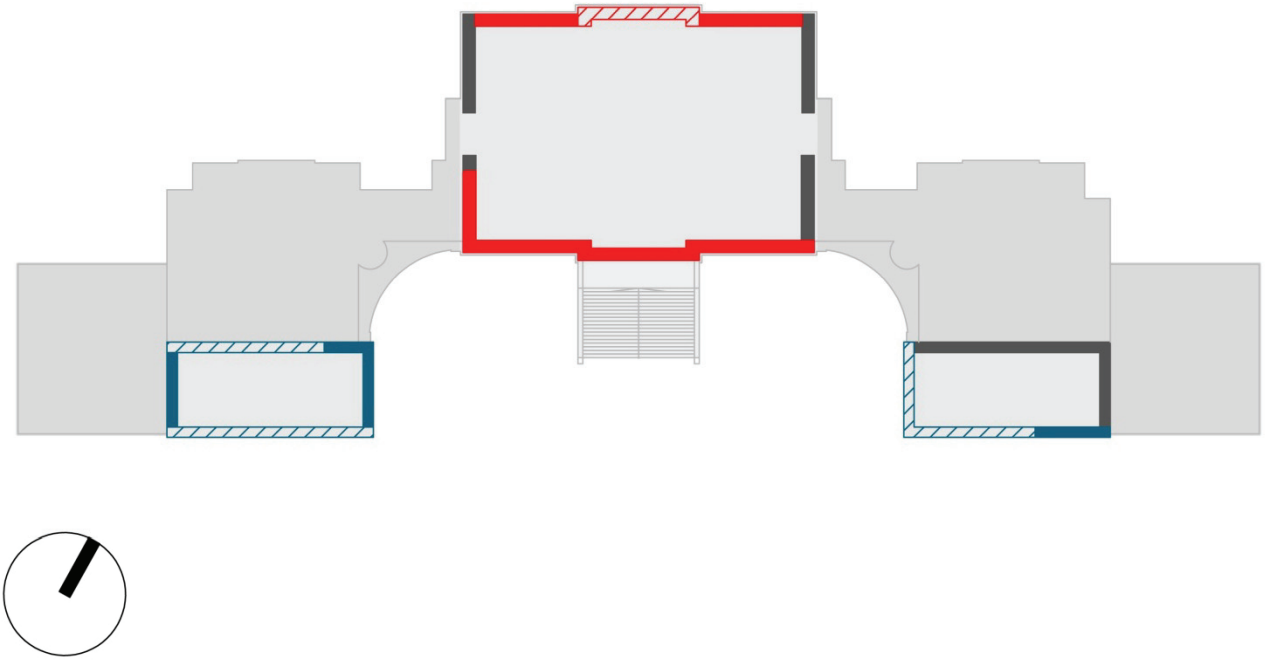


Courses determined by quoins
Courses determined by jambs
Other courses

DUNFRIES HOUSE _ EAST AYRSHIRE

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50 | 50-65 | 70-75 | 80-85 | 90-95 | 100-105 | 110-120 | 125-150 | 155-200 | >200 | Unknown | Not considered

Type of data / accuracy (hatch type)

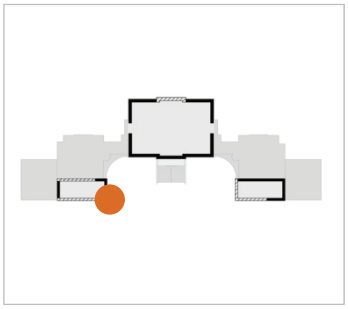
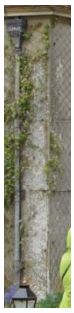
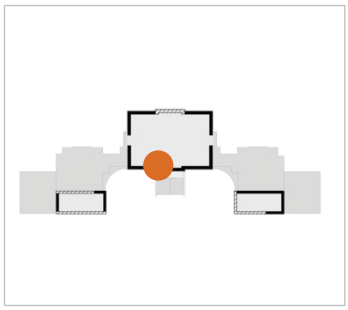
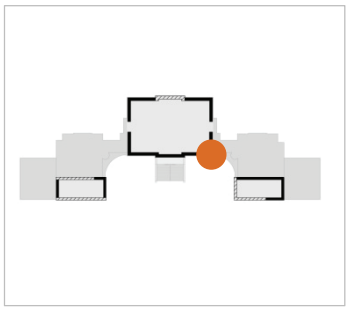
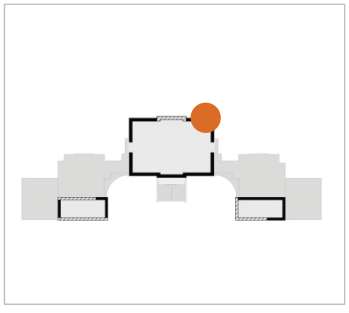
Measured onsite | Estimated

Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

DUNFRIES HOUSE _ EAST AYRSHIRE

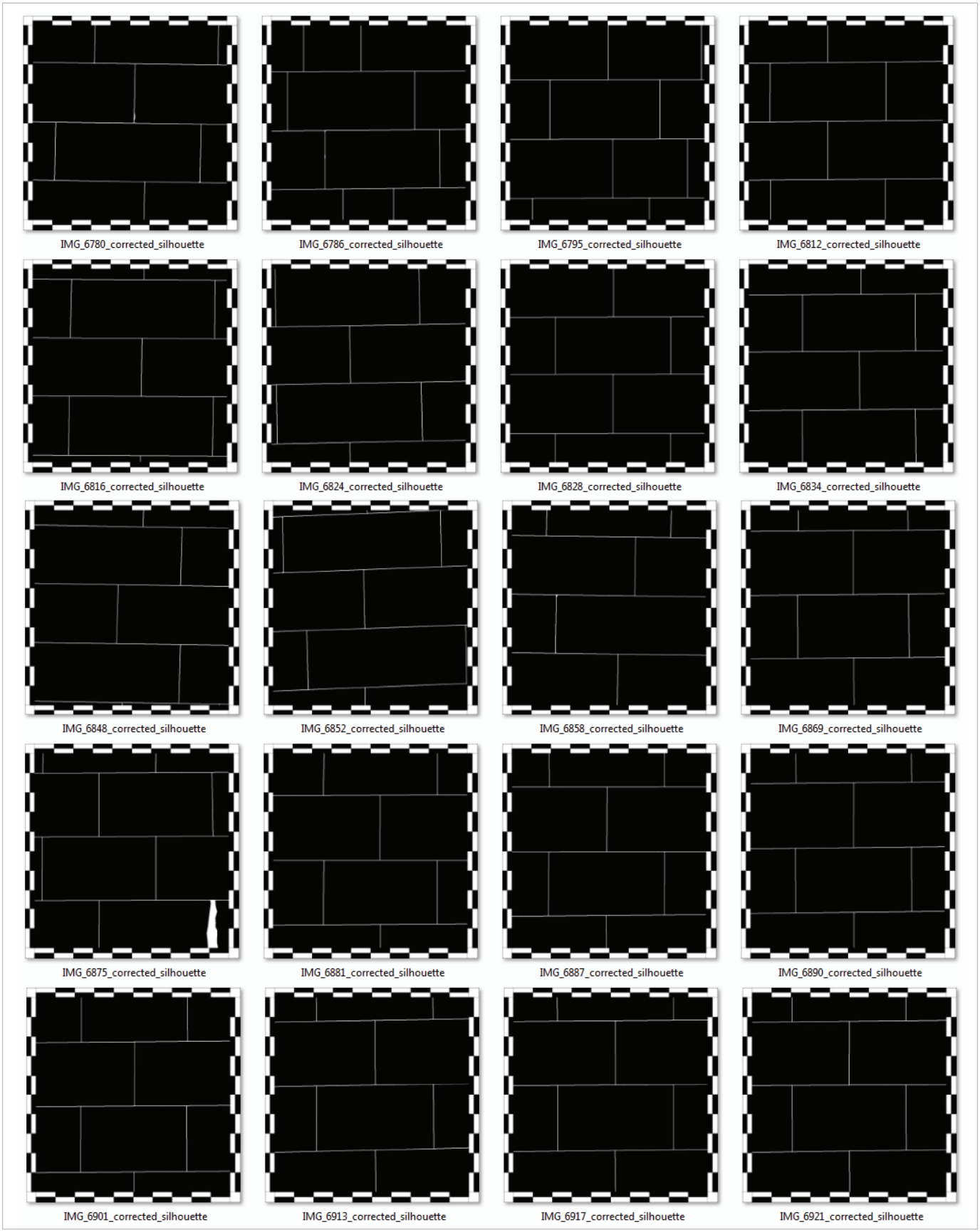
CORNERS

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			

DUNFRIES HOUSE _ EAST AYRSHIRE

MASONRY PATERNS: 1x1 FRAMES

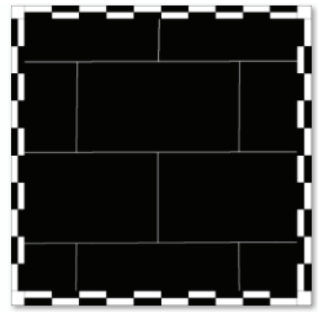
WALL CENTRAL PORTION



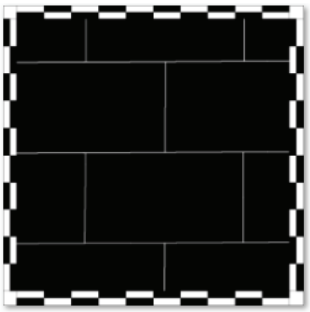
DUNFRIES HOUSE _ EAST AYRSHIRE

MASONRY PATERNS: 1x1 FRAMES

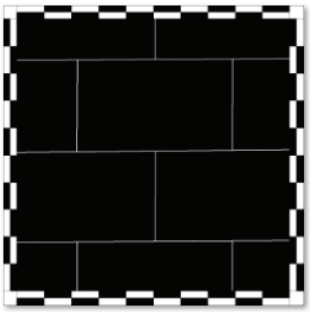
WALL CENTRAL PORTION



IMG_6928_corrected_silhouette



IMG_6934_corrected_silhouette



IMG_6940_corrected_silhouette

DUNFRIES HOUSE _ EAST AYRSHIRE

OTHER FEATURES







GILBERTFIELD CASTLE_SOUTH LANARKSHIRE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

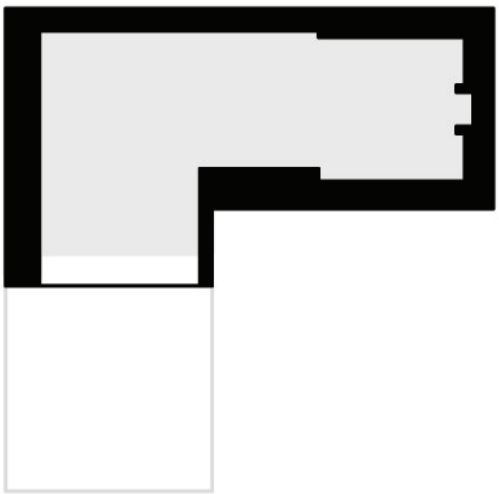


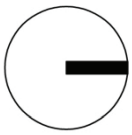
Image form Google maps 2017

GENERAL IMAGE



IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





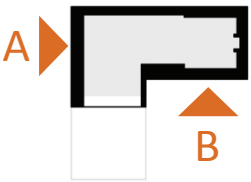
Area included in the research

Area not included in the research

Walls inspected

GILBERTFIELD CASTLE_SOUTH LANARKSHIRE

IMAGES OF THE BUILDING



A

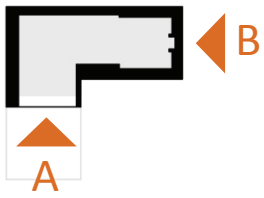


B



GILBERTFIELD CASTLE_SOUTH LANARKSHIRE

IMAGES OF THE BUILDING



A

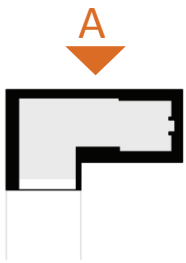


B



GILBERTFIELD CASTLE_SOUTH LANARKSHIRE

IMAGES OF THE BUILDING



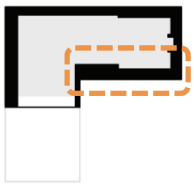
A



GILBERTFIELD CASTLE_SOUTH LANARKSHIRE

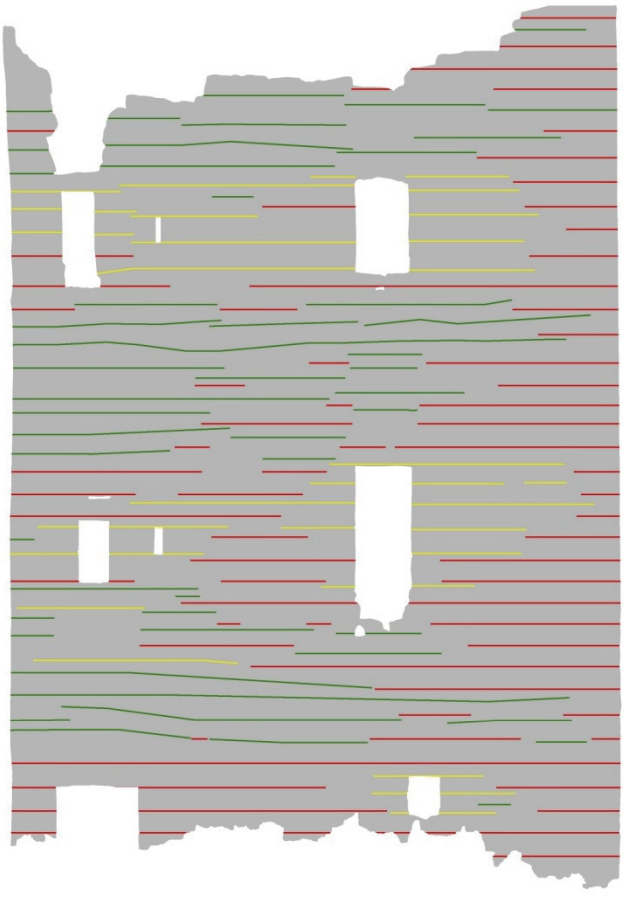
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

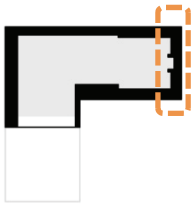


Courses determined by quoins
Courses determined by jambs
Other courses

GILBERTFIELD CASTLE_SOUTH LANARKSHIRE

ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

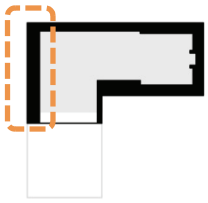


Courses determined by quoins
Courses determined by jambs
Other courses

GILBERTFIELD CASTLE_SOUTH LANARKSHIRE

ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

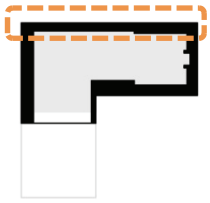


Courses determined by quoins
Courses determined by jambs
Other courses

GILBERTFIELD CASTLE_SOUTH LANARKSHIRE

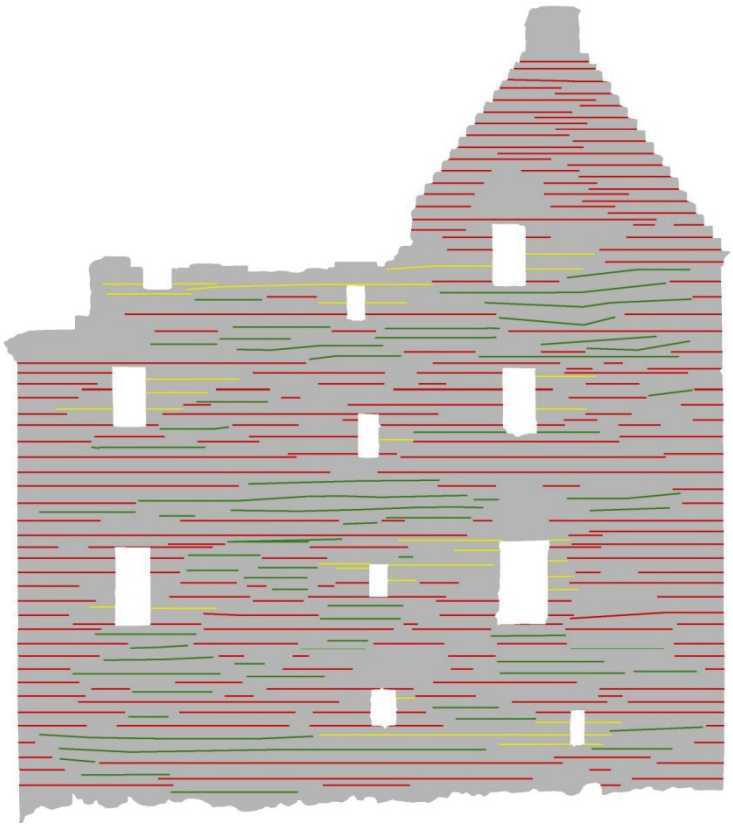
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES



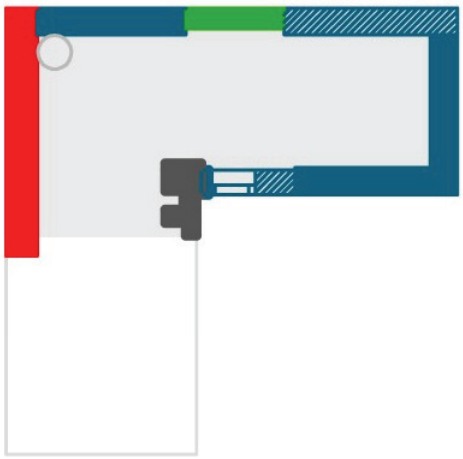
Courses determined by quoins
Courses determined by jambs
Other courses

GILBERTFIELD CASTLE_SOUTH LANARKSHIRE

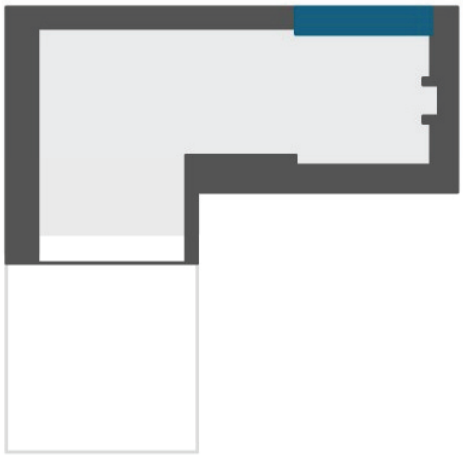
WALL THICKNESSES

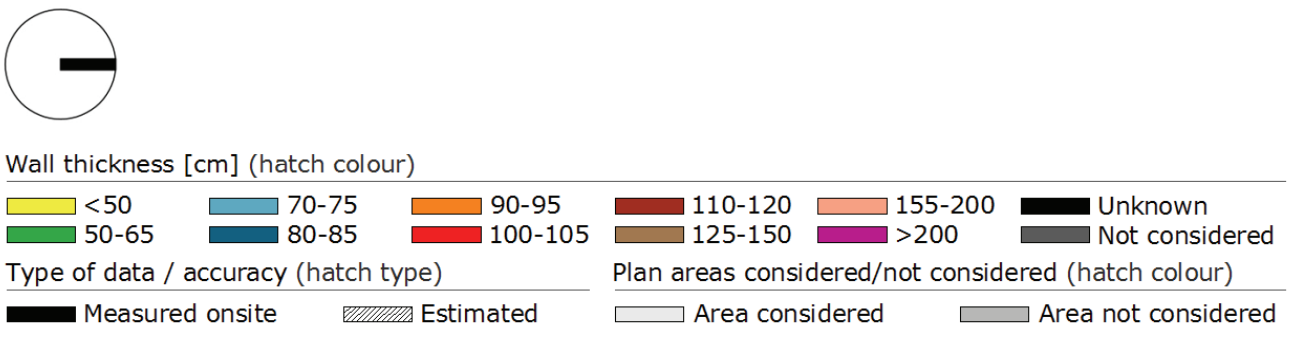
WALL THICKNESSES: GROUND FLOOR

BASEMENT



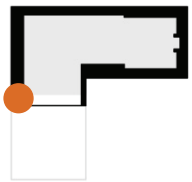
MAIN FLOOR

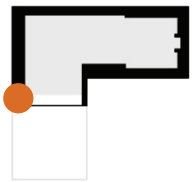


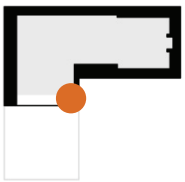


GILBERTFIELD CASTLE_SOUTH LANARKSHIRE

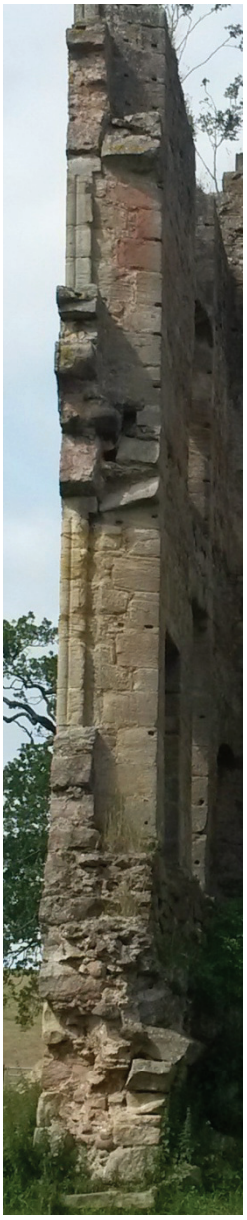
WALL SECTIONS

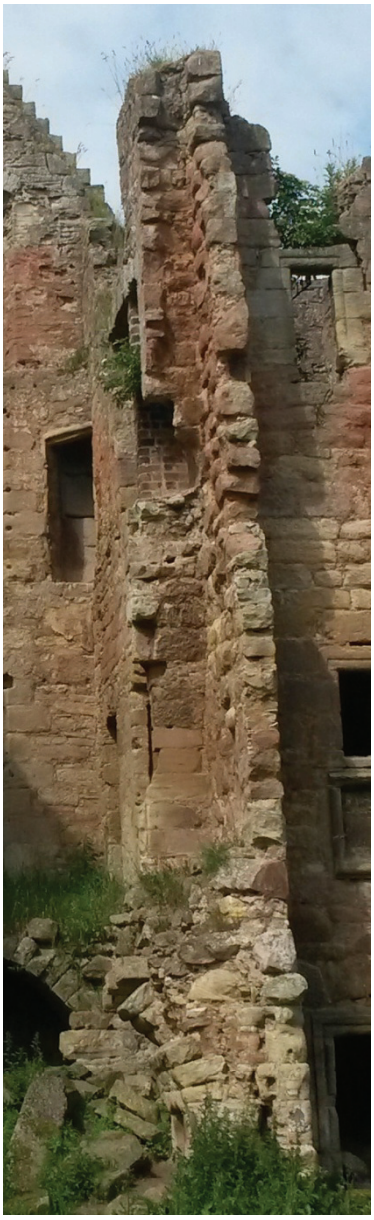








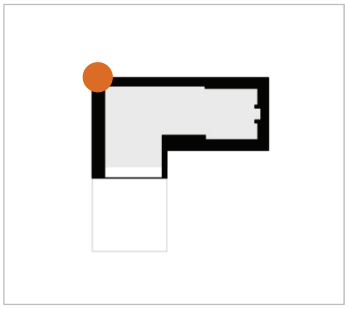




GILBERTFIELD CASTLE_SOUTH LANARKSHIRE

CORNERS

LOCATION



CORNER



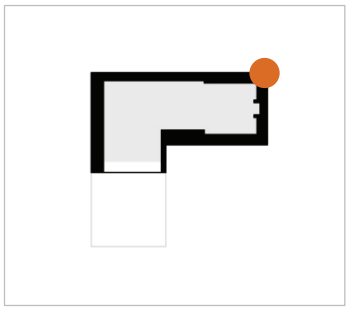
CORNER -SIDE 1



CORNER –SIDE 2



LOCATION



CORNER



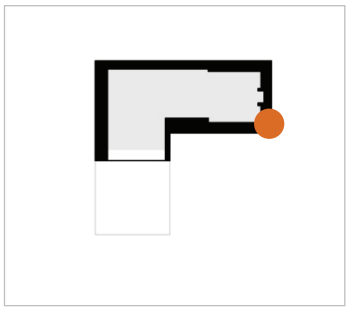
CORNER -SIDE 1



CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2

GILBERTFIELD CASTLE_SOUTH LANARKSHIRE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



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20150716_105801_corrected_silhouette



20150716_105919_corrected_silhouette



20150716_110249_corrected_silhouette



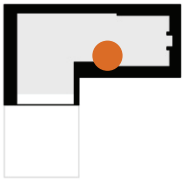
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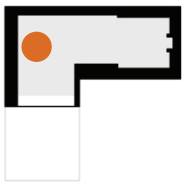
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GILBERTFIELD CASTLE_SOUTH LANARKSHIRE

OTHER FEATURES





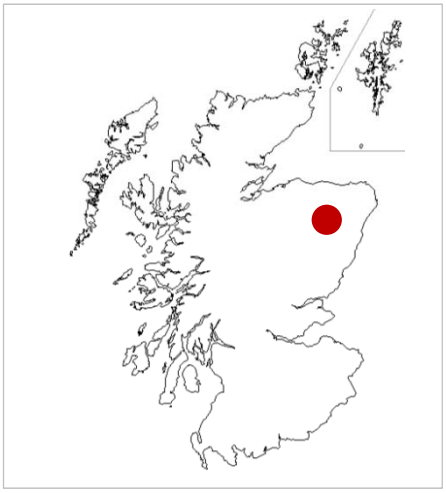




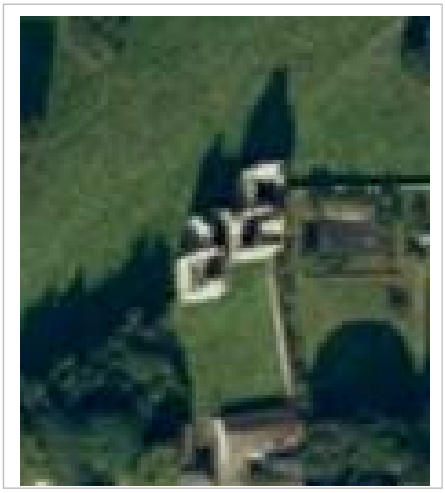
GLENBUCHAT CASTLE_ABERDEENSHIRE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

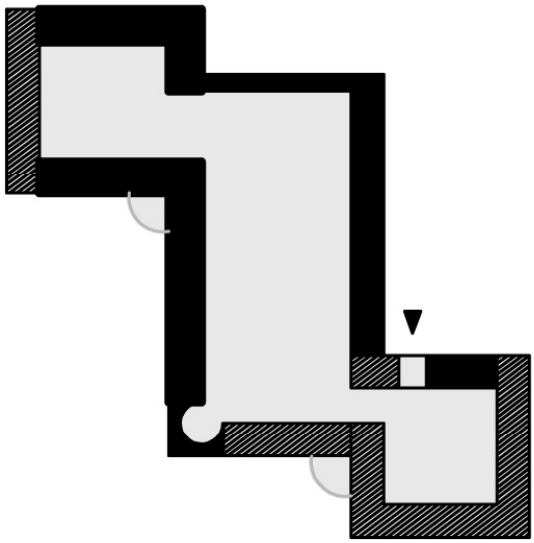


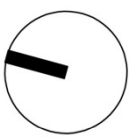
GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





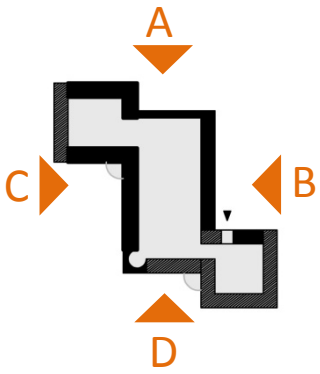
Area included in the research

Area not included in the research

Walls inspected

GLENBUCHAT CASTLE_ABERDEENSHIRE

IMAGES OF THE BUILDING



A



B



C



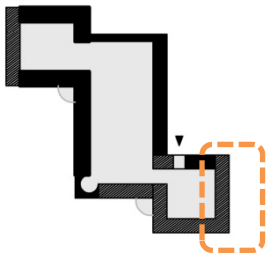
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GLENBUCHAT CASTLE_ABERDEENSHIRE

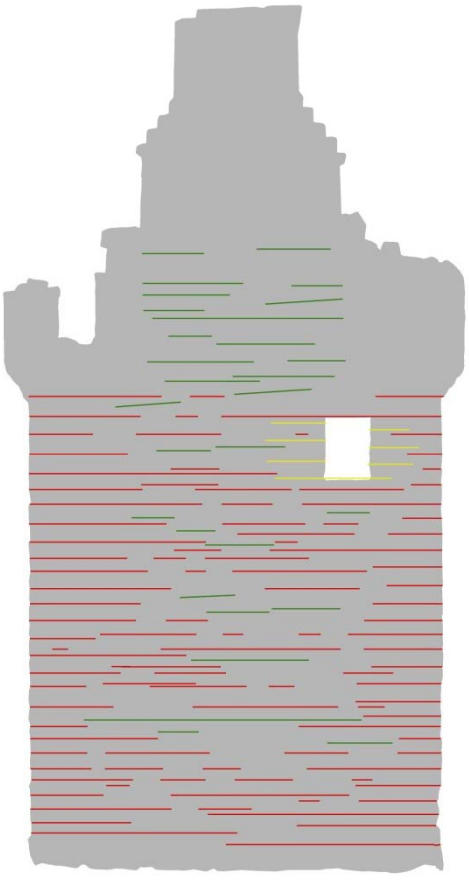
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

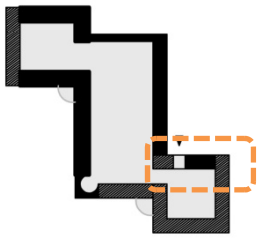


Courses determined by quoins
Courses determined by jambs
Other courses

GLENBUCHAT CASTLE_ABERDEENSHIRE

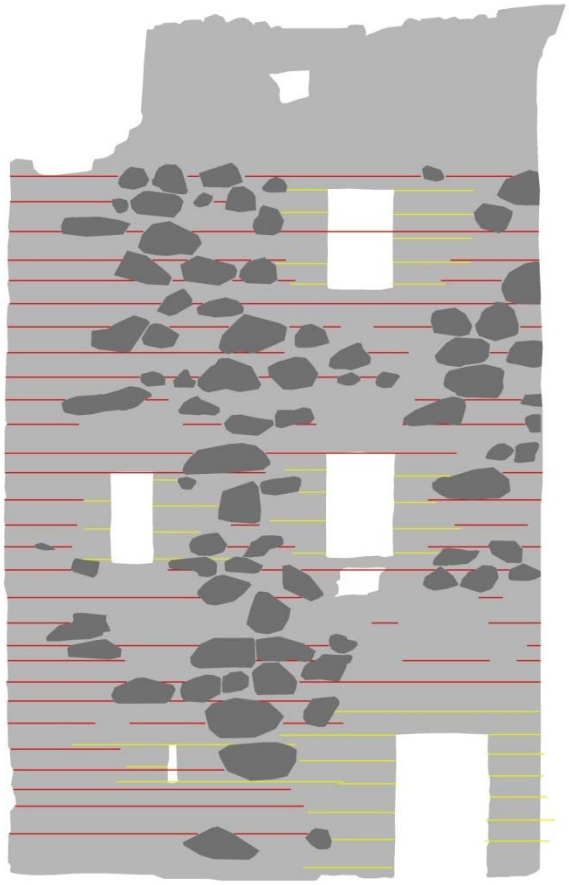
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES



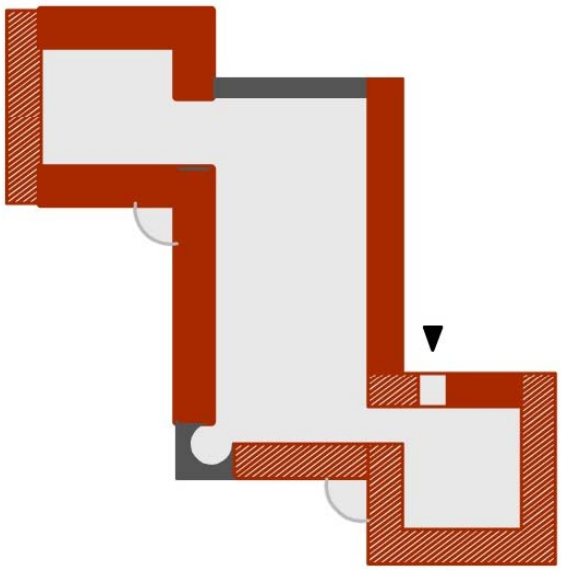
Courses determined by quoins
Courses determined by jambs
Other courses

GLENBUCHAT CASTLE_ABERDEENSHIRE

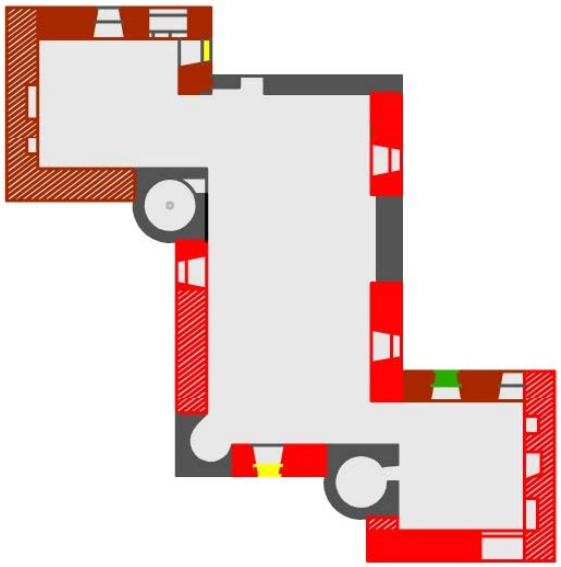
WALL THICKNESSES

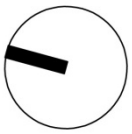
WALL THICKNESSES: GROUND FLOOR

BASEMENT



MAIN FLOOR





Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

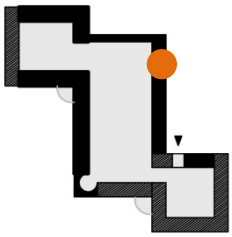
Measured onsite | Estimated

Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

GLENBUCHAT CASTLE_ABERDEENSHIRE

WALL SECTIONS

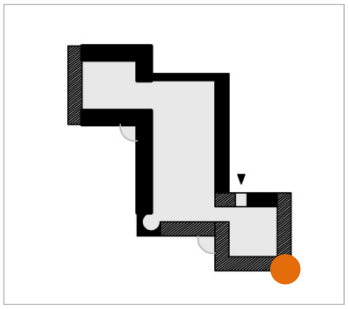




GLENBUCHAT CASTLE_ABERDEENSHIRE

CORNERS

LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



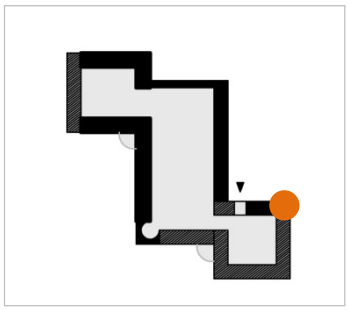
CORNER -SIDE 1



CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



CORNER -SIDE 1

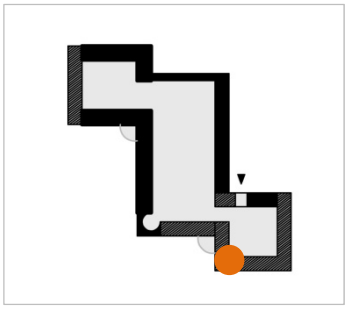
CORNER –SIDE 2



GLENBUCHAT CASTLE_ABERDEENSHIRE

CORNERS

LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



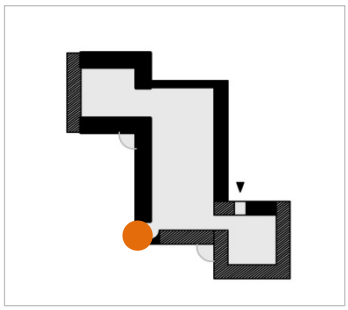
CORNER -SIDE 1



CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



CORNER -SIDE 1



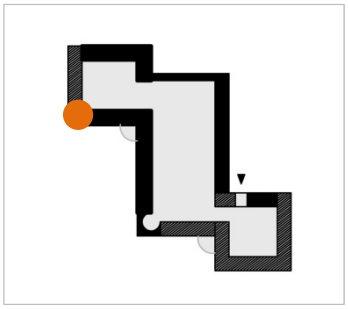
CORNER –SIDE 2



GLENBUCHAT CASTLE_ABERDEENSHIRE

CORNERS

LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



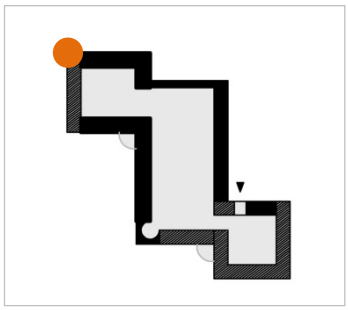
CORNER -SIDE 1



CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



CORNER -SIDE 1

CORNER –SIDE 2



GLENBUCHAT CASTLE_ABERDEENSHIRE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



IMG_6303_corrected_silhouette

GOSFORD HOUSE_ EAST LOTHIAN

GENERAL INFORMATION

LOCATION



BUILDING PLAN

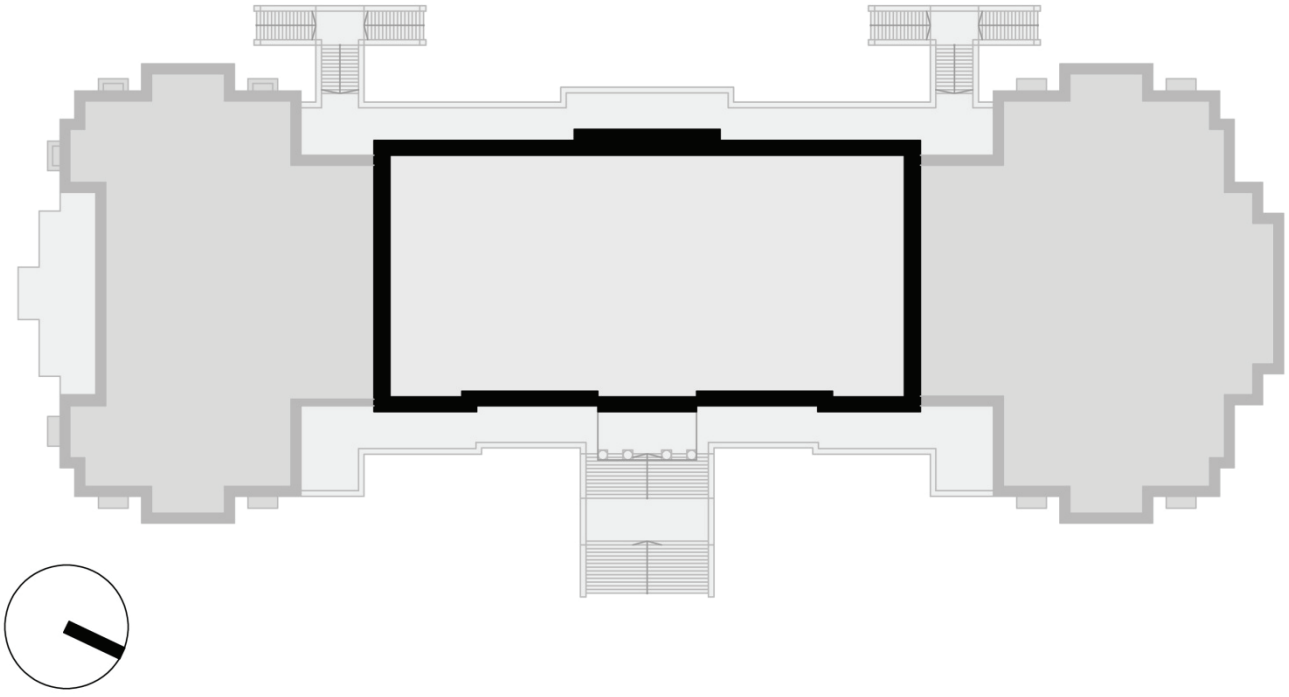


Image form Google maps 2017

GENERAL IMAGE



IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



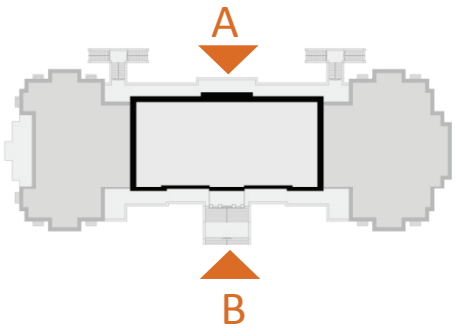
Area included in the research

Area not included in the research

Walls inspected

GOSFORD HOUSE_ EAST LOTHIAN

IMAGES OF THE BUILDING



A



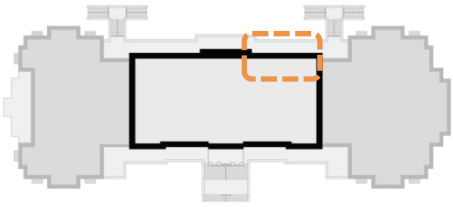
B



GOSFORD HOUSE_ EAST LOTHIAN

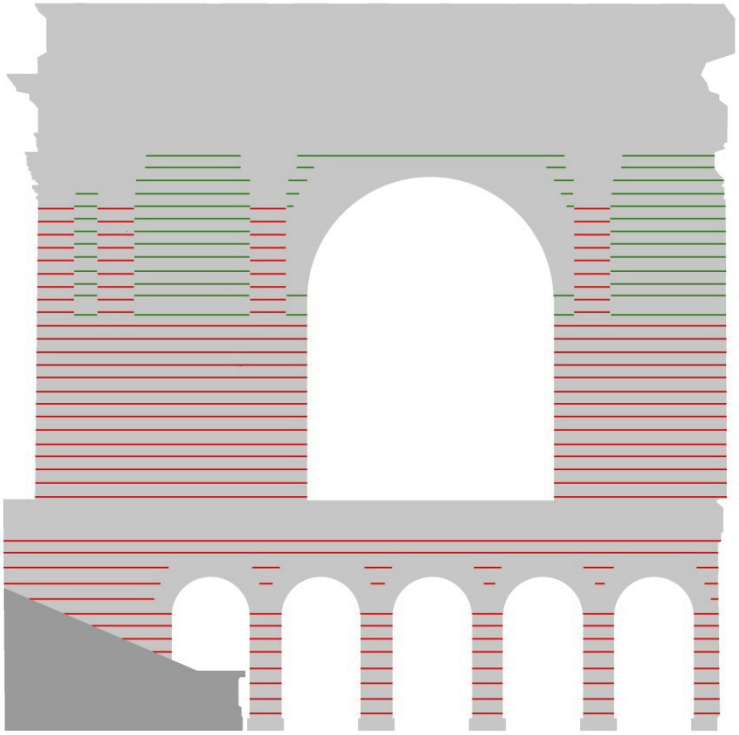
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

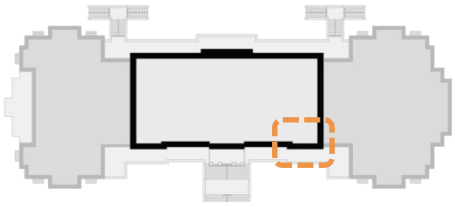


Courses determined by quoins
Courses determined by jambs
Other courses

GOSFORD HOUSE_ EAST LOTHIAN

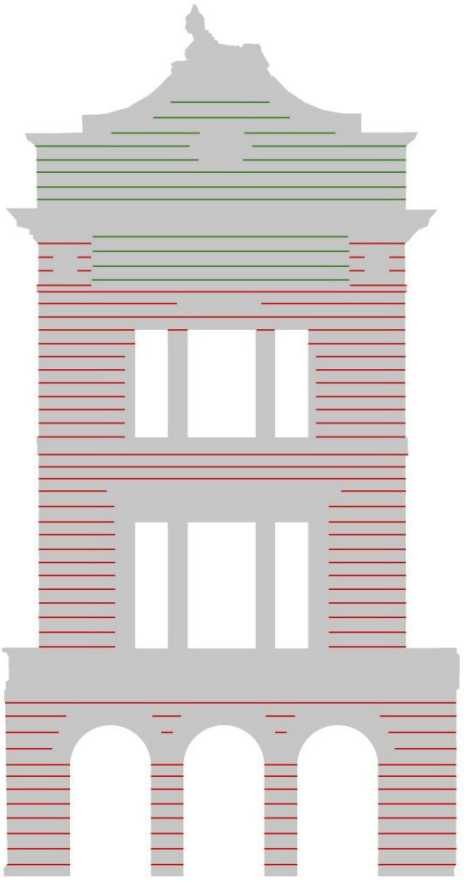
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

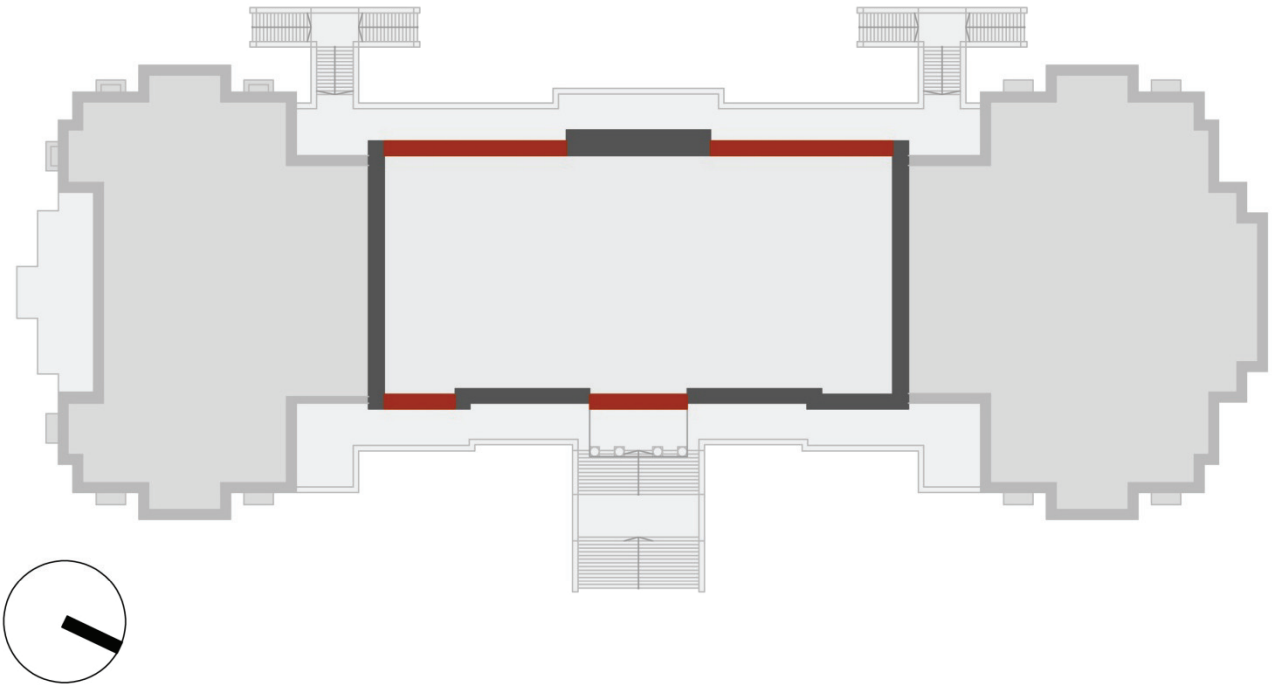


Courses determined by quoins
Courses determined by jambs
Other courses

GOSFORD HOUSE_ EAST LOTHIAN

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50 | 50-65 | 70-75 | 80-85 | 90-95 | 100-105 | 110-120 | 125-150 | 155-200 | >200 | Unknown | Not considered

Type of data / accuracy (hatch type)

Measured onsite | Estimated

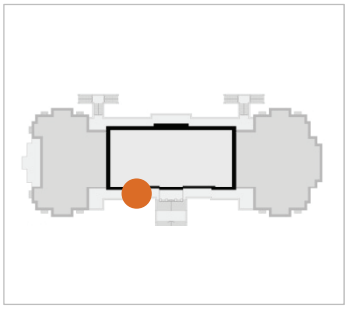
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

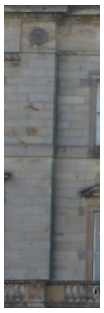
GOSFORD HOUSE_ EAST LOTHIAN

CORNERS

LOCATION



CORNER



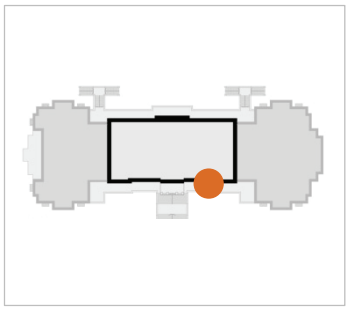
CORNER -SIDE 1



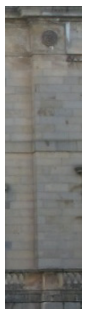
CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1

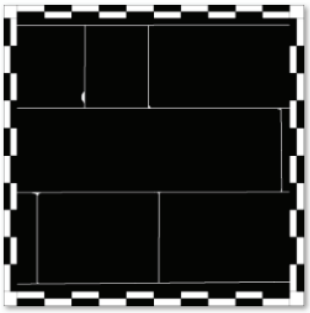
CORNER –SIDE 2

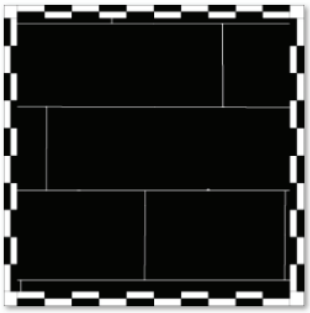


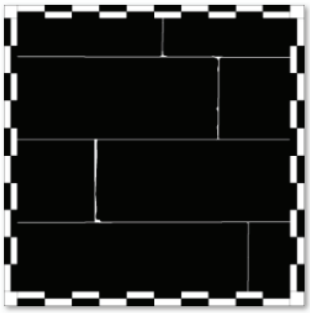
GOSFORD HOUSE_ EAST LOTHIAN

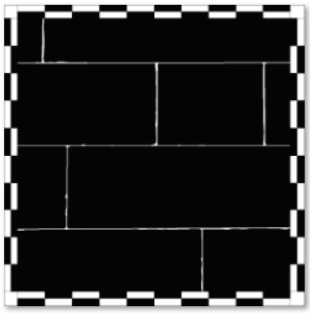
MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION

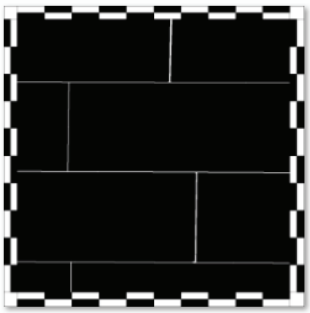

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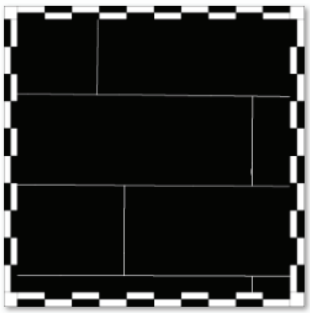

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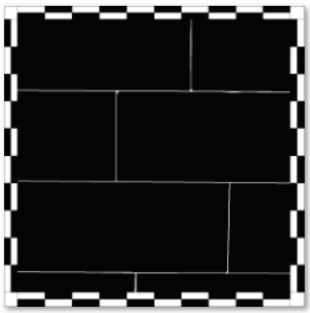

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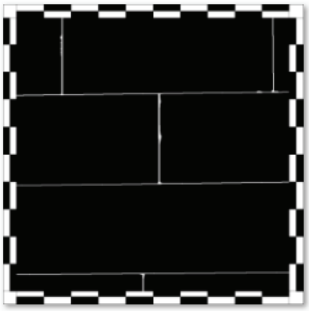

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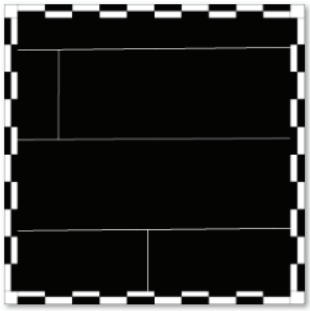

IMG_6504_corrected_silhouette


IMG_6515_corrected_silhouette


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IMG_6522_corrected_silhouette


IMG_6526_corrected_silhouette

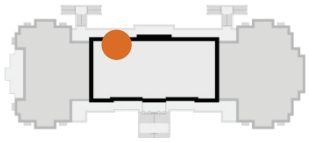

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IMG_6565_corrected_silhouette


IMG_6567_corrected_silhouette

GOSFORD HOUSE_ EAST LOTHIAN

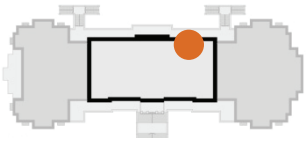
OTHER FEATURES





GOSFORD HOUSE_ EAST LOTHIAN

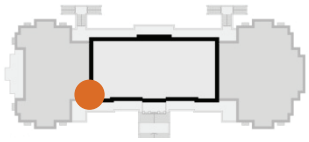
OTHER FEATURES





GOSFORD HOUSE_ EAST LOTHIAN

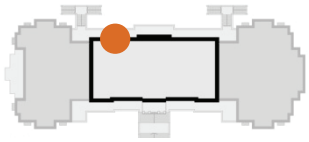
OTHER FEATURES

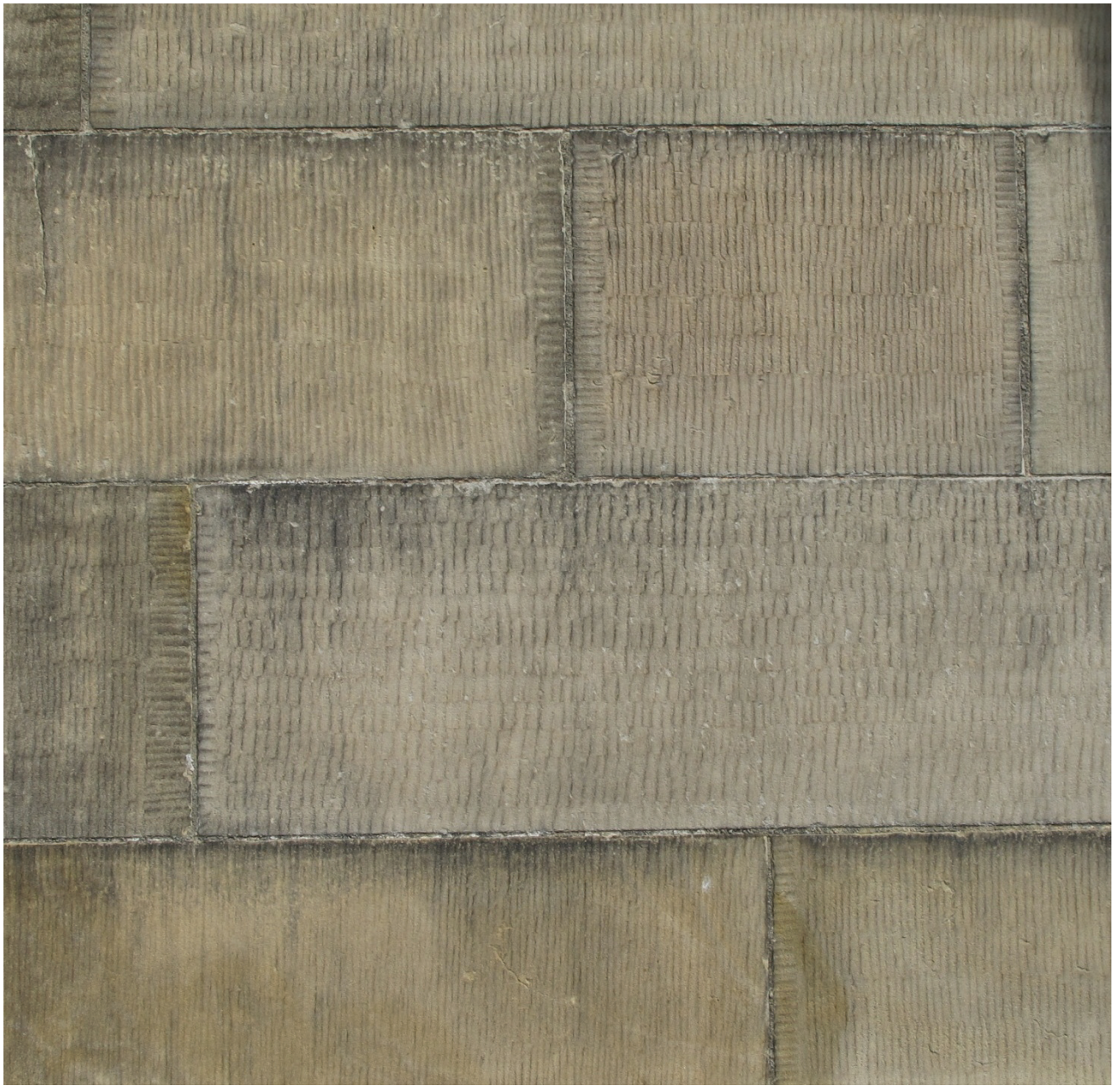




GOSFORD HOUSE_ EAST LOTHIAN

OTHER FEATURES

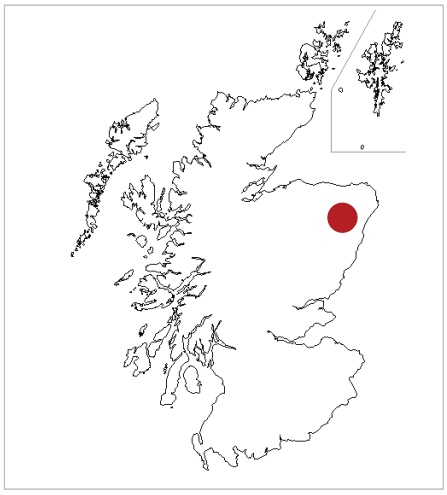




HADDO HOUSE _ ABERDEENSHIRE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

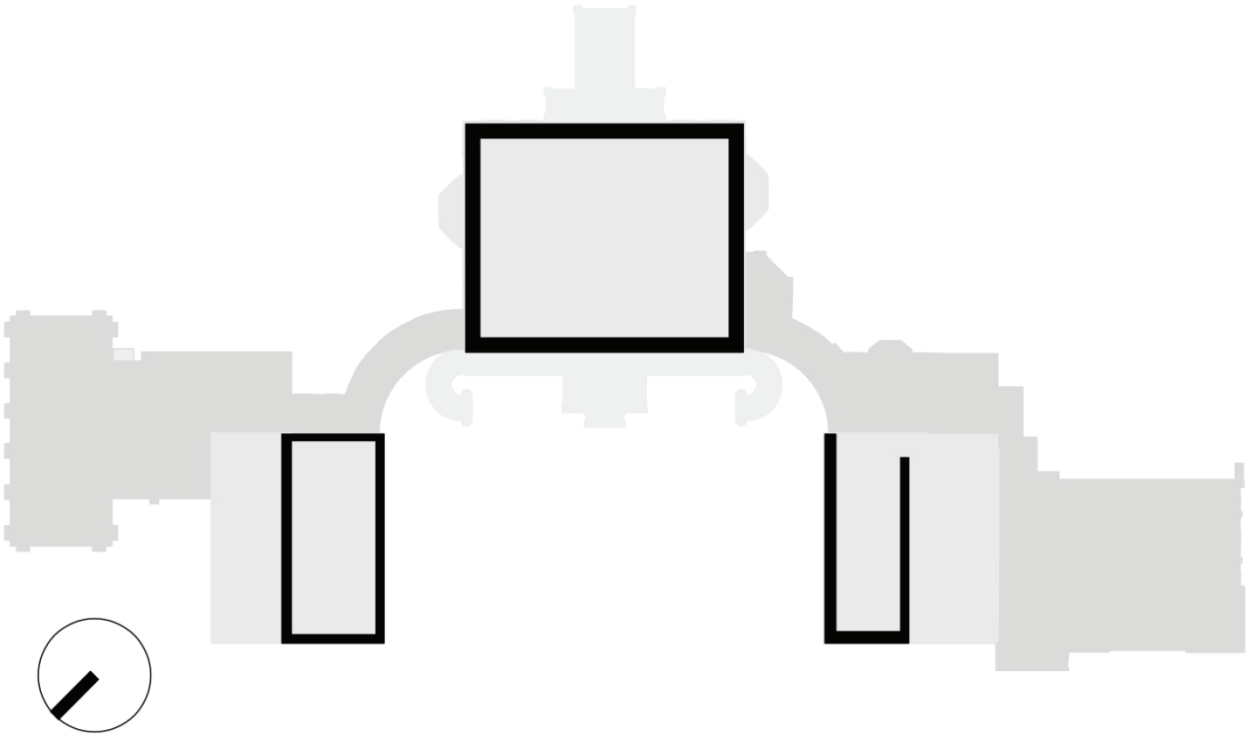


GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



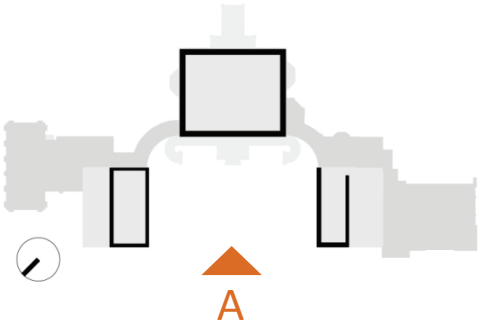
Area included in the research

Area not included in the research

Walls inspected

HADDO HOUSE _ ABERDEENSHIRE

IMAGES OF THE BUILDING

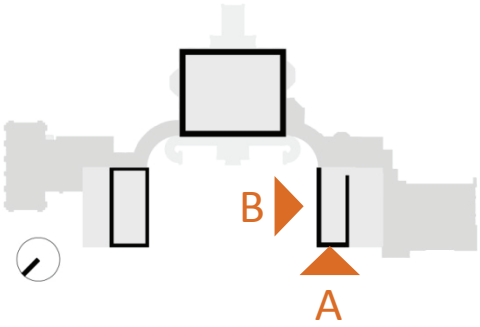


A



HADDO HOUSE _ ABERDEENSHIRE

IMAGES OF THE BUILDING



A

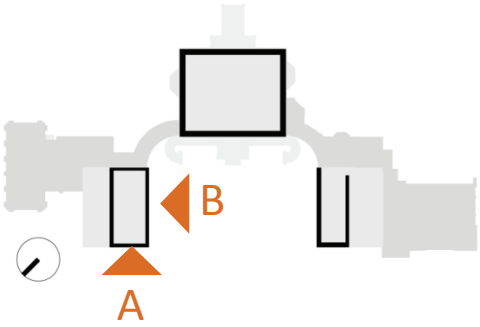


B



HADDO HOUSE _ ABERDEENSHIRE

IMAGES OF THE BUILDING



A

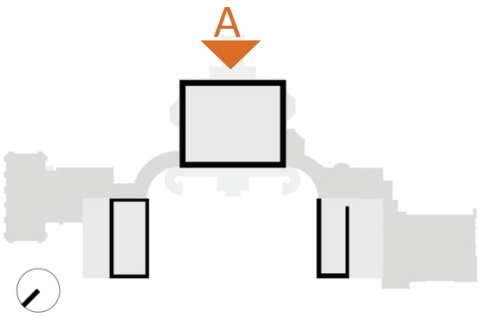


B



HADDO HOUSE _ ABERDEENSHIRE

IMAGES OF THE BUILDING

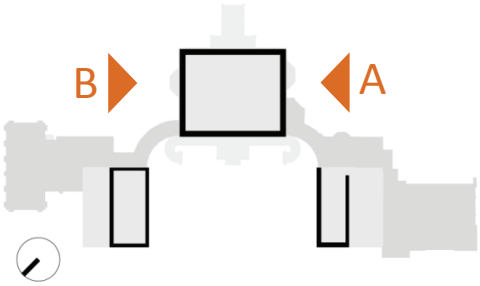


A



HADDO HOUSE _ ABERDEENSHIRE

IMAGES OF THE BUILDING



A



B



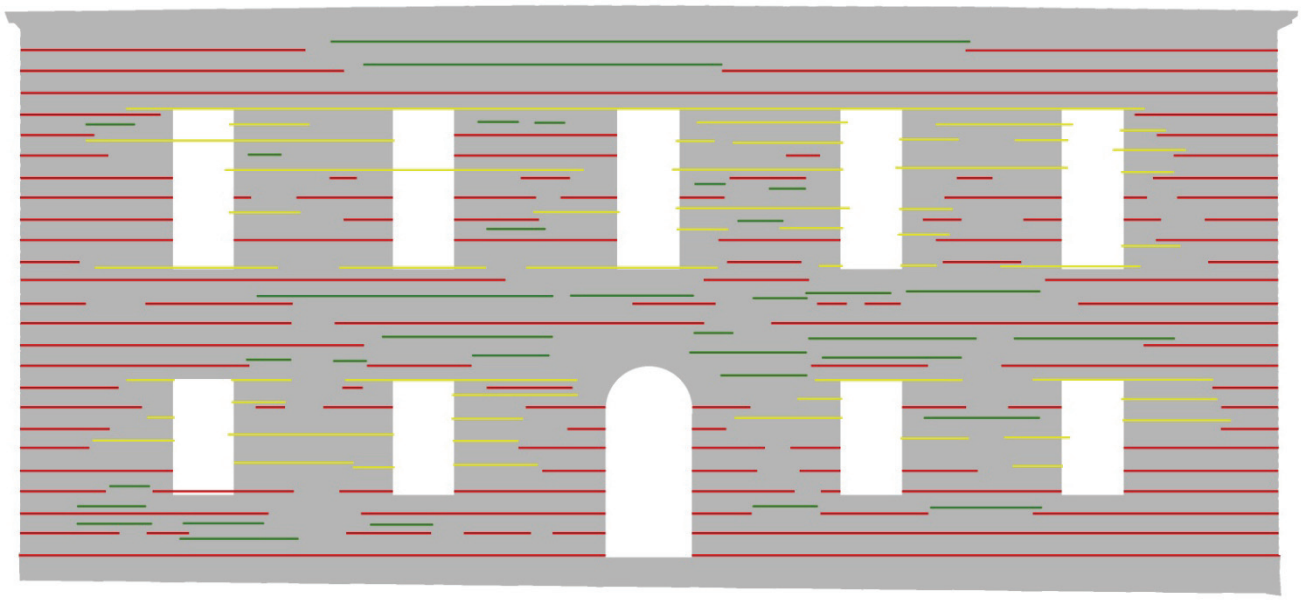
HADDO HOUSE _ ABERDEENSHIRE

ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE



ANALYSIS OF COURSES



Courses determined by quoins
Courses determined by jambs
Other courses

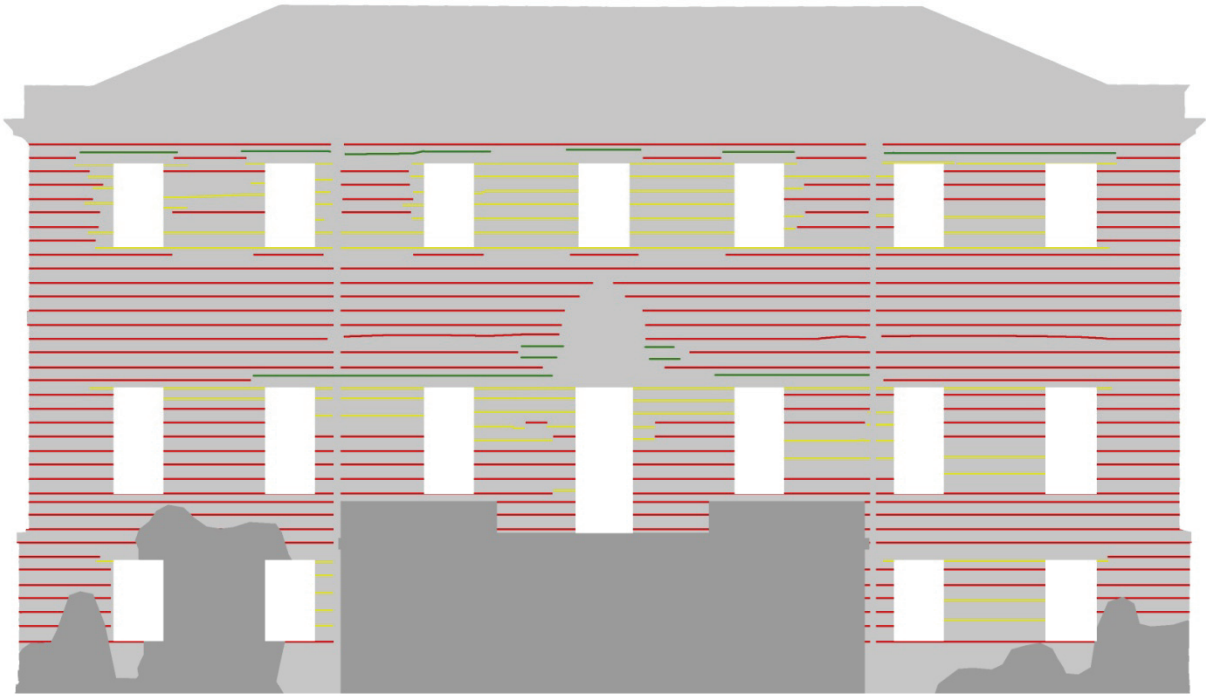
HADDO HOUSE _ ABERDEENSHIRE

ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE



ANALYSIS OF COURSES



Courses determined by quoins
Courses determined by jambs
Other courses

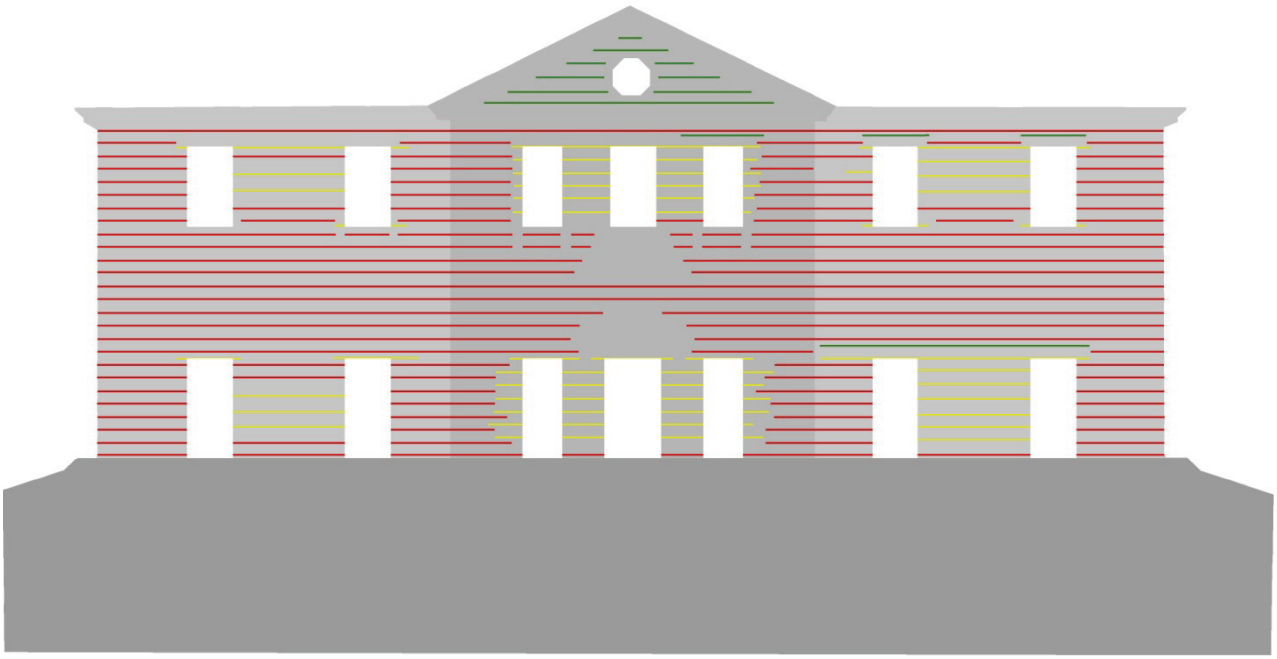
HADDO HOUSE _ ABERDEENSHIRE

ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE



ANALYSIS OF COURSES

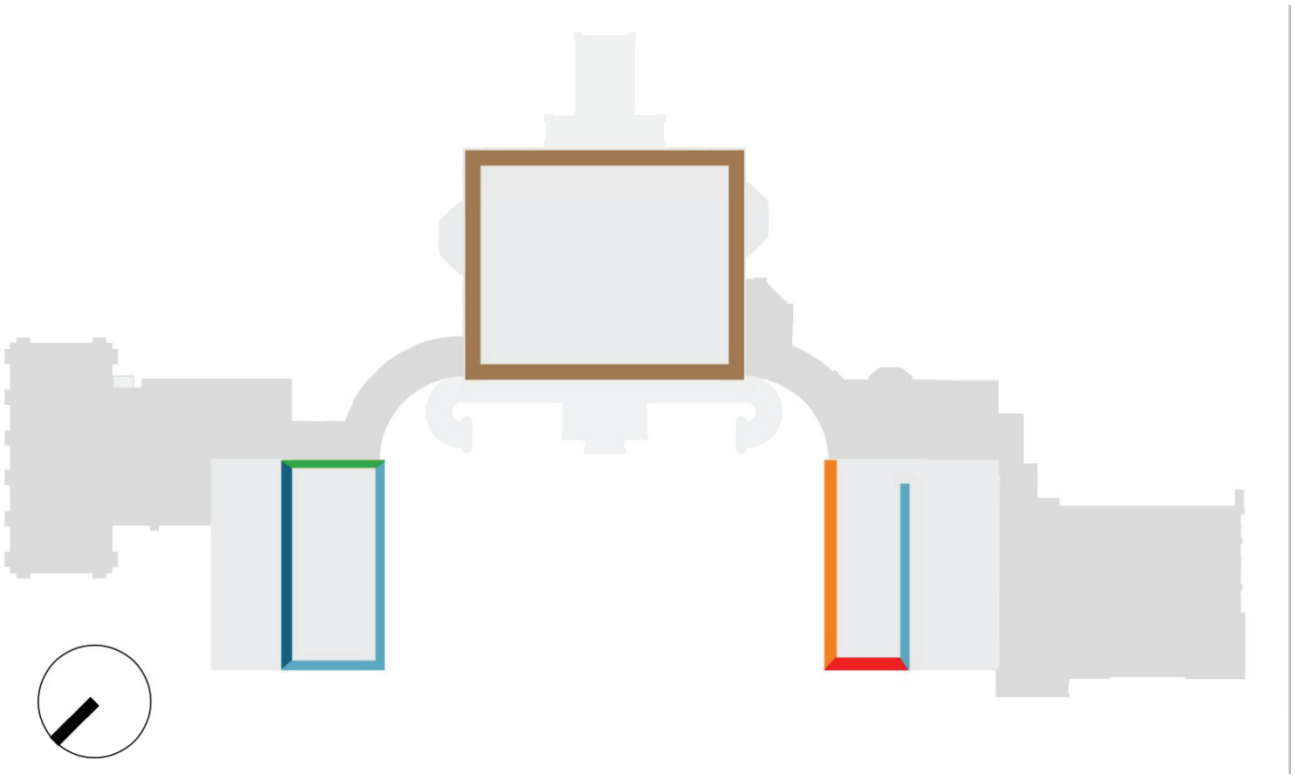


Courses determined by quoins
Courses determined by jambs
Other courses

HADDO HOUSE _ ABERDEENSHIRE

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

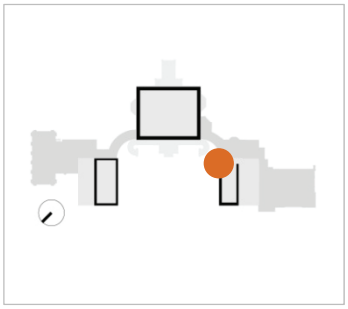
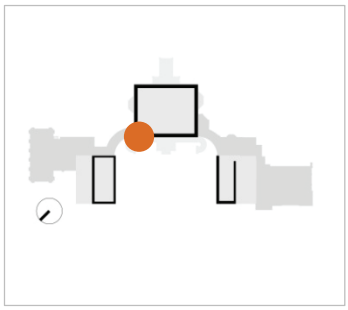
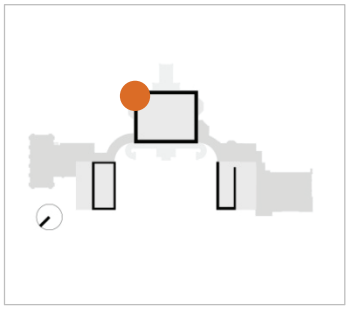
Measured onsite | Estimated

Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

HADDO HOUSE _ ABERDEENSHIRE

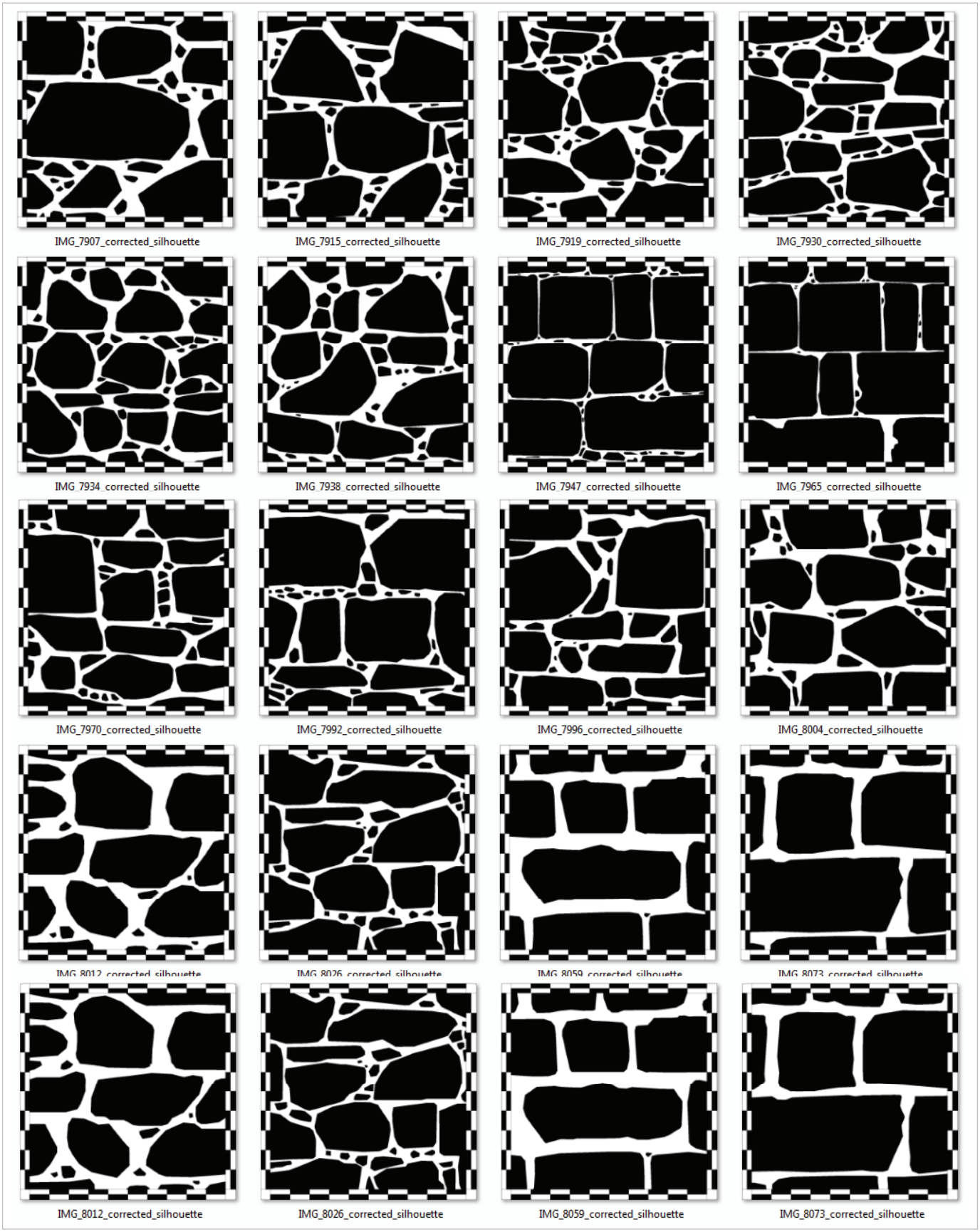
CORNERS

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			

HADDO HOUSE _ ABERDEENSHIRE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



HADDO HOUSE _ ABERDEENSHIRE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



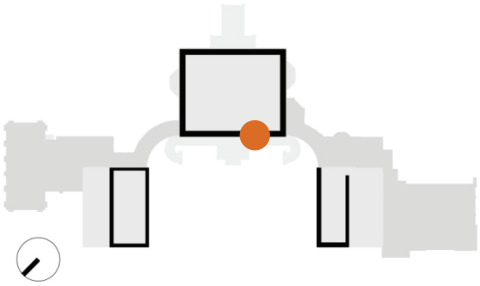
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IMG_8088_corrected_silhouette

HADDO HOUSE _ ABERDEENSHIRE

OTHER FEATURES

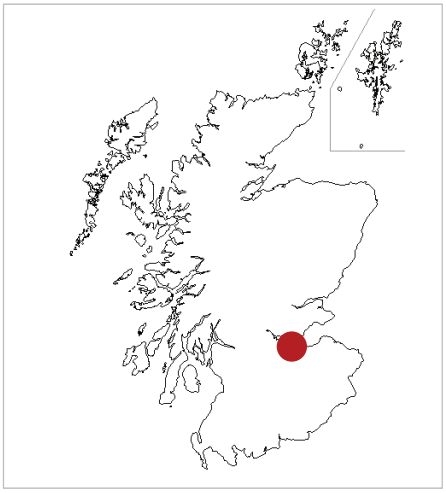




HOLYROOD PALACE _ EDINBURGH, CITY OF

GENERAL INFORMATION

LOCATION



BUILDING PLAN

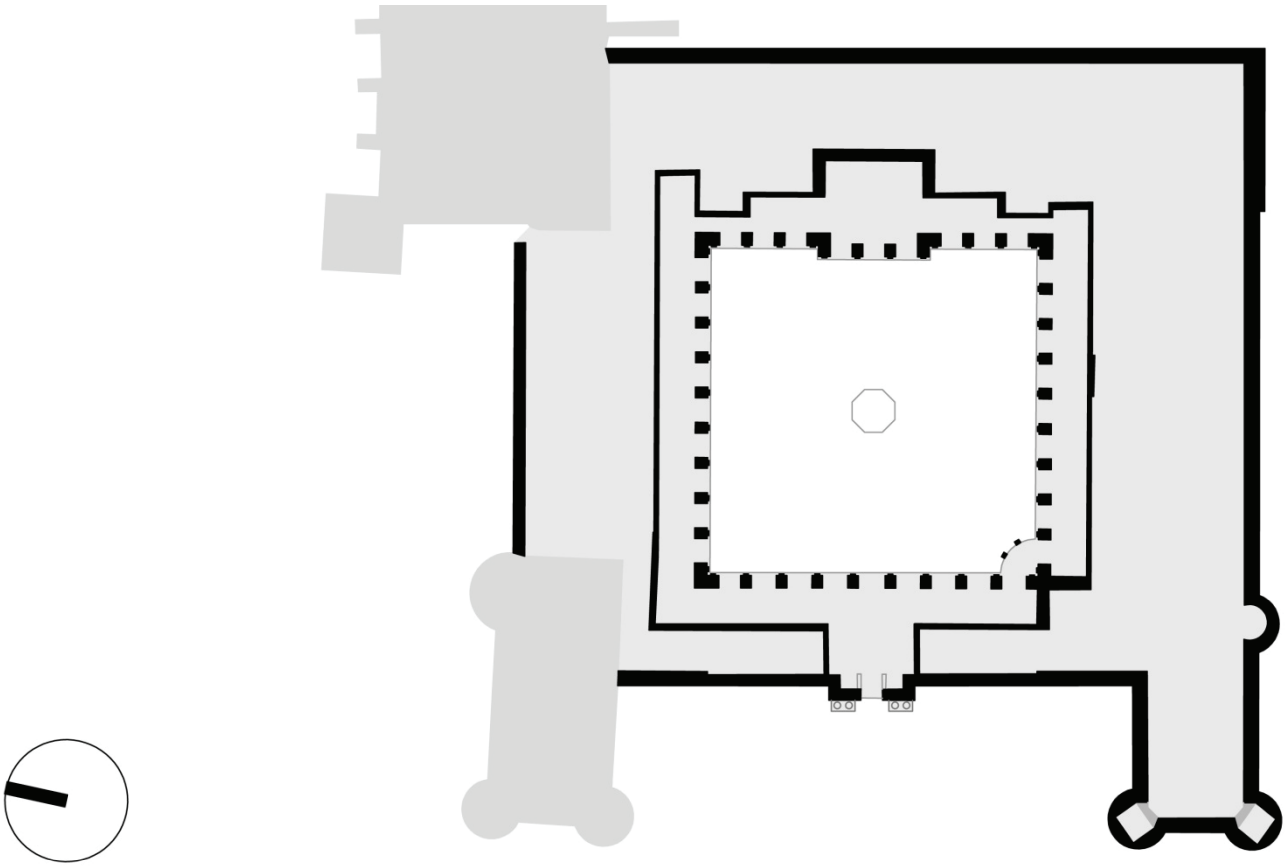


Image form Google maps 2017

GENERAL IMAGE



IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



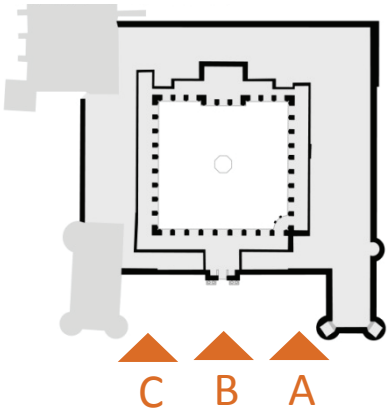
Area included in the research

Area not included in the research

Walls inspected

HOLYROOD PALACE _ EDINBURGH, CITY OF

IMAGES OF THE BUILDING



A



B

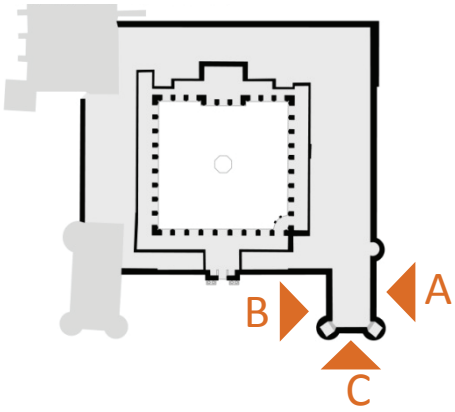


C



HOLYROOD PALACE _ EDINBURGH, CITY OF

IMAGES OF THE BUILDING



A



B

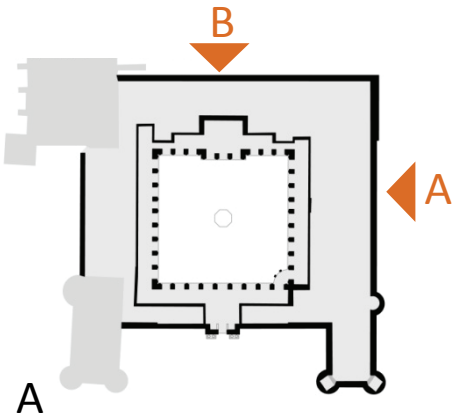


C



HOLYROOD PALACE _ EDINBURGH, CITY OF

IMAGES OF THE BUILDING



A

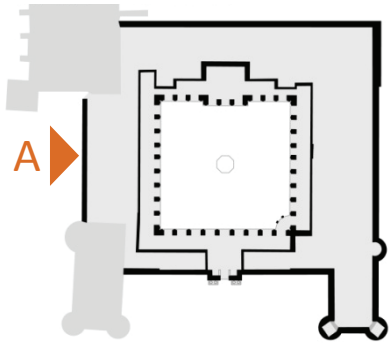


B



HOLYROOD PALACE _ EDINBURGH, CITY OF

IMAGES OF THE BUILDING



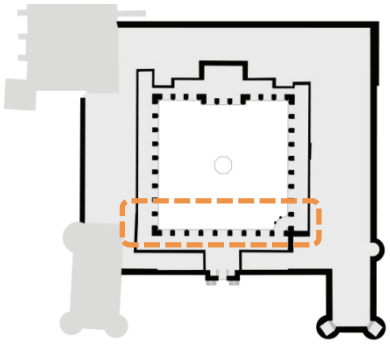
A



HOLYROOD PALACE _ EDINBURGH, CITY OF

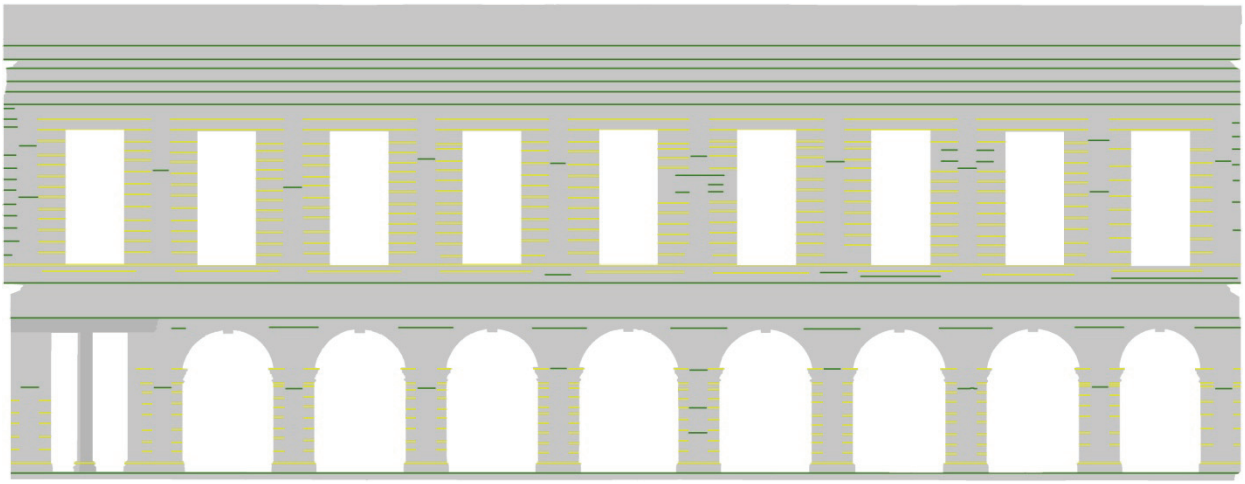
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

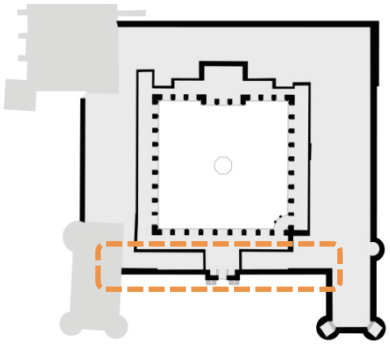


Courses determined by quoins
Courses determined by jambs
Other courses

HOLYROOD PALACE _ EDINBURGH, CITY OF

ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE

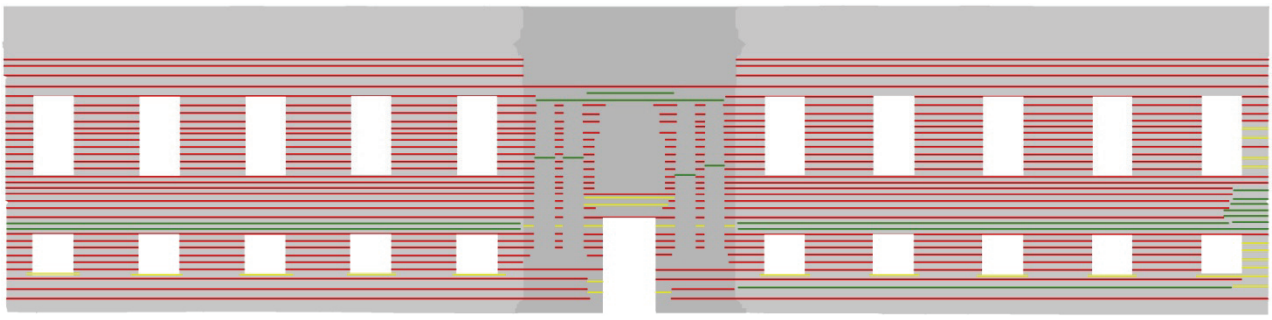








ANALYSIS OF COURSES

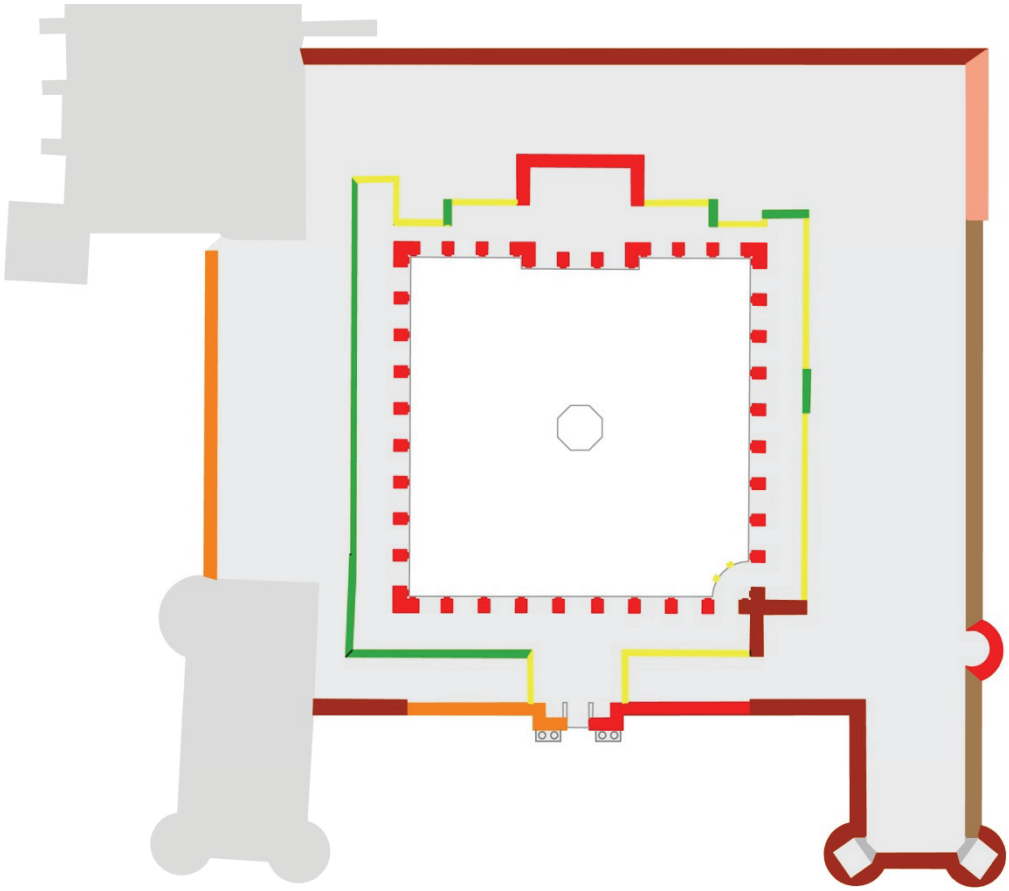


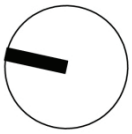
Courses determined by quoins
Courses determined by jambs
Other courses

HOLYROOD PALACE _ EDINBURGH, CITY OF

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR





Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

Measured onsite | Estimated

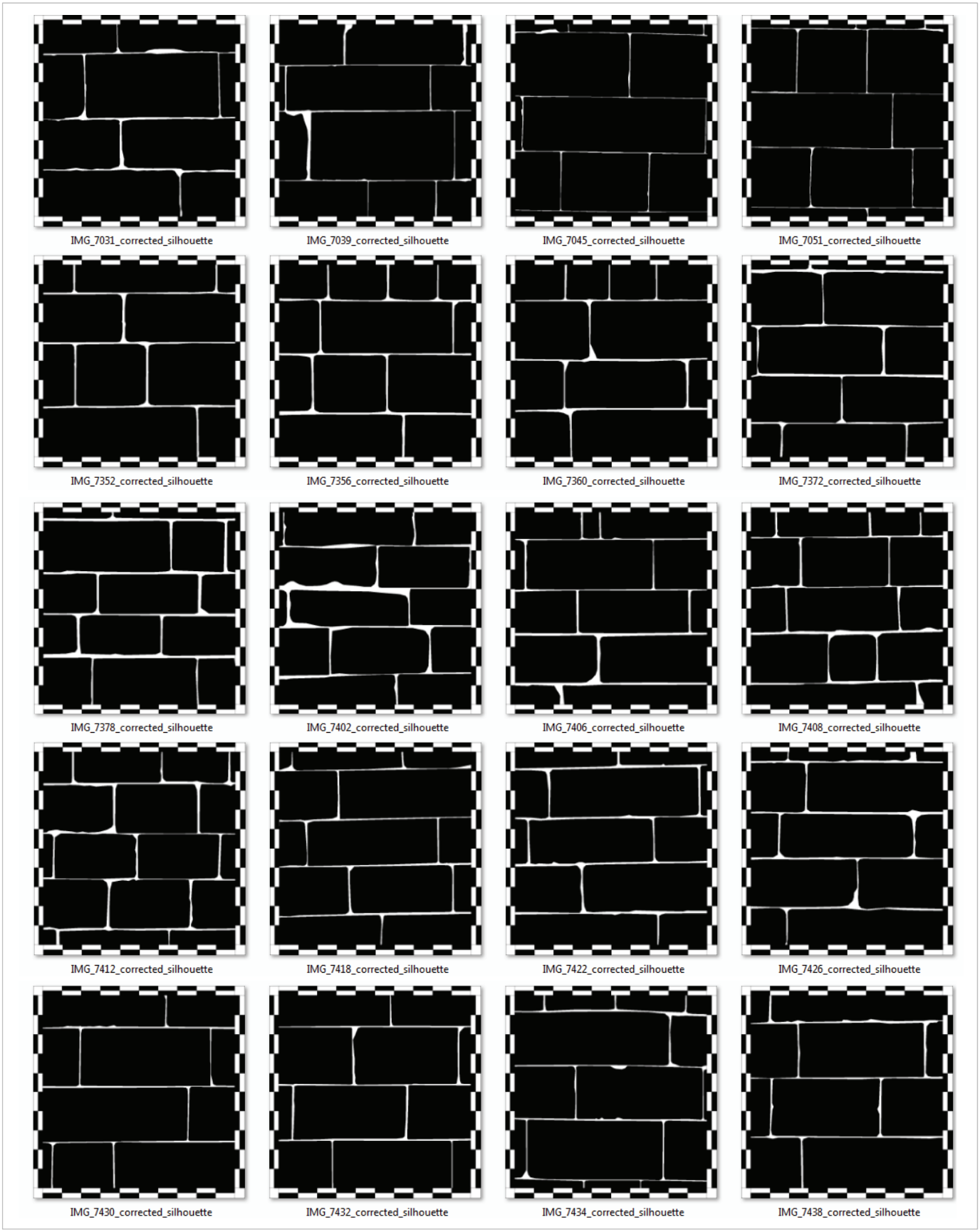
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

HOLYROOD PALACE _ EDINBURGH, CITY OF

MASONRY PATERNS: 1x1 FRAMES

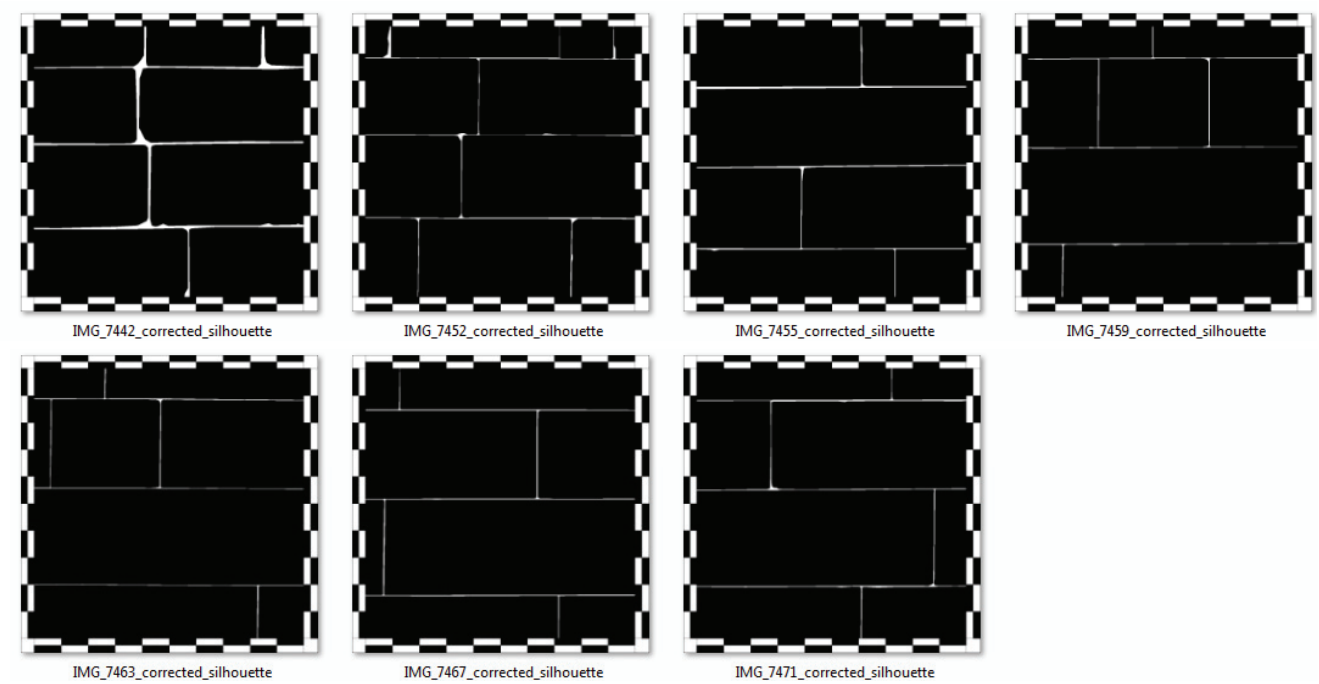
WALL CENTRAL PORTION



HOLYROOD PALACE _ EDINBURGH, CITY OF

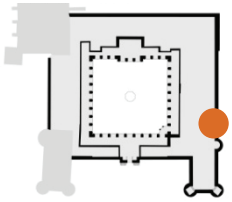
MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION

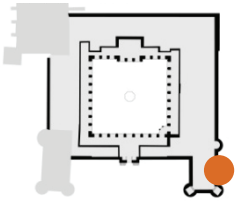


HOLYROOD PALACE _ EDINBURGH, CITY OF

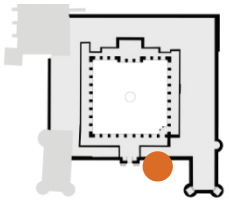
OTHER FEATURES



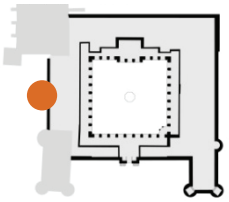














HOLYROOD PALACE OLD TOWER_ EDINBURGH, CITY OF

GENERAL INFORMATION

LOCATION



BUILDING PLAN

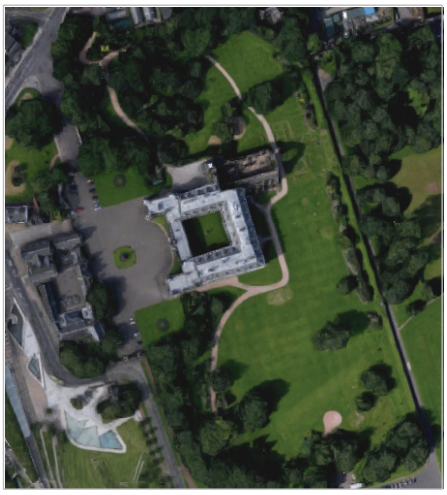
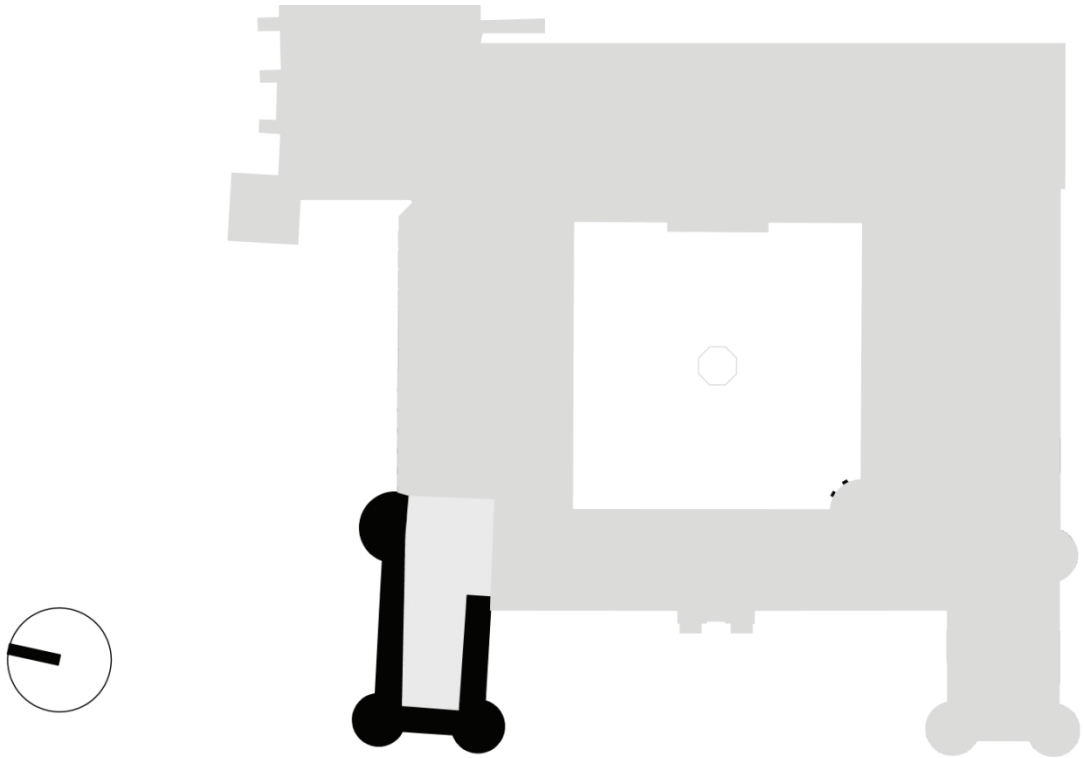


Image form Google maps 2017

GENERAL IMAGE



IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



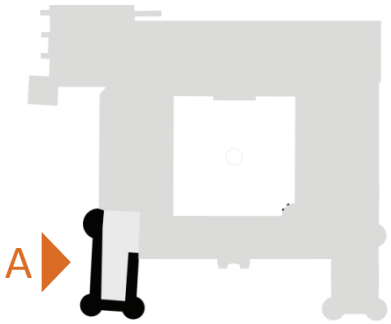
Area included in the research

Area not included in the research

Walls inspected

HOLYROOD PALACE OLD TOWER_ EDINBURGH, CITY OF

IMAGES OF THE BUILDING

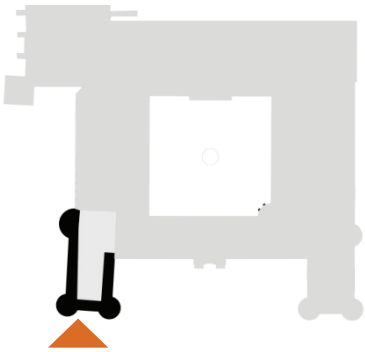


A



HOLYROOD PALACE OLD TOWER_ EDINBURGH, CITY OF

IMAGES OF THE BUILDING



A



HOLYROOD PALACE OLD TOWER_ EDINBURGH, CITY OF

IMAGES OF THE BUILDING



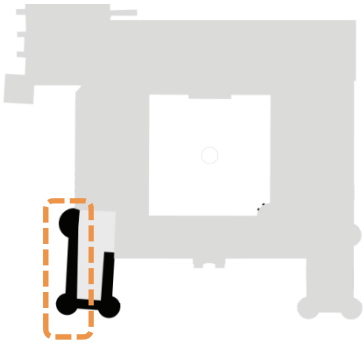
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HOLYROOD PALACE OLD TOWER_ EDINBURGH, CITY OF

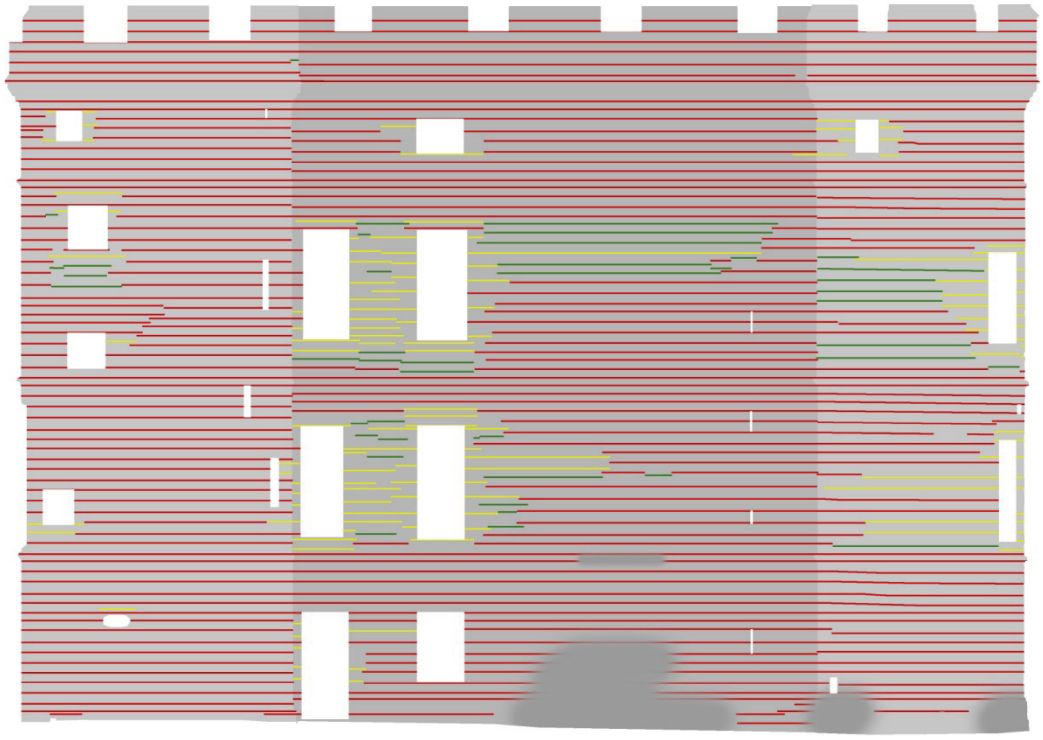
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

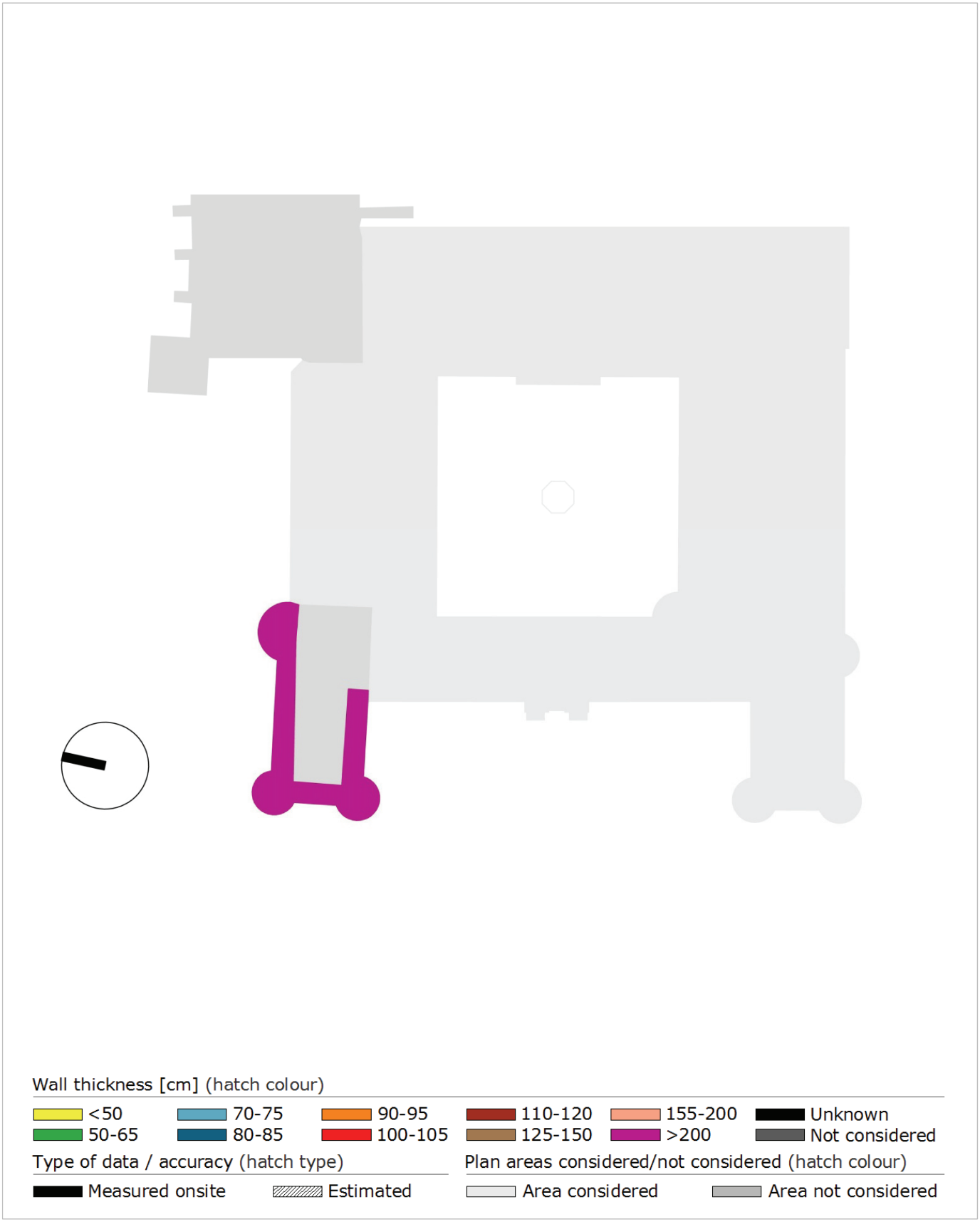


Courses determined by quoins
Courses determined by jambs
Other courses

HOLYROOD PALACE OLD TOWER_ EDINBURGH, CITY OF

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



HOLYROOD PALACE OLD TOWER_ EDINBURGH, CITY OF

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


IMG_7382_corrected_silhouette


IMG_7384_corrected_silhouette


IMG_7386_corrected_silhouette


IMG_7388_corrected_silhouette


IMG_7400_corrected_silhouette

HOLYROOD PALACE OLD TOWER_ EDINBURGH, CITY OF

OTHER FEATURES



KILCHURN CASTLE _ARGYLL AND BUTE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

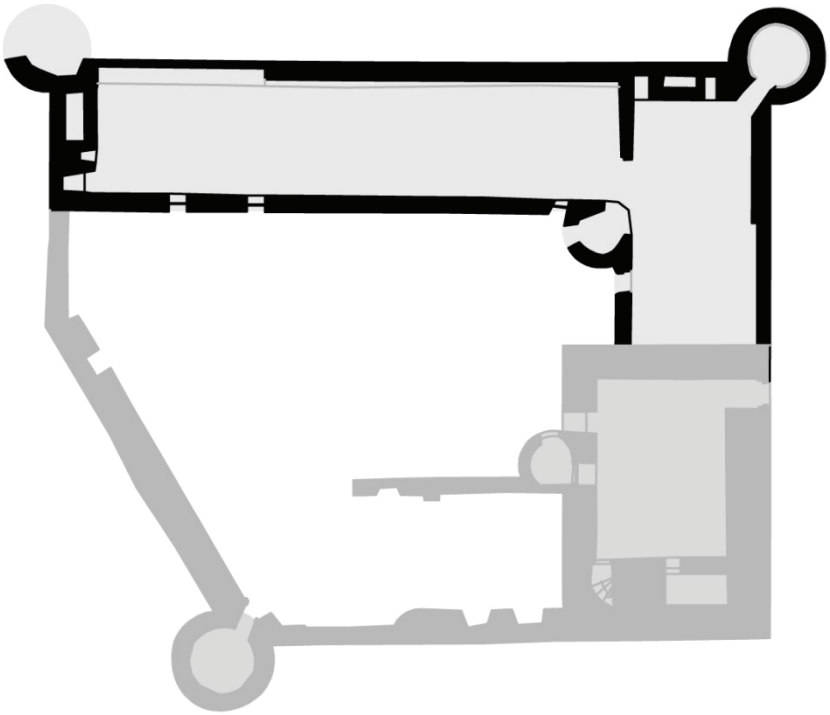


GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



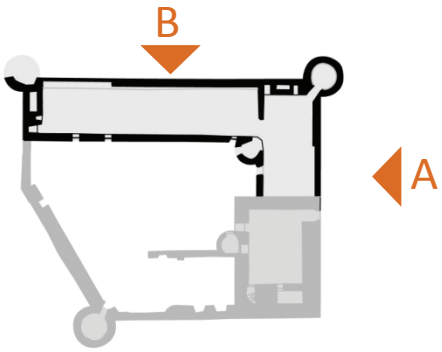
Area included in the research

Area not included in the research

Walls inspected

KILCHURN CASTLE _ARGYLL AND BUTE

IMAGES OF THE BUILDING



A



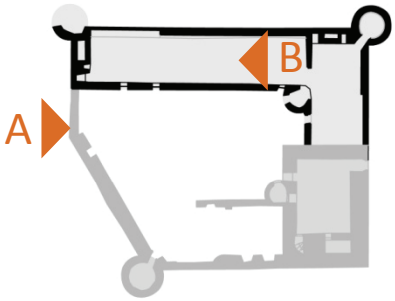
B





KILCHURN CASTLE _ARGYLL AND BUTE

IMAGES OF THE BUILDING



A



B

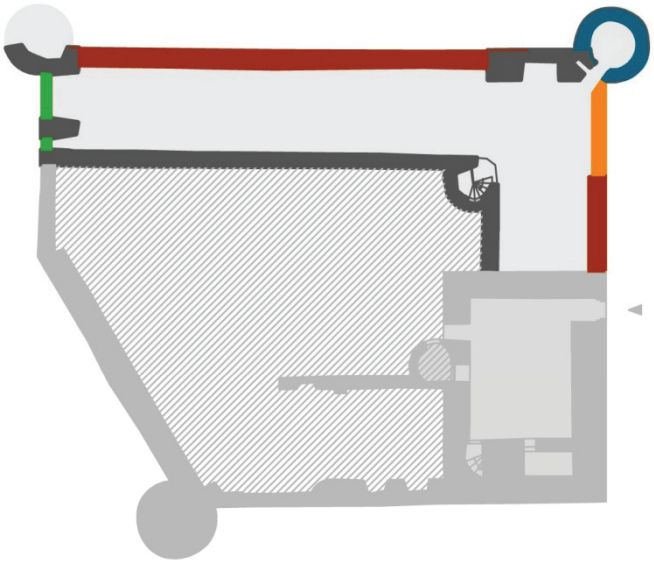


KILCHURN CASTLE _ARGYLL AND BUTE

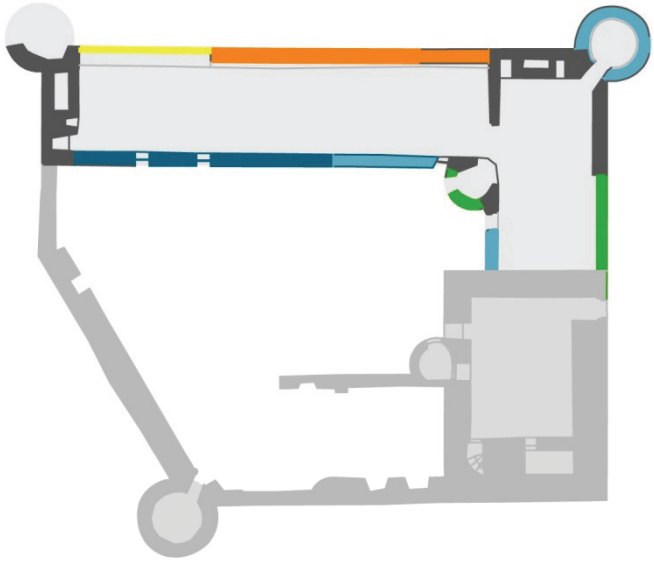
WALL THICKNESSES

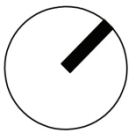
WALL THICKNESSES: GROUND FLOOR

BASEMENT



MAIN FLOOR





Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

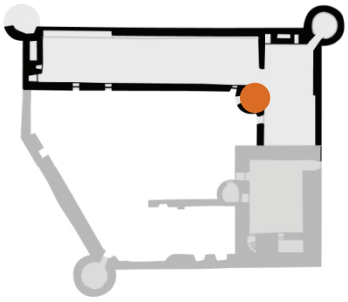
Measured onsite | Estimated

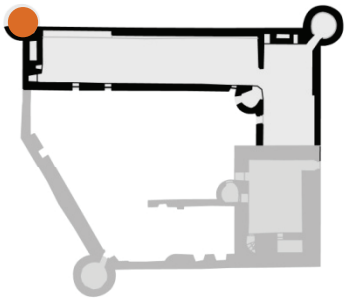
Plan areas considered/not considered (hatch colour)

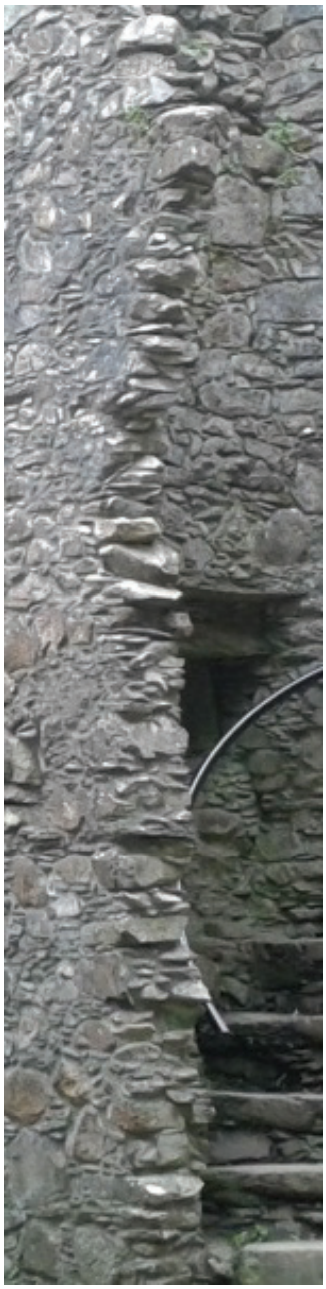
Area considered | Area not considered

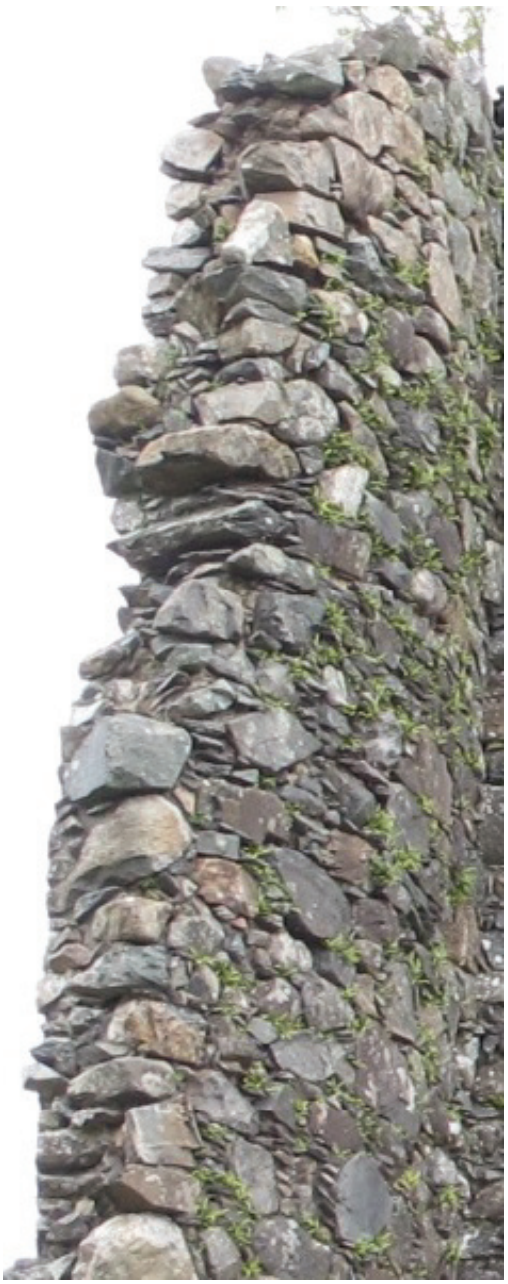
KILCHURN CASTLE _ARGYLL AND BUTE

WALL SECTIONS





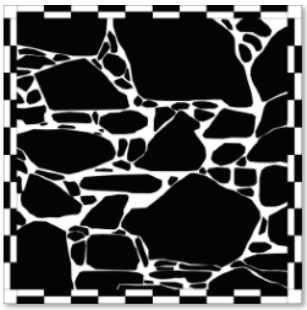


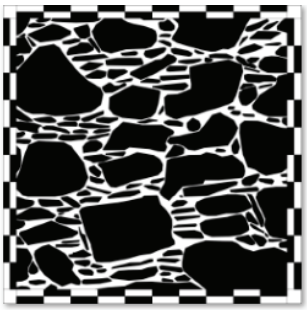


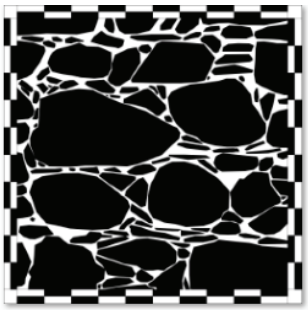
KILCHURN CASTLE _ARGYLL AND BUTE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


IMG_5719_corrected_silhouette


IMG_5733_corrected_silhouette


IMG_5745_corrected_silhouette


IMG_5761_corrected_silhouette


IMG_5941_corrected_silhouette


IMG_5955_corrected_silhouette

KILCHURN CASTLE TOWER_ARGYLL AND BUTE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

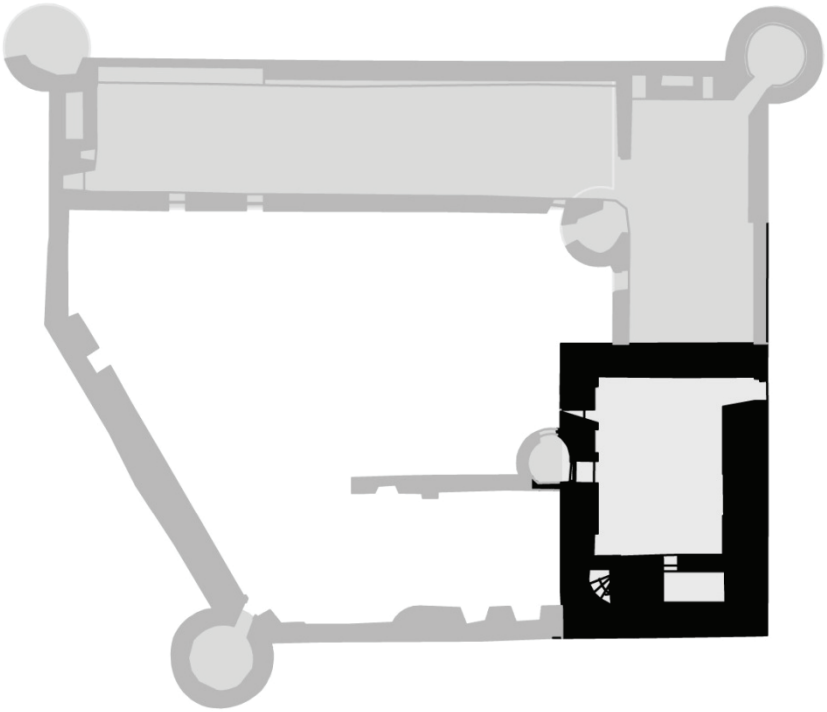


GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



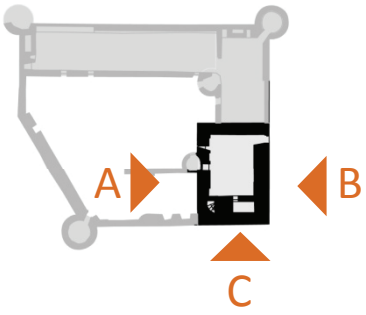
Area included in the research

Area not included in the research

Walls inspected

KILCHURN CASTLE TOWER_ARGYLL AND BUTE

IMAGES OF THE BUILDING



A



B



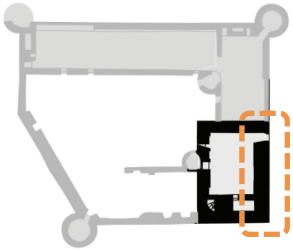
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KILCHURN CASTLE TOWER_ARGYLL AND BUTE

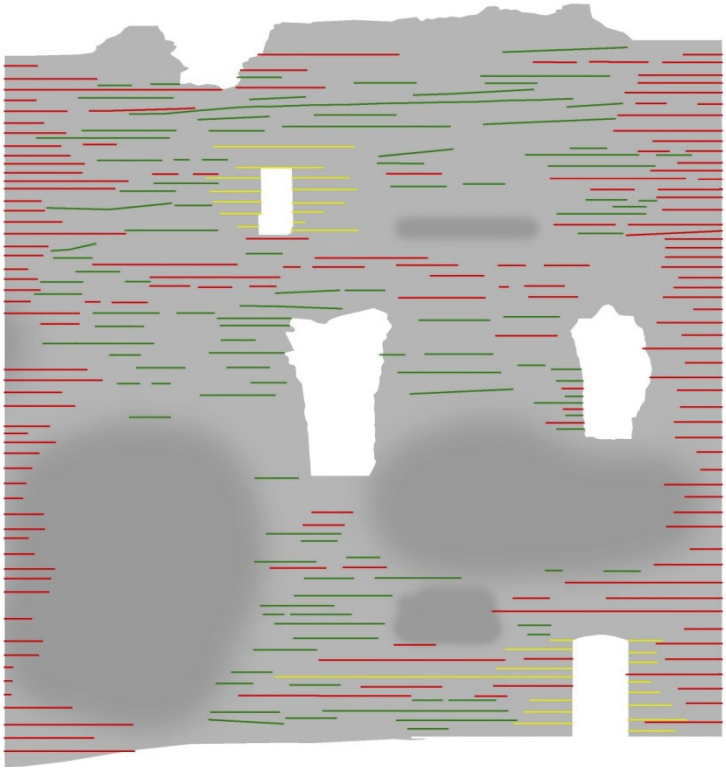
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

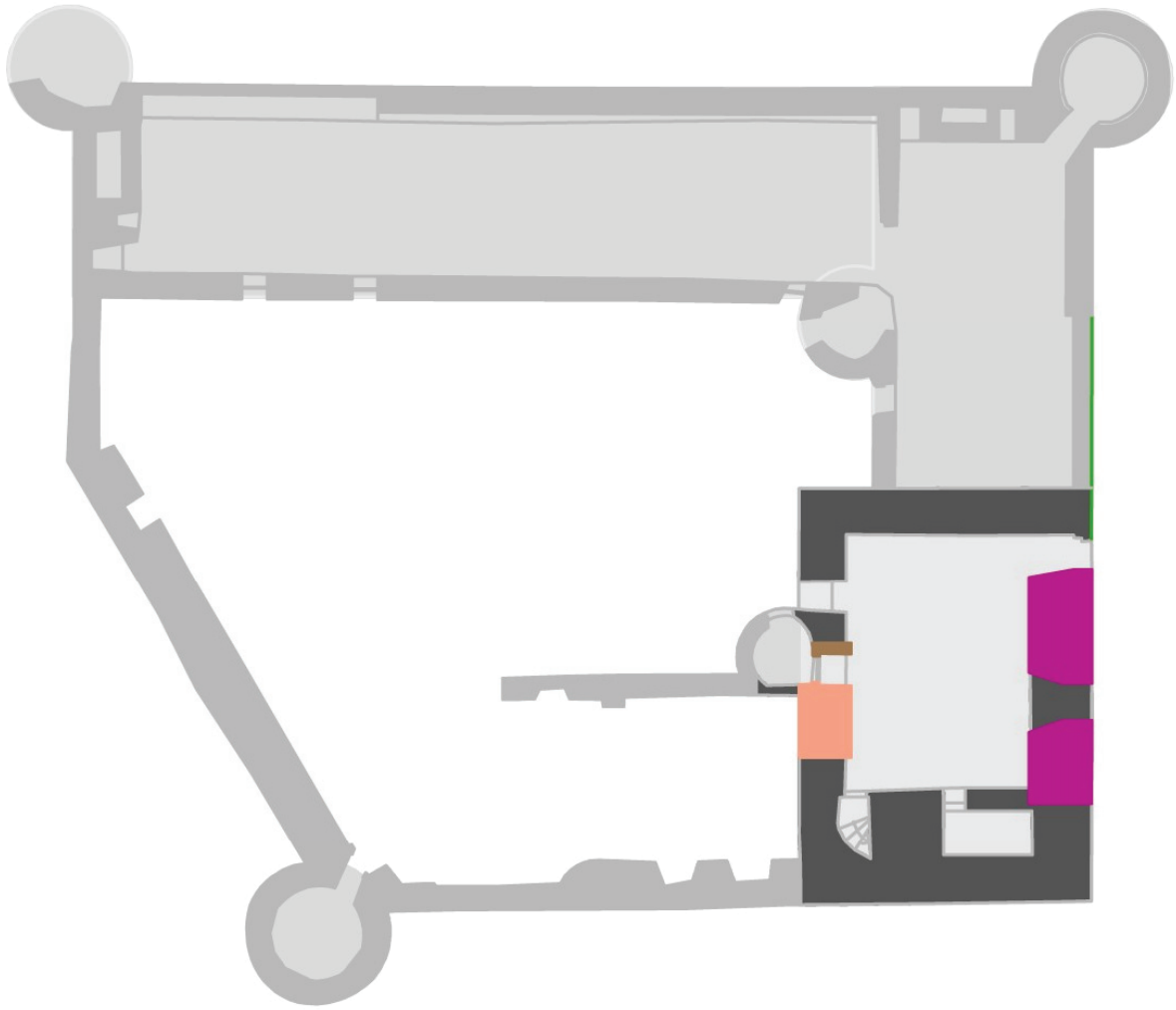


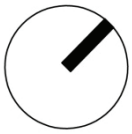
Courses determined by quoins
Courses determined by jambs
Other courses

KILCHURN CASTLE TOWER_ARGYLL AND BUTE

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR





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50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

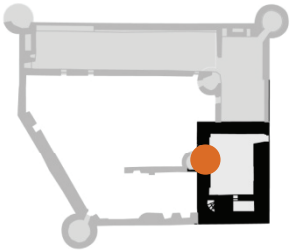
Measured onsite | Estimated

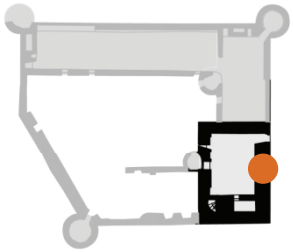
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

KILCHURN CASTLE TOWER_ARGYLL AND BUTE

WALL SECTIONS





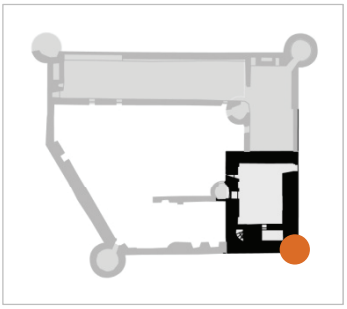




KILCHURN CASTLE TOWER_ARGYLL AND BUTE

CORNERS

LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



KILCHURN CASTLE TOWER_ARGYLL AND BUTE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



IMG_5709_corrected_silhouette



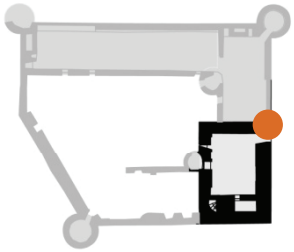
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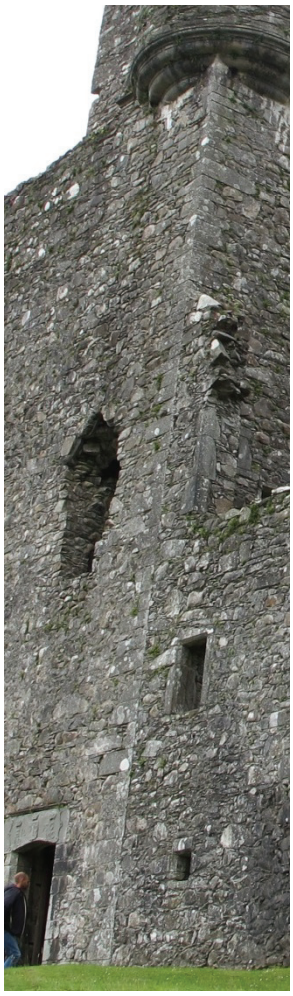
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KILCHURN CASTLE TOWER_ARGYLL AND BUTE

OTHER FEATURES





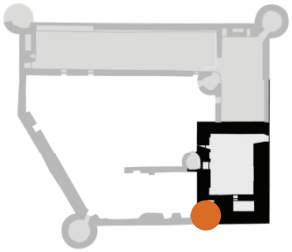


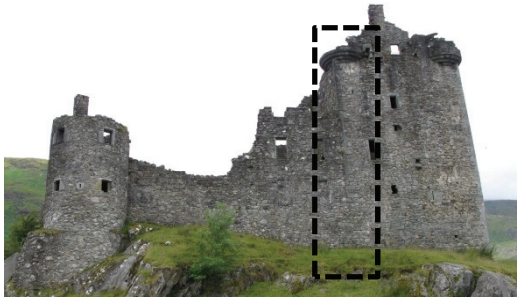




KILCHURN CASTLE TOWER_ARGYLL AND BUTE

OTHER FEATURES









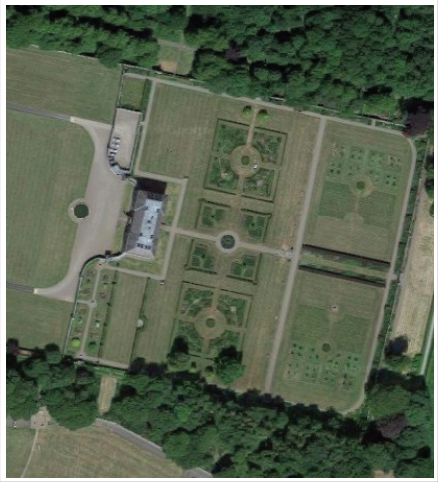
KINROSS HOUSE_PERTH AND KINROSS

GENERAL INFORMATION

LOCATION



BUILDING PLAN



GENERAL IMAGE

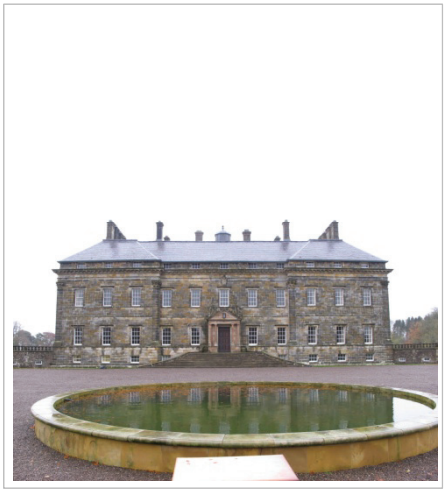
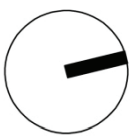


Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





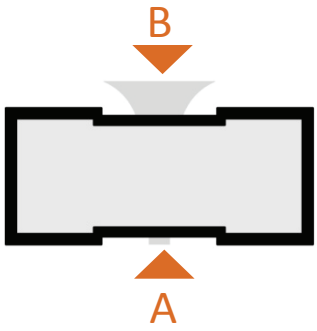
Area included in the research

Area not included in the research

Walls inspected

KINROSS HOUSE_PERTH AND KINROSS

IMAGES OF THE BUILDING



A



B



KINROSS HOUSE_PERTH AND KINROSS

IMAGES OF THE BUILDING



A



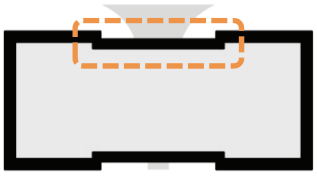
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KINROSS HOUSE_PERTH AND KINROSS

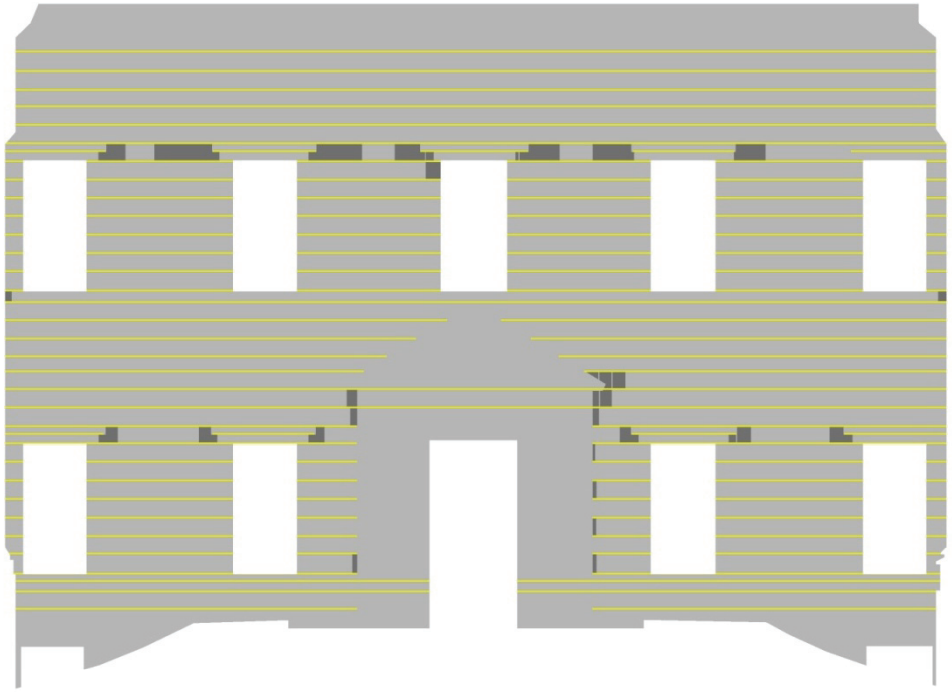
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES



Courses determined by quoins
Courses determined by jambs
Other courses

KINROSS HOUSE_PERTH AND KINROSS

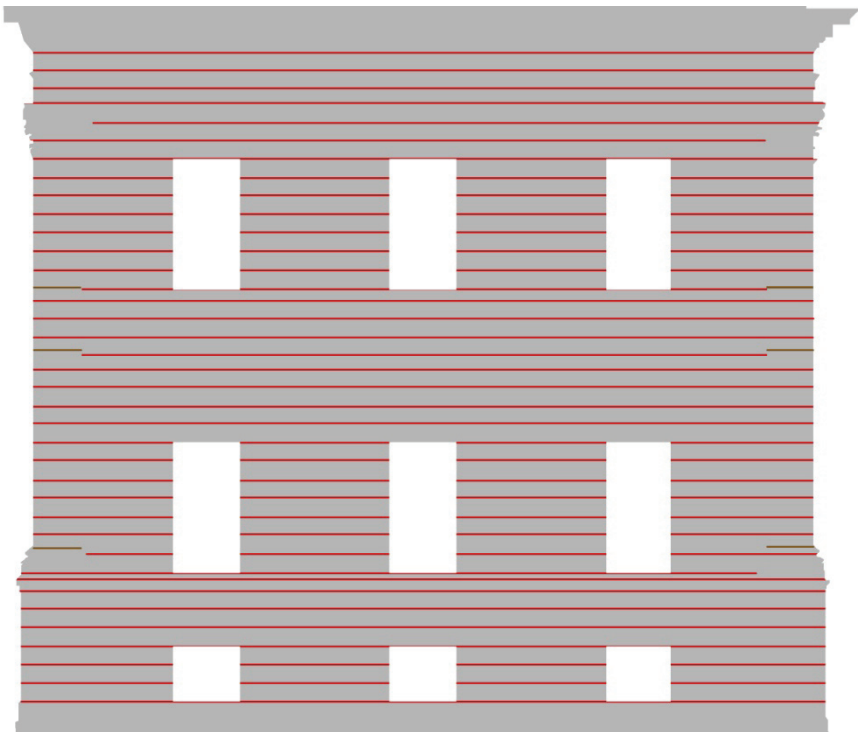
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES



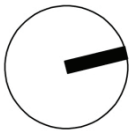
Courses determined by quoins
Courses determined by jambs
Other courses

KINROSS HOUSE_PERTH AND KINROSS

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR





Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

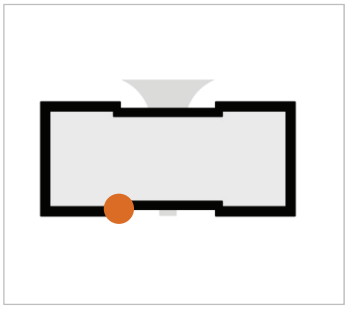
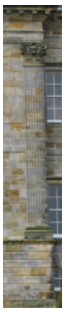
Measured onsite | Estimated

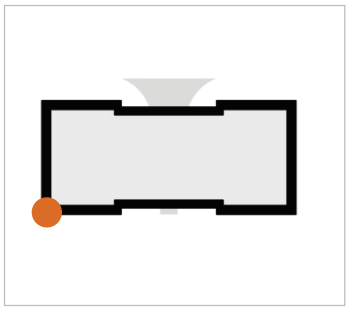
Plan areas considered/not considered (hatch colour)

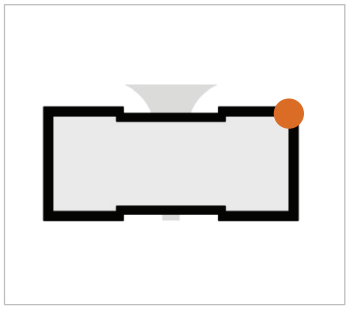
Area considered | Area not considered

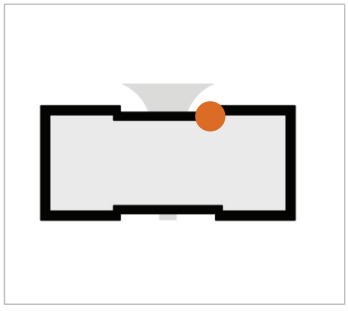
KINROSS HOUSE_PERTH AND KINROSS

CORNERS

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			

KINROSS HOUSE_PERTH AND KINROSS

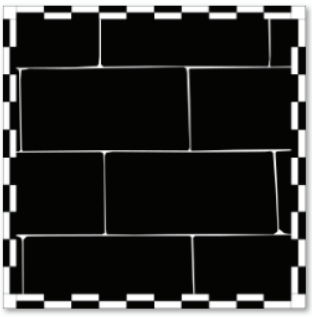
MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION

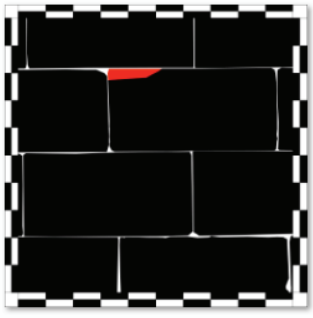

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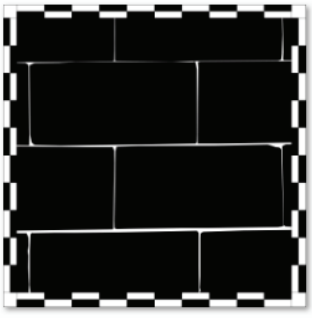

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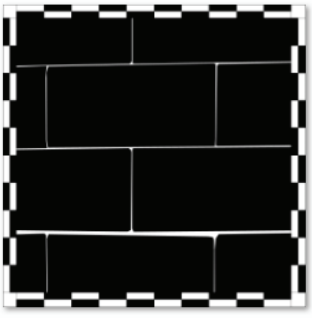

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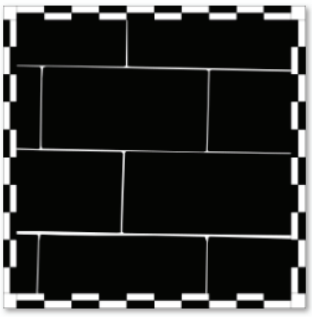

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IMG_1805_corrected_silhouette


IMG_1807_corrected_silhouette


IMG_1848_corrected_silhouette


IMG_1864_corrected_silhouette


IMG_1936_corrected_silhouette


IMG_1990_corrected_silhouette

KINROSS HOUSE_PERTH AND KINROSS

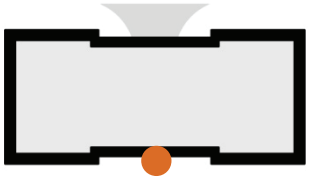
OTHER FEATURES





KINROSS HOUSE_PERTH AND KINROSS

OTHER FEATURES







KINROSS HOUSE_PERTH AND KINROSS

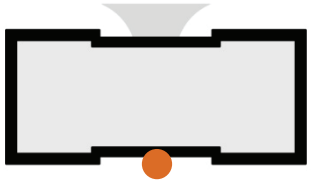
OTHER FEATURES





KINROSS HOUSE_PERTH AND KINROSS

OTHER FEATURES





LINLITHGOW PALACE _ WEST LOTHIAN

GENERAL INFORMATION

LOCATION



BUILDING PLAN

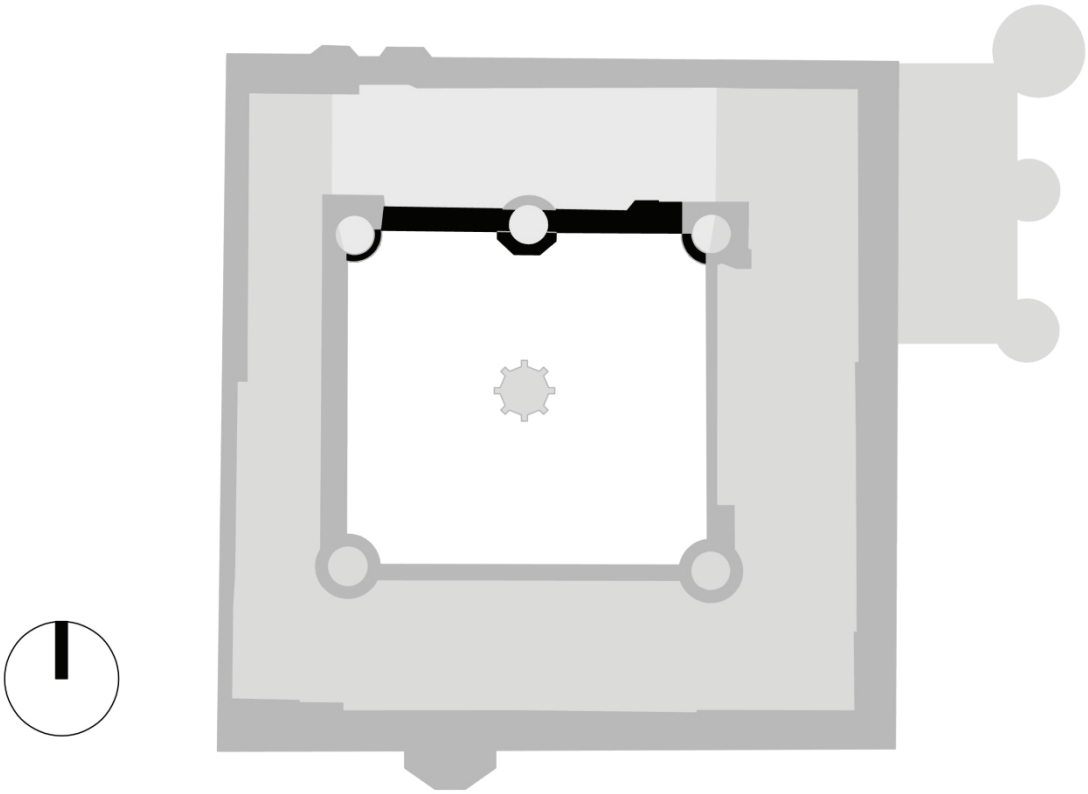


GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



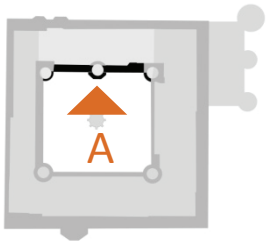
Area included in the research

Area not included in the research

Walls inspected

LINLITHGOW PALACE _ WEST LOTHIAN

IMAGES OF THE BUILDING



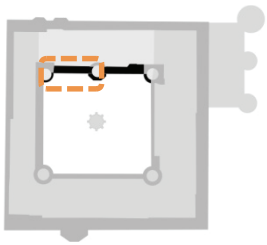
A



LINLITHGOW PALACE _ WEST LOTHIAN

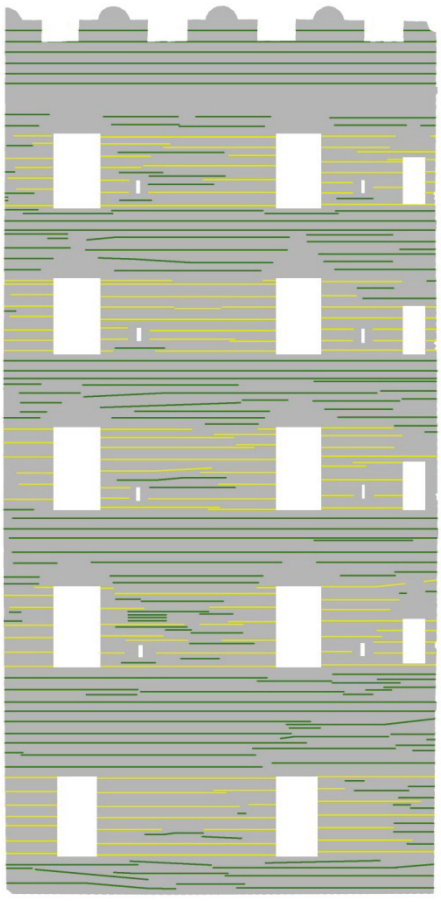
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

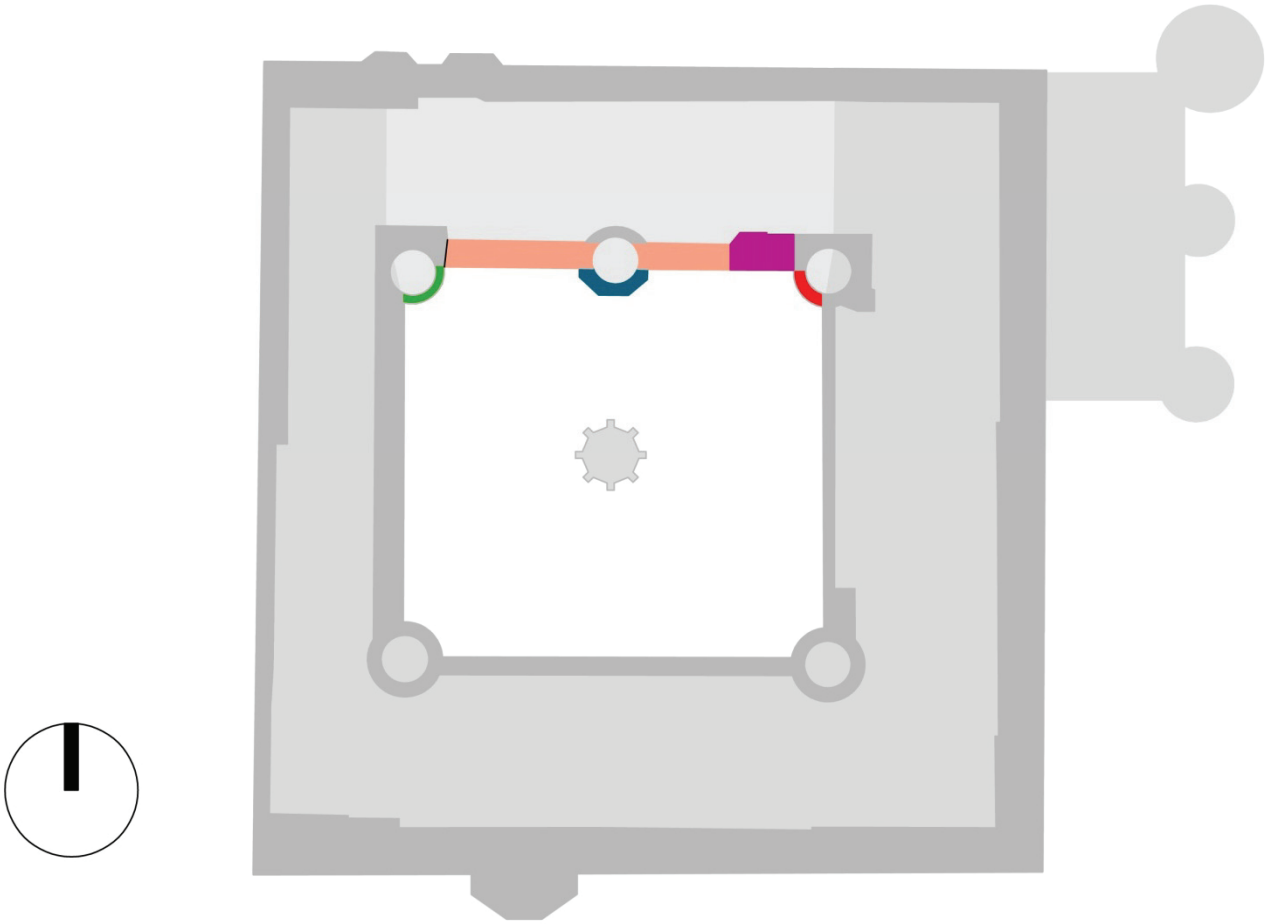


Courses determined by quoins
Courses determined by jambs
Other courses

LINLITHGOW PALACE _ WEST LOTHIAN

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

Measured onsite | Estimated

Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

LINLITHGOW PALACE _ WEST LOTHIAN

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



IMG_5142_corrected_silhouette



IMG_5172_corrected_silhouette

MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

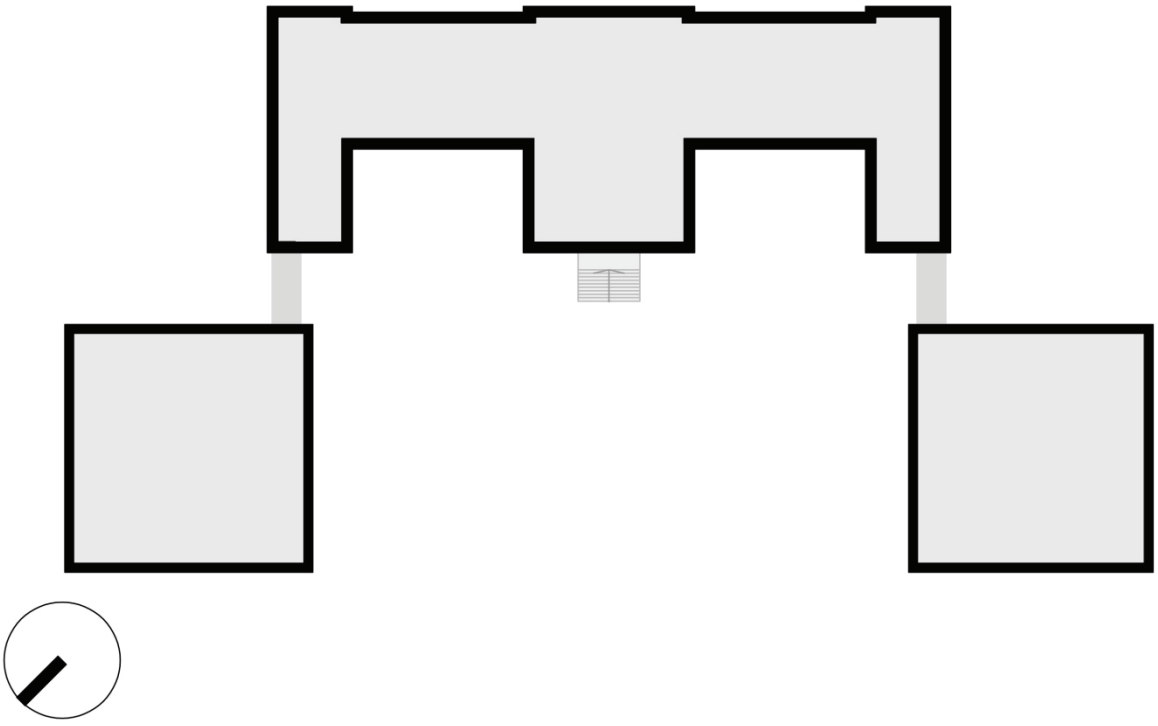


GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



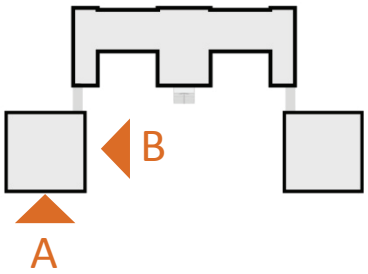
Area included in the research

Area not included in the research

Walls inspected

MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

IMAGES OF THE BUILDING



A

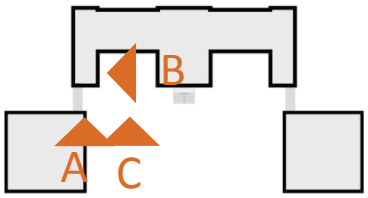


B



MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

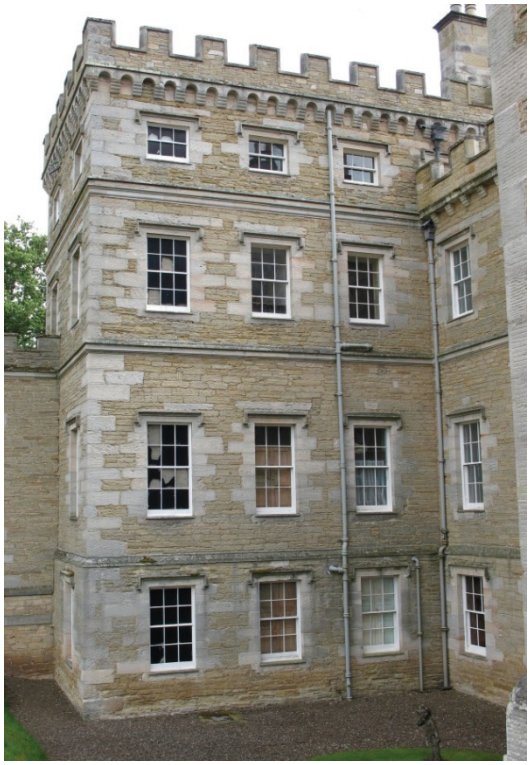
IMAGES OF THE BUILDING



A



B

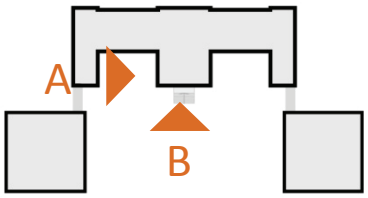


C



MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

IMAGES OF THE BUILDING



A

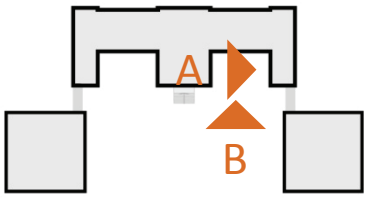


B



MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

IMAGES OF THE BUILDING



A

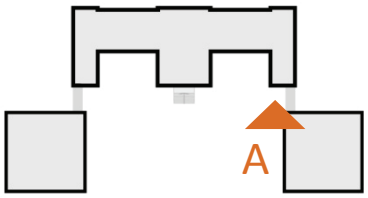


B



MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

IMAGES OF THE BUILDING

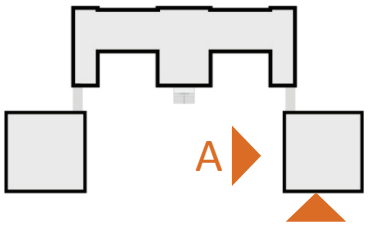


A



MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

IMAGES OF THE BUILDING



A

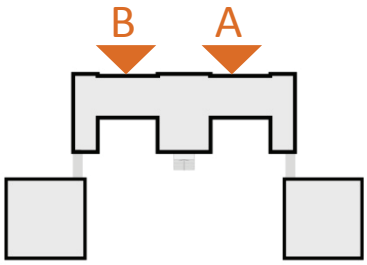


B



MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

IMAGES OF THE BUILDING



A



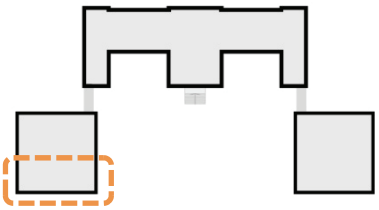
B



MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

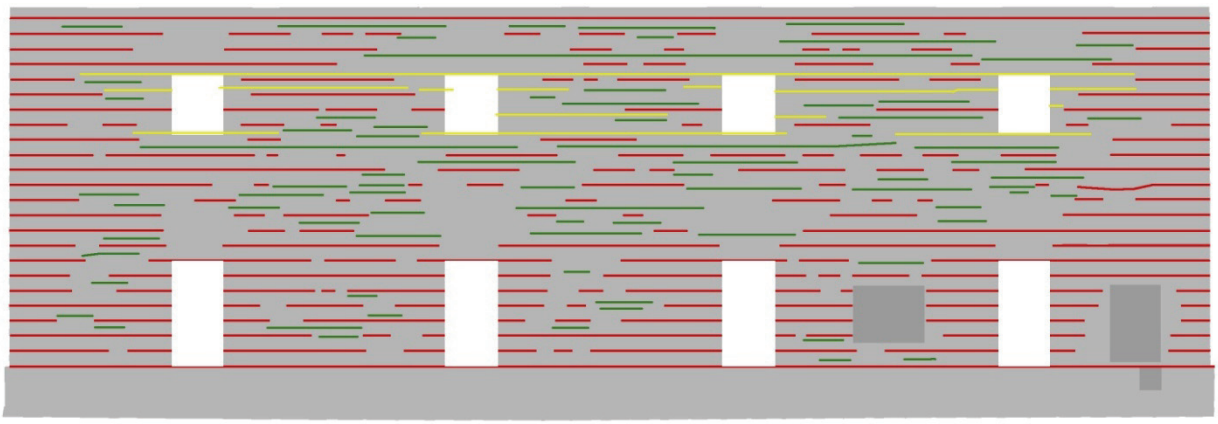
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

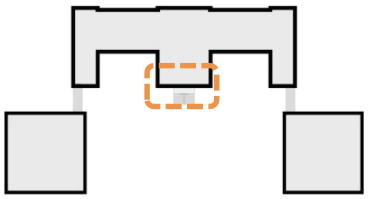


Courses determined by quoins
Courses determined by jambs
Other courses

MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

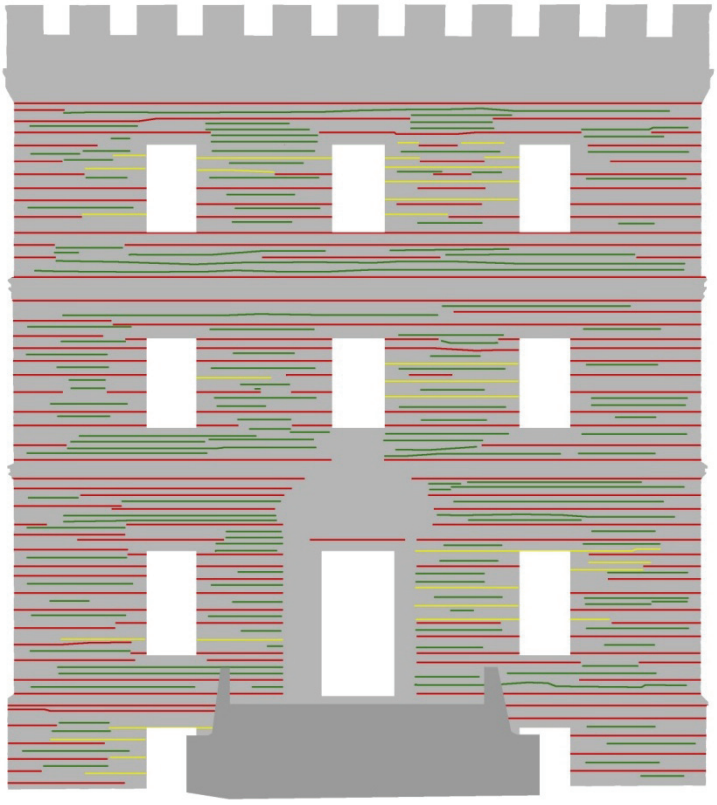
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

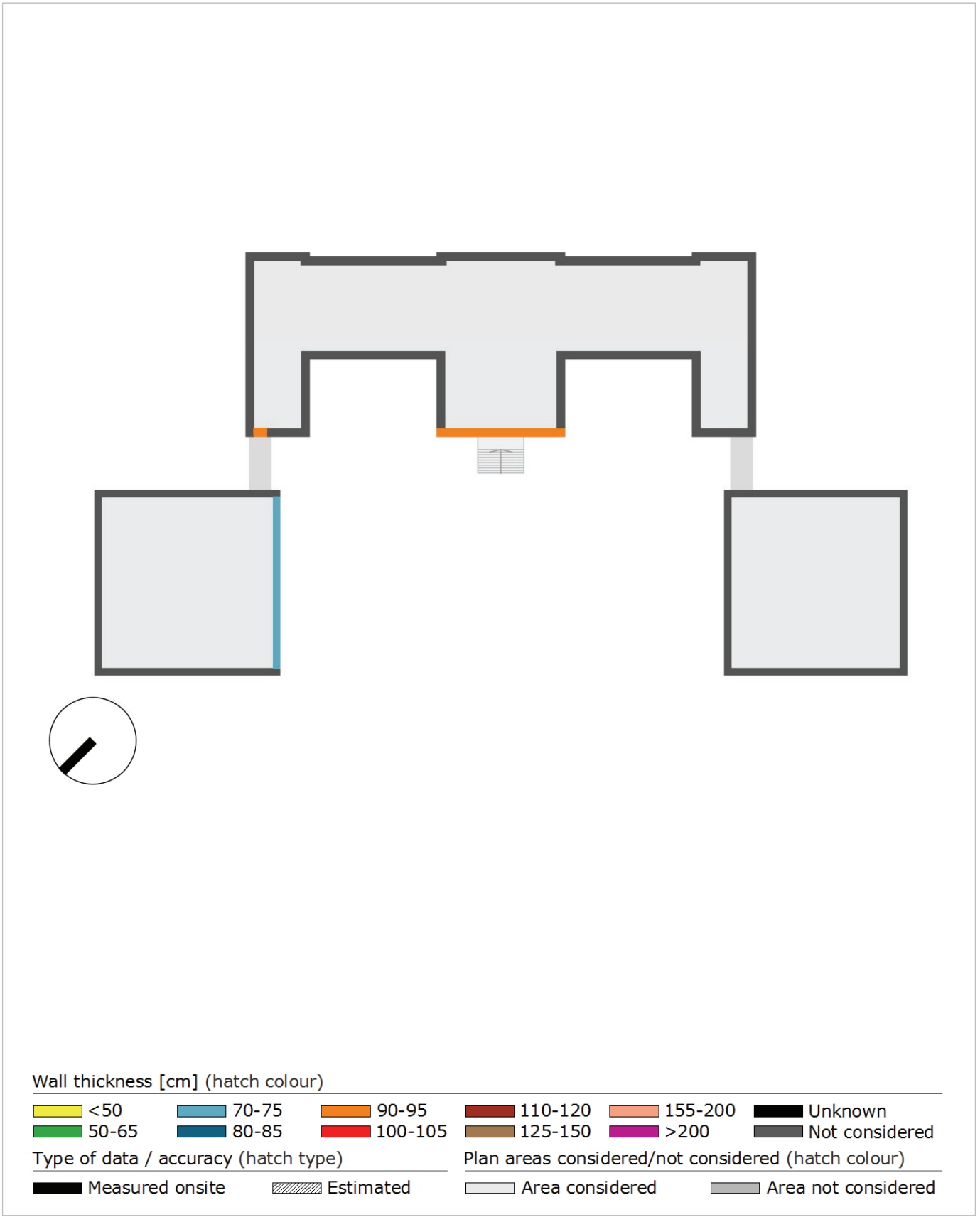


Courses determined by quoins
Courses determined by jambs
Other courses

MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

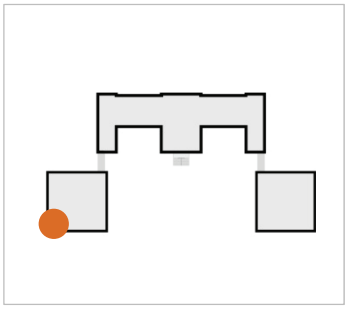
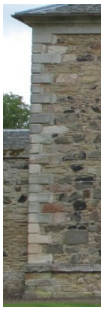
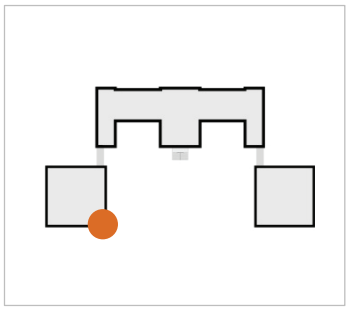
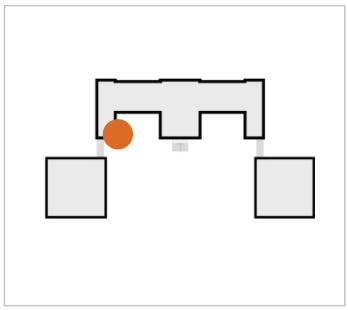
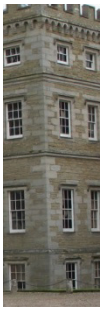
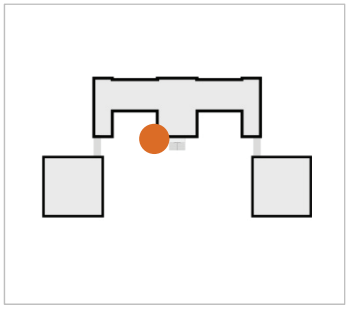
WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



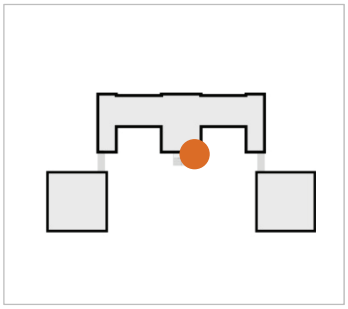
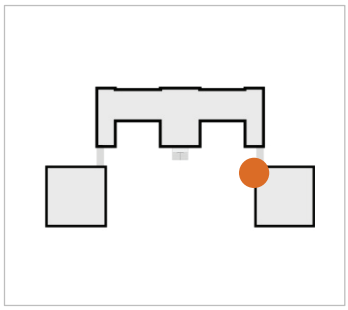
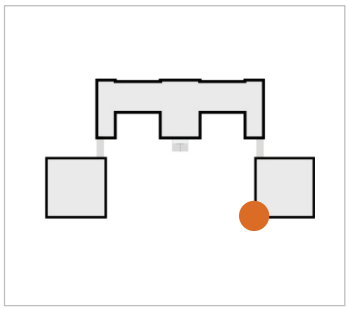
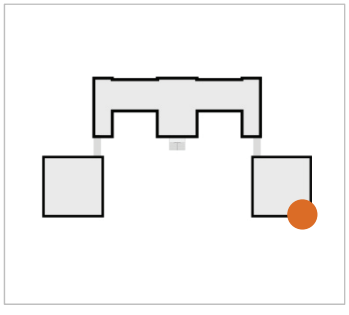
MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

CORNERS

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			

MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

CORNERS

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			

MELLERSTAIN HOUSE _ SCOTTISH BORDERS, THE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


IMG_6602_corrected_silhouette


IMG_6608_corrected_silhouette


IMG_6614_corrected_silhouette


IMG_6624_corrected_silhouette


IMG_6631_corrected_silhouette


IMG_6650_corrected_silhouette


IMG_6656_corrected_silhouette


IMG_6662_corrected_silhouette


IMG_6668_corrected_silhouette


IMG_6672_corrected_silhouette


IMG_6676_corrected_silhouette


IMG_6693_corrected_silhouette


IMG_6705_corrected_silhouette


IMG_6719_corrected_silhouette


IMG_6730_corrected_silhouette


IMG_6734_corrected_silhouette


IMG_6739_corrected_silhouette


IMG_6742_corrected_silhouette


IMG_6745_corrected_silhouette


IMG_6759_corrected_silhouette

NEWLISTON HOUSE_ EDIBURGH, CITY OF

GENERAL INFORMATION

LOCATION



BUILDING PLAN

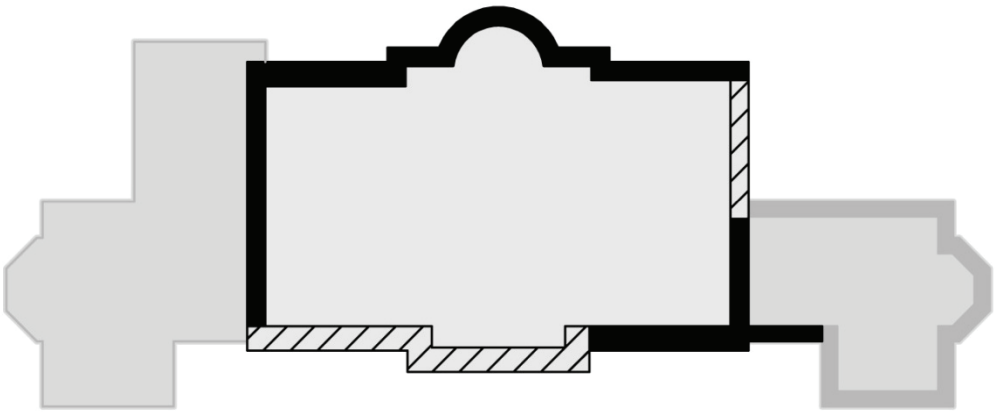


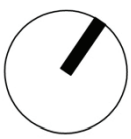
GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





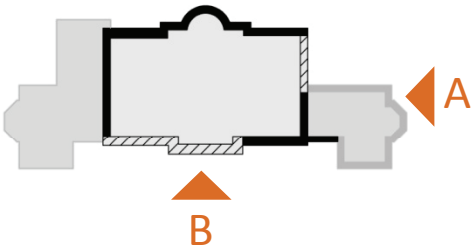
Area included in the research

Area not included in the research

Walls inspected

NEWLISTON HOUSE_ EDIBURGH, CITY OF

IMAGES OF THE BUILDING



A

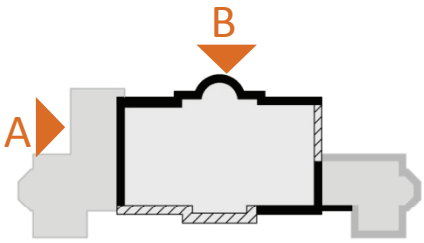


B



NEWLISTON HOUSE_ EDIBURGH, CITY OF

IMAGES OF THE BUILDING



A



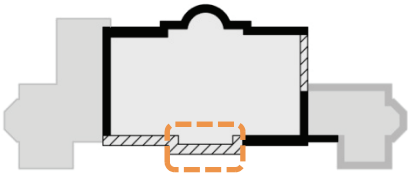
B



NEWLISTON HOUSE_ EDIBURGH, CITY OF

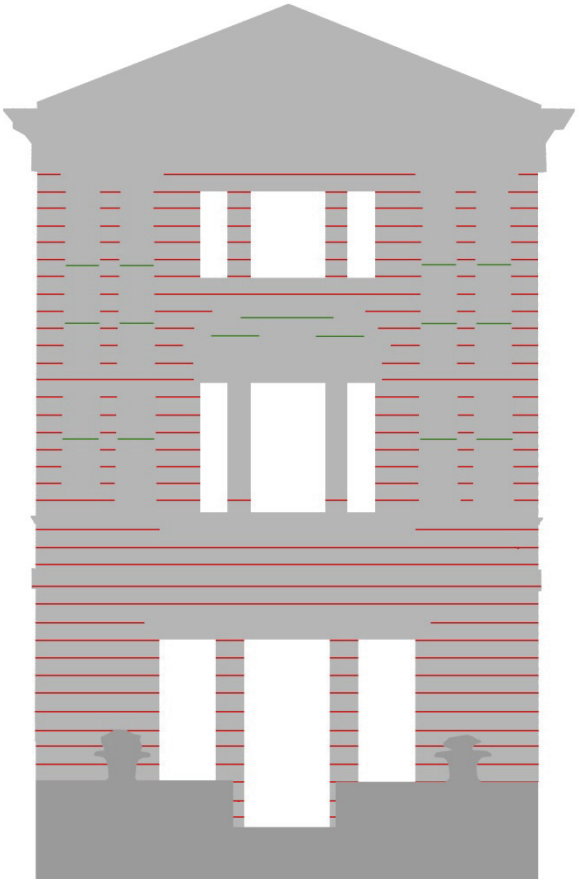
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

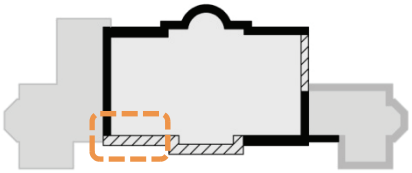


Courses determined by quoins
Courses determined by jambs
Other courses

NEWLISTON HOUSE_ EDIBURGH, CITY OF

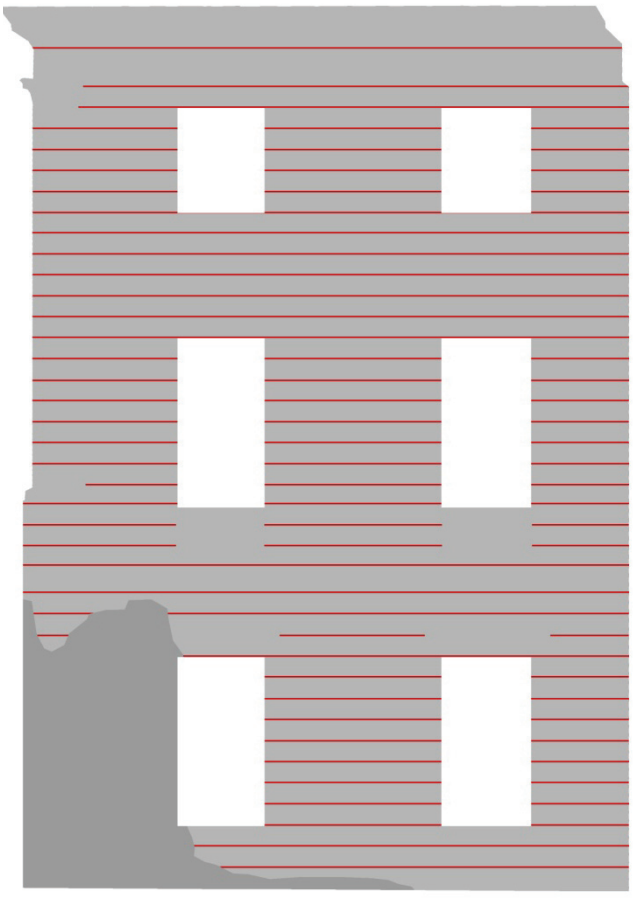
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

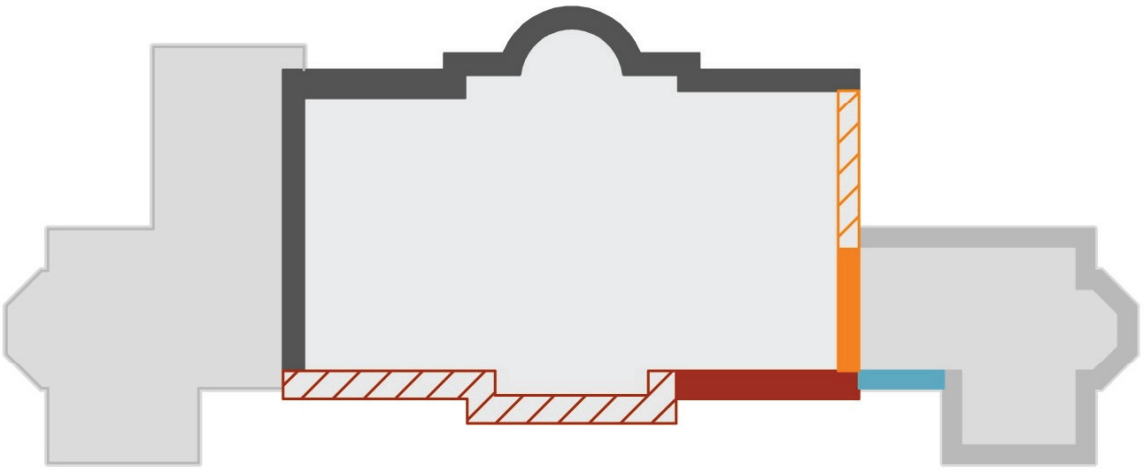


Courses determined by quoins
Courses determined by jambs
Other courses

NEWLISTON HOUSE_ EDIBURGH, CITY OF

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

Measured onsite | Estimated

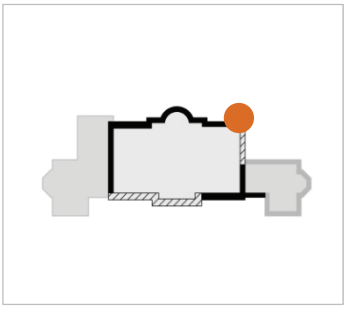
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

NEWLISTON HOUSE_ EDIBURGH, CITY OF

CORNERS

LOCATION



CORNER

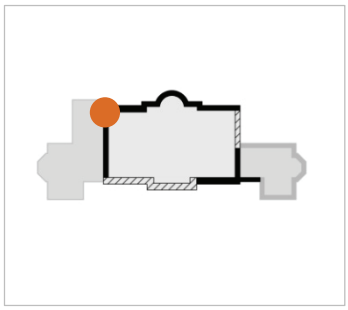
CORNER -SIDE 1



CORNER –SIDE 2



LOCATION



CORNER

CORNER -SIDE 1



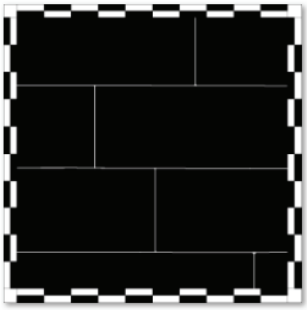
CORNER –SIDE 2



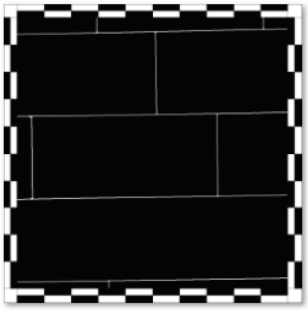
NEWLISTON HOUSE_ EDIBURGH, CITY OF

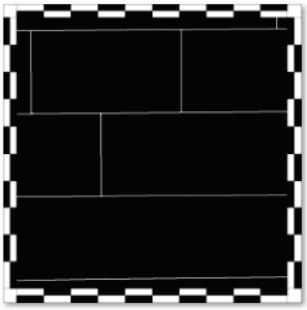
MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


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IMG_5485_corrected_silhouette


IMG_5494_corrected_silhouette

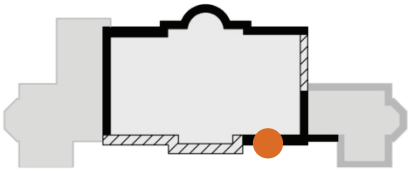

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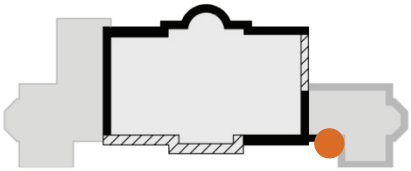

IMG_5519_corrected_silhouette


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NEWLISTON HOUSE_ EDIBURGH, CITY OF

OTHER FEATURES









NEWLISTON HOUSE_ EDIBURGH, CITY OF

OTHER FEATURES



PENICUIK HOUSE _ MIDLOTHIAN

GENERAL INFORMATION

LOCATION



BUILDING PLAN

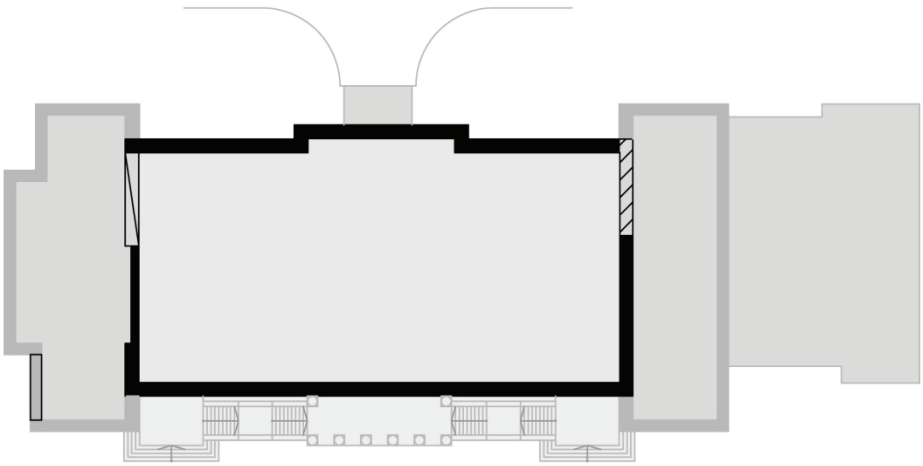


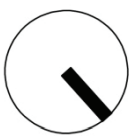
GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





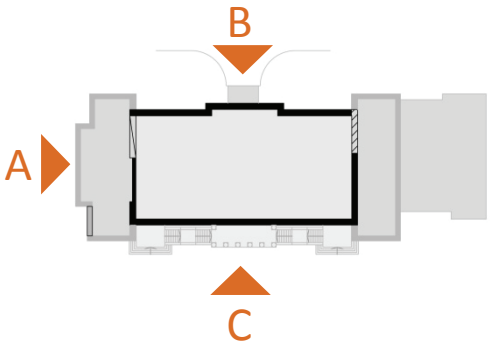
Area included in the research

Area not included in the research

Walls inspected

PENICUIK HOUSE _ MIDLOTHIAN

IMAGES OF THE BUILDING



A



B



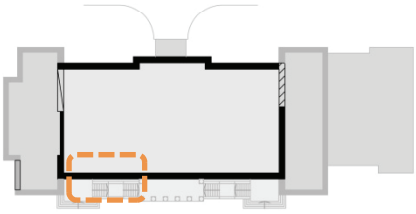
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PENICUIK HOUSE _ MIDLOTHIAN

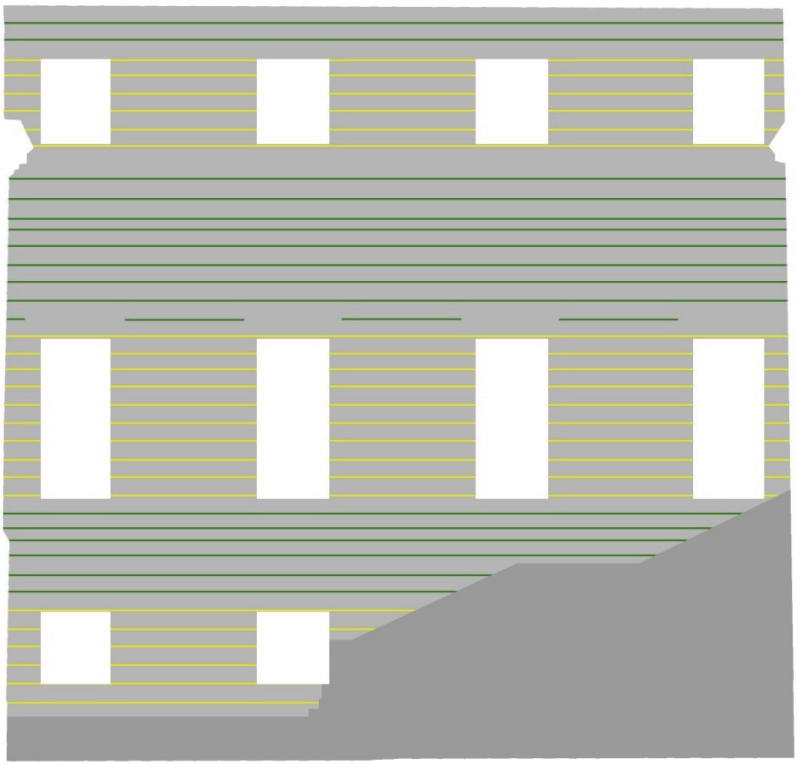
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

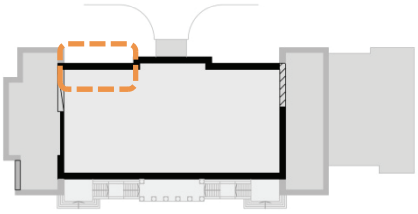


Courses determined by quoins
Courses determined by jambs
Other courses

PENICUIK HOUSE _ MIDLOTHIAN

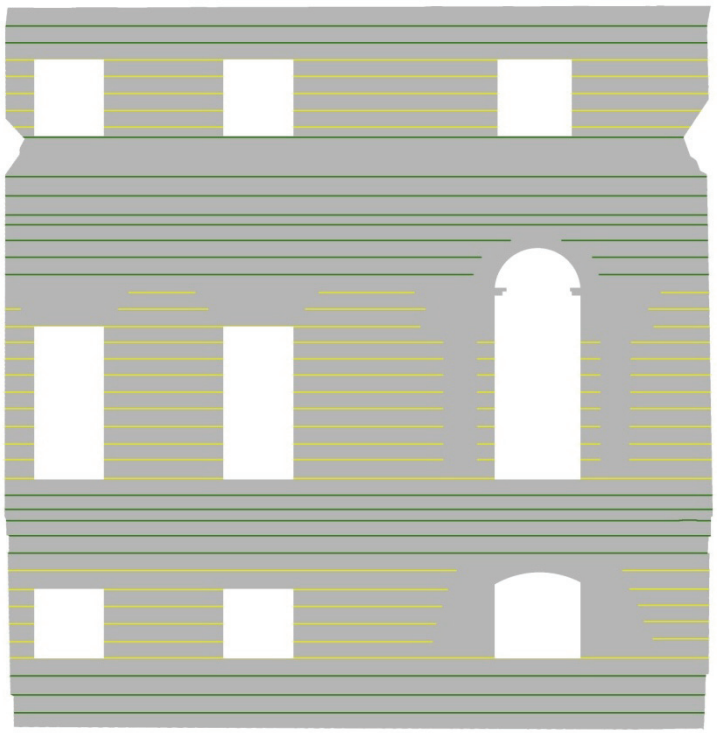
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

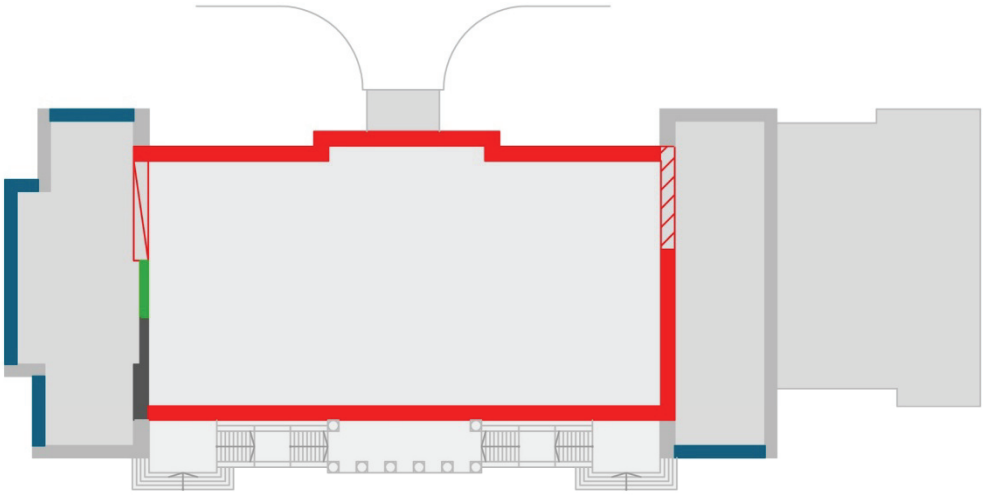


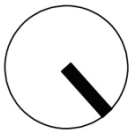
Courses determined by quoins
Courses determined by jambs
Other courses

PENICUIK HOUSE _ MIDLOTHIAN

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR





Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
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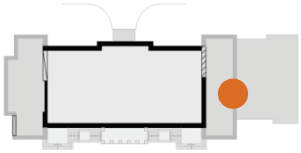
Measured onsite | Estimated

Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

PENICUIK HOUSE _ MIDLOTHIAN

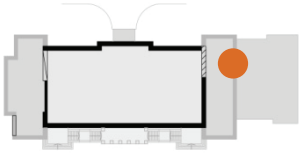
WALL SECTIONS





PENICUIK HOUSE _ MIDLOTHIAN

WALL SECTIONS

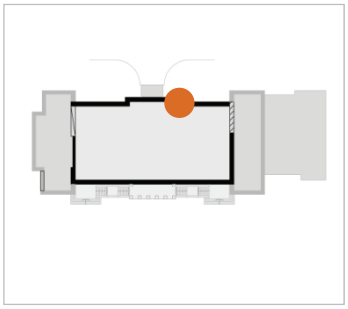




PENICUIK HOUSE _ MIDLOTHIAN

CORNERS

LOCATION



CORNER

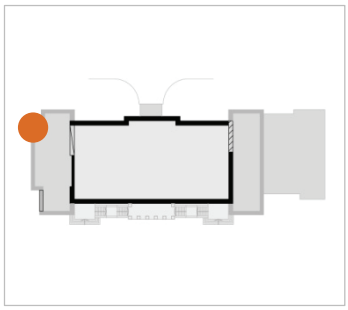


CORNER -SIDE 1

CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1

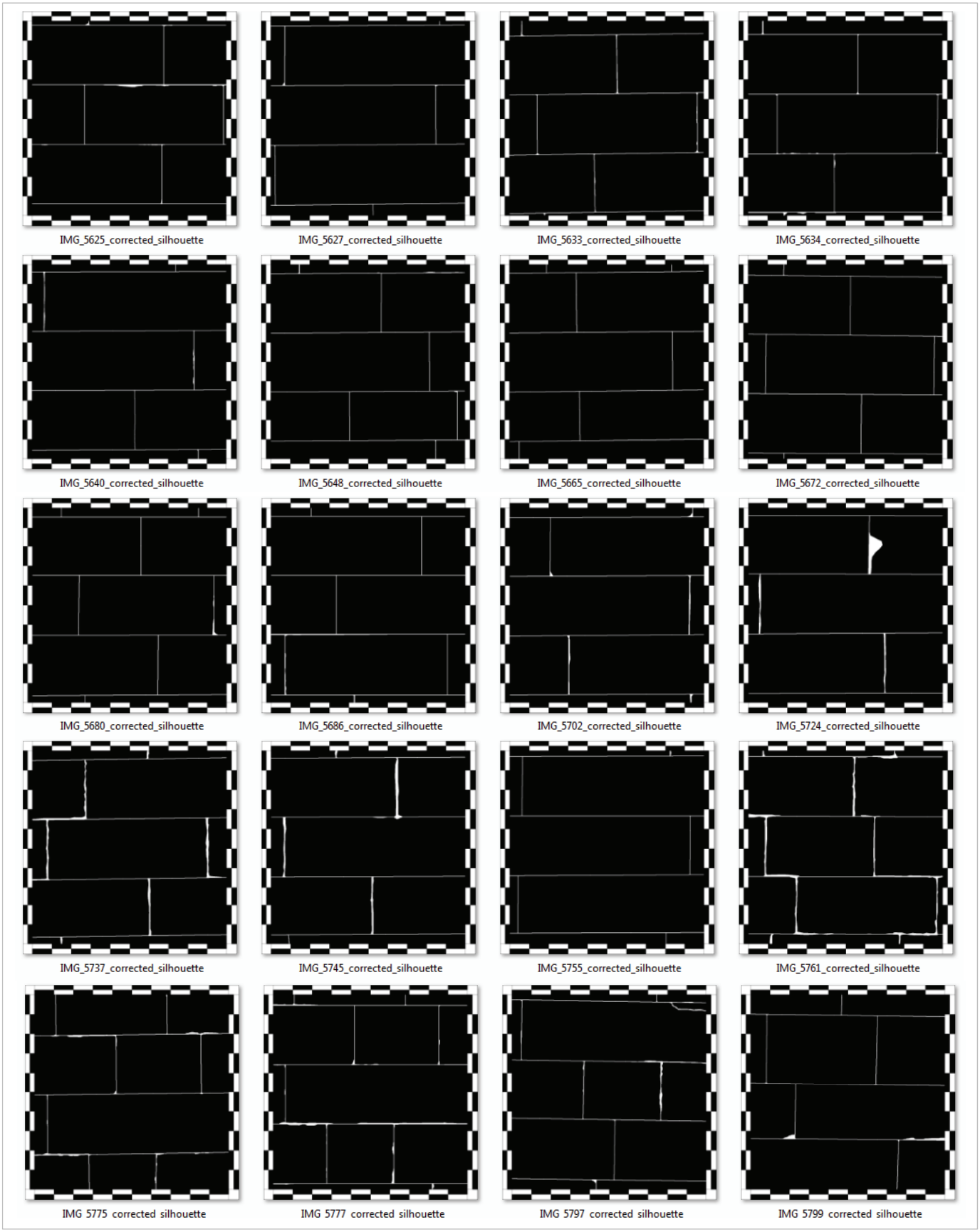
CORNER –SIDE 2



PENICUIK HOUSE _ MIDLOTHIAN

MASONRY PATERNS: 1x1 FRAMES

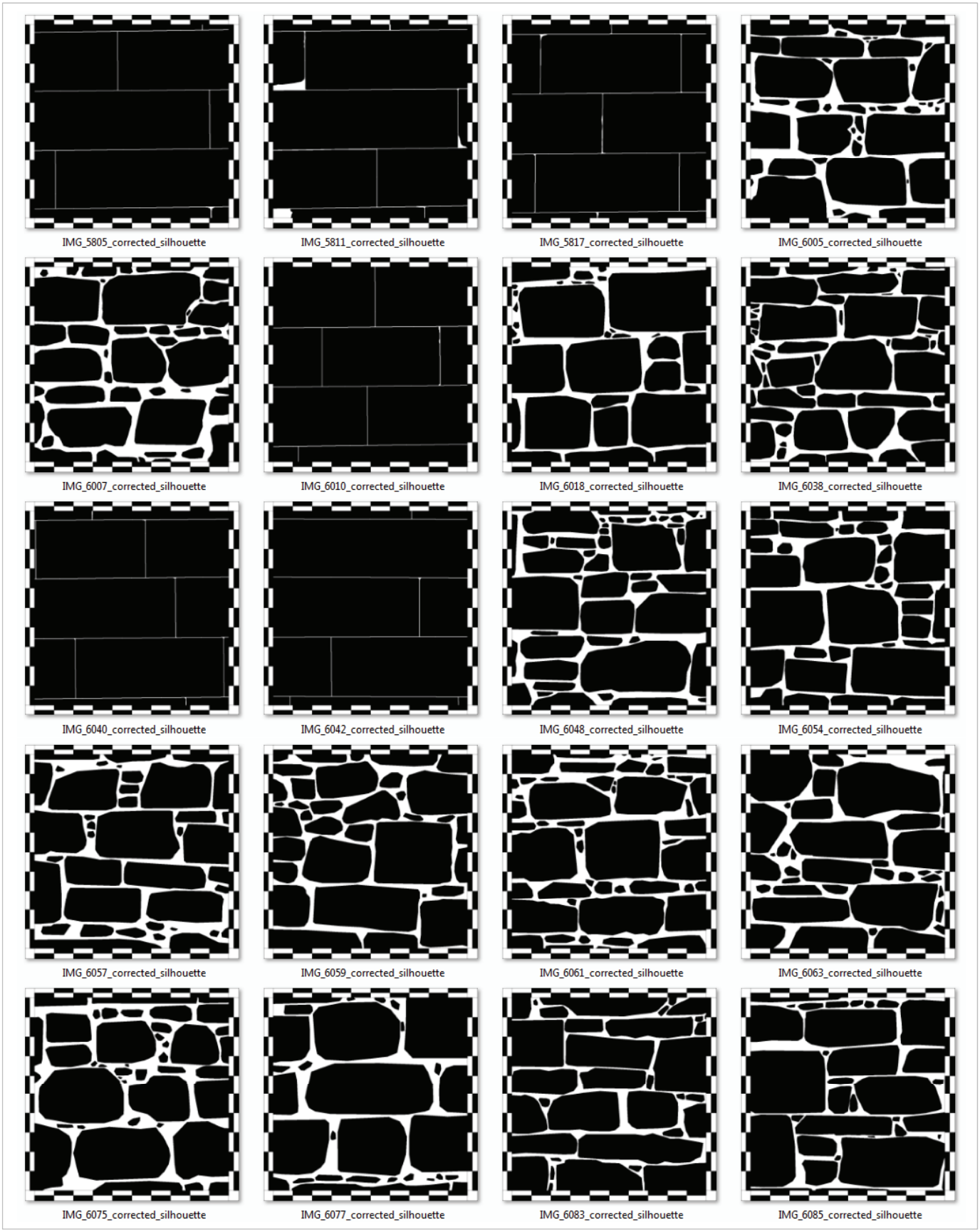
WALL CENTRAL PORTION



PENICUIK HOUSE _ MIDLOTHIAN

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



PENICUIK HOUSE _ MIDLOTHIAN

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


IMG_6089_corrected_silhouette


IMG_6109_corrected_silhouette


IMG_6110_corrected_silhouette


IMG_6112_corrected_silhouette


IMG_6115_corrected_silhouette


IMG_6118_corrected_silhouette


IMG_6123_corrected_silhouette


IMG_6129_corrected_silhouette


IMG_6135_corrected_silhouette


IMG_6141_corrected_silhouette


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IMG_6158_corrected_silhouette


IMG_6170_corrected_silhouette


IMG_6176_corrected_silhouette

PENICUIK HOUSE _ MIDLOTHIAN

OTHER FEATURES



PITTARTHIE CASTLE_FIFE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

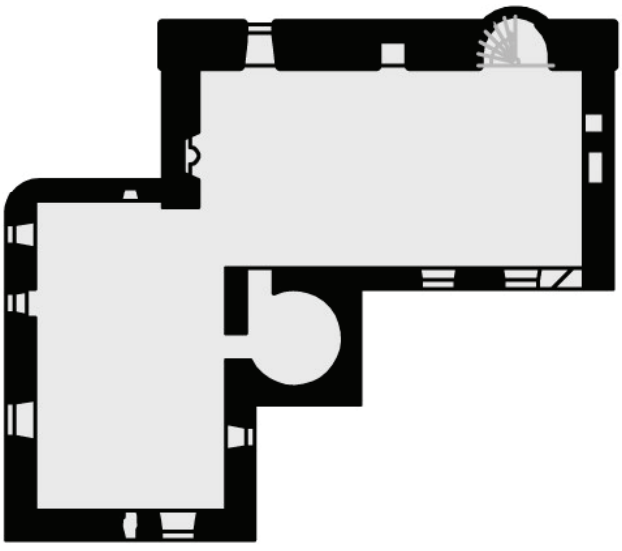


Image form Google maps 2017

GENERAL IMAGE



IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





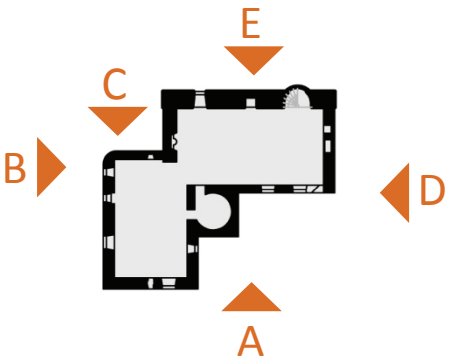
Area included in the research

Area not included in the research

Walls inspected

PITTARTHIE CASTLE_FIFE

IMAGES OF THE BUILDING



A



B



C



D



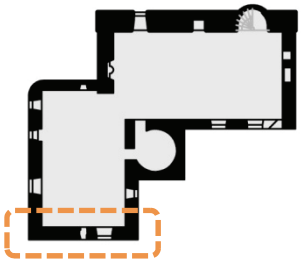
E



PITTARTHIE CASTLE_FIFE

ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

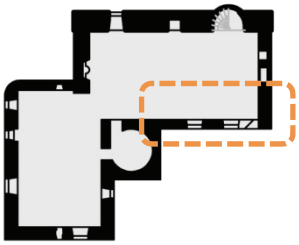


Courses determined by quoins
Courses determined by jambs
Other courses

PITTARTHIE CASTLE_FIFE

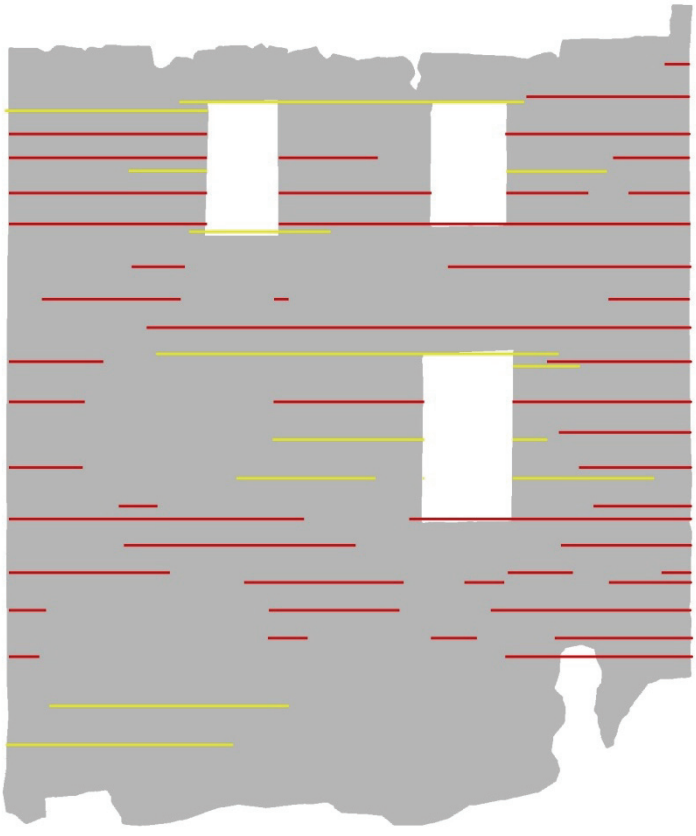
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

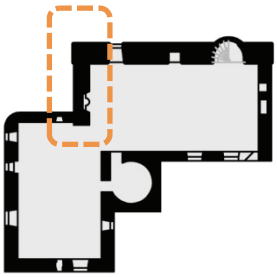


Courses determined by quoins
Courses determined by jambs
Other courses

PITTARTHIE CASTLE_FIFE

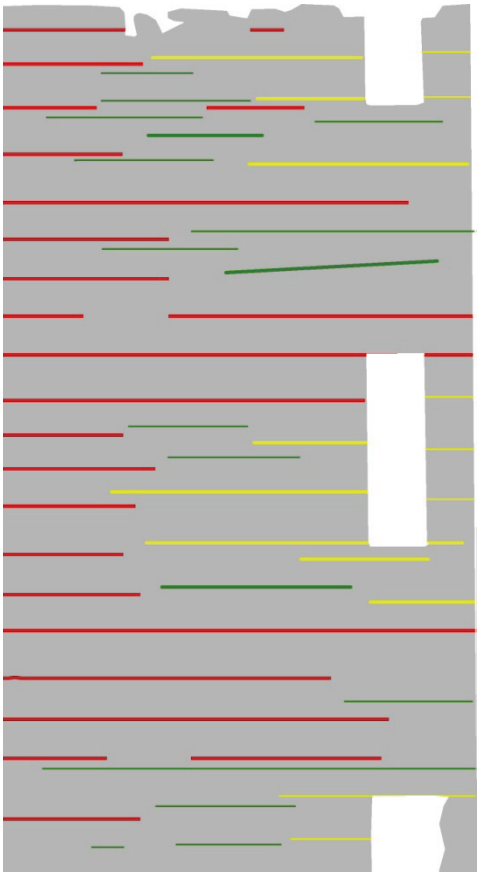
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES



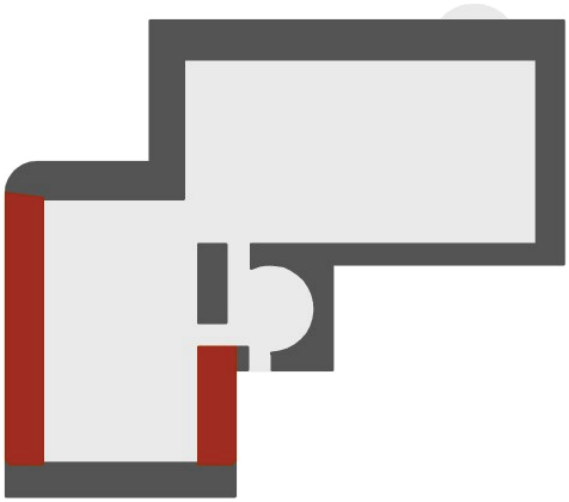
Courses determined by quoins
Courses determined by jambs
Other courses

PITTARTHIE CASTLE_FIFE

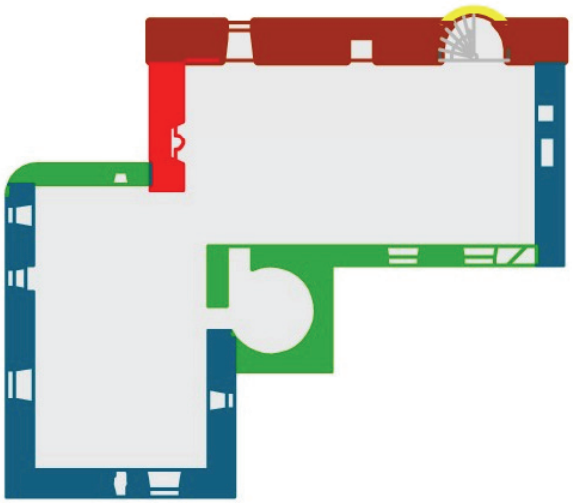
WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR

BASEMENT



MAIN FLOOR





Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

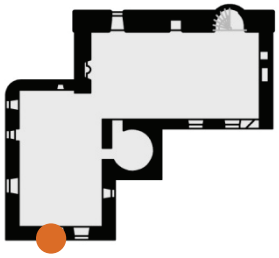
Measured onsite | Estimated

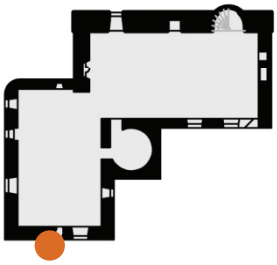
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

PITTARTHIE CASTLE_FIFE

WALL SECTIONS



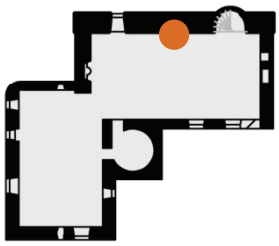






PITTARTHIE CASTLE_FIFE

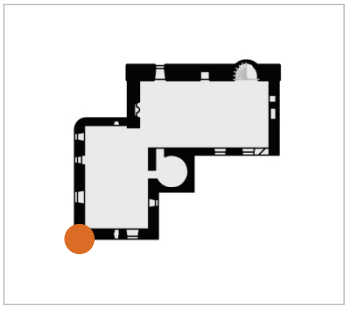
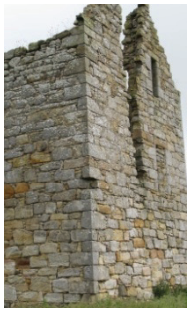
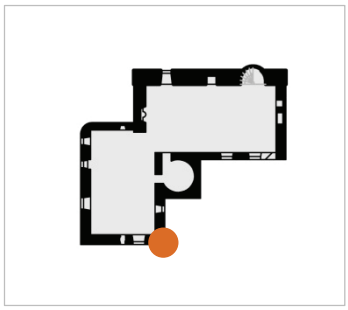
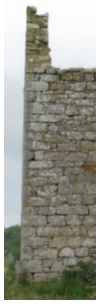
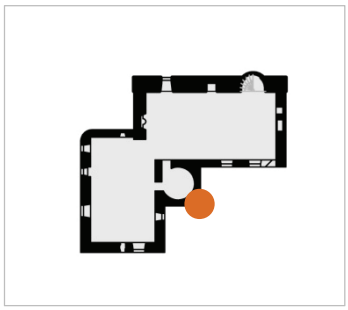
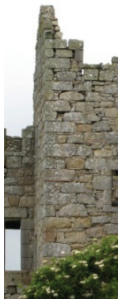
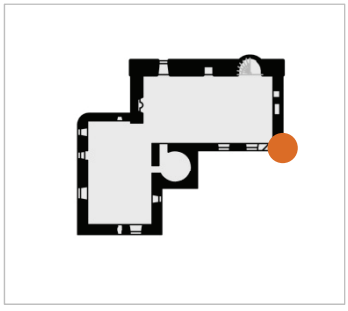
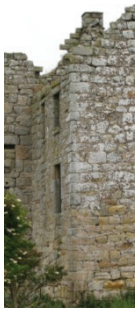
WALL SECTIONS





PITTARTHIE CASTLE_FIFE

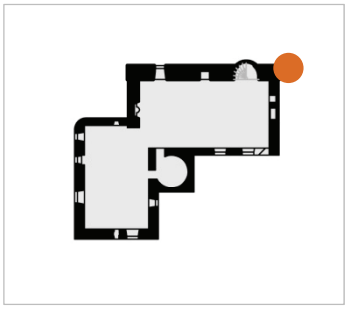
CORNERS

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			
LOCATION	**CORNER**	**CORNER -SIDE 1**	**CORNER –SIDE 2**
			

PITTARTHIE CASTLE_FIFE

CORNERS

LOCATION



CORNER

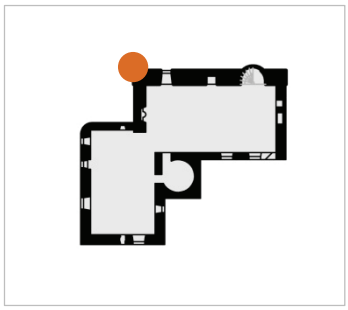


CORNER -SIDE 1

CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



PITTARTHIE CASTLE_FIFE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION


IMG_1492_corrected_silhouette


IMG_1503_corrected_silhouette


IMG_1505_corrected_silhouette


IMG_1508_corrected_silhouette


IMG_1512_corrected_silhouette


IMG_1533_corrected_silhouette


IMG_1540_corrected_silhouette


IMG_1542_corrected_silhouette


IMG_1554_corrected_silhouette


IMG_1568_corrected_silhouette


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IMG_1680_corrected_silhouette


IMG_1721_corrected_silhouette

REDHOUSE_EAST LOTHIAN

GENERAL INFORMATION

LOCATION



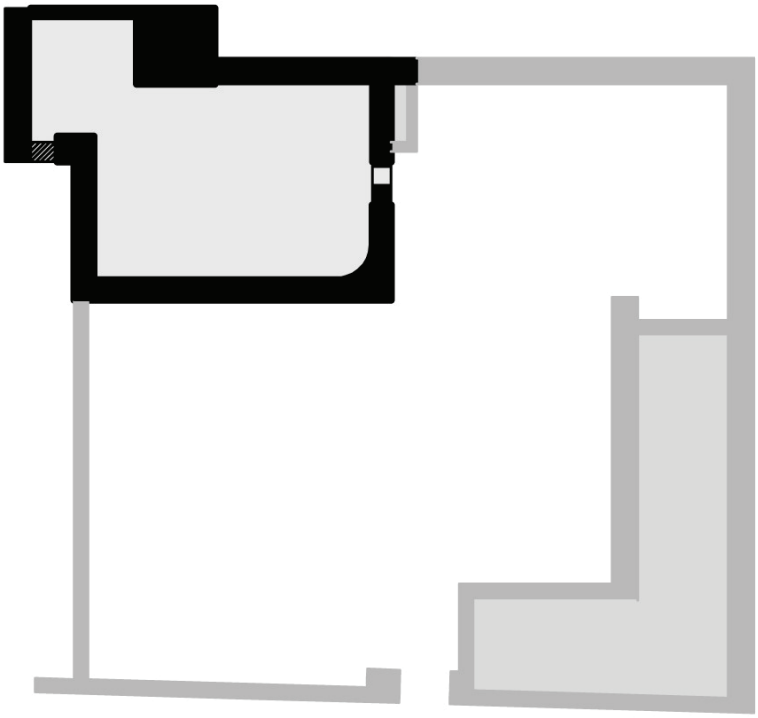
BUILDING PLAN

GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



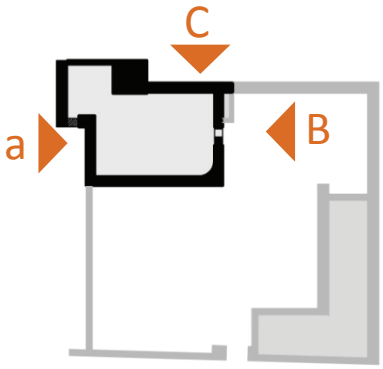
Area included in the research

Area not included in the research

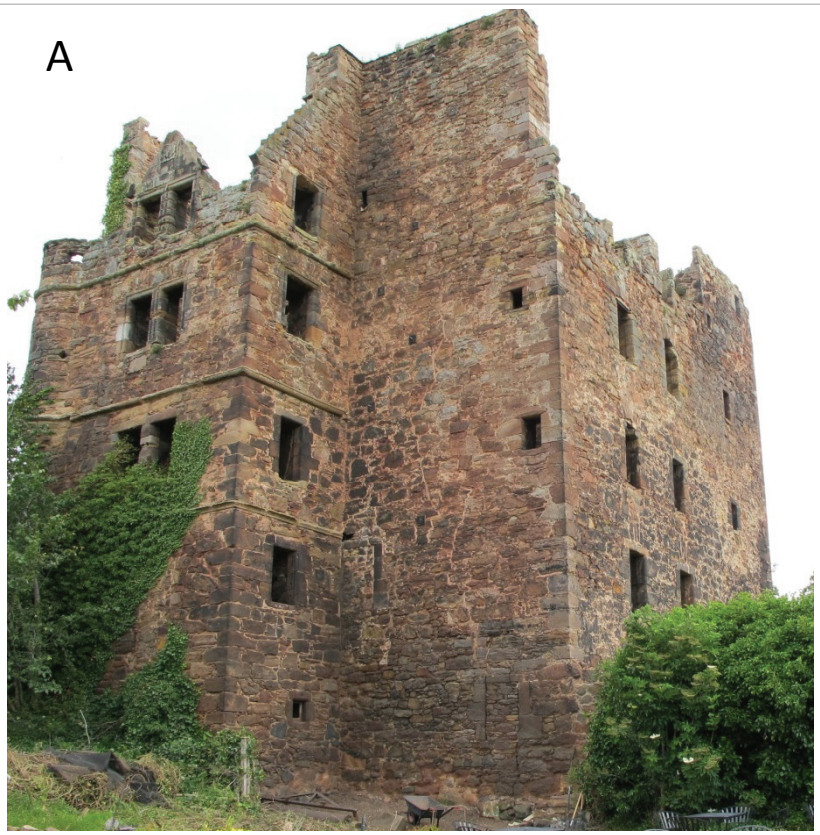
Walls inspected

REDHOUSE_EAST LOTHIAN

IMAGES OF THE BUILDING



A



B



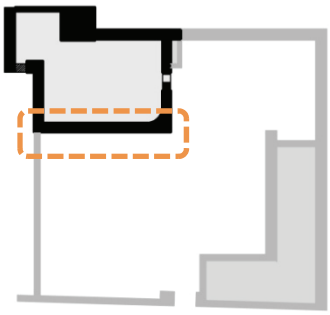
C



REDHOUSE_EAST LOTHIAN

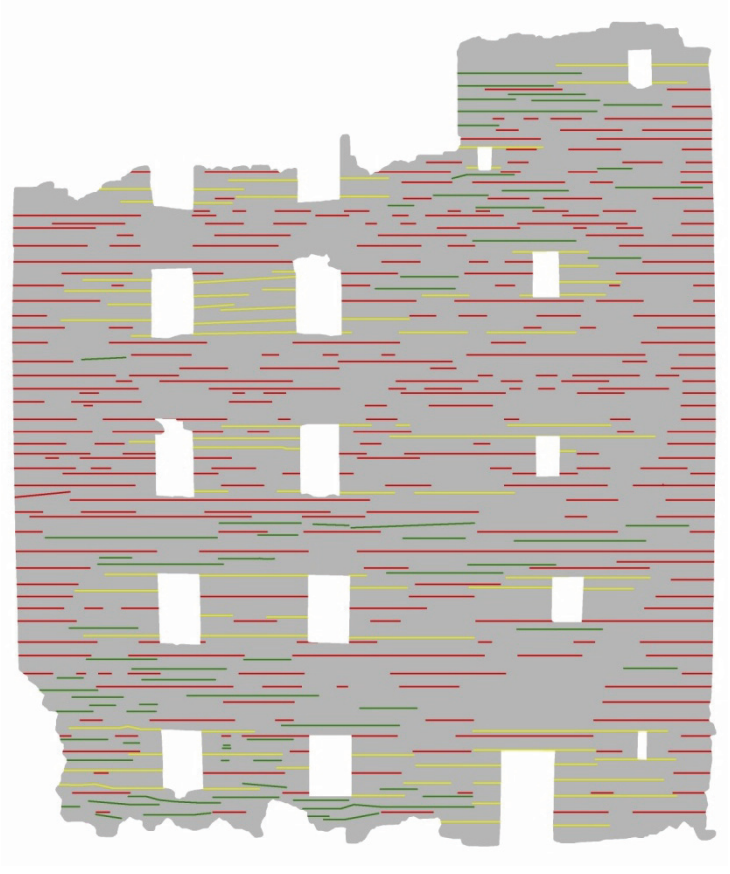
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

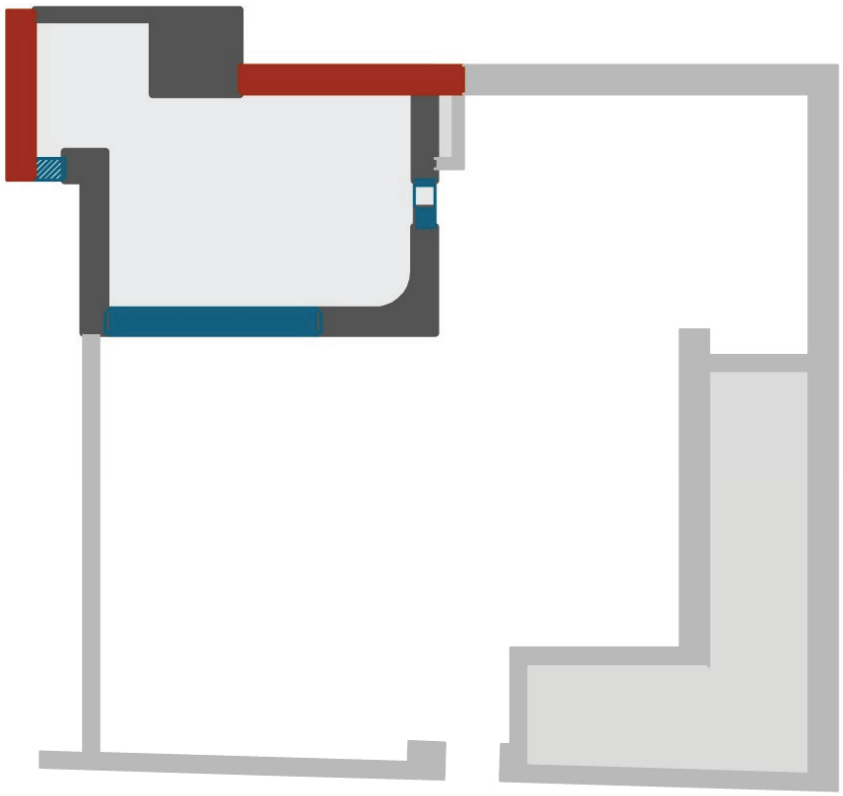


Courses determined by quoins
Courses determined by jambs
Other courses

REDHOUSE_EAST LOTHIAN

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

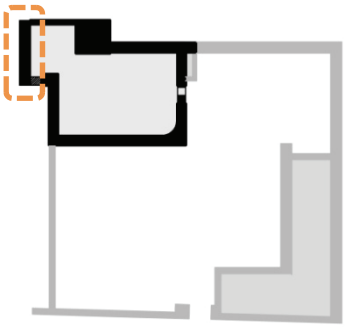
Measured onsite | Estimated

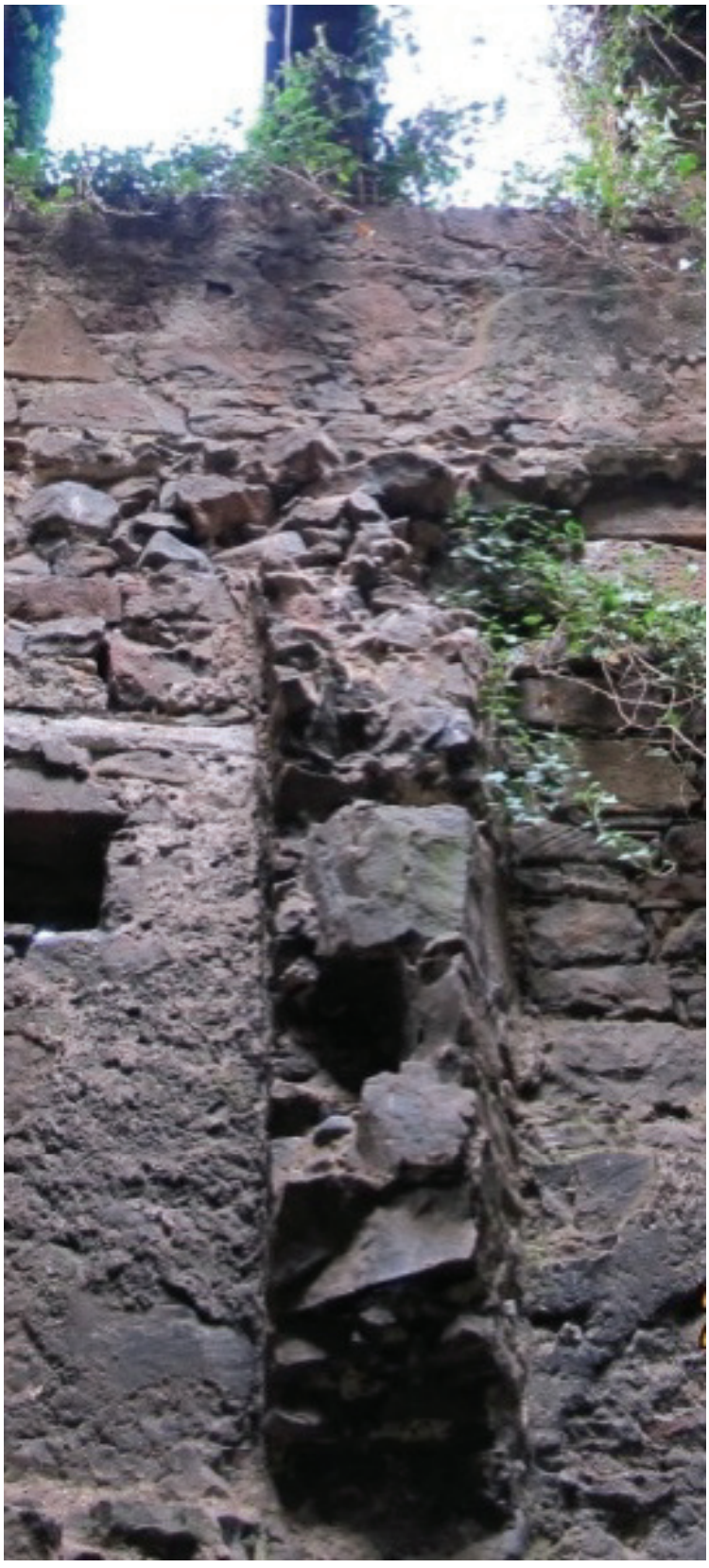
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

REDHOUSE_EAST LOTHIAN

WALL SECTIONS

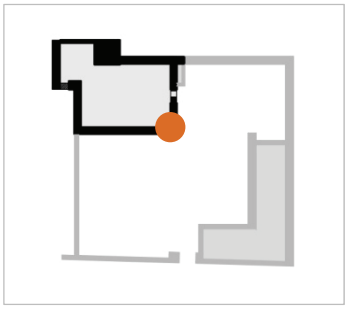




REDHOUSE_EAST LOTHIAN

CORNERS

LOCATION



CORNER



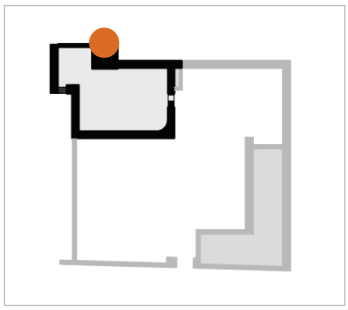
CORNER -SIDE 1



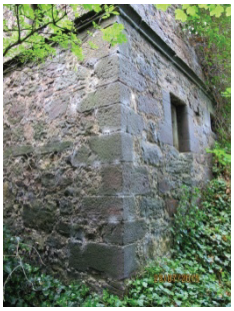
CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



REDHOUSE_EAST LOTHIAN

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



IMG_2470_corrected_silhouette

TOLQUHON CASTLE_ABERDEENSHIRE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

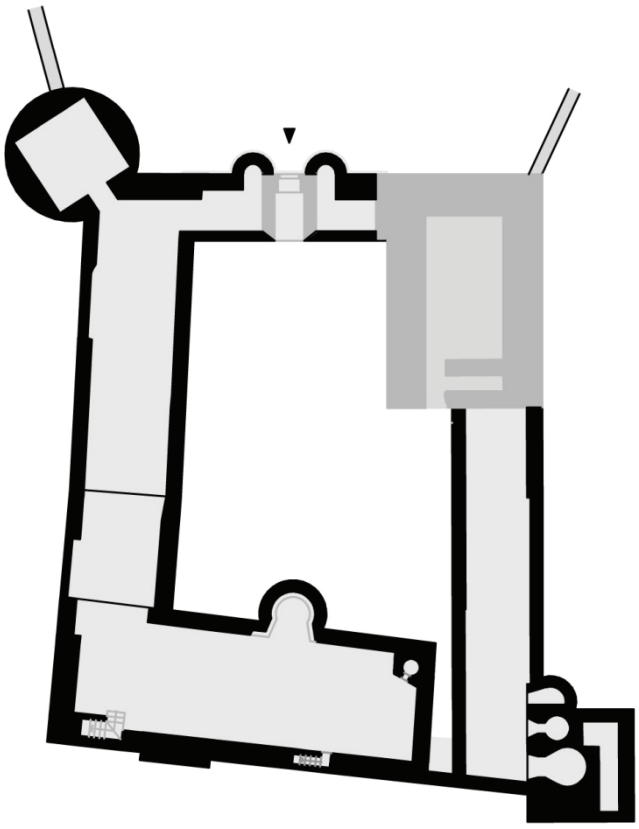


Image form Google maps 2017

GENERAL IMAGE



IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



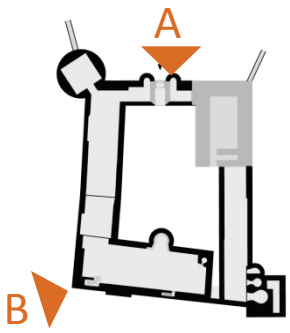
Area included in the research

Area not included in the research

Walls inspected

TOLQUHON CASTLE_ABERDEENSHIRE

IMAGES OF THE BUILDING



A

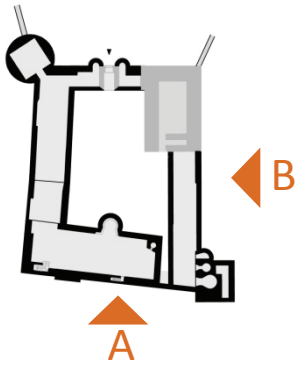


B



TOLQUHON CASTLE_ABERDEENSHIRE

IMAGES OF THE BUILDING



A

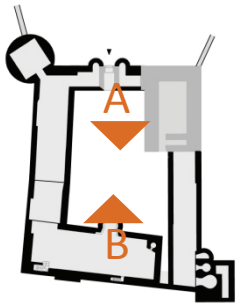


B



TOLQUHON CASTLE_ABERDEENSHIRE

IMAGES OF THE BUILDING



A





B

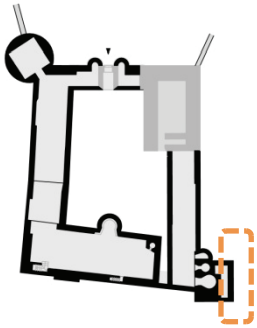




TOLQUHON CASTLE_ABERDEENSHIRE

ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

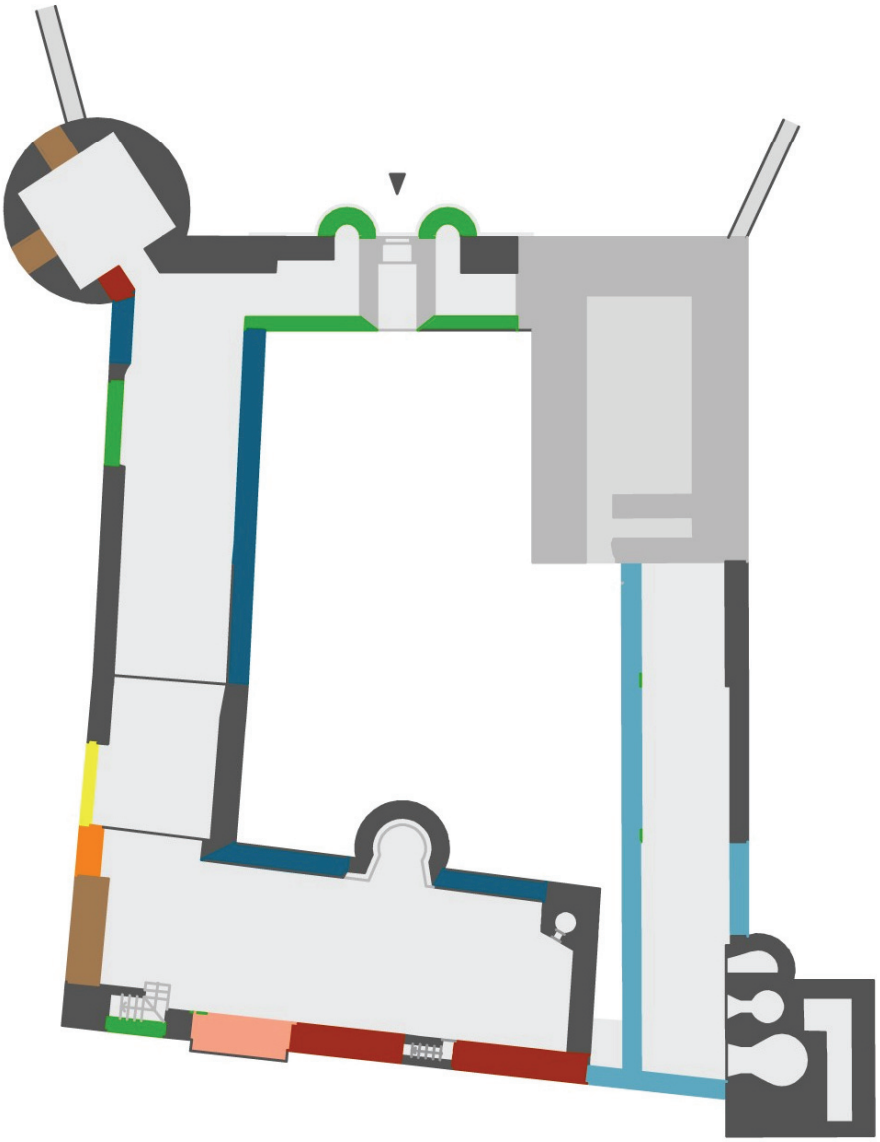


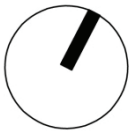
Courses determined by quoins
Courses determined by jambs
Other courses

TOLQUHON CASTLE_ABERDEENSHIRE

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR





Wall thickness [cm] (hatch colour)

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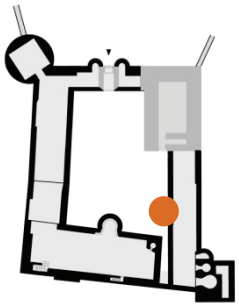
Measured onsite | Estimated

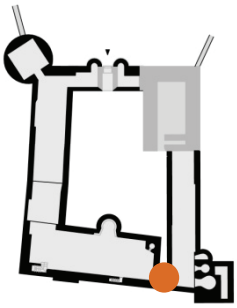
Plan areas considered/not considered (hatch colour)

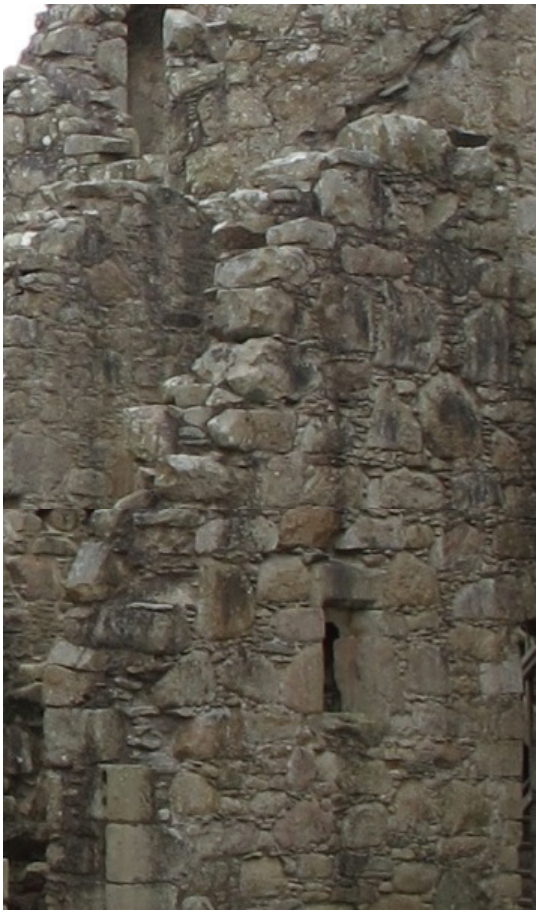
Area considered | Area not considered

TOLQUHON CASTLE_ABERDEENSHIRE

WALL SECTIONS



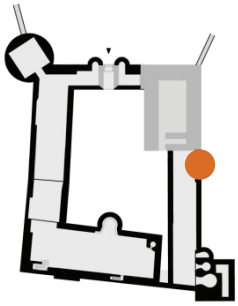






TOLQUHON CASTLE_ABERDEENSHIRE

WALL SECTIONS

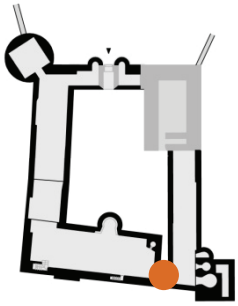






TOLQUHON CASTLE_ABERDEENSHIRE

WALL SECTIONS

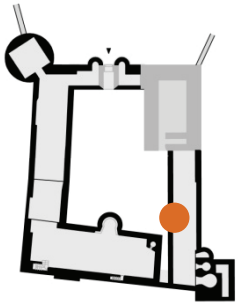


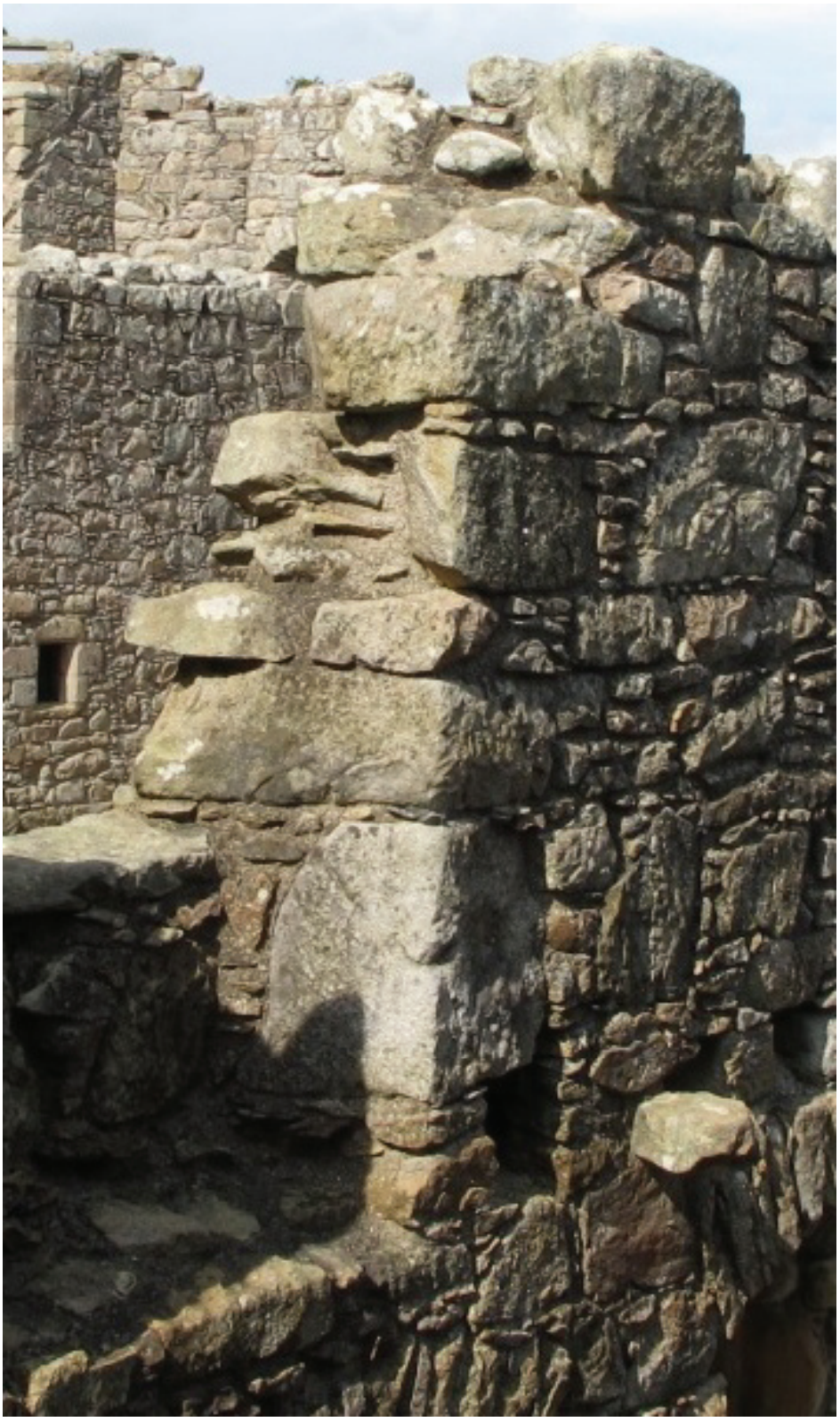




TOLQUHON CASTLE_ABERDEENSHIRE

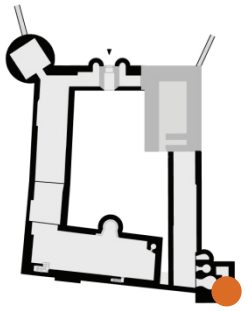
WALL SECTIONS





TOLQUHON CASTLE_ABERDEENSHIRE

WALL SECTIONS







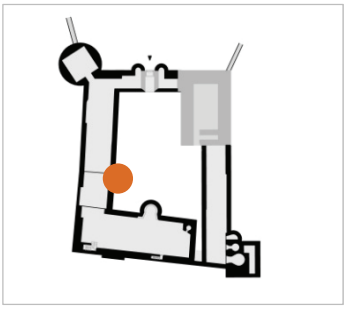




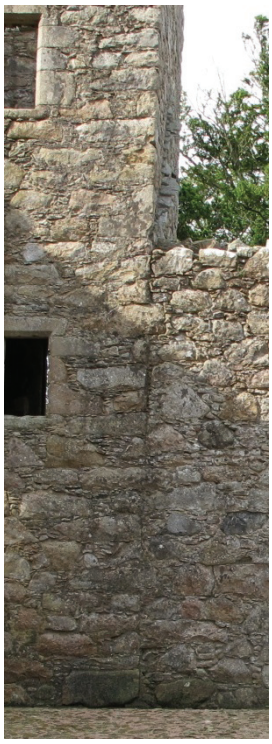
TOLQUHON CASTLE_ABERDEENSHIRE

CORNERS

LOCATION



CORNER



CORNER -SIDE 1



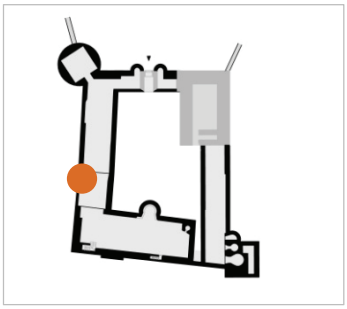
CORNER –SIDE 2

CORNER -SIDE 1

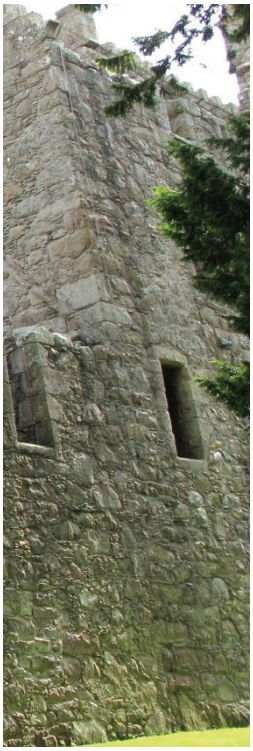


CORNER –SIDE 2

LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2

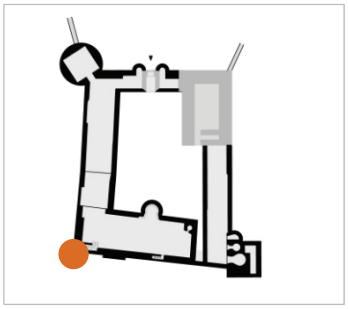
CORNER -SIDE 1



CORNER –SIDE 2

CORNERS

LOCATION



CORNER

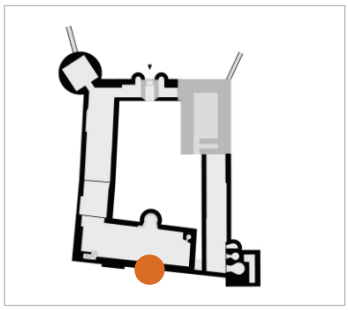


CORNER -SIDE 1

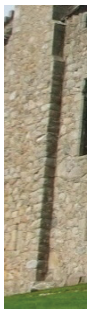


CORNER –SIDE 2

LOCATION



CORNER

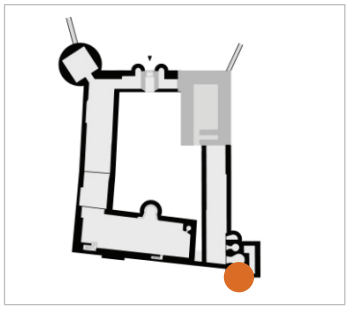


CORNER -SIDE 1



CORNER –SIDE 2

LOCATION



CORNER



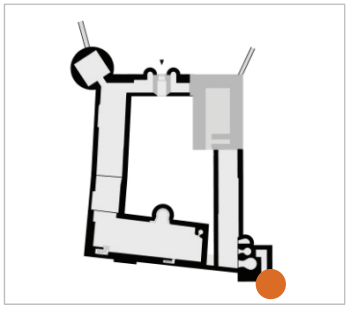
CORNER -SIDE 1



CORNER –SIDE 2



LOCATION



CORNER



CORNER -SIDE 1



CORNER –SIDE 2



TOLQUHON CASTLE_ABERDEENSHIRE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



IMG_7196_corrected_silhouette



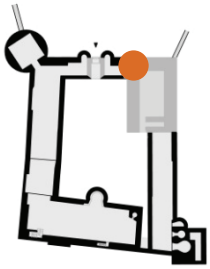
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IMG_7650_corrected_silhouette

TOLQUHON CASTLE_ABERDEENSHIRE

OTHER FEATURES



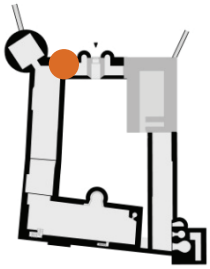






TOLQUHON CASTLE_ABERDEENSHIRE

OTHER FEATURES



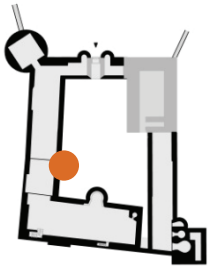






TOLQUHON CASTLE_ABERDEENSHIRE

OTHER FEATURES





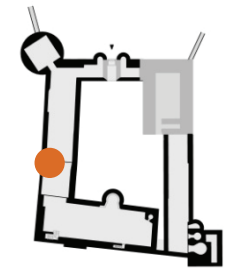






TOLQUHON CASTLE_ABERDEENSHIRE

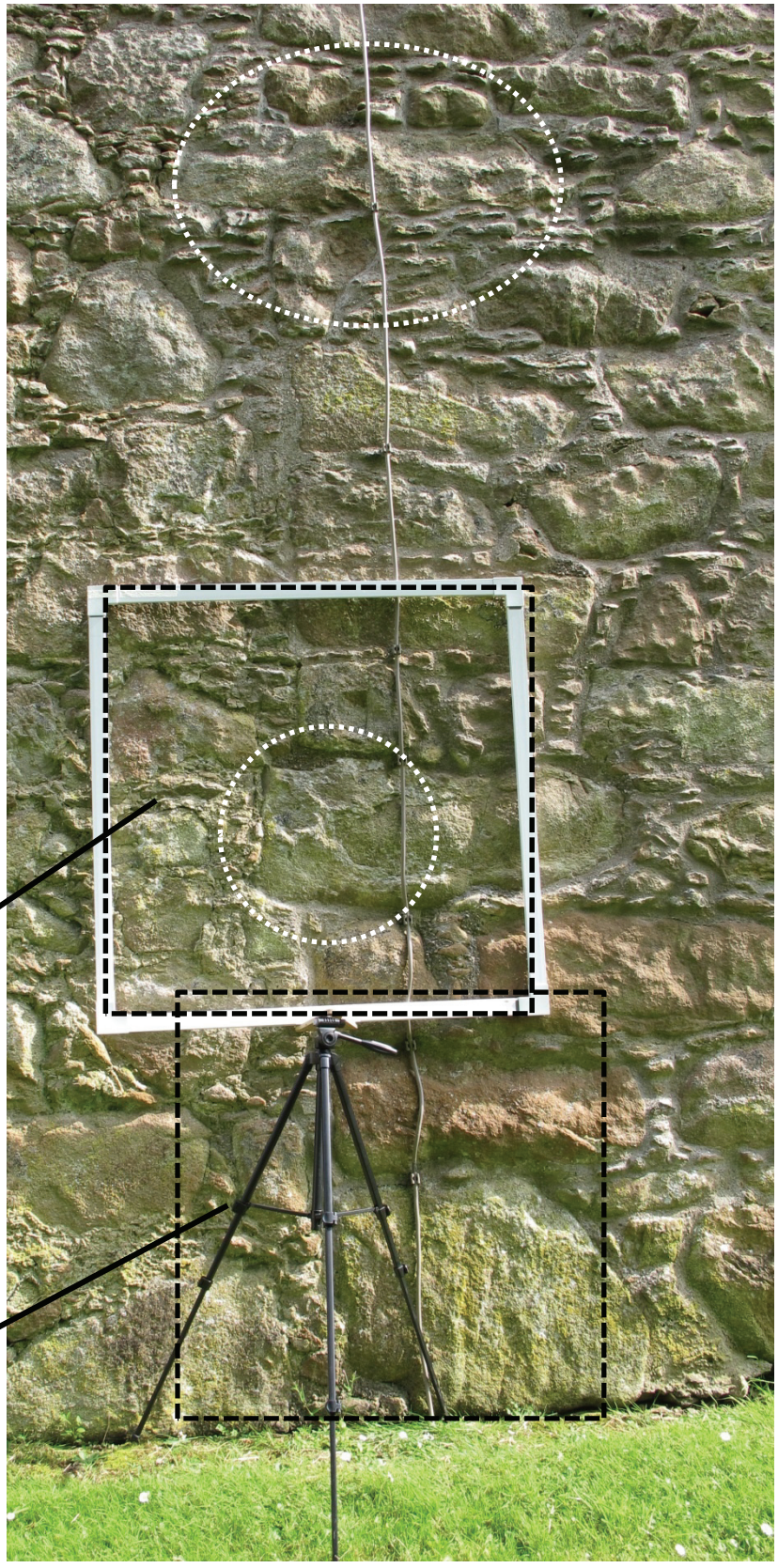
OTHER FEATURES











TOLQUHON CASTLE TOWER_ABERDEENSHIRE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

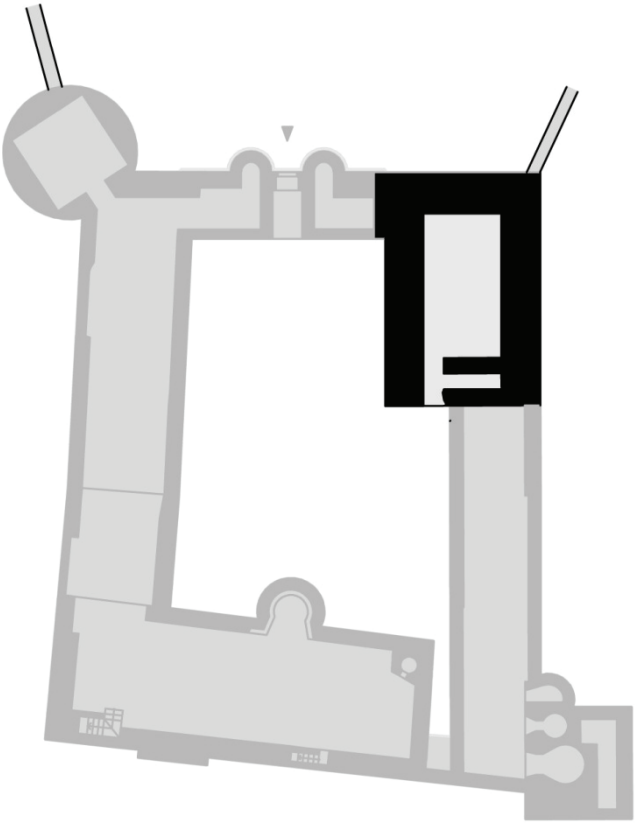


GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH



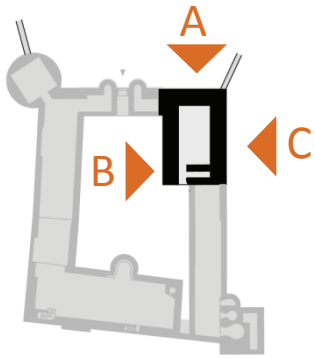
Area included in the research

Area not included in the research

Walls inspected

TOLQUHON CASTLE TOWER_ABERDEENSHIRE

IMAGES OF THE BUILDING



A



B



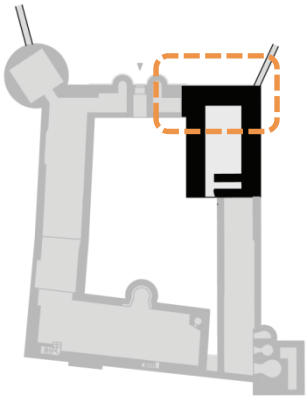
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TOLQUHON CASTLE TOWER_ABERDEENSHIRE

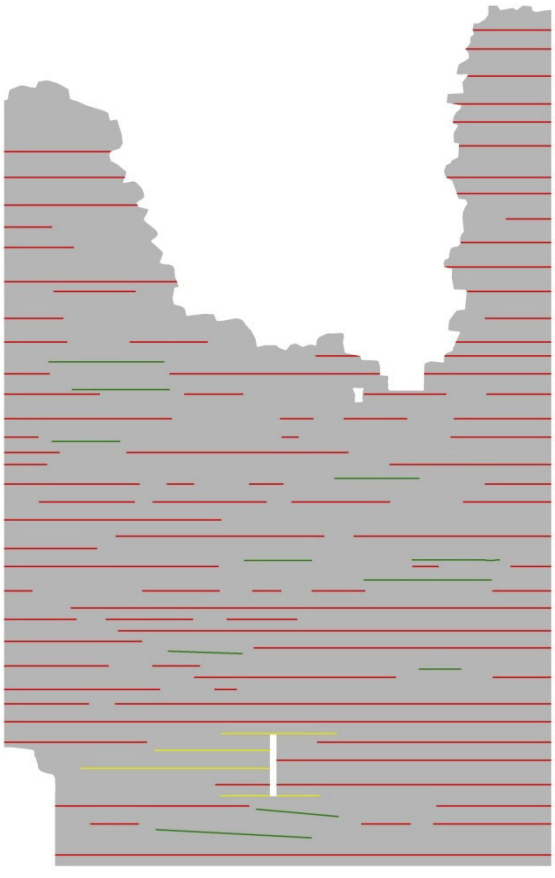
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

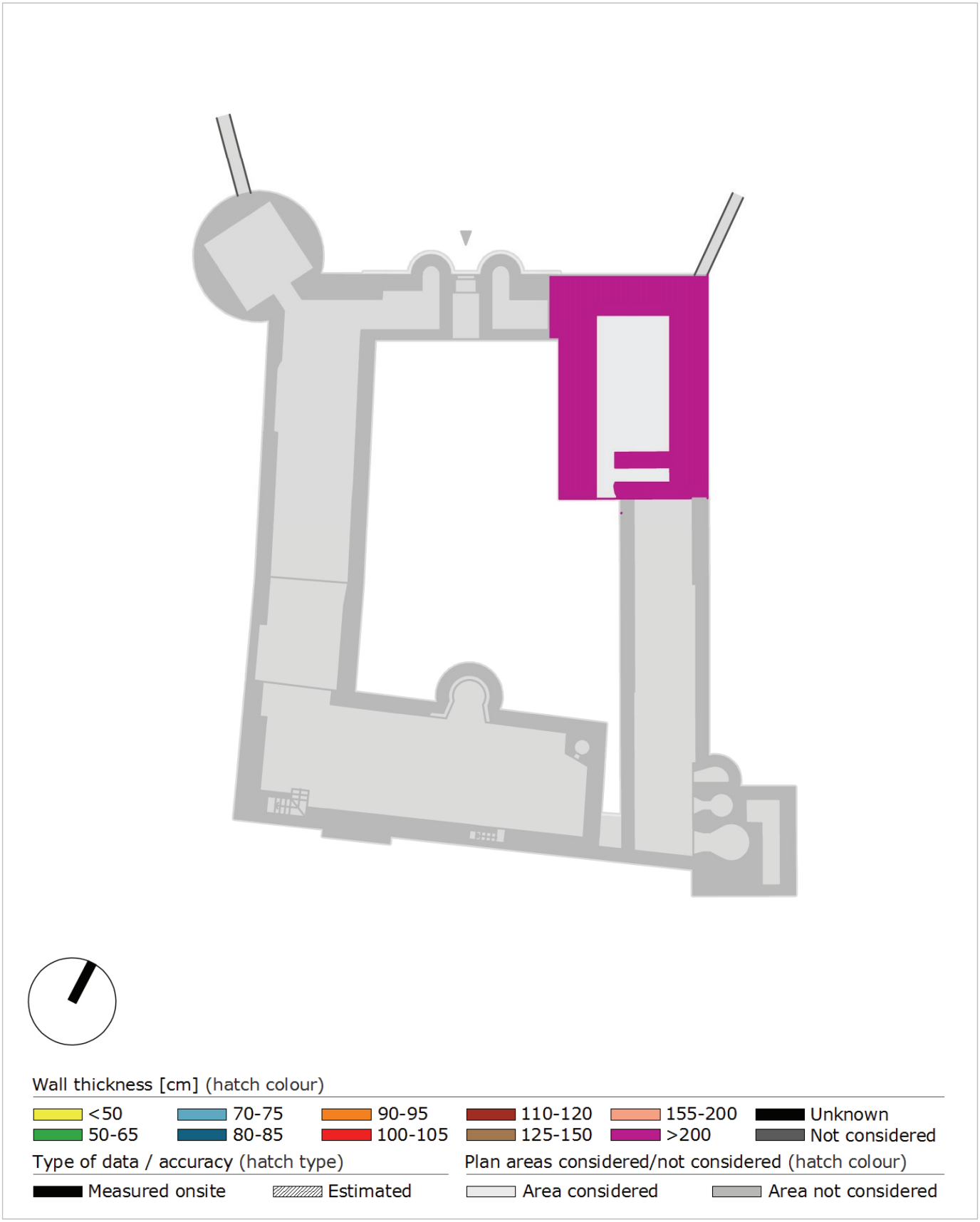


Courses determined by quoins
Courses determined by jambs
Other courses

TOLQUHON CASTLE TOWER_ABERDEENSHIRE

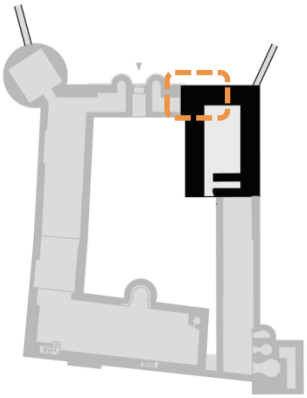
WALL THICKNESSES

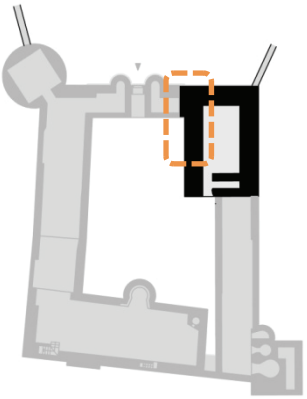
WALL THICKNESSES: GROUND FLOOR



TOLQUHON CASTLE TOWER_ABERDEENSHIRE

WALL SECTIONS



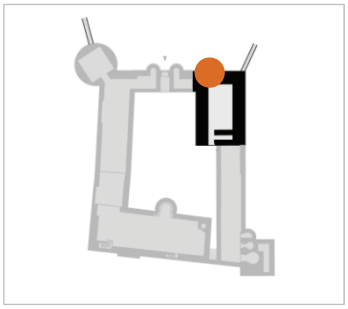


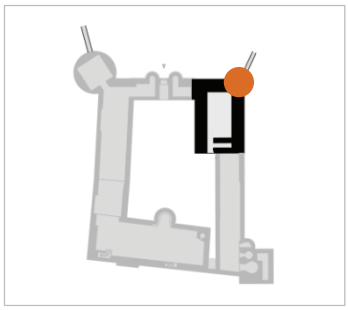


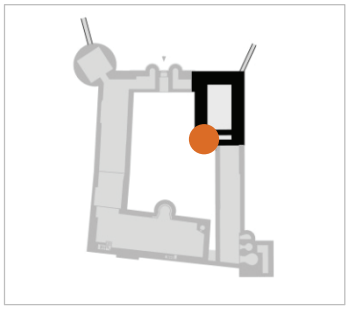


TOLQUHON CASTLE TOWER_ABERDEENSHIRE

CORNERS

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			

LOCATION	CORNER	CORNER -SIDE 1	CORNER –SIDE 2
			

TOLQUHON CASTLE TOWER_ABERDEENSHIRE

MASONRY PATERNS: 1x1 FRAMES

WALL CENTRAL PORTION



IMG_7188_corrected_silhouette



IMG_7514_corrected_silhouette



IMG_7675_corrected_silhouette

WEDDERBURN CASTLE _ SCOTTISH BORDERS, THE

GENERAL INFORMATION

LOCATION



BUILDING PLAN

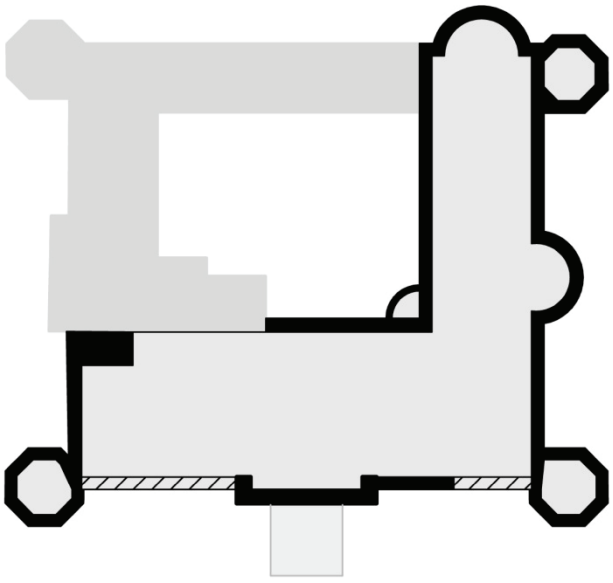


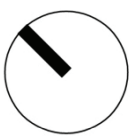
GENERAL IMAGE



Image form Google maps 2017

IDENTIFICATION OF THE PARTS INCLUDED IN THE RESEARCH





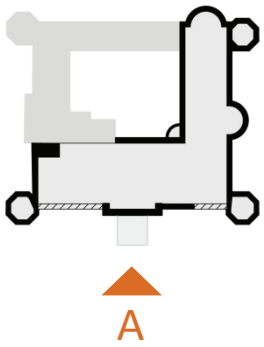
Area included in the research

Area not included in the research

Walls inspected

WEDDERBURN CASTLE _ SCOTTISH BORDERS, THE

IMAGES OF THE BUILDING

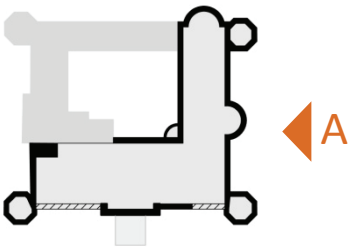


A



WEDDERBURN CASTLE _ SCOTTISH BORDERS, THE

IMAGES OF THE BUILDING

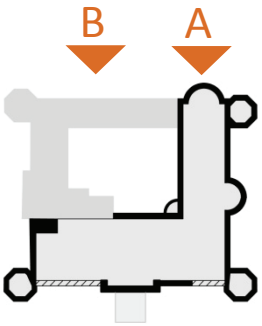


A



WEDDERBURN CASTLE _ SCOTTISH BORDERS, THE

IMAGES OF THE BUILDING



A

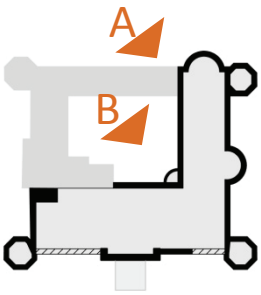


B



WEDDERBURN CASTLE _ SCOTTISH BORDERS, THE

IMAGES OF THE BUILDING



A

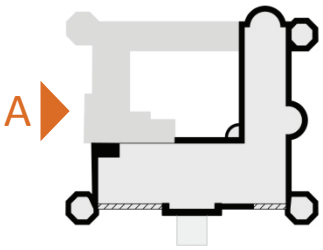


B



WEDDERBURN CASTLE _ SCOTTISH BORDERS, THE

IMAGES OF THE BUILDING



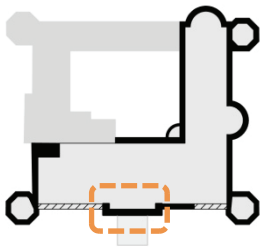
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WEDDERBURN CASTLE _ SCOTTISH BORDERS, THE

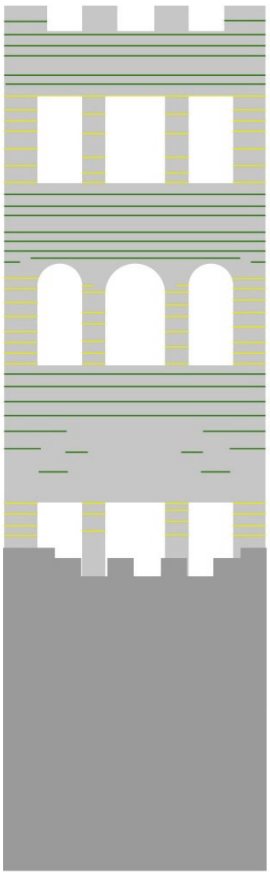
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

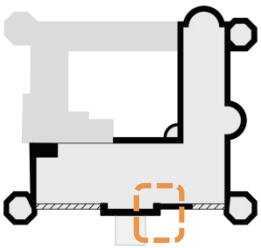


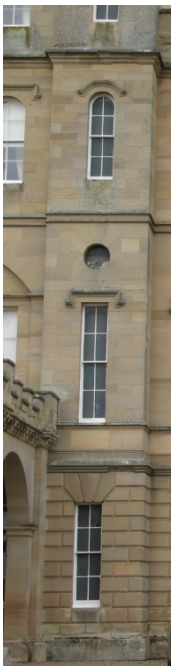
Courses determined by quoins
Courses determined by jambs
Other courses

WEDDERBURN CASTLE _ SCOTTISH BORDERS, THE

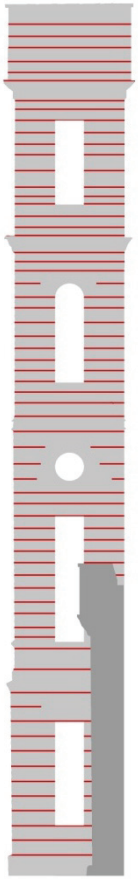
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

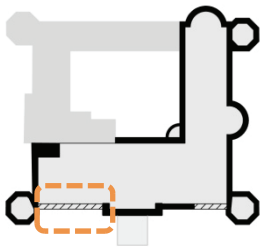


Courses determined by quoins
Courses determined by jambs
Other courses

WEDDERBURN CASTLE _ SCOTTISH BORDERS, THE

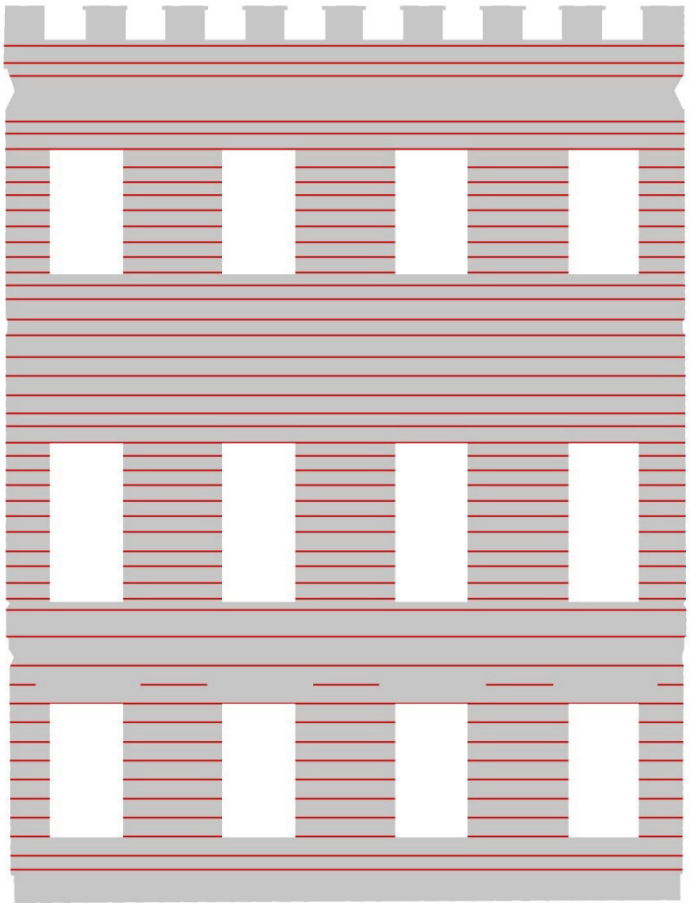
ANALYSIS OF ELEVATIONS

LOCATION AND GENERAL IMAGE





ANALYSIS OF COURSES

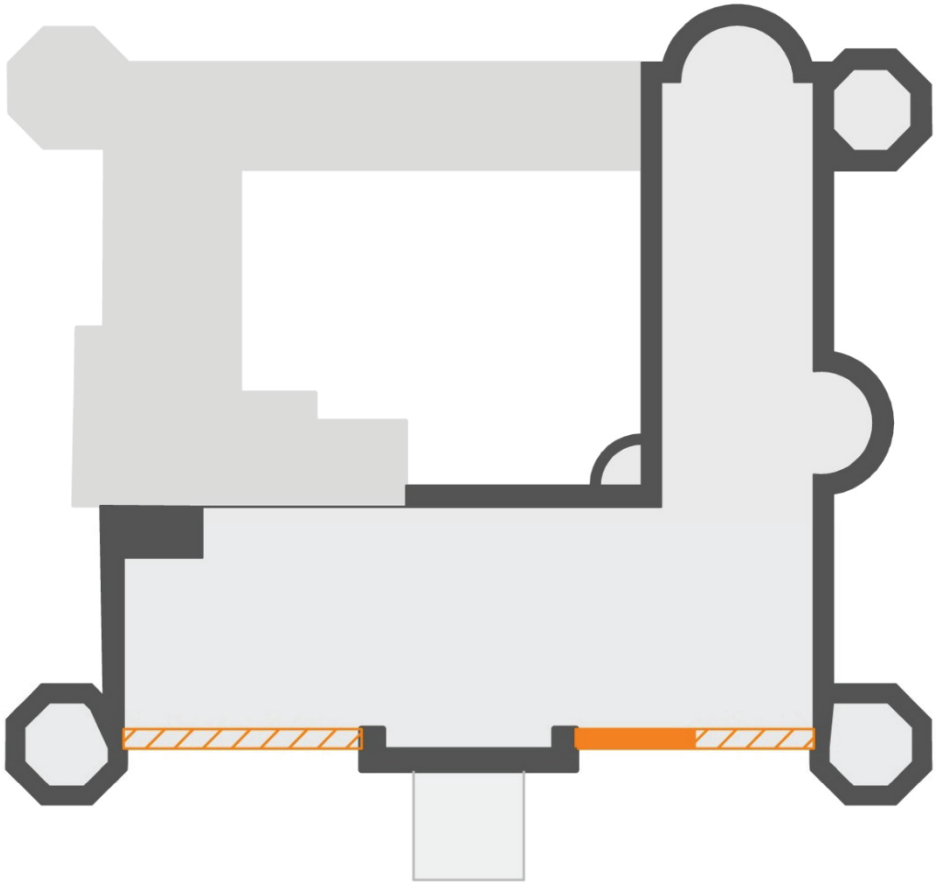


Courses determined by quoins
Courses determined by jambs
Other courses

WEDDERBURN CASTLE _ SCOTTISH BORDERS, THE

WALL THICKNESSES

WALL THICKNESSES: GROUND FLOOR



Wall thickness [cm] (hatch colour)

<50	70-75	90-95	110-120	155-200	Unknown
50-65	80-85	100-105	125-150	>200	Not considered

Type of data / accuracy (hatch type)

Measured onsite | Estimated

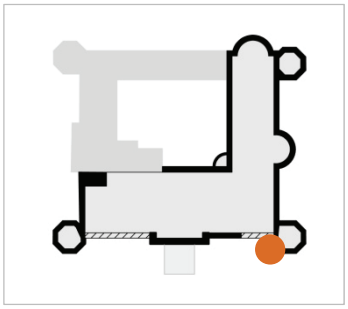
Plan areas considered/not considered (hatch colour)

Area considered | Area not considered

WEDDERBURN CASTLE _ SCOTTISH BORDERS, THE

CORNERS

LOCATION



CORNER



CORNER -SIDE 1

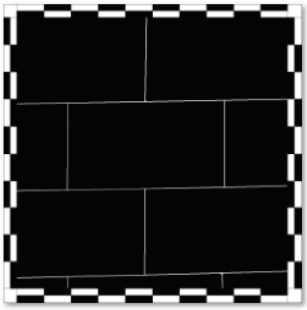


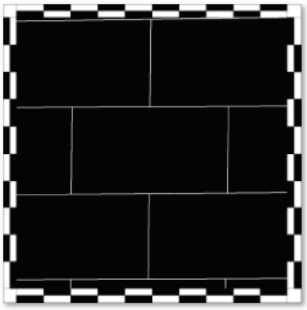
CORNER –SIDE 2

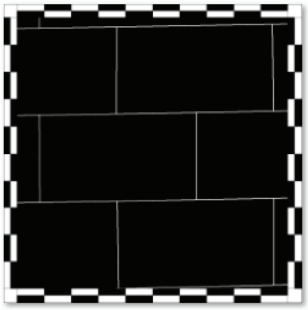
WEDDERBURN CASTLE _ SCOTTISH BORDERS, THE

MASONRY PATERNS: 1x1 FRAMES

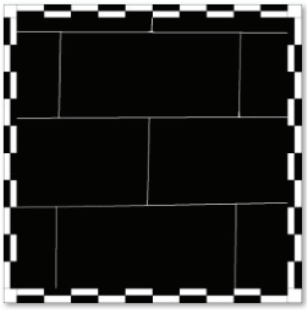
WALL CENTRAL PORTION


P7131773_corrected_silhouette

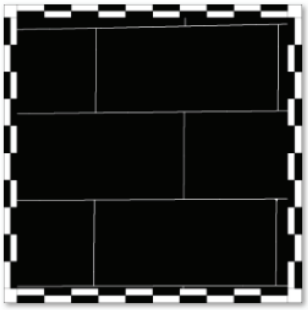

P7131777_corrected_silhouette


P7131781_corrected_silhouette


P7131791_corrected_silhouette

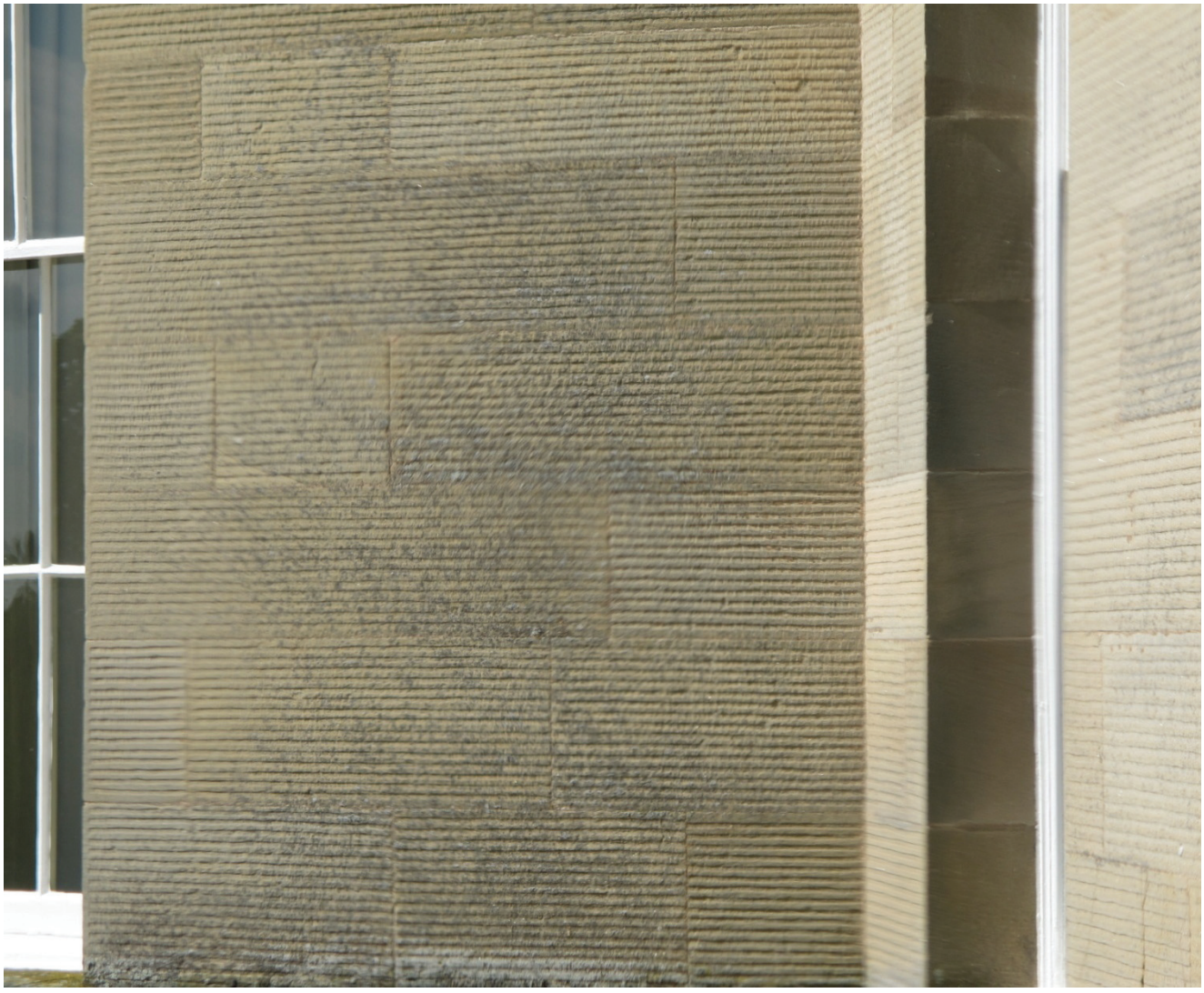

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OTHER FEATURES



APPENDIX 4
PUBLICATIONS

Exploring the use of image processing to survey and quantitatively assess historic buildings

C. González Manich, T. Kelman, F. Coutts, B. Qiu,
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ABSTRACT

This paper presents the results of a collaborative and cross-disciplinary research project which assessed the feasibility of applying a new methodology for the survey and assessment of historic buildings based on applying state-of-the-art image processing. The combination of technologies allows for efficient data capture while minimising the requirement for manual data analysis. Therefore, it can facilitate surveys with minimal disruption to the general public in cities while providing more accurate estimates of intervention costs.

The case study selected was a section of a stone masonry wall of Glasgow Cathedral with a regular ashlar pattern. It was surveyed using two different methods focused on identifying and classifying existing decay processes. The first method was the traditional architectural-conservation condition survey. Based on a visual inspection, the data was manually marked and annotated on a scaled elevation drawing (Figure 1 and Figure 2). The second method was based on image processing techniques. Both RGB and hyperspectral images were captured and processed using intelligent algorithms which embedded the architects' expert knowledge and automatically detected and classified the existing types of decay (Figure 3 and Table 1).

The comparison of the two methods shows promising results. Apart from the speed and reduction in site disruption, a number of significant improvements are offered by the new method based on image processing techniques. However, at this stage, the mortar detection and pathology classification results provide an estimate of the condition of the wall. Only planar walls have been considered to allow algorithm development and testing. Future work will include improving the accuracy and efficiency of these techniques as well as extending them for application to more complex geometries and non-planar walls thus making the proposed techniques more generally applicable as useful tools for architectural surveys.

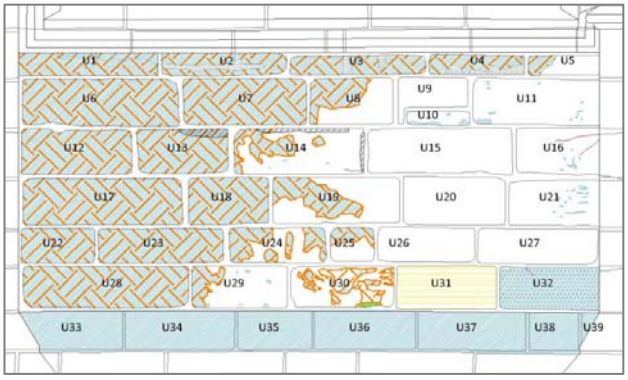


Figure 1: Survey elevation (from the traditional methodology)

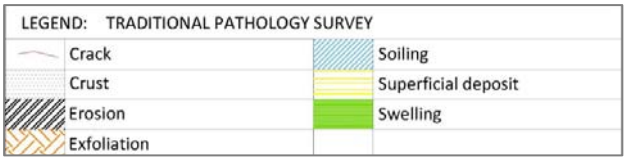


Figure 2: Graphic code used to note pathologies.

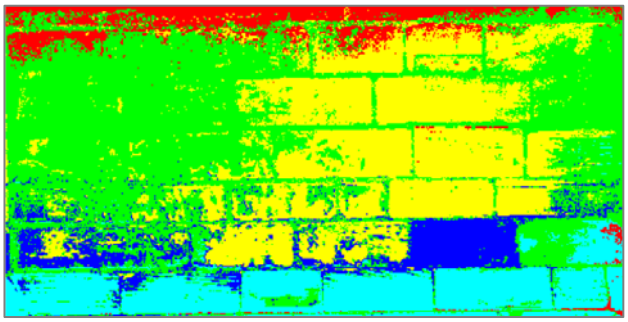


Figure 3: Classification result (from image process techniques)

Class	Colour
Exfoliation and Soiling	Green
Superficial Deposit	Blue
Soiling	Cyan
Crust, Soiling and Exfoliation	Red
No pathology	Yellow

Table 1: Classes and Colours.

Exploring the use of image processing to survey and quantitatively assess historic buildings

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ABSTRACT: Before architectural conservation takes place, a survey is conducted to assess the condition of the building and estimate the cost of the work. For façades, scaffolding is erected so that experts can access the building's whole extent and gather data for analysis. This paper presents the results of a collaborative and cross-disciplinary research project aiming to automate data capture and analysis techniques for conservation of stone façades. Our research demonstrates the feasibility of a new methodology for the survey and assessment of historic buildings and will facilitate frequent surveys with minimal disruption to the general public in cities. The project has embedded architects' expert knowledge into intelligent algorithms for automatically analysing images of facades. The combination of technologies allows for an efficient data capture while minimising the requirement for manual data analysis as well as more accurate estimates of its cost.

1 INTRODUCTION

1.1 *Context and aim of the project*

This paper presents a study which assessed the feasibility of applying a new methodology for the survey and assessment of historic buildings based on applying state-of-the-art image processing. This has the potential to facilitate frequent surveys with minimal disruption to the general public in cities.

The conservation of Built Heritage is a high value market and there is the need to continuously survey, assess and monitor historic buildings and structures. However, this is not always possible using the current state-of-the-art manual data gathering and data analysis approaches which can be labour intensive and time consuming. This can result in insufficient maintenance and monitoring leading to major problems and causing the loss of the heritage's value.

Nevertheless, the latest developments in image processing make this a technology with great potential to address this challenge. The possibility of automating the data capture and processing opens new opportunities in fields such as architecture conservation as it can reduce the time and cost of inspections making them more accessible.

In this work, we use traditional cameras and hyperspectral imaging systems. Where conventional digital imaging devices capture light over one (grey-scale) or three (red, green, blue) distinct portions of the electromagnetic spectrum, a hyperspectral imaging system acquires light at hundreds or even thousands of different spectral bands. Similar to the way in which a spectrometer produces a spectrum of the light captured at a single point, a hyperspectral system produces a spectrum for each pixel in the image, see Figure 1. This combination of spatial and spectral detail provides significantly more information about a scene. In recent years it has been used in a number of different applications such as classification of Chinese tea (Kelman et al. 2013) and beef quality assessment (Qiao et al. 2015) and a number of new signal processing techniques have been developed to efficiently process the data (Zabalza et al. 2014) (Zabalza et al. 2015) .

In this context, the Architectural Design & Conservation Research Unit (ADCRU) and the Centre for Signal and Image Processing (CeSIP) from the University of Strathclyde (Glasgow, UK) started collaborating in the research project presented in this paper.

The aim of the work is to create a new methodology for the survey and assessment of historic buildings based on state-of-the-art image processing technolo-

gies. First, image data related to the condition of a historic building is captured. Then, its analysis is automated using new and intelligent image processing software modules developed for this purpose. Finally, the resulting information can later be used to assess the building condition and design the most adequate intervention in every case.

In the end, the outputs of the research can provide a more accurate, time and cost effective solution for estimating the cost of architectural conservation and to carry out better assessments and monitoring of the condition of the existing buildings.

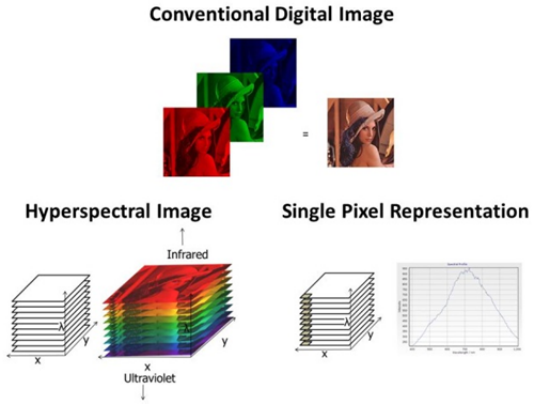


Figure 1: Conventional digital imaging and Hyperspectral imaging.

1.2 *Literature survey: precedents*

Image processing techniques have been implemented in a wide range of areas such as medicine (Dougherty 2009), automation (Bulanona et al. 2002), security (Sewaga et al. 2006) and defence (Colloquium 1990). In recent years, it has been adopted in the architecture field using a number of different devices and technologies as explained below.

One method, (Lerma et al. 2000) used a digital colour camera integrated with a near infrared (NIR) camera. This allowed the capture of multispectral images of building façades as well as texture images generated from the four spectral regions – red, green, blue (RGB) and an NIR band. This data was found to be useful for recognising different kinds of limestone. This research also indicated that better classification of visually similar materials was achieved when using the NIR band rather than the RGB data. Later research (Lerma 2001) indicated that not only multispectral images but also multitemporal and multisensory images helped to increase classification accuracy. In further work, (Lerma 2005) different methodologies of classification were compared. A supervised maximum-likelihood classifier was considered as the best way to classify different wall materials. A minimum-distance classifier was quicker but had significantly lower accuracy.

Hemmleb et al. (2005) considered a variety of illumination conditions as a problematic source of error. Therefore, a new multispectral scanner was developed to apply active illumination which mapped different materials and corrosion (Hemmleb et al. 2006). However, this method was time consuming and it was concluded that further work was required to improve the robustness of the results.

Fluorescence LiDAR has been used at the Coliseum in Rome (Palombi et al. 2008). It was not only able to distinguish different materials, but also able to differentiate stone masonry from different historic periods, allowing to identify previous conservation works that were not well recorded.

Riveiro et al. (2015) focused on the structural assessment of masonry buildings, using a 2.5D approach to process 3D point clouds acquired with moving and stationary LIDAR technology. The authors present an effective segmentation algorithm which operates on 2D intensity images extracted from the LIDAR data. The results are then back-projected to the 3D point cloud and used for further analysis through which the authors demonstrate that it is possible to characterise individual masonry blocks in facades.

Thermal images, showing temperature fluctuations of material surfaces are also a complementary set of information. As different materials have different specific heat capacities, the measured fluctuations can be used as a means of identification. Combining the thermal fluctuation data and the analysis of the RGB images, materials on a façade have been classified using a maximum likelihood classifier (Sidiropoulou-Velidou et al. 2012).

Based on this previous work, this paper aims to develop new image processing techniques to support automated analysis of stone masonry facades while identifying the different materials used as well as pathologies. This novel approach aims to improve the efficiency of the current manual survey process by using data from multiple sensors including traditional colour cameras and hyperspectral imaging systems.

2 METHODOLOGY AND SCOPE

In order to explore the possibility of applying state-of-the-art image processing to the challenge of sur-

veying historic buildings, one case study was selected and surveyed using two different methods.

The first method was a traditional architectural conservation condition survey. It was carried out by ADCRU and was entirely based on professional expertise, involving visual inspection and manual work.

The second method used image processing techniques and was carried out by a team from CeSIP with the support of ADCRU. The objective in this case was to obtain RGB and hyperspectral images and process them to identify the mortar joints and classify the different pathologies.

In both cases, the scope of the survey only considered two types of information: the geometry of the masonry (stone units and mortar joints), and the pathologies.

The comparison of the results obtained in both methods is used to evaluate the potential of this new proposed methodology.

2.1 *The case study*

The case study selected is a wall section (371 cm × 167 cm) of the Glasgow Cathedral, located at the bottom right side of its main façade, as shown in Figure 2.

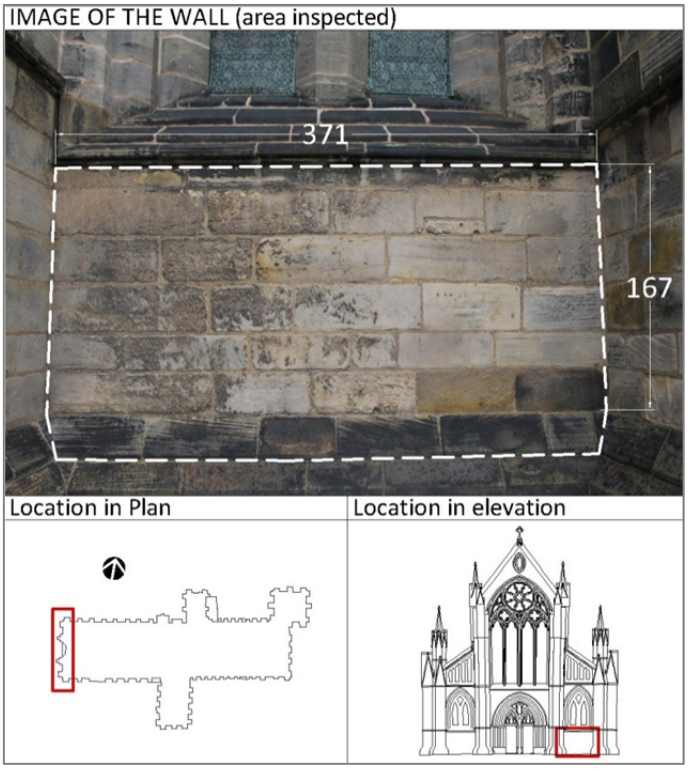


Figure 2: Image of the surveyed wall from the Glasgow Cathedral, including reference to its location in plan and elevation.

This area was chosen because the surface comprised of a regular ashlar masonry pattern simplifies the analysis and facilitates the comparison of the results from both studies. At the same time, it contains several different pathologies (and therefore colours and textures) making it an ideal sample for this study.

2.2 *Traditional survey*

Traditional surveys are mainly based on a manual process. Usually, an expert team gathers information about the geometry, history, construction details, materials and pathologies of a building. Every type of data is recorded separately in a set of plans and reports. Then, this layered information is combined and analysed to assess the condition of the building and propose the most adequate conservation. However, in this case, the scope of the work determined that it was only necessary to collect information about geometry and pathologies of the wall under study.

The data regarding geometry was provided by Historic Environment Scotland (HES) from a photogrammetry survey performed by one of their qualified teams. The resulting elevations contained the definition of the stone unit sizes and mortar joints thicknesses.

The condition survey was based on a visual inspection carried out by an experienced specialist conservation architect. By carefully examining the different stone units, it was possible to identify the different pathologies present in the wall section, based on consistency and appearance of the surfaces and deposits - including texture and colour aspects - considering also the location and exposure of the individual stones and surfaces. This data was manually marked and annotated on a scaled elevation drawing using a graphic code based on the Italian Standard Normal 1/88 as shown in Figure 7 and Figure 8.

2.3 *Image processing survey*

2.3.1 *Data Capture*

For the RGB capture, a Canon PowerShot G11 with Canon Zoom lens 5X15 was used. The images were captured at a resolution of 3648 × 2736 pixels.

Several hyperspectral images were also captured of the same wall. These were captured using a Hamamatsu ORCA-05G camera connected to a Specim V10E imaging spectrograph with a Schneider Compact VIS-NIR Lens. Using 4 × 4 binning, the images

were captured at a resolution of 336 × 1478 spatial pixels, with each pixel containing 256 spectral bands ranging from 400 nm to 1000 nm. Since this camera system is a line-scan system, either the object or the camera must be moved in order to construct an image of the scene. To achieve this, the system was mounted on a Zolix RAK100 motorised rotational stage attached to a tripod. See Figure 3.

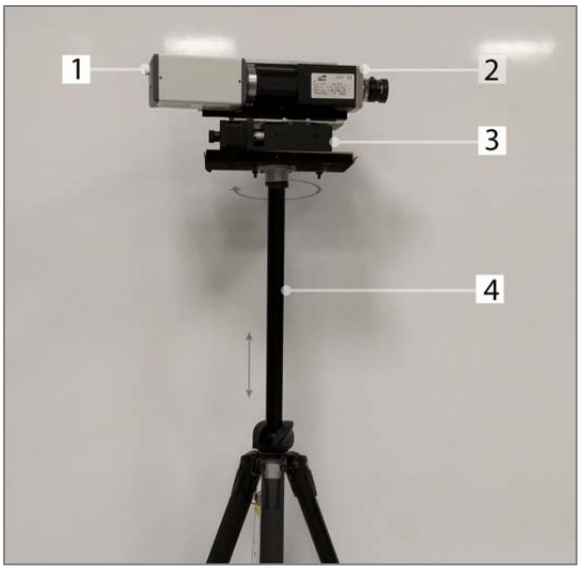


Figure 3: Hyperspectral camera used during the research work. 1) Camera 2) Spectrograph 3) Motorised Stage 4) Tripod.

The image was built up line by line as the system rotated. This rotation caused some distortion, as can be seen in Figure 4 where the horizontal lines have a slight curve to them. This can be corrected in future by translating the camera past the scene rather than rotating it or by registering points to the CAD model. The image shown in Figure 4 is the 100th spectral band in the data cube. To calibrate each band to a specific wavelength, a mercury calibration lamp with known spectral peaks was used. In this case, band 100 corresponds to 628 nm.

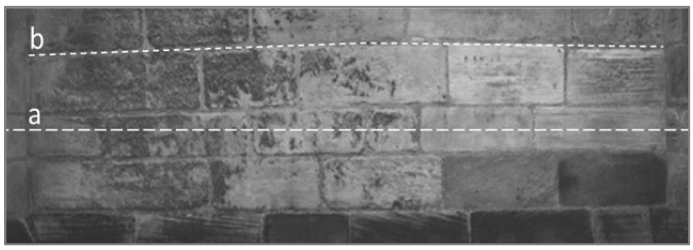


Figure 4: HSI_2563 part of the west facing wall at 682 nm. a) Horizontal reference line. b) Deformed line.

2.3.2 *Signal Processing Methodology*

2.3.2.1 Mortar Detection

A number of different signal/image processing techniques were used to detect the mortar regions of the image. The following algorithms were used: Law's texture analysis (Laws 1980) to extract feature vectors; Principal Component Analysis (PCA) (Jollie 2002) to reduce the dimensionality of the hyperspectral data; Support Vector Machines (SVM) (Cortes & Vapnik 1995) to classify the texture features; 2-D filtering to enhance mortar regions; morphological openings, closings and top hats (Serra 1988) to remove noise; and marker controlled watershed segmentation (Beucher 1991) to segment the classification result.

Law's texture analysis uses 25 two-dimensional kernels obtained via the convolution of 5 one-dimensional kernels with each other. The five one-dimensional kernels are:

L5 = [+1 +4 6 +4 +1] (Level)
E5 = [-1 -2 0 +2 +1] (Edge)
S5 = [-1 0 2 0 -1] (Spot)
W5 = [-1 +2 0 -2 +1] (Wave)
R5 = [+1 -4 6 -4 +1] (Ripple)

The 25 two-dimensional kernels produced are then convolved with each band in the input image. An RGB image has three bands, so after this technique has been applied each pixel has 25 × 3 = 75 features. The hyperspectral images have 256 bands. However some of these contain large amount of noise due to the properties of the spectrograph and the sensor.

The 200 useable bands would produce 25 × 200 = 5,000 features for each pixel. Rather than using these 5,000 features, PCA is employed to reduce the dimensionality of the hyperspectral data before texture analysis. PCA exploits the redundancy in multi-dimensional data and reorders it in such a way that most of the variance is contained within the first few components. The 200 band hyperspectral image can therefore be reduced to a 10 band PCA image with minimal loss of information. After texture analysis, this produces 25 × 10 = 250 features for each pixel.

As well as using the principal components from the hyperspectral image, three bands roughly corresponding to the response of the human eye can be selected to project an approximate colour RGB image. Texture analysis on this image also produces 75 features per pixel.

This provides 3 different data sets which can be analysed before their results are combined to produce the final result. From each image, 20 mortar and 20 stone unit regions are selected to be used as training data for an SVM classifier. In each case (RGB, hyperspectral and projected RGB), the classification result is filtered first by a vertical line identifying filter and by a horizontal line identifying filter. After morphological post-processing to remove noise, a logical OR operation is used to combine these two

results into a binary image. This binary image is then combined (using a logical OR) with a marker controlled watershed segmentation of the unprocessed SVM output to produce the final result.

Two flowcharts describing the whole process are shown in Figure 5 and Figure 6 and the results of applying this method are shown and described in Section 3.2.

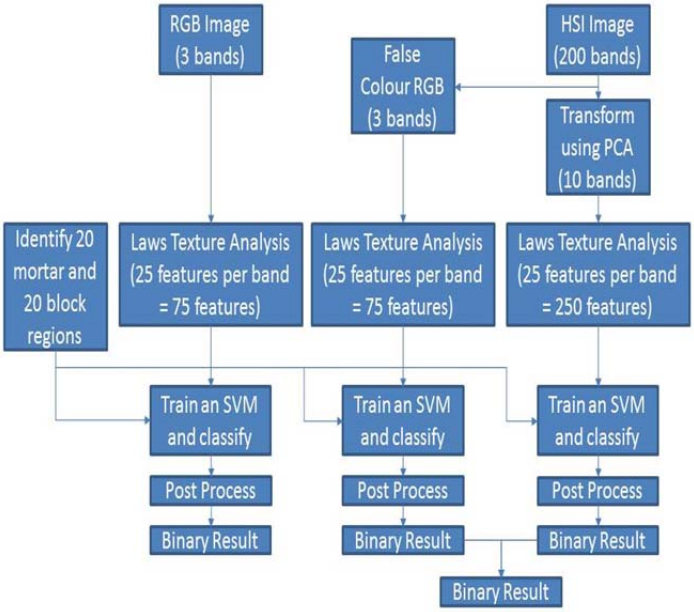


Figure 5: Flowchart describing the mortar detection process.

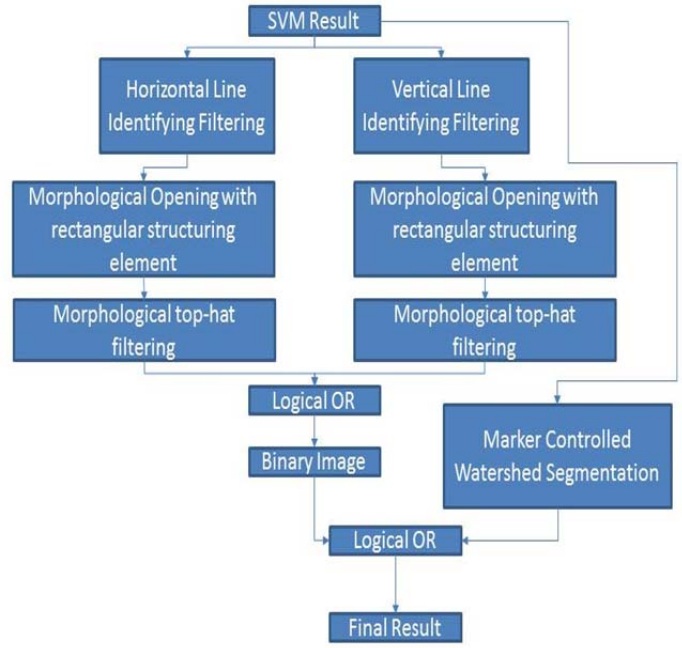


Figure 6: Flowchart describing the post-processing process.

2.3.2.2 Pathologies Classification

As well as identifying mortar, the hyperspectral data can also be used to classify the wall based on the pathologies identified in the manual survey. As with the mortar detection, PCA is used to reduce the data to just 10 bands. This significantly improves the classification speed. An SVM is trained using different class regions which are selected based on the manual survey. Every pixel in the image is then assigned a class by the SVM.

3 ANALYSIS

3.1 *Manual survey*

As previously mentioned, the pathologies present in the section of the wall were identified, manually marked and annotated in situ on a scaled elevation drawing. This mark-up drawing was then used to produce a CAD drawing (Figure 7).

Seven different pathologies were identified. The most prevalent was soiling, which is found in sheltered areas exposed to moisture (below string course and to the left hand side of the wall section considered). In some areas, it is also combined with stone exfoliation; some crust has also already been formed.

Other pathologies have also been identified in some stone blocks, such as superficial deposits and swelling. Three stones also have visible cracks which may develop with time into loss of material and structural damage. Table 1 summarises the pathologies identified and the stone units affected.

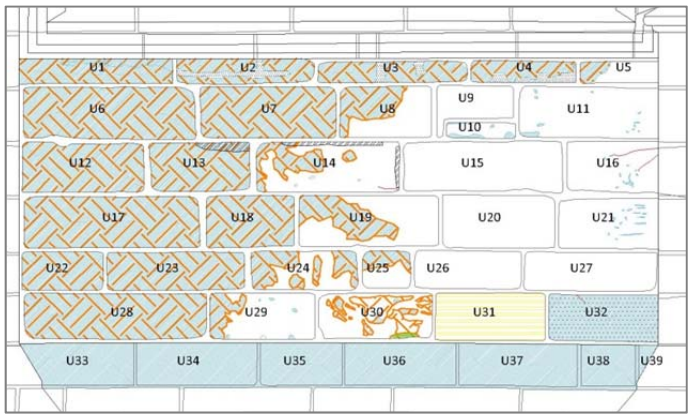


Figure 7: Survey elevation, identifying the different pathologies found on the wall.

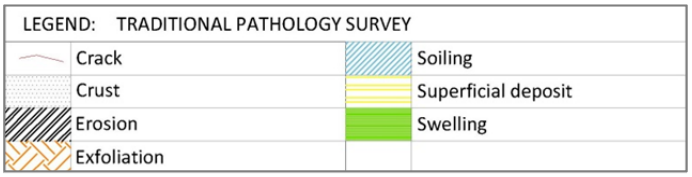


Figure 8: Graphic code used to note pathologies.

Pathologies identified	Stone Units affected
Crack	U14, U16,U32
Crust	U2-U4, U32
Erosion	U13,U14
Exfoliation	U1-U8, U12-U14, U17-U19, U22-U25, U28-U30
Soiling	U1-U8, U10-U14, U16-U19, U21-U25, U28-U30, U32-39
Superficial deposit	U31
Swelling	U30

Table 1: List of identified pathologies and stone units affected.

3.2 *Image Recognition Survey*

3.2.1 *Mortar Detection*

As explained in section 2, three different images were used in total for mortar detection: a standard RGB image, a hyperspectral image and a projected colour RGB image generated from three bands of the hyperspectral image. 20 different mortar regions and 20 different block regions were manually selected to be used as training data for the SVMs. Figure 9 shows the output result of the classifier in each case.

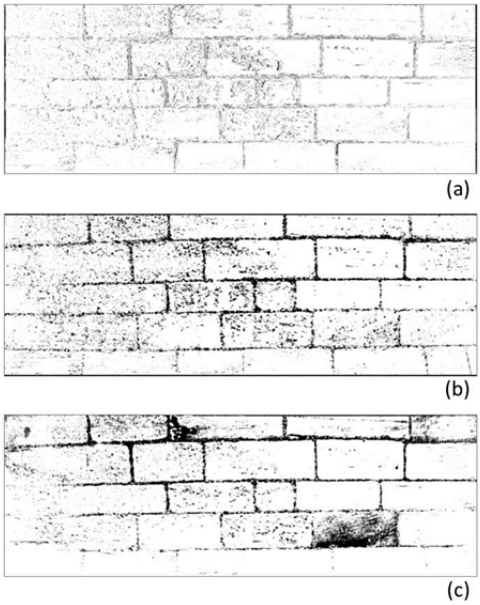


Figure 9: SVM Mortar Classification Results. (a) RGB, (b) HSI, (c) False Colour RGB.

As can been seen from the SVM mortar classification results, all three images have identified the mortar in different ways. Using the post-processing explained in the methodology section and shown in Figure 6, each of these classification results was used to generate a final binary image where mortar has been detected. These results are shown in Figure 10 (a), (b) and (c). Since (b) and (c) were both generated from the same hyperspectral image, these results were combined using a logical AND function which highlights only regions of mortar that were identified in both results. This is shown in Figure 10 (d).

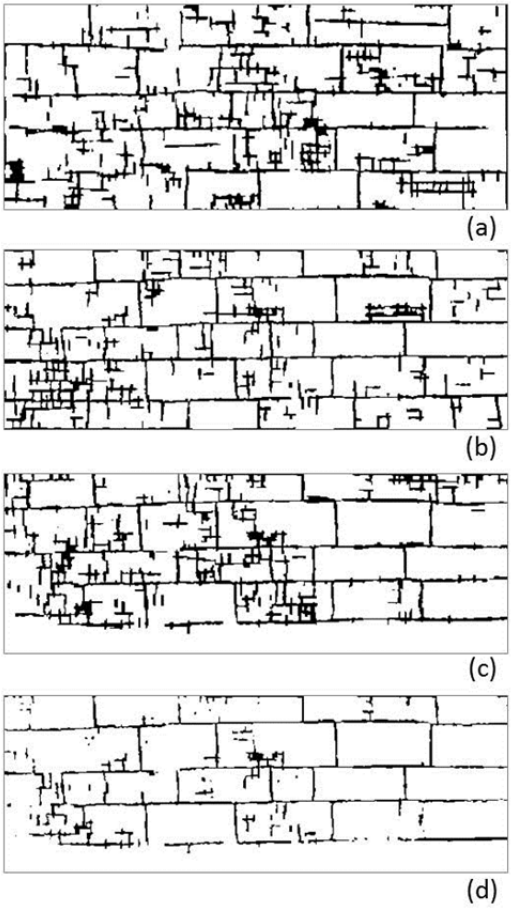


Figure 10: Post processed mortar classification results (a) RGB (b) Hyperspectral (c) False Colour RGB (d) Combination of hyperspectral and false colour results.

3.2.2 *Pathology Classification*

In the manual survey, 7 different pathologies were identified. However, in many cases, parts of the wall were affected by more than one pathology. For the image processing survey, 5 classes were identified corresponding to different combinations of pathologies. Each of these classes was then assigned a colour. Table 1 shows these classes and colours.

Class	Colour
Exfoliation and Soiling	Green
Superficial Deposit	Blue
Soiling	Cyan
Crust, Soiling and Exfoliation	Red
No pathology	Yellow

Table 2: Classes and Colours.

Small regions consisting of each of these classes were selected manually. These regions were used as the training data for an SVM classifier and are shown in Figure 11. Since PCA was used, each pixel vector in each training region is made up of 10 values corresponding to the 10 principal components.
The whole image was then classified based on the SVM generated from the training regions. Each pixel was assigned a colour based on the class to which the SVM determined it belonged. This result is shown in Figure 12.

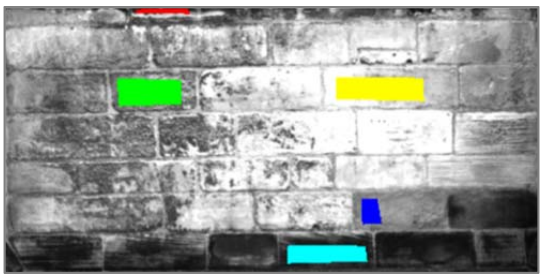


Figure 11: SVM Training Regions.

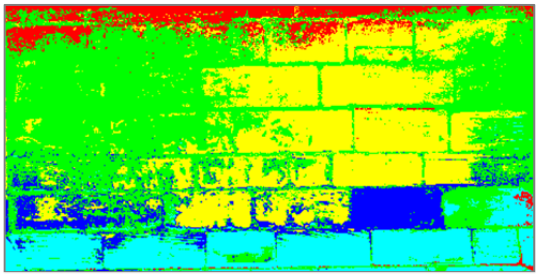


Figure 12: Classification Result.

DISCUSSION

3.3 *Comparison between the two methods*

Having presented both the image processing based survey and the traditional survey, this section looks to compare the two methods and evaluates the potential of the image processing based approach as a new methodology for surveying historic sites. To compare the methods, three metrics for comparison were identified: speed, accuracy and site disruption.

3.3.1 *Speed*

The traditional survey in this study took around 2 hours on site with a further 2 hours to draw the results. This does not include the photogrammetry survey of the cathedral provide by Historic Environment Scotland, however it is estimated that for this wall section it would add an additional 4 hours to the process, taking the total time to around 8 hours of work. The data capture required for this image processing survey took around 30 minutes. The algorithms used to detect the mortar regions and classify the pathologies took around 15 minutes to run (on a desktop computer with a 3.6 Ghz Intel Core i7-490 processor running Windows 8 64-bit with 16 GB RAM). Since this was the first trial of the proposed method, several weeks were spent developing the required algorithms. For future surveys, the same algorithms will be used so this process will not need to be repeated meaning the total processing time for a wall of this size could be as little as 45 minutes. Clearly, the image processing based method has great potential to improve the efficiency of the survey process.

3.3.2 *Accuracy*

The traditional method produces a highly accurate representation of the existing mortar joints and stone units. The results of the mortar detection using the developed image processing approach are representative of the real wall, however, in several cases, some regions were incorrectly classified. See Figure 2, Figure 7 and Figure 10(d). The results of the pathology classification look similar but there are clearly some areas where misclassification has occurred. The stone is not always a homogenous material and exhibits variations in colour and texture and this is where the most of the misclassification occurs. This can be seen by comparing Figure 2, Figure 7 and Figure 12.

3.3.3 *Site Disruption*

For the traditional survey, accessibility has a significant impact on the disruption caused to the building. The wall section surveyed in this paper was at ground-level and so access was not an issue. In other cases, however, scaffolding is often required to allow the expert to get close enough for inspection. This can cause temporary closure of the building and a significant increase in costs. With the image processing based approach the disruption to the building can be minimised as general access to the area only needs to be restricted during imaging. In cases where scaffolding would be required for a manual survey, drones equipped with cameras and other image sensors could be used to carry out the data capture.

3.4 *Future Work*

3.4.1 *Mortar Detection*

So far, the mortar detection results have only been used to produce a drawing highlighting where the system detected mortar. From these results, however, it is expected that further analysis could automatically determine the thickness of the joints and the size and geometry of the masonry units. At this stage, the results are just images. In further work, these images can be transformed into CAD drawings by establishing a relationship between the pixels of the image and the (x,y,z) coordinates in CAD space.

3.4.2 *Pathology Classification*

In this study, the training regions were selected from the same image that was classified. In future, a comprehensive spectral library of pathology classes can be developed and maintained. This library will reduce the need for training data to be selected for future surveys allowing the analysis of a much wider range of stone masonry walls.

4 CONCLUSIONS

In this paper, an alternative method of surveying historic buildings using image processing techniques is proposed. Both RGB and hyperspectral images were captured and processed in order to identify mortar joints and to classify different pathologies. The comparison with the traditional method shows promising results. Apart from the speed and reduction in site disruption, a number of significant improvements are offered by the new method based on image processing techniques. However, at this stage, the mortar detection and pathology classification results provide an estimate of the condition of the wall. Only planar walls have been considered to allow algorithm development and testing. Future work will include improving the accuracy and efficiency of these techniques as well as extending them for application to more complex geometries and non-planar walls thus making the proposed techniques more generally applicable as useful tools for architectural surveys.

5 ACKNOWLEDGEMENTS

The authors wish to acknowledge Historic Environment Scotland (HES) for giving permission to survey the Glasgow Cathedral and providing them with the CAD files resulting from the photogrammetry survey and 3D laser scanner point cloud as well as site induction and assistance while carrying out the works.

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La fábrica de piedra durante los siglos XVII y XVIII en Escocia: estudio preliminar

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Escocia es un territorio de gran riqueza geológica. La disponibilidad de piedra apta para la construcción en canteras locales, y la tardía introducción del ladrillo a finales del s. XVIII, son factores que tienen una influencia directa en el carácter predominantemente pétreo de su arquitectura. Los siglos XVII y XVIII representan un periodo fundamental en el desarrollo de dicha arquitectura. Uno de los elementos clave en este proceso es la evolución del papel desempeñado por el maestro de obras y la aparición en la segunda mitad del s. XVII del «gentleman-architect» Sir William Bruce, un mercader convertido en arquitecto (Dunbar et al. 1976). Hasta entonces, los edificios estaban diseñados y construidos por los maestros de obras [«master masons»], profesionales altamente educados en el diseño y construcción de estructuras de piedra, registrados en un colegio profesional [«Incorporation»] (McKean 2001). El cliente desempeñaba en muchas ocasiones un papel decisivo en la elección de modelos arquitectónicos e incluso de materiales (Wemyss 2014). James Smith, mencionado en contratos primero como maestro de obra y poco después como arquitecto, marca un cambio de dirección a su regreso de Roma en 1676, siendo el primer arquitecto escocés en un sentido moderno (González-Longo 2012, González-Longo et al.2013). Poco a poco la profesión se irá afianzando hasta consolidarse a finales del s. XVIII (Colvin 1986).

La ampliación y alteración de las casas aristocráticas y señoriales se convierte en una práctica habitual en el s.XVII y parte del XVIII. Esto añade un grado de complejidad arquitectónica y constructiva que Charles McKean (2003) ilustra en su estudio de la *Innes House* en Moray. McKean defiende la importancia del análisis de la fábrica como una herramienta de investigación clave para contrastar el estudio histórico documental y alcanzar un correcto entendimiento de la construcción. La identificación de cambios de nivel en forjados, inconsistencias en los espesores de muro, variaciones en el ancho de las aberturas, juntas inoportunas, o cambios significativos de material, son interpretadas como intervenciones de las cuales no siempre existe evidencia documental. McKean reivindicaba así la necesidad de abrir una línea de investigación nueva en Escocia, centrada en el estudio histórico de las fábricas de piedra, estudios por otra parte bien desarrollados en otros países como Italia. El trabajo aquí presentado continúa esta línea y la amplía con la revisión de metodologías de análisis de muros de fábrica existentes en Italia, país de referencia en este campo de estudio y con amplia experiencia en conservar y a veces reconstruir fábricas históricas afectadas por sismo. El gran número de ruinas existentes en Escocia construidas durante los s. XVII y XVIII ofrece una oportunidad para el estudio de la estructura interna de los muros.

Estudios precedentes

Pocos son los trabajos que consideran en Escocia la fábrica como parte de una investigación histórica. Los arquitectos David MacGibbon y Thomas Ross

(1887, 1896) desarrollan el primer trabajo sistemático de visitas y levantamientos de castillos (s. XII–XVIII) e iglesias (hasta el s. XVII) en Escocia. Este trabajo se recoge en dos publicaciones de cinco y tres volúmenes respectivamente, e incluye notas históricas, planimetrías, dibujos arquitectónicos, y una descripción general de los edificios en la que generalmente se mencionan aspectos como el número de plantas, dimensiones, la existencia o no de bóvedas, y en ocasiones, el espesor de muro. Es importante entender este estudio en su contexto histórico y cultural, ya que la selección de edificios hecha por McGibbon y Ross responde a la historiografía de su tiempo en la que el interés se focalizaba en la arquitectura medieval. McKean (2001) también cuestiona esta interpretación de la historia alegando que en este trabajo muchos de los denominados «castillos fortificados» construidos durante los s. XVII y XVIII no son tales, sino interpretaciones erróneas de edificios señoriales de ascendencia renacentista con apariencia defensiva.

El arqueólogo Joachim Zeune (1992) estudia lo que llama «últimos castillos escoceses» construidos entre los s.XV y XVII. Zeune critica el enfoque tipológico-cronológico utilizado por MacGibbon y Ross ya que, a su modo de ver, simplifica la historia de la construcción debido a la omisión de detalles arquitectónicos y hechos históricos cruciales. Por este motivo, propone revisar la datación de los edificios del periodo definido a partir del estudio de aspectos como la geometría en planta, la forma y características de las aberturas, el estudio de las marcas de cantero, o los elementos de piedra tallados como dinteles y jambas. Su investigación no parece tener continuidad. El arquitecto Robert Naismith (1985) toma una dirección distinta, focalizándose en la identificación de las estrategias de composición empleadas en edificios vernaculares. Estudia las características compositivas de una muestra de 23.500 edificios de este tipo construidos entre 1750 y 1914 con el objetivo de identificar zonas en la que los edificios comparten características [«character zones»]. Dicha caracterización incluye una breve referencia descriptiva a la fábrica pero desde el punto de vista estético, no constructivo.

Como hemos ya mencionado, Italia tiene una larga tradición en el estudio de estructuras de fábrica. Los numerosos tratados históricos que se conservan son muestra de la sólida cultura arquitectónica y constructiva. El análisis de estos documentos permite reconstruir lo que se conoce como *regola d'arte* (regla de arte), que es el conjunto de reglas constructivas, generalmente transmitidas oralmente a través de la práctica profesional, que garantizan el buen comportamiento del muro y aseguran su monolitismo (Donà et al. 2011). Esta cultura arquitectónica y constructiva, la cultura de la restauración en la que Italia ocupa también un destacado lugar, y la necesidad de intervenir después de los frecuentes terremotos, ha favorecido el desarrollo de un sólido conocimiento histórico-constructivo y una metodología científica para el análisis y caracterización de las estructuras de fábrica en ese país. El documento producido por el *Istituto Centrale per il Catalogo e la Documentazione* (ICCD, 2013) en Italia resume las distintas fases de este proceso situando su inicio en el trabajo del ingeniero Antonino Giuffrè (1991). Este autor es el primero en proponer una evaluación de la calidad de un paramento de fábrica de piedra, y a través del estudio de la *regola d'arte* local clasifica los tipos de muro prevalentes en la región de Ortigia (Giuffrè 2006). Las investigaciones subsiguientes contribuyen a desarrollar una metodología basada en la interdisciplinariedad y el conocimiento de las técnicas y soluciones constructivas a nivel local, que adopta el uso de fichas técnicas como herramienta clave para la recolección sistemática de los datos in situ.

Siguiendo esta metodología de estudio, el estudio histórico de la construcción realizado por Renzo Chioveli (2007) en Viterbo demuestra cómo una investigación sistemática de las fábricas de piedra contribuye a escribir la historia de la arquitectura, combinando el trabajo de campo con el estudio de la documentación de archivo. Tomando esta documentación como base consigue, a través de un análisis gráfico y dimensional, caracterizar las mamposterías e identificar y documentar las técnicas constructivas empleadas, diferenciando las distintas etapas del periodo medieval.

Otro ejemplo de calificación de los muros en relación a su comportamiento estructural es el llamado *método dell'Indice di Qualità Muraria (IQM)* (método del índice de la calidad de los muros) (Donà et al. 2011). Este método evalúa la calidad de la fábrica a partir de la identificación visual *in situ* de las distintas características que definen la *regola d'arte* de la construcción de una pared. El resultado proporciona un índice que permite calificar el comportamiento de

la fábrica frente a las distintas acciones a las que está sometida.

Metodología

A diferencia de Italia, Escocia no es una zona sísmica y presenta unas condiciones climáticas más desfavorables. Consecuentemente no sería adecuada una aplicación literal del método italiano, aunque sí podría hacerse con algunas variaciones que lo adapten a las necesidades específicas del territorio. Este estudio busca continuar las ideas de McKean y aprender de la experiencia italiana. Basado en estas dos referencias principales, este artículo presenta un estudio preliminar sobre la morfología de los muros de fábrica de piedra utilizados en la construcción de arquitectura señorial durante los s. XVII y XVIII en Escocia, y propone una metodología orientada a la caracterización constructiva de los muros de piedra en contraposición a los estudios tipológicos, arqueológicos y compositivos antes mencionados. Esta metodología desarrolla en primer lugar un estudio del contexto, en el que se analiza la evolución de las características constructivas generales de los edificios de los s. XVII y XVIII, y continúa con el estudio detallado de dos casos representativos de la época.

El estudio de contexto se realiza aplicando un análisis estadístico. Este tipo de análisis, habitual en campos como la biología (McDonald 2008), se aplica en este caso para evaluar de forma objetiva las características de los edificios de la época. La base de datos analizada está compuesta por 366 edificios seleccionados del grupo designado como Periodo 4 (1542–1700) en el estudio de MacGibbon y Ross (1887), y está elaborada a partir de la revisión bibliográfica de distintas fuentes y bases de datos: MacGibbon y Ross (1887), el catálogo online del *National Record of the Historic Environment (Canmore)*, y el catalogo de edificios de *Historic Environment Scotland*. Cada edificio está caracterizado por diez parámetros que proporcionan una descripción sobre el contexto, la planta, la sección, y los muros de fábrica de piedra del edificio. La tabla 1 lista estos parámetros especificando su abreviación y definiendo el grupo de variable (categórica o cuantitativa) al que pertenecen.

Los muros de fábrica de piedra están caracterizados por 3 de los 10 parámetros definidos: T1 y T2 definen los espesores de muro prevalentes, y MT define el tipo de aparejo. El objetivo del análisis estadístico es determinar el grado de dependencia entre estos 3 parámetros y los 7 restantes. Para ello se estudian las posibles combinaciones de pares de variables, que pueden ser de tres tipos: (1) categórica-categórica, (2) categórica-cuantitativa, y (3) cuantitativa-cuantitativa. En las combinaciones categórica-categórica se aplica el test exacto de Fisher o la prueba χ^2, según sea el tamaño de la muestra (Agresti 2007); mientras que en las combinaciones categórica-cuantitativa se aplica la prueba de Kolmogórov-Smirnov (Marsaglia et al. 2003). En ambos casos se estudian las variaciones en las distribuciones de la primera variable (categórica o cuantitativa) de acuerdo a los distintos niveles de la segunda (categórica), y se obtiene el p-valor de cada combinación. Las combinaciones cuantitativa-cuantitativa se estudian mediante análisis de regresión (Green et al. 1994) cuyo objetivo es definir la correlación entre ambas. El resultado es el coeficiente de determinación R^2 para cada par de variables. Dependiendo de la significación de los p-valores y los valores R^2, se califica el grado de dependencia entre parámetros (w) en una escala de 0 (mínima dependencia) a 1 (máxima dependencia). El sistema de relaciones de dependencia resultante se visualiza aplicando análisis de redes (Csardi et al. 2006). Los nodos de la red (no-

VARIABLES CATEGÓRICAS	
LOR	Zona geográfica
MT	Tipo de aparejo de piedra predominante en el edificio
NF	Número de plantas promedio sobre el nivel del terreno
NV	Número de plantas abovedadas
PE	Periodo cronológico
PL	Composición/diseño en planta
VARIABLES CUANTITATIVAS	
AA	Superficie construida en PB en m2
MS	Luz máxima en m de planta primera
T1	Espesor de pared predominante en planta baja respecto al total de metros lineales de muro en m
T2	Segundo espesor de pared predominante en planta baja respecto al total de metros lineales de muro en m

Tabla 1
Parámetros definidos para el análisis estadístico.

des) corresponden a cada uno de los parámetros del sistema, mientras que las conexiones entre ellos (edges) están definidas por los valores *w* calculados previamente (figura 1). A partir de las conclusiones obtenidas se seleccionan dos casos de estudio representativos para un análisis detallado de sus fábricas.

La caracterización de las fábricas de piedra toma como referencia el método IQM mencionado anteriormente (Donà et al. 2011). Aunque en este caso el objetivo no es la calificación de la calidad del muro, la identificación de aspectos relacionados con la *regola d'arte* permite definir las características de la fábrica. Debido a la condición de ruina de los edificios seleccionados, el aparejo de los paramentos interior y exterior de los muros es visible e incluso, en algunas áreas, la sección está expuesta. El análisis se realiza a partir de fotografías de ambas caras del muro que comprenden un área de 1 m^2. Para obtener estas imágenes a escala se coloca un bastidor de 1m × 1m sobre el paramento, enmarcando el área seleccionada. Más tarde, las imágenes se procesan de forma semiautomática: primeramente, las fotografías se transforman manualmente en imágenes binarias; posteriormente se analizan mediante un sistema automatizado utilizando procesamiento de imagen.

El análisis de estas imágenes a escala se focaliza en la extracción de valores considerados determinantes en la configuración de los muros:

1) distribución en porcentajes de junta de mortero, ripio, y unidades de piedra
2) coeficiente de regularidad medio de las unidades (CRM), calculado como el área real de la unidad de piedra en alzado dividido entre el área del rectángulo circunscrito
3) altura media de las unidades
4) línea mínima de trazado (LMT) según propuesto por F. Doglioni y G. Mirabella Roberti (2003)
5) continuidad de las hiladas

El análisis de los muros incluye además la identificación de la composición en sección (identificando también el grado de trabazón transversal) y el tamaño y trabazón de las unidades de piedra en los encuentros en esquina.

Los puntos mencionados se definen adaptando los parámetros definidos en el método IQM referido, a la *regola d'arte* identificada en Escocia. Este conjunto de valores caracteriza los muros y posibilita el posterior análisis comparativo de las distintas fábricas.

Estudio de contexto

La Figura 1 muestra el mapa sistema de relaciones de dependencia resultante del análisis estadístico descrito en el apartado anterior. En este sistema, el parámetro más determinante para los espesores de muro (T1 y T2) es el tipo de planta (PL).

El estudio detallado del espesor de muro T1 en relación a los distintos tipos de planta definidos permite identificar dos casos extremos respecto al rango de espesores de muro posibles. Los rangos máximos corresponden a los edificios con plantas tipo *torre* y a las plantas en Z, que pueden tener espesores entre 0.6 m y 2.7 m (en el primer caso) o 0.6 y 3.3 m (en el segundo caso), aunque la mayoría de estos casos varían entre 1.1 m y 1.9 m (el 65% de los casos con planta tipo *torre*) o entre 1 m y 1.5 m (el 73 % de los casos con planta en Z). El caso opuesto es el de los edificios con plantas tipo *Villa*, cuyos espesores varían entre 0.7 m y 1.2 m (rango más reducido) aunque en la mayoría de los casos (71 %) está entre 0.9 m y 1.1 m. El resto de tipos de plantas presenta situaciones

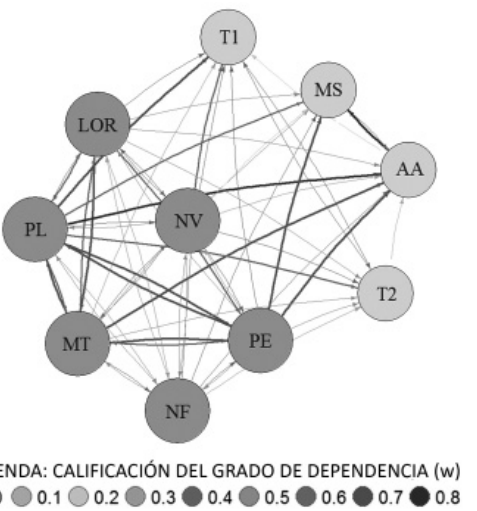


Figura 1
Mapa del sistema de relaciones de dependencia.

intermedias con espesores más frecuentes entre 0.8 m y 1.1 m según el caso.

Las plantas tipo *torre* son habituales anteriormente al s. XVII, mientras que los edificios tipo *Villa* aparecen a finales del XVII. El análisis del espesor T1 respecto al periodo de construcción (PE) confirma la sabida tendencia a reducir el espesor de los muros con el paso del tiempo, y permite identificar valores específicos. Los edificios construidos anteriormente al s. XVII (80 casos) tienen espesores de muro en planta baja que varían entre 0.7 m y 2.3 m, siendo 1.1 m el valor más habitual (figura 2-A). En cambio, aquellos construidos durante los s. XVII y XVIII (56 casos) tienen un rango más reducido, con espesores inferiores a 2 m, siendo el valor más habitual 0.9 m (figura 2-C). Finalmente, los edificios cuya construcción es anterior al s. XVII pero que incorporan alteraciones o extensiones de los s. XVII y XVIII (81 casos) presentan una situación intermedia (figura 2-B).

Parámetros como el número de plantas (NF) o la luz máxima en la primera planta (MS) suelen ser determinantes en el diseño y definición del espesor de muro ya que están directamente relacionados con el nivel de solicitación de la estructura. Contrariamente, en el mapa de dependencias no comparten una conexión relevante con los espesores (T1, T2) o el tipo de aparejo (MT). Esto es debido a que todos los edificios de la muestra tienen valores parecidos. En el caso de NF, la mayoría de los edificios considerados (81 %) están compuestos por 3 o 4 plantas. Igualmente en el caso de MS, el 87 % de los edificios tienen luces inferiores a 6.5m. Sin embargo, el número de plantas abovedadas (NV) comparte una relación de dependencia discreta con T1 a pesar que la mayor parte de los edificios (81 %) tiene solamente una de sus plantas abovedada (normalmente el nivel inferior). El estudio detallado de estos dos parámetros muestra una cierta tendencia a crecer del espesor de muro cuando incrementa el número bóvedas. Así pues, edificios con 2 o más plantas abovedadas tienen espesores de muro mayores de 1.1 m, mientras que edificios sin bóvedas suelen tener espesores entre 0.9 m y 1 m. Sin embargo, la situación más habitual (sólo una planta abovedada) presenta una distribución homogénea con un amplio rango de espesores (entre 0.7 m y 2.5 m), y un ligero pico entre 0.9 m y 1.1 m que representa el 42 % de los casos.

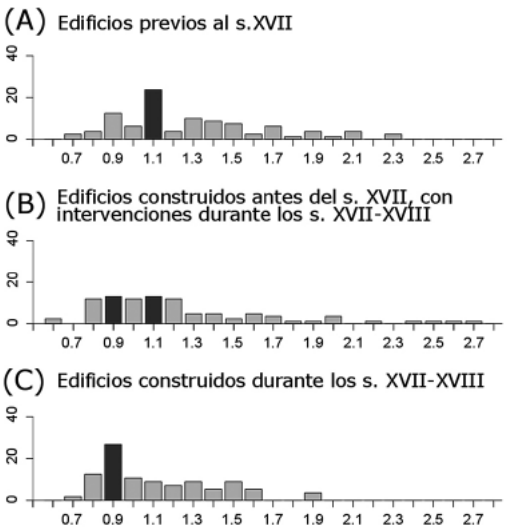


Figura 2
Histogramas T1 vs. PE. El eje X corresponde a los espesores de muro (T1) en cm. El eje Y define frecuencia en porcentajes.

Finalmente, el tercer parámetro que caracteriza las fábricas es el tipo de aparejo (MT). MT, T1 y T2 no tienen una interdependencia directa relevante en el sistema, pero todos están conectados con el tipo de planta (PL). El estudio del tipo de planta PL respecto al tipo de fábrica MT, destaca que la mayoría de los edificios (88 %) están construidos con fábrica ordinaria regular o irregular. La planta tipo *Villa* es el único tipo de planta que incluye en todos los casos sillería, ya sea en una parte o en todo el edificio.

En conclusión, se identifica una tendencia decreciente en el tiempo del espesor de los muros de la planta de acceso, en la que se abandonan los valores superiores a 2 m y los espesores más habituales pasan de 1.1 m a 0.9 m. El parámetro más condicionante en este proceso es el tipo de planta, aunque cabe remarcar la influencia discreta del número de bóvedas en el sistema. En cambio, parámetros como el número de plantas o la luz del espacio interior no son determinantes debido a que la mayoría de los edificios de la muestra tienen los mismos valores. Finalmente, la identificación de sillería en todas las plantas tipo *Vila*, habituales en el s. XVIII, podría interpretarse como un indicador de evolución en el uso del tipo de fábrica.

Análisis de los casos de estudio

Como hemos visto, el estudio de contexto identifica una evolución de las mamposterías utilizadas durante los s. XVII y XVIII, tanto en términos de espesor como de tipo. Considerando este resultado se seleccionan dos casos de estudio, uno de inicios del s. XVII y otro de finales del XVIII para analizar en detalle esta evolución.

Gilbertfield Castle

El primer caso de estudio es Gilbertfield Castle (figura 3), construido cerca de Glasgow con fábrica ordinaria. Gilbertfield Castle corresponde al tipo de edificio conocido como casa-torre, habitual durante s. XVI aunque sus últimos exponentes datan de principios del XVII. La planta presenta una geometría en L, con el nivel inferior abovedado y los tres niveles superiores originalmente formados con forjado de viguetas. De autor desconocido, el año 1607 tallado en una de sus piedras es la única evidencia de la fecha de su construcción. La presencia de alguna inconsistencia en el grueso de las paredes de fachada y discontinuidades en las hiladas podría ser indicios de intervenciones de las que no existe evidencia documental.

De la planta original en L hoy sólo queda en pie la estructura de piedra del ala noroeste dejando vista la sección del edificio (figura 3). En planta baja se definen 5 espesores distintos de muro (figura 4). Las particiones interiores están formadas por muros de piedra de una sola hoja, de entre 30 cm y 35 cm de espesor. Las fachadas tienen un espesor de muro de unos 85 cm, excepto en dos casos: el tramo de fachada oeste correspondiente a la escalera, que mide 65 cm; y la fachada sur, que tiene un espesor de 100 cm. En este último caso, el muro está seccionado en toda su altura quedando a la vista su composición. La sección en PB está compuesta por dos hojas exteriores de fábrica ordinaria regular y un núcleo interior compacto a base de mortero y piedras de distintos tamaños bien acuñadas. La presencia de elementos de conexión transversal (trabas) es un indicador de un buen grado de trabazón en sección. En las plantas superiores el corte ocurre por las aberturas, donde los antepechos están formados por una hoja de piedra de 40 cm de espesor pese a que el total de fachada es 85 cm.

Las imágenes A y B (figura 5) corresponden respectivamente a la cara exterior e interior de la fachada sur (figura 4). En la cara exterior (figura 5-A), el 17.6 % de la superficie corresponde a las juntas de mortero, mientras que el resto se divide entre un 77 % de bloques de piedra y un 5.4 % de ripio. El coeficiente de regularidad medio de las unidades (CRM) es de 0.82, la altura media de las unidades es de 26 cm, y la línea de mínimo trazado (LMT) 109.5 cm. En este caso pueden identificarse 3 hiladas completas



Figura 3
Ala noroeste del castillo Gilbertfield.

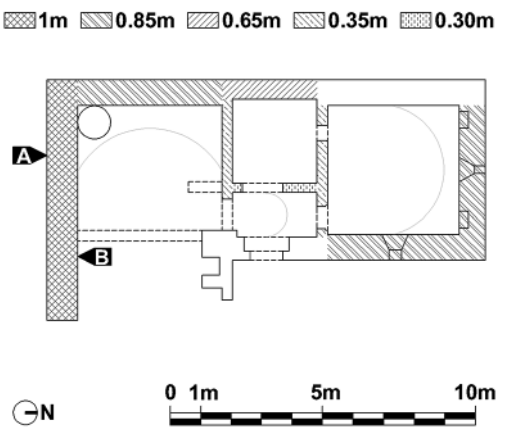


Figura 4
Planta baja del castillo Gilbertfield con indicación de los distintos espesores de muro. A y B definen la posición de las imágenes de 1m² obtenidas a nivel de planta baja.

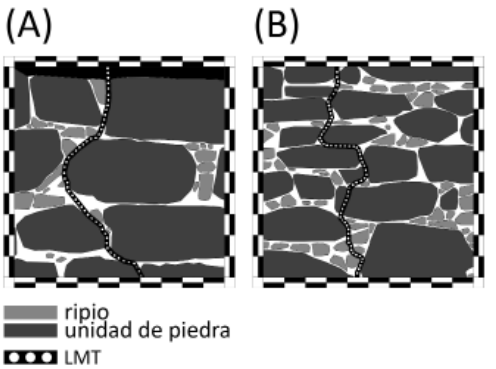


Figura 5
Imágenes a escala (1 m^2) de la fachada sur del castillo Gilbertfield. A) Cara exterior, y B) interior.

más o menos continuas, de altura variable. La cara interior (figura 5-B) mantiene el mismo porcentaje de juntas de mortero (17.6 %), disminuyendo los bloques de piedra al 71.4 % e incrementando el ripio al 11 %. El CRM se mantiene en 0.81 y la altura media de las unidades baja a 12 cm. En este caso es difícil identificar hiladas, pero la LMT crece levemente hasta 118.9 cm. Ambos paramentos tienen características parecidas aunque la cara exterior está compuesta por unidades de mayor tamaño que la interior.

Finalmente, los remates en esquina están formados por una alternancia regular de unidades de piedra de tamaño medio 66 cm × 29 cm × 35 cm correspondientes a la base, altura y profundidad respectivamente.

Dalquharran Castle

El segundo caso de estudio es Dalquharran Castle, en el South Ayrshire (figura 6), diseñado y construido con sillería por el arquitecto Robert Adam a finales del s. XVIII siguiendo los cánones neoclasicistas conocidos como «Adam Style» (Davis 1991). La ampliación posterior documentada de las alas laterales es difícil de distinguir a simple vista, aunque puede corroborarse a través de una observación detallada de la fábrica existente. La planta del edificio es rectangular y podría clasificarse como una *Villa compacta*. El edificio está compuesto por una planta baja y dos niveles principales de forjado ligero. El sótano, probablemente abovedado, ventila a través de un patio ingles que discurre alrededor de todo el perímetro del edificio .



Figura 6
Imagen de la fachada noroeste del castillo Dalquharran.

La estructura de piedra del castillo Dalquharran se mantiene prácticamente intacta pese a su condición de ruina, y está compuesta por paredes de distintos espesores en planta (figura 7). Las fachadas y muros

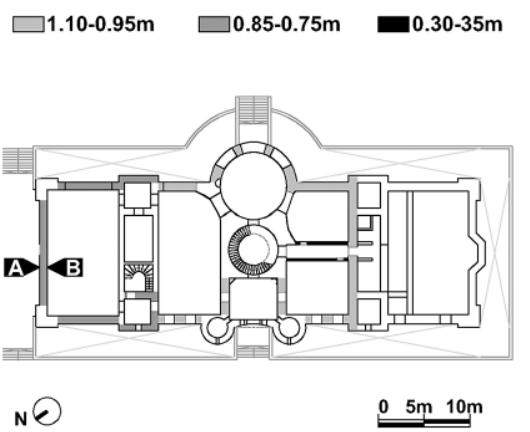


Figura 7
Planta baja del castillo Dalquharran con indicación de los distintos espesores de muro identificados in situ. A y B definen la posición de las imágenes de 1m^2 fotografiadas a nivel de planta baja.

portantes de la parte original del edificio (parte central) tienen espesores entre 110 cm y 95 cm, mientras que los de la extensión posterior (alas laterales) presentan espesores de 85–70 cm. Finalmente, las particiones interiores son de 30–35cm de espesor.

Las imágenes A y B de la figura 8 corresponden respectivamente a la cara exterior e interior de la fachada noreste, según se indica en la Figura 7. El muro estudiado tiene un espesor de 85 cm tanto en PB como en los niveles superiores. En el caso de la imagen correspondiente a la cara exterior (figura 8-A), las juntas representan el 2.9 %, mientras que el 97.1% restante corresponde a las unidades de piedra. No se detecta presencia de ripios, y el coeficiente de regularidad medio de las unidades (CRM) es igual a 1 (sillares con aristas rectas). La altura media de las unidades es de 30 cm, y la línea de mínimo trazado (LMT) 168 cm. Las hiladas son continuas en todo el perímetro del edificio, coincidiendo con las aberturas y demás elementos de composición de la fachada. La imagen B (figura 8-B) presenta unas características diferentes. En este caso, el porcentaje de piedra es del 80 %, las juntas representan el 16.4 %, y el 3.6 % restante es ripio. El CRM desciende a 0.84, y la altura media a 26 cm. La LMT también presenta un valor inferior, igual a 107.9 cm. Sin embargo se mantiene la continuidad en las hiladas.

Debido al buen estado de conservación de la estructura, la sección del muro no es visible en ningún punto del edificio. Pese a todo, la comparación de las imágenes A y B definen una pared compuesta por una hoja exterior de sillería y una interior de fábrica ordinaria, construidas manteniendo la continuidad de las hiladas en todo el edificio. El espesor total de 85 cm podría incorporar núcleo interior. La observación detallada de los alzados interior y exterior del muro permite identificar la presencia regular de los elementos de conexión transversal referidos en el caso anterior, e indicativos de una buena trabazón en sección. Finalmente, las esquinas están formadas por una alternancia regular de unidades de piedra de tamaño medio 92 cm × 31 cm × 33 cm correspondientes a la base, altura y profundidad respectivamente.

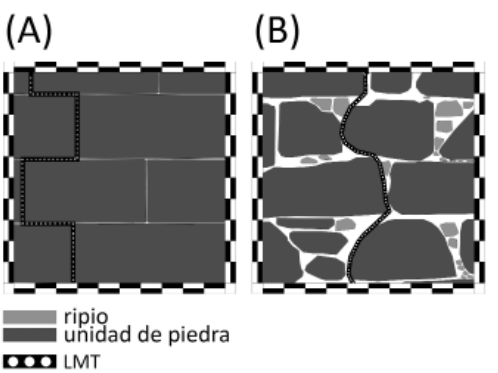


Figura 8
Imágenes a escala (1 m²) de la fachada sur del castillo Dalquharran. A) Cara exterior, y B) interior

Discusión de los resultados

La definición de parámetros cuantificables posibilita la caracterización y comparación objetiva de las distintas fábricas.

Los muros analizados tienen características diferentes. Por un lado, el muro del castillo Gilbertfield, edificio tipo casa-torre de inicios del s. XVII, tiene una sección variable en altura, de espesor 100 cm en planta baja y 85 cm en las plantas superiores. Por otro lado, el muro del castillo Dalquharran, edificio tipo *Villa* de finales del XVIII, tiene una sección vertical de 85 cm de espesor tanto en planta baja como en los niveles superiores.

En el caso del castillo Gilbertfield se identifica una fábrica ordinaria (5.4 % de ripio en el exterior y 11 % en el interior) con unidades de piedra irregulares ligeramente labradas en algunos casos (coeficiente de regularidad 0.8), compuesta por un núcleo interior compacto y dos hojas con el mismo porcentaje de junta (17.6 %) pero con unidades de tamaño mayor en el exterior. Las hiladas no son continuas en todo el edifico, y la traba en alzado no se respeta ya que las LMT interior y exterior presentan valores inferiores a 140 m. Por otro lado, el castillo Dalquharran está compuesto por una fábrica de dos hojas con características diferentes. La hoja exterior es de sillería con juntas muy finas (2.9 %) y sillares escuadrados (coeficiente de regularidad 1). El paramento interior es de una fábrica ordinaria con características muy parecidas a la hoja exterior del castillo Gilbertfield, aunque en este caso las hiladas horizontales se mantienen continuas en todo el perímetro del edificio para ambos paramentos. La traba en alzado se cumple parcialmente, ya que sólo el paramento

exterior presenta una LMT mayor a 160 m. En cambio, las fábricas de ambos casos tienen una buena traba en sección debido a la presencia de conectores, y las esquinas también tienen una correcta alternancia de elementos aunque las dimensiones varían de un caso a otro.

Conclusión

Los s. XVII y XVIII son un periodo fundamental en la evolución de la arquitectura en Escocia. Este estudio preliminar centrado en las residencias aristocráticas y señoriales construidas durante este periodo permite reconocer la evolución de su arquitectura a través de los cambios en el diseño y morfología de los muros. La complejidad de estos edificios, muchas veces compuestos por distintas fases constructivas, requiere el desarrollo de una metodología adecuada. El estudio de las fábricas es fundamental para entender la arquitectura del periodo, no siempre documentada en archivos, y así informar los proyectos de restauración.

La metodología propuesta comienza con el estudio de contexto a través de un análisis estadístico que identifica la reducción del espesor de los muros con el tiempo. A través de este análisis se establece que los muros de más de 2 m de espesor en la planta acceso desaparecen en el s. XVIII, y la mayoría de los espesores de muro disminuyen aproximadamente 20 cm entre el s. XVI y finales del XVIII, resultando en valores cercanos a 90 cm. Por otro lado, la identificación de sillería en todas las plantas tipo *Villa*, habituales a finales del s. XVIII y principios del XVIII, podría interpretarse como un indicador de la evolución arquitectónica, cada vez más eficiente y planeada. La segunda parte del estudio analiza en detalle las fábricas de dos casos de estudio representativos: uno de principios del s. XVII y otro de finales del s. XVIII. El análisis tiene como referencia principal la extensiva experiencia italiana en este tipo de análisis y define parámetros específicos que posibilitan la automatización parcial del proceso empleando técnicas de procesamiento de imagen. El estudio comparativo de los resultados evidencia un grado de diseño superior en la fábrica perteneciente al edificio de finales del s. XVIII que parece estar relacionado con el desarrollo de la profesión de arquitecto. Esta mampostería tiene una hoja exterior de sillares perfectamente escuadrados, hilaras de 30cm de altura y juntas muy finas (2.6%) continuas en todo el perímetro del edificio; mientras que el caso de principios del XVII está compuesto por una mampostería ordinaria con un 17.6% de junta, bloques mas irregulares e hiladas de una media de 26cm de altura en la cara exterior. No obstante, es necesaria la aplicación de esta metodología en un número mayor de casos para verificar estas hipótesis, y es así como la investigación continua actualmente. El objetivo final es crear un conocimiento histórico-constructivo detallado de la arquitectura del periodo que contribuya a la correcta interpretación y consecuente conservación de este importante patrimonio.

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