REALITY AND REALISM IN VIRTUAL ARCHITECTURAL RECONSTRUCTION

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Abstract

Computer-aided modelling and visualisation techniques have found widespread use in architectural practice as tools to illustrate proposed buildings and environments. The same techniques have also been utilised to aid in the interpretation of the architecture of the past, principally by recreating, in a virtual environment, structures which either no longer exist or which have been substantially altered or damaged over the years. However, much interest in this area has been focused on creating visually alluring images with a strong public appeal, with rather less emphasis given to illustrating the uncertainty that usually underlies any attempt at reconstructing the past. This thesis consists of a critical analysis of the way in which the computer-aided visualisation techniques are commonly perceived and employed by researchers in architectural history and archaeology, with the 11th century church of Sant Vicenç de Cardona in Spain being used as a case study. The main issues raised are then discussed, both in terms of current trends and possible future directions, with a view to identifying a general approach to the illustration of uncertainty in virtual architectural reconstructions.

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Introduction

In his account of a tour of Scotland undertaken in 1773, James Boswell recounts a visit to the Isle of Skye accompanied by his fellow traveller, the celebrated writer and savant Dr. Samuel Johnson. Whilst on the island they are taken to see a collection of ruins which the local minister and amateur antiquarian, a certain Donald McQueen, vows are the remains of a temple of the minor Greek goddess Anaitis (Boswell 1955 [1785]:154-155). Boswell is distinctly unimpressed by the ruins of the supposed temple, and subsequently both he and Johnson press the antiquarian to justify what appear to be rather far-fetched conclusions based on very slight evidence. McQueen proceeds to point out that the local Gaelic name for the site happens to be *Ainnit*; he also explains that there is a stream not far from the ruins, and, from his readings of the classical authors Pausanias and Pliny the Elder, knows that the shrine of this particular goddess in Lydia was sited near a river so that the statue may be periodically washed. This obviously faulty line of reasoning, based as it is on personal fantasy and wild conjecture, is ridiculed by Johnson, who remarks to the still recalcitrant McQueen (Boswell 1955 [1785]:155):

> You have one possibility for you, and all possibilities against you. It is possible it may be the temple of Anaitis. But it is also possible that it may be a fortification; – or it may be a place of Christian worship, as the first Christians often chose remote and wild places: – or, if it was a heathen temple, it may have been built near a river, for the purpose of lustration; and there is such a multitude of divinities, to whom it may have been dedicated, that the chance of its being a temple of Anaitis is hardly any thing. It is like throwing a grain of sand upon the sea-shore to-day, and thinking you may find it to-morrow. No, sir, this temple, like many an ill-built edifice, tumbles down before it is roofed in.

This account highlights in a rather entertaining manner the dangers inherent in constructing images of the past based on incomplete, or indeed non-existent, archaeological or textual evidence. What is even more interesting, however, is that this approach to interpreting the past has been common throughout history up to the present day, even though, with the development of scientific archaeology and source-based history in the 19th century, we are no longer groping in the dark to the same extent as the hapless McQueen. The past holds an irresistible fascination for many of us; however, we tend to approach it in a highly emotionalised way, and, as a consequence, popular images of history (architectural or otherwise) are on the whole simplistically and one-dimensionally formed. This is perhaps due the fact that there are always certain interpretations that are more favoured – for reasons of expediency or self-aggrandisement, for instance – than others which might be equally or even more plausible based on the evidence to hand. Thus, like McQueen, we tend to construct images of the past that are largely devoid of rigorously analysed content, and which do not stand up to closer examination – as Johnson eloquently puts it, ill-built edifices that collapse even before there is a chance to put on the roof.

The historic built environment plays a large part in forming our images of what life in the past was like. For example, in the common imagination, ancient Egypt is inextricably linked with the Pyramids of Giza; similarly, mention of ancient Rome and Greece evoke images of the Coliseum and the Parthenon respectively. The built environment that past societies leave behind – or indeed, that they do not leave behind – is also a fundamental component in the way that they are judged by subsequent ones. Indeed, this attitude is criticised in excoriating but ultimately somewhat simplistic terms by the 19th century American philosopher and writer Henry David Thoreau (1997 [1854]:52-53):

> Nations are possessed with an insane ambition to perpetuate the memory of themselves by the amount of hammered stone they leave. What if equal pains were taken to smooth and polish their manners? One piece of good sense would be more memorable than a monument as high as the moon. I love better to see stones in place. The grandeur of Thebes was a vulgar grandeur. More sensible is a rod of stone wall that bounds an honest man's field than a hundred-gated Thebes that has wandered farther from the true end of life. The religion and civilization which are

> barbaric and heathenish build splendid temples; but what you might call Christianity does not. Most of the stone a nation hammers goes toward its tomb only. It buries itself alive. As for the Pyramids, there is nothing to wonder at in them so much as the fact that so many men could be found degraded enough to spend their lives constructing a tomb for some ambitious booby, whom it would have been wiser and manlier to have drowned in the Nile, and then given his body to the dogs. I might possibly invent some excuse for them and him, but I have no time for it.

One of the reasons as to why the built environment plays such a fundamental part in our knowledge of the past is that it is generally, by its very nature, permanent, and tends to endure long after the decay of what may actually have been more meaningful, and perhaps enlightening, artefacts. There is a very real danger inherent in forming historical opinions based on isolated objects of this sort: throughout the ages, many non-sedentary, non-farming-based societies have been seen as savage and lazy, and as a consequence, worthy of exploitation and even destruction, mainly because they took no interest in creating large-scale artefacts by which they could be compared to the so-called great civilisations. This is emphasised by Thoreau (1997 [1854]:53) as follows:

> Many are concerned about the monuments of the West and the East, – to know who built them. For my part, I should like to know who in those days did not build them, – who were above such trifling.

However that may be, we cannot gain any objective knowledge based on what does not exist, and any attitudes thus formed would be on the same level of conjecture of McQueen and his temple described earlier. Therefore, given the importance that images of the built environment play in our perceptions of the past, it is important that we form rational and well-considered opinions based on archaeological and historical research, rather than pure supposition.

The accurate representation of the architectural past – in relative terms, subject to the available information – has been an important subject in much of Western art since the 14th Century at least, when, with the emergence of the Renaissance, much emphasis was placed on attempting to regain what were considered to be the lost glories of the Classical world. However, as we shall see during the course of this discussion, an academically rigorous approach to the reconstruction of the lost built heritage is a relatively recent phenomenon, one that sprang from the growth of scientific archaeology, source-based history, and not least, public literacy and interest in the past, during the 19th Century. To these influences may be added the political dimension which has, certainly since the emergence of the modern nation state, exploited largely fanciful notions of glorious histories to create various race- and culture-based mythologies. An interesting phenomenon in this early period, especially where public appeal was an important objective, was the creation of full-size site reconstructions on top of the original archaeological remains, a course of action that would today be unacceptable. Along with this, the practice of creating historical theme parks was – and continues to be – given considerable importance, although, again, much of the material contained within these so-called reconstructions tended, at least in the early days, to be historically inaccurate or misleading.

The development of computer visualisation techniques in the 1960s and 1970s brought about a paradigm shift in the practice of representing architectural subjects, although, on the whole, this had to wait until the development of non-specialist hardware and software in the 1980s. Along with the use of these techniques to represent proposed buildings and environments, they have also been utilised to aid in the interpretation of the architecture of the past, principally by recreating, in a virtual environment, structures which either no longer exist or which have been substantially altered or damaged over the years – what will be termed throughout this discussion as *virtual architectural reconstructions*. Typically much interest in this area has been focused on creating visually alluring, photorealistic images with a strong public appeal, with rather less emphasis given to illustrating the uncertainty that usually underlies any attempt at reconstructing the past. While this is a perfectly valid approach where the ultimate objective is the creation of information in an easily digestible format aimed at the general public, it is perhaps more important, in an academic or research context, to employ these computer-aided tools to explore the building itself than to communicate definitive single-interpretation scenarios. This is in many ways a squandering of the potential of the underlying techniques, which, due to the fact that computer models are really three-dimensional simulations in addition to be being representations, offer numerous tools that can be profitably employed in gaining a fuller insight into historic architecture than would have been possible with traditional models and drawings.

We shall, in the course of this investigation, discuss the ways in which the computer-aided visualisation techniques are commonly perceived and employed by researchers in architectural history and archaeology, along with the manner in which individuals and societies appreciate and manipulate the architectural past. As a case study, several architectonic features of the 11th Century church of Sant Vicenç de Cardona in Spain are investigated using computer-aided visualisation techniques, with the intention of testing the hypothesis that the nave of the structure was originally conceived to be significantly lower than what was eventually constructed. Finally, important methodological issues raised during the various stages of the modelling process will be discussed and evaluated with a view to formulating a general approach to the illustration of uncertainty and multiple interpretations in virtual architectural reconstructions.

1

Reconstructing the Past

In H. G. Wells' classic science-fiction fantasy *The Time Machine*, the Time Traveller decides to project himself forward in time in the hope of finding a utopian future, only to see the gradual decay of humanity ultimately ending in total savagery. Many people, given the power to travel through time, would perhaps decide to travel backwards into a utopian past where everything is perfect, known and knowable. The past, in the common perception, is imbued with an idealised and almost mythical dimension; we look back with fondness at the Elizabethan era for example, choosing to remember its perceived achievements – the exploits of Drake and Raleigh, the defeat of the Spanish Armada, the music of Tallis and Byrd, the literary works of Spenser and Shakespeare. We prefer to remain oblivious to the fact that life at this time was far from ideal for most people – the squalor, the widespread disease, the social exploitation and the religious persecution of the 16th century do not form a part of our imaginary reconstructions. This phenomenon is nothing new, for Homer, looking back probably in the 8th Century BC at what was to him the dim Arcadian past, sees a gloriously perfect state of affairs, a veritable Golden Age (Keen 1999:242-243). As E.V. Rieu points out in the introduction to his translation of Homer's *Iliad* (1950 [?]:xix-xx):

> Every manufactured object that he [Homer] mentions is well and truly made. A ship is always fast, well benched and seaworthy; a spear is stout, long and sharp, and (we are charmed to note) it is its custom to throw a long shadow on the ground and also to be 'wind-fed' even when resting in a warrior's hand; that is to say, it looks back to the time when its shaft was part of an ash-tree on the windswept mountain-side, or else forward to the moment when it is going to hurtle through the air. Natural phenomena such as the rosy-fingered dawn and the ambrosial and mysterious night are all given adjectives which search out the quintessence of their quality or beauty. Homer's men are all noble,

> peerless, brave, wise or characterized by some other excellence; and his women are all lovely, or at least well-dressed and with hair beautifully done.

It is hardly necessary to emphasise that the Greece that Homer talks about (which we now know to be the Bronze Age Mycenaean civilisation) was not, in reality, the heroic utopia where every object and person existed as its perfect Platonic prototype. The work of Ventris and Chadwick, the decipherers of the Mycenaean Linear B script, reveals instead a group of people who were more preoccupied with the singularly mundane activities of accounting and keeping records of every conceivable item, from fire-tongs to tripod cauldrons, than contending with each other and with the gods in the manner that Homer portrays them (Chadwick 1958:101-133).

1.1 Uses of the Past

According to the 19th Century theorist and writer John Ruskin, the architecture of an age is its most visible legacy to the future – in fact, he refers to architecture as the Lamp of Memory (Ruskin 1989 [1880]:178). It comes as no great surprise, in the light of the foregoing discussion, that future generations often wish to brighten the feeble flame of the original lamp and to give it a shiny polish that it never possessed in reality. The fact remains that people throughout the ages have looked back at a sanitised version of the architecture of the past to lend validity to their own interpretations of what the built environment should be like (and by extension, what society should be like). This has been the case from Vitruvius in the 1st century AD idealising the architecture of Classical Greece in his *Ten Books of Architecture*, to Le Corbusier and his simplistic analyses of the Parthenon and the Cathedral of Notre Dame put forward in his *Vers une Architecture* (Towards a New Architecture) of 1923 (Le Corbusier 1986 [1931]:69-83). It is difficult to pinpoint the reasons for this extreme interest in identifying with, deriving legitimacy from and recreating an idealised past, but it may have something to do with the consciousness of our own impermanence in both the personal and societal contexts – unable to free ourselves

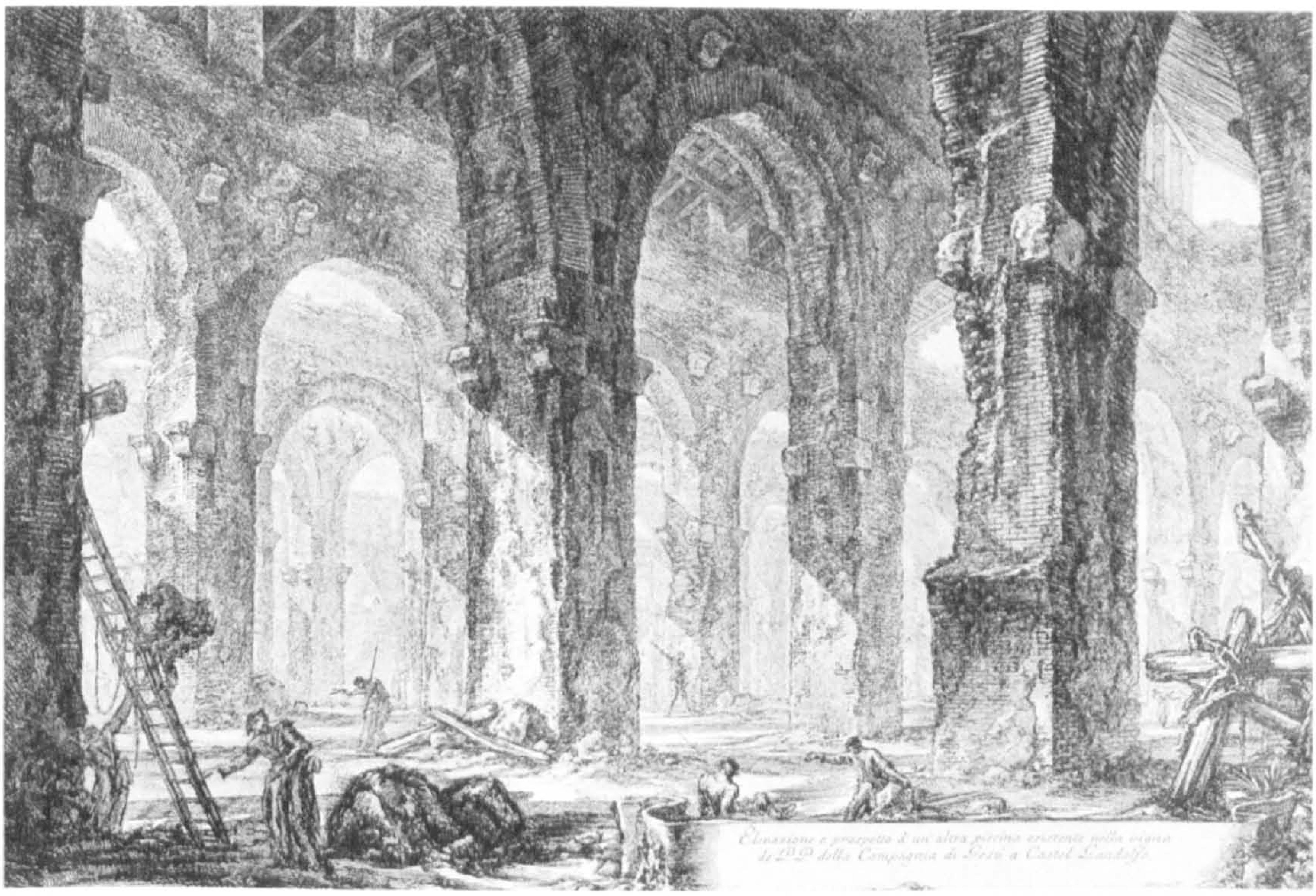


Fig 1.1 *Interior of a Cistern near Castel Gandolfo*, by Giovanni Batista Piranesi, 1764 (from Anon.1988)

from the constraints of our own age, we project ourselves onto a putative continuity in an attempt to adopt a spurious sort of immortality. It also provides a partial explanation for our fascination with ruins, and why many architects during the last few centuries, from Piranesi and Fuseli in the 18^{th} and 19^{th} centuries to Lebbeus Woods in the 20^{th}, have demonstrated a morbid desire to illustrate buildings in a ruined form (Fig. 1.1). As Harbison (1991:99) notes:

> Feelings about decadence are some of the most twisted and interesting in all culture, and by our taste for ruins we affirms our belief in decadence, our half-voluntary imprisonment in it. Ruins are models or heralds of the disintegrating mind and collapsing principles of the age after the end of stable belief, the half-loved companions of post-religious man haunted by ghosts of faith.

From this point of view, by recreating a lost historic building, either in our imaginations or in a more concrete form, we are in effect resurrecting something that was dead, and not only are we giving it back the life it once had, we are in fact, by idealising the original, giving it back the life it *should* have had. This attitude towards the architectural past is exemplified by the work of Sir Jeffrey Wyatville, who was active in England in the early 19th century, 'improving' and 'perfecting' original medieval buildings by giving them all manner of sham Gothic features (Davey 1995:13).

There are also a number of very practical reasons for attempting to reconstruct the architecture of the past. Many ancient buildings have fallen into such a state of disrepair that it can often be almost impossible to piece together their original appearance from what is visible today. Many other buildings have disappeared altogether, so the archaeologist or building historian finds himself restricted to using a few random excavation finds and pieces of documentary or iconographic evidence to piece together what is largely an inferential view with many gaps and conjectures. It is convenient in such cases to create a simulation of the building in order to place the evidence in context, and to be able to visualise and examine various hypotheses about what the original structure may have looked like or may have been used for in the past. In addition to providing a tool to test hypotheses, reconstructions are also a means to present any discoveries that might have been made during the research.

Interest in ancient buildings is by no means restricted to the academic sphere, for there is an ever-increasing public demand for access to historic sites in the form of 'heritage tourism'. This phenomenon has become especially prominent over the last few decades, so much so that heritage management is a extremely important political issue. Presenting historic buildings to a lay audience, however, can be a difficult matter for a number of reasons. Firstly, the vast majority of historic buildings and sites are extremely fragile and susceptible to physical or atmospheric variations. It is therefore not difficult to imagine that uncontrolled access by large numbers of visitors could be extremely harmful and even disastrous to the building fabric. Indeed, visitor access to a number of important historic sites, such as some of the more important Egyptian tombs, has been restricted or stopped altogether for this very reason. In addition to the danger posed to the fabric, there is also a possible danger to the visitor in some sites in the form of unstable buildings, and it is clearly not good practice to do extensive stabilisation work and alter the character of the remains. The entire question of visitor access is a difficult matter – many sites are dependent on the funds generated by the public for their maintenance, but then they are paradoxically destroyed by their putative sources of funding. The provision of reconstructions in a museum environment is part of a possible solution to this problem, for the members of the public are thus kept off the original fabric, and they also have the more satisfying experience of seeing the building as it may have originally appeared instead being forced to conjure up mental images (the ethical implications of this approach are discussed in the remainder of this Chapter).

1.2 Can the Past be Reconstructed?

It is worth asking the question as to whether the past can ever be known in an objective manner, and if so, whether this knowledge can be effectively communicated to a lay public. This issue is all the more relevant in the case of architectural reconstruction from physical or documentary remains, for a non- or partially-existent building is unable to speak for itself: it is nothing but an incomplete framework that must be filled in with various conjectures in a time and culture different from when the building was created and used. Even with the best of intentions, therefore, the final version owes as much to the person doing the reconstructing as to the original structure. So, is the pursuit of historical accuracy a worthwhile, possible or credible aim?

1.2.1 The Unknowable Past

We all have nostalgic tendencies, and we enjoy trying to imagine what the past was like, and moreover, we tend to place ourselves in the past that we have created. Whether it is the archaeologist, politician, educator or any other person with an interest in the past, we have our own vision of it, and by extension, what the present and the future should be. Thus, in the final analysis, we are not necessarily reconstructing something that actually existed; what we are doing instead is constructing an ideal which probably never existed, using various facts, experiences, fantasies and conjectures as building blocks. This is explained by Stone and Planel (1999:1-2):

> The past in fact cannot be *re*-constructed as it actually happened, but rather it is continually *constructed* by individuals or groups who, for whatever reason, choose to interact with it. Those constructing such pasts work within their own particular frameworks created by their own social position and *mores* – in our own case, essentially the Western scientific tradition. It is a particular characteristic of this tradition as we draw to the end of the millennium that most adherents believe it to be crucial to those producing such 'constructed pasts' accept that they are working within their own ethnocentric and intellectual frameworks, for to do otherwise confers a spurious legitimacy on their view of the past that can all too frequently be passed on as fact to those for whom the interpretation is intended.

It is interesting to note that the reconstructed past often has more to do with the goals, fears and pressures of the present. The current popularity of television programmes with historical and archaeological themes is a good example of this phenomenon. Stone and Planel (1999:4) comment on the public response to the BBC fly-on-the-wall documentary programme, *Living in the Past*, which broadcast the trials and tribulations of a group of ordinary people who "lived in wattle and daub houses, dressed in 'authentic' iron age costumes and supposedly lived off food that they had grown and prepared themselves." They write:

> It is almost certain that the wide interest shown in the programme was not only based on the scientific aspects of the experiment, but also on the social dynamics of the group living under those conditions. This interest in the social aspects of the past is very important and is identified in a growing body of archaeological opinion that has come to recognize that

> interest in the past and the ways in which we choose to project the past are very much rooted in the concerns of the present.

Given that much of the public interest is in the everyday social and inter-personal aspects of the past, it is the responsibility of those with a professional interest in to ensure that the presentation is not exaggerated or otherwise sensationalised in order to attract attention and give added impact.

1.2.2 Analogies and Multiple Interpretations

The principal way in which experts attempt to reconstruct the past is by drawing analogies between what is unknown and what is known, or rather, what is thought to be known. As Sabloff (1987:156) explains, with special reference to Pre-Columbian Mesoamerica:

> A simple analogy may be used by an archaeologist when, for example, he or she interprets a single row of stones in the shape of a rectangle, with a stone-lined burned area inside the rectangle, as the remains of a house originally made of wood. The archaeologist is using the similarity in a few aspects between the archaeological remains and modern houses made of perishable materials as a warrant to project the other aspects of the modern houses onto the archaeological record.

He goes on to highlight the dangers of this approach as follows (Sabloff 1987:158):

> There is an inherent danger with the use of analogy in that, over time, the speculativeness of the approach may be lost so that the analogy becomes an accepted fact. Instead of the original "*x* might be interpreted as *y* on the basis of a particular analogy," archaeologists begin to say "*x* is *y*." The original analogy is forgotten. In some instances the equation $x=y$ may seem quite reasonable. A series of connected furrows next to a site clearly were irrigation canals, or two parallel rectangular buildings must

> have been a ball court. Such situations helped advance the situation whereby interpretation became fact, and as this change in usage spread from "safe" inferences to more problematical ones potential variability was often overlooked.

It is thus fundamentally important on the part of the academic that the notion of an un-knowable past is acknowledged, and that the existence of multiple interpretations leading to differing original scenarios is accepted both by academics and by the public. This issue becomes especially significant, and indeed highly problematic, when we take into account the fact that it is common to interpret and communicate ideas about the past using images, both two- and three-dimensional. This dilemma is explained by Sommer (1999:166):

> In a scholarly discussion, it is not only possible, but indeed necessary for the sake of scientific honesty, to try to set aside all private fantasies and implicit assumptions transferred from daily experience that form our notions of what the past was 'really' like. Yet without the use of images, no presentation of the past is possible. There are no value-free means of presentation. Even, for example, a classical museum exhibit, a glass case filled with various pots, with labels saying 'pot, clay, height 12 cm, late second quarter of the third century' and the like, conveys a picture, presents a message. The message is: 'This is science!' It preserves the hegemony of those who are allowed to select the objects to put in the glass cases, who put labels on objects and claim that they confer knowledge.

It is therefore evident that there can be no such thing as a definitive reconstruction of the past, architectural or otherwise. Indeed, any attempt to do so is likely to become an exercise in architectural misinformation and audience manipulation. Every reconstruction, even the most academically rigorous, is informed by extraneous phenomena which necessarily influence the way in which the original data is obtained, interpreted and communicated; in another time and place the same evidence would invariably be reconstructed in a different manner. Consequently, Sommer (1999:166) argues against presentation of images of the past altogether, citing the reason that "all images are false":

> They [images of the past] are too easily consumed, uncritically accepted, believed in. Following the argument of a well known German art critic ... : in order to criticize a book, you have to at least read it, but a picture is assessed at a single glance, without further perusal, simply taken in at face value ... Reconstructions are treated in the same way.

Now this would indeed be a serious problem if the ultimate aim of an architectural reconstruction was to uncover absolute dogmas, but this is not, or rather should not be, the primary objective of such a project. According to Keen (1999:243):

> [A reconstruction], whether its purpose is 'legitimate' – in other words concerned with authenticity – or 'frivolous', has a useful role if it simulates an interest in the reality of the past. If that process leads the student to recognize the difference between what we imagine we know and what we can legitimately expect to know from the evidence, it will have been worthwhile.

This approach provides a solution to the dilemma of historical accuracy and credibility. Architectural reconstructions are created, therefore, not to be an authoritative recreation of an essentially unknowable past, but rather to query what we think we know, and in the process to admit to the possibility of alternative interpretations that have not hitherto been considered.

1.3 Objectives and Ethics

It was mentioned at the start of the current discussion that there is a widespread need to identify with the architecture of the past, and to see the present as an unbroken continuation of it. We have also noted that perceptions of the past are often more an

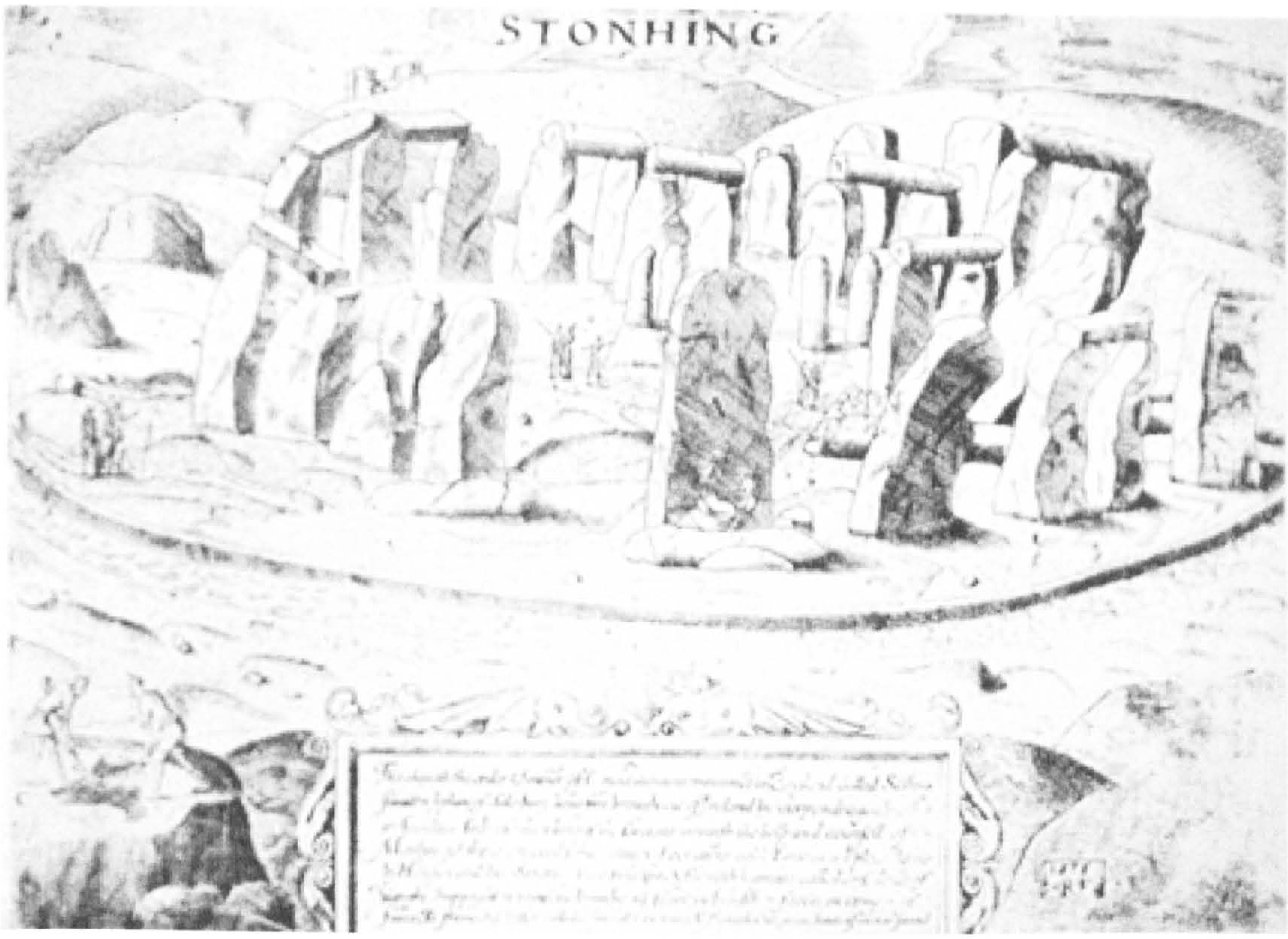


Fig. 1.2 Reconstruction of Stonehenge, 1575, author unidentified
(from Witcombe, undated)

indication of the present than the era which is being examined. In the majority of cases, these imaginary visions perform the role of harmless entertainment, as in the case of the paintings and movies described above. There are other situations, however, when the past is reconstituted in such a way as to be either baseless, misleading, dangerous, or sometimes all three. This becomes especially problematic when political, regional and national interests lie at the source of the reconstruction project, and it is therefore vitally important to address the ethical dimension of the entire practice of architectural reconstruction.

1.3.1 Cultural Identity

The architectural past has been, and continues to be, a political and ideological playground of sorts, where historical images are manipulated to further the agendas of all manner of regional, national and international authorities. While the

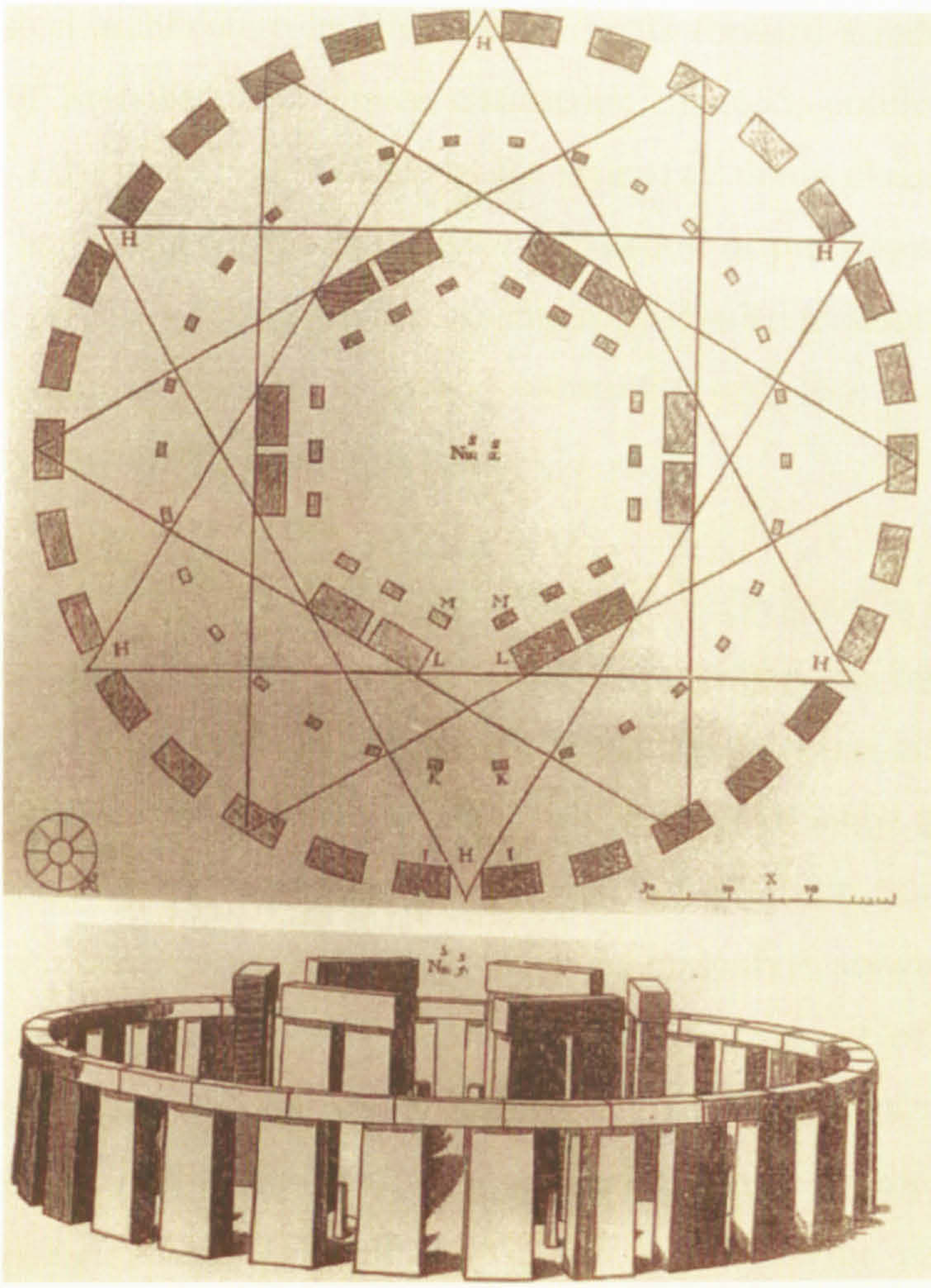


Fig. 1.3 Inigo Jones' *Stonehenge Restored*, 1655 (from Tavernor 1996)

preservation of historic architecture is no doubt of vital importance, it is rather more debatable whether this should be carried out as the means of essentially creating a cultural identity. More often than not in such cases, the innocent preservation of the existing past rather surreptitiously turns into the highly-politicised 're'-construction of an imagined past, with, as we shall see, rather less than desirable results.

The Neolithic monument of Stonehenge was the subject for some of the earliest architectural reconstructions in Great Britain, such as the portrayal of 'Stonhing' by an unidentified H.F. dating to 1575, which shows the structure in an uncompromisingly rustic light, crudely built and peopled with spear-carrying half-naked savages, completely in line with the notions of prehistoric barbarism that were current at the time (Fig. 1.2). Inigo Jones, the first of the English Palladians and the father of Classical architecture in Great Britain, puts forward a radically different interpretation of Stonehenge in his reconstruction of 1655, entitled 'Stonehenge Restored' (Fig. 1.3): strongly influenced by his love of all things classical and unable to credit what he considered the uncivilised population of pre-Roman Britain with such a vast and precisely conceived monument, he proceeded to identify Stonehenge as a Roman temple in spite of its utter dissimilarity with any surviving Roman temples. As Tavernor (1996:150-151) explains:

> He had no textual evidence to suggest that it was designed in this way, and his inspiration was remote and secondary; the diagrams by Palladio after Vitruvius, and texts on ancient symbolism. Nonetheless he was still able to convince the Court of James I, which commissioned the study, that Stonehenge was a Roman temple and had not been built by the Druids as was previously (and most commonly) assumed. The geometrical underlay he had revealed was proof, he argued, of Britain's great Roman past, to which the Stuarts were the natural heirs ... This is one of the foremost examples of a design analysis being appropriated for some ideological and political end, and it highlights the dangers of constructing theories based on wishful thinking, or opinion, alone.

With the opening up of the Near East in the aftermath of Napoleon's Egyptian campaign of 1798-1801 and the independence of Greece from Turkish rule in 1832, scholars were no longer limited to using second-hand documentary evidence, sometimes of antique vintage in itself, and piecing together scenarios from widely disparate sources and wild conjectures – they could visit the ancient sites and see the surviving fabric for themselves. Having said that, this situation did not immediately translate into a more rigorous approach to architectural reconstruction, for there was still a tendency among many scholars to use historic data to conform with and further their own preconceived notions of the past. The demands of Nationalism and Romanticism often subsumed any genuine attempts at addressing ancient civilisations and their remains on impartial terms. This, combined with the development of the notion of the heritage site/museum aimed at the general layperson (who demanded entertainment in the form of easily-digestible education), led to the creation of many highly idealistic and historically inaccurate architectural reconstructions, sometimes on top of the original physical ruins.

One of the earliest examples of this practice is the excavation/reconstruction of the Minoan Palace at Knossos in Crete, carried out by Sir Arthur Evans at the turn of the 20th century (Stone and Planel 1991:2). He was determined that "the Palace should be presented to the world in a form that not only the archaeologist could appreciate but so that the even the least imaginative visitor could feel and respond to its wonder" (Cottrell 1953:154). This was a noble aim, no doubt, but it was also one that resulted in the use of vast quantities of reinforced concrete to create fake Minoan architectural elements. The Palace of Minos was among the first steps in the path that eventually led to the highly ideological and utterly misleading historical fantasies created in Germany under the influence of the Nazi regime such as the open air museum at Oerlinghausen, touted at the time as "A Germanic farmstead from the first century" (Schmidt 1999:148-150):

> The buildings in the Oerlinghausen museum presented a compelling illustration of the image of German racial superiority (*Herrenmenschentum*). There was the house of the leader (*Führer*), with a high quality interior. The furniture was crafted from massive beach or oak timber, bearskins adorned the walls and weapons hung within easy reach over the leader's bedstead. The furnishing was a crude mix, combining everything from second-century BC Celtic cauldron fittings to seventh-century furniture from the Alemannic cemetery of Oberflacht. In addition, there were chests, of a form developed in the medieval period, decorated with swastikas.

In the aftermath of the of the Second World War, this monstrous fantasy met with an ignominious end when it was sold off to a carpenter who dismantled it to re-use the timber, in what, according to Schmidt (1999:150) "was, in itself, a kind of de-Nazification."

What is most disturbing about this sort of myth-making is not only the underlying architectural and historical falsehoods that are being communicated to a naïve public, but rather the use of a constructed past to lend authority to state policies which in any normal society would be considered utterly outrageous. Although Post-war architectural reconstructions have not on the whole been as blatantly misleading as the example described above, there is still a perceived need in political circles to sensationalise the past in order to justify their points of view. In addition, architectural reconstructions continue to offer a means of emphasising political, national and communal identities, as exemplified by the former Iraqi Ba'athist regime's recent fanciful rebuilding of Babylon (which, incidentally, destroyed some of the original remains). As Blockley (1999:18) points out:

> The restoration of Babylon the Great, Mother of Harlots is seen as a potent symbol. Every fiftieth brick bears the stamp 'restored in the era of Sadaam [sic]', in imitation of Nebuchadnessar [sic], who stamped bricks with his own name during his restoration of Babylon in 600 BC ... Sadaam [sic] fabricated these highly emotive symbols of the past to imply the re-emergence of the old Mesopotamia as a world force.

Van Schalwyk (1999:280), in his description of the modern reconstruction of the Zulu royal kraal at oNdini in post-apartheid South Africa, describes an approach that is not as crudely ideological as the examples mentioned above, but one that is nevertheless driven by the objective of making a politico-nationalistic statement:

> The reconstruction at oNdini has also come to embody and extremely strong sense of 'political place' in its perceived marking of lost Zulu sovereignty and the colonial and subsequent subjugation of its people. Its establishment as a monument in the early 1980s, seen against the internal liberation politics and the wrestling with apartheid structures in the region, was thus also a strong political statement: one of the assertion of Zulu primacy in the province, and a recognition of the role of the

traditional leadership and the institution of *umNdlunkulu* (royal house).

It is evident form the examples mentioned above that architectural reconstructions carried out with primarily ideological aims result in mere caricatures of what probably existed in reality. Although it is difficult to know anything as absolute fact, we can be fairly sure that 1st century German farmers did not in all probability own medieval furniture emblazoned with Nazi-party swastikas. This sort of manipulatory attitude towards the past invariably meets with derision from serious academics, but if in the process the general public is being fed with such outrageously false images of its history, a fair amount of damage is still being done. Moreover, the fact that ideological reconstructions are often carried out in non- or pseudo-democratic societies where there is little or no scope for open debate on what is presented, makes this approach not only misleading but potentially dangerous.

1.3.2 Architectural Theory

While reconstructions like Oerlinghausen and oNdini are attempts to manipulate the perceptions of the general public towards the past, it has been just as common to employ imaginative architectural reconstructions to appeal to the architectural profession in an attempt to correct a perceived 'loss of way'.

The romantic concept of the 'noble savage' – man unencumbered by the trappings of so-called civilisation – came into prominence in the mid-18th century, particularly in association with the early writings of the Swiss-born French philosopher Jean-Jacques Rousseau. It was essentially a political and social theory, but had widespread architectural implications, of which the most influential example was perhaps the conjectural 'primitive hut' of the French cleric Abbé (Marc-Antoine) Laugier (Fig. 1.4). Contained within his *Essai sur l'Architecture* (Essay on Architecture), it is in effect an attempt to imaginatively hypothesise the prototypical hut that was supposed to lie at the origin of all architecture (Groat and Wang 2002:82). Although the hut is in itself implausibly idealised and harks back to a primitivist Golden Age of sorts, the entire project must be viewed, not necessarily as

Fig. 1.4 Laugier's primitive hut (from Groat and Wang 2002)

a piece of historical or archaeological research, but rather as a polemic in reaction to what Laugier considered the ostentation and superficiality of the Baroque and Rococo styles of his own time, a sort of architectural *rappel à l'ordre*. This entire attitude was encapsulated in Laugier's proto-Primitivist credo: "*Tenons-nous au simple et au naturel*" (Fitch 1998:20). Although it lacks much in the way of archaeological credibility, Laugier's hut, with its notions of purity and simplicity, was hugely influential in shaping the architectonic ideas of the period, and was reflected in the work of Ledoux, Gilly and Boullée in late 18th century France, ultimately reaching its apotheosis in the work of Karl Friedrich Schinkel in early 19th century Prussia. Particularly significant was Laugier's insistence on a simple Greek idiom as opposed to a more elaborate Roman one; as Kostof points out (1985:560):

> Without knowing much about real Greek buildings, Laugier advocated a return to simple Greek architecture when simple structural logic had

> dictated the form. The Roman contribution had been not so much an improvement but a deceptive elaboration of the principles of statics. Laugier condemned the use of pilasters, arched openings, and pillars, and considered broken pediments, spiral columns, the projection and recession of entablatures, the entire stock-in-trade of Baroque architecture, as intolerable abuses. Free-standing, load-bearing columns and the straight entablatures that bridged them – these were the essence of good architecture.

This type of thinking was a contributing factor to creation of pro-Roman and pro-Greek camps among architectural practitioners of the time, which in turn led to the destruction of the unity of the Classical orders that had been largely unquestioned since the Renaissance. And if the entire Classical canon was open to debate, what was there to prevent the adoption of an entirely different idiom, such as the Gothic?

Attempts at employing a Gothic idiom of sorts had become fairly widespread in northern Europe towards the early 19th-century, especially where ecclesiastical buildings and medievalist follies were concerned. It remained in a fringe interest, however, and even what was built was usually a mish-mash of random pseudo-medieval details applied to what were essentially Classical buildings in conception and construction, a style that is commonly derided with the term Gothick. In 1836, however, the British Gothicist A.W.N. Pugin published a pamphlet entitled *Contrasts*, which was essentially a polemic calling for the reinstatement of scholarly Gothic architecture in place of the prevalent Classicism of his time (Fig. 1.5). In a burst of enthusiasm following his recent conversion to Catholicism, Pugin argued that the Gothic was the only true Christian style, and objected to the pagan origins of Classicism. The pamphlet featured ridiculously idealistic and grossly inaccurate representations of an imaginary medieval architecture and society set against illustrations of 19th century society at its meanest, most commercial and, not surprisingly, most Classical (Davey 1995:15). Indeed, Pugin's message was that society and its architecture were inextricably linked: adopt a Christian way of building, and with it will automatically come a Christian society, and vice versa. In

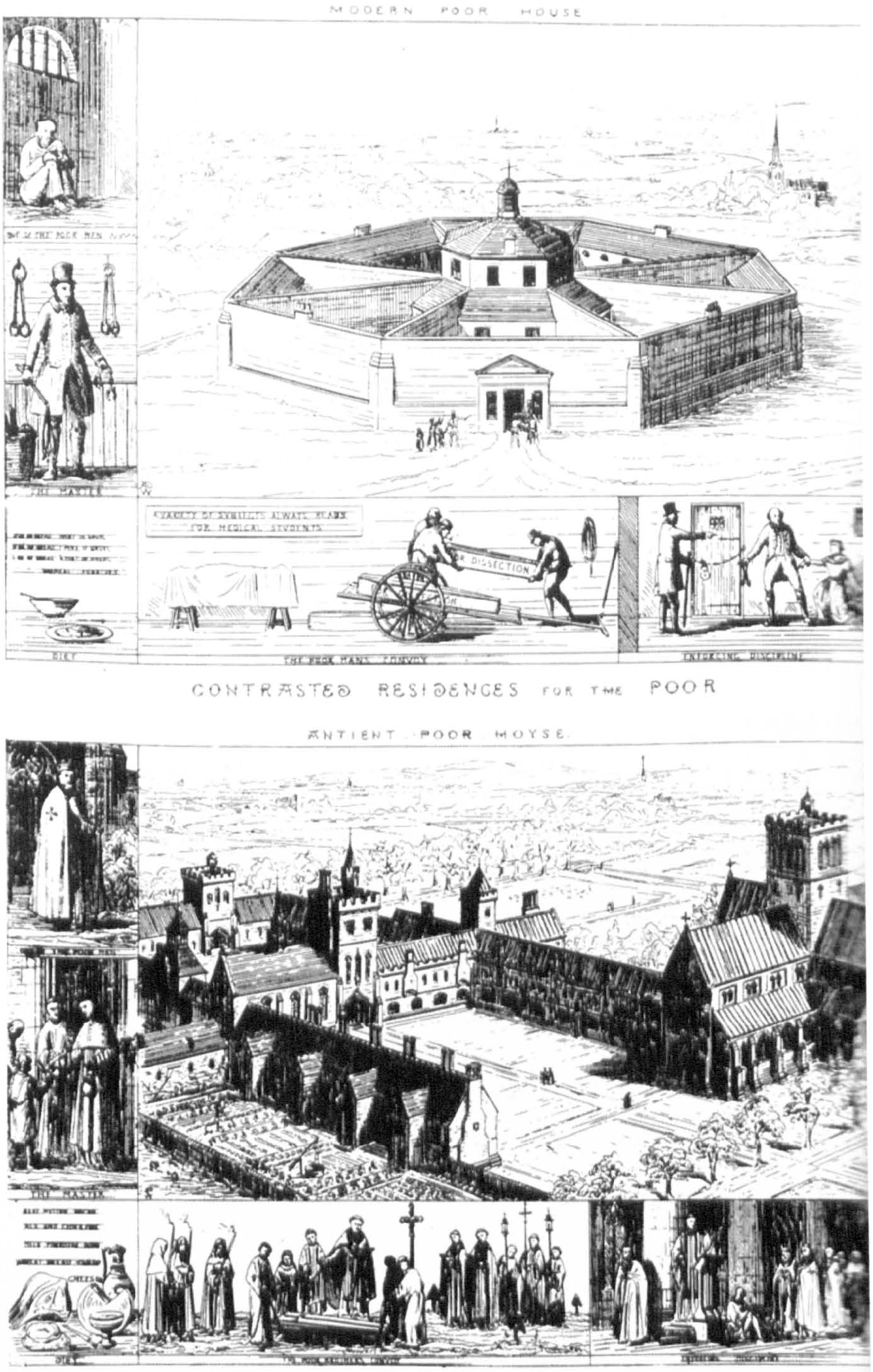
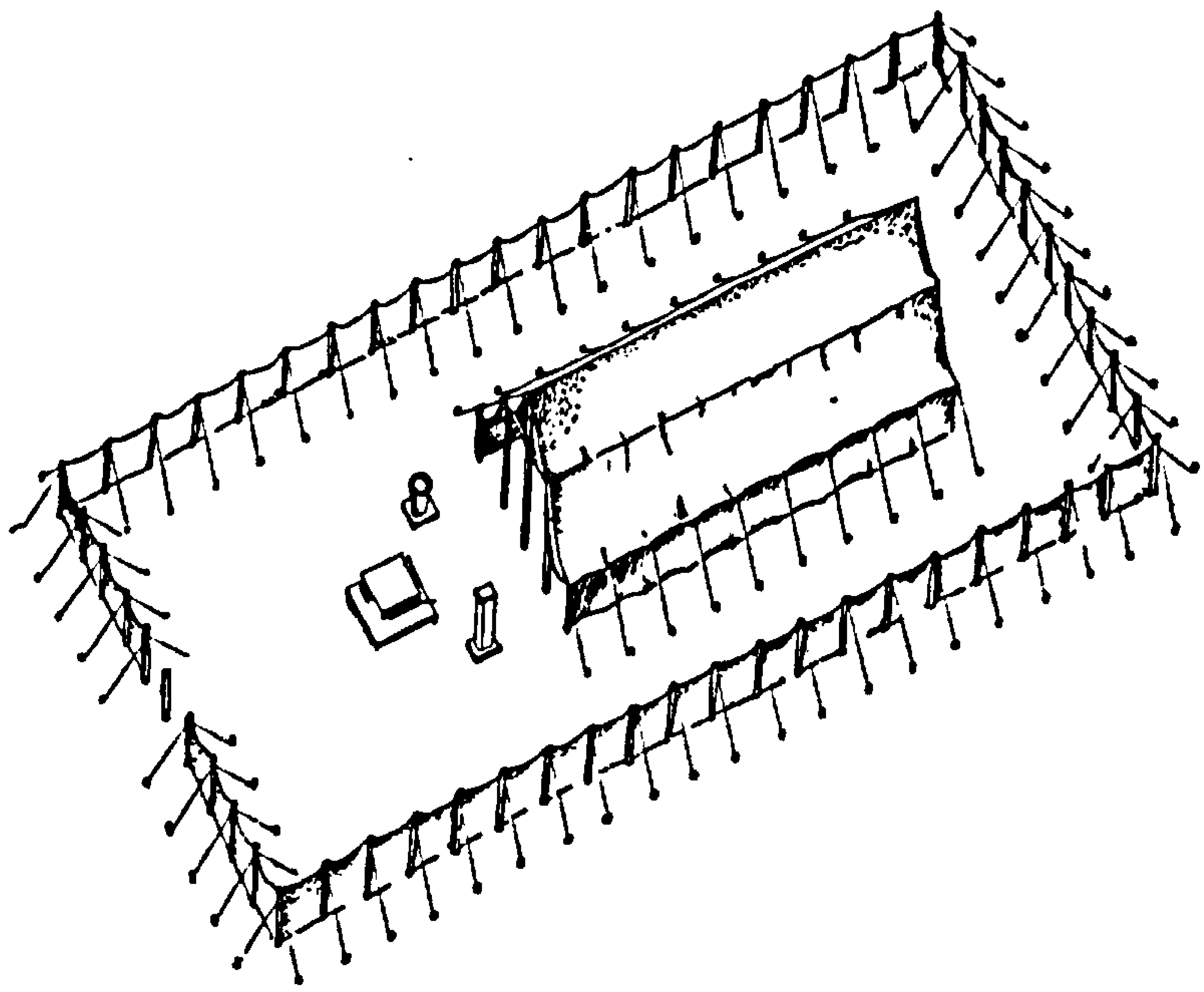


Fig. 1.5 Pugin's *Contrasts* (from Davey 1995)

spite of the naivety and utopianism of much of his writings and work, Pugin and his reconstructions had enough influence to contribute to the Gothic Revival becoming a major force in the British architectural scene of the 19th century.

Both Laugier's hut and Pugin's medieval paradise provide instances of the



A PRIMITIVE TEMPLE

Fig. 1.6 Le Corbusier's primitive temple (from Le Corbusier 1986 [1931])

iconographic representation of an idealised past being used as a vehicle to comment on, and frame a reaction to, the architectural status quo, and that with great success in terms of influence in these two cases. This practice started to gradually lose its impact in the early 20th century with a shift of emphasis in architectural theory: writers on the whole were no longer interested in validating their points of view primarily by appealing to a mythical past, but rather by calling up images of an equally mythical future. For example, the conjectural representations of futuristic cities produced between the turn of the 20th century and the First World War by Antonio Sant'Elia are certainly as idealistic in their utopianism as anything produced by Pugin, yet in the prevailing theoretical climate of the time, it was such representations that were most influential in forming the architectural ideals of the Modernists that held sway for much of the century. It is interesting, nevertheless, that the Le Corbusier (1986 [1931]:69) still felt the need to concoct a description of 'primitive man' erecting his tent as a validation of his discourse on the so-called new architecture of the 1920s:

Primitive man has brought his chariot to a stop, he decides that he shall

> be his native soil. He chooses a glade, he cuts down the trees which are too close, he levels the earth around ; he opens up the road which will carry him to the river or to those of his tribe whom he has just left ; he drives in the stakes which are to steady his tent. He surrounds the tent with a palisade in which he arranges a doorway. The road is as straight as he can manage it with his implements, his arms and his time. The pegs of his tent describe a square, a hexagon or an octagon. The palisade forms a rectangle whose four angles are equal. The door of his hut is on the axis of the enclosure – and the door of the enclosure faces exactly the door of the hut.

This description continues on to depict the erection of a temple, on similarly orthogonal and symmetrical principles (Fig. 1.6). By presenting this appeal to the ideal of the primordial dwelling, Le Corbusier is in fact very close in spirit to Laugier some 170 years before him.

2

Practical and Historical Background

We are for the most part familiar with the Western tradition of recorded history and so-called scientific archaeology, a tradition that sees the past as L.P Hartley did when he pointed out that "the past is a foreign country, they do things differently there." This compartmentalising attitude is the way in which much of architectural history perceived as well – all one has to do to obtain proof of this is to glance at the chapter headings of any of the number of modern publications on the subject. Within the context of this way of thinking, any attempt to reconstruct the past is seen as futile, and worse, morally bankrupt, and no doubt there is some validity to this point of view in light of the discussion in Chapter 1. The proliferation of museums and historical re-enactment centres of varying merit, along with the veritable flood of television programmes with historical themes attests to the fact that, for many people, experiencing the past is not too dissimilar from visiting a foreign country. This may be contrasted with societies where the past is not perceived in this way, and where the present is seen as no different from what went before; in many such societies, the idea of preserving ancient architectural fabric would be considered as outlandish as jealously guarding last week's leftovers. The author recalls a talk by the Indian conservationist Vikas Dilawari where it was mentioned that, with respect to a particular temple, no attempt was made to retain original material – when a stone was found to be decayed, it was immediately replaced with a new one. The difference here is that the new stone is seen as being part of the same tradition that cut and laid the ancient one. A similar approach is exemplified by the Japanese idea of continuous preservation where a building is reconstructed from scratch at specific intervals. For instance, Fitch (1990:85) points out that the "temple complex of Ise Naiku in Honshu has been replicated every twenty years since the reign of Emperor Temmu (673-686)." Blockley (1999:21) highlights one of the philosophical dilemmas of this course of action as follows:

> According to Greek legend, Theseus' galley was preserved by the

> Athenians for many years. Over time, as the old timber was gradually removed and replaced with new, the question of whether it was still the same ship arose. Was it the authentic ship? If not, when did it cease to be?

On the whole, however, these are attitudes that seem alien in the West today, with its concepts of discrete historical periods and *zeitgeist*. The observations that are made in this study are therefore purely restricted to this Western tradition, and do not necessarily apply where a different way of thinking is pre-eminent.

2.1 Representation Techniques

There are a number of ways in which the architecture of the past can be represented, ranging from images, models and textual descriptions to full-size reconstructions of archaeological sites. We are mainly concerned in this discussion with the ways in which this task can be accomplished using two- and three-dimensional representations; we shall restrict ourselves to the non-computerised methodologies for the moment, and examine the digital techniques in due course. For the sake of clarity we shall categorise these techniques into *two-dimensional images*, *scale models* and *full-size reconstructions*. That said, these terms are in fact open to debate, since, strictly speaking, all representational methods are in fact images of one sort or another. In addition, as we have seen in Chapter 1, there are those who would quite vociferously argue that there is no such thing as a historical reconstruction, that there can only be entirely new constructions based on our understanding of, and attitudes towards, the past.

2.1.1 Two-dimensional Images

Two-dimensional images – that is to say, representations of buildings or environments on a flat surface such as paper, or more recently, video and computer screens – have a long history of use in the illustration of architectural reconstructions, with an entire system of conventions built up around them. The

Fig. 2.1 *Ideal View of the City of Athens*, by Leo von Klenze, 1846
(from Stamp and McKinstry 1994)

form of image that is most commonly employed for this purpose is the perspective, although other types of projection, such as orthographic and axonometric, are used with lesser frequency as well. Perspective projections are often, and erroneously, referred to as 'three-dimensional' images – the fact that this is not that case is pointed out by Egerton and Hall (1999:179), who note that a true three-dimensional representation of an object is in fact a physical model of it, not a paper-based image.

The use of images to communicate reconstructed impressions of ancient buildings dates back at least as far as the Renaissance. Early reconstruction images were carried out with religious or polemical motives, or indeed as exercises of the artist's imagination to form the backdrop to a pictured event. Towards the early 19th century, however, following a spate of archaeological discovering and the consequent rise in interest in all things ancient, we see the beginnings of a more erudite approach to the visualisation of the buildings of antiquity (Fig. 2.1). The art historical aspects of architectural reconstruction will be examined in fuller detail in the second part of this chapter.

Sketch perspectives can be executed in a relatively short time, and do not require much in the way of material or indeed skill to give a general impression of what a building or environment may have looked like in the past. The inherent lack of accuracy of a sketch can be exploited to communicate a sense of uncertainty about what is being illustrated. At the other end of the scale, even a carefully rendered, accurately constructed perspective is relatively easy to produce, and can be highly informative and evocative. Whereas a sketchy line implies a certain level of doubt, precise execution, on the other hand, can give the impression that the illustration is based on absolute underlying knowledge, and as a consequence archaeological artists have long resorted to the use of such devices as wisps of smoke, clouds and clumps of foliage to conceal areas of uncertain interpretation (Miller and Richards 1995:20). Indeed, one of the great advantages of this technique is that the artist has at his or her disposal a continuum of precision that can be employed to portray varying levels of probability, and thus give the appropriate degree of realism to the illustration.

Images, however, are severely limited in that it is not possible to accurately represent the full spatial qualities of a three-dimensional object on a two-dimensional surface. A further and just as serious failing of paper-based illustration is that the viewer is invariably restricted to a single viewpoint chosen by the artist – if further views are required, it is necessary to construct them from scratch, with the attendant waste of labour and time, and also increasing the likelihood of introducing discrepancies between the individual illustrations. It is also a concern that once a perspective image has been produced it is notoriously difficult to work back from it and extract dimensional information, and so if this aspect of a represented building is to be covered, a series of true-to-scale orthographic projections would need to be carried out as well. As a consequence, a complete architectural reconstruction of a building would necessarily have to consist of a series of illustrations from different viewpoints and at different scales, a requirement that is practical only in research and academic situations.

2.1.2 Scale Models

Scale models have the advantage of being able to condense a large physical area into a smaller space without any loss of three-dimensionality, and thus are a more realistic method of representation than the two-dimensional images mentioned above (Fig. 2.2). A further advantage of a model is that the view is not restricted to a certain position, as with a perspective, but that it can be displayed so as to be viewed from a variety of angles. The fact that the viewer may walk around the model and examine the relationship of parts allows for a dynamic experience, which, at least in the case of an archaeological presentation, is something to be desired. Actual materials may be used in the construction of the model to provide added realism and provide tactile features, and lighting effects can be replicated with a high level of faithfulness.

In spite of their many advantages over perspective images, physical scale models do

Fig. 2.2 Physical model of Ancient Rome
(from Forte and Silliotti 1997)

have a number of distinct shortcomings. Firstly, it can often be difficult to obtain a view out of a model, for the simple reason that the viewer cannot fit inside, and in this respect, there is a limit to their versatility. While this problem can be remedied by the construction of small models without a fixed base that can be picked up by the viewer and rotated to the appropriate viewpoint, a more effective solution involves the use of an endoscope and camera (Terlingen and Engelbregt 1996:41). This allows views to be taken from within the model, but is cumbersome and suitable only in research contexts. Models also generally tend to be too large to allow for convenient portability. A final concern is that their scale, necessarily smaller than the original object, places restrictions on the level of detail that can be represented. This is discussed by Ryan (1996:96):

> For example, the 1:250 scale model of the city of Rome in the time of Constantine I at the Museo della Civiltà Romana is perhaps one of the largest and most impressive models of its type. It embodies considerable structural detail and provides a clear impression of the spatial relationships between the buildings and the landscape. The scale of the model precludes much known decorative detail and there are few attempts to model interior spaces.

In addition to their role as presentation tools in museums, scale models also have a long history of use as research tools. The fact that they are inherently three-dimensional means that it is possible, with a model, to simulate and examine characteristics of a building that would simply not be possible with two-dimensional images alone. This is particularly relevant where the structural or spatial characteristics of a building are being researched. In such cases, it is not usually necessary to model the building in full detail in its entirety, but rather to focus on the area under examination, which can then be simulated at a large scale. In addition, by constructing the model in a modular way, it is possible to iteratively alter the representation as new evidence becomes available.

In the final analysis, the use of scale reconstruction models represents a highly versatile and complete method of testing and presenting theories about the architecture of the past. A constant problem with any method of presentation is that of how to avoid giving the impression of objectivity, and it is not difficult, by varying the level of detail of a model, to imbue it with a sense of uncertainty. Unfortunately, though, the vast majority of models are usually found in museums and other heritage centres, where the main aim is to draw in as many visitors as possible with highly realistic and spectacular reconstructions. This issue is perhaps more important in the case of models than of two-dimensional drawings, for as we will see shortly, there seems to be a direct correlation between the expense and complexity of a representation and its perceived level of credibility.

2.1.3 Full-Size Reconstructions

It was mentioned that one of the main failings of reconstruction models is that their small scale prevents the incorporation of high levels of detail. One way of dealing with this problem is to model the reconstruction at full size. It is obvious that this approach is feasible only where fairly small self-contained buildings are concerned – it is inconceivable that anything on an urban scale could be represented in this way. The advantage, however, is that the viewer is free to walk around and inside the building, appreciate light and materiality in a dynamic and even tactile manner and thus get a very real impression of the interpretation that is being put forward, although such constructions can be difficult to alter once completed. One of the rather less desirable attributes of full size reconstruction is that they are liable to have a spurious sense of authority and accuracy, even more so than drawings and scale models. As Blockley (1999:15) points out:

> Certainly these monumental creations at actual size are more impressive than two-dimensional artists impressions and therefore, presumably, appear more credible to the visitor. If large sums of money and effort have been invested in an interpretation which passes the test of durability and longevity it is more likely to be viewed as authentic.

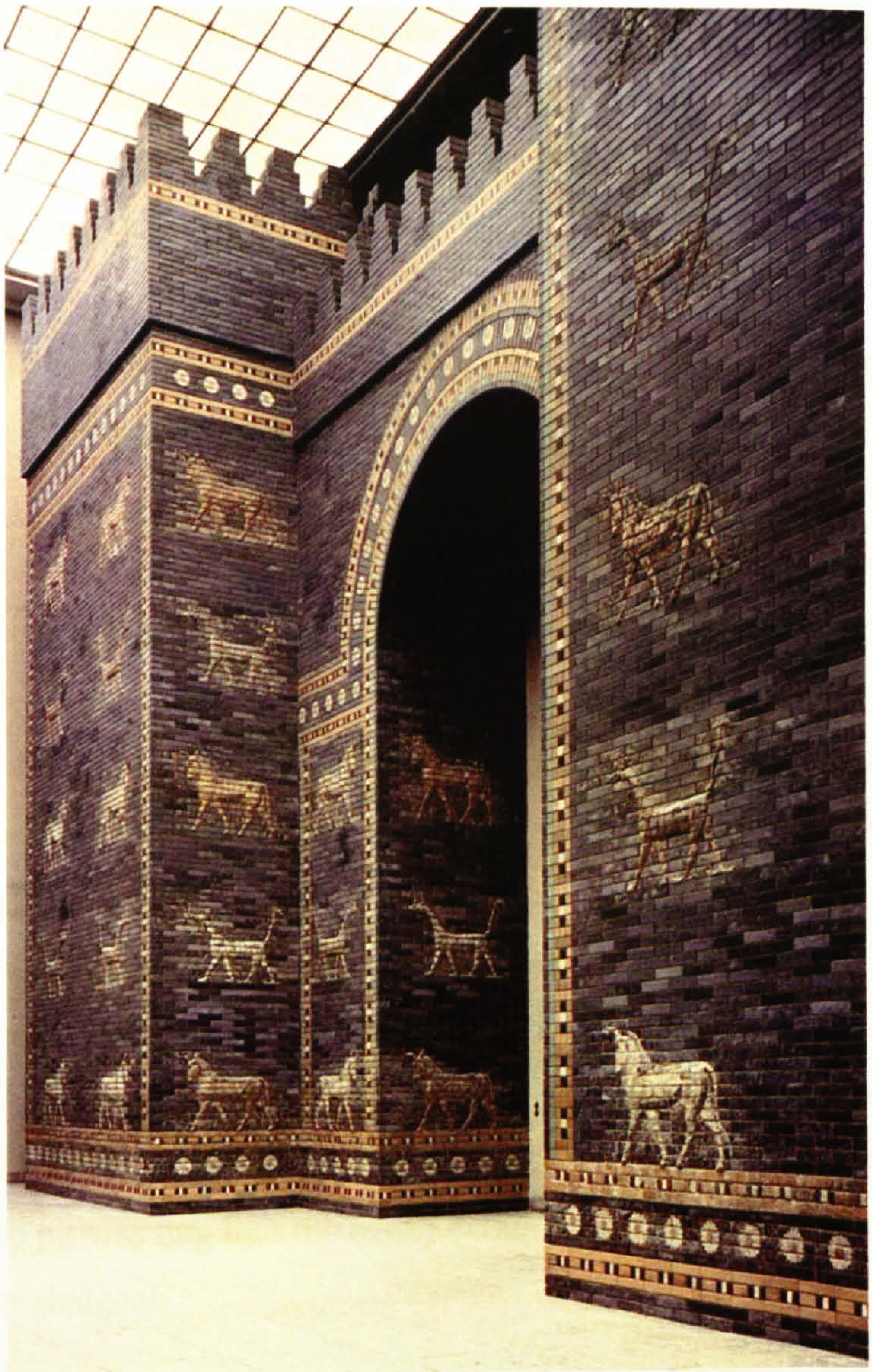


Fig. 2.3 Reconstruction of the Ishtar Gate, Museum of the Ancient Orient, Berlin (from Forte and Silliotti 1997)

There is considerable debate as to whether full size reconstructions should be carried out on top of the remains of the original structure, or in an off-site location such as a museum or visitor centre, and also, whether the reconstruction should be composed of original excavated material or not. The practice of creating full-size reconstructions in an off-site location is obviously not damaging to archaeological remains, provided, of course, that the original fabric is not recycled. It is evident that only very large and well-funded museums and heritage bodies could afford to carry out this sort of reconstruction. One well known and indeed early example is the replica of the Ishtar Gate of Babylon found in Berlin's Musuem of the Ancient Orient, a structure that does reuse a significant amount of material from the archaeological site, and due to incomplete excavation, varies somewhat in size from the original structure (Fig. 2.3).

As far as *in situ* reconstruction is concerned, Blockley (1999:16) comments on the approach in the following terms:

> One alarming consequence of *in situ* reconstruction is the impact of visitor erosion of the site and damage to the surviving deposits. It is quite incredible that Scheduled Monument Consent was granted by English Heritage (the national body for advising government on the protection of archaeological sites) for the development of the in situ reconstruction at Stansted Mountfichet Castle ... While the consent specified that the reconstructed timber palisades should be set on a framework placed on top of the surviving earthwork so as not to damage it, the insertion of concrete pathways and wooden steps, as well as uncontrolled visitor access, have led to significant erosion ... In addition, a 2-metre deep flint-lined pit was dug into the bailey (courtyard) of the castle to create an 'authentic dungeon.'

It is thus clearly not good archaeological practice to disturb the original fabric of a historical site by inserting a modern reconstruction of doubtful authenticity and value. The only situation where this approach may be sanctioned is where a site has been fully excavated, and where no further original fabric remains. In any case, as Blockley (1999:22) notes, full size reconstructions juxtaposed with modern buildings can appear utterly incongruous and surreal – for example, the 'reconstruction' of Stansted Mountfichet Castle mentioned above is approached through and looks over a disused railway yard. Finally, if the reconstruction has to conform to current planning and building regulations, its fundamental accuracy is very severely brought into question (Fitch 1990:84).

2.1.4 Appraisal

It is impossible to make a simple value judgement as to which of the foregoing representation methods is best. Each reconstruction project has its own aims, and the appropriate method in one case might not necessarily be that in another. For example, a full-scale replica may perform admirably as a public attraction, but would very likely be far in excess of requirements in the context of a research project. In general terms, however, a fully three-dimensional representation is preferable to a two-dimensional one in that it is possible to form a complete, internally consistent interpretation, but having said that, there are many instances where a sketch image may be perfectly adequate for the task in hand.

One point that has already been made is the ability of different techniques to carry varying impressions of authority – we have seen that this factor relates directly to the level of time and effort that is perceived to have gone into the creation of the reconstruction. The techniques also differ in their ability to illustrate uncertainty. For example, while it is not difficult to create a sketch image, or even a sketch model, it would be very demanding task indeed to make a sketch full-size replica that does not look unfinished and unconvincing.

2.2 Architectural Reconstruction and Art

It is not unreasonable to assume that iconographic portrayals of the architectural past have been carried out for as long as pictorial space has been represented, certainly so in Western Art. One of the main reasons for this phenomenon, and for its marked absence in any of the many other artistic traditions in the world, is that the primary source of subject matter for Western iconography, certainly until the Enlightenment in the 18th century, was the Bible (particularly the Gospels that deal with the life of Christ), a source that is inherently historic. Although the early examples of Biblical iconography do not represent individuals inhabiting architectural, or indeed any other type of definite pictorial space but rather 'floating' on a nondescripts flat plane, by the early 14th century Giotto, in such paintings as the *Confirmation of St. Francis*,

Fig. 2.4 *The Confirmation of St. Francis*, by Giotto, ca. 1325 (from Kemp 1990)

was placing his characters within a pseudo-perspectival built environment (Kemp 1990:8-9) (Fig. 2.4). What is also interesting is that the architectural past represented in many of these paintings is virtually indistinguishable from the present in which the artists lived. We see Biblical characters wearing medieval dress and inhabiting medieval streets, squares and palaces. Indeed, it seems as if the artists were not fully aware of the huge temporal gulf separating them from the past that they were attempting to portray. This lack of interest in historical accuracy is perhaps an indication of the objective of such paintings as the *Confirmation*. They were intended, not necessarily as objects of devotion per se, but certainly as instigators of a religious state of mind – the main focus is the person of Christ and the event being portrayed, not the surrounding buildings or the environment in which the action is taking place. All the architectural details are merely a sort of set dressing to create the stage for the main event, and furthermore, historical accuracy was neither asked for by the patron nor provided by the painter. It is highly unlikely that the artist could have attempted an accurate architectural reconstruction even if he had so wished, since he would not have had any reliable sources on which to base his conjectures.

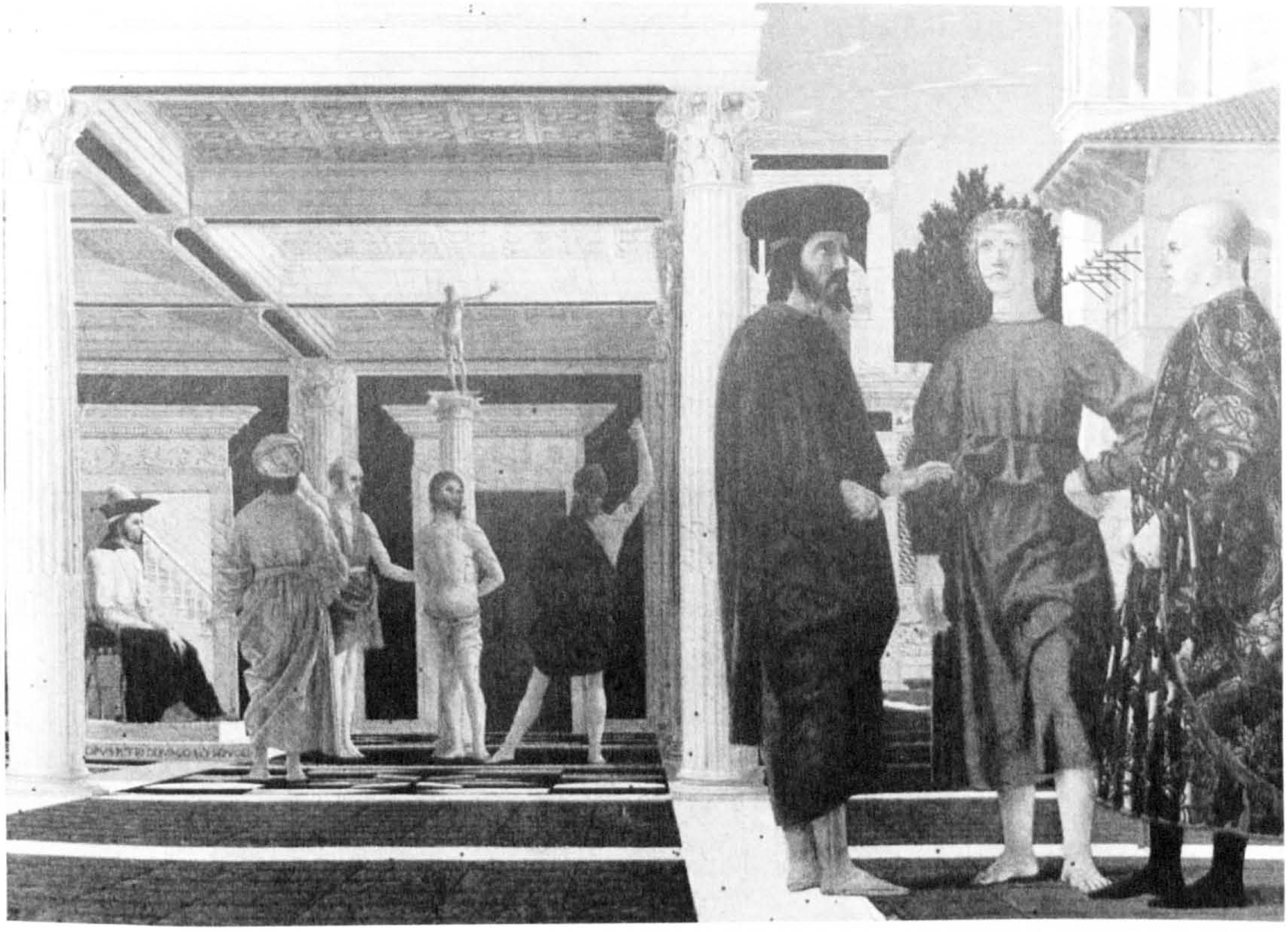


Fig. 2.5 *The Flagellation of Christ*, by Piero della Francesca, 1469 (from Kemp 1990)

2.2.1 The Renaissance

The invention of accurate linear perspective in the early 15th century by the Florentine architect Filippo Brunelleschi (Kemp 1990:12-13), and its subsequent codification by Leon Battista Alberti in his small book of 1435, *On Painting* (or, *De Pictura*, to give it its original Latin title), gave painters the necessary tools to illustrate precisely measurable spaces in place of the improvised and rather ad hoc constructions that had hitherto been the norm. Fundamental to the idea of the Renaissance was the attempt to recreate what were perceived to be the lost glories of Antiquity, and more specifically, those of Ancient Rome. In opposition to this was held the immediate past of the Middle Ages, seen largely as an age of ignorance during which the learning of the ancients was lost (Kostof 1985:403). As Alberti himself notes (1991 [1436]:34):

> I used both to marvel and to regret that so many excellent and divine arts and sciences, which we know from their works and from historical accounts were possessed in great abundance by the talented men of antiquity, have now disappeared and are almost entirely lost. Painters, sculptors, architects, musicians, geometers, rhetoricians, augurs and suchlike distinguished and remarkable intellects, are rarely to be found these days, and are of little merit.

Kostof (1985:404-405) points out that one of the consequences of this attempt to resurrect the past was the renewal of the arts, especially painting, architecture and sculpture, driven on by the newly invented 'muse' of linear perspective.

As an example of a typical Renaissance painted reconstruction, let us examine the *Flagellation of Christ* by Piero Della Francesca, dating from 1469 (Fig. 2.5). Something that immediately strikes us is that there is a fundamental difference from, say, Giotto's *Confirmation*, in that there is an attempt to model the architectural past with as much accuracy as was possible at the time. This interest in historical accuracy extends only to the architecture that forms the backdrop to the main event – Piero has clearly made an effort to represent what a Roman city of the period may have looked like, which, interestingly, corresponds closely to the image of the ideal Renaissance city –while the characters in the painting are dressed in clothes more appropriate to the 15th Century. This selective recognition of the past being different from the present may be contrasted with the woodcut of Jerusalem found in Hartman Schedel's *Weltchronik* (or Chronicle of the World) printed in Nuremberg in 1493, a roughly contemporary representation to that of Piero, but one which continues to adhere to the older tradition of representing the past (at least the Biblical past) as the present – in fact, in this case, as a sort of pseudo-orientalist fantasy (Fig. 2.6). This difference may be explained, at least in part, by the fact that the ideals of the Renaissance which were well established in Italy by the end of the 15th Century had yet to take root in areas north of the Alps, and perhaps also by the comparative dearth of Classical architectural models in Germany and the Low Countries.

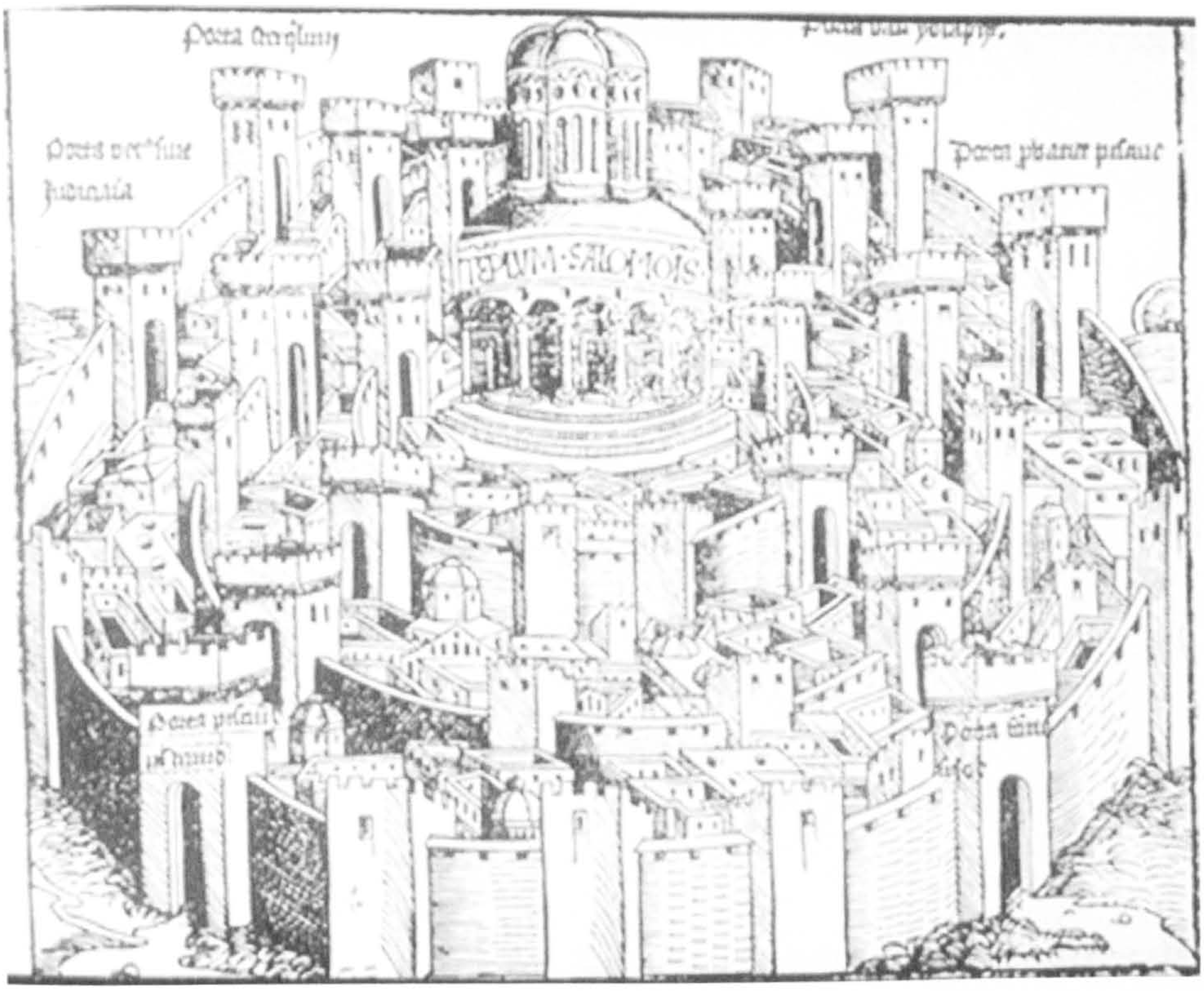


Fig. 2.6 *Jerusalem*, from Schedel's *Weltchronik*, by Michael Wolgemut and Hans Pleydenwurff, 1493 (from Van Den Berg 2001)

Thus, from the Renaissance onwards we start to discern a clear understanding that the past was architecturally different from the present. A further example of this idea is given in Pieter Bruegel the Elder's attempt at representing the Biblical Tower of Babel, described in Genesis 11:1-9, and possibly also by Herodotus (Fig. 2.7). Leaving aside the question of whether the Tower actually existed, Bruegel in 1563 could not conceivably have had any idea of what it might have looked like, since the excavations in southern Iraq that uncovered the Sumerian ziggurats – the possible source of the Tower of Babel account – were yet several centuries away (Cottrell 1957:49-65). Not surprisingly, therefore, his reconstruction bears no resemblance to a ziggurat, apart from, perhaps, its stepped profile, which can be attributed to straightforward logic allied with a reading of the textual descriptions. Rather interestingly, Bruegel's main source of inspiration seems to have been the 9th century AD spiral minaret in Samarra (Fig. 2.8), which he evidently interpreted as the remains of the tower of Babel. Nevertheless, we see a clear attempt at architectural reconstruction based on what were thought to be the archaeological remains of the

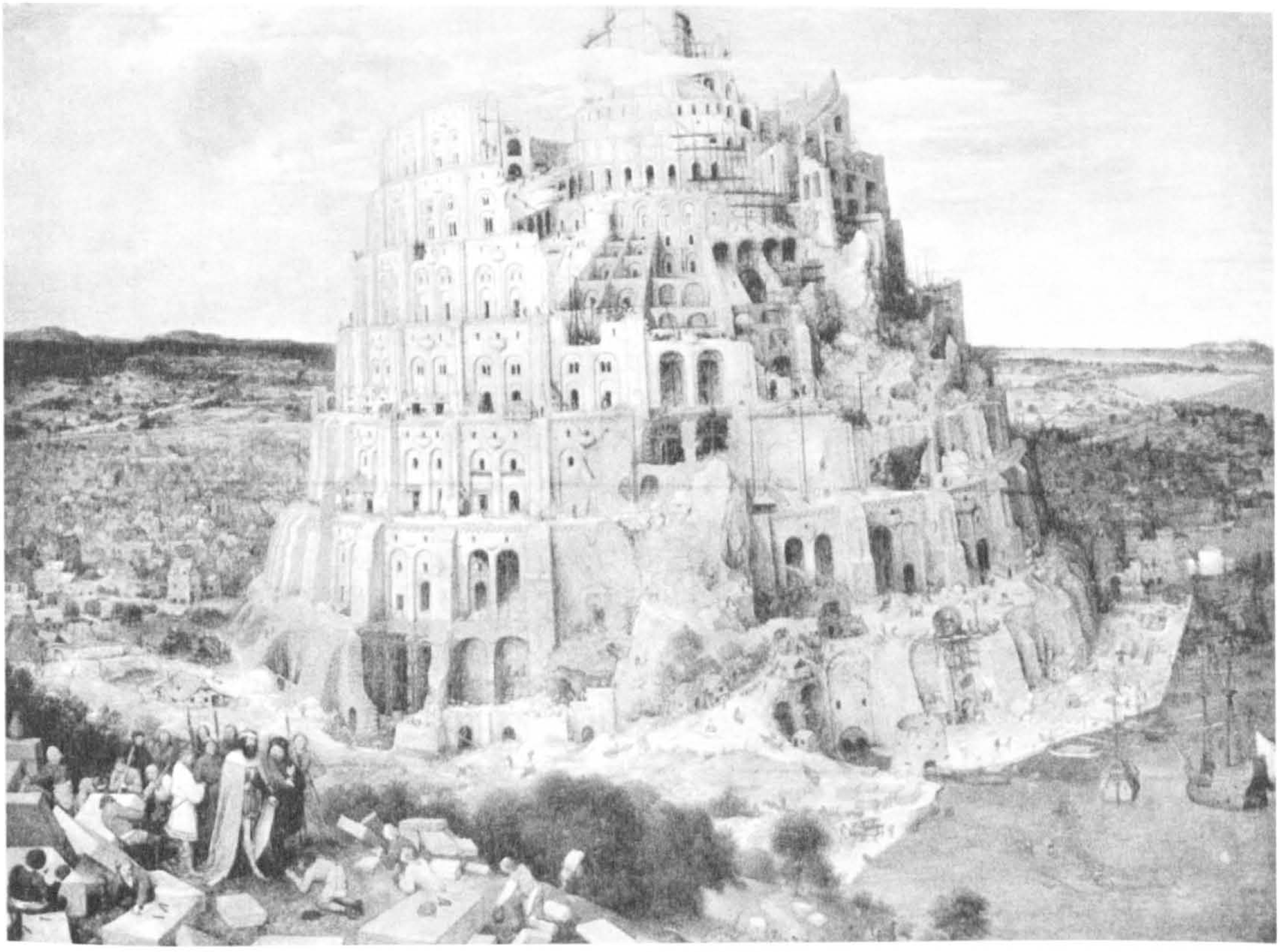


Fig. 2.7 *The Tower of Babel*, by Pieter Bruegel the Elder, 1563
(from Grossman, undated)

structure, with some of the missing information being sourced from ancient literature (Gibson 2004). This approach of Bruegel's becomes all the more unique when his Tower is compared with a typical pre-Renaissance representation of the same structure, such as that in the Bedford Book of Hours (1423), which shows it as a Gothic building, though, very interestingly, one of a spiral form (Fig. 2.9).

The Tower of Babel continued to be of enduring interest as a subject for imaginative reconstruction, and even in Bruegel's day there existed numerous representations of it, so much so that art historians argue for the existence of a Babel School during the late 16th and early 17th centuries. These paintings are all highly similar to the representation discussed above in that the tower is shown as a spiral structure with arched openings. This characteristic was further elaborated by the Jesuit priest and polymath Athanasius Kircher, who, in his reconstruction of the *Turris Babel* dating from 1679, showed a structure with a double spiral at its base, but which is on the

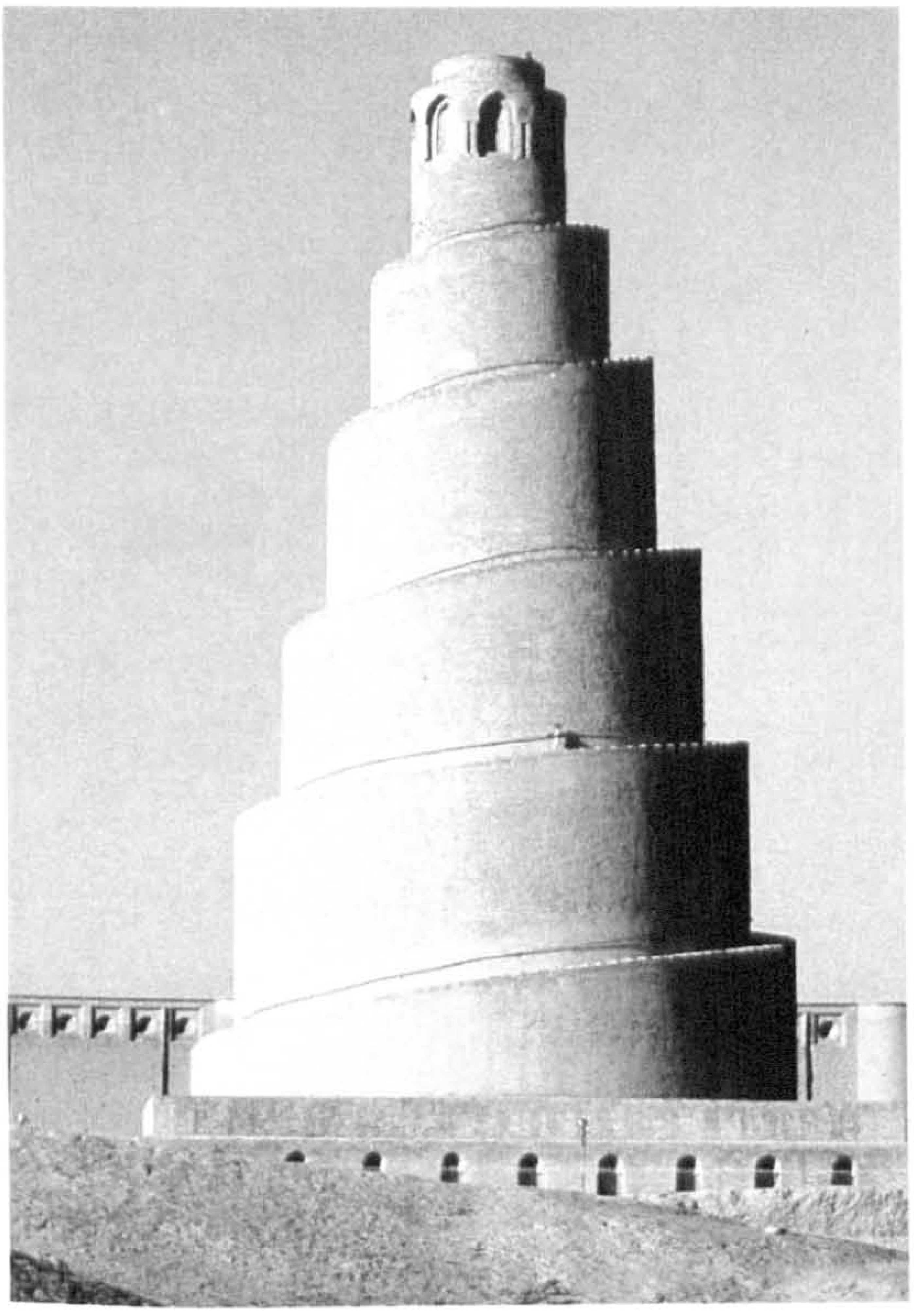


Fig 2.8 Spiral minaret, Samarra (from The Threat to World Heritage 2003)

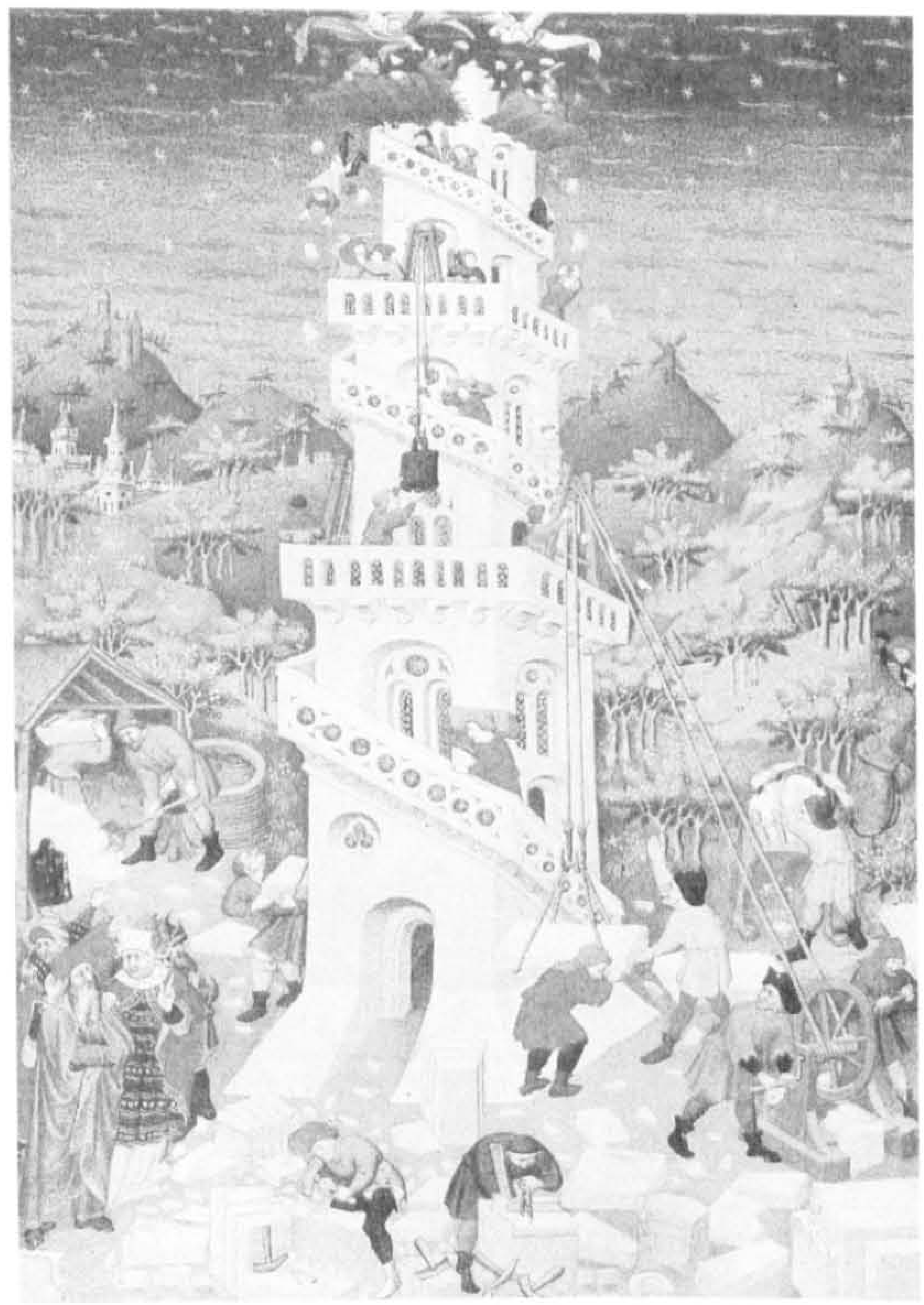


Fig 2.9 Tower of Babel, 1423 (from The Virtual Babel Encyclopaedia)

whole taller and thinner than the one postulated by Bruegel and his contemporaries (Fig. 2.10). This notion of a spiral tower formed a sort of myth in itself which continued well into the 19th century, as evidenced by Gustav Doré's hypothetical illustration of the structure in an edition of the Bible from 1866 (Fig. 2.11).

2.2.2 The Art of Archaeology

The 19th century saw a fundamental shift in the public and academic perception of the past, caused principally by the development of what we would recognise today as scientific archaeology in the place of the makeshift antiquarianism of the preceding centuries. The early archaeologists, with their crude and destructive techniques, nevertheless managed to make spectacular discoveries that captured the public imagination of the time: the Minoan civilisation of Crete, the ancient Assyrians of present-day Iraq, and quite possibly the greatest archaeological event of the century, the discovery of the supposed sites of Troy and Mycenae described in Homer's epics

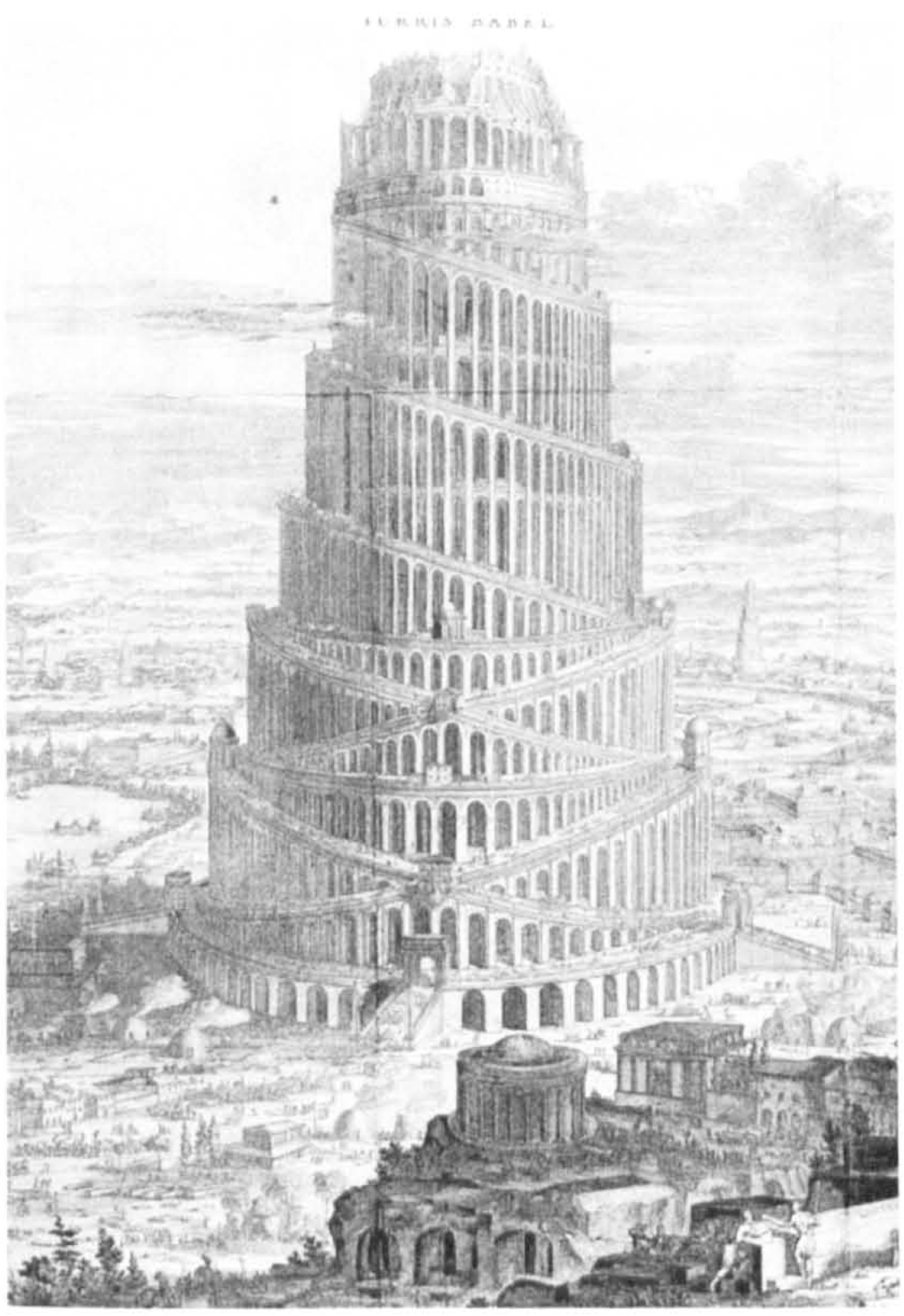


Fig 2.10 Athanasius Kircher's *Turris Babel*, 1679 (from Virtual Babel)

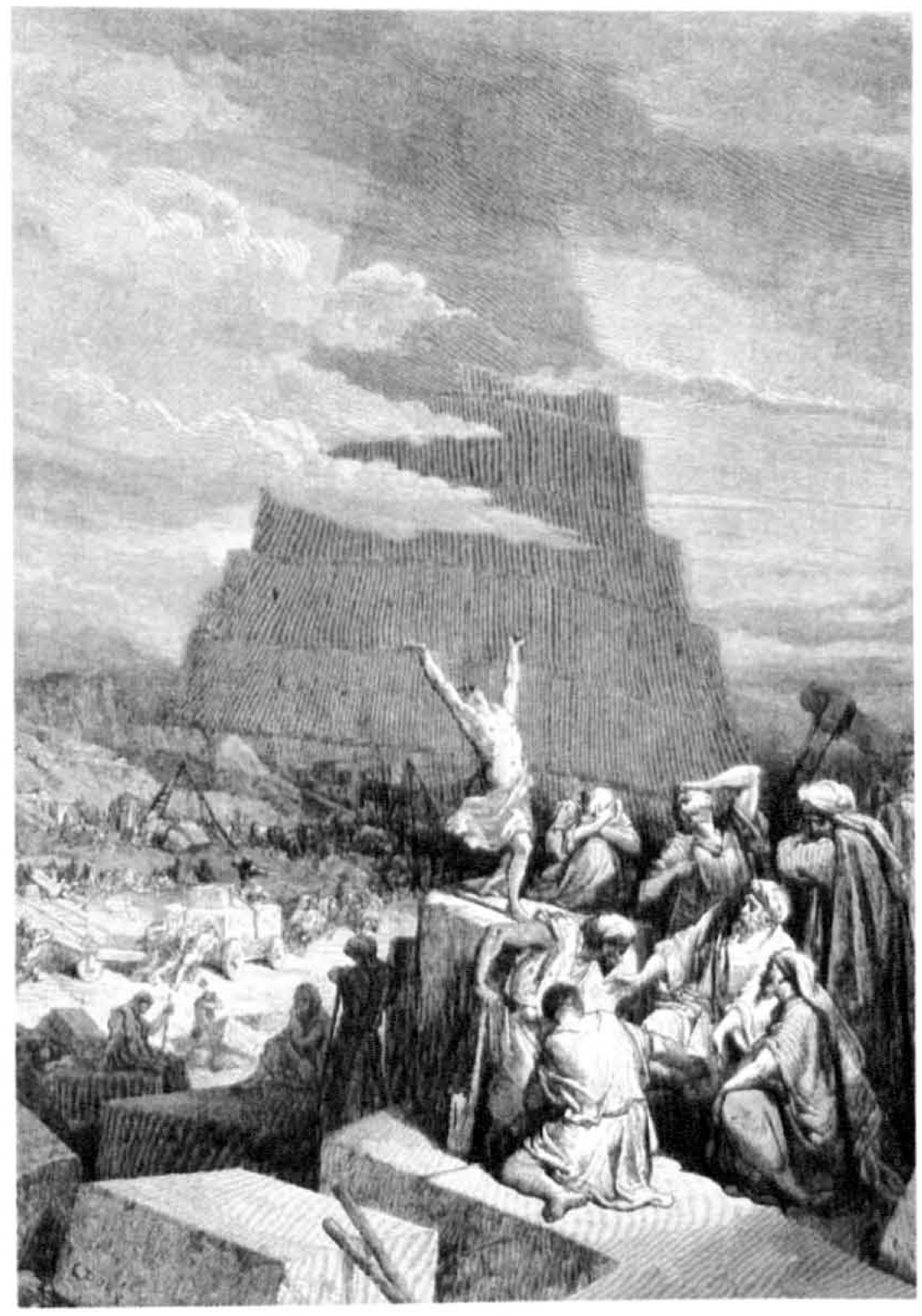


Fig 2.11 Tower of Babel, by Gustav Doré, 1866 (from Virtual Babel)

by Heinrich Schliemann in the 1870s and 1880s (Cottrell 1953:126-142; Cottrell 1957:11-22; Wood 1996:34-73). These achievements, which were preceded by the long-awaited decipherment of the ancient Egyptian hieroglyphic script by Jean-François Champollion in 1822 (Calvet 1996:249-253), opened up an entirely new world to the eyes, not only of scholars, but also of an inquisitive public. Indeed, Johnston (1991:31) argues that "the popular excitement generated by ongoing archaeological triumphs in the second half of the century can be regarded as corresponding to our generation's enthusiasm for the conquest of space."

It was not long before artists were feeding off the public enthusiasm for all things ancient. Some of the most spectacular pictorial representations of historic events and settings are found in the apocalyptic visions of a Biblical Mesopotamia produced by John Martin (also known as 'Mad Martin'). His paintings, with such evocative titles as *The Fall of Babylon* and *Belshazzar's Feast*, generally featured monumental expanses of columned halls and furiously stormy skies that threaten to engulf the

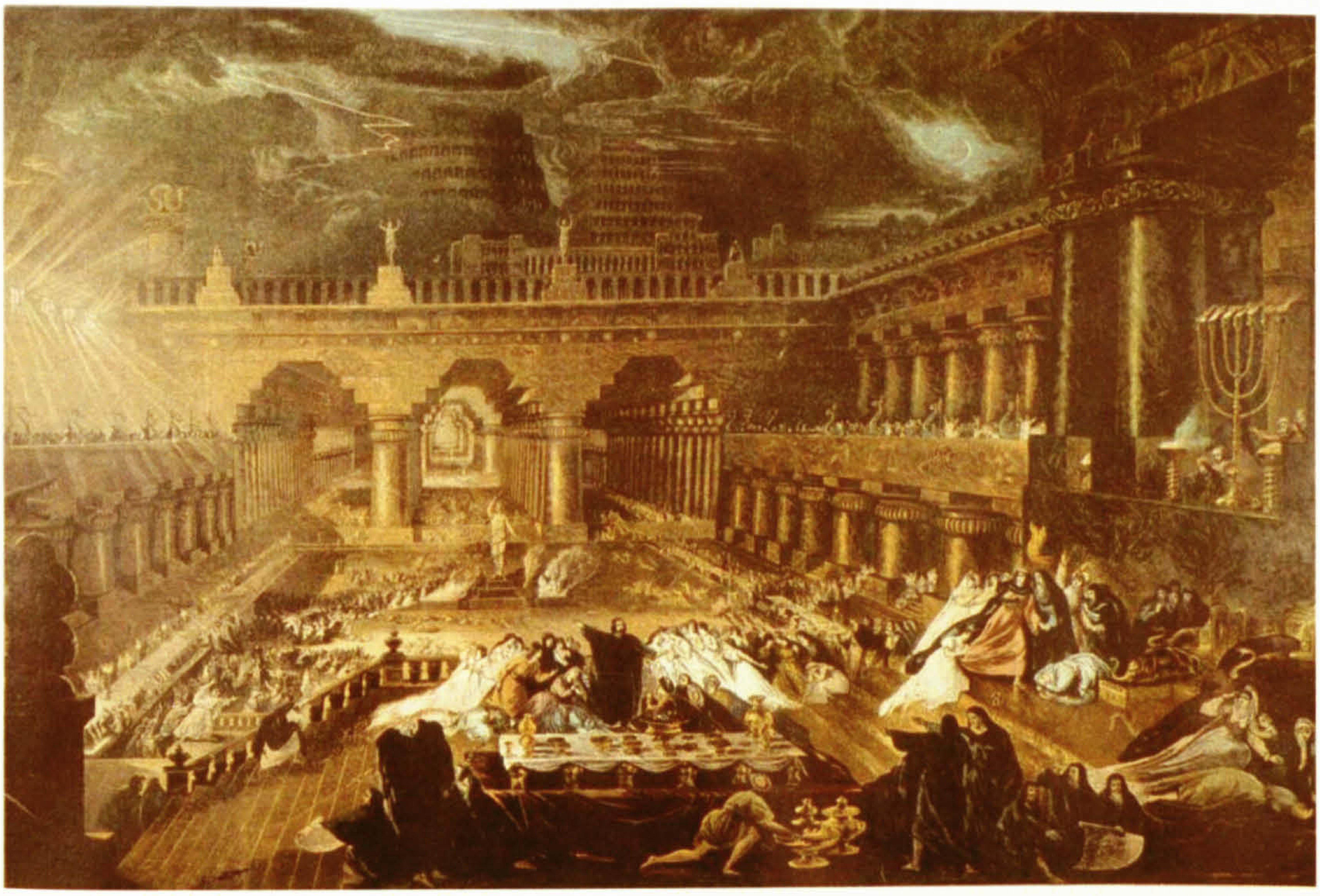


Fig. 2.12 *Belshazzar's Feast*, by John Martin, 1821
(from Stamp and McKinstry 1994)

tiny human figures that populate the buildings (Stamp 1994:67) (Fig. 2.12). Indeed, towards the end of the 19th century a group of British painters known as the Classicists (or the Olympians) specialised in producing rather sanitised representations of the ancient civilisations of Greece and Rome to huge public acclaim, so much so that one of their number, Frederic Leighton, later Lord Leighton, managed to obtain a peerage for himself on the strength of his paintings. It is necessary to emphasise, though, that artists like Leighton were not archaeological illustrators by any means; they were merely catering to the public obsession with the past by producing representations with historic themes and settings, with historical accuracy being of no real importance (Asleson 1999:67).

One particular painter of this school, however, stands out from the rest. Sir Lawrence Alma-Tadema was an Anglophile Dutch émigré who arrived in Great Britain in his mid-30s, and who, after a brief dalliance with medieval subjects, decided to devote himself almost exclusively to the representation of scenes from ancient Greece,

Fig. 2.13 *Tibullus at Delia's House*, by Lawrence Alma-Tadema, 1866 (from Lovett and Johnston 1991)

Rome, and to a lesser extent, Egypt. His highly polished images of a cosy and intimate ancient domestic life were extremely attractive to the art-loving public of the time (Fig. 2.13), as explained by Lovett (1991:9):

> … His meticulously imagined details of antiquity provide an instructive view of Victorian society. The carefully researched settings are peopled with contemporary Britons. His paintings were therefore reassuring to a bourgeois public that enjoyed seeing its lifestyle mirrored in the citizens of ancient Rome.

The series of paintings Alma-Tadema executed during a prolific period between 1865 and 1870 included scenes based on reconstructions of actual Pompeian villa interiors. Alma-Tadema's architectural reconstructions were almost universally admired, and his facility in painting realistic marble textures, usually featured in conjunction with glowing Mediterranean skies and seas, was held in special regard.

Indeed, Alma-Tadema's work was so convincing that he was invited to lecture to the Royal Institute of British Architects in 1907, choosing as his topic the persistence of Classicism and the supposed reflection of ancient Rome in the British Empire.

Mention has already been made of the largely 20th century phenomenon of heritage tourism, with its imperative to open up historical sites and buildings to the public. We have also noted that, although some of the consequences of this course of action have hardly contributed to the preservation of original fabric, the use of reconstruction images and models in a museum environment at some distance from the building itself can help to prevent the most severe sort of damage. The use of archaeologically informed but attractive reconstruction images was pioneered in Great Britain in the immediate Post-war decades, and the entire practice is largely due to the influence of two men: Lord Molson, the Minister of Works at the time, and Alan Sorrell, an artist with a casual interest in archaeology (Stempel 1983:18-21). The legacy of Sorrell remains extremely influential to this day, and it is worth looking at his output in greater detail.

Alan Sorrell's involvement with the Ministry of Works started in 1956, when he was commissioned to carry out a reconstruction of Hadrian's Wall for public exhibition. The Ministry's policy until this time was to avoid using reconstruction images at heritage sites, principally in order to avoid the controversy about historical accuracy and realism, and also not to give the impression of supporting a single interpretation where others would be equally plausible. Instead, what was usually done was to make comparisons between a ruined building and an existing one so as to give a general idea of what the ruins might have looked like in the past. This was found to be impossible in the case of Hadrian's Wall, a structure that is unique in Great Britain. Sorrell's reconstruction of the Wall, carried out in consultation with architects, archaeologists and historians, made no claims to absolute accuracy but was obviously scientifically-based and drew from historic iconography, such as the reliefs on Trajan's Column in Rome. Lord Molson was so impressed by Sorrell's work that he not only insisted that this procedure be followed in all future reconstruction images of monuments, but he also fielded questions on the subject in

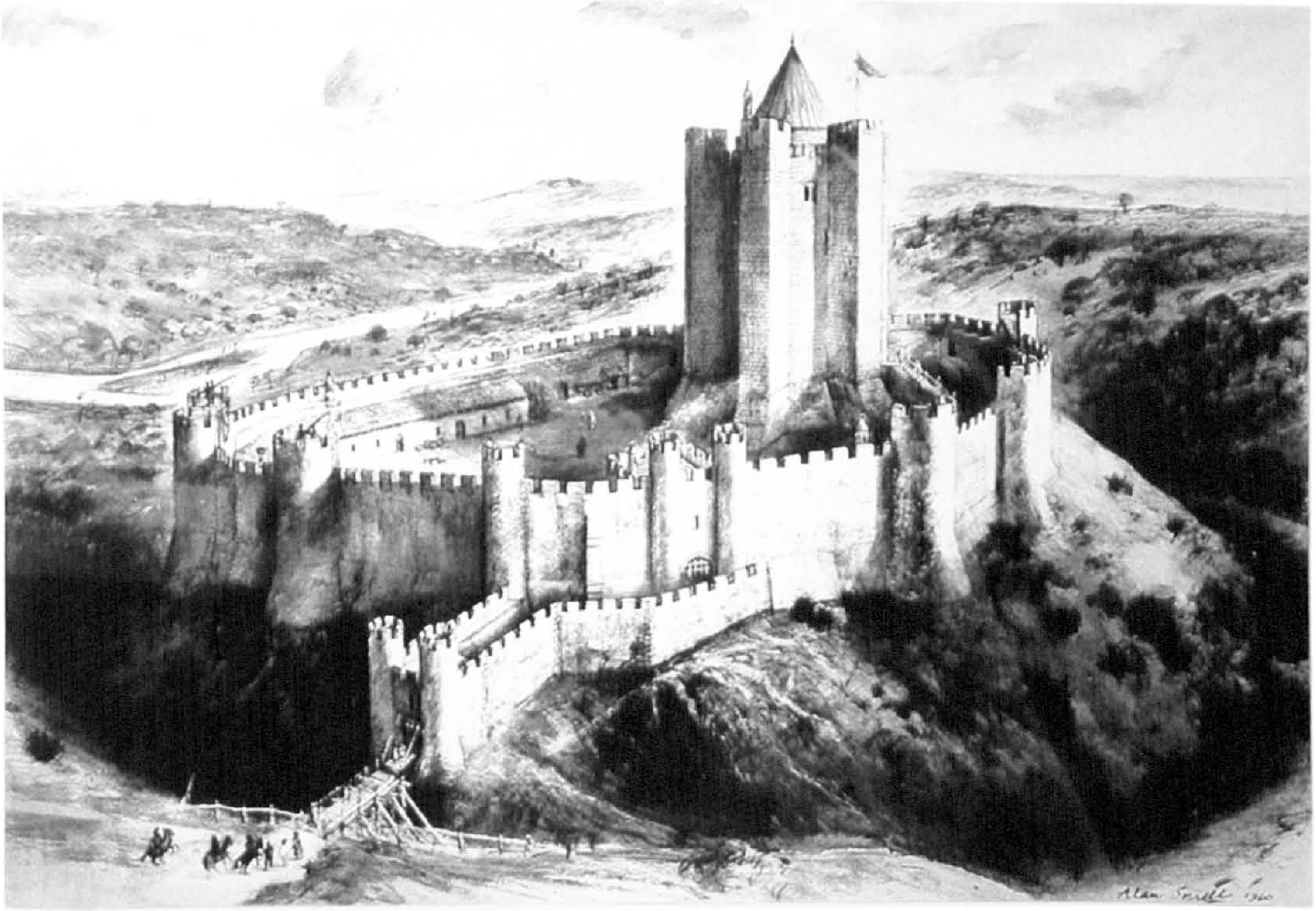


Fig. 2.14 Reconstruction of Conisbrough Castle by Alan Sorrell, 1960
(from Conisbrough Castle web pages 2005)

the House of Commons in an attempt to convince sceptics of the validity of this approach. As a result, between 1956 and his death in 1974, Sorrell was involved in the creation of reconstruction images of seventy historical monuments throughout the country, and in many ways work and that of his colleagues represents the apotheosis of the tradition of archaeological art (Fig. 2.14).

2.2.3 Movies and Television

The early decades of the 20th century witnessed the arrival of a radically different form of visual presentation to anything seen before: the motion picture. The earliest examples of this art were mere curiosities and usually contained nothing more than short vignettes of relatively mundane events like galloping horses and trains pulling into stations, but before long the new film-makers were creating increasingly impressive productions geared towards public entertainment. It is interesting that films with historical themes were extremely popular in the in the early and middle

Fig. 2.15 Still from *The Ten Commandments* (1956) (from TVfilm 2004)

parts of the 20^{th} Century, and the works of such directors as Cecil B. DeMille and David W. Griffith are especially notable in this respect. Films like Griffith's *Intolerance* (1916) and DeMille's *The Ten Commandments* (1956) (Fig. 2.15), with their vast imaginative reconstructions of ancient Babylon and Egypt, made up for their lack of historical accuracy by sheer extravagance. In this respect, it is worth emphasising that the motion picture sets necessitated the physical three-dimensional reconstruction of the environment that was being represented, in strong contrast to the two-dimensional portrayals carried out by the Victorian archaeological painters. This of course demanded a higher level of intimacy with the subject matter on the part of the set designer, and also an interest in historical subjects from the cinema-going public to justify the enormous cost of building sets in the first place.

Historical epics remained a staple of the cinema until well into the 1960s, when a waning public interest in the past was replaced, as Johnston (1991:31) points out, with an equally intense fascination with an imaginary (and usually utopian) future. Stanley Kubrick, for example, found himself moving in the space of a few years

Fig. 2.16 Still from *Gladiator* (2000) (from Toby's Film Stills 2002)

from the ancient Rome of *Spartacus* (1960) to the futuristic societies of *2001: A Space Odyssey* (1968) and *A Clockwork Orange* (1971). This is not to say that historical subjects have been altogether abandoned by modern film-makers, although by the 1980s this certainly appeared to be the situation. Film-makers on the whole found themselves unable to justify the cost of the sets and personnel required in view of the waning interest in historical subject matter, and as a consequence, many such films of this period are rather smaller scale dramas which do not attempt to impress the viewer with their extravagance. Over the last few years, however, the use of computer graphics has provided a means to create historical environments at a fraction of the cost of building traditional sets, a phenomenon exploited in such recent films as Ridley Scott's *Gladiator* (2000) (Fig. 2.16) and Wolfgang Petersen's *Troy* (2004). It is now possible to create the vast historical built environments favoured by DeMille and Griffiths and also to have the thousands of extras called for in historical epics without necessarily having to build gigantic sets or hire armies of actors. As with the directors of the last century, there is usually little interest in historical accuracy, with the fundamental aim being to impress the viewer with special effects. What we do find is that, although the cinema going public of today is far less acquainted with Biblical and Classical subjects than that of, say, fifty years ago, there is generally a renewed interest in the spectacle and exoticism of the past.

A closely allied medium to the movies is television, with the fundamental difference that, while the movies in general are purely about entertainment, television usually takes an interest in educating the general public. Historical topics have continued to be of enduring interest as subjects for television documentaries and dramas since its earliest days, but have been somewhat hampered by the fact that television programme producers cannot command the huge budgets of movie directors, thus limiting the scale of the reconstructions that can be attempted. As a consequence, the portrayal of the past has been dealt with in a number of ways, for example:

- Incorporating footage from high–budget films.
- Setting the action in an existing historical building.
- Using small scale action to hint at the event being portrayed.

Again the advent of computer graphics has had a fundamental impact on televised architectural reconstructions. It is now possible to give a visual impression of, for example, an ancient Egyptian tomb reconstruction, without having to incur significant expenses. The quality of such representations is not usually inferior to that seen in modern historical movies, for, while a movie might include several hours of continuous animation, a television programme might not have more than a few minutes' worth. One of the most impressive examples of this approach was shown on the BBC2 programme *The Mystery of the Taj Mahal*, which postulated that, in addition to the well known structure in white marble, a second monument in black marble was originally planned on the opposite bank of the River Jamuna, with an animated sequence being used to give an impression of what this design may have looked like had it been completed.

Holtorf (2005), citing a series of surveys carried out in Sweden, the USA and Canada, points out that television plays a increasingly significant role in exposing the public to historical themes and issues, and has largely displaced such traditional methods of getting to grips with the past as museums and travel. This being so, it is interesting that one of the major criticisms that has been levelled at televised historical reconstructions is that it is not uncommon to attempt to win ratings by employing impressive graphics at the expense of historical fact and educated discussion. There is also concern that simplistic and highly speculative scenarios are represented as absolute certainties so as to be easily digestible to the average television viewer who might not have a particularly deep interest in the subject matter being portrayed. While this is undoubtedly true to an extent, the real value of television is not necessarily as a means of disseminating closely argued theories for the benefit specialists or educated laymen, but rather as a method of reaching out to members of the public who might not otherwise have been exposed to the subject matter being presented. In this respect, televised reconstructions are similar to the drawings of such illustrators as Alan Sorrell, and the challenge to producers is to create a balance between engaging public interest and communicating some idea of the complexity and uncertainty of the past without resorting to journalistic hyperbole. Unfortunately, the current proliferation of programmes with such overblown and simplistic titles as *Stonehenge: The true story* (recently shown on Channel 5) does little to foster a balanced and educated view of historic architecture among the viewing public.

3

Architectural History and Computing

The advent of digital computers in the Post-war period has had an important impact in almost every area of human endeavour, and architectural practice and research is no exception. While the application of computers in the sciences, engineering and economics was established fairly early on, their usefulness as architectural tools was handicapped for a long time by the lack of the proper visual interfaces that are essential for creating and manipulating graphics. The vacuum tube equipped machines of the 1950s and the transistorised ones of the following decade were deficient in the power needed to carry out any substantial graphical work, and so the early attempts at using computers in architecture were generally restricted to the quantitative evaluation of building designs, particularly in the area of energy consumption (Day 1997:39). The situation that was prevalent in the late 1960s is described by Stotz (1968:51):

> The graphic CRT's [cathode ray tubes], which require a small computer memory, start at about thirty thousand dollars and go up. At present, most of these machines are seriously lacking in software support from the manufacturer, particularly in the area of applications. In fact, if you get involved with any graphic display you're going to have to do a good deal of programming yourself. Most of these devices are either one-of-a-kind or are so few in number that there is virtually no graphic language standardization.
>
> Although computer graphics is a very powerful tool, it has had very little impact on the practicing architect. One explanation of course is just the expense of the device. Another is the lack of useful programs. But all this is due in large part to the fact that it's still a very young field.

The situation changed drastically with the development of the silicon chip and the high resolution visual display unit in the 1970s. It led not only to a vast increase in the power of computers, but also to a significant drop in their production and maintenance costs, and perhaps most importantly, to their becoming more accessible to the non-specialist. The Apple and IBM personal computers of the late 1970s and early 1980s started the process of democratising the computer, and soon the graphics potential of the standard machine was adequate for interactive two- and three-dimensional work. This, along with the development of commercially available Computer-aided Design (CAD) software, precipitated a revolution in the architectural office: the drawing board and its associated paraphernalia were increasingly replaced by CAD workstations, so much so that today it is rare to find an office that adheres to the old methods (Bertol 1997:43-44). Indeed, by 1990 over 80% of large architectural firms in Great Britain had adopted CAD in one form or another (Day 1997:41).

3.1 Computer-Aided Architectural Simulation

In general terms, data visualisation is the use of computers and the related digital technologies to "allow visual interpretation of data through the representation, modelling and display of solids, surfaces, properties and animations, involving the use of graphics, image processing, computer vision and user interfaces" (Reilly, 1992:147). The importance of this notion is that it allows the coherent and systematic representation of large volumes of multi-dimensional data. The majority of computer-generated architectural visualisations are carried out by architectural firms or by specialist visualisation companies, with the goal of producing representations of proposed buildings, components or environments for presentation to clients, the general public or statutory authorities. It is therefore understood that the representation should highlight the strengths of the proposal and attempt to conceal flaws or unresolved issues, if there are any. It is not uncommon to use unrealistic lighting arrangements or to exaggerate the qualities of materials to produce, what is in effect, a 'pretty picture'.

Concurrently with the use of digital representation techniques to portray the built environment as proposed, computer-literate architectural researchers and archaeologists adopted the same methods to conjecturally reconstruct vanished buildings of the past. A cursory glance at the body of literature in the discipline demonstrates that much of the interest has come from the archaeological, rather than the architectural, field. The reason for this is difficult to ascertain; it may have something to do with architects' "infatuation with their own drawings" (Bertol 1997:45), manifested in a reluctance to adopt what are perceived to be less immediate methods of illustration. What is clear, however, is that as a result of this situation many virtual reconstructions are aimed at addressing archaeological issues, sometimes at the expense of architectonic ones. This is explained by Mehta in the following way (2002:189):

> In some cases like the Indus Valley Civilization, there is a great quantity of accumulated archaeological data and ruins photography on this architecture, but very little information on theoretical visual reconstructions. Many sites have never been imaged or modelled in any way, other than measured plans, elevations and cross sections. Serious reconstruction pictures, perspective pictures or study models are rare. This limits our understanding of many important archaeological remains. Surely architecture offers us an equally important, if not more important, axis to the anthropology of historical landmarks.

Computer-aided Design tools are used in two separate roles in architectural representation, a dichotomy that can be summarised, according to Bertol (1997:50), in two buzzwords: 2-D and 3-D. The 2-D use of CAD is fundamentally the simple transfer of traditional drawing board procedures into the digital domain, with the objective of producing plans, sections and elevations much as would be done using a pen and paper. The translation of a paper drawing into a CAD drawing typically increases its power several fold. For instance, the amount of data that can be included in a traditional paper drawing is limited by the concerns of legibility, scale, viewpoint and the size of the paper. The corresponding CAD drawing has no size constraints since the virtual drawing board is of unlimited size, and this enables all data to be registered at real world scale. Additionally, as Bertol (1997:45) points out, "while the only editing feature of manual drafting is the eraser, CAD menus include very powerful capabilities for manipulating an initial set of graphic entities." In spite of all its advantages, however, the straightforward CAD drawing is still an abstract two-dimensional representation of a three-dimensional object; it suffers in this respect by being limited to a single viewpoint, requiring the creation of a series of drawings from scratch if different views are to be portrayed.

A different approach to building visualisation is the use of computer-aided modelling techniques. The building blocks of the computer model are not mathematically described two-dimensional objects as with a CAD drawing – lines and circles, for instance – but full three-dimensional entities such as cubes, cylinders and planes (this topic will be considered in fuller detail in Chapter 5) . These primitive elements can be manipulated using Constructive Solid Geometry (CSG) to permit the creation of unlimited forms from simple constituents, all fully three-dimensional. The array of tools available to the researcher is enriched by various surface modelling techniques, such as meshes and spline-based procedures. The fundamental advantage of digital models over drawings is that they are inherently three dimensional, and thus permit the extraction of multiple views from a single model with no significant increase in workload.

It is also significant that a drawing, whether manual or electronic, is always an abstract representation of an existing or imaginary real-world object. A digital model, on the other hand, can be either a representation or a simulation. Groat and Wang (2002:278) explain the difference as follows:

> We use the word representation to denote a fixed image that stands for a "real" object because the image has measurable qualities that describe and depict the real thing. By this definition, architectural drawings are representations. Photographs, the images that much of architectural education is dependent upon, are also representations (although studies of the efficacy of photographs as "simulations" have been done). To-scale

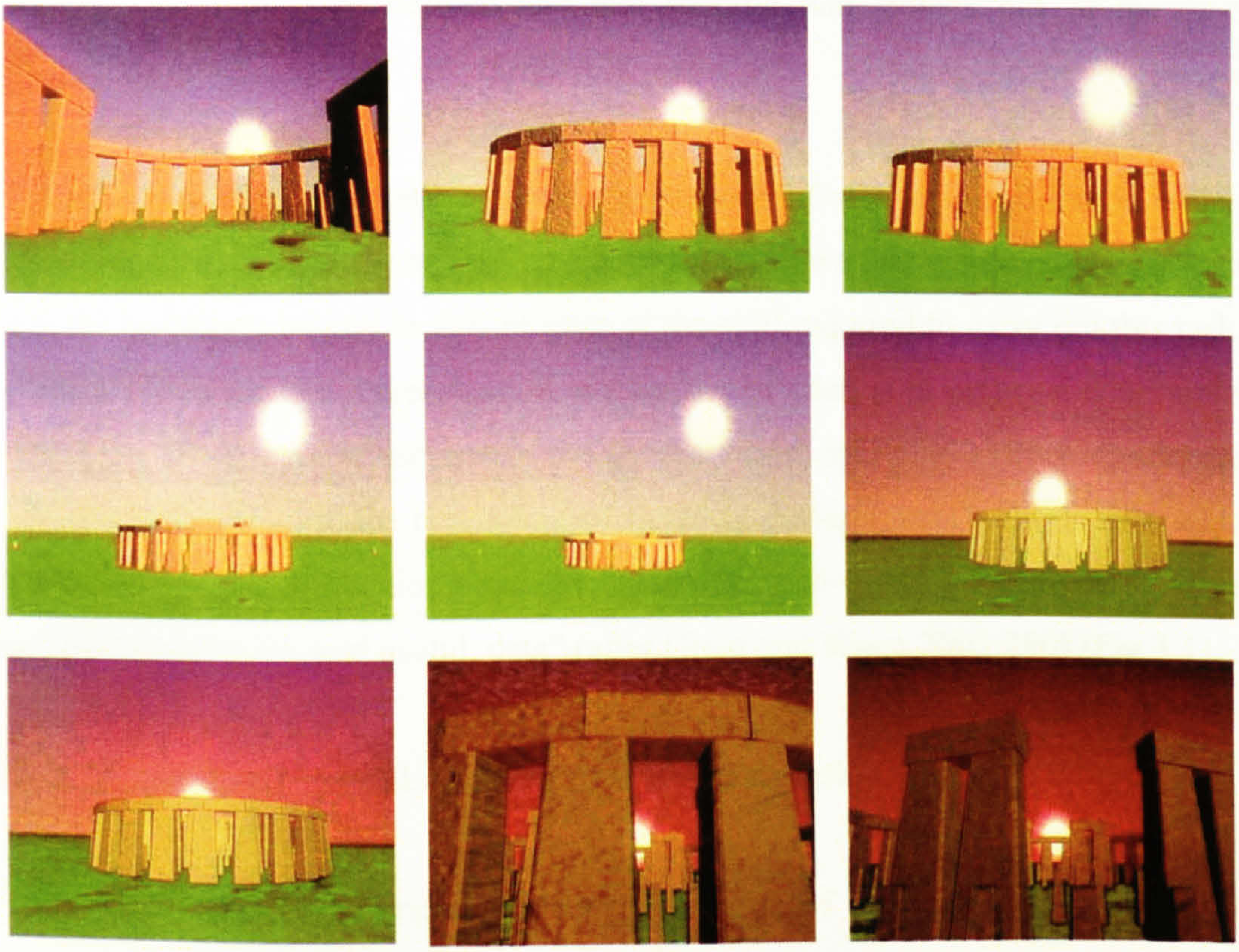


Fig. 3.1 Computer-aided sun movement simulation at Stonehenge (from Forte and Silliotti 1997)

architectural models are representations as well. All these remain "merely" representational unless they are included in a larger research program in such a way that the manipulation of specific factors results in useful data that can be applied back into the real-world context under study.

For our purposes, *simulation occurs when a replication of a real-world context (or a hypothesized real-world context) contains within it dynamic interactions that are the result of manipulated factors. These interactions are reflective of interactions actually occurring in the real world, a simulation research design is one that is able to collect data on these interactions for application into the real-world context.* Simulation studies can certainly make use of fixed representations such as drawings, to-scale models, and photographs. The key, however, is that a controlled replication must be defined and that specific data comes out of the replication.

As an illustration, we may take an artist's impression of a historic building in which he casts shadows which correspond exactly to the shadows that would have been cast when the building was still in use. In spite of the skill required to carry out this task, the artist's drawing is a representation, a snapshot of what is in reality a continuous event. Now if we were to use one of the commercially available software packages to dynamically visualise the movement of shadows through, say, a single day, what we would have is a simulation "because it provides real-world information in ways that yield measurable, and useful, data" (after Groat and Wang 2002:280) (Fig 3.1).

3.2 Evolution of Virtual Architectural Reconstruction

Pioneering work in the computer-aided visualisation of the built heritage in Great Britain was carried out in the 1980s, usually in the form of collaborations between archaeologists and computer scientists. Much of the visualisation work was outside the control of the researcher, simply because the software of the time was so complex as to be accessible only to experts. In each case the computer scientist acted as the intermediary between the raw data and the final visualisation, and given that he frequently had no particular interest of the building being studied, this arrangement was hardly conducive to any detailed architectural or archaeological analysis. Indeed, many of the early projects were funded by large corporations such as IBM and Fiat, who "had cynically targeted archaeology as a discipline in which they could gain public relations points in an area which was politically safe, and at relatively little cost to them" (Miller and Richards 1995:20). Reilly (1992:147-173), in his seminal paper on the subject, documents a number of early examples of virtual architectural reconstruction, and observes that the subject matter was generally Roman or Romanesque building complexes. He also notes that "a cynic might suggest that the original grounds for applying advanced modelling techniques to the reconstruction of ancient remains amounted to little more than an archaeological flirtation with an exotic technology in search of a new application, and resulted in mere intellectual curiosities" (Reilly 1992:148). However that may be, there is no doubt that some of these early attempts produced remarkable results with what would today be considered fairly primitive software and hardware.

A neat summary of the evolution of computer-aided built heritage visualisation is put forward by Earl and Wheatley (2002:6), who identify three distinct chronological phases: adoption, examination and critique. They write:

> As elsewhere in computing, this has tended to begin with the largely unconsidered application of a new technique or technology to archaeological remains. It then moves on through a process of analysis and reanalysis, until it reaches a kind of equilibrium ... it is at this point that the problems and benefits inherent in it are understood and research can develop beyond the ethics and problems of adoption.

Their conclusion is that the discipline is still at a middle stage in its development, and that the theoretical implications of the techniques are yet to be fully investigated, in spite of numerous academic demonstrations of their value. It is certainly true that the full potential of the technology has yet to be exploited by architectural researchers, as we shall be discussing in due course. Nevertheless, judging by recent publications in the discipline (Kantner 2000, Strothotte et al 1999), there are signs of a rigorous evaluation of the place and relevance of computer-aided visualisation within the context of architectural research, so it is perhaps correct to say that the evolutionary process is now at the third stage, that of critique, though perhaps not convincingly so.

3.2.1 Adoption

As an illustration of an early computer-aided built heritage visualisation project, we can look at the reconstruction of Furness Abbey, carried out by Lancaster University Archaeological Unit in 1988 in order to produce video sequences of the structure (Wood and Champan 1992:124-134). Due to the unavailability of specialised

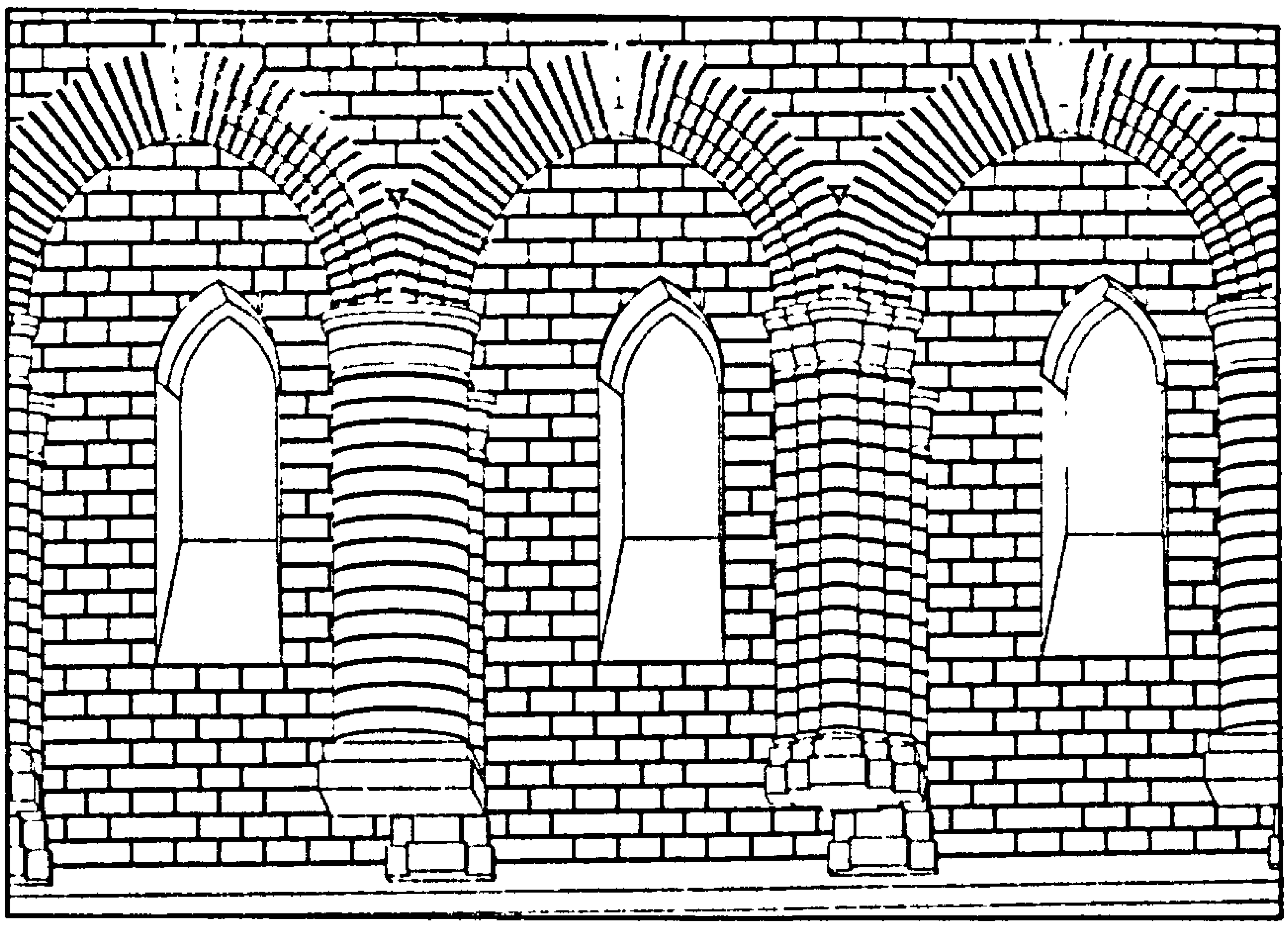


Fig. 3.2 Wireframe image of Furness Abbey (from Wood et al 1992)

building modelling software, PDMS, a modelling system designed for use with plant layout and pipework design was used to create a stone-by-stone reconstruction of the nave and aisles of the Abbey:

> To make the piers, for example, one stone was created, and then copied, and positioned until there were sufficient stones to form the first course. This course was then copied, the second positioned above it, and so on, until the whole pier was complete. Advantage was taken of using PDMS's special programs (or macros) for producing all of the various architectural features (piers, arches, windows, aisle responds, vaults, roofs, parapets etc.). Such 'elements' were duplicated by simply copying and mirroring the appropriate macros, thus saving much inputting time.

This very laborious process is all the more remarkable given the sheer size of the task. Furthermore, it should be borne in mind that early graphics software did not necessarily incorporate a graphical user interface, and it was necessary to input dimensions and other object descriptions in code (Reilly 1992:153). The final product was wireframe rendered, because the software of the time was not capable of

Fig. 3.3 Particle-traced rendering of Hal Saflieni hypogeum, Malta (from Chalmers and Stoddart 1996)

the photorealistic standards that are often expected today (Fig. 3.2). It is notable that this project was aimed at testing "the merits, problems and potential relating to the application of solid modelling techniques to the computer reconstruction of a complex and detailed historic building" (Wood and Chapman 1992:134), and not necessarily with testing any hypotheses about the building itself. In other words, we have yet to start dealing with computer models as simulations of real world scenarios.

3.2.2 Examination

Chalmers and Stoddart (1996:85-93) document an altogether more advanced approach to virtual reconstruction. They describe INSITE, a system to aid in the visualisation of prehistoric temples in Malta, believed to be the oldest free-standing stone structures anywhere in the world. The emphasis throughout is extreme photorealism, down to the inclusion of smoke, dust, fog and other environmental phenomena which the authors believe might have had a notable effect on the way in which a site was illuminated, and by extension the way in which it could have been used in the past (Fig. 3.3). Interestingly, Ryan (1996:107), commenting on this approach, sees the visualisation of atmospheric details not as a means to imbue computer-generated images with a bogus sense of reality, but rather as a legitimate method of obscuring areas of uncertain interpretation, much in the same way that these phenomena were employed by traditional archaeological illustrators like Alan Sorrell. Nevertheless, what the INSITE project does demonstrate is that researchers of the historic built environment were no longer restricted to testing the capabilities of computer systems but were able to start using them in a productive way to test various architectural and archaeological hypotheses.

3.2.3 Critique

The most recent stage in the evolution of virtual reconstruction is exemplified by such projects as that described by Vranich (2002:83-94), concerned with the simulation of human behaviour in the context of a historical reconstruction in the modern state of Bolivia. The subject for the study, the Pumapunku Temple Complex in the pre-Columbian city of Tiwanaku (Tihuanaco), was recorded using computer-aided surveying techniques involving the use of an EDM (electronic distance meter). The data was transferred to the CAD software with no human intervention, and the final result was a virtual reconstruction of the temple complex that was far more accurate than anything that could have been accomplished using traditional techniques. A series of views are then extracted from the model in order to determine the possible directions of entry into the complex. This is followed by the conclusion that the western side is more likely to have contained the entrance, for a number of reasons that could not have been perceived in any other way but by reconstructing the structure and by then viewing it dynamically from the perspective of a 1.5 meter high individual. The final proposition is that the entire temple complex was conceived in a manner similar to a modern amusement park, "where visitors are guided through areas with fantastic architecture and personalities, without ever seeing behind the scenes to the flimsy facades of plywood, plastic, and exposed maintenance works" (Vranich 2002:87). It is thus evident that computer modelling was an invaluable tool in the interpretative process, not necessarily to illustrate the temple complex, but rather to test various ideas about the architecture and throw up suggestions about the way in which it was designed, built and used in the past.

3.3 Aims of Virtual Architectural Reconstruction

Kantner (2000), writing from an archaeological perspective, points out that many virtual modelling projects are embarked on without a clear goal or a vision of the model's future use, taking, in his own words, a 'wouldn't it be cool if I could do this' attitude. He emphasises that it is important to consider the purpose of the reconstruction in order that the model may be designed accordingly, and to ensure that if any compromises are necessary, that they are the appropriate ones. According to him, a virtual architectural reconstruction is carried out to satisfy one (or more) of three fundamental objectives: *research, pedagogy* or *public entertainment*. It is interesting that Stone and Planel (1999:4-5) identify these same criteria as the basis of full-size archaeological construction sites as well.

3.3.1 Research

The virtual reconstruction is an increasingly valuable tool in the arsenal of the architectural researcher, primarily because it fills in many of the lacunae of traditional illustration and modelling techniques. A virtual model permits the researcher to test hypotheses that would not even be considered with, say, a physical scale model, and obtain perspectives of the structure from what would otherwise be impossible viewpoints. While this implies a fairly significant research project, Mehta (2002:184) points out that, "at the very least, the process of creating architectural models can identify inconsistencies in the actual archaeological data and rectify incorrect assumptions about the appearance of non-recorded features." Gifford and Acuto (2002:96) identify two projects that exemplify the interpretative potential of virtual reconstruction in an academic context:

> Two particularly interesting (and relevant) recent examples of visualisation in archaeology come from southern Greece and British Columbia, Canada. In the first, researchers were able to recreate the 14^{th} century AD Frankish town of Agios Vasilios in southern Greece ... By studying their 3D model from the perspective of the surrounding area, the researchers were able to better understand the forceful and intimidating role this settlement played in local political relations when it was originally settled.
>
> In the second example, Philip Peterson and his colleagues created a detailed 3D model of a pithouse structure from the Keatley Creek site in British Columbia ... By visually integrating spatial data concerning the distribution of artifacts [sic] across the pithouse floor, the researchers were able to test ideas about the location of domestic activity areas in relation to ambient sun light inside the structure.

While there can be little doubt of the value of virtual reconstructions in architectural research, instances of applying these techniques to their full potential are unfortunately somewhat rare. As we shall be discussing in due course, many researchers are driven by the need to impress funding bodies and purse-holders who might not necessarily be convinced of the value of a detailed research project, allied with the need to persuade them that the process can deliver a seductive, exciting and profitable product (Boland and Johnson 1996:230). As a result, the objective is often extreme realism, sometimes at the expense of accuracy. That this need not necessarily be so is emphasised by Kantner (2000):

> The modeling of prehistoric architecture to address research questions is obviously concerned with the faithful replication of the archaeological record. Since the goal is to address questions about the past reality, achieving a completely realistic view of the architecture is not important. It may not be important for the walls to be covered with realistic textures or for artifacts to be placed on the floor. Exactly what is modeled will be

determined more by the research agenda than by the goal of creating a detailed representation of the past.

3.3.2 Pedagogy

Virtual reconstructions can be profitably used as educational tools in architecture and archaeology. However, the emphasis of a pedagogical reconstruction is fundamentally different from one used as a vehicle for research, in that it is expected to be a complete and realistic representation of the subject. This may not always be feasible given the quality of the archaeological and documentary evidence, which in turn may necessitate a series of conjectural leaps that obscure the factual basis of the reconstruction. As Kantner (2000) points out:

> For example, if no organic remains were identified during excavations, should baskets or wooden bowls be put in the 3D reconstruction? If they are not there, then students may be led to believe that such objects were never used by the prehistoric society in question. The essential problem is that if the model is a perfect recreation of the archaeological record, the result may be an austere representation that can mislead students into thinking that the structure was devoid of household goods. A similar but perhaps even more important problem is whether or not people should be included in a model, for their absence dehumanizes the representation of prehistory.

By using fully detailed virtual reconstructions as a pedagogical tool the educator runs the risk of undermining the imaginative and interpretative skills of the students, leaving them unable to visualise what a structure may have looked like based on archaeological and documentary evidence. As a solution to developing a dependence on being spoon-fed in this way, Kantner (2002) recommends that ready-made virtual reconstructions be used only at the more advanced stages of the students' education At the earlier stages, he considers it more profitable to have the students create their own reconstructions, using raw archaeological and documentary sources (preferably

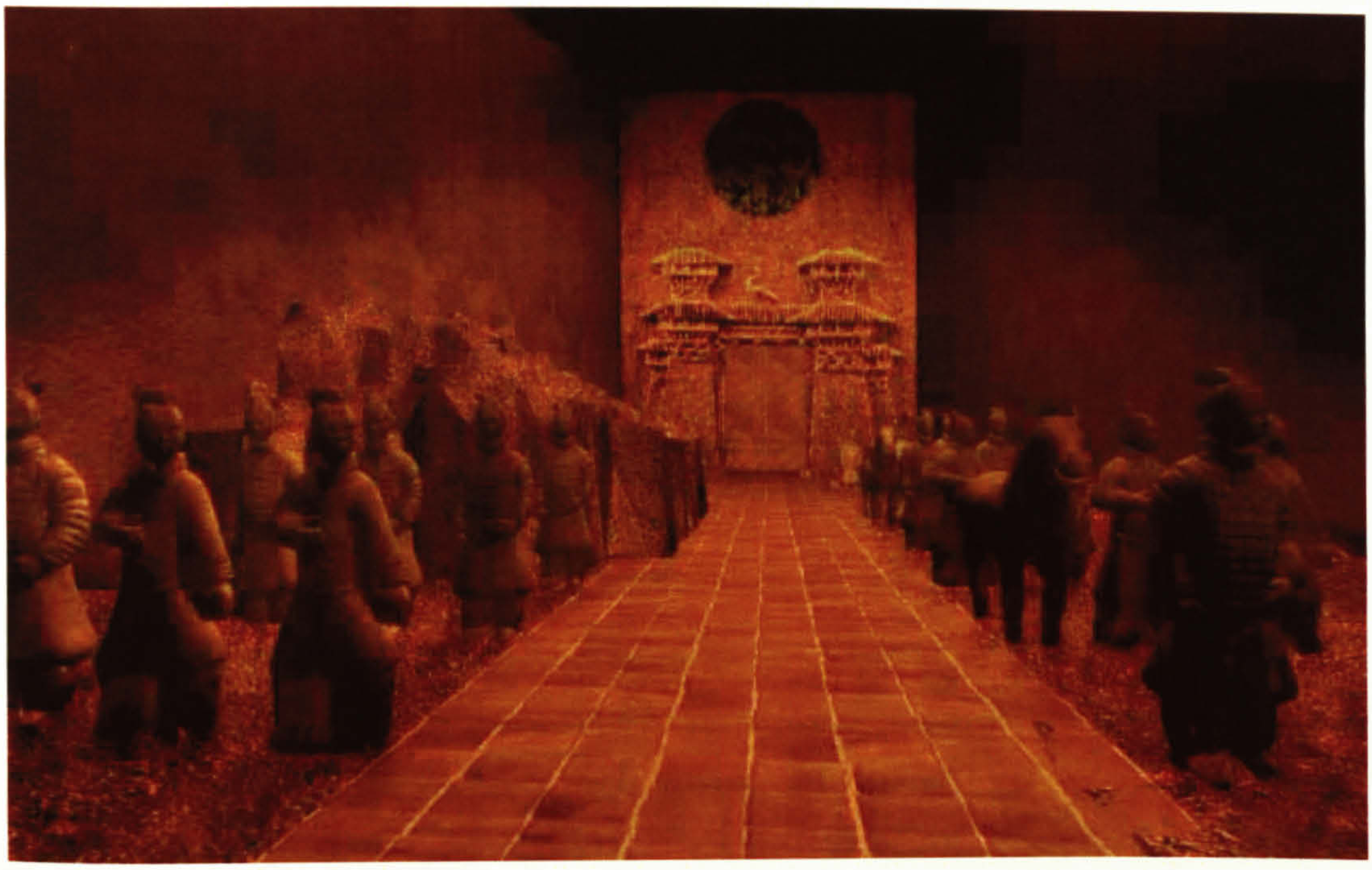


Fig. 3.4 Screenshot from *Qin: Tomb of the Middle Kingdom*
(from Interview with Luyen Chou, undated)

as multiple interpretation scenarios), with the aim of developing the required skills to bridge the gap between the physical remains and the virtual reconstruction.

3.3.3 Public Entertainment

Virtual reconstructions are perhaps most often created for the entertainment and casual education of the general public, and indeed it is in this role that they are most profitable in purely economic terms. Computer games are well known for incorporating all manner of recreations of historic buildings and environments, some utterly fanciful, others somewhat more plausible. Kantner (2000) points out as an example the models presented in the game *Qin: Tomb of the Middle Kingdom*, which are reconstructed based on archaeological reality although with a significant number of unsupportable interpretative leaps (Fig. 3.4). A similar situation can be found in the reconstructions shown in television programmes on popular history, motion pictures with historical subjects, and to a certain extent, in the multimedia presentations used in museums and visitor centres. Although the ultimate value of this approach as a vehicle for disseminating objective and balanced information is debatable, it is nevertheless necessary to recognise the value of these entertainment-oriented models as a launching pad for young people to develop an interest in historic architecture, an interest that can be pursued through a more rigorous study in later life.

A cursory examination of the Internet inevitably throws up a plethora of virtual reconstructions of historic architecture, most of which are of limited value as serious information sources. Many of these reconstructions appear to have been developed with research or pedagogical aims, and subsequently placed on the Internet, usually without significant explanatory information, and with the apparent goal of impressing the casual web-surfer. There is generally no mention of the credentials of the person or body presenting the reconstruction, no identification of sources and no attempt to put forward alternative interpretations. This is perhaps indicative of the way in which web-based information is commonly viewed among academics and researchers: a sort of inferior alternative to traditional paper-based methods of information dissemination. In fact, Kanter (2000) argues that "architectural reconstructions presented on the Internet have the most potential to be both misrepresented and misinterpreted since so many people with a wide variety of backgrounds both produce the online materials and view the resulting models." This does not negate the fact that the Internet represents a method of publishing information on a global scale virtually instantaneously, and it would indeed be a pity if it were to be dismissed by academics and other serious researchers as simply a source of unreliable information.

3.4 Objectivity in Computer-Generated Imagery

Although some of the arguments for the use of computer-generated architectural reconstructions are evident, there has been a tendency to view the underlying tools and methodologies in a fairly uncritical light. That this is not restricted to the layman is attested to by the fact that a large proportion of academic papers in the discipline are in effect straightforward descriptions of experiments in using computer-generated imagery, with little or no interest in formulating a rigorous evaluation of the tools being used. The advantages of computer-aided visualisation tools are made out to be apparent, while giving the impression that any failings they might have are so slight as to be negligible. This is perhaps symptomatic of the way in which information technology is perceived in the popular imagination: as an unquestioned technological advance over the pre-digital age. Any attempt to criticise this point of view is usually brushed off as reactionary Ludditism. It is, however, essential to recognise some of the implications of using computer-aided tools in architecture, and one of the most fundamental is the way in which computer-generated photorealistic images often imbue their subject with an air of objectivity and authority that is absent from manually produced images.

Even a decade ago, it was observed that the main impetus for creating reconstructions of the built heritage "has not been the search for improved techniques for discovering new knowledge but rather for improved ways for presenting existing knowledge to the public" (Miller and Richards 1995:19). The reconstructions were generally of buildings that had already been fully excavated and documented using other means, but which were in such a poor physical condition that the visitor or casual inquirer had difficulty in visualising any coherent structure. The use of Classical or Romanesque buildings as the subject matter of many visualisations is not purely co-incidental, according to Miller and Richards (1995:20): the underlying architectural principles and formulae of a Classical building are well understood, and it is usually not difficult make an accurate guess at the complete appearance of such a structure from incomplete remains. Thus, the architect or archaeologist tends to form a clear impression of what the building looked like before constructing the computer model; the development of the model does not come up with any additional knowledge of the building.

Whereas a traditional painter of historical subject matter like Alan Sorrell would attempt to conceal uncertain or fudged areas using such artistic devices such as wisps of smoke, with the modern computer reconstruction "the question marks and qualifications of the excavation report are reduced to the clinical fixed measurements of the architectural plan" (Miller and Richards 1995:20). In addition, computer-generated reconstructions have an air of objectivity about them, especially to the casual observer brought up on the myths of computerised efficiency and infallibility – in other words, the 'if the computer says it, it must be right' perception of information technology. The presentation of the past as 'known and knowable' and the reluctance to publish or display multiple-interpretation scenarios are cited by several authors as significant dangers inherent in the computer-generated image; in effect, the public is being fed a view of the past that is divorced from the underlying academic discussion. Indeed, Ryan (1996:95), documenting the virtual reconstruction of a Roman building for Canterbury Museums, admits as much in saying that "the display shows a sequence of views of a single model of a multi-phase building and omits much of the archaeological complexity and the uncertainty inherent in the interpretation of a structure from incomplete remains."

Although it is tempting to believe that academics would wish to emphasise that the past can be interpreted in numerous ways, and that we can rarely if ever know anything as absolute fact, Earl and Wheatley (2002:6) are of the opinion that even most academics view the computer as nothing more than a glorified presentation tool that can be conveniently used to add a spurious authority to previously framed conclusions. They criticise the case studies presented in *Virtual Archaeology* (Forte and Silliotti 1997), a high profile publication on the subject, as exemplifying the 'computer-as-panacea' approach. All the reconstructions in the book are put forward in a visually alluring but uncritical and positivist manner, as single interpretation scenarios with no attempt to highlight any alternative possibilities. The underlying theme of the publication seems to be the wish to prove that computer-generated imagery offers a valuable and attractive illustration tool. In fact the authors of *Virtual Archaeology* go so far as to claim that computers make it possible to "do it in a logical and structured and more fruitful way" (Forte and Silliotti 1997:7), implying that using computer-aided tools enables the architect or archaeologist to circumvent the interpretative problems inherent in developing a reconstruction. This is patently incorrect, and the fact that the book is aimed at the general public and not at an academic readership does nothing to do away with the popular myth of computer-generated infallibility.

It is evident that the ability to visualise levels of probability instead of absolute certainty is indispensable in the study of any type of historic artefact, and Miller and Richards (1995:20) suggest that the cause of this problem may lie to certain extent in the fact that most, if not all, visualisation software packages have traditionally not had adequate capabilities to portray uncertainty or fuzzy data in a coherent way. If a reconstruction is to be truly accurate, the need is not to create a single authoritative representation but a series of representations showing different scenarios, and in the case of detailed research, this is more important than the appearance of the image. In other words, "as disseminators of information to a data-naïve public, we must find techniques for displaying areas of fudged data within our models, and attempt to educate people in the skills of visual data analysis: an awareness of scale, and understanding of the fact that lines ... often represent fuzzy boundaries, and a perception of the limitations inherent in our data" (Miller and Richards 1995:20). However, as Ryan (1996:95) points out, computer models in fact offer far greater potential for illustrating uncertainty and multiple interpretations than do physical scale models, which have a long history of use in museums.

The increased use of computer models in built heritage visualisation is due to a number of inter-related factors (Miller and Richards 1995:20). Most importantly, perhaps, there has been a massive growth in the heritage industry in Great Britain over the last few decades, so much so that many monuments, irrespective of their real relevance, have attached visitor centres or museums equipped with all manner of alluring images and reconstructions. Needless to say, there is an added impetus to attract a fee-paying public to these sites, and attractive computer graphics are one way of achieving this goal. In addition, as commissioning computer models is often a cheaper option than hiring a draughtsman or traditional model-maker, they are all the more tempting to the commercially-minded built heritage custodian. That this is a self-perpetuating cycle is obvious when considering the fact that the modern visitor is highly demanding with respect to entertainment and visual excitement than was his pre-digital era counterpart; accustomed to thrilling graphics on the television and the cinema screen, he expects to be offered a similar standard of easily-digestible entertainment at the heritage site as well. This becomes all the more important if the original structure is in such a poor state that it cannot be easily visualised by the layman.

The situation is complicated somewhat by the fact that many historic buildings have political or nationalistic implications, two areas of human activity which in general do not have any scope for uncertainty or fuzziness. The recreation of a mythical and glorious past has long been a tactic of nationalistic demagogues intent on hoodwinking a gullible public, and it is a cause for concern that many notable virtual reconstructions have been carried out in the context of larger politico-nationalistic agendas that have little in common with detailed architectural or archaeological research. For example, Collins et al (1995:19-24) describe the German project to rebuild the baroque Frauenkirche in Dresden, destroyed by the firestorms that swept through the city after the air raids of 1945 (this project, carried out by IBM, is also mentioned by Bertol (1997:131) in her review of the Bath Virtual Heritage Conference of 1995). In order to raise funds for rebuilding the church which had become an icon of national unity and pride, a computer-generated virtual tour of the structure, portrayed in its former glory, was made. Indeed, it is significant that all the principal personnel involved in this project were computer scientists, and as a result, their account of it reads more like an extended advertisement for computer equipment than a serious academic paper. It is not difficult to see that the ultimate goal of this sort of effort is simply to manipulate the emotions of the audience, to prop up fragile communal identities and to gain corporate credibility, and it is therefore just as well to bear in mind the caveat propounded by Miller and Richards (1995:21), that computer graphics should carry a health warning, especially when the target audience is the general public, and when the main aim of the reconstruction is to elicit responses such as awe and wonder from the viewer.

4

Data Sources

A fundamental step in any architectural reconstruction project is to identify and obtain the information on which the virtual model is to be based. In fact, it is not too much of an exaggeration to say that any reconstruction is ultimately only as good as its source. After all, a reconstruction model is nothing more than a fairly complex illustration of a hypothetical state of affairs based on a series of known facts, and the more accurate and dependable these facts, the more plausible the hypothesis is likely to be. In any form of historical inquiry it is important to recognise that sources are usually incomplete or indeed biased towards specific points of view; thus, access to a wider range of sources will facilitate a more thorough interpretation and, consequently, the construction of a more balanced hypothetical scenario. This issue is described by Evans (2000:104) in his book *In Defence of History* as follows:

> The language of historical documents is never transparent, and historians have long been aware that they cannot simply gaze through it to the historical reality behind. Historians know, historians have always known, that we can only see the past 'through a glass darkly'. It did not take the advent of postmodernism to point this out. What postmodernism has done is to push such familiar arguments about the transparency or opacity of historical texts and sources out to a set of binary opposites and polarized extremes.

Although Evans is here discussing sources with respect to standard historical research, much of what he says is relevant to architectural research as well, especially as far as the fundamentally biased nature of historical sources is concerned. After all, it does not take much analysis to see that all sources were created for specific purposes by fallible human beings dealing with the concerns of their own times and societies, with the ensuing likelihood of error, fallacy and exaggeration. We have discussed at some length the idea of multiple interpretations and the concept of an objectively unknowable past at some length in Chapter 1, and it is perhaps now a logical point to discuss the types of sources that are available to the researcher carrying out a virtual reconstruction, along with the ways in which these sources may be approached if they are to be used to their fullest potential.

4.1 Primary and Secondary Sources

In traditional historiography, sources are commonly divided into two types (Evans 2000:18):

- Primary sources: based on first hand accounts and portrayals by individuals who were present at or participated in the events which are being described
- Secondary sources: descriptions and illustrations that originate in a time removed from that of the original events.

An example of a primary source with relation to, say, the Spanish Civil War, would be a document written by a participant in that war for a specific purpose related to the war, and not necessarily as an analytical account of the event – a military despatch, say. Secondary sources would be the many books that have been written since the end of the war by individuals who may or may not be intimately connected with the events they are describing, but which in turn depend on primary sources for their own material – for example, accounts such as George Orwell's *Homage to Catalonia* (1938), which describes his experiences as a militiaman in the Republican forces. The fundamental difference between these is that a secondary source is effectively an interpretation, and sometimes a distillation, of a series of primary sources, and by consequence, is more likely to be impartial and balanced, although this is not always the case (Evans 2000:48). Indeed, James Boswell (1955 [1785]:88) quotes Dr. Samuel Johnson, the 18th century lexicographer and savant, as remarking, "how seldom descriptions correspond with realities; and the reason is, that people do not write them till some time after, and then their imagination has added circumstances." A primary source, on the other hand, due to its immediate connection with the events being recounted, has a higher likelihood of bias. This characteristic is admitted by Orwell (1938:227) with respect to his account of the Spanish Civil War as follows:

> I have tried to write objectively about the Barcelona fighting, though, obviously, no one can be completely objective on a question of this kind. One is practically obliged to take sides, and it must be clear enough which side I am on. Again I must inevitably have made mistakes of fact, not only here but in other parts of this narrative. It is very difficult to write accurately about the Spanish war, because of the lack of any non-propagandist documents. I warn everyone against my bias, and I warn everyone against my mistakes. Still I have done my best to be honest.

Indeed, a recent tendency among historians of a more post-modern persuasion has been to deny the essential difference between primary and secondary sources, an attitude that is flatly refuted by Evans (2000:126) in the following terms:

> The distinction between primary and secondary sources on the whole has survived the withering theoretical hail rained down upon it by the postmodernists. The past does speak through its sources, and is recognisable through them. There is a qualitative difference between documents written in the past, by living people, for their own purposes, and interpretations advanced about the past by historians living at a later date.

Although we have highlighted the greater likelihood of bias with respect to primary sources, it is nevertheless important to recognise that all historical sources are biased in some way or another. For example, the architectural historian who decides to illustrate a historic building for a monograph invariably concentrates on a certain portion of the building in an attempt to highlight his or own perceptions of what is important and what is not. To give a rather more theoretical example, we may look at the original edition of David Watkin's *History of Western Architecture* (1986), which devoted an inordinate amount of space to the so-called modern Classicism of that decade. This phenomenon was either utterly ignored or viewed with derision by other architectural writers, for many of whom it represented a rather inconvenient retrogression in what they perceived to be the inexorable march of architecture from the primitive hut to Modernism. It is therefore incumbent upon researchers using historical sources not to accept sources at face value, but rather to be cognisant of the fact that all information is produced for a specific end.

History, as it is commonly perceived, is mainly interested in events, and consequently the main source of information is the documented narrative; other sources include, for example, imagery and artefacts. Architectural history is rather different from most other types of historical research in that the focus of study is the artefact itself (i.e. buildings) and not necessarily the event, and thus the narrative is not usually of fundamental importance as a source of information. It is thus convenient for our purposes to realign the definitions of primary and secondary sources. The primary source thus becomes the building itself, or where it is has decayed, its remains, both in terms of original fabric and historical accretions. This type of information is usually obtained by means of architectural and archaeological surveys. The secondary sources are the imagery and narratives dealing with the building in question; this could include historical photographs, previous survey drawings and architect's contractual documents. It will be seen that, in this method of analysis, the primary source is what exists in terms of physical material, and is thus completely objective. After all, a building is essentially what it is; subjectivity enters the picture only with the observer's interpretations what is perceived and in the way in which he or she records these perceptions. Jalmain (1990:155) comments, with specific reference to aerial photography but with equal relevance to all types of physical surveying, that photographs are testimony of 'real' facts, and are certainly more accurate than most commentaries and texts which often tend to be hagiographical in nature. Thus, for the purposes that we are dealing with, bias only becomes an issue where secondary sources are concerned, that is to say, where we are dealing with pre-interpreted material.

The fundamental aim of data collection is to gather a mutually consistent body of information that graphically describes the structure that is being reconstructed. As we are dealing with the virtual reconstruction of buildings, it is also important to raise the issue of how to obtain source data on a building of which no vestiges remain. In such cases, researchers are often restricted to using historical textual descriptions and images. These types of sources pose significant problems of their own; for instance, in addition to the question of intentional bias as pointed out above, there could also be issues of meaning and whether the source was ever meant to be taken at face value in the first place. Comparison with existing buildings of the same type may also provide clues, but the point is, that unless there is an accurate source of measurable data, such reconstructions are likely to remain conjectural at best. Indeed, as Terlingen and Engelbregt (1996:41) point out, it is possible to view the entire reconstruction modelling process as a means of testing the accuracy and consistency of the original sources.

4.2 Surveying Methodologies

The main way in which primary information on a historic building is obtained is by carrying out archaeological surveys. It is evident that this course of action is only applicable to buildings where at least some vestiges remain – where the building has disappeared in its entirety, there will obviously be no archaeological remains to record. The goal of this process is purely to identify and measure what remains of the original structure, not to hypothesise what the original appearance may have been and what it should be in the future; these are both issues that become relevant in the later stages of the reconstruction project (Fitch 1998:312). Historically, all archaeological surveys were carried out by hand, using such equipment as measuring tapes, rulers, and theodolites. An integral part of such surveys is the taking of standard non-metric photographs which can be used off-site for reference. Manual surveying continues to be a practical solution where the building being recorded is very small or simple, or both (Fig. 4.1). In more complex situations, however, this technique has a number of very serious limitations. For example, a large structure cannot be measured to any significant level of detail without erecting scaffolding and employing an army of on-site operatives, a rather laborious process that is not only extremely time-intensive, but also contains significant scope for error in measurement and recording. The development of optical and computer-aided

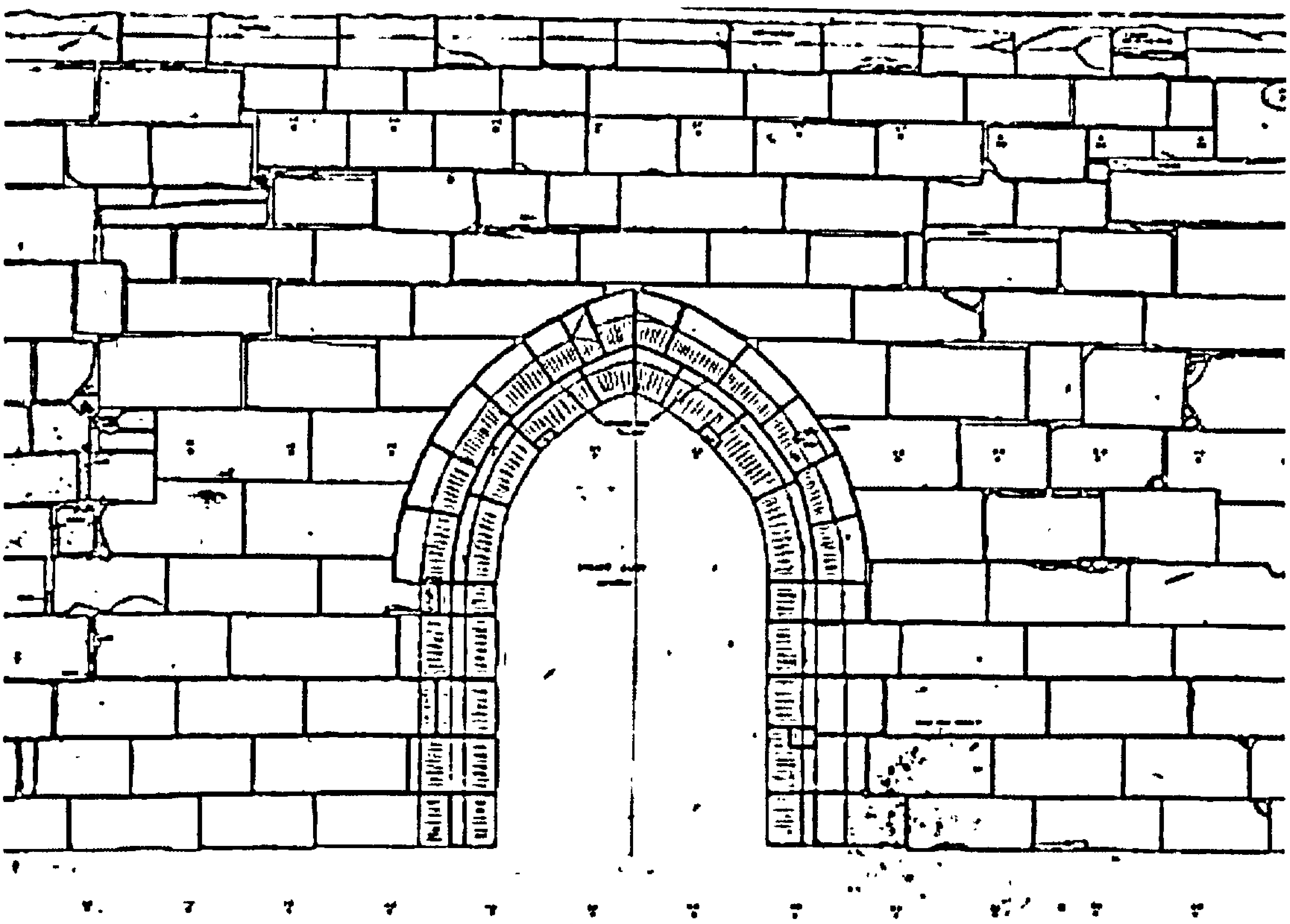


Fig. 4.1 Hand-drawn survey of Rosslyn Chapel (courtesy of Tom Addyman)

surveying techniques has increased the number of available options, and also contributed to making the entire process of historic building recording more economical and reliable. There are a number of different principles at work here, the most important of which will be discussed in further detail below. These various methodologies can be classified into to broad types: *close range techniques*, where the operator is in relative proximity to the object being measured (these include geodetic and photographic surveying techniques), and *remotely sensed* or *remotely captured techniques*, where there is a significant distance between the operator and the object, such as satellite and aerial images (Brenner 1999:24).

4.2.1 Geodetic Surveying

Geodetic surveying involves the close-range recording of a building or site using such tools as total stations, laser rangefinders and, more recently, 3D scanners. The important issue here that differentiates it from other methodologies is that the

Fig. 4.2 A total station (from Leica Geosystems 2005)

surveyor is potentially in contact with the object being measured, and he or she has to make on the spot decisions as to what to record and what to leave out. Another point in common is that many of these tools operate on the 'time of flight' principle, using electromagnetic or laser beams to ascertain distances. The majority of these instruments were originally developed for land surveying and military rangefinding, and have since been adapted for built heritage applications. We will have a closer look at some of the more common of these devices in this section.

One of the most commonly seen tools in computer-aided surveying is the total station, which has a fairly long and well documented history of use in archaeological and architectural surveying (Eiteljorg 1998; Eiteljorg 1994). A total station is fundamentally an electronic device that consists of three elements: a telescopic sighting device used to aim at the target (usually a prismatic reflector), sensors to determine the vertical and horizontal orientations of the sighting device, and finally, an electronic distance meter (EDM) (Fig. 4.2). The distance between the sight and the target is ascertained using an infra-red signal, effectively by timing the gap between firing the signal and receiving its reflection. In addition, most total stations include some form of computer-based data collecting device (Kammermans, Verbruggen et al 1995:127).

The main advantage of total stations over manual surveying is that the entire surveying process is carried out electronically, with no need for translation between paper-based and digital formats. Although data collectors do not typically store information in CAD-ready formats, it is possible to use an intermediate programme to carry out the necessary formatting. It is also possible to collate the data using a spreadsheet programme, which can then be automatically transferred into a CAD package (Eiteljorg 2000). Accuracy levels of total stations are extremely high, usually in the range of several millimetres.

Having said that, total stations do not necessarily automate the recording process itself, as the operator must still make decisions as to what to record. This is explained by Vranich (2002:84) as follows:

> Like any form of data collection, the measurements taken need to be selective and pertinent to the research questions being asked. A common misconception is that the more measurements one takes the better or more accurate the results will be back in the lab. For example, though a single rectilinear stone can be measured with hundreds of points showing every facet and divot of its surfaces, unless one is interested in the specific nature of the stone, it is much more useful to simply record the 8 points that represent its corners and provide its basic form, location, orientation and inclination.

It should also be noted that total station surveys are not inherently geo-referenced, and so, if Ordnance Survey (OSGB36) or World Geodetic Survey (WGS-84) referencing is required, this must be done separately.

Laser rangefinders operate on a similar principle to total stations, but differ in that a laser is used instead of an infra-red signal to determine distances. They are a fairly new development in heritage surveying (although they have a fairly long history of use in military applications), and therefore do not have the same level of tested reliability as total stations. The level of accuracy (±1m) is also much lower than that generally available with total stations. Laser rangefinding has the advantage of requiring only a single operator, and consequently is capable of higher survey speeds. In this respect, this technique works best in reconnaissance situations rather than those where highly detailed surveys are called for (Barrat, Bullas et al 1999).

Another fairly recent development in built heritage recording involves the use of global positioning systems (GPS). This technology is dependent on the use of third-party satellites (such as the US Department of Defense navigational satellites), which constantly transmit radio signals. A ground-based GPS system triangulates between the signals transmitted from a number of satellites, usually four, to obtain a fairly precise geo-referenced location. Basic GPS systems are accurate to within 50 to 100m due to the deliberate introduction of an error component in the Department of Defense satellite signals (Ryan 1999:271), and are thus of little use in architectural recording. However, the use of Differential GPS, which records data with reference to a fixed receiving station, enables the measurement of details of up to a few centimetres apart. In this case, the data is gathered by the operator in the form of a 'kinematic chain', following his or her movements on a hand-held data logger; the data can then be downloaded onto a computer and processed using specialised software to obtain information corresponding to latitude/longitude or Cartesian co-ordinates. The fact that data is recorded as a continuous chain of points facilitates the construction of digital elevation models (DEMs). Although GPS systems tend not to function properly in heavily wooded or built up areas where the satellite signals meet with interference, they are particularly suitable for use in open terrain, and have been used with much success in recording ancient earthworks on Exmoor (Riley

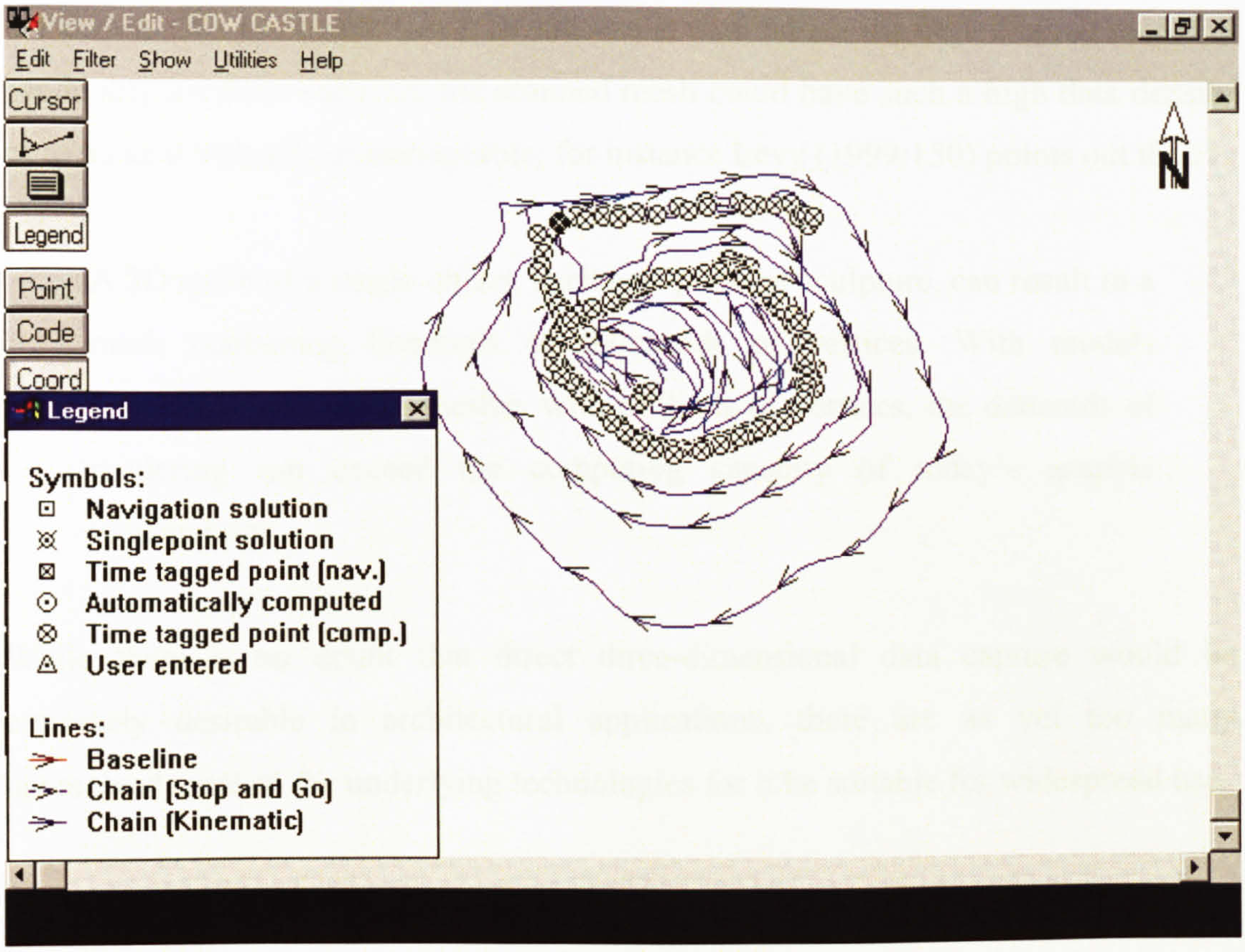


Fig. 4.3 GPS survey of Cow Castle, Exmoor (from Riley 1999)

1999:189-194) (Fig. 4.3).

The use of three-dimensional scanning devices in archaeology is also very much in its infancy, although experiments having been taking place since the 1990s. The technologies themselves have tended to be adaptations from other areas of research and industry. The majority of scanning devices work on the principals of active or passive stereometry, using lasers to scan the surface of an object to obtain a three-dimensional description, although Forte, Tilia et al (2001:28) document the use of a different system, one based on tactile surface scanning, to record the walls of the Vatican Necropolis. Avern (2001:5-6) tested several three-dimensional scanning systems, and found that none of them was particularly suitable for large scale built heritage recording. Some systems were discovered to be restricted in their fields of vision and were thus more suited to artefact scanning, while those systems that were capable of scanning larger areas were generally so unwieldy as to be impractical to use on site. An additional factor of concern is that, where the object being recorded has highly irregular surfaces, the scanned mesh could have such a high data density as to make it virtually unmanageable; for instance Levy (1999:150) points out that:

> A 3D mesh of a single object, such as a piece of sculpture, can result in a mesh containing hundreds of thousands of vertices. With models potentially containing meshes with millions of vertices, the demands of rendering can exceed the computing capacity of today's graphic workstations.

While there is no doubt that direct three-dimensional data capture would be extremely desirable in architectural applications, there are as yet too many unresolved areas in the underlying technologies for it be suitable for widespread use.

4.2.2 Photographic Surveying

The use of photographs as sources of survey information dates back to the very invention of the technique in the early decades of the 19th century. Photographs have a distinct advantage over drawings in the sense that they are non-selective in what they record, and it goes without saying that taking a photograph is a much less time-consuming process than making a drawing. Standard photographs are limited in their usefulness in heritage applications by the fact that they invariably contain perspective distortions, and are thus unsuitable as sources of dimensional data. A number of techniques have been developed to address this problem.

Photogrammetry in its basic form is a surveying technique that involves using non-standard metric cameras to produce a set of stereoscopic pairs of photographs (stereopairs), which are then processed using a special stereoplotter to produce a true-to-scale representation, or stereomodel. The origins of this technique lie in the 1860s, when Albrecht Meydenbauer started carrying out experiments in metric photography (Dallas 1993:3). Until the 1950s all stereoplotters operated on optical/mechanical principles directly from the original stereo photographs, and were only usable by operators with extensive training and experience. This, allied with the expense of the machines themselves, meant that photogrammetry was only viable in the very largest of surveying projects. These analog stereoplotters were gradually replaced by analytical stereoplotters, which interfaced the mechanical component of the machine with a computer that could recognise and interpret the co-ordinate system of the stereomodel. These later machines were on the whole cheaper and easier to operate than the analog stereoplotters, and as a consequence, a range of new applications, including building surveying, were opened up. Having said that, analytical photogrammetry is not wholly computer based: the stereoplotters still work directly from the original hardcopy images, thus placing a limit to the level of image manipulation that can be carried out. An early example of the very effective use of photogrammetry was the survey of the temple of Abu Simbel in Lower Egypt launched by UNESCO in the early 1960s, with the aim of recording the structure in as complete a way as possible before physically dismantling the temple and moving it to a new site (Forte and Silliotti 1997:67-69) (Fig. 4.4).

The most recent stage in the evolution of photogrammetry is represented by softcopy

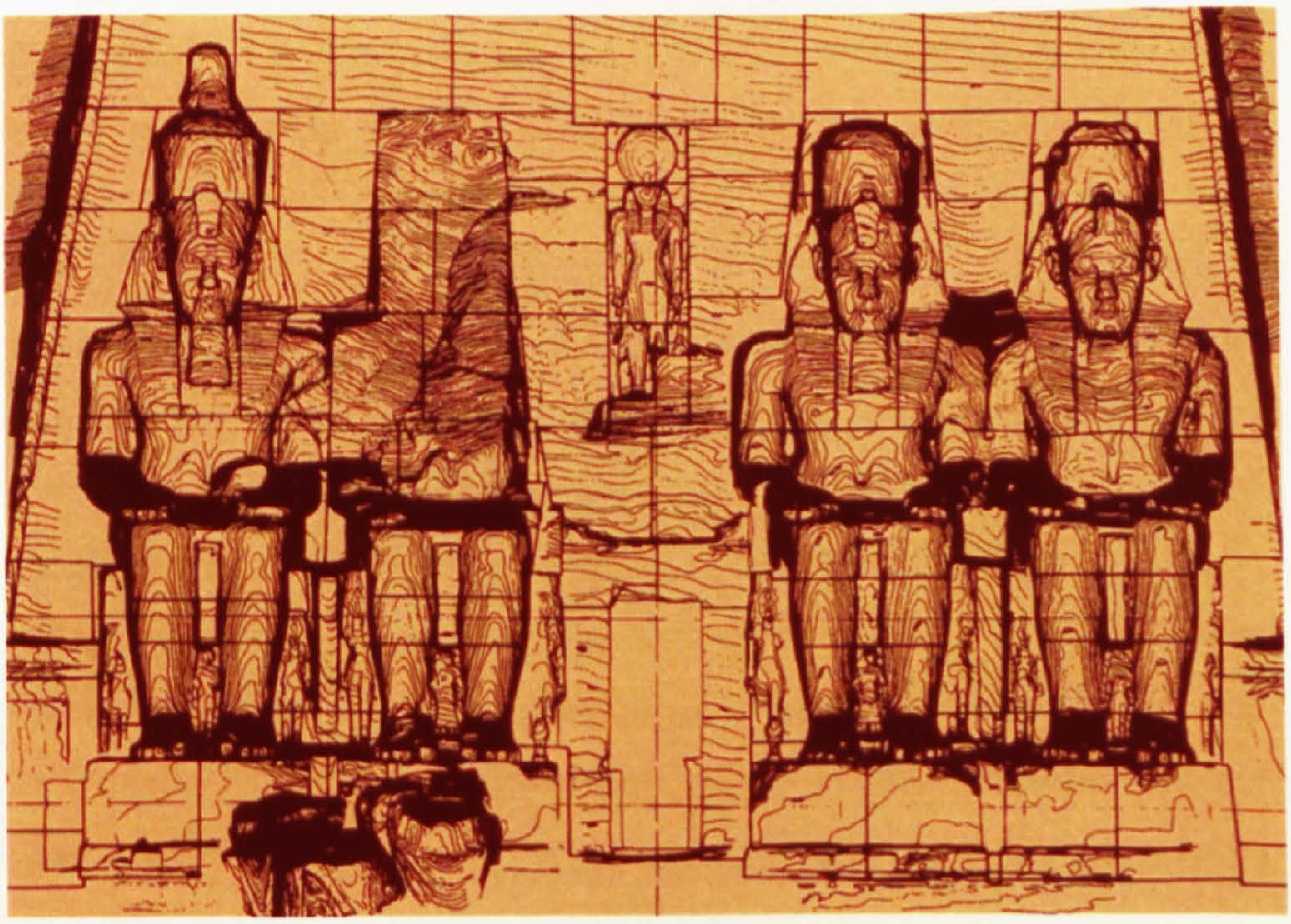


Fig. 4.4 Photogrammetric survey drawing of Abu Simbel temple (from Forte and Silliotti 1997)

photogrammetry. In contrast to analog and analytical photogrammetry, the entire plotting process is computerised, and the operator sits, not at a mechanical plotter, but at a graphics workstation equipped with specialised photogrammetric software. All the work is done from digital images and not hardcopies, a characteristic that has not only increased the versatility of photogrammetry, but made it altogether more affordable and accessible (Cooper, Gisiger et al 1996:11). Streilein (1995) identifies the following characteristics of softcopy architectural photogrammetry:

- Digital image acquisition using solid state devices
- Semi-automated procedures for measurement and processing
- Early data segmentation for use with CAD systems

Binney, Brown et al (1995:237-238) describe using a survey of Pendragon Castle in Cumbria as a testbed for various surveying techniques, including hand measurement, rectified photography (described below) and photogrammetry, and come to the conclusion that photogrammetry proved not only to be most accurate and efficient methodology, but rather surprisingly, the most cost effective as well.

The fact that much of the work involved in a photogrammetric survey is actually carried out indoors and offsite is also an advantage in that long periods in the field are not required. The Comité International de Photogrammetrie Architecturale, in a monograph published by UNESCO and quoted by Fitch (1998:313), highlights this advantage in the following terms:

> Only photogrammetry allows the separation of the survey work on the site from the drawing up of the plans. (The on-site work is also achieved far more quickly and with less effort). The photogrammetric record makes a true technical record of building and sites, an archive which can be used for differing purposes and one which is always possible to refer back. These records – the establishment of which is of prime importance – completely fulfil the requirements of the Hague convention on the protection of cultural objects. They are one of the essential requirements on which to base inventories and research.

Photogrammetry is a tried and tested technology with a long history of use in built heritage applications. In many ways, it represents the most accurate, versatile and (in the broader sense) the most economical method of recording historical buildings and remains, and as a consequence, one which is rapidly becoming the standard against which other methodologies are compared.

Rectified photography, known variously as single-photo or monoscopic photogrammetry, is a simpler alternative to the stereoscopy-based methodology described above. It essentially involves the setting up of a normal non-metric camera, sometimes with a gridded viewfinder, in as parallel a plane as possible to the façade being photographed so as to minimise any perspective distortions. Although the photographs themselves do not contain dimensional information, control measurements may be taken by hand or using a total station to obtain a true-to-scale photographic representation. It should be noted, however, that a rectified photograph will always remain an approximation and are only really suitable for use with flat façades with little or no surface variation (Dallas 1993-17-18; Binney, Brown et al 1995:237). In much the same way as photogrammetry, rectified photography has also benefited from the application of computer technologies, and a number of software packages are now available to improve the rectification process. Indeed, it is even possible to use a non-specialised image manipulation programme such as PhotoShop to remove perspective distortions in images of building façades. One of the main advantages of this approach is that the camera need no longer be perfectly parallel to the façade being surveyed. That said, however, the entire principle of rectified photography is based on the idea that building planes are always perfectly flat, and is thus a critical limiting factor even with the use of digital rectification aids.

One of the newest and indeed most promising streams of work in photographic recording involves that of metric reconstruction, where unspecialised non-metric images of a building (such as standard 35mm prints) are used as a source of dimensional information. In contrast to photogrammetry and rectified photography, the majority of metric reconstruction systems operate independently of any reference to camera parameters; instead, they create a virtual 3-dimensional model of the building by identifying homologous points on the images, and using this as a basis to create an "approximate projective framework which is then progressively refined" (Avern 2001:6). The obvious benefit of metric reconstruction is that, ideally, only a digital camera and the relevant software is required to carry out a building survey. Another very real advantage is that a ruined or non-existent structure can effectively be reconstructed where there is an adequate photographic record of it.

4.2.3 Remote Sensing

Remote sensing involves the use of various detection systems to carry out surveys of historic buildings and environments at long range. These tools are typically non-invasive and non-destructive, and have the advantage of being able to survey large areas and also sites where no features can be discerned by the naked eye. Remote sensing methodologies are fundamentally different from the geodetic and photographic methods described above in that they are primarily concerned with discovery-oriented surveying, that is to say, in the identification of features that can subsequently be measured using other techniques. Indeed, the term remote-sensing is misleading in that it implies a fixed methodology, whereas the truth of the matter is that it is an umbrella term to describe a series of systems which operate on different principles. As an example, Brenner (1999:24) points out that satellite imagery has a ground resolution in the order of several meters, whereas the minimum resolution required for accurate measurement would be in the range of 20-25 cm; indeed, the commonality between most remote sensing techniques is that they operate at roughly identical resolution levels.

One of the earliest and best known examples of remote sensing is aerial photography. Although this is often understood in terms of visual imagery, electromagnetic surveying using aircraft has been in use for at least five decades (Gao 1999). Such techniques involve obtaining images in electromagnetic wavelengths outside the visible range (infra-red and radar, for example), which can then be processed to identify architectural features. For example, Liu (1999) documents the use of infra-red imagery to identify subsurface features of ancient

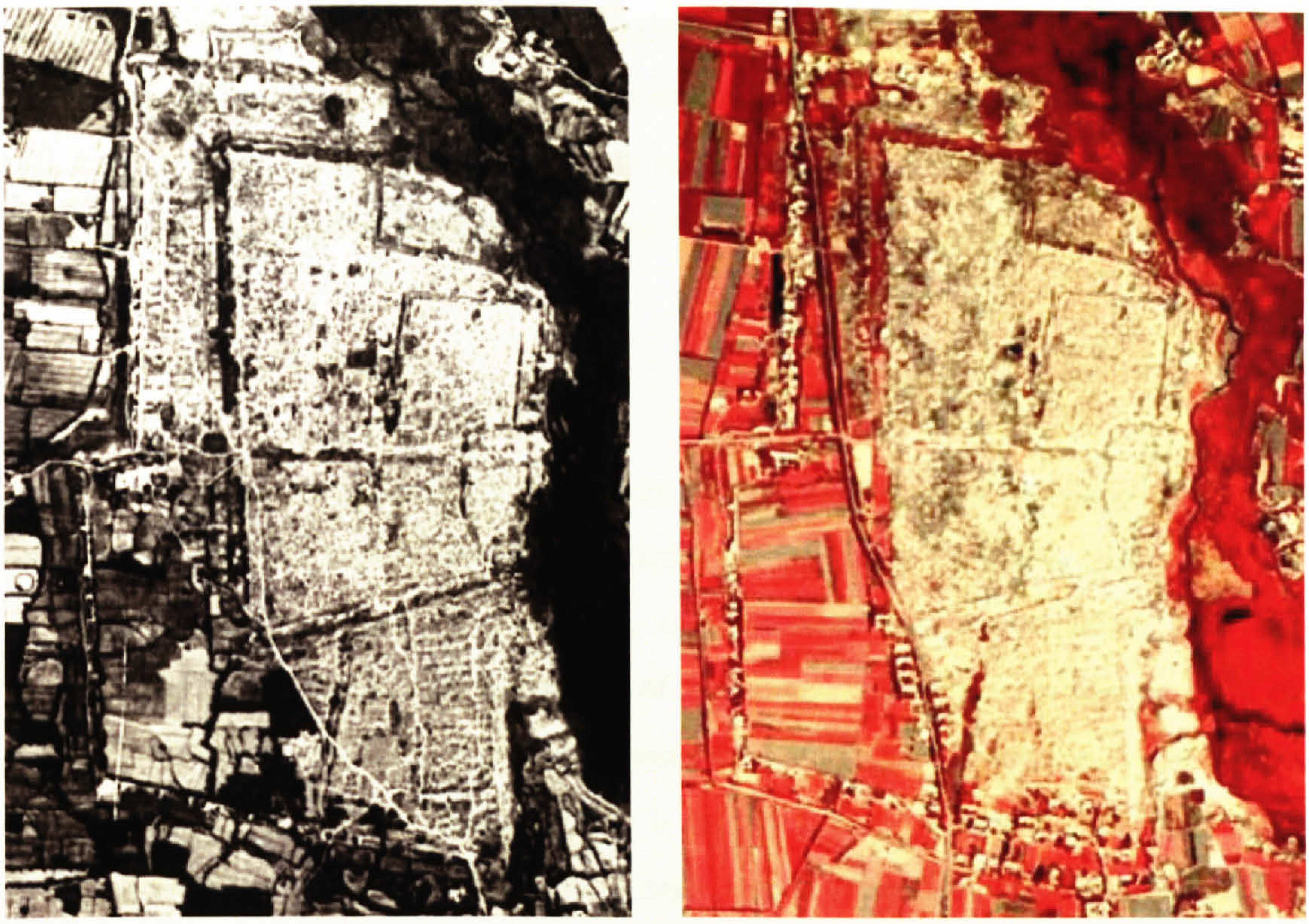


Fig. 4.5 Remote sensing used in the survey of Ancient Beiting (from Gao 1999)

Beiting in northwestern China (Fig. 4.5), and an even more spectacular result is described by Preston (2000:100), when analysis of radar imagery by NASA revealed a hitherto unknown Khmer temple hidden beneath the dense forests of northern Cambodia.

The advent of computer-aided tools has had a significant effect on the way in which remotely sensed imagery is analysed and interpreted (Aspinall and Haigh 1999). Such images usually contain far more information than a human eye can extract without assistance, and while manual/optical techniques have been around for some time to aid in this process, it is now common to see the use of digital photogrammetry and image processing techniques to exploit the source images to the full. Redfern (1999), for instance, documents a computerised system to aid in the interpretation of aerial photographs, which is capable, up to a point at least, of detecting possible edges within the photographic images and using these as a basis to identify coherent shapes. Computer-aided tools also offer the significant advantage of speed in analysis – for example, whereas it was necessary in the past to carry out the survey and subsequently analyse the results off-site, it is now possible to do both tasks more or less concurrently, with the results generated by the equipment in the field being interpreted in real-time (Becker 1990:31; Gaffney and Linford 1999).

4.3 Historical Imagery

All the recording techniques we have thus far considered involve obtaining source data at first hand. It should not be forgotten, however, that there is a vast collection of second hand sources in the form of historical images, whether they be photographs or paintings and drawings of buildings that either no longer exist or which have been substantially altered. Being ready-interpreted sources, so to speak, historic imagery must be approached in a highly critical manner, with an inquiry being made into the meaning of the image itself. Historical photographs are an especially rich source of information on the built environment of the past. The fact that a photograph by its very nature is non-selective in what it records, means that it is possible to extract information that the original photographer was unaware of recording when the image was first produced – for example, it is not unusual to be able to draw more useful information from the background of a photograph than from what was intended to be its focus. A photograph is invariably correct in terms of visual perspective, and thus, by reconstructing the pictorial space either manually or using a computer-aided system, it is theoretically possible to extract dimensional information on the objects it represents. The fundamental drawback with photographs is that they are a fairly recent invention, and thus are only of use where the subject matter dates from the mid 19th century or later. It is also notable that, until the widespread use of colour film toward the middle of the 20th century, all photographs were in black-and-white, and in consequence, contain limited information on the material qualities of any represented buildings.

4.3.1 Orthographic Projections

The most useful sort of graphical document for the creation of a virtual

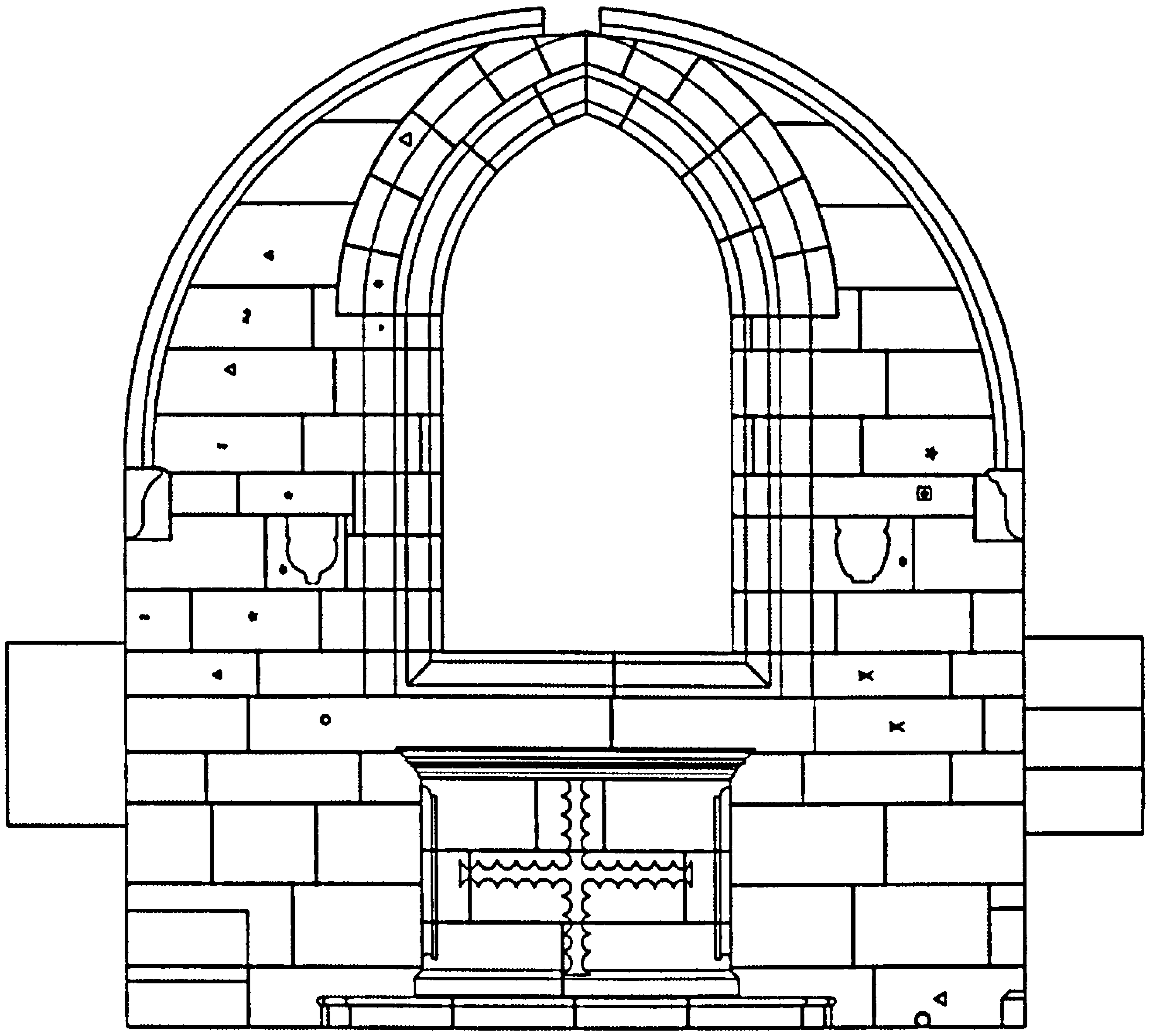


Fig. 4.6 CAD survey drawing of Rosslyn Chapel

reconstruction is the fully measured and dimensioned orthographic projection, i.e., plans, sections and elevations (Fig. 4.6). This is explained by Levy (1999:151) as follows:

> Building a model that is geometrically consistent and accurate requires at minimum a plan and elevation. Most objects demand multiple elevation views: left, right, front and back. Sections and detail drawings revealing construction techniques and architectural detail are essential for an accurate reconstruction. Different scales, format and styles of recording will make reconciling differences in actual measurement difficult. Rarely are drawings complete for every aspect of the site.

There is a vast body of such drawings to be found in monographs, survey reports and other publications, but in addition to the issues raised above, there is also the question of how to transfer what is essentially a paper-based record into a machine-readable format for use with modelling software. There are a number of ways in which this task can be accomplished. The simplest, most straightforward and also most unreliable system would involve simply scaling the published drawings to a recognised scale, such as 1:50 or 1:100, and then simply using a ruler to work out the dimensions; where the drawing is dimensioned, these figures can be directly transferred onto the model. That this approach is highly error prone need not be emphasised, nor that it would be highly impractical in the case of a large building involving multiple drawings. Having said that, there is the advantage that the original record is constantly under scrutiny, and the fact that every dimension is effectively worked out from scratch means that the researcher develops an intimate knowledge of the building under consideration. The second method of translating paper-based data into digital format involves scanning the original drawing, and then effectively tracing the scanned images using a CAD or other vector-based drawing program. Although this would at first sight appear to be more reliable than simply scaling the drawings by hand, it should be noted that scanners introduce inevitable distortions to the original images, and if such data is blindly used without any sort of critical analysis, the distortions would be transferred on to the model itself. In addition, there is the question of repeatability: as the scan is a raster image, it is impossible to 'snap' on to definite points, and consequently it is impossible to obtain identical results when the same dimension is queried a number of times. Although automated vectorising software has been available for at least a decade, in the author's experience these programs do not tend to live up to the original promise. In addition to introducing distortions, the software has no intelligence to work out which lines should meet or which shapes should be closed, a situation that leads to much time being subsequently expended in cleaning up the drawing and making it even vaguely usable. The use of a digitiser, in effect an electronic drawing board, offers the most effective way of transferring paper-based data into a CAD package. A digitiser is fundamentally co-ordinate- and vector-based and is capable of operations such as snapping and the creation of closed shapes, and thus, unlike where a scanner is used, it is possible to introduce a level of rigour to the process that would otherwise not be possible. It should be noted, however, that digitisers tend to be an expensive investment, and one which is rather specialised in its applications.

An article in CAD User Magazine entitled 'Supercharging Archaeological Data' (Anon. 2000) includes a case study of a proprietary system developed to aid in the use of existing paper-based data with CAD packages. An add-on to the popular AutoCAD drafting package, the system, known as Autodesk CAD Overlay, is described as offering a means of combining "information from a wide range of hand-drawn, printed and photographic sources in a useful and meaningful way to show the whole story of an archaeological site." The case study documents efforts made by Wessex Archaeology to produce a study of the area around Stonehenge:

> Wessex Archaeology found that the pre-existing hand-drawn archive of the site was extremely variable in terms of scale, size, detail, annotation, orientation and physical condition. More than 100 pencil-drawn imperial-scale maps dating from 1916 and 1970 were scanned, pieced together and added to a master drawing based on the English Heritage 1990 survey of the ancient stones. Inaccuracies in some of the drawings became evident when they were laid over each other. There were discrepancies in the recorded positions of trenches and stones. CAD Overlay enabled them to be adjusted to give a 'best fit'. In the course of past excavations, some of the stones had been removed or re-erected and so they appear in different positions on different plans. 'Before' and 'after' information was used to relocate these excavations accurately.

This project highlights one of the main advantages of computer-aided manipulation of paper-based data: it is possible to create multi-layered drawings, using which it is possible to identify discrepancies in the original information. In addition, the use of 'best fit' procedures as described above enables the creation of a data set with at least a certain level of internal consistency, and a holistic approach to all the available information sources is encouraged. It should be noted, however, that such computerised overlay systems are not widely used, perhaps due to a concern that such a specialised application would not justify the significant initial cost of the software, although the system described above is actually an add-on to an already popular CAD package.

4.3.2 Paintings as Information Sources

As we have seen in Chapter 2, one of the prime objectives of much of Western art in the period between roughly 1400 and 1900 was the representation of accurate and measurable space. Vast numbers of such paintings are available in museums and other collections, and many of them have been extensively studied, not only in purely art historical or architectural terms, but also as sources of information on the development of visual representation norms. In this respect, historical perspectives are somewhat similar to photographs in that they theoretically enable the extraction of dimensional information, and by doing so, enable the reconstruction of the space that is portrayed in the painting. This is an especially valuable resource where there is no other source of information on the building that is represented, and even where the painting is seen to be incomplete or erroneous, some information is clearly better than none at all. It should be noted, however, that whereas a photograph is invariably accurate in terms of the represented pictorial space, a painting might not necessarily be so, for the level of perspectival accuracy is dependent on the painter's skill and even on his or her desire to faithfully represent a measurable space. There is also no guarantee as to what the painter represented was exactly what was observed; for example, the paintings of Venice and London carried out by Antonio Canaletto in the mid 18^{th} century give the impression of being faithful representations of reality, which, in a way, they were (Fig. 4.7). In another sense however, Canaletto clearly felt at liberty employ various artistic devices to heighten the effect of his paintings, as explained by Kemp (1990:144-146):

> Canaletto's paintings and drawings bear witness to the enormous effort

of constructional precision which went into the geometrical control of foreshortened and unforeshortened elements. The compass, the divider and the ruler were essential tools for him. His greatest paintings achieve an extraordinary control over the viewer's eye ... These effects are clearly based on a rigorous scrutiny of the actual scenes ... but they are also based on a knowing measure of optical contrivance.

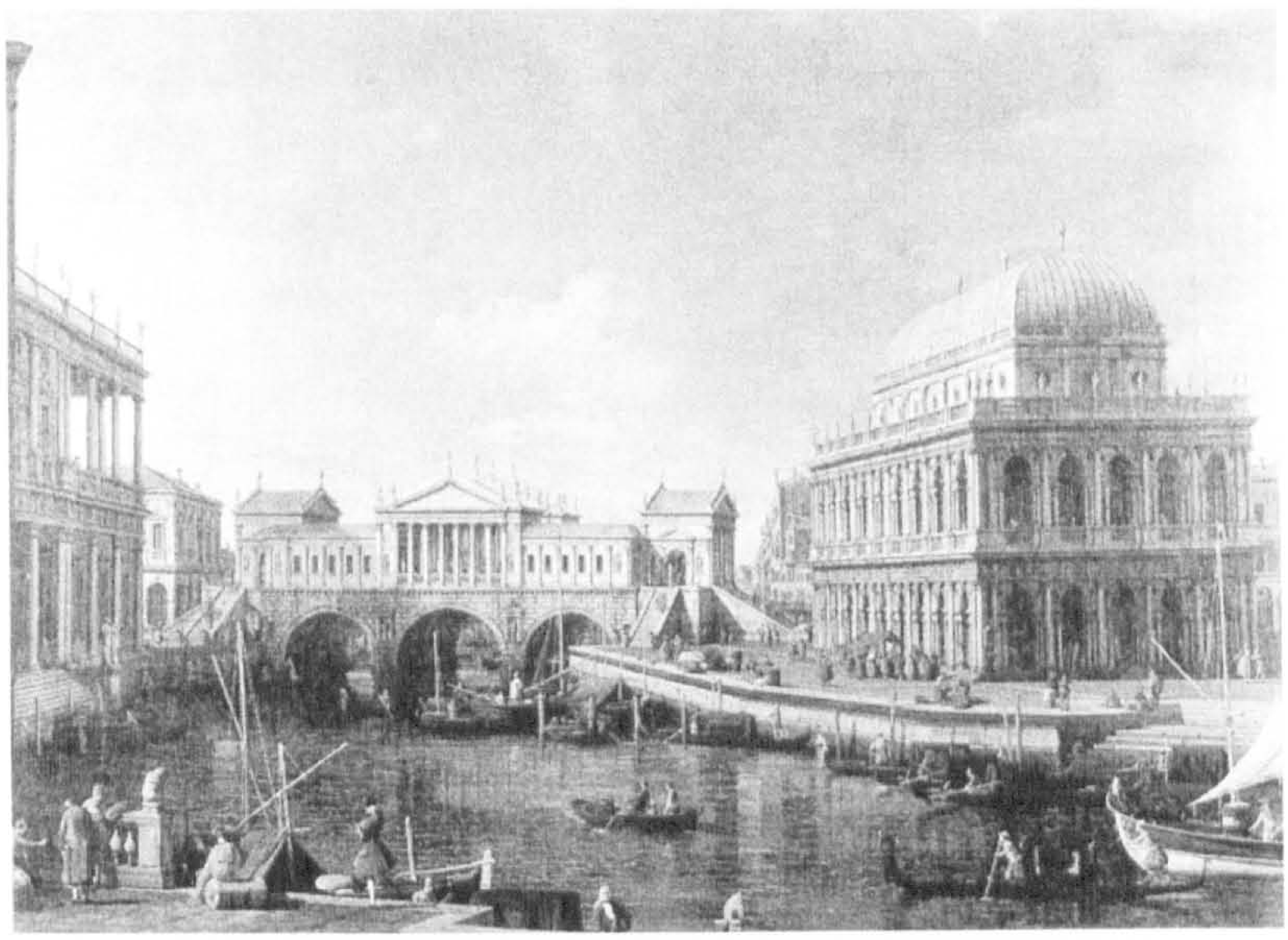


Fig. 4.7 *The Rialto, Venice, Embellished with Palladian Bridge and Palaces*, by Antonio Canaletto, 1749 (from Kemp 1990)

A further example of this sort of approach is described by De Mey (1995:159), who points out that the *Trinity* of Masaccio (Fig. 4.8), an early 15th century fresco that was "referred to for a long time as an impeccable and prototypical application of the rules of perspective", did in fact contain a number of anomalies. While De Mey explains that some of these violations of the rules of perspective seem to have been carried out with the intention of heightening the effect of the fresco, others seem to have been caused by inaccuracy or unimportance. The point being made here is that, whatever the apparent level of realism of a painted architectural representation, there is a strong likelihood of underlying perspective anomalies, either consciously introduced as in the case of Canaletto, or else due simply to ignorance, error or inattention on the part of the painter. It is thus clear that a painting cannot generally

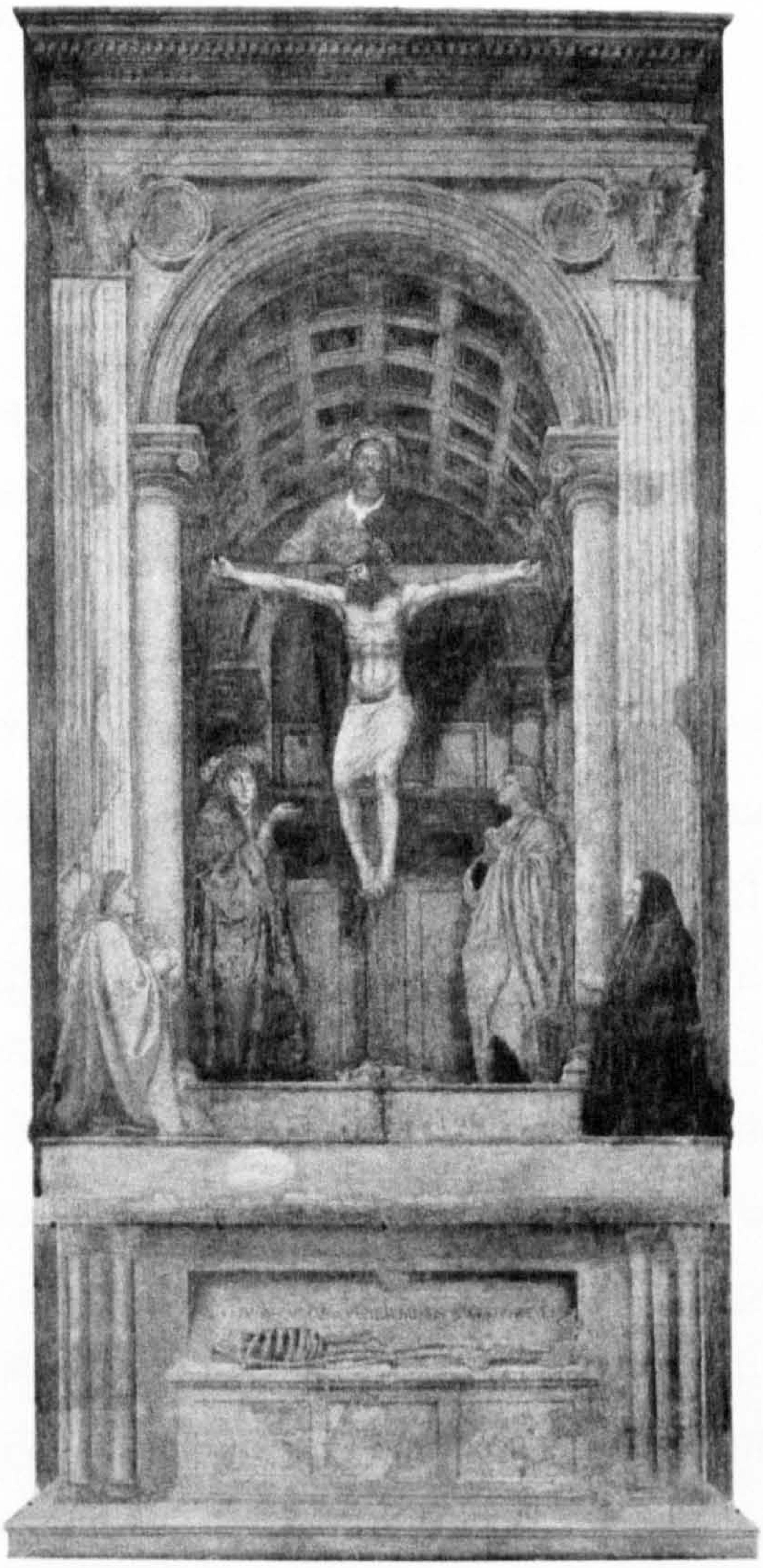


Fig. 4.8 *The Trinity*, by Masaccio, ca. 1426 (from Kemp 1990)

be taken at face value as a source of metric information for a virtual reconstruction without carrying out an analysis of the painting itself beforehand. This is a hugely laborious and indeed impractical task where large or complex scenes are involved, especially if the underlying perspective construction has been obscured; where small internal scenes are concerned, however, metric reconstruction from paintings offers an interesting method of analysing environments that were recorded in this way. Before discussing the ways in which this can be carried out, it is perhaps useful to briefly look at the underlying principles of architectural perspective.

4.3.3 The Basis of Linear Perspective

In Chapter 2 we briefly discussed the invention of linear perspective, possibly by Filippo Brunelleschi in early 15th century Florence, and its subsequent codification in 1435 by Leon Batista Alberti in *De Pictura* (White 1957:113). Using this system, it was possible for a painter to create an illusion of depth and also to precisely place objects within a measurable and mutually consistent space framed by a regular spatial grid. As Steadman (2001:73) points out:

> The painter, knowing the true three-dimensional shape of any object, figure, or building that he wanted to depict, and knowing its position on this ground surface, could derive a perspective image of the object with reference to the grid .

The fundamental step in the creation of a perspective space, then, consists of laying down this grid which will consequently dictate the placement and size of all the other elements in the scene. The vast majority of paintings of the period use a tiled floor for the purpose, a rather inventive device which plays the dual role of being a gridded scale and also an integral part of the painting as well. In keeping with the Renaissance idea of man being the measure of all things, the system described by Alberti employs a modular unit known as the *braccia* (or length of an arm), three of which are taken to equal the height of a man (Alberti 1991[1436]:54). It is important to note that this system, called *construzione abbreviata,* is really a shorthand for creating a cube of perspective space in which objects can be placed at the appropriate depth, and, apart from simple cuboids and cylinders, offers no clue as to the representation of the foreshortened objects themselves. This is in contrast to an alternative system which Ruurs (1987:29) argues may have been used by Brunelleschi, known as *construzione legittima,* where the objects themselves are derived from their ground plans and elevations.

The Albertian perspective construction process may be summarised as follows (Fig. 4.9):

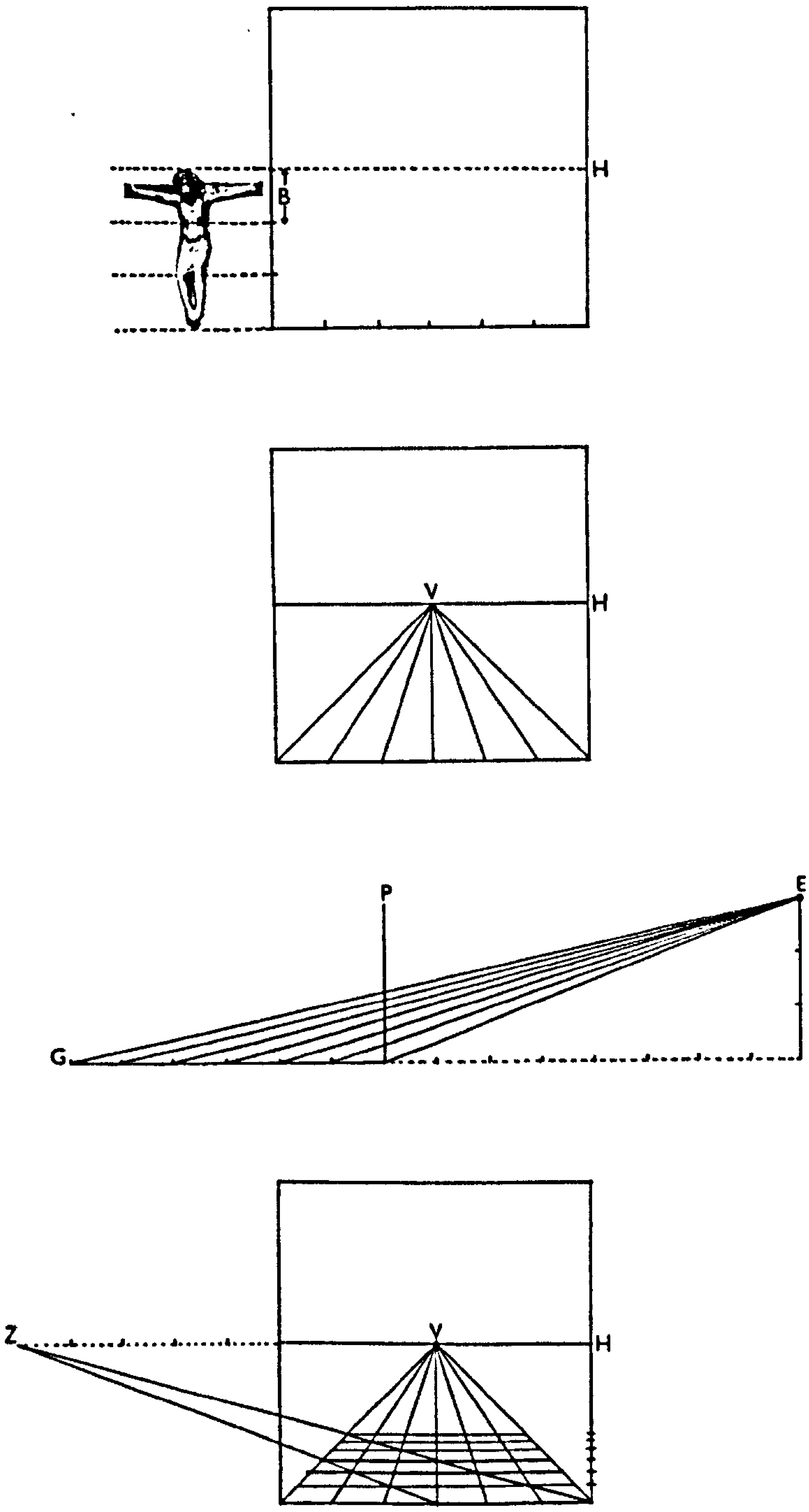


Fig. 4.9 Alberti's perspective construction system (from Kemp 1990)

Step 1: A rectangle is drawn. This, according to Alberti, represents the window through which the scene is observed.

Step 2: The ground line of the rectangle is divided into as many units of one *braccia* (B) as it will contain.

Step 3: The vanishing point (V) is marked. This represents the point to which all lines perpendicular to the picture plane converge, and is placed upon a line at a height of three *braccia* above the ground line (the horizon line, H, which is at the viewer's eye level). The division marks on the ground line are joined to the vanishing point.

Step 4: In order to obtain the subdivisions of space into the depth of the painting, a second horizontal line is drawn at the same level as the ground line, and is marked at the same intervals. To one side of this new drawing, the eye point (E) is marked level with the horizon line.

Step 5: The distance between the viewer and the picture plane is marked by means of a vertical line (P).

Step 6: The divisions on the baseline (e.g. G) are joined to the eyepoint, and the intersections of these lines with the vertical picture plane P represent the heights of the transversals above the ground line.

Step 7: The transversals may now be drawn to give a perfectly consistent foreshortened grid, which may be used to accurately position the various elements in the scene at the appropriate depth.

Step 8: The consistency of the grid may be tested by joining the opposite corners of a grid unit, and projecting this line onto the horizon. If this procedure is repeated for a number of grid units, it is found that the projected lines will always converge to a pair of points either side of, and equidistant from, the vanishing point. These are known as the distance points (Z).

Having created the base plan, so to speak, the question of how to transfer vertical dimensions is raised; this is accomplished using a device that is now known as the perspective wall. Although Alberti (1991[1436]:68-69) describes in which this job can be done, it is simpler to imagine that the vertical distance in any plane of the picture will be in proportion to the corresponding height on the picture frame; thus, by projecting a line to the vanishing point from the required height, it is possible to ascertain the relevant height at any depth. The notion of the wall involves the fact that it is possible to transfer heights in both the longitudinal and transverse dimensions using what is effectively a dimensioned vertical plane (Ruurs 1987:54).

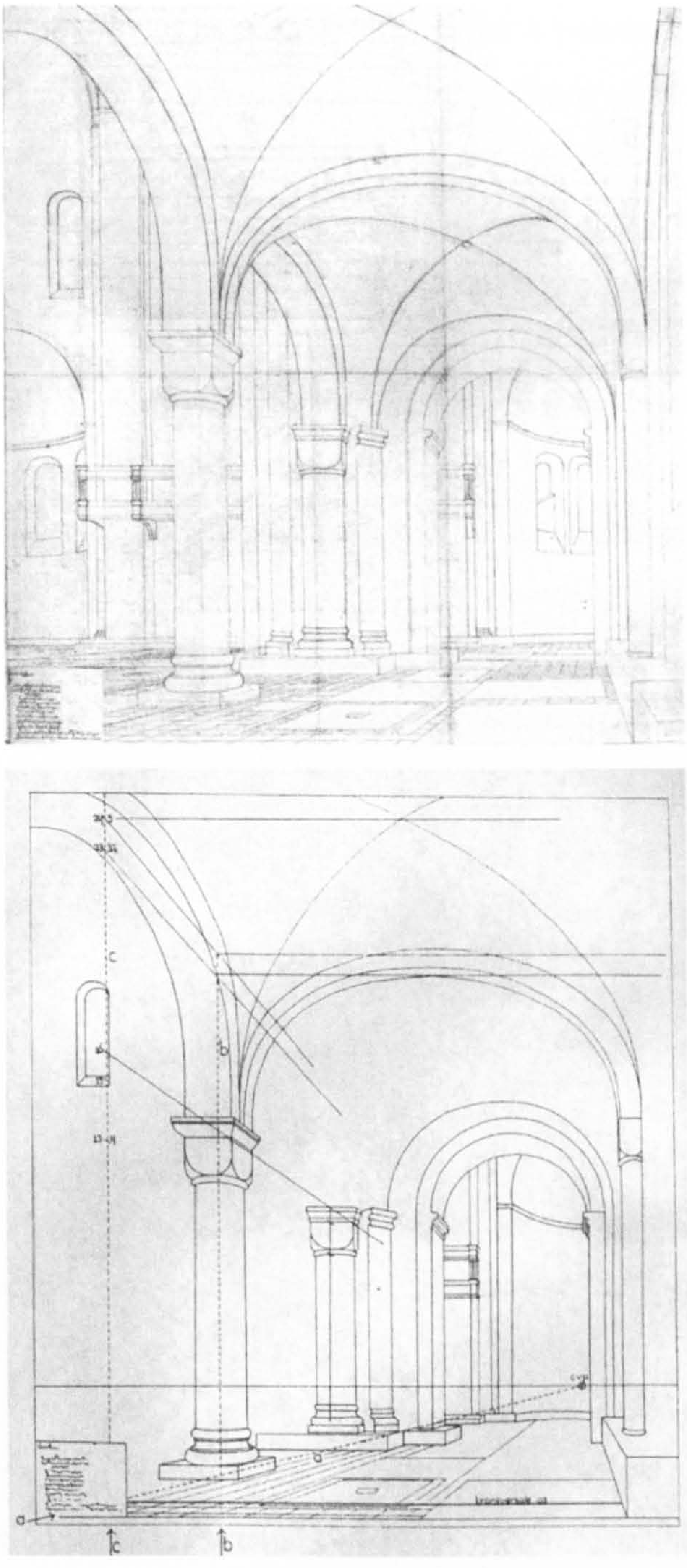


Fig. 4.10 Mariakerk, Utrecht: Preliminary drawing by Jan Saenredam, 1637 (top), and extracted construction marks (bottom) (from Ruurs 1987)

The resulting perspective configuration is found to have a number of interesting properties, which are especially relevant to the idea of perspective reconstruction. The most important of these is that the distance between the vanishing point and either of the distance points is always found to be equal to the distance between the eyepoint and the picture plane; in other words, given a painting with a consistently gridded floor, it is always possible to work out the distance points, and from this, to identify the point at which the painter sat when the image was originally created. Indeed, some of the illustrations of church interiors by the 17th century Dutch painter Jan Pieterszoon Saenredam are especially enlightening in this respect. Not only do they contain the obligatory gridded floor, but the preliminary construction drawings for the paintings contain clearly indicated eyepoints, horizon lines, perspective walls and other markings which could theoretically be used to extract dimensional information and thus reconstruct the perspective of the representations (Fig. 4.10). Indeed, Terlingen and Engelbregt (1996:41-52) document just such a project, involving the reconstruction of the no-longer extant Mariakerk of Utrecht based partly upon the paintings of Saenredam. Although the reconstruction was carried out in physical model form (the authors claim that such a model would give a more direct representation than a computer model), it is not difficult to see the translation of the fundamental perspective reconstruction techniques into a virtual modelling environment.

4.3.4 Perspective Reconstruction

The question of how to reconstruct the space portrayed in a mathematically constructed perspective, known as reverse perspective, has been of interest to painters and other savants, including Leonardo da Vinci, at least since the Renaissance. Much research was done in this area by art historians in the 20th century, with extremely important results; in recent years, we have seen the application of computer-aided visualisation techniques for this task. De Mey (1995:145-155), for example, documents a number of historical attempts at reconstructing the hypothetical space represented in Masaccio's *Trinity*, points out their shortcomings and ambiguities, and goes on to describe a computer modelled reconstruction of the same space. In concluding his study, De Mey points out that, although it is possible to create a model of this sort, this is no way a proof of the correctness of his approach, for "Masaccio's use of perspective goes beyond the straightforward application, [and] any implementation of a computer model would

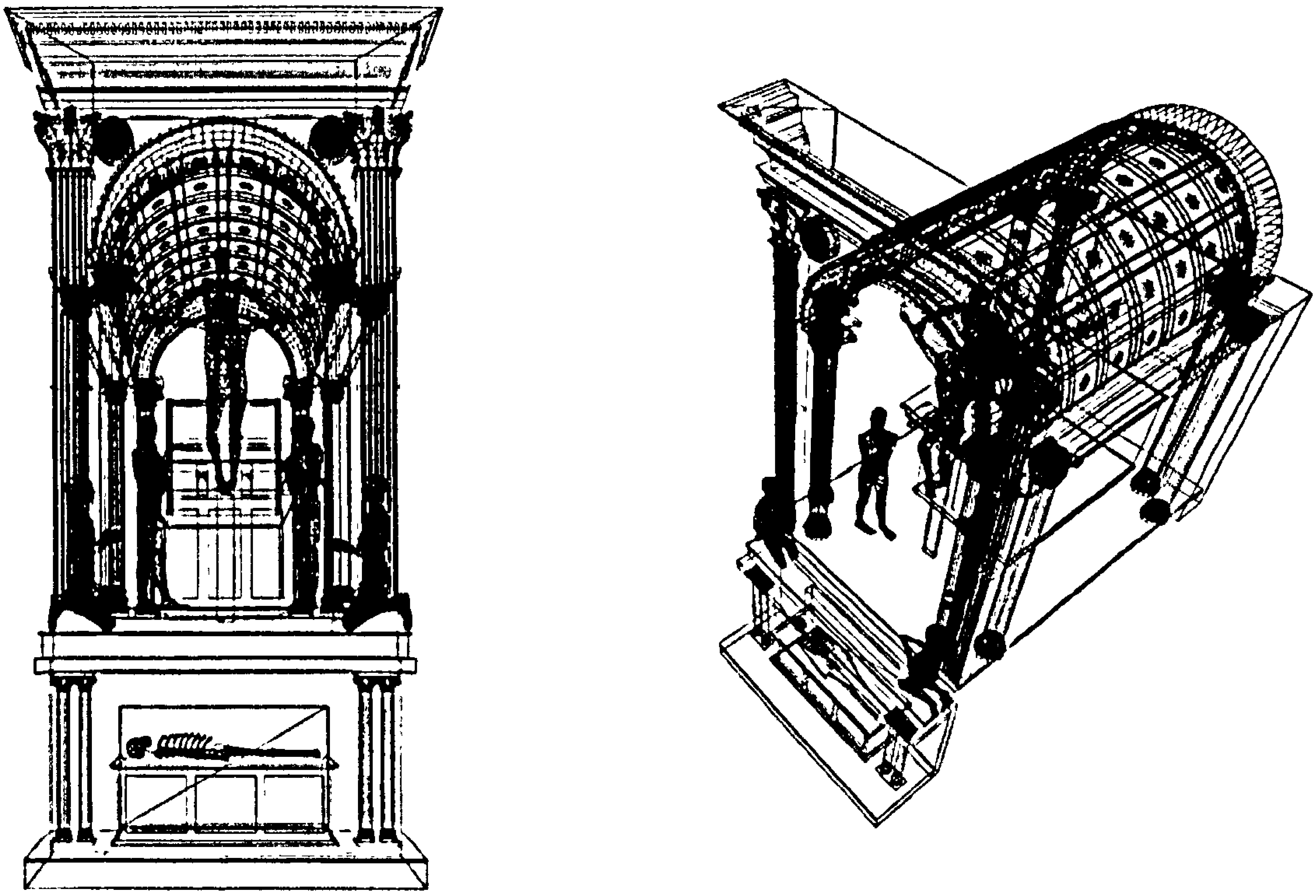


Fig. 4.11 Computer-aided reconstruction of Masaccio's *Trinity*
(from De Mey 1995)

ultimately fail as a complete reconstruction of his achievement". What is notable, however, is that De Mey does not indicate whether a computer-aided system was used to reconstruct the perspective itself, and from his description, the impression is that the computer was used purely as an illustrative tool (4.11).

If we are to use computer-aided techniques to reconstruct this sort of painting, we enter into a completely new area of research, known, not technically as computer graphics *per se*, but rather as computer vision. The majority of computer vision research projects, such as that documented by Debevec, Taylor et al (1996), have been restricted to the use of photographs as source materials, partly for the rather obvious reason that the perspective structure of a photograph is entirely straightforward and consistent – the researcher does not have to deal with the kind of visual artifice encountered when dealing with a representation such as the *Trinity*. It should be noted, however, that even where the source image appears to be entirely consistent, the researcher has to put in a fair amount of empirical knowledge about the represented scene in order to reconstructed, for, in the final analysis, any given perspective image has an infinite number of reconstructions. It is only by making reasonable assumptions – for example, that a building is orthogonal – that a reasonable reconstruction is arrived at. In the case of the famous Ames Room (named after its inventor, Adelbert Ames), all these perceptual consistencies are subverted; by using sloping walls and ceilings, it is possible to create rather bizarre and disturbing views which superficially appear to be set in a normal orthogonal room (Atkinson, Atkinson et al 1990:182-183).

The perspective reconstruction methodology described by Criminisi, Reid et al (1999) is one of the few systems conceived for use in conjunction with historical painted representations. Known as Single View Metrology, the authors claim that this system "can be seen as reversing the rules for drawing perspective images given by Leon Battista Alberti in his treatise on perspective (1435)", the very rules that were followed by the painters of the Renaissance. It is interesting, however, that the system described here is heavily dependent upon the application of the principles of projective geometry, a discipline that did not in fact exist during the Renaissance. The painters of the period were firmly based in the principles of Euclidean or plane geometry, and while the publication of the theory of projective geometry by Girard Desargues in 1636 may have had widespread implications to mathematics, it had next to none in art. This is not in any way to question the effectiveness of the system described by Criminisi et al; in a series of highly impressive case studies, they reconstruct the spaces represented in, among others, Piero Della Francesca's *Flagellation of Christ* and Masaccio's *Trinity* (Criminisi 2001). What is at issue here is whether the technique employed in carrying out the reconstruction is indeed a true reversal of the system originally employed in creating the representation, and given its heavy dependence on a discipline that was entirely unknown to the original painters, it is difficult to see how this should be the case.

As we have seen with respect to the many reconstructions of Masaccio's Trinity, it is indeed possible, within limits, to reverse the *construzione abbreviata* of a Renaissance painting to create a reconstruction of the space represented in it. An

Fig. 4.12 *The Music Lesson*, by Vermeer, 1662-5 (left), and reconstruction model (right) (from Kemp 1990)

extremely interesting example of this technique is documented by Steadman (2001:73-100), who analyses a series of paintings by the 17th century Dutch painter Johannes Vermeer. The system employed here is effectively a manual reversal of the original perspective description, with two major restrictions. Firstly, it is necessary to make "plausible assumptions about the general nature of the geometry of the scene" in order to dispel any perspectival ambiguities of the sort we have already discussed. It is also clear that the original paintings offer no indication as to the exact scale of the representation; as Steadman (2001:74) points out, "the pictures, speaking strictly geometrically, might equally well show dolls in dolls' houses as living people in normal-sized rooms." Again, it is necessary to apply some empirical everyday knowledge as to the sizes of people and objects to deal with the ambiguity. These questions aside, Steadman's experiment produced a number of very important results (Fig. 4.12) – it now appears that, not only do the paintings represent what is essentially the same room (Vermeer's studio, perhaps), but using the reconstructions, one can also postulate that Vermeer used a optical device such as a camera obscura in the creation of the paintings (Steadman 2001:156). While these reconstructions appear to have been carried out by hand, it is also possible to hypothesise a computer-aided methodology for the same task.

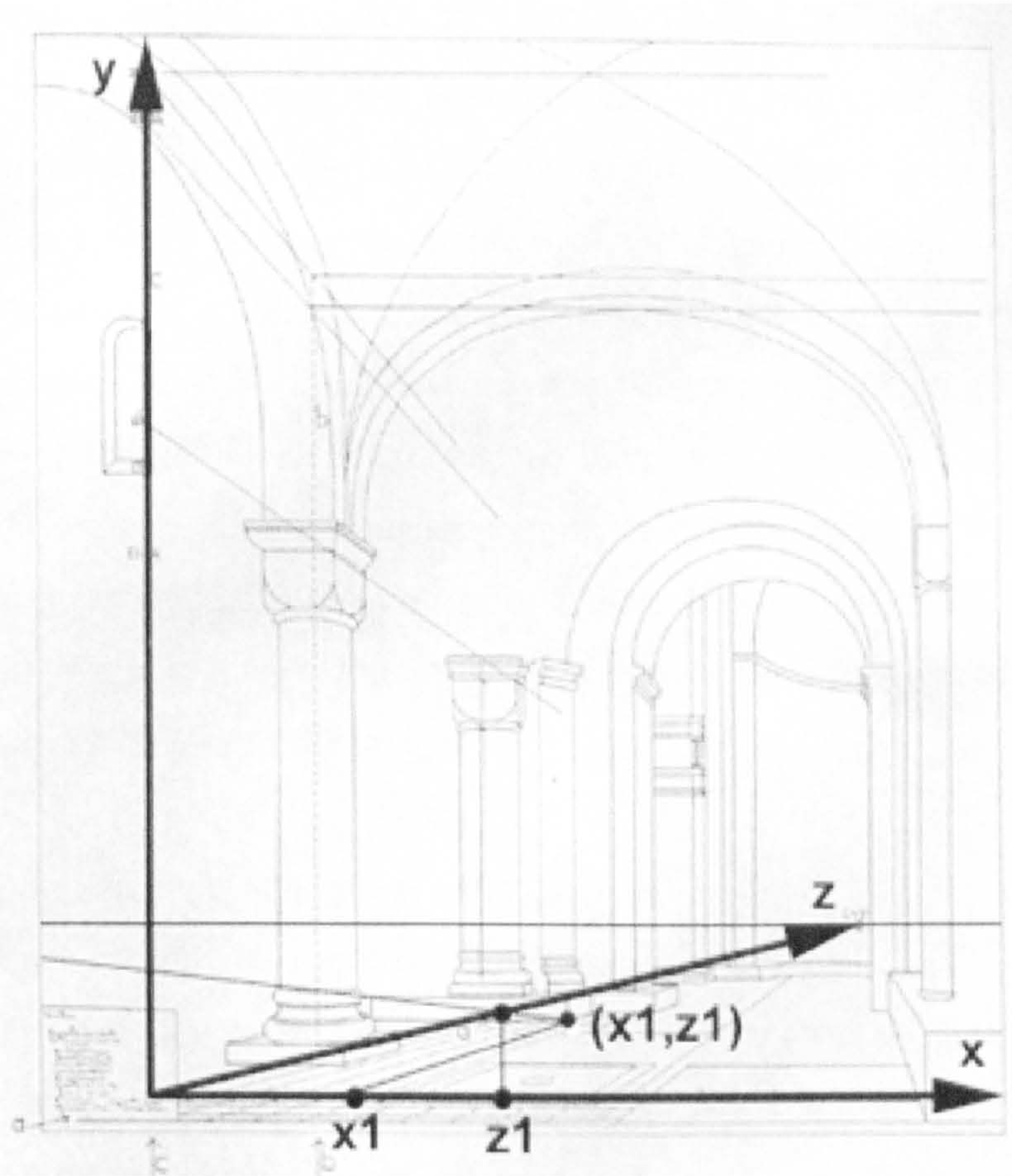


Fig. 4.13 Extracting Cartesian co-ordinates from Saenredam's preliminary measured perspective of the Mariakerk (see Fig. 4.10)

While the detailed implementation of a computer-aided perspective reconstruction methodology would be beyond the scope of this study, it is nevertheless possible to identify some broad outlines that may be followed. For example, such a system would be based essentially on the use of a rasterised version of the painting in question, which would enable the exact and repeatable querying of dimensions (Fig. 4.13). Taking the horizontal and vertical boundaries of the picture plane as the *x*- and *y*-axes respectively, it is possible to postulate the *z*-axis by projecting a line from the junction of the other two axes to the central vanishing point, or CVP (if this point is not marked on the image itself, it can be fairly easily identified by projecting the parallel sides of an object to their point of convergence). The horizon is then established by drawing a line parellel to the *x*-axis through the CVP. Once these constructional devices have been established, the next step is to identify the distance point (DP). Where this point hasn't been explicitly marked, the gridded floor can be employed in the following way: the opposite sides of a unit square are joined, and this line is projected onto the horizon; it is necessary to repeat this operation several times to obtain a fairly good approximation of the distance point. For verification purposes, it is perhaps advisable to identify both distance points either side of the CVP; if correctly identify, the distances between the individual points and the vanishing point should be identical. As we have seen, the distance between the distance point and the central vanishing point is exactly equal to the distance at which the painter nominally position him or herself when originally creating the representation. We now have a framework that may be used to work out a plausible perspective reconstruction of the image.

For a given point on the ground plane (x_I, z_I),

x_I = intersection with x-axis of a line through x_I and CVP;

z_I = intersection with x-axis of a vertical line dropped from z-axis; the intersection point of this line with the z-axis is given by a second line through z_I and DP.

In this way, it is possible to identify the x- and z-values of every point on an identified ground plane. The main shortcoming of this method is that it is impossible to identify the y- value of a point independently of a reference point on the ground plane. It is also impossible to obtain dimensional information on occluded areas of the images, although with some judicious assumptions based on the empirical knowledge of what is represented, it is possible to surmount this problem to a certain extent. Indeed, it should be noted that these are problems that are inherent in any form of perspective reconstruction methodology, whether based on projective geometry, or, as in this case, on straightforward plane geometry. Thus it is feasible, at an absolute minimum, to use such a computer-aided system in order to obtain plan information for the unoccluded parts of a painted representation, which can then be developed upon using other sources of information and reasonable assumptions.

5

Methodological Considerations

The creation of a virtual architectural model is usually a multi-stage process that involves taking into account a number of factors. The most fundamental consideration is the final aim of the model, for, as we have seen, the type of reconstruction that is appropriate for a scholarly audience is vastly different from that which is suitable for public consumption in a television programme or museum environment. Another issue that must be evaluated is the level of computing and personnel resources that are available for the reconstruction project, and also the time-frame in which the project must be completed. As we have discussed in the preceding chapter, it is also necessary to have an accurate and reliable set of source data for the reconstruction. Consequently it is possible to discuss a number of issues that are common to almost every virtual reconstruction project, regardless of the underlying objective. We shall consider this subject in the common order of workflow for a typical virtual reconstruction project.

5.1 Modelling Techniques

The creation of a computer-aided reconstruction can be considered as essentially a two stage procedure. The first involves the construction of the model itself in a process not too dissimilar in concept to creating a physical model, and then of processing the model to create a visible image of it. The first step of this process is by far the more intensive in terms of human involvement. Ryan (1996:97) points out that:

> Computer-based models often require no less work to produce than physical models and, whilst they may lack tactile benefits, they do offer much greater flexibility in presentation. Size and restriction of viewpoints are no longer a problem of the model itself, only of the viewing technology. Whilst a physical model is usually static and limited

> by possible viewpoints, a computer model may be presented in many different forms, ranging from a fixed sequence of still images through to more interactive forms in which the viewer exercises choice over what is displayed and when.

It is necessary to bear in mind that the majority of modelling techniques are generic solutions, and are not tailor-made for built heritage applications. Indeed, the significant majority of them are the products of the engineering and entertainment fields which have then been adapted to archaeological and archaeological use.

5.1.1 Surfaces and Solids

A computer model is essentially a database that carries geometric information on all the elements that constitute the represented objects. Two types of geometric description are fundamental to computer modelling: *surfaces* and *solids*, with two separate modelling typologies based on these two types of geometry.

A surface model, as its name implies, depends on the use of polygonal, two-dimensional entities (faces or patches) to describe the elements in the model. Thus, to describe a cube, it is necessary to define six rectangular faces joining at its vertices. As a result, although a representation of a cube is thus formed, it is not a true solid in that there is no information on what is contained within the object. Ryan (1996:97) highlights the main features of this particular typology as follows:

> Surface modelling techniques can be used to describe highly complex surfaces but, conversely, many simple geometric shapes require quite complex descriptions when approximated only by polygons. For example, the surface of a cylinder may be represented by a number of long thin rectangles, each divided into pairs of rectangles, that of a cone or sphere by many triangular patches. Cut-out shapes, such as those representing doorways, arches and windows, add further complexity as the inner faces must be represented by further polygons, otherwise the

thin surface skins of the wall through which they are cut may be visible in the rendered image.

Surface modelling is vaguely analogous to creating a physical model using cardboard, in that it is only possible to represent the faces of solid objects. For example, the only way in which a curved surface can be constructed using traditional surface modelling is, as described above, by the use of individual abutting flat surfaces, a situation that creates visible facets and tessellation lines instead of a smooth surface. Having said that, there are situations when the only practical way of modelling a certain form is by the use of surfaces. An obvious example would be where the represented object is itself quasi-two-dimensional, for example, fabric or glass.

An altogether different approach to modelling involves the use of constructive solid geometry (CSG), as briefly mentioned in Chapter 2. This particular technique models entire solids, usually primitive three-dimensional forms such as cubes, spheres, cylinders and cones. These objects can then be manipulated by the application of set-theoretic Boolean operations of union, subtraction and intersection to create an almost unlimited array of three-dimensional forms. For example, the subtraction operation (effectively the intersection of a negative object with a positive one) has the effect punching a hole in one of the objects, and can be applied to the creation of such building elements as doors and windows. As the element is a complete solid, no additional work is required to represent the surface of the cut area. It is also possible to create solids of extrusion and revolution, further increasing the palette of tools available to the modeller. Indeed, a convenient everyday analogy for solid modelling would be that of physically sculpting forms using a material like clay or plasticine (Bertol 1997:45). Kemp (1995:249-250) identifies another fundamental advantage of solid modelling in that it facilitates structural analysis by incorporating complete volumetric information. She goes on to summarise the two forms of modelling in the following way:

Surface Models

Main applications	Computer graphics for presentation, entertainment and advertising.
Accuracy	Lower (designed to fulfil the more superficial presentation needs).
Ease of construction	It is not so easy to construct purely cosmetic structures which produce an illusion, particularly for people who are not computer graphics experts.
Robustness	Good.
Flexibility	Good.
Renderability	There are more highly developed rendering algorithms available, but highest possible quality is lower than with solid models.
Ease of analysis	Harder (it is difficult to cut holes in surface models and to take them apart, cut sections through them etc.)
Memory requirements	Generally smaller, because volumetric information is not stored.
Validity	Impossible surface objects are possible.
Future potential	Probably not so great in scientific and analytical applications, for reasons shown above.

Solid Models

Main applications	Computer graphics for design and manufacture.
Accuracy	Higher (fulfilling the needs of CAD for "complete, accurate and unambiguous models").
Ease of construction	Easier. One of the great advantages of such accurate models for graphics is that they are usually much easier to construct than surface models. They do not rely on the user to create the required set of faces.

Robustness	Not so good.
Flexibility	Representation of non rigid, jointed objects is not possible. Bending and twisting of objects is still undergoing development.
Renderability	Fewer rendering algorithms exist for solid models, but a higher degree of realism is possible.
Ease of analysis	Easier (especially analysis which requires volumetric information). It is easier to cut sections in and holes through a solid model. They are easily interfaced to programs which can do finite element analysis or test for the effect of stresses on construction.
Memory requirements	Generally greater because volumetric information is stored.
Validity	Invalid representation is impossible.
Future potential	Greater in scientific and analytical applications.

Although much of this analysis holds true today, it is also necessary to bear in mind that it is written from the perspective of a decade ago. Both modelling typologies have made advances in the meantime; to take an example, the bending and twisting of rigid objects as highlighted above does not pose a serious problem in some of the new modelling packages (Khemlani 1999:321). The use of parametric modelling tools such as NURBS (non-rational uniform B-splines) allows the creation of smooth surface objects in a way that avoids problems of visible facets. It is also important to note that surface and solid modelling techniques are not necessarily mutually exclusive – it is possible to construct a reconstruction model using both techniques, choosing the appropriate one for the situation (this is described fully in Chapter 6). For instance, walls lend themselves immediately to a solid modelling treatment, whereas other elements where the volumetric content is not important can be profitably modelled using surfaces. In addition, some of the newer software packages also include hybrid surface/solid modelling tools, although this is not entirely without its own problems. On the whole however, as Lock (2003:160) argues, the distinction between solid and surface modelling has become so blurred now that computer models should perhaps be classified, not according to the technique used to create them, but rather based on their intention, i.e. either as perception models (for high-quality presentation) or as structural models (for analytical purposes).

5.1.2 Optimisation and Limiting Factors

In addition to choosing the appropriate modelling methodology, there are a number of other factors that affect the success of a reconstruction model. The most significant of these are the following:

- Level of detail
- Data segmentation
- Workflow and personnel

Although it is technically possible to model a historic building to include every detail that would have existed in reality, such an approach is usually neither desirable nor useful. For example, it would be considered a waste of time and resources to attempt to replicate an exact door or window detail in a large urban model, given that much of this detail would not be visible when the model is finally presented; in addition, this redundant detail would clog up the available computing resources and significantly increase the rendering time of the model. At the same time, an over-simplified model may have an incomplete appearance that could detract from its use as a testing or presentation tool. As a consequence, the choice of an appropriate level of a detail is a crucial decision that must be taken at as early a stage as possible in the modelling process (Kemp 1995:250).

The choice of the appropriate level of detail for a modelling project is dictated by two major factors: the available time and computing resources, and the ultimate purpose of the model. It is fairly evident that the construction of a large, highly detailed model is likely to be a difficult or even impossible task where there are limited resources. The difficulty becomes more apparent during the intermediate stages of the modelling process as the data set increases in size, leading either to a reappraisal of the project or to its being abandoned. For instance, Kemp (1999:250) indicates that this problem was encountered during the virtual reconstruction of Rievaulx Abbey:

> The first objects constructed (the columns) were given a lot of detail. Thereafter the level of detail was reduced, as a great deal of memory was involved in creating each object.

It is also to be expected that, where a reconstruction model is being constructed with a view to extracting a few still images, a higher level of detail may be more appropriate than, say, where an animation or VR environment is being contemplated. The widely available computer graphics hardware and software of today is as yet not at a sufficiently developed stage to permit the rendering of complex scenes in real time, and for this reason, most models designed for VR adopt a very low level of detail. As Levy (1999:150) explains:

> Balancing the need for detail against performance is always a constraining factor in the design of a VR environment. Constraints on the number of polygons and the size of texture maps that can be rendered in real time can make a model look like a crude 8 bit video game as made just a few years ago. If the model is intended to give the observer a sense of architectural space, it may be possible to reduce the complexity of the geometry and sculptural detail that exists on the site. Nonetheless, if the objective is to create a sense of depth for the viewer, projecting in stereo will cut performance in half. Developers of computer games have traditionally relied on simplified geometry or low-polygon count models as one strategy to create VR worlds with high frame rates.

Although it is possible to get away with crudely built textured models where computer games and public-oriented VR worlds are concerned, balancing level of detail with performance is a significant problem with highly detailed architectural models in academic and research contexts. Although some writers express optimism that this situation will probably disappear with the development of yet more powerful hardware and software, it is perhaps more likely that the principle of technological determinism will ensure that we shall always want to do just what is beyond the reach of the available resources.

Another factor that is an important consideration in reconstruction modelling involves the way in which the data set is organised. While a small model might not include more than a few (that is to say, in the region of up to a hundred or so) individual geometric elements within a single file, a more complex model is likely to involve several thousands of elements, possibly stretching out over several files. For any form of coherence, it is thus necessary that the data is organised in a way in which the task for both the human and the computer is as made as easy as possible.

Data segmentation in computer modelling is usually achieved by the use of *layering* (different software packages refer to this concept with various terms). The fundamental concept here is that modelling elements which are notionally similar are grouped together in a uniquely named layer, which can then be turned on and off depending on need (Kemp 1995:250; Lucet and Lupone 1995:146). This facilitates the selection of elements during the modelling process, and during rendering, layers that would be invisible can be turned off. Furthermore, some software packages like formZ feature the concept of nested layers, where layers can be placed within a parent layer to create a hierarchy. Indeed, the importance of the use of data segmentation cannot be exaggerated, for a badly layered or unlayered model is highly inefficient and frustrating to work with.

The concept of data segmentation can be further extended to a state where different parts of the building are modelled as discrete but interconnected files. This task further simplifies working with the model, especially where there are so many elements that a single large model would be overwhelming both to the modeller and the computer. This concept is usually known as *external referencing*, but again, the specific terminology varies between different software packages. However, there is no doubt that the use of such a system greatly enhances the power and scope of a model, as demonstrated by the Jerusalem Temple Mount reconstruction that is currently available on the Internet (http://www.archpark.org.il/virtual.shtml).

It is important that a virtual reconstruction project is carried out according to some sort of plan. Obviously, in the case of a research project, the plan is likely to change according to the interim results; it is nevertheless desirable, for example, to mock up a rough massing model based on the available data before proceeding onto the more detailed areas of modelling. Otherwise there is a fairly good possibility of a lot of time and effort being wasted on details which are later found to be at variance with the base data, with the result that much of the work is repeated. In an ideal situation, the modelling process is approached in an iterative manner, where the reconstruction is completed in a series of passes progressing gradually from coarse to fine detail.

The question of who exactly should be involved in reconstruction modelling is a topic that has elicited widely differing points of view. We have already seen that much of the early virtual models were carried out by computer experts with little or no interest in architecture or archaeology, for the simple reason that they were the only people capable of taming the rather complex and unwieldy software that was available at the time (Miller and Richards 1995:20). As the interfaces have become more manageable, the modelling task has passed on to specialised computer animators and artists, personnel who are as dissociated from the underlying architectural and architectural arguments as the early computer programmers. Although some writers are in favour of this arrangement where an architect feeds information to a computer artist who then translates into a visual form (Forte, Borra et al 1998; Bakker, Meulenberg et el 2003:3), it is clear that this is cumbersome and is probably likely to lead to various communication problems. Indeed, most modern visualisation packages are fairly straightforward, and the creation of a virtual model should be within the capabilities of a visually-literate architect or archaeologist. Therefore, the opinion put forward by Kemp (1995:253) almost a decade ago remains the optimal approach to the question of who should do the modelling:

> .. ARV [archaeological reconstruction visualisations] should ideally be carried out by archaeologists who can use them directly as an analytical tool to test their theories, so that a direct feedback loop can be established.

5.2 Rendering Techniques

The second component of the visualisation process – rendering – is almost entirely computer-based, and typically involves less user input than the modelling stage. Having said that, there is usually a significant amount of work involved in setting up the scene for rendering, for example, with the setting up of lights and texture maps. As Levy (1999:153) argues:

> The final rendered appearance of any computer model will depend on the lighting treatment and effects. In many computer-modelling applications this is a product of the of the creative efforts of the modeller, rather than a strict application of science. Although applications like Lightscape can create accurate representations of light, most applications rely on the modeler's skill at the placement of lights in the space for a convincing image.

Rendering typically involves the simulation of a lighting arrangement in a scene in order to replicate a more or less realistic impression of what the model represents. Early wire-frame rendering methodologies were restricted to the removal of hidden lines by working out which polygons in the scene would be obscured by others, and were unable to portray such features as colour, shadow, transparency and specularity. To add these extra features, it was necessary to manually 'paint' the image using an image manipulation programme (Wood and Chapman 1992:140-141). Before long, a constant shading algorithm was in widespread use; with such an algorithm, it is possible to colour the facets of a model with a uniform shade but not necessarily to simulate any of the other characteristics listed above. Subsequent

Fig. 5.1 Wireframe (left), wireframe with hidden lines removed (centre) and flat shading techniques (right)

advances, such as the Facetted, Gouraud and Phong algorithms allow more realistic shading including many of the other requirements mentioned above, but are all more computer intensive than simple constant shading (Fig. 5.1).

5.2.1 Raytracing and Radiosity

Photorealism was something of a buzzword for the early researchers in virtual architectural reconstruction, and was commonly viewed in a rather idealised and uncritical manner. This was not altogether surprising, for such graphics (especially in terms of animations) were restricted to the most powerful of machines, which were usually beyond the reach of archaeological and architectural researchers (Gifford and Acuto 2002:95). By the mid-1990s, however, an average desktop machine was capable of producing highly photorealistic images and even short animations (Ryan 1996:107). This is a situation that is currently being fully exploited in virtual architectural reconstruction, sometimes even, as we have seen in Chapter 3, at the expense of accuracy and credibility, since real-time photorealism continues to be a holy grail of sorts. There are a number of algorithms that can be used to create photorealistic graphics, of which the most widespread are *raytracing* and *radiosity*.

Raytracing uses a rendering algorithm that in may ways is superior to the scan-line methodologies described above. This is a technique that, in effect, traces individual rays of light in the scene back to their sources, taking into account the way in which they reflect and refract along the way (Fig. 5.2). This is actually the reverse of what happens in reality, where light is projected from a source (Birn 2000:233). An obvious advantage with this rendering model is that it is not only possible to cast accurate shadows, a feature that is essential for depth perception, but also to simulate reflection and refraction through transparent or semi-transparent media such as glass and water. It should be noted, however, that raytracing can be extremely computationally intensive, especially where a complex model with many light sources is concerned. A further drawback with this technique is that it does not necessarily take into account the way in which real-world objects are not always

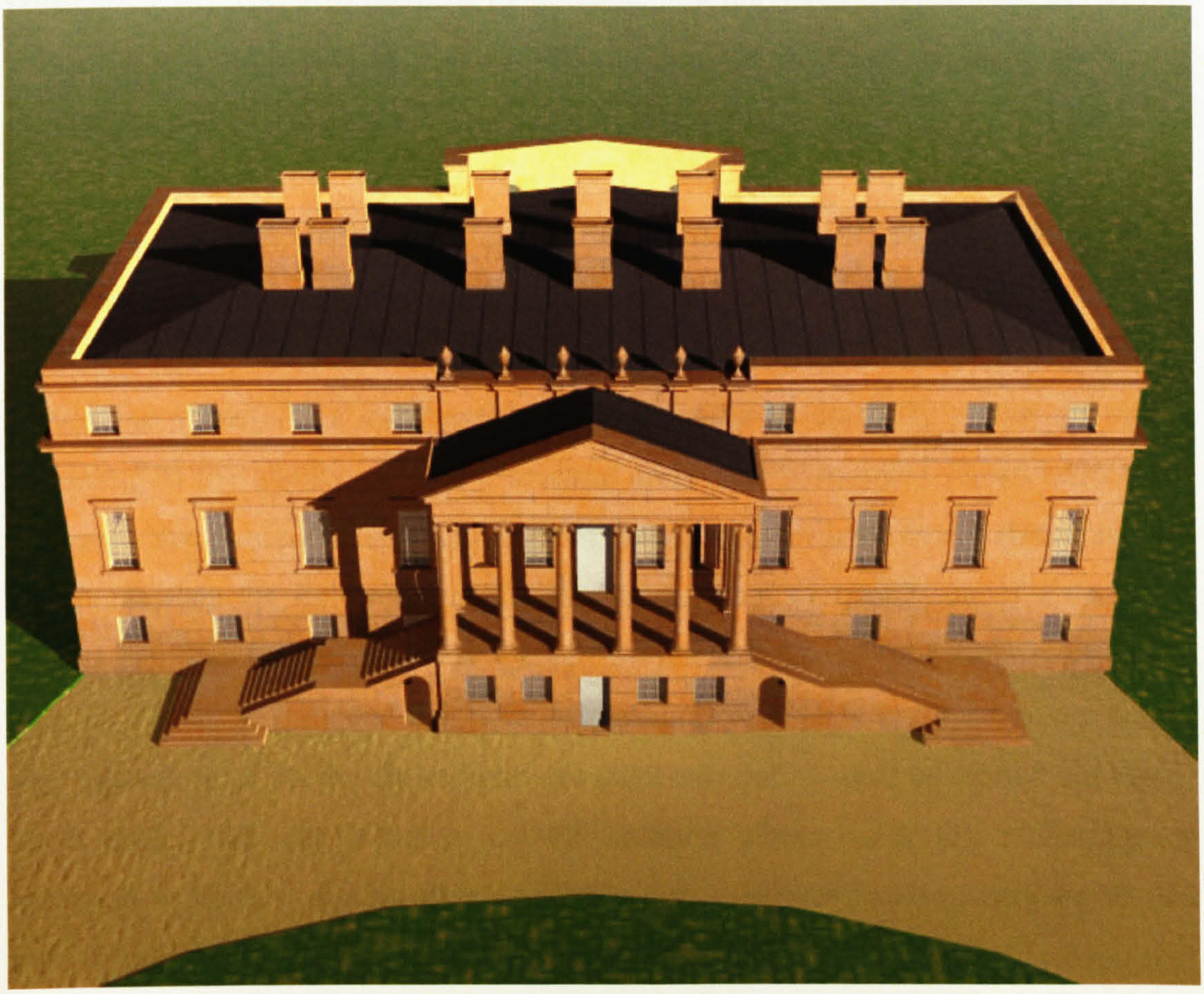


Fig. 5.2 Raytraced reconstruction image of Penicuik House, Penicuik

crisply defined as if they were in direct sunlight, but are somewhat softened by the effect of diffuse light. As Ryan (1996:100) explains:

> The use of direct light rays and point light sources produces very crisp images with hard edged shadows. Combined with perfectly smooth and highly reflective objects these produce the ubiquitous highly striking, but equally unreal, images of shiny balls hovering over checker-board floors that typified the early development of the technique.

A trick that is often use to soften the quality of light in raytraced images is to incorporate a global ambient light, which can sometimes produce a washed out and altogether unrealistic effect. A more successful solution is to use multiple low-intensity light sources instead of large single ones to simulate real-world diffusion, at the expense, however, of significantly increasing the load on the rendering engine (Birn 2000:94). It is also possible to simulate, at a fairly basic level, such devices as skies, fog and atmospherics to reduce the hard-edged nature of the basic raytracing procedures (Fig. 5.3).

Radiosity is an alternative approach to the problem of diffuse light. This is not dependent on the use of global ambient lights or multiple light sources; instead, an algorithm works out a full description of the way in which light is inter-reflected within the scene. As a consequence, it is possible to correctly colour an object according to the quality of light it receives from its environment (Ryan 1996:100). Although this particular technique is extremely processor intensive, it does have the advantage that the lighting model needs to be calculated only once; a series of images can then be fairly quickly extracted without the need for further calculation. This is, of course, provided that none of the lights or objects in the scene are in any way altered, for if so, the entire lighting model calculation must be carried out again. As a result, radiosity is not a suitable solution where quick test renderings or animated sequences are involved. Furthermore, they are usually restricted to use within indoor scenes with a limited level of diffuse light, for the simple reason that

Fig. 5.3 Using environmental features to simulate realism

calculating the lighting model would otherwise take so long as to make the entire rendering process impracticable. Birn (2000:241-242) does however point out that:

> Radiosity can be calculated progressively, so that light can bounce as many times as needed to create a refined, accurate simulation of real lighting. The number of bounces in a progressive radiosity solution is only limited by the amount of time available to compute the radiosity solution.

Other rendering algorithms with clear applications in virtual reconstruction include photon mapping (Birn 2000:242-243) and particle tracing (Chalmers and Stoddart 1996:85-93), both highly computationally intensive methods that are not as yet in common use. A different approach to the problem of reconciling photorealism and

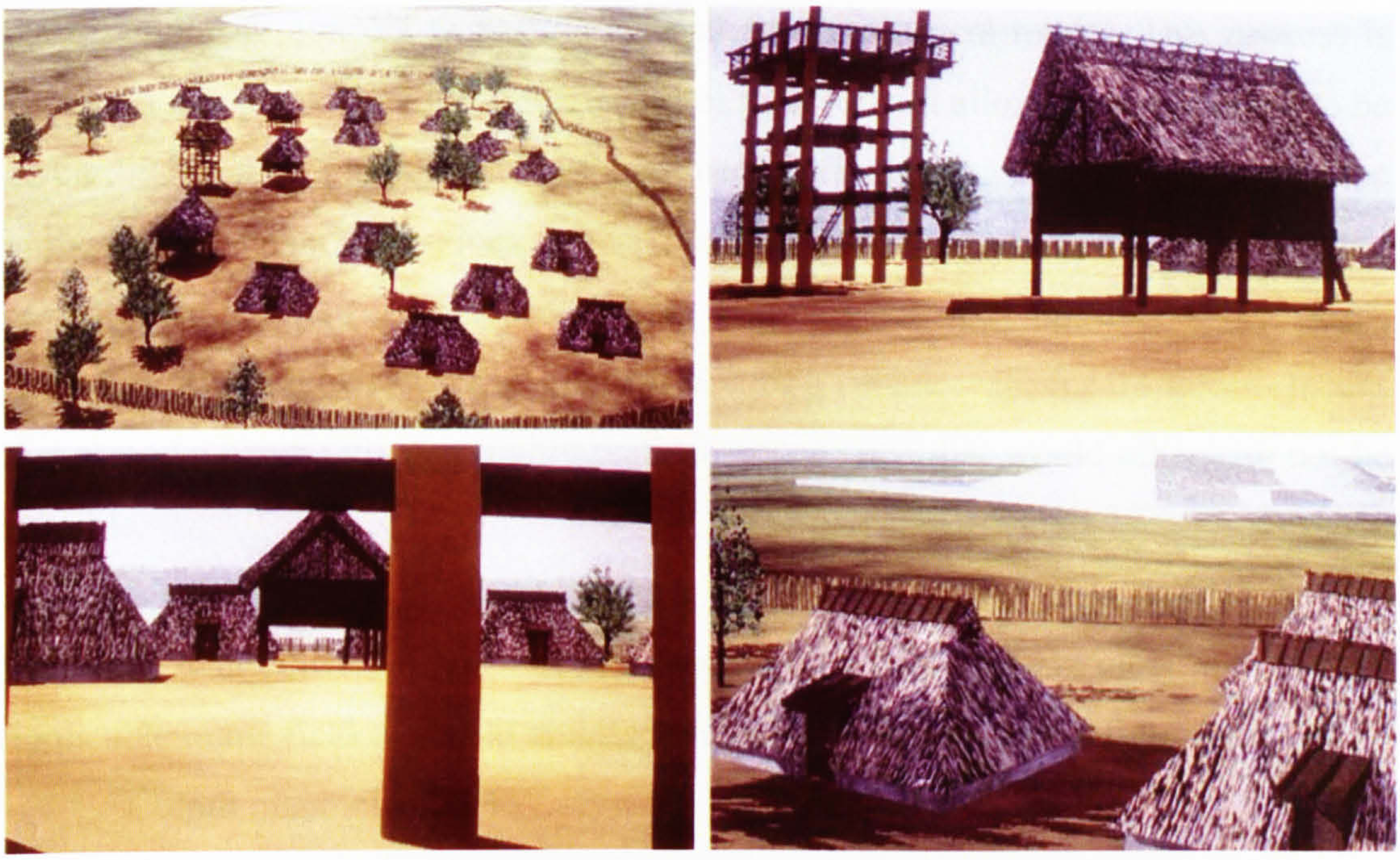


Fig. 5.4 The Ancient Scenery Modeller (from Ozawa 1996)

time is described by Ozawa (1996:117); in this case, his Ancient Scenery Modeller (ASM) software uses a mixed rendering system (Fig. 5.4):

> In practice, to reduce computing time, ASM uses two different [rendering] models depending on whether the object is near or far from the viewing point. If the object is near a precise algorithm is used, whereas if the object is far away, coarse rendering is used.

Such hybrid rendering engines, though not in widespread use at the moment, could in fact be extremely useful tools in virtual architectural reconstruction, especially where animation and real-time rendering is concerned.

5.2.2 Mapping and Compositing

It is possible to use two-dimensional images to alter or otherwise influence the way in which a model appears without necessarily changing the underlying geometry. This is accomplished by applying the image onto a face of the model, in a way not too dissimilar in concept to pasting a decal onto a physical model. This process is known as mapping. The most obvious use of this is that it allows coarse models to be given the illusion of higher detail without necessarily having to physically create the individual elements themselves, a characteristic that can save much modelling and rendering time when used appropriately. The fact that it is possible to use maps extracted from the real world – a photograph of a rubble wall, for instance – means that a model can be given a highly realistic appearance that would otherwise not be possible.

There are many different types of mapping, but the ones that are most immediately applicable to the field of virtual architectural reconstruction are the following:

- Colour mapping
- Transparency mapping
- Bump mapping
- Displacement mapping

Colour mapping is by far the most common and straightforward variety of mapping, where the surface colour of the model is replaced with the colours of an image (Birn 2000:204). In consequence, this technique is often referred to as texture mapping, though this term is perhaps misleading in that all forms of mapping are in fact to do with textures. In a similar way to colour mapping, transparency mapping uses an image to vary the transparency of a modelled object, a characteristic that is useful in portraying windows and railings, for instance. Bump maps work in a similar way to create the impression of relief and surface variation, and displacement maps, although similar to bump maps, are used to physically change the shape of a surface. Indeed, it is possible to use a single image in multiple channels - for example, a photograph of a stone wall could serve both as a colour map and a bump map.

Some of the problems involved with mapping are:

- Some software packages place a limit on the number or size of maps that can be used within a scene.
- Maps are resolution dependent, so a surface texture may appear highly pixellated when viewed in close-up.

- If a large area is to be covered, small maps must be tiled; when improperly done, this can produce a disturbing 'repeating' effect.
- Maps are external image files that are linked to the model file, and if any links are lost, the mapping must be redone from scratch.

Mapping has a fairly long history of use in virtual architectural reconstruction, especially where there is a requirement for high frame rates. However, a significant concern with using maps derived from real life with architectural reconstructions is that they might not necessarily be indicative of what the building would have looked like when in use; this is explained by Levy (1999:153), with respect to the temple complex in Phimai, Thailand, as follows:

> Creating an accurate surface treatment is both an art and a science. If the goal is to show the monuments as they existed centuries ago, as in the case of Phimai, current photos of the surface detail must be renewed or reversed in age. Samples of cut quarry stone ca[n] help in establishing the colour and luster [sic] of materials as they once appeared in the past. For sculptural detail, well preserved examples of carvings can serve as the source for creating surface textures.

An alternative to using maps to colour surfaces is to use procedural textures, which are in effect mathematically generated textures that can be made to approximate the appearance of many natural materials. They do not need a source image and are thus independent of resolution and file linking; furthermore, they can also be used to cover large areas without repetition. The downside is that realism may suffer, so in the end, a judicious choice must be made between using image maps and procedural textures depending on the circumstances.

A related technique to mapping is that of compositing, where a real life image is used to form a background for a reconstruction model. The obvious advantage of this is that there is no need to model a large area, thus easing the task for the modeller and also for the computer at rendering time. With respect to their visualisation of an

Inca complex in Argentina, Gifford and Acuto (2002:97) point out that:

> Finally, with careful planning, a photographic image of the landscape as it looks today can be inserted as the background of the model. For example, using a photograph of the landscape taken from a given, fixed point in the ruins of our structure, our 3D model was superimposed over it, resulting in a reconstruction of the view someone might have had standing in the exact same location in the past. The subsequent effect is profound as the overall view offers an original sense of what it was like to stand amid the architecture in its original state.

It is thus possible, by the careful use of compositing, to simulate the visual impact of a reconstruction upon its environment. This technique is of course restricted to situations where the environment has remained largely unchanged, although it is equally possible to overlay a reconstruction model onto the existing environment to form comparisons between existing and past urban fabrics, for instance. An example of this approach is the reconstruction of the Templo Mayor of Tenochtitlan overlaid on modern Mexico City (Forte and Silliotti 1997:262), an image that is extremely enlightening in that it shows just how large and imposing the temple originally was (Fig. 5.5).

5.2.3 Non-Photorealistic Rendering

Thus far we have looked at the subject of rendering virtual architectural reconstructions with the notion that the ultimate aim of the process is to produce as photorealistic an image as possible, which is indeed the common perception of rendering as a whole (Jesse, Isenberg et al 2004:3). An entirely different approach is to attempt to give the image an artificial appearance, know commonly as non-photorealistic rendering, or NPR. This is rather a new development in the field, for, although some of the early rendering algorithms were non-photorealistic as well, this was rather through necessity than conscious choice. It is, however, important that modern non-photorealistic algorithms are viewed differently – not as limited and

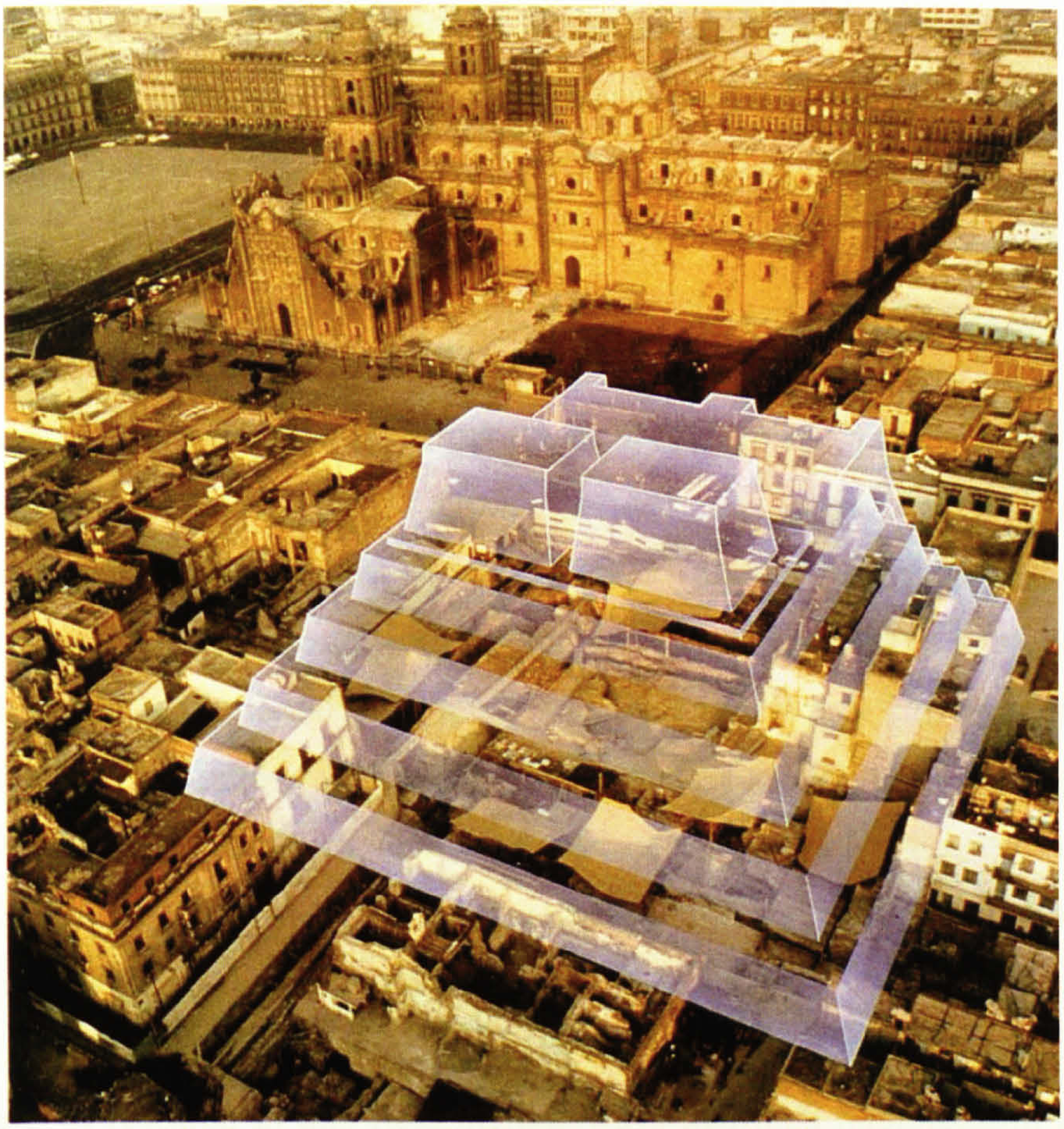


Fig. 5.5 Reconstruction of the Templo Mayor of Tenochtitlan superimposed on modern Mexico City (from Forte and Silliotti 1997)

somehow inferior alternatives to raytracing or radiosity, but as valuable tools in their own right.

Many of the current approaches to general NPR involve the use of distorted cartoon-like images (Halper, Mellin et al 2003:72), which, although full of meaning and capable of evoking a range of responses in certain respects, are rather less useful in architectural research contexts where dimensional accuracy and measurability are important characteristics. What is important is not so much the appearance of the reconstruction but the ability of the image to incorporate the notion of fuzziness without necessarily distorting the underlying framework. The stream of NPR research that is of immediate relevance to analytical applications can be considered in terms of two different visual products: surface shading methods and line-oriented methods (Jesse, Isenberg et al 2004:3). Whereas a standard wireframe rendering usually has the appearance of being incomplete and utterly dull, some line-oriented NPR methods can produce highly expressive illustrations that are similar to hand drawings.

An interesting development in NPR, specifically targeted at virtual architectural reconstruction, is documented by Strothotte et al (1999): researchers in Magdeburg and Leipzig have developed a visualisation system, called AncientVis, which permits the "rendering of images with less detail, using techniques for emphasizing and deemphasizing." The absence of texture and colour, instead of being seen as a drawback, was actually found to be a distinct advantage in that it invited discussion on the subject by not putting forward any representations that might be interpreted as absolute fact (Masuch and Strothotte 1998; Masuch and Freudenberg 1999). Indeed, many of the later versions of popular modelling and rendering packages include tools or plugins to create non-photorealistic images.

Other areas of research in this field include ways in which photorealism and NPR can be used in combination. It is not difficult to see that a system that includes hybrid representation of this sort could be used in an architectural reconstruction visualisation to differentiate between areas of uncertain interpretation, represented by NPR, and known fact, represented by hard-edged photorealistic elements. Similar techniques have been used for many years in engineering illustration and also in entertainment (such as the recent *Star Wars* films, where real actors interact with computer generated ones), but have not as yet, on the whole, filtered down into use in architectural and archaeological applications.

5.3 Presentation Techniques

The presentation of a virtual reconstruction involves taking into consideration the way in which it can be used to its greatest potential, and in this respect, a basic criterion is the ultimate purpose of the model: the requirements of an academic project are often very different from those to be taken into account when catering to the general public. As a summary of the different ways in which virtual reconstructions may be presented, Bertol (1997:117) forms a hierarchy of the various techniques in the following way:

- Static perspective renderings
- Animated non-interactive walkthroughs
- Interactive screen-based walkthroughs (low–level immersion)
- Immersive virtual environments

To this list can be added the rather recently developed technique of rapid prototyping, that is to say, the direct creation of physical models from CAD data.

5.3.1 Still Images

For the first few decades of the discipline the majority of presentations were in the form of still images, mainly because that was the limit of the capabilities of the systems of the time. Computer-generated perspective images are very similar to hand produced versions; they are essentially two-dimensional simplifications of three-dimensional real world objects. It should be noted, however, that computer-generated images are perspectivally correct by default, unless of course this feature has been consciously overridden, and in this respect they are a considerable step forward from the exaggerated and unrealistic viewpoints often seen on manually produced perspective images. It is perhaps correct to say that still images are of greatest use in the context of academic research where there is no specific need to impress a lay audience. They also provide an obvious vehicle for the examination of inherently two-dimensional building elements such as frescos and murals (Lange 1996:1-11; Lupone and Lucet 1995:245-248; Zarifis 1999:55-57).

5.3.2 Animations

The development of animated walk-throughs of the historic built environment is an alternative to the presentation of still images. The techniques involved are typically not too dissimilar from those used in creating a traditional cartoon: a series of individual still images are displayed at an adequately high frame rate to give the

Fig. 5.6 Views from a flythrough of Dudley Castle
(from Boland and Johnson 1996)

impression of fluid motion. In this respect, all but the simplest and most trivial of animated sequences can be significantly resource and labour intensive, a situation that is unlikely to change in the foreseeable future: the technological determinism that underpins the discipline ensures that, as the capabilities of the technology increase, so do the demands placed on it by its users. Because of this, computer-generated architectural animations have traditionally been restricted to a few minutes' duration at the most, and are usually incorporated into larger multimedia or video presentations.

A characteristic of the sort of animation we have been discussing is that there is no scope for the viewer to dynamically interact with what he is shown. This is not necessarily a failing in this approach; the viewer is not asked to expend any effort, and consequently a pre-programmed animation is much more accessible than a sequence where user interaction is required. According to Boland and Johnson

(1996:229):

> For general presentation of a computer reconstruction many people are simply happy to watch a 'flythrough' video without any element of interaction required on their part. This is by far the easiest method of presentation and when well produced and allied with commentary can be extremely informative within a short space of time.

Animations are, therefore, most useful in situations where the primary objective is to impress the viewer and perhaps disseminate superficial information to the casual observer (Fig. 5.6). Nevertheless, animated sequences can also be very profitably used in an academic context, especially in visualising buildings and environments where the notion of the route and ritual movement is of importance. This is emphasised by Forte and Silliotti (1997:32):

> Until now, though, all the systems of representation used for architecture have taken into consideration only the three traditional dimensions, ignoring a fourth element that relates to the sequential movement of the viewer's angle of vision over time. In order to experience and interpret the interior of a building, we need to be present within it and also to move within it. It is only by moving within the building, observing it from all points of view, that we ourselves create the fourth dimension, that of time.

5.3.3 Virtual Reality

An altogether different approach to presenting historic buildings is represented by the use of Virtual Reality (VR) techniques. The aim here is to remove the human-computer interface altogether, and to have the user (not the viewer, in this case) carry out natural movements within a simulated environment in order to generate appropriate reactions from the machine. These reactions usually take the form of images rendered in real-time, although they may include other sensory signals such as sound and force feedback. Much has been written about the application of VR technologies to virtual architectural reconstruction (Bertol 1997:131-137), but a lot of what is discussed is not necessarily VR – there is a widespread tendency to use the term to describe *any* computer-aided presentation format, a case in point being the examples presented in *Virtual Archaeology* (Forte and Silliotti 1997), very few of which involve any form of real-time human-computer interaction in an immersive environment.

Fully immersive systems represent the common perception of VR technology as a whole, and indeed, this was the model envisaged by Ivan Sutherland, the originator of the concept (Heim 1995:269). Such systems generally involve the projection of images onto some form of head-mounted display (HMD), with the user being fully encased, so to speak, in an imaginary world. It is worth noting, however, that there are still a number of significant issues that have to be addressed in a convincing manner before this technology can be adopted on a wider basis (Boland and Johnson 1996:229):

> It may be argued that Virtual Reality (VR) in its fully immersive form has by far the most potential as a medium for interpretation – the ability to place yourself within an artificial environment where you can see, touch and hear the world as it once was is truly exciting. However, its current complexity and expense allied with the fact that VR is essentially an individual, rather than group, experience makes its use in a museum setting problematic.
>
> VR hardware is expensive, cumbersome to wear, image quality is low, and perhaps worst of all as far as a museum type of application is concerned a high level of manual dexterity is required. Even after a period of training it is still easy to find yourself 'trapped' within an imaginary wall or floor, or flying off a balcony into a black abyss.

A further concern with HMD-based system is that they do not offer high levels of peripheral vision, a factor that seriously limits the user's ability to judge horizontal distances. Additionally, due to the generally low quality of HMD images, it can be difficult for the user to differentiate between objects in the foreground and those in the background (Strothotte and Strothotte 1997:296).

A variation on the notion of total immersion in a completely artificial environment is represented by the concept of *augmented reality*, where the real world is interpreted, so to say, through the computer system. A well-known example of this technology is the head-up display (HUD) used in modern fighter aircraft, a mechanism that superimposes additional data onto the pilot's field of vision to enrich and extend his natural senses. Heim (1995:270) describes such a system in the following way:

> When you are flying low in an F-16 Falcon at supersonic speeds over a mountainous terrain, the less you see of the real world, the more control you have over your aircraft. A virtual cockpit filters the real scene and re-presents a more readable world. In this sense, VR preserves the human significance of an overwhelming rush of split-second data. In such cases, the simulation is an augmented rather than a virtual reality.

It is not difficult to see the potential applications of such systems in built heritage presentation. Using such a system, it would theoretically be possible to look at a ruined structure in reality, but to then have it augmented in the form of an overlaid reconstruction where it would be immediately possible to relate what is existing with what is hypothesised. For instance, Seichter (2003:451-459) describes a software prototype that employs augmented reality as an architectural design aid. However, as far as the author is aware, no such work has been carried out with respect to architectural reconstruction, but there is no doubt that such a system would be fascinating and also extremely useful, and indeed, quite close to the notion of the computer as 'mind-amplifier' put forward by such pioneers in computer graphics as Vannevar Bush and Douglas Engelbart (Rheingold 1991:68-69).

A further direction is VR applications involves the use of *low-level immersion*, where the user is not an inhabitant of an artificial world, but navigates through a screen-based visualisation using a pointing device, much as in a normal computer game. The application of low-level VR to the presentation of virtual reconstructions would address some of the issues highlighted above. Such a system is not restricted to being a personal experience, but can be extended to a group, perhaps under the control of a properly trained guide. Thus the user is not required to concern himself with his technical ability or manual dexterity, and input can be restricted to a minimum, as was done at the Virtual Tour at Dudley Castle: "the user has only to make simple left, right or forward travel decisions via one of the three large pushbuttons to find that they are guiding themselves through the reconstruction, helped by commentary pertinent to the path they are on" (Boland and Johnson 1996:229). A further interesting example of the low-level immersion approach is documented by Grant and Paterson (1997), who describe a virtual tour of the Neolithic village of Skara Brae, Orkney, using the commercially available QuickTime VR on-screen software to navigate through the archaeological remains. Although the tour does not involve a complete reconstruction of the village, it does, however, enable the viewer to place and visualise various artefacts, found on site and then subsequently moved to museums, in their original context. Due to its cost effectiveness and non-dependence on sophisticated hardware and software, low-level immersion of this type is fairly common in virtual heritage applications. However, the downside of the technique, obviously, is that the user is constantly aware of the artificiality of the presentation, mainly due to the lack of adequate peripheral vision on a flat screen. Curved screen and head-tracking systems have been developed to deal with this issue, but as yet such mechanisms remain expensive and restricted in their applications.

5.3.4 Rapid Prototyping

A further recent development in architectural visualisation which has numerous potential applications in historical research is that of *rapid prototyping*. This term refers to a series of related technologies that have the common objective of creating physical three-dimensional models directly from CAD data sources with no, or at least minimal, human intervention in the fabrication process. While computer-aided manufacturing (CAM) technologies are not especially new, they have generally been restricted to creating objects in a subtractive fashion using stereolithography, such as, for example, by milling steel to create automotive components. Although this method of object creation has by no means been superseded, the main advantage represented by some of the newer techniques is that fabrication usually takes place in an additive manner employing so-called 3D printers, where progressive layers of material are used to create forms that would be simply impossible to create in a subtractive way. Rapid prototyping technologies are still very much in the experimental stage in the context of architectural visualisation, although one of the main proponents for their use is the Los Angeles based firm of Frank Gehry. As Sheerin (2005) points out:

> Frank Gehry has been intimately involved in pushing the envelope of CAD use in architecture for the past decade, eschewing architecture-specific CAD software for Dassault's CATIA. The ability to create multiple iterations of buildings throughout the design process is critical to allowing computers to enable the design methods Frank has practiced for the past 40 years

The main advantage to Gehry and similar architects in the use of rapid prototyping is that it enables them not only to visualise the complex forms of their designs, but also to form a direct link with the manufacturing process, where the individual building components are created directly from CAD models. Sheerin (2005) explains this aspect of the rapid prototyping process as follows:

> … rapid prototyping is making huge changes in how the company works. Long before any computers were a part of architecture, Frank Gehry relied on physical 3D models as his primary design tool. Thus, using advanced 3D modeling tools and outputting the results via RP tools is about the only sensible way to make computer-aided design work in the firm. Trying to transfer complex, hand-built 3D models into 2D paper drawings was nearly impossible – not to mention having the actual

buildings constructed properly based on them.

The question of creating physical building components does not necessarily arise in the disciplines of architectural history and archaeology (although the use of rapid prototyping could offer a very effective tool in building conservation). The main issue, especially in the context of this thesis, is how to create spatially coherent visualisations in a manner that can show the likelihood of uncertainty and multiple interpretations. This has not always been an achievable objective with hand-made physical models, not least because of the cost and labour involved in creating individual representations to illustrate different possibilities. It is here that rapid prototyping offers a very real advantage over traditional physical models. It is possible, without undue effort, to create a series of reconstruction models to illustrate varying hypotheses; the fact that these are real 3-dimensional objects effectively addresses the questions of immediacy, spatial coherence and comprehensibility. In his article on rapid prototyping Sheerin (2005) explains these advantages in the context of general design visualisation, but what he says is eminently applicable to the illustration of architectural reconstructions as well:

> The automated prototyping machines produce far more accurate models that can be replicated many times if needed – at a lower cost, in less time. Why tie up an intern for three months cutting balsa wood and Styrofoam when a machine can build the same model in three hours? Besides, the errors and fudging introduced by the manual process of interpreting 2D plans can render a hand-built model less than useful or aesthetic. Since a complex model can be made in hours or days, it can be used for more than just the final design model.
>
> One recurring theme I heard from nearly all those I interviewed for this story was that, unlike the mechanical engineers who can readily understand 2D drawings and 3D renderings, many of the people involved in architectural and civil engineering design – such as the clients – are not technical people trained to interpret 2D images; they require physical 3D models to completely understand the design.

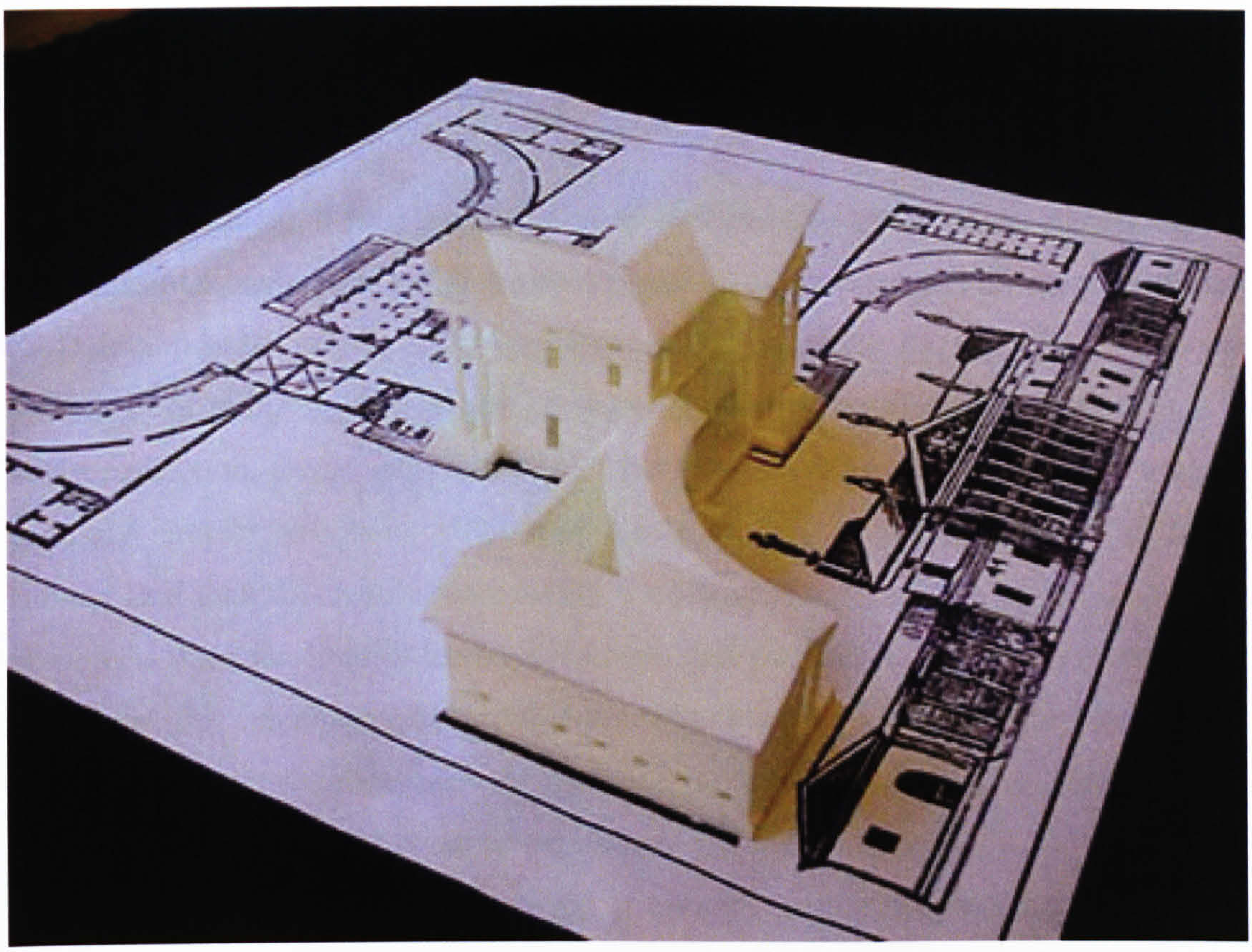


Fig. 5.7 Using rapid prototyping to analyse Palladio's unbuilt designs (from Sheerin 2005)

Sheerin (2005) goes on to provide evidence of the advantages of the use of rapid prototyping in architectural historical research by citing the example of Larry Sass, a PhD candidate at the Massachusetts Institute of Technology studying the unbuilt works of the 16th century architect Andrea Palladio (Fig. 5.7). In addition to claiming that the use of highly accurate scale models offered Sass distinct advantages over the use 2-dimensional images and renderings, Sheerin (2005) also indicates that:

> Sass started to think in much more detail about wall thickness, column construction, down to the detail of how many bricks should be used in different features. This changed his perspective about architecture from one focused on how buildings look to one also concerned with how they go together. Sass says some of these things just can't be understood without actually building them. Holding real objects in your hand will

give you a much clearer understanding if they can actually stand on their own, and if the pieces will fit together as you envisioned.

The majority of rapid prototyping systems that are available today operate on the principles of Constructive Solid Geometry, and as a consequence, all the preliminary CAD data must be created and manipulated in this particular form. While this has the advantage of obliging the creation of spatially coherent models, in some ways it is also a restriction, for, as we shall see in Chapter 6, there are certain forms which are certainly simpler and more straightforward to model in surface than solid form. Having said that, this restriction of sorts is nothing if not logical – in the real world all objects must necessarily have a thickness, and surfaces, in the sense that they do not have this characteristic, could not theoretically exist outside the virtual environment of a computer model. It is also worth noting that current stereolithography and 3D printing techniques are not really capable of representing such effects as realistic surface textures or colours, in that they are restricted by the nature of the modelling material. As a consequence, rapid prototyped models would typically require some sort of hand finishing if they are to be used as presentation tools. Having said that, it is only to be expected that such issues as the representation of textures and colours would be addressed during future stages of the development of architectural rapid prototyping.

In spite of its obvious advantages as a representational and analytical tool, the main obstacle to the widespread adoption of rapid prototyping in architectural applications remains the cost of the equipment. As a consequence, much of the work in this field is currently restricted to research centres and universities. It is interesting to note, however, that until fairly recently, paper plotters required a significant financial outlay, but are now so widely available and economically viable as to be hardly an issue worthy of concern. If this is any indication of the way things work, there is a real possibility that we may see affordable and manageable rapid prototyping equipment being used on a wide basis in the visualisation and critical analysis of architectural reconstructions.

6

Conjectural Reconstruction of Sant Vicenç de Cardona

As we have seen in the foregoing discussion, computer simulations are generally used in architectural history and archaeology to replace traditional manually produced perspectives or physical models – in other words, to give an idea of what a building may have looked like at a certain time in history. They are often used in situations where the ultimate goal is to communicate a general impression to the layman or casual inquirer, for example, in displays in museums and in television programmes on popular archaeology. The underlying aim is generally to produce visually alluring images and animations, and the vast potential of computer modelling as an aid in the interpretation and evaluation of historic buildings is often left largely untapped. Many reconstructions of buildings and sites are pictured as 'definitive', when, in fact, there might not be enough evidence to come to any concrete conclusions. It is also rare to see any attempt made to represent the fact that buildings tend, in the course of their lifetimes, to grow, shrink and otherwise change to accommodate the needs of users or as a result of circumstances (Ryan 1996:95). While these self-imposed limits are perfectly valid where the main impetus is commercially driven public entertainment, there is an equally valid case for approaching the subject from a theoretical standpoint where the ultimate purpose is the production of rigorous and academically sound results.

This chapter describes the way in which computer models were used to test a number of architectural hypotheses based on evidence found in the fabric of an existing historic building, the goal being to examine whether the building as originally conceived might have been significantly different from what is visible today. The subject of the project was the church of Sant Vicenç de Cardona in Catalonia, carried out in the context of wider research into the building by Professor Peter Reed, which is published separately.

6.1 Historical Background

Sant Vicenç de Cardona has been identified as an extremely important building within the context of medieval architecture in general, and of the Romanesque in Catalonia in particular. It has as a consequence received the attention of a number of architectural historians from the late 19th century onwards. Reed (2002a) summarises the historical background of the church as follows:

> The collegiate church of Sant Vicenç de Cardona is recognized by architectural historians as the foremost example in Catalonia of what has been called the First Romanesque style. What has particularly interested them is that in Sant Vicenç we have one of the earliest church buildings in western medieval architecture in which the articulations of the ground plan are carried up in a consistent and logical way into the vaulting system – the implication being that the whole construction was prefigured in the setting-out of the plan. Sant Vicenç has thereby been seen to anticipate the structural rationalism of later Romanesque and Gothic architecture.
>
> In Sant Vicenç the connections between plan and vault are most impressively demonstrated within the nave, where the transverse arches compartmentalizing the barrel vault are seen to be continuations of giant orders that rise from ground level through the full height of the interior elevation ... But there is compelling evidence that what we see here is, in fact, not what was originally intended when the plan was laid out and that during the construction there was a significant change in the direction of the scheme. At ground level the giant orders start with a two-stepped profile but the outer steps stop abruptly not far above the nave arcade [Fig 6.1]. It is only the inner stages that are continued upwards to carry the transverse arches. Furthermore, at the east end of the nave there is an opening just below the vault that is most likely to have been intended as an external window [Fig. 6.2]. The conclusion is that at some stage in the

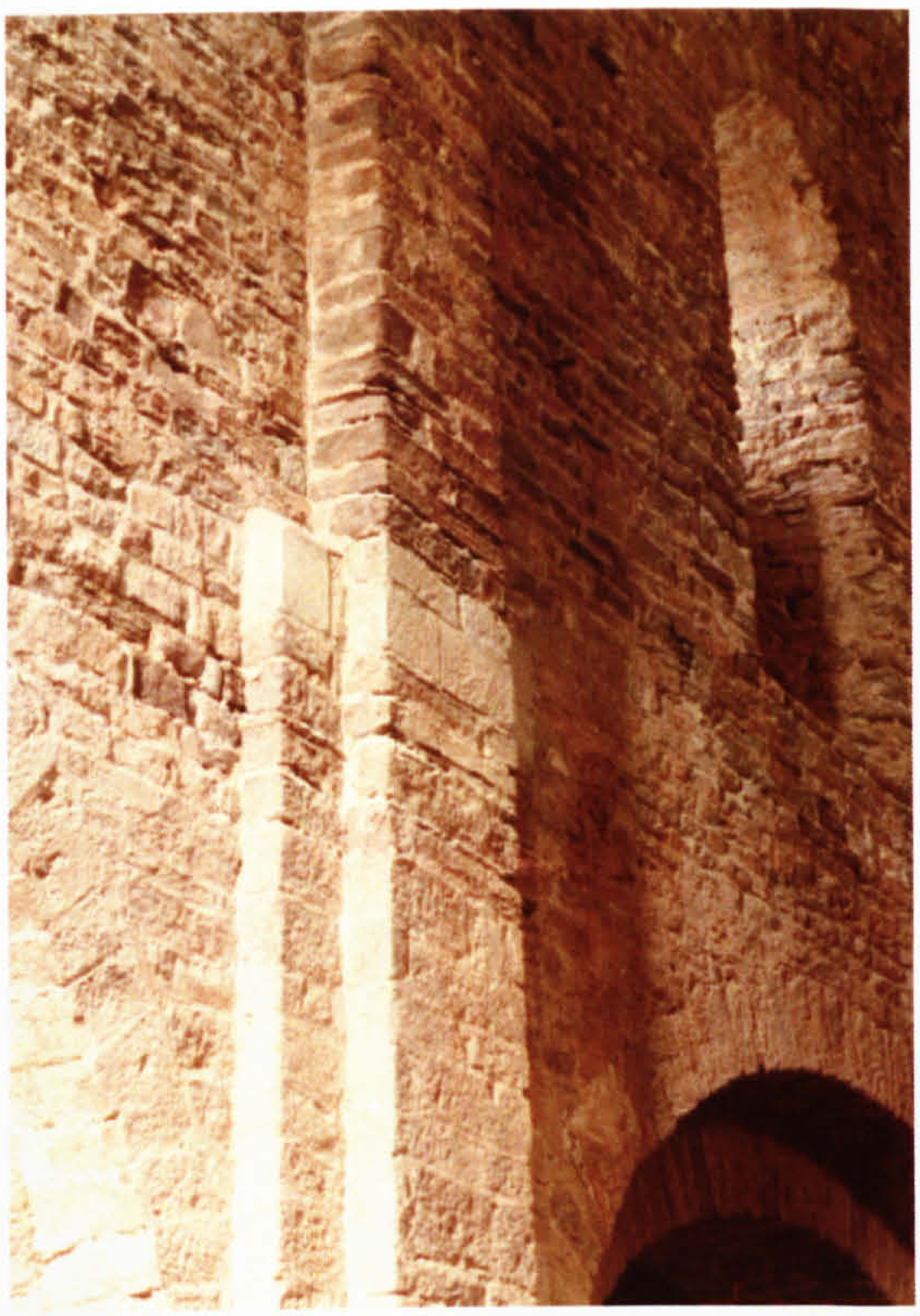


Fig 6.1 Giant order detail in nave (courtesy of Peter Reed)

Fig 6.2 Nave vault and clerestory (courtesy of Peter Reed)

building campaign the decision was made to make the vault at a higher level than was first intended to allow clerestory lighting to the nave. Sant Vicenç was begun in (or shortly after) 1019 and dedicated in 1040. Some have argued that these years encompassed the construction of the whole building but it is possible that by the time of the dedication only the eastern parts of the church had been completed. To the west construction may have proceeded only up to the level at which the two-step profile of the giant order is maintained. It was probably some time not long thereafter that the building was finished, the nave with the high vault that we see today.

It is of considerable interest to conjecture what form may have originally been intended for Sant Vicenç. This could have some bearing on its place in the development of medieval architecture and, as importantly, might also suggest possibilities for the sources of its design. Various models

Fig 6.3 External view showing apse at east end (from Barral i Altet 2001)

> using barrel vaults over the nave were constructed by computer in the Department of Architecture and Building Science of the University of Strathclyde and the results were incorporated in an article published in the Journal Architectural History … [subsequently reproduced in *Lambard: Estudis d'Art Medieval*]. This, in turn, prompted a suggestion from T.A Heslop of the University of East Anglia that since the groin vaults are used in other parts of the building (the crypt, aisles, and narthex) the nave could have been intended for groin- rather than barrel-vaulting.

Sant Vicenc is essentially a basilican church on an east-west axis with two groin-vaulted aisles, a nave and a barrel-vaulted clerestorey which allows the nave to be lit from above. Two shallow transepts project either side of the crossing which is crowned by an octagonal lantern. To the east, the building is terminated by a semicircular apse (Fig. 6.3). The modelling exercise described here concentrates only on the aisles, nave, clerestorey and crossing, as the rest of the building is not particularly relevant to the main hypothesis. The two main aims of the modelling project were to investigate ways in which the nave of Sant Vicenc could have been groin vaulted, and to test the hypothesis that the existing clerestorey windows were originally conceived as part of this system of groin vaulting.

6.2 Sources and Previous Work

The main source of information on Sant Vicenç was quite obviously the building itself. It still stands in a fairly unaltered state apart from the loss of most of its internal murals, a reminder of its use as an armoury during the Napoleonic Wars. However, due to the nature of the project and the cost (and time) implications, it was not viable to carry out a full site survey, although this would doubtless have been ideal to gather first-hand dimensional data. While a few figured sketches of the nave were in fact available, they were inadequate to provide anything apart from a very rough idea of the principal dimensions. Having said that, even a few accurately measured sketches provide an invaluable set of control dimensions against which the consistency of secondary sources can be measured. In this case, however, it was necessary to resort to the use of information sourced from elsewhere, comprising mainly drawings and photographs in publications.

One of most influential measured surveys of Sant Vicenç is to be found in Josep Puig i Cadafalch's *L'Arquitectura Romànica a Catalunya*, the three volumes of which appeared between 1909 and 1918. These drawings are not particularly suitable for our purposes, however, in that the plan and axonometric projection are quite obviously incorrect and mutually inconsistent (Fig. 6.4). This may perhaps be due to the fact that Puig i Cadafalch was unable to see the entire building at once, for at the time the interior had been divided into three makeshift storeys (a consequence of the role played by Sant Vicenç as an armoury). As Reed (2000:28) explains:

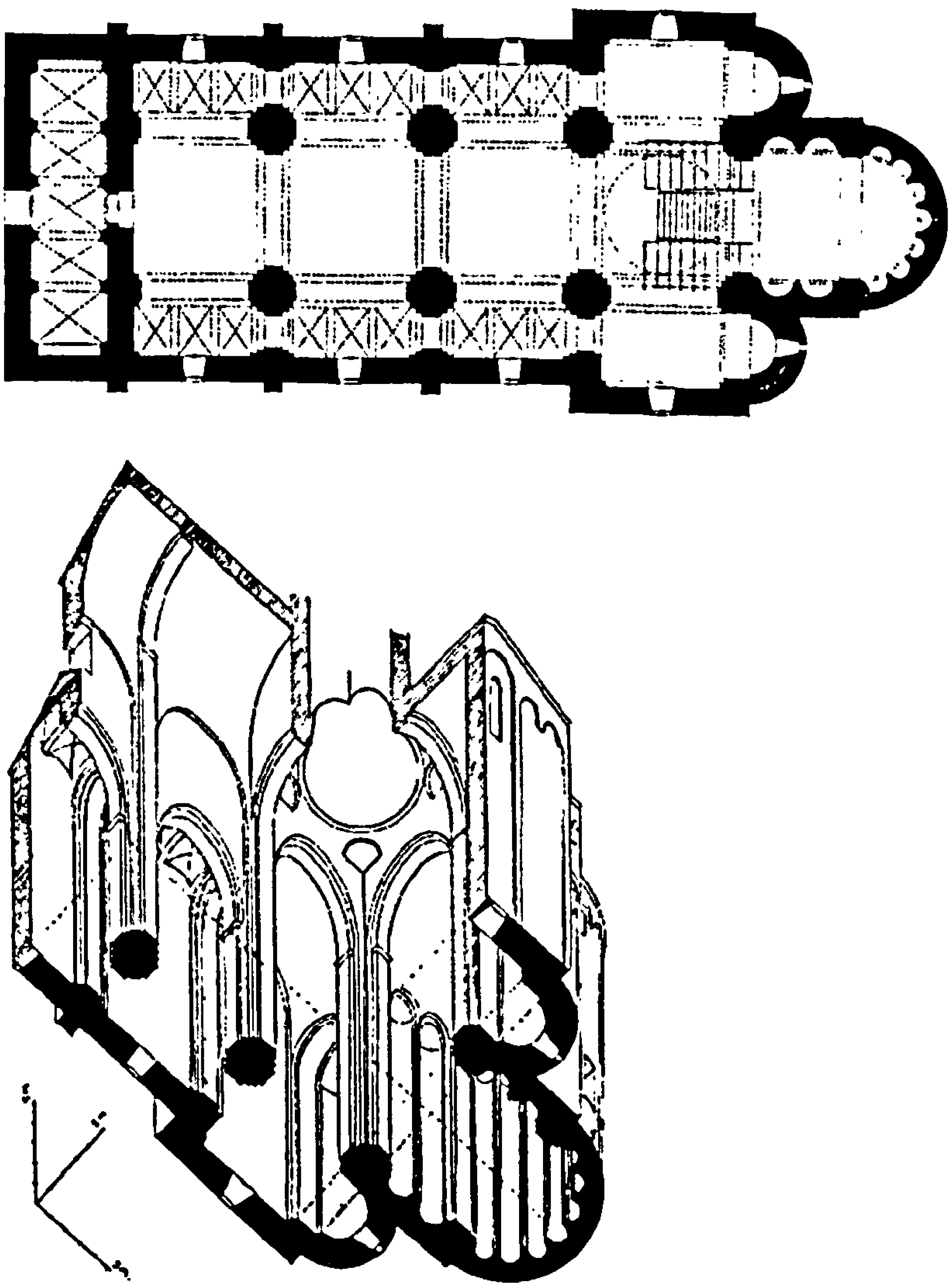


Fig 6.4 Plan and sectional axonometric of Sant Vicenç de Cardona from *L'Arquitectura Romànica a Catalunya* (from Reed 2000)

Puig i Cadafalch's frequently reproduced plan ... indicates, wrongly, that the stepped profile from the giant order is carried up into the transverse arch, being continuous from one wall of the nave to the other. Given Puig i Cadafalch's viewing conditions, it is an understandable mistake. But what is impossible to understand is why his axonometric projection ... shows quite a different system. Here the outer steps, instead of continuing into the transverse arch as he shows in the plan, peel off and

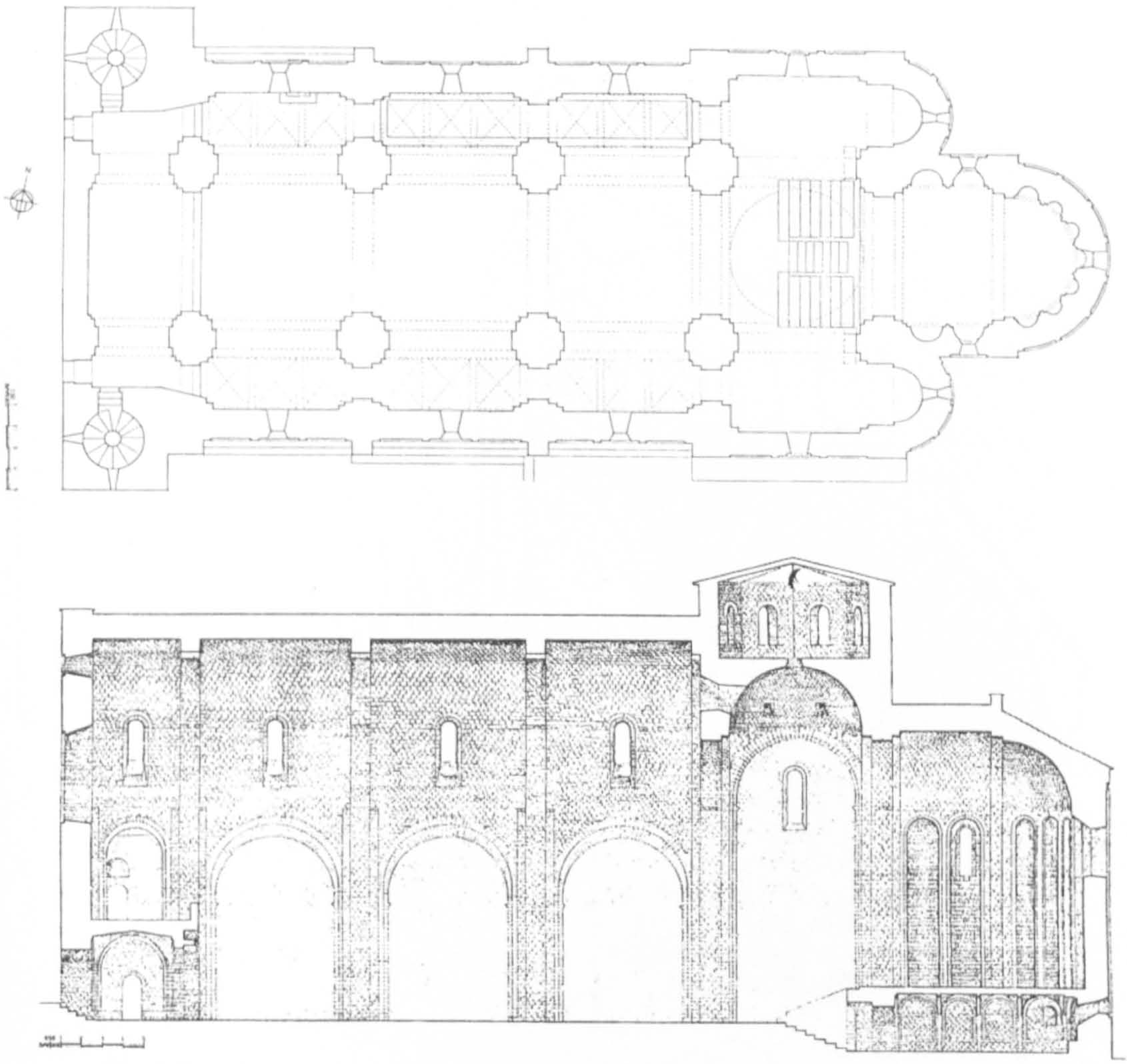


Fig 6.5 Plan and longitudinal section of Sant Vicenç de Cardona from *Catalunya Romànica* (courtesy of Peter Reed)

become wall arches, spanning from pier to pier in the direction of the nave arcade and encompassing the clerestory windows. There is nothing in the text to indicate that this drawing was intended by Puig i Cadafalch to be an hypothesis for an arrangement hidden from his view, so it may be presumed that this is what he deduced from the evidence available to him.

It is interesting, however, that numerous modern writers, including Barral i Altet (2001:26), Kubach (1975:136) and Radding and Clark (1992:13) continue to

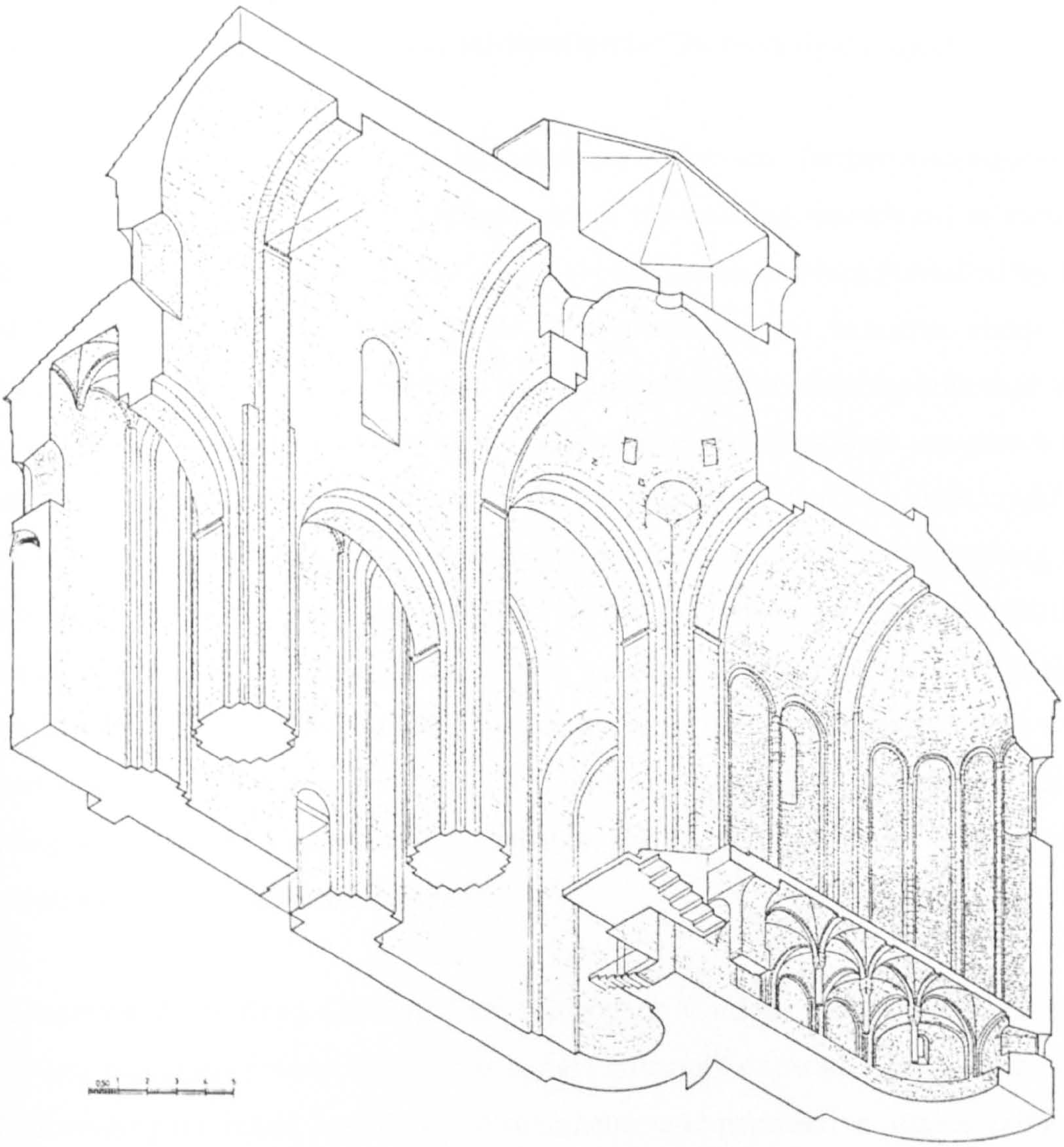


Fig 6.6 Sectional axonometric of Sant Vicenç de Cardona from *Catalunya Romànica* (courtesy of Peter Reed)

reproduce Puig i Cadafalch's drawings, along with their inadequacies, in a rather uncritical manner to illustrate Sant Vicenç, which in effect renders much of the literature on the topic of limited use as a source of accurate survey information. Fortunately however, a set of drawings based on a completely different and much more modern survey are to be found in the multi-volume review of Catalan Romanesque architecture, *Catalunya Romànica*, published in 1994. The illustrations, which are more reliable and mutually consistent than those produced by Puig i Cadafalch, include a ground plan, longitudinal section (Fig. 6.5) and cutaway worm's eye-view axonometric (Fig. 6.6), all with scale markings indicated. These drawings formed the primary source of survey information for the modelling project.

In addition to the survey drawings in *Catalunya Romànica*, further information on Sant Vicenç was to be found in photographs of the building reproduced in various other publications, most notably in the guidebooks to the building published by the Catalan Department of Culture. There were obviously no concerns about the accuracy of the photographs, but there was a general limit to their usefulness in that the viewpoints and targets chosen by the original photographers were sometimes not necessarily those that were most useful for the modelling exercise. Little could be done about this problem apart from carrying out a site visit and photographing the building in exactly the way that was best for the job, which, as mentioned earlier, was clearly impractical. In any event, it was usually possible to obtain a fairly clear idea of any one part of the building by comparing different photographs with each other and with the survey drawings. A significant number of photographs taken during an earlier site visit were also available, and these proved to be an invaluable complement to the measured drawings.

As mentioned by Reed (2002a), Sant Vicenç de Cardona was the subject of a previous modelling project carried out at the University of Strathclyde with the aim of illustrating his initial hypothesis. Axonometric and perspective images extracted from these models were published in Reed (2000), showing both the aisle as existing with a full-height barrel vault, and as hypothesised with a barrel vault lowered to an appropriate level to enable direct lighting of the crossing lantern. While the images were still available for the current project, the original models (presumably also based on the illustrations contained in *Catalunya Romànica*) were not, so it was necessary in this case to carry out the modelling process from scratch, starting from the data collection stage.

In conclusion, the source data set for the modelling project may be summarised as follows:

- Survey drawings published in *Catalunya Romànica*

- Dimensioned sketches taken on site
- Original detailed photographs
- Photographs from other publications
- Puig i Cadafalch's partly erroneous survey drawings
- Images extracted from previous computer modelling project

Obviously with such a varied collection of sources, mutual consistency was a critical issue. In addition, as all these sources were available only in paper-based format, it was necessary as a preliminary step to translate the relevant information into a machine-readable form before use in the modelling software. The ways in which these issues were dealt with will be described in due course.

6.3 Methodology

The goal of the Sant Vicenc modelling project was to produce a series of still images (cut-away worm's eye views and perspectives) to accompany a separate paper putting forward the hypothesis that the nave could have originally been conceived as single-level groin vaulted space. Most of the work was carried out on a standard desktop personal computer, a Pentium II 350 MHz with 128 Mb of RAM and 16Mb graphics card; additional work was done on a Pentium III 1 GHz with 256 Mb of RAM and a 32Mb graphics card. A range of software was used for different purposes at the various stages of the modelling process – Adobe Photoshop 5.5 and 6.0 for image manipulation, Autodesk AutoCAD 2000 for draughting and auto-des-sys FormZ 4.0 for modelling and rendering.

6.3.1 Preliminary Decisions

Before starting work on the Sant Vicenç model itself, it was important to clarify a number of issues which could have had a significant impact on the final product and the success of the project as a whole. The first of these was quite simply what was going to be modelled. As the entire project revolved around testing two conjectural groin vaulting arrangements in the nave, it was decided to construct two separate

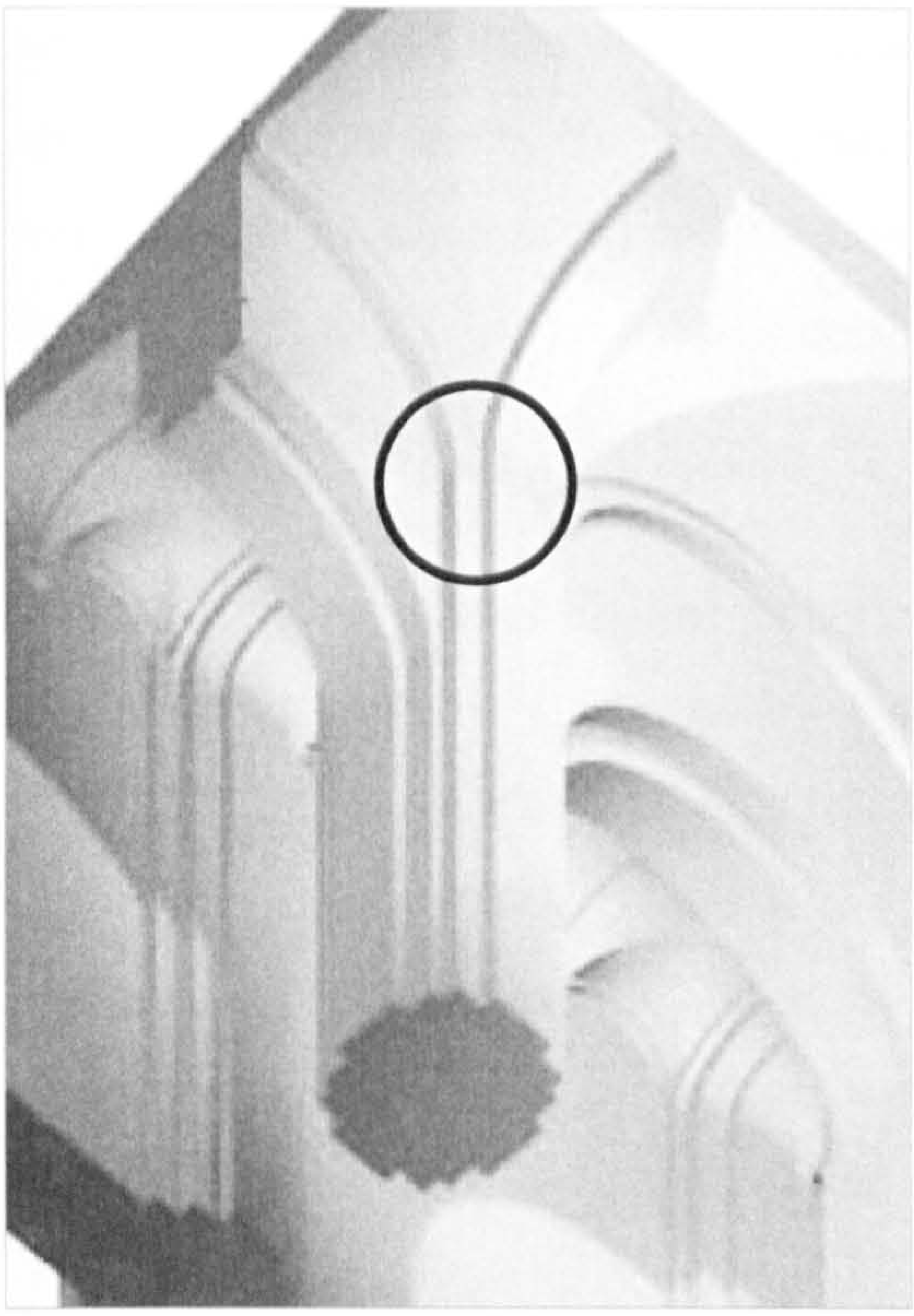


Fig 6.7 Groin vault rising between profiles of giant order

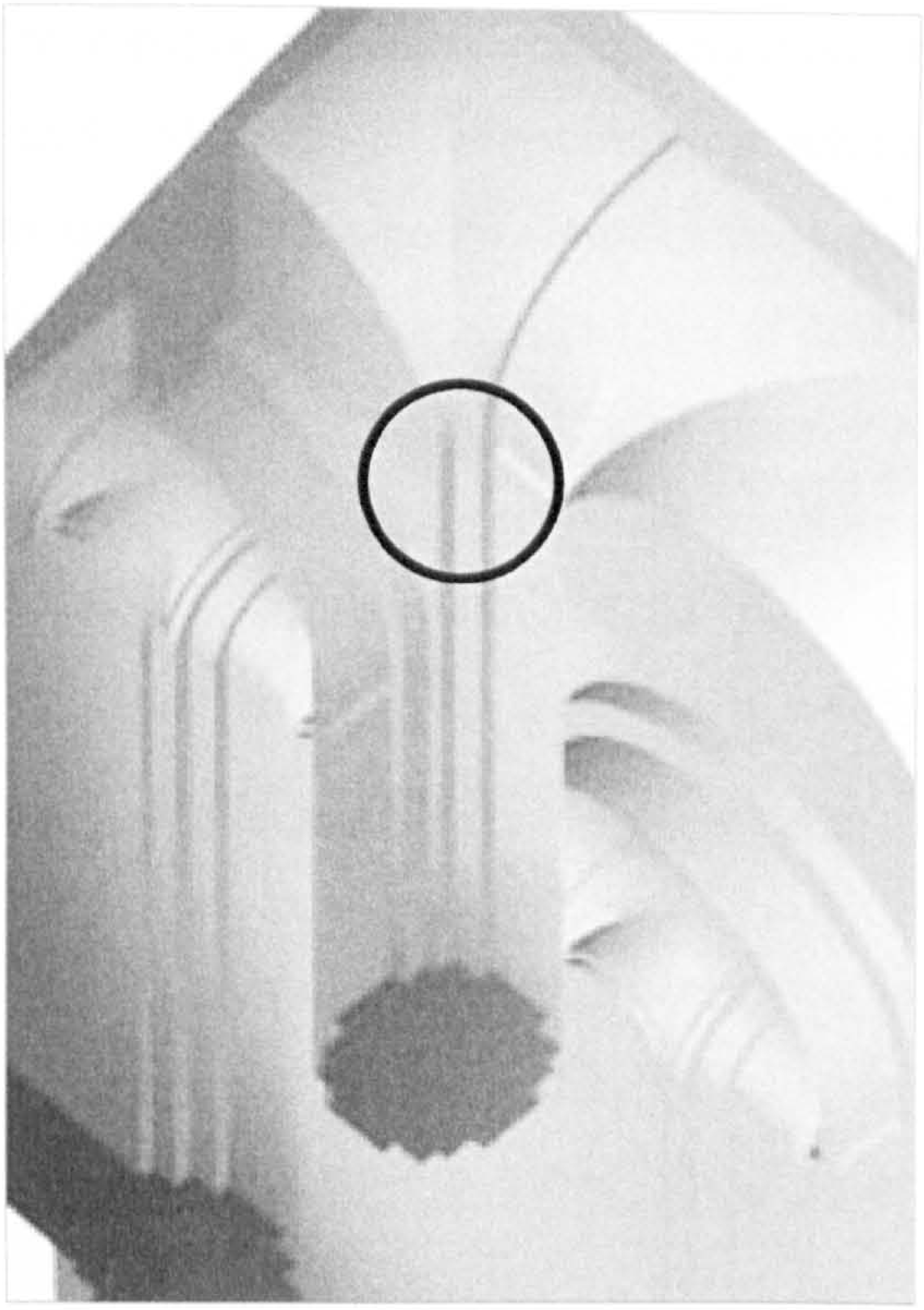


Fig 6.8 Groin vault rising from arris of giant order

corresponding models. The first model represented the groin rising unsupported from the angle between the inner and outer profiles of the giant order, with the outer order becoming a longitudinal wall arch (Fig. 6.7), while in the second the groin rises from the arris of the outer order without a wall arch (Fig. 6.8). While it would have been possible to have incorporated both arrangements in a single model, the result would have been larger, more complex, and, consequently, less manageable and robust than two separate models. It was also decided to include a model of the building as it appears today for reference and comparison. The decision was also made fairly early in the project that there was no imperative to model Sant Vicenç in its entirety, as the western part of the building was extraneous to the hypothesis being tested, and as a result, all three models cover only the crossing, transepts, chancel and one and a half nave bays.

Another decision that was made quite early on in the project related to the way in which the Sant Vicenç models were going to be presented. As the models were aimed at providing illustrations for an academic paper, the most obvious method of presentation was in the form of rendered inverted sectional axonometrics, which would reveal as much of the nave vaulting as possible. This had a significant impact on the way in which the model was constructed. For example, a greater level of detail could be incorporated, since there was no need to render vast numbers of frames at high speed, as would have been the case had the requirement been for an animated walkthrough or virtual reality experience. That said, there was little logic to incorporating extremely fine modeled detail due to the fact that much of it would simply not be visible when the illustrations were finally presented.

The final issue that was clarified at an early stage of the modeling process was to determine the best way to extract sectional axonometrics from the Sant Vicenç models. While formZ includes a clipping plane tool to enable sectional views to be taken through a model this technique does not work where the clipping plane is not parallel to the picture plane, as in the case of an axonometric. It was therefore decided to make the models literally in sectional form, and hence avoid the use of clipping planes.

6.3.2 Data Translation

Ryan (1996:97) describes computer-based modelling as essentially a two stage process, the first involving creating the model itself, followed by processing the model to produce a visible image of it, i.e., rendering the model. It is perhaps just as true to say that it is usually a three stage process, with the addition of the preliminary preparation of source data. Therefore, the first step in the modelling process was to convert the survey drawings of Sant Vicenç into a machine-readable format for use with draughting and modelling software. There were a number of ways in which this task could have been carried out. The method adopted here, in many ways the simplest and most straightforward, was to scan the drawings using a flatbed scanner, resulting in a series of TIF image files corresponding to each of the projections. As the TIF files were of a fairly substantial size the files were converted into JPG format, with the loss of some detail, but with a notable decrease in file size. Only the

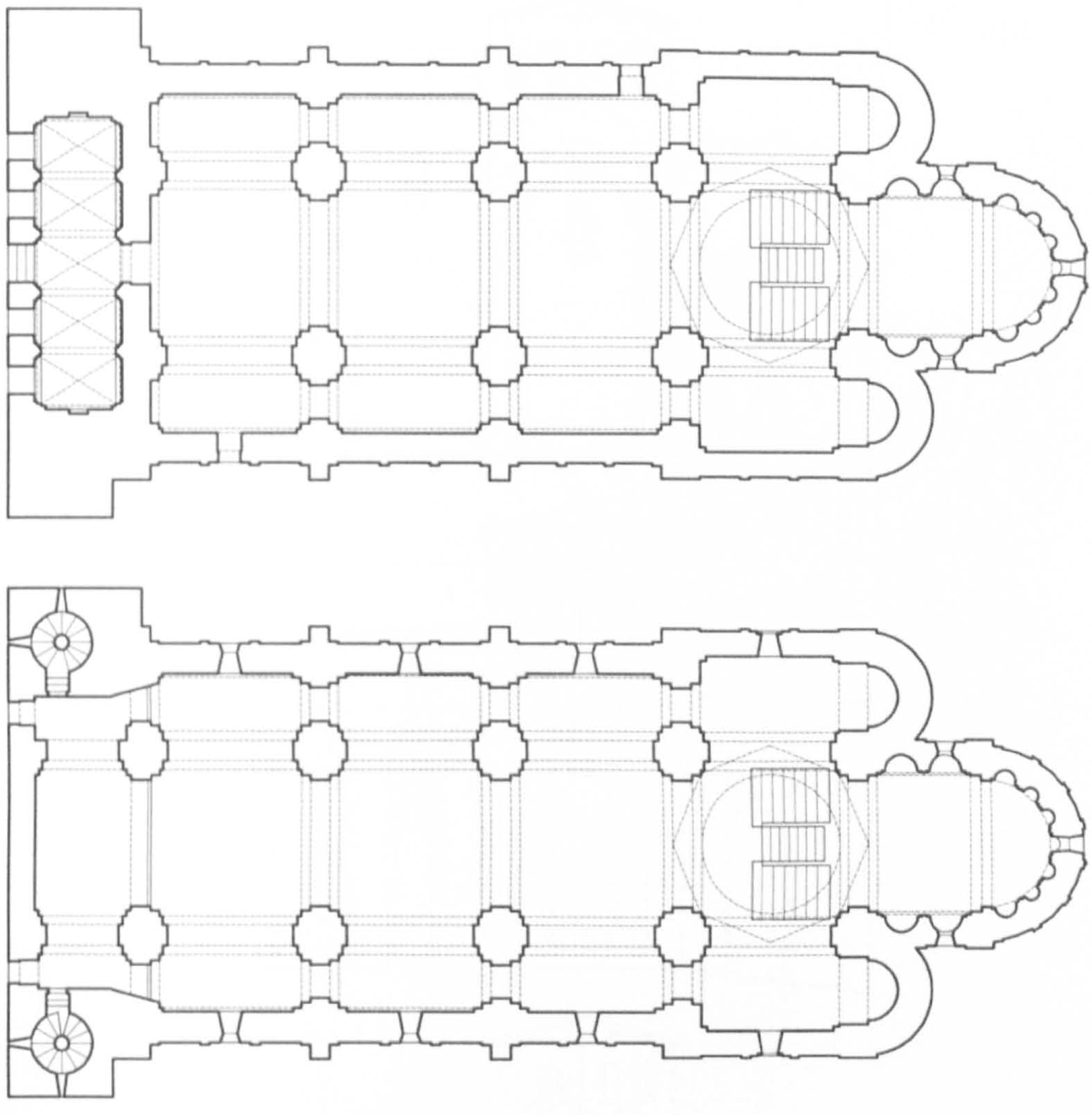


Fig 6.9 CAD plan drawings of Sant Vicenç de Cardona, lower level (above) and conjectured upper level (below)

plan and section were scanned, as there was little point in making a digital version of the axonometric drawing. The image files were then imported into AutoCAD and virtually 'traced' with a mouse, much as would be done traditionally using tracing paper on a drawing board. The result was a series of editable vector files of the individual raster images, achieved, admittedly, with a considerable amount of manual work and at the risk of introducing minute distortions to the original information.

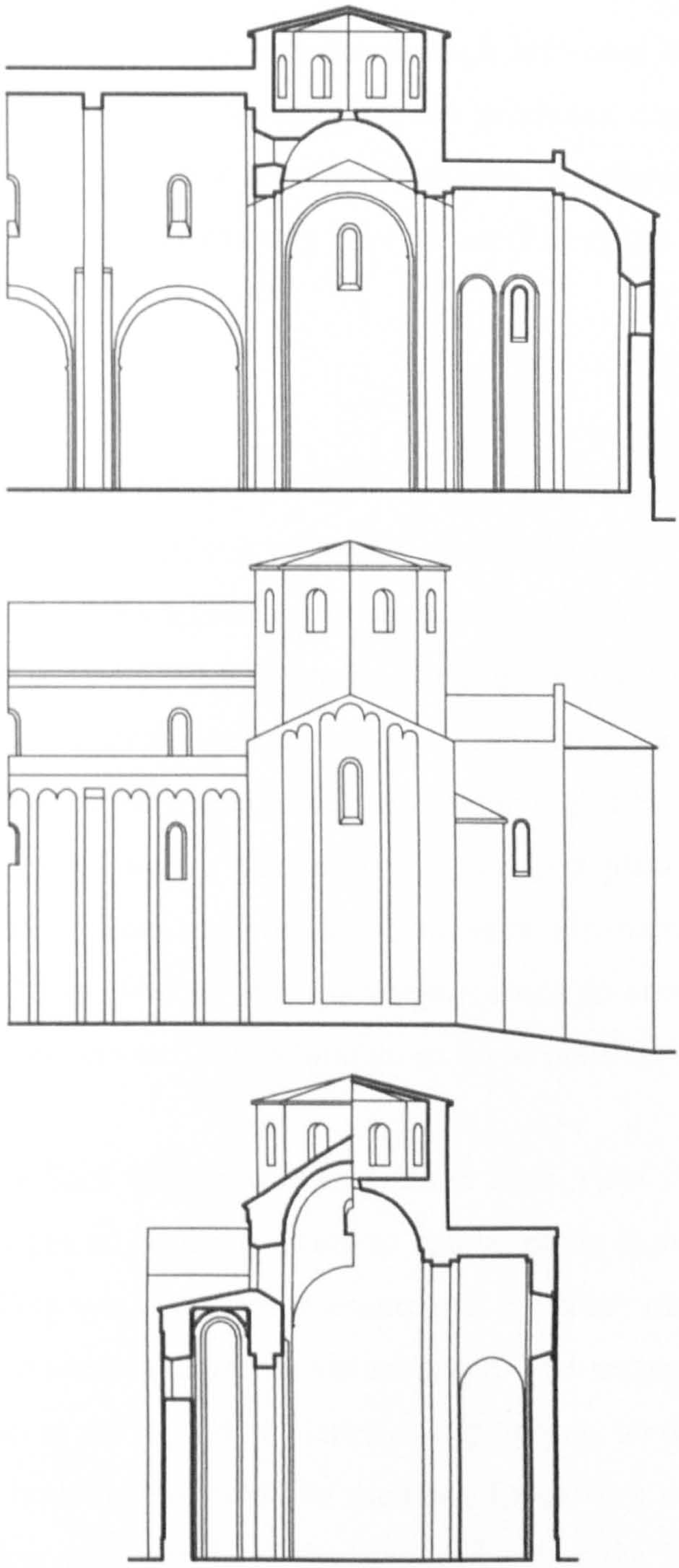


Fig 6.10 CAD sections and elevations of Sant Vicenç de Cardona, long section (top), south elevation (middle) and cross sections (bottom)

The procedure described above resulted in digital versions of the plan of Sant Vicenç (Fig. 6.9). It was, however, decided that the modelling task would be considerably eased if a set of longitudinal and transverse (cross) sections were to be available as well. While this information did not exist in the main source of information, it was nevertheless possible to construct the sections through inference from the available drawings and photographs. The transverse sections produced comprised a section through the crossing and a section through the nave. Furthermore, an external elevation was also drawn using the existing information (Fig. 6.10).

6.3.3 Modelling

The most straightforward and logical system to model Sant Vicenç involved the use of constructive solid geometry (CSG), although, as will be noted later, there were areas of the building where this approach did not produce the desired results. On the whole, however, the standard CSG procedures of extrusion and Boolean operations (addition, subtraction and intersection) proved to be completely adequate for the task at hand. CSG models are on the whole robust and versatile, and by representing each building element as a solid with a thickness and not as a plane, they are closer approximations to reality than models based on such alternative techniques as meshes and surfaces (Ryan 1996:97-99). For these reasons an attempt was made to confine the modelling process to CSG techniques as far as possible.

The vector drawings of Sant Vicenç were transferred from AutoCAD to formZ, and the plan was carefully placed on the *xy* plane so that an easily identifiable point was at the origin (0,0,0). This was important to ensure that the entire model was properly referenced, and not randomly situated in virtual space. The sections were precisely placed around the plan in the *zx* and *zy* planes as appropriate, so that in effect there was a skeleton of the building that could be used as a framework for the model (Fig. 6.11). Using the section as an accurate reference for heights, the vector polylines of the plan were then extruded to the required height in the *z* axis. Where required, critical dimensions were manually checked against the original drawings to ensure that there were no glaring errors that could seriously compromise the model at a later stage. Obviously it was not necessary to model every single part of the building individually, as objects could be copied to create arrays of identical objects where required. Openings were made by using the extruding the sectional profiles, moving

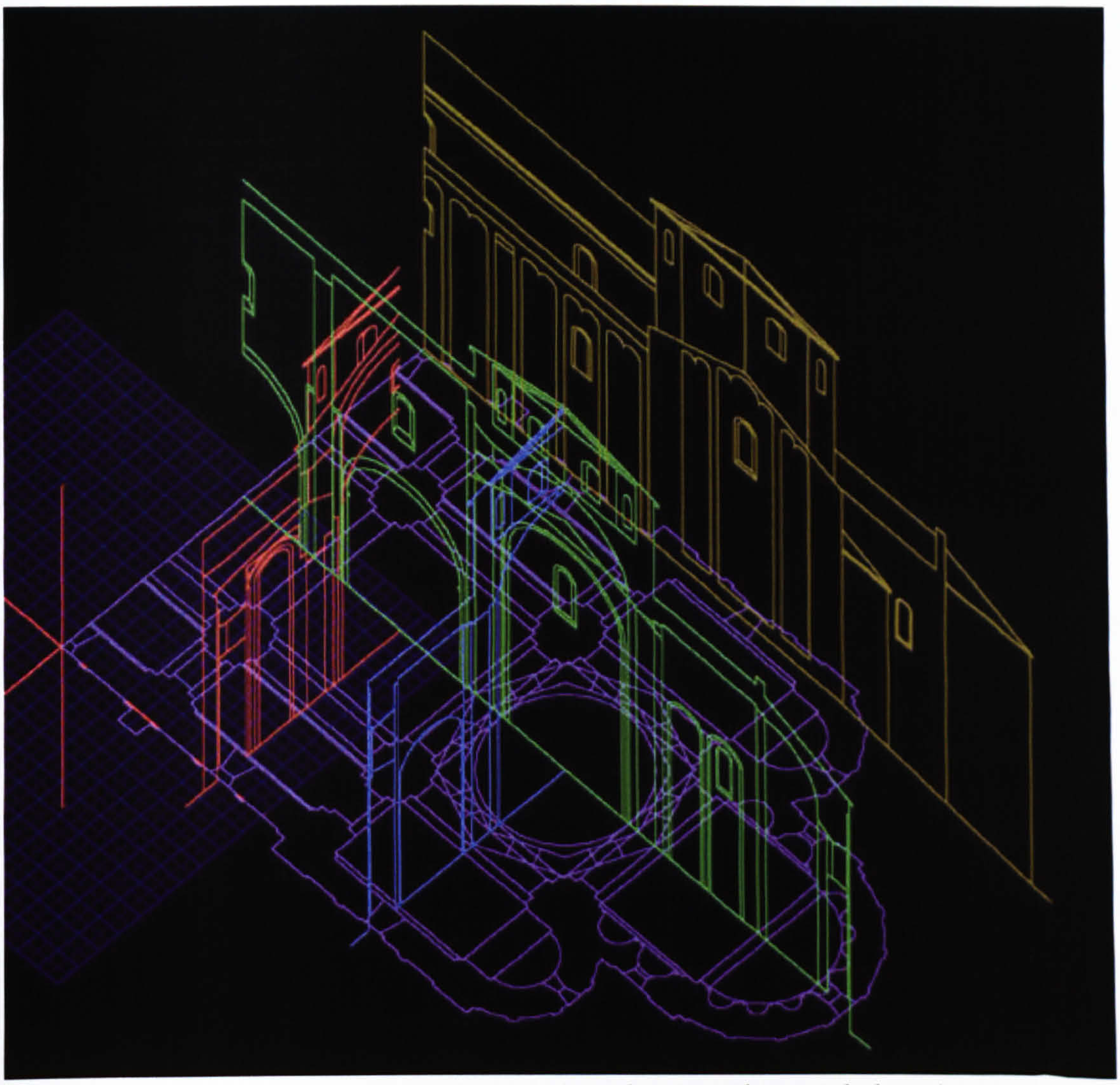


Fig. 6.11 3-D skeleton incorporating plans, sections and elevation, used as a framework for the computer model

the resulting object to intersect the appropriate wall at the correct position, and applying the Boolean operation of subtraction. Where required the resulting shapes could be further edited by transforming them on a topological level (by moving or deleting individual points, line segments, faces, or a combination of all three). Effectively the entire wall structure of Sant Vicenç was modelled in this way using CSG with slight variations as required. The result was a model that could almost be regarded as a sculptural representation of the original building in that no information was contained on the interstitial areas of the structure (Reilly 1992:150).

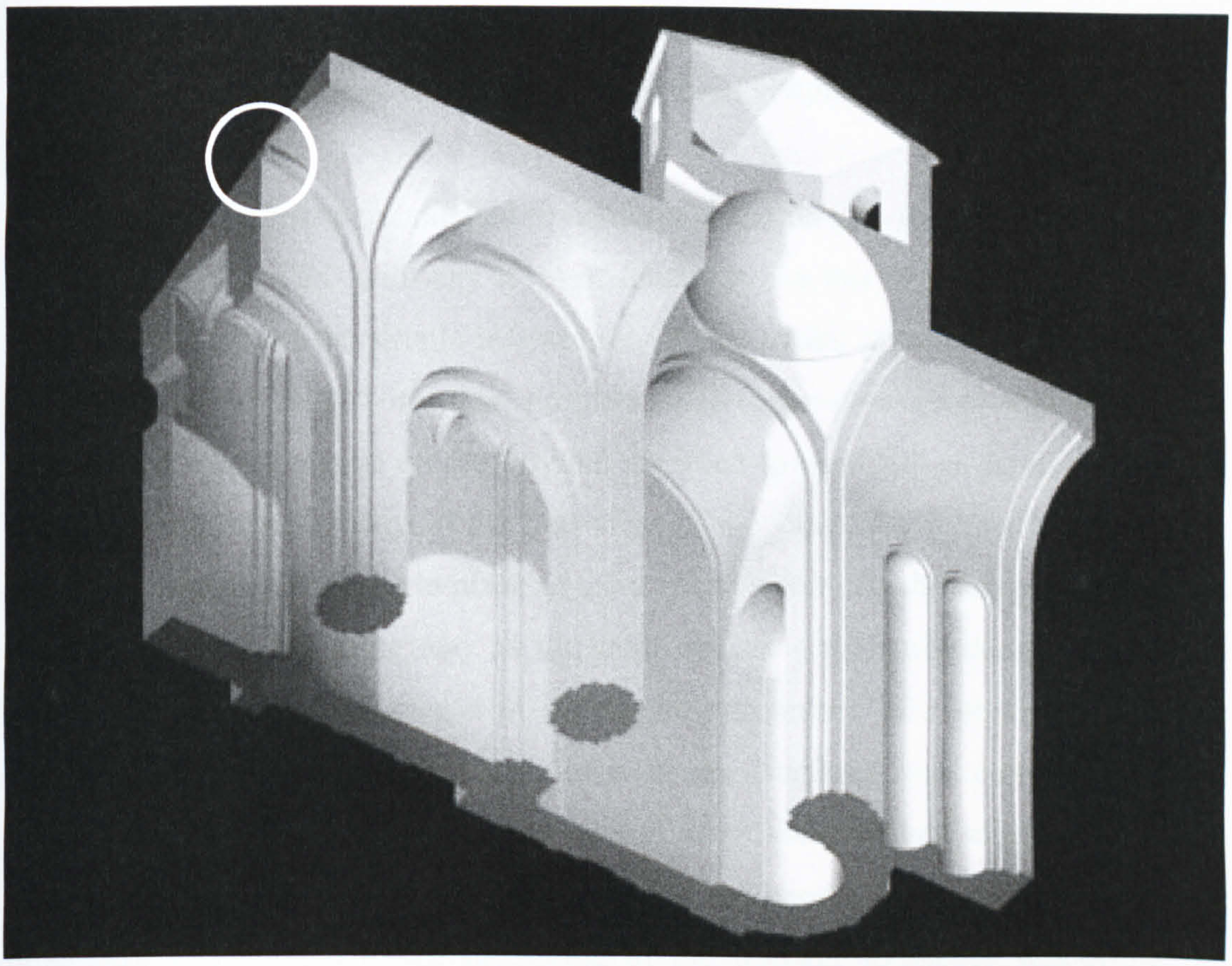


Fig. 6.12 Model in progress showing error at junction between vault and roof

The Sant Vicenç modelling project revolved around the nave vaulting system, as the original hypothesis was that this area was groin vaulted at a lower level than the barrel vault that exists today. An attempt was initially made to model the vaults using CSG, effectively by working out the three-dimensional intersection of two semicircular vaults at right angles to each other. This effectively produced a groin vault of which the longitudinal and transverse axes running through the apex of the vault lay in the *xy* plane. When this vault was viewed in the context of the building as a whole it was discovered that the highest point of the vault in the north-south axis was at an impossibly high level, leaving virtually no material at all between the vault and the pitched roof (Fig. 6.12). It was therefore evident that either the roof was of a shallower pitch (highly unlikely as the pitch is extremely shallow to start with), or that the vault sloped down from the apex on to the supporting nave walls, a far more likely situation. Furthermore, it was also clear that one aspect of the original hypothesis, that the existing nave windows with their dropped cills were a part of the original groin-vaulted design, was highly unlikely, for if they did, the original windows would have been very small indeed (Reed 2002b).

The vault was therefore remodelled to conform with this new theory. It was however impossible to use CSG with any level of reliability for this new vault, as it was no longer a question of the simple intersection of two vaults of equal dimensions. The method used to deal with this problem was somewhat more circuitous and represented a compromise on the original intention to use CSG as far as possible in the modelling process. Each of the four areas of the vault was defined separately by creating composite surfaces in place of the original solids. As the composite surfaces did not render in the same way as the solid objects – the surfaces appeared to be punctured and disjointed instead of giving the appearance of a smooth continuous profile (noticeable in Fig. 6.12) – each of the surfaces was converted into a triangulated mesh. All the individual meshes were then stitched together to give a higher level of robustness and coherence to the model as a whole. The same procedure was applied to the modelling of the trumpet squinches supporting the dome over the crossing. In the final rendered versions of the Sant Vicenç model it is virtually impossible to distinguish between the areas of solid modelling and mesh modelling. That said, further fine-tuning was required to the vaulting to make the illustrations suitable for publication, a description of which will be given in due course.

A layering system was adopted fairly early in the modeling process, with the model being segmented according to physical level. As a consequence, layers not being used at any particular time could be turned off to speed up the work being done to other parts of the model. An added advantage of adopting a data segmentation system was that it was possible to retain the original CAD survey drawings separately on an invisible layer (locked to prevent unwanted accidental alterations), which could be made visible as required for reference and to ensure that the model conformed to the original information. Finally, similar layers were collected into a series of layer groups, a very useful procedure that allows the manipulation and querying of multiple layers simultaneously.

6.3.4 *Visualisation*

Once the three models of Sant Vicenç had been constructed, it was necessary to create rendered views suitable for publication. Since there was no requirement to simulate the material properties of the building, all the modeling objects were set to a uniform white. In fact, the lighting of the models was an important part of the rendering procedure. FormZ uses a distant light as a default for rendering scenes when no other lights have been defined by the user. It was, however, discovered that this was inadequate for our purpose, where a more subtle lighting arrangement was required to clearly define the form of the building. The final lighting solution involved the use of the well-known three-point lighting system, with minor variations to bring out the subtleties of the form of the building (Birn 2000:38-39). This involved the creation of a key light to create the overall illumination of the scene, a fill light to soften the illumination, and a back light to emphasise the edges of the building. In addition, a further backlight was used to define the edges even further. Finally, the default light was turned off so as not to interfere with the custom lighting arrangement.

The next step was the rendering process proper. While test renders of the models were produced throughout the entire modelling process for verification purposes, the final rendering was a different proposition altogether, where the goal was to produce as clear and as visually informative a series of images of the hypothetical Sant Vicenc as possible. FormZ includes a number of different rendering algorithms, although only two of these were viable choices for producing the final illustrations of Sant Vicenç. The first was radiosity, capable of producing extremely realistic simulations of interior spaces, but at the expense of considerable amounts of time and computer resources (Birn 2000:241-242). It was decided that such a high level of realism was neither called for nor practical, and the second rendering technique, ray tracing, was chosen. While this particular algorithm does not offer the same level of realism as radiosity (ray-traced images can often be identified by the almost unnatural hardness of shadows), it is in fact vastly more economical on computer

Fig. 6.13 Model in progress showing imperfect rendering of vault meshes

resources. The axonometric and perspective views of the three models were rendered separately to create six corresponding TIF image files.

Additional work was required to make the renderings of Sant Vicenç suitable for publication. The most obvious area that required attention was briefly mentioned earlier – the junctions between the areas of solid and mesh modelling. In the FormZ images it was still possible to identify this transition, and furthermore, the vault meshes did not render as smoothly as the solid areas (Fig. 6.13). This was remedied by importing the TIF images into Adobe PhotoShop and then using the latter's retouching tools to 'fake' the required effect. There is unfortunately a widespread stigma against the idea of retouching renders among computer graphics users, which is entirely unjustified provided that the integrity of the final product is not compromised. In the case of the Sant Vicenç illustrations, the final product was enhanced to a degree that could otherwise only have been attained at the expense of

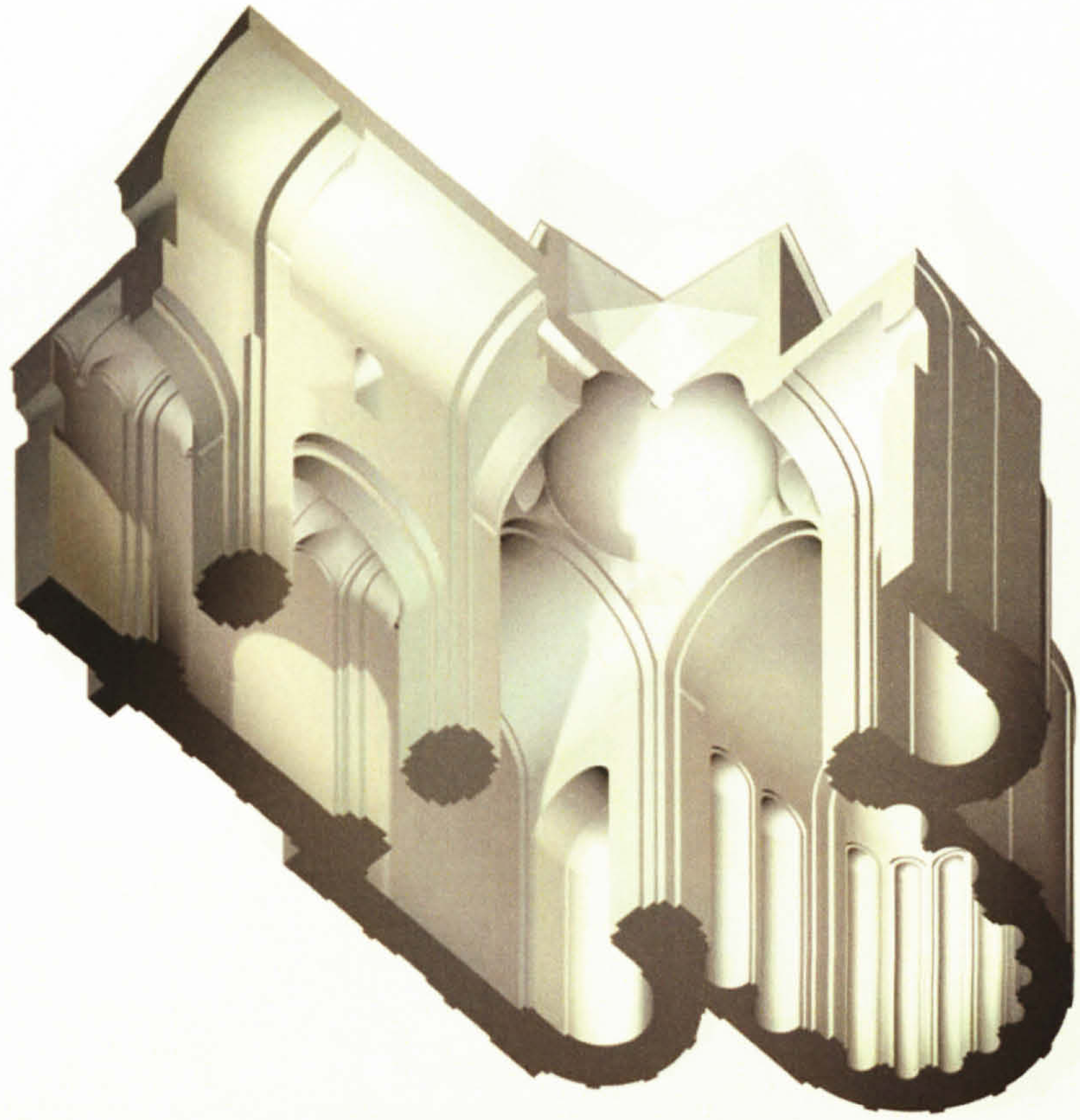


Fig 6.14 Barrel vaulted model of Sant Vicenc, as existing

much effort and time at the rendering stage. The only serious drawback to using an image processing program to retouch renders is that the entire task must be repeated for every illustration in need of alteration. However, in the current case, the amount of retouching was so minimal as to make this concern virtually insignificant. The final renderings included axonometric and perspective views of the church as existing (Fig. 6.14), along with corresponding views of the two hypotheses tested during the modelling project (Figs 6.15 and 6.16).

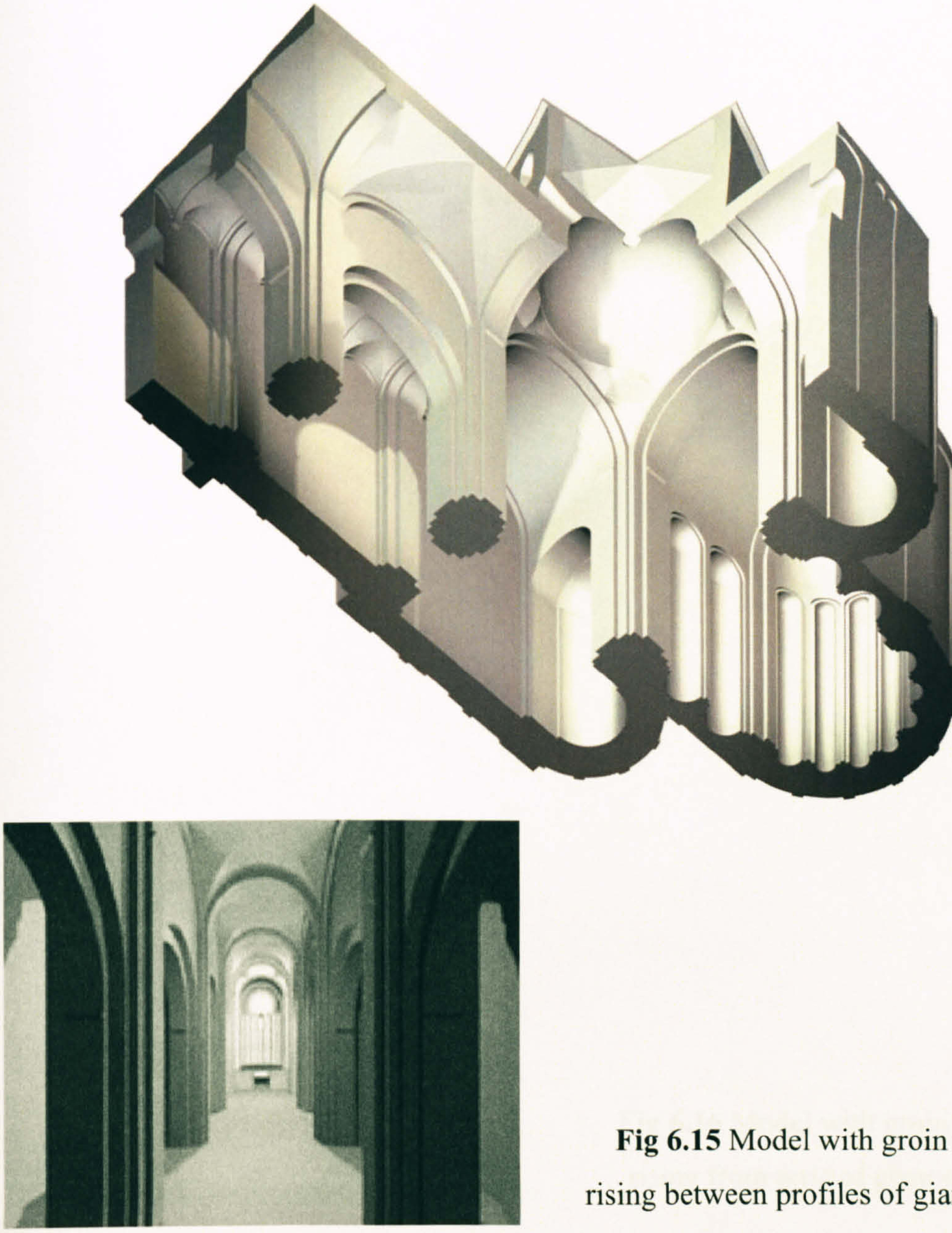


Fig 6.15 Model with groin vault rising between profiles of giant order

While there was no specific requirement to differentiate between the existing and conjectured areas of the Sant Vicenç in the illustrations for publication, it is nevertheless possible to step back from complete photorealism using some of the tools available in the rendering software used for visualisation. For instance, it is possible to use various non-photorealistic rendering techniques as described in Chapter 5 to give an impression of uncertainty (Fig. 6.17). One of the main limitations of the software was that was not possible to selectively apply different

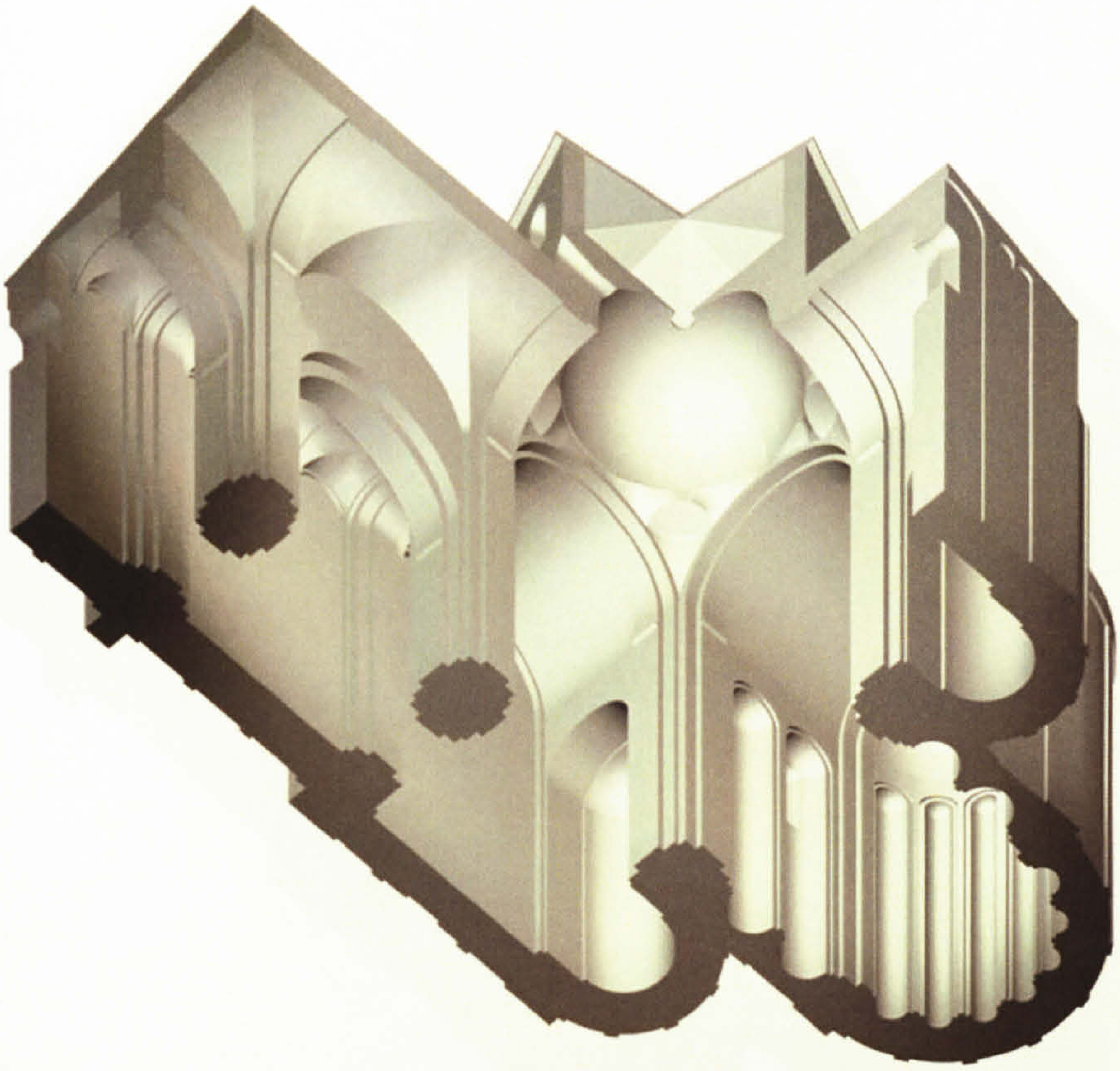


Fig 6.16 Model with groin vault rising from arris of giant order

rendering algorithms to different parts of the model, and thus the resulting non-photorealistic image did not necessarily distinguish between varying levels of certainty. It is, however, possible to leave certain parts of the model un-rendered altogether in an attempt to portray this distinction, although this tends to give a rather confusing appearance to the image. Apart from resorting to the use of specialised non-photorealistic algorithms (which are not widely available for architectural applications and are still very much in the experimental stage), one solution to this problem involves the use of different levels of transparency to reflect

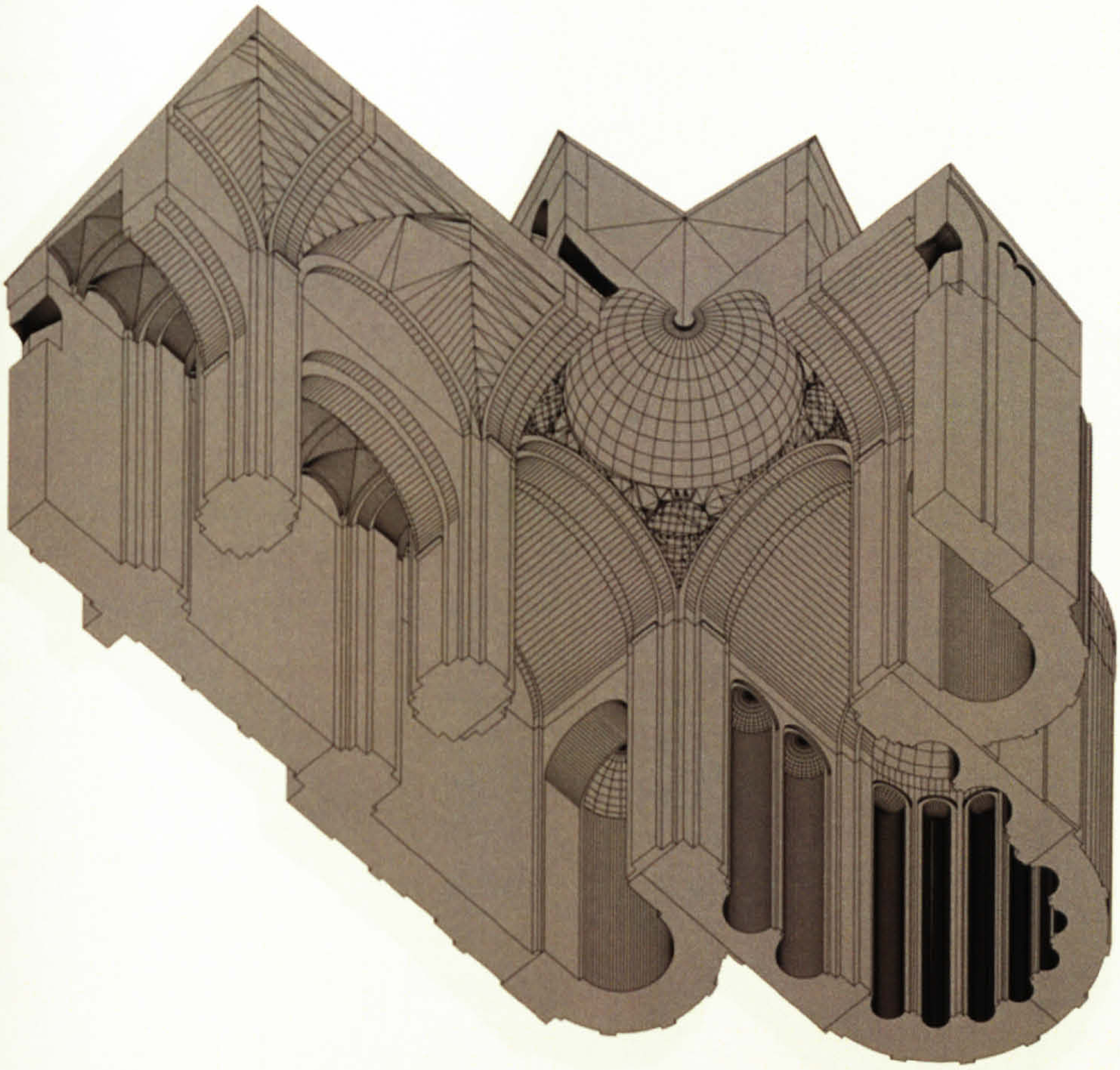


Fig. 6.17 Sketch rendered model (compare with Fig. 6.15)

the relative levels of certainty of interpretation of the model (Fig. 6.18). This course of action involves grouping the building elements into layers based on level of certainty, and applying the appropriate level of transparency when rendering the image. In addition to illustration uncertainty, such an approach also has the effect of visually distancing the resulting image from the ideal of photorealism, and is consequently less likely to be taken uncritically at face value by the viewer.

6.4 Discussion

The modelling of Sant Vicenc raised a number of interesting questions which were dealt with satisfactory at the time, but could perhaps have been addressed differently. For example, the data acquisition and entry method used here was cumbersome and

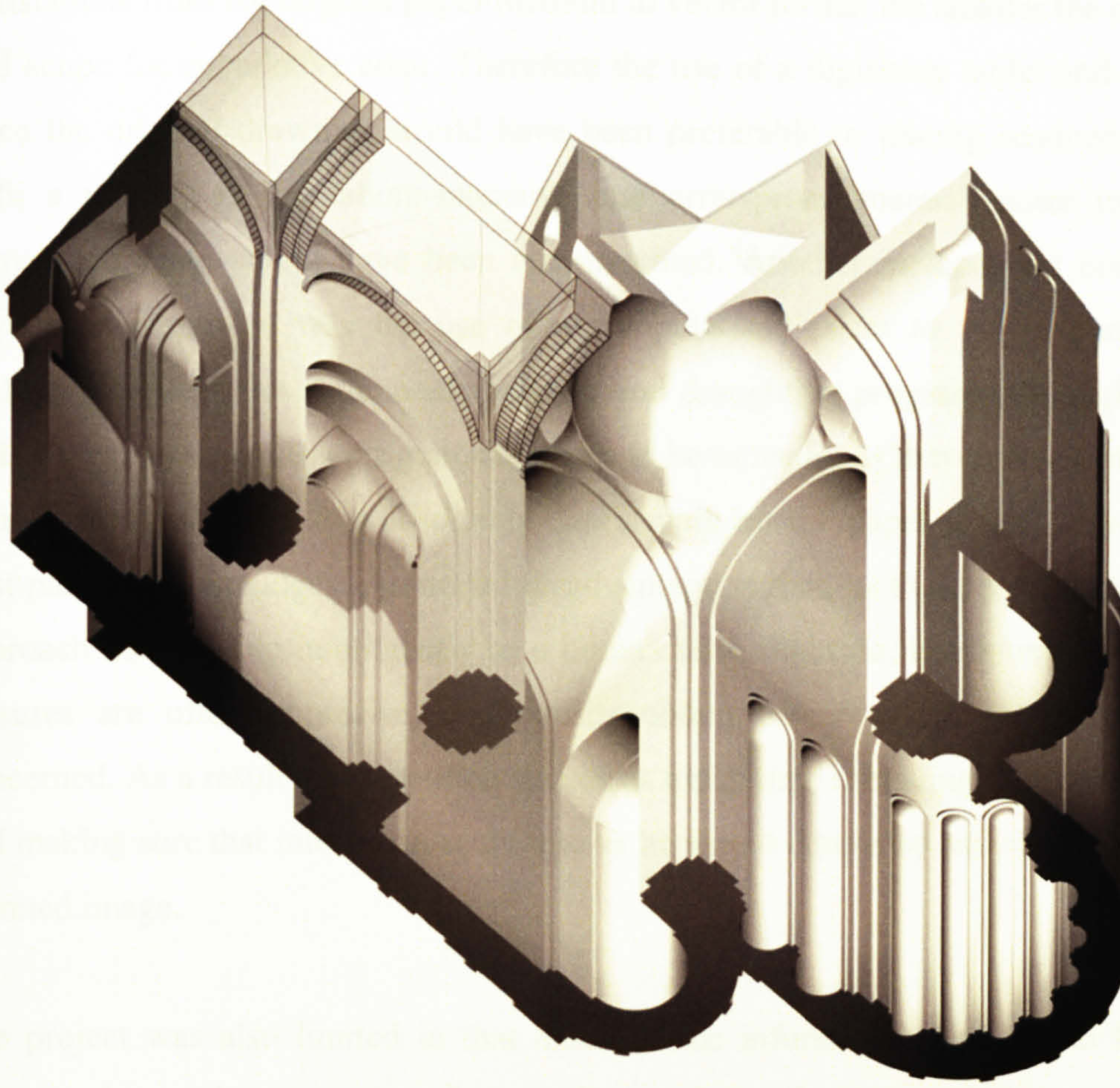


Fig. 6.18 Conjectured areas visualised as transparent

prone to error due to the lack of sufficiently accurate source information. It would doubtless have been preferable to have used as much first-hand survey information as possible, with minimal recourse to published material except where the information in question could not otherwise be obtained or as a back-up reference source. It would have been doubly useful if the survey information was collected and stored in digital form, with no intervening paper-based stages whatsoever.

The translation of information from paper to a machine-readable format could also have been carried out differently to ensure that the information retained its accuracy and integrity as far possible. While the method described above was relatively straightforward in practice, it is not necessarily the most desirable way of carrying out this task. It goes almost without saying that the fewer the number of data translations from the original paper medium to vector format the smaller the data loss and scope for cumulative error. Therefore the use of a digitising tablet and puck to trace the original drawings would have been preferable to tracing scanned images with a mouse, as the labour-intensive and error-prone manual raster to vector conversion stage would have been circumvented. Another method that could also have been employed was the use of a computerised raster to vector conversion routine, effectively an automated scanning and draughting program, although in the author's experience these programs tend not to be as useful as they first appear to be, mainly due to the fact that absolutely every mark on the paper is vectorised, from dust particles to smudges. An added disadvantage is that, as these programs do not approach the drawing intelligently as a human user might do, line intersections and closures are often imprecise, a serious problem where computer modelling is concerned. As a result the user often spends as much time removing unwanted marks and making sure that intersections are true as he would otherwise have done tracing a scanned image.

The project was also limited in that much of the information was in the form of photographs or other non-vector formats. It was obviously not possible to query these documents for dimensional information. In addition, there was also a significant amount of scaling of paper drawings for the same purpose, which did not necessarily hamper the progress of the project due to the generally low level of accuracy of data to start with. Nevertheless, this is clearly not good practice, and could prove to be a serious problem where the primary source of data is highly accurate. It is therefore important to have a much of the information as possible in an editable vector format before starting on the modelling itself. This enables easy, accurate and repeatable dimensional querying instead of having to deal with inaccurate and approximate manually-measured dimensions (Eiteljorg 2001).

The vital importance of deciding on an overall modelling strategy was also demonstrated by this project. For example, much time and effort was saved by limiting the Sant Vicenç model to parts of the building that were directly relevant to the hypothesis, and by concentrating in this way, it was possible to test the ideas under examination more rigorously without being encumbered by extraneous material. Eiteljorg (2000) also draws attention to the advantages and importance of adopting a data segmentation system when using CAD for scholarly work, and by adopting such a system at an early stage of the current project, there is no doubt that the modelling task was carried out in a more efficient and rigorous way than would otherwise have been possible. It is also important to point out that the CAF model was effectively a rationalised representation of the original structure, in that it was essentially impossible to replicate the anomalies that are an invariable feature of pre-industrial buildings. The level of rationalisation is further increased when individual elements are copied in the modelling environment (for example, the nave orders, which were assumed for expediency to be identical). This was not seen as a major failing in the context of Sant Vicenç, for the building in itself is an early example of what is probably a highly rational design, but it is nevertheless clear that greater care would required where highly irregular buildings are being modelled.

The point has been already made that the rendering process took up a noticeable portion of the project time, a common experience when complex building models are being dealt with (Ryan 1996:100). As the model had already been optimised for rendering, there was little else that could have been done about this apart from upgrading the system hardware. However, it was also clear that it is not absolutely necessary to spend inordinate amounts of time trying to get small details right in rendered images, when these could always be corrected by touching up the renders in an image editing program. Obviously the suitability of retouching depends largely on the level of correction required and also on whether the integrity of the final product is likely to be compromised.

The modelling of Sant Vicenç highlighted a number of issues that are relevant to the application of computer modelling techniques to the reconstruction of historic buildings in general, and the ecclesiastical buildings of medieval Europe in particular. While reservations have been expressed about some aspects of the methodology adopted here, there is no doubt about the ultimate value of the project. Our understanding of Sant Vicenç has been enriched and indeed somewhat altered by it – not only has the hypothesis that the nave of Sant Vicenç could originally have been conceived as a groin vaulted space been tested, it has also been demonstrated that the groin vaults would necessarily have been rather unconventional in that they would have had to slope down from the apices on to the nave walls. In addition, it has also been made evident that the existing clerestory windows with their dropped cills were unlikely to have been envisaged as part of this original hypothetical plan.

It is fairly evident that the use of computer modelling to analyse Sant Vicenç has conferred significant advantages over other techniques that may have been employed for this task. For example, the fact that it was possible to analyse the entire structure as an inherently 3-dimensional object was in itself extremely important. Hence the building was being dealt with, not only in aesthetic terms but also in terms of spatial coherence, with the issue of how the different parts of the building relate to each other in three-dimensional space being of fundamental importance. In addition, it was possible to quickly and accurately test different hypotheses without making irreversible changes to the entire model, and as a result, there is little doubt that the analysis was more rigorous. It was also possible to view the hypothetical construction from different angles, even those that would be impossible in the real world. Finally, the resulting models also represent an accessible and easily altered resource for further research.

7
Observations and Conclusions

In the course of this brief survey on the use of computer-aided modelling and visualisation techniques in the reconstruction of the built heritage, we have discussed a number of issues that are of wider relevance to the way in which the discipline is approached. The conjectural reconstruction of the Church of Sant Vicenç, described in Chapter 6, also raised important questions that are generic to the field of virtual heritage visualisation. Based on these insights, in the first part of this chapter we shall summarise and evaluate the commonly adopted approach to the subject in a critical manner, and also highlight areas that are sources of concern. We shall then go on to examine a number of recommendations that would enable projects to be approached and carried out in an intellectually rigorous manner, and finally we shall identify several areas of the underlying technologies that show potential for the future development of the field of virtual architectural reconstruction.

7.1 Current Trends

Architectural history and archaeology continue to be subjects of enduring public and academic interest, and certainly have been so, at least in the Western world, since the Renaissance. This interest is often motivated by an interest to identify with the past and to project its perceived glories onto the present, an aim which, although not inherently problematic, often becomes so when allied with such phenomena as public opinion, national and cultural identity and political manoeuvring. It is indeed regrettable that these attitudes have often driven research into the built heritage. Although the demands of rigorous academic practice would essentially preclude such wilful representations of historical themes, we sometimes find that this is not always the case – the increasing dependence of academia on public funds and acceptability means that much work is carried out with shortsighted and populist aims. While this is not in itself a bad thing, popular representations of the past are often sensationalised and are, more often than not, the result of emotionalism and exposure to one-sided journalism than of balanced research. Evans (2000:260) explains that this phenomenon is nothing new:

> Popular representations of history have always been widespread, and whether in folksong and ballad, saga and legend, or broadside and chapbook, and they have always structured the historical perceptions of the majority. Two and a half thousand years ago, the Greek historian Thucydides complained in the preface to his history of the Peloponnesian War that poets and others were purveying false and imaginary accounts of what had happened, and announced his intention of setting the record straight.

The role played by folksongs and ballads in the past have now been taken over by television, newspapers, magazines, and increasingly, the Internet. The sort of simplified 'feel-good' history that is frequently purveyed in these media is highly dependent on the use of alluring imagery to put forward what are usually single interpretations chosen, usually for rather non-intellectual objectives, from among many others that could be equally or perhaps even more likely, and it is in this role that computer generated architectural reconstructions are most often encountered.

While it is unreasonable to expect members of the public with nothing beyond a casual interest in architectural history to devote themselves to the critical analysis of the information which they are faced on the television and in the newspapers, it is indeed incumbent upon architectural historians and researchers to qualify their hypotheses to reflect the inherent uncertainty that underlies any form of inquiry into the past, especially where reconstructions are proposed from incomplete or non-existent remains. However, as we have repeatedly seen during the course of this discussion, many academics remain content to use computer-generated visualisations purely as presentation tools to impress and persuade fellow academics and members of the public, instead of exploiting the many possibilities inherent in these technologies to critically analyse and appropriately illustrate the architecture of the past. While this course of action was certainly understandable during the adoption of computer graphics into architecture and archaeology, we are now at least two decades on from that stage. Television viewers and movie goers have the opportunity of seeing photorealistic computer-generated imagery almost on a daily basis, and it is indeed a pity that much effort and time is spent on creating visually alluring images in an effort to outdo what has just gone before at the expense of perhaps more enduring and important architectural issues. A further consequence of this over-riding requirement for instant public appeal and palatability is that architectural reconstructions, at least in their illustrated form, find themselves drawn progressively further away from the underlying intellectual issues. While elitism is not a particularly laudable attitude – in fact, it is rather reprehensible, in that decision making is retained in the hands of an interested few, thus denying laypeople the opportunity to make up their own minds – it is nevertheless important to recognise that some of the historical and architectural arguments that are being investigated by the use of computer graphics are not necessarily comprehensible, at least in their minutiae, to individuals without a grounding in the basics of the subject. Indeed, it is somewhat ludicrous to expect members of the general public to form coherent and considered opinions on the basis of bite-size pseudo-historical journalism as purveyed on the television, newspapers and general Internet news websites.

As an example, we may take Time Team, the television programme on popular archaeology shown on Channel 4. Holtorf (2005) quotes the heritage expert Henry Cleere, who points out that Time Team offers a distorted and over-simplified view of what archaeology is all about, and insists that producers must have enough confidence in the subject as to be able to provide a more balanced picture without resorting to attracting viewer ratings. Holtorf calls this fundamental approach the Public Relations Model of popular archaeology, and goes on to point out how Time Team has progressed to a different level of public appeal altogether in adopting what he terms the Democratic Model, where members of the public, usually with no archaeological training apart from a vague interest in the subject, carry out their own archaeological digs. This so-called Big Dig, shown on television in 2003, met with widely differing reactions from the professional archaeological community. Whereas some were vehemently critical of this approach, others were rather more sympathetic, and in turn, attacked the critics as being driven by professional elitism. Holtorf (2005) reports Time Team archaeologist Mick Aston as remarking that:

> I walked down the High Street with Tim Taylor at lunch time and nearly every garden had people digging a hole and filling out recording sheets. It's brilliant to see so many people getting involved with their archaeology. This really is what it's all about. People learning about and enjoying their past in a constructive way.

As Holtorf (2005) goes on to point out, however, "the event would arguably have been even less elitist and more democratic if people had actually been allowed and encouraged to do anything and only what they wanted with the finds from their back gardens!"

Time Team as a phenomenon is doubly interesting in that it has championed the use of computer-aided architectural reconstructions to ostensibly aid in the popular comprehension of the archaeological digs that it purports to document. Although we have not yet come to the stage where the viewing public gets directly involved in choosing their favourite reconstruction by means of casting telephone votes, given the current craze for this type of television programme, it is perhaps not too improbable an outcome of the current trends in popular televised archaeology and architectural history.

The main concern here is not necessarily to do with the popular appeal of many computer aided architectural reconstructions; it is rather the fact that photorealistic graphics tend to take on an air of objectivity – usually unwarranted – by their very realism, a situation that can very easily trick not just the casual observer with no particular interest in the subject matter, but educated amateurs and even academics into thinking that what they are presented with is definitive and completely objective. The fact that this phenomenon is not restricted to the audience alone was pointed out as long as a decade ago by Miller and Richards (1995), who refer to an article in New Scientist by Kiernan entitled 'Lies, Damn Lies and Slick Graphics'. They point out that the persuasive quality of computer graphics could be such that, not only the lay public, but even the academics and researchers producing the images are sometimes misled into believing that conjectural speculations are actually proven facts. Lewin, Ehrhardt et al (1997), also referring to Kiernan's article, point out that computer forecast air pollution images were far more influential on policy makers than were the corresponding charts and tables; they come to the conclusion that "seeing is believing: images tend to sway viewers more easily than numeric data and textual information". Rather worryingly, the entire discipline of architecture is based to an inordinate extent on the image (sometimes to the exclusion of the represented building itself), and therefore this observation is highly pertinent.

This problem is due, at least in part, to the fact that the majority of commercially available visualisation software have not typically incorporated routines to permit the illustration of conjecture and fuzziness. In a way, we are dealing with a sort of technological determinism where the limits, or indeed the demands, of the technology dictate the way in which information is manipulated, presented and perceived. Although there are always limiting factors in any form of human endeavour, it is certainly a matter for concern if the tools that are being used to ostensibly ease the task in hand are actually contributing to an ultimate loss of integrity in the results. Having said that, it must be pointed out that some software packages that have been released recently – most notably, Piranesi – have devoted a significant amount of attention to the development of non-photorealistic visualisation tools, which, incidentally, could profitably be applied to the illustration of conjecture in virtual architectural reconstructions. Unfortunately, however, this discipline continues to remain a niche market for software developers, and as we have seen in the course of the case study discussed in Chapter 6, most mainstream visualisation packages are extremely limited in the sense that the ultimate objective is taken almost by default to be extreme photorealism. As a consequence, it is likely that computer-literate researchers of architectural history and archaeology will remain dependent, at least in the short term, on trends within the wider computer graphics and computer vision communities, and find themselves adapting methodologies that have been developed for use within other disciplines. Thus we have seen how architectural history researchers at the cutting edge of the field have taken advantage of techniques originally conceived for use in such widely different spheres as plant and pipe layout (the reconstruction of Furness Abbey described in 3.2.1) and the aerospace industry (rapid prototyping, discussed in 5.3.4).

A significant area that remains largely unexploited by researchers is the scope that computer visualisation techniques offer for the illustration of multiple interpretations of architectural reconstructions. While this would invariably be a laborious process where hand-produced illustrations and models are concerned (it would effectively be necessary to create each image from scratch, or in the case of a physical model, to create the relevant parts) it is possible to significantly reduce the human workload by reusing common parts of the building under investigation. We saw in Chapter 6 how three different vaulting arrangements at Sant Vicenç were modelled using the same base model, and how, as a consequence, it was possible not only to significantly reduce the time expended, but also to significantly increase the integrity of the hypotheses. Given the relative ease with which multiple interpretations can be analysed and illustrated, it is indeed surprising that a significant number of virtual reconstructions continue to persist with the notion of the computer as advanced painting tool. An explanation may be given by the phenomenon of public appeal that was discussed at the beginning of this chapter – researchers find themselves compelled, both for financial and political reasons, to produce images with a strong visual impact that are also completely in line with majoritarian notions of history, a history that is generally based on simplistic and one-dimensional characters and events. This situation is not restricted to the illustrator or animator producing alluring computer-generated imagery for public consumption; even the researcher must meet the demands of his or her peers, and, not least, what has been referred to as academic dogma, which in a sense limits the range of interpretations that may be examined and presented.

Although it is vital to recognise the likelihood of multiple interpretations in any sort of historical inquiry, it is just as important not to confuse the interpretation with the underlying reality – that is to say, not to equate the image with the object. Without entering into a lengthy ontological discussion of the nature of historical reality, it is nevertheless commonly understood that such a concept does exist in such a way as to be independent of private interpretations. Evans (2000:260) explains this dichotomy in the following way:

> Everyone, even the most diehard deconstructionist, concedes in practice that that there is extratextual reality. History is an empirical discipline, and it is concerned with the content of knowledge rather than its nature. Through the sources we use, and the methods with which we handle them, we can, if we are very careful and thorough, approach a reconstruction of past reality that may be partial and provisional, and certainly would not be objective, but is nevertheless true. We know, of course, that we will be guided in selecting materials for the stories we tell, and in the way we put these materials together and interpret them, by literary models, by social science theories, by moral and political beliefs, by an aesthetic sense, even by our own unconscious assumptions and desires. It is an illusion to believe otherwise. But the stories we tell will be true stories, even if the truth they tell is our own, and even if other people can and will tell them differently.

An illustration – albeit of a rather extreme sort – of this distinction is given by the so-called Germanic farmstead of Oerlinghausen, constructed under the influence and auspices of the Nazi regime in Germany during the 1930s (discussed in Chapter 1). While hardly any right-thinking person would agree that this simplistic and highly ideological concoction was anything other than a fantastic – and perhaps dangerous – parody of a German farmstead of 2000 years ago, at the same time it is impossible to deny the reality of the parody itself. The dangers of confusing reality with representation – of confusing the object with the image – is made clear by the fact that many visitors to this site in the late 1930s and early 1940s would have uncritically accepted the largely nonsensical images with which they were faced. Although this sort of blatant exploitation of public gullibility for political and nationalistic ends is now thankfully rarely seen, it nevertheless offers an extreme case of what is still a common way of thinking both among the creators and viewers of architectural reconstructions. As Holtorf (2005) explains:

> In other words, even a false image may need to be cultivated if that is what secures public support and interest in an entire discipline, ultimately perhaps even assuring its survival. This kind of reasoning is a far cry from genuine attempts to make all sections of society understand and appreciate the past and the realities of archaeology. It becomes evident that in the Public Relations Model people are sought to be manipulated in order to make their opinions more compatible with the interests of professional archaeology. Peter Addyman ..., creator of the fabulously successful Jorvik Viking Centre ..., was not afraid to describe its function as an "effective propaganda machine" that "brainwashed 5% of the population into our view of the Viking age and of archaeology".

Consequently, in any form of historical representation, especially where the lay public is involved, it is essential that the limits of knowledge and the nature of the interpretation is made clear, and that the notion of using alluring graphics as a means of persuasion is approached in a very considered manner. After all, if one is to follow the train of thought put forward by Evans (2000:260) quoted above, an architectural reconstruction ultimately reveals as much, if not more, about the academic, social and political climates in which it was created as it does about the 'real' object of which it is supposed to be a representation. It is not surprising that Piero della Francesca's *Flagellation of Christ* tells us more about the Renaissance than it does about the environment in which the event originally took place, and similarly, the cosy images of Ancient Rome produced by Lawrence Alma-Tadema are essentially a reflection of the hubris of Victorian Britain and its Empire. While it is tempting to think that our own age has somehow escaped from this cycle of projecting itself onto the past, and that we are dealing with ultimate reality in a reasoned and objective way, there is every likelihood that our own reconstructions of the past may be viewed by future generations with the same mixture of interest and ridicule that we sometimes adopt when looking at the work of those who have gone before us.

In order to emphasise the dangers of confusing the 'real' object and its representation, mention must be made of the rather alarming tendency in certain quarters, especially over the last few years, to question the need for historic buildings at all. One of the most recent examples of this attitude is documented by Gates (2005) in Building Design under the title 'Treasures Face Cyber Scrapheap', which points out that the current Culture Secretary, Tessa Jowell, is in favour of the idea of demolishing listed buildings and 'preserving' them (really reconstructing them in the sense that we have been discussing) as computer models. The motive for this rather extreme course of action is apparently to find "'a third way' for listing which would balance the need to preserve a building for architectural history with the need to open up the site for 'innovative new design'". While the underlying questionability of this proposal does not need to be emphasised at any great length, what does need to be made clear is that a computer model is not a replacement for a building, for, as we have seen, it is only a subjective and selective interpretation of a real-world object. Furthermore, a historic building is similar to a living species or a language: once lost, it cannot be reconstructed in a totally identical way to the original, either in physical or virtual form. Thus, the fact that Jowell talks in terms of 'a perfect virtual moving image' indicates, in the final analysis, a lack of recognition of the difference between reality and its representation.

Although this proposal has apparently won the 'cautious backing' of the general architectural profession (which, incidentally, is in itself a rather damning indictment of its own values and priorities), we would indeed be committing an act of cultural vandalism of major proportions were such a proposal to be put into action. Indeed, Gates (2005) quotes the Classical architect Robert Adam, who vehemently opposes this notion:

> "Would we burn the Mona Lisa and keep a digital record because it gets in the way?" Adam said. "This is barmy and dangerous. You will end up destroying works of art because people think you can preserve them digitally."

Irrespective of personal architectural persuasions, it is difficult not to agree with Adam. While it is one thing to create virtual reconstructions of buildings that have already disappeared, it is another matter altogether to destroy them in the simple-minded hope that it is somehow possible to replace the actual object with computer representations. It can only be hoped that this proposal would meet with such a high level of public and academic opposition as to be blocked before any steps are taken to implement it.

7.2 Recommendations and Future Directions

Due to the rather ad hoc nature of its development and practice, the methodologies adopted in the field of virtual architectural reconstruction remain largely a matter of personal choice, initiative and indeed talent on the part of the researcher, and as a result of the fact that the majority of such visualisations are created purely for the entertainment and casual education of laypeople, often finds itself divorced from the underlying intellectual debate. It is indeed difficult, if not impossible, to lay down any strict methodologies for such a diverse and potentially unpredictable field, for, in the final analysis, each reconstruction is unique both in terms of the building under investigation and also in terms of the objective of the project. What is possible, however, is to put forward a number of recommendations in the light of the foregoing discussion in order to bring the same sort of intellectual rigour to the discipline that is often found to be lacking, and which, as a consequence, has meant that much of the work has been delegated to computer artists and animators, usually individuals with minimal interest or knowledge of architectural history and archaeology, instead of being carried out by specialists in the subject themselves. In many ways, this is the primary recommendation: that virtual reconstructions be carried out by researchers who are intimately familiar with the underlying architectural and archaeological issues, or where the skills are lacking, that every effort be made to acquire them. Modern CAD and visualisation programmes are not particularly demanding to use, and it is hardly believable that visually literate, well-educated adults would have difficulty in acquiring the requisite skills to carry out their own visualisation work. The argument that is often advanced is that architectural historians and archaeologists are generally too occupied with the intellectual and professional side of the subject to be concerned with getting their hands dirty, so to speak, which is exactly the attitude that leads to much of the computer work being carried out by individuals lacking the underlying skills to make fairly basic decisions. The specialist, unfamiliar with CAD methodologies, usually finds himself or herself unable to comprehend the work that is being done by the computer artist, and thus there is little possibility of guiding the project based on a rigorous intellectual argument in the place of producing attractive, but ultimately meaning-deficient, images.

As far as the specific methodologies are concerned, it is perhaps true to say that the emphasis in research has shifted away from the modelling stage proper. Certainly many of the early architectural reconstruction projects were primarily concerned with formulating procedures that would enable the representation of the rather complex 3-dimensional forms that make up most historical buildings. As we have seen in Chapter 3, much of the discussion in these projects centred around the techniques of solid and surface modelling, file sizes and ways in which wireframe images could be made more visually comprehensible; true photorealism in the form of raytracing or radiosity was an ideal which was beyond the reach of many of these early researchers. It is perhaps true to say that today we are in a position where the creation of the forms themselves does not pose a significant problem, due, perhaps, to the adoption of CAD and visualisation systems that were originally conceived for use with character modelling and animation, where complex forms are abundant. As an example, we may take the computer modelling of the Rievaulx Abbey groin vaulting described in Kemp (1995:252). She documents a rather contorted trial-and-error process, which may be compared with the way in which the same task was accomplished during the modelling of Sant Vicenç described in 6.3.3, where, once the underlying geometrical problem had been solved, the modelling itself was not significantly problematic in technical terms. The areas of the reconstruction methodology which demand attention, on the other hand, are the data collection and visualisation stages, both of which are highly subject-specific and are thus not suitable candidates for the wholesale importation of techniques from other related disciplines.

In spite of the availability of fully digital on-site surveying methodologies such as softcopy photogrammetry, such techniques tend to be restricted to very large and well funded research projects, usually in the context of building conservation rather than academic research. Most scholars find themselves dependent on hand surveyed and non-metric photographic data, supplemented by secondary sources of varying levels of dependability and usefulness. This certainly was the situation that was faced during the Sant Vicenç modelling project documented in Chapter 6 (see 6.2 for a full description of the sources that were available). In addition to issues about the accuracy of secondary sources, there is the very real question of the way in which such information may be converted into a machine-readable form with minimal distortion and loss of integrity. In many ways, the ideal situation would be to directly capture the three-dimensional form of the building under investigation using a device such as a laser scanner, but as we saw in 4.2.1, such techniques are not as yet at a sufficiently developed stage as to be useful and economic in contexts outside experimentation into computer-aided surveying.

There is no straightforward solution to this problem, but it is advisable to obtain as much of the primary data in digital form, either using photogrammetry or, where this proves impossible, using a total station. If the size of the project does not warrant a full survey programme, a total station may be used to obtain a minimum set of control dimensions around which the model may be built, thus introducing an objective framework. In addition, it is possible, by linking the data logger of the total station with a spreadsheet package, to create a table of spatial co-ordinates that have been recorded on site which can then be automatically transferred to a CAD program for semi-automated modelling. Thus the number of data translations and even the level of human intervention is reduced to a minimum. This is very much in contrast to the situation encountered when using drawings and other images from secondary sources: the inevitable discrepancies that arise leave the researcher in doubt as to which source to follow, and the result is that the final model is a chaotic amalgamation of dimensional information from all manner of sources, with very little guarantee as to its ultimate accuracy. Consequently, it goes almost without saying that any hypotheses examined on such a model are likely to be provisional at best. What is being advocated here, incidentally, is not the complete elimination of human interaction in the data visualisation process, but rather its restriction to a decision-making role as far as possible, minimising the level of human involvement with laborious mechanical and numerical tasks, where computer-aided tools naturally have the edge. Indeed, buildings in general, and historic buildings in particular, tend to be objects of such complexity and variability that they do not readily lend themselves to fully-automated processes.

Although historic paintings are an extremely valuable source of information on the built environment of the past, they are in some ways highly undependable as sources of dimensional information. As we discussed in Chapter 4, paintings that superficially appear to be true to life may actually have been embellished by all manner of artistic devices, or indeed suffer from the incompetence or carelessness of the artist, thus rendering them of limited value in the data collection process. An additional issue is that there is no guarantee of perspectival rigour – for example, it is not unusual, as in the case of Masaccio's *Trinity*, to see the selective use of the underlying techniques to heighten the impact of the overall image. For these reasons, it is difficult to conceive of a fully automate perspective reconstruction methodology for paintings. This is very much in contrast to historic photographs, where the invariable 'truthfulness' of the images lend themselves well to this sort of treatment. Attempts at formulating perspective reconstruction processes for paintings have typically been image-based, and due to the fact that this approach is inherently imprecise, such projects tend largely to be aimed at public entertainment and information. In an academic context, it is preferable to have a geometry-based methodology, and although it is clearly impossible to formulate fully automated processes for this task – the underlying complexity of the historic building is compounded by the nature of the visualisation medium – it is not too difficult to imagine the profitable use of a system to extract limited dimensional information from paintings such as that described in 4.3.4.

It has already been emphasised in Chapter 5 that the use of non-photorealistic rendering (NPR) techniques is critical for the effective graphical communication of virtual architectural reconstructions. However, the point has also been made that the majority of commercially available rendering programmes do not offer such tools, or if they do, they are of such a basic standard to be of limited use. Although a vast amount of research has been carried out into NPR over the last decade, the prime impetus, as always, continues to be the entertainment industry and its requirement to produce computer-generated cartoons. Although some academic research has been carried in university environments – notably at the University of Magdeburg, where one of the applications for NPR was specifically identified as the illustration of uncertainty in architectural reconstructions – much of this work has not filtered down to the level where the non-computer-specialist architectural historian or archaeologist is able to profit from it. Therefore, although there is a growing tendency for NPR to be seen as a valid and highly expressive form of computer graphics, especially in the aftermath of the craze for photorealism, the widespread use of such techniques in virtual architectural reconstruction lies very much in the future. In the meanwhile, there are other techniques that can be exploited by architectural historians to illustrate fuzziness in their conjectures, one of the most simple being the use of wireframe or flat rendering techniques instead of full radiosity or raytracing. In addition to being much less intensive on computer resources than photorealism, wireframe or flat rendered images do not in any way carry with them a notion of objective authority, although, unless carried out in a competent manner, they may give the impression of amateurishness that may ultimately be counter-productive. A rather more complex technique is to use levels of transparency for the same task; paradoxically, a model with transparently rendered elements would actually be more demanding on hardware resources than the same model rendered in an opaque manner, due to the fact that the rendering engine must trace the path of the light rays through numerous parts of the model. Nevertheless, by the judicious use of levels of transparency to reflect the levels of sureness of the various areas of the reconstruction, it is possible to give a very clear, and at the same time, non-authoritative impression of subjectivity in interpretation.

One of the criticisms commonly levelled against the use of computer graphics in architectural visualisation is that there is perceived to be a lack of immediacy in computer-generated images (Terlingen and Engelbregt 1996:41). This was undoubtedly true in the early days of the discipline, where researchers were restricted to using cumbersome hardware and recalcitrant software, and even then, were only able to work at an extremely slow pace. The resulting wireframe or flat-shaded images were often unclear and could not be manipulated on screen at all, let alone on a real-time basis – creating new images was a process that took in the order of several minutes at least. It is difficult, however, to see how this criticism would apply today, with the recent proliferation of graphics-capable laptop and handheld computers. Such machines are fully capable of creating and manipulating architectural models, and then viewing them on-screen in the form of animations or low-level virtual reality. Although immersive virtual reality continues to remain beyond the scope of commonly available hardware and software, judging by the quality of images now seen in commercial computer games, for example, it is perhaps only a matter of time before architectural visualisations could be viewed on portable computing devices using such equipment as head-mounted displays, tracking devices and data gloves instead of the flat screens and mouse- and joystick-like pointing devices to which we are restricted today. In addition to fully immersive virtual reality, augmented reality techniques have just as much, if not more, potential as interpretative tools in virtual heritage applications. In many ways, they offer a source-based technique of visualising a historic building – the building itself is used as the framework for the computer generated imagery, with the addition or subtraction of relevant details to make the interpretation more informative or entertaining.

Rapid prototyping probably represents the one computer-aided technology that holds the greatest promise in architectural reconstruction. Such systems have substantial potential as analytical tools in addition to their obvious advantages as representational tools that offer a quick, cheap and effective means of creating physical models directly from CAD data. Although a computer model is theoretically spatially coherent, it is still nevertheless possible to create forms that have the appearance of reality, but which at the same time are inconsistent in their relationships. This is often a consequence of the three-dimensional nature of the model being manipulated and viewed through the two-dimensional interface of the computer screen, which has the effect of filtering out certain features that would aid in the full spatial comprehension of the model. With rapid prototyping, however, perfect spatial coherence is a must, and the fact that the output is essentially in physical form means that it is possible to intuitively test and analyse the spatial characteristics of the model in a way that is virtually impossible through two-dimensional interfaces such as paper or computer screens. As discussed in Chapter 5, architects such as Frank Gehry have very successfully adopted rapid prototyping software not only to conceive and then to translate highly complex building forms into physical form, but also to aid in the creation of the actual building components. It is not difficult to see such technologies being applied to building conservation, where computer models are used to test, visualise and ultimately even contribute to the preservation of the monument that is being investigated. This is all still very much in the future, however; certainly the hardware required for rapid prototyping is far too costly and labour intensive for widespread use at present. Furthermore, research in architectural history and building conservation does not in general tend to receive such single-minded and financially generous political backing as does the construction of high-profile public buildings, the sort of backing that enables architects such as Gehry to experiment with cutting edge technologies. To cite an example from Glasgow, one only has to look at the neglect and apathy with which such a building of global importance as Alexander Thomson's St. Vincent Street Church is perceived among public purse holders, who at the same time are only too willing to spend liberally on all manner of short-sighted and ill-thought out architectural projects that are, more often than not, of little or no lasting value.

7.3 Concluding Remarks

It is clear that attitudes towards virtual architectural reconstruction, in common with most forms of historical inquiry, are very much linked to contemporary social, political and academic priorities. After all, the significance of reconstruction projects must be justified to funding bodies and other authorities who concern themselves with such matters, and it is unlikely that approval would be forthcoming were the ultimate value of the project itself to be in question. As we have seen, this has always been the case, from Inigo Jones's conjectural images of Stonehenge created to strengthen the claim of James I to the English crown in the early 17th Century, to the virtual reconstruction of Dresden Cathedral to emphasise the notion of German unity in the aftermath of the fall of Communism in Eastern and Central Europe just over a decade ago. It is naïve to suppose that a subject with as strong a public appeal as national and cultural history can somehow be dealt with in isolation, but, as pointed out above, the very need for non-specialist approval and backing means that many virtual reconstructions are presented in ways that are simplistic and misleading. The challenge remains to formulate a methodology where the strong public appeal of computer graphics can be exploited in such a way as to connect the illustrations that are put forward for general consumption with the underlying academic debate. This has been an issue that has received scant attention in the past, mainly due to an intense fascination with the technologies themselves on the part of all concerned, but it is essential that we – meaning the researchers who create the images that are so easily believed – do not get carried away into thinking that the apparent objectivity of computer graphics somehow represents indubitable fact. In this respect, there is much to be learned from traditional archaeological illustrators, who in general work within a tradition with a much longer history of development, one where in general there are higher standards of intellectual rigour, and where the idea of photorealism does not figure as prominently as it does in the field of virtual reconstruction.

In order to illustrate this point, we can take as an example Alan Sorrell's graphical approach, which was intimately linked to the way in which he wanted his illustrations to be interpreted; it had little to do with the sort of mere showmanship that seems to underlie a noticeable number of comparable virtual reconstructions. In fact, many of his illustrations have a distinctly unfinished appearance that lends itself well to the illustration of fuzziness. Indeed, the common approach to computer-aided architectural reconstruction is in sharp contrast to the traditional methods, where although the illustrators themselves may not have been archaeologists or architectural historians themselves, a significant number of practitioners devoted themselves exclusively to this particular field. This enabled them to build up a body of knowledge that could eventually be used to fill in minor gaps without significantly affecting the integrity of the interpretation. It is notable that there is an Association of Archaeological Illustrators in Great Britain, the majority of whose members tend to rely solely on traditional graphical methods, and even among those who have ventured into the domain of computer-aided visualisation, there is a strong tendency to adopt a painterly approach and to emphasise the notion of subjectivity in interpretation. It is perhaps high time that such methods were studied and adopted on a wider basis by researchers who have hitherto generally been so enamoured with the idea of photorealism, and also the production of attractive imagery for non-specialist consumption, as to lose sight of the fact that, in any manner of historical investigation, the unknowns tend to outnumber the facts. As Forte and Silliotti (1997:12-13) argue:

> Why is the virtual reconstruction of an archaeological site so important? Because, over and above its strong popular impact, computer reconstruction allows the presentation of complex information in a visual way that enables it to be used to test and refine the image or model that has been created. It is very much more than a graphic reproduction; it is a simulation. And, because it is a simulation, it provides a non-intrusive and non-destructive means of exploring a model in three dimensions and from an infinite number of viewpoints. Furthermore, it allows objective verification to be made of possible interpretations of architecture, material culture, topography, palaeo-environmental data, restoration, museum display, and any number of other factors.

What is being put forward here is not necessarily a general critique of the various computer-aided modelling techniques that are applied to built heritage visualisation; it is rather a statement of concern about the general direction of the discipline. Indeed, as repeatedly pointed out during the course of this discussion, there are a host of tools and methodologies, some of them very straightforward, that can be profitably used in the analysis and illustration of the buildings of the past, but which continue to be largely ignored as a result of the fixation with the provision of, what are essentially, pretty pictures. The dangers of this approach were highlighted as long ago as a decade in the seminal paper by Miller and Richards (1995), but much of what was said seems to have been forgotten in the rush to generally create newer and better computer imagery, with scant regard for the integrity of the underlying content. The criticisms that are advanced against this approach are almost identical to those with respect to full-size reconstructions, detailed in 2.1.3 – too much detail and realism is being used to represent objects about which little is known as absolute fact, with the consequence that the representations are taken at face value both by their creators and their audiences. It is vital that this approach is used highly selectively, and in the appropriate context, if at all. Although Lock (2003:xiii) is of the impression that "computers not only change the way we do things, but more importantly, change the way we think about what we do and why we do it", it is clear that this is not always the case; we often tend to adopt new technologies with the simple aim of adding extra gloss to what are already well-established procedures and mentalities. In many ways, this attitude is excusable – practitioners have not, in general, got over the excitement of being able to create highly realistic images and animations at a few clicks of a mouse. As this approach becomes more widespread, however, it is likely that the glamour of photorealism will fade (indeed, we are seeing signs of this already); after all, it was not long ago that a word-processed document was a sensational object. It is only when such a stage is reached that the real underlying issues – including those of reality and realism – can be addressed in a coherent manner, and that computer graphics techniques may be exploited to their full potential in the field of virtual architectural reconstruction.

References

Alberti, L. B. (1972 [1435]). *On Painting*, C. Grayson (Trans). London, Penguin Books.

Anon. (1988). *Ruins in British Romantic Art from Wilson to Turner.* Nottingham, Nottingham Castle Museum.

Anon. (2000). Supercharging Archaeological Data. In *CAD User*, May. 8-10.

Asleson, R. (1999). On Translating Homer: Prehistory and the limits of classicism. In *Studies in British Art No. 5: Frederic Leighton: Antiquity, Renaissance, Modernity*, T. Barringer and E. Prettejohn (Eds). London, Yale University Press. 67-86.

Atkinson, R.L, Atkinson, R.C., Smith, E.E. et al (1990). *Introduction to Psychology.* San Diego, Harcourt Brace Jovanovitch.

Avern, G. (2001). A New Technique for Recording Archaeological Excavations. In *Computer Methods and Quantitative Applications in Archaeology 2000*, Z. Stancic and T. Veljanovski (Eds). Oxford, British Archaeological Reports International Series 931. 3-7.

Aspinall, A., and Haigh, J. (1999). Twenty Five Years of Archaeological Prospection. In *Computer Applications and Quantitative Methods in Archaeology 1997*, L. Dingwall, S. Exon et al (Eds). Oxford, British Archaeological Reports International Series 750. 13-18.

Barral i Altet, X. (2001). *The Romanesque: towns, cathedrals, monasteries.* Cologne, Taschen.

Barrat, G., Bullas, S. and Doyle, S. (1999). Digital Mapping and Remote Sensing at Merv (Data Integration in a Field Context). In *Computer Applications and Quantitative Methods in Archaeology 1997*, L. Dingwall, S. Exon et al (Eds). Oxford, British Archaeological Reports International Series 750. On CD-ROM.

Bakker, G., Meulenberg, F. and De Rode, J. (2003). *Truth and Credibility as a Double Ambition: Reconstruction of the built past, experiences and dilemmas.* Uncorrected proof, viewed October 2003. <http://www.derode3d.nl/publicaties.htm>.

Becker, H. (1990). Combination of Aerial-Photography with Ground-Magnetics in Digital Image Processing Technique [sic]. In *Aerial Photography and Geophysical Prospection in Archaeology: Proceedings of the Second International Symposium*, C. Léva (ed). Brussels, Centre Interdisciplinaire de Recherches Aériennes. 25-35.

Bertol, D. (1997). *Designing Virtual Space: an architect's guide to virtual reality.* New York, John Wiley and Sons.

Blockley, M. (1999). Archaeological Reconstructions and the Community in the UK. In *The Constructed Past: Experimental archaeology, education and the public*, P.G. Stone and P.G. Planel (Eds). London, Routledge. 15-34.

Binney, C., Brown, J., Ely, S. et al (1995). Survey Data Enhancement and Interpretive Works for the Recording and Conservation of Pendragon Castle. In *Computer Applications and Quantitative Methods in Archaeology 1993*, J. Wilcock and K. Lockyear (Eds). Oxford, Tempus Reparatum. 237-244.

Birn, J. (2000). *Digital Lighting and Rendering.* Indianapolis, New Riders.

Boland, P. and Johnson, C. (1996). Archaeology as Computer Visualisation: 'Virtual tours' of Dudley Castle c.1550. In *British Museum Occasional Paper Number 114: Imaging the past,* T. Higgins, M. Main and J. Lang (Eds). London, British Museum. 237-234.

Boswell, J. (1955 [1785]). *The Journal of a Tour to the Hebrides with Samuel Johnson.* London, Collins.

Brenner, C. (1999). Interactive Modelling Tools for 3D Building Reconstruction. In *Photogrammetric Week 99*, D. Fritsch and R. Spiller (Eds.). Heidelberg, Wichmann Verlag. 23-34.

Calvet, Louis-Jean (1996). *Histoire de l'Ecriture.* Paris, Editions Plon.

Chadwick, J. (1961). *The Decipherment of Liner B.* London, Pelican Books.

Chalmers, A. and Stoddart, S. (1996). Photo-realistic Graphics for Visualising Archaeological Site Reconstructions. In *British Museum Occasional Paper Number 114: Imaging the past,* T. Higgins, M. Main and J. Lang (Eds). London, British Museum. 85-94.

Collins, B., Williams, D. et al (1995). The Dresden Frauenkirche – rebuilding the past. In *Computer Applications and Quantitative Methods in Archaeology 1993*, J. Wilcock and K. Lockyear (Eds). Oxford, Tempus Reparatum. 19-24.

Conisbrough Castle web pages (2005). Viewed April 2005. <http://www.conisbroughcastle.org.uk/>.

Corbusier, Le (1986 [1931]). *Towards a New Architecture*, F. Etchells (Trans). New York, Dover Publications.

Cooper, E., Gisiger, A., Limp, W. et al (1996). *Development and Implementation of a Rapid Low-Cost Photogrammetric Data Archival System for Artifact and Osteological Invenntory*. Fayetteville, University of Arkansas. Viewed January 2001. <http:web.cast.uark.edu/cast/projects/arch/photogram>.

Cottrell, L. (1953). *The Bull of Minos*. London, Pan Books.

Cottrell, L. (1957). *Lost Cities*. London, Pan Books.

Criminisi, A., Reid, I. And Zisserman, A. (1999). *Single View Metrology*. Viewed August 2002. <http://www-2.cs.cmu.edu/~ph/869/papers/Criminisi99.pdf>.

Criminisi, A. (2001). *The Virtual Trinity*. Viewed August 2002. <http://galileo.imss.firenze.it/news/intlabor/ecriminis.html>.

Dallas, R. (1993). *Photogrammetric Techniques for Measured Surveys of Buildings*. Course Notes for RICS Diploma in Building Conservation.

Davey, P. (1995). *Arts and Crafts Architecture*. London, Phaidon Press.

Day, A. (1997). *Digital Building*. Oxford, Laxton's.

Debevec, P.E., Taylor, C.J. and Malik, J. (1996). *Modeling and Rendering Architecture from Photographs: A hybrid geometry-and image-based approach*. Viewed February 2004. <http.cs.berkeley.edu/~debevec/Research/>.

De Mey, M. (1995). Masaccio's Bag of Tricks. In *Understanding Images: Finding meaning in digital imagery*, F. T. Marchese (Ed). New York, Springer-Verlag. 143-170.

Earl, G. and Wheatley, D. (2002). Virtual Reconstruction and the Interpretative Process. In *University of Southampton Architectural Monograph No. 3: Contemporary Themes in Archaeological Computing*, D. Wheatley, G. Earl and S. Poppy (Eds). Oxford, Oxbow Books. 5-15.

Egerton, P.A. and Hall, W.S (1999). *Computer Graphics: Mathematical first steps*. London, Prentice Hall.

Eiteljorg, H. (1988). *Surveying for Computer-Aided Drafting and Design – Experiments in Three-Dimensional Techniques*. Viewed January 2001. <http://www.csanet.org/inftech/srveybk.html>.

Eiteljorg, H. (1994). *CSA Newsletter 7: Using a total station.* Viewed January 2001. <http://www.brynmawr.edu/web1/Aug94/nl089407.html>.

Eiteljorg, H. (2000). *CSA Newsletter 13: Using a Spreadsheet to Speed AutoCAD Data Entry.* Viewed May 2000. <http://www.165.106.5.82/web1/spring01/nls0105.html>.

Evans, R. J. (2000). *In Defence of History*. London, Granta Books.

Fitch, J. M. (1990). *Historic Preservation.* Charlottesville, University Press of Virginia.

Forte, M. and Silliotti, A. (1997). *Virtual Archaeology: Great discoveries brought to life through virtual reality.* London, Thames & Hudson.

Forte, M., Borra, D et al (1998). *The Estense Castle of Ferrara: Multimedia project and virtual reconstruction.* Viewed August 2004. <http://www.dea.polimi.it/dea/heritage/events/benire98/speakers/forte/Pescarin.htm>.

Forte, M, Tilia, S., Bizzarro, A. et al (2001). 3D Visual Information and GIS Technologies for Documentation of Paintings in the M Sepulcher in the Vatican Necropolis. In *Computer Methods and Quantitative Applications in Archaeology 2000*, Z. Stancic and T. Veljanovski (Eds). Oxford, British Archaeological Reports International Series 931. 25-32.

Gaffney, V., and Linford, P. (1999). The Application of Geophysical Techniques at Wroxeter Roman City. In *Computer Applications and Quantitative Methods in Archaeology 1997*, L. Dingwall, S. Exon et al (Eds). Oxford, British Archaeological Reports International Series 750. On CD-ROM.

Gao, L. (1999). Archaeological Prospection with GPR Approaches: Case studies in Xian and Shangqiu, China. In *Computer Applications and Quantitative Methods in Archaeology 1997*, L. Dingwall, S. Exon et al (Eds). Oxford, British Archaeological Reports International Series 750. On CD-ROM.

Gates, C. (2005). Treasures Face Cyber Scrapheap. In *Building Design*, 24 March. Viewed April 2005. <http://www.bdonline.co.uk/story.asp?encCode=2335223881BC840759808JTBS737226611&storyCode=3048748>.

Gibson, M. (2004). Professor of Archaeology, Oriental Institute of Chicago. Email, 3 September.

Gifford, C. and Acuto, F. (2002). Space, Place and Inka Domination in Northwest Argentina. In *Experimental Archaeology: Replicating past objects, behaviours, and processes*, J.R. Mathieu (ed). Oxford, British Archaeological Reports International Series 1035. 95-110.

Grant, M. and Paterson, I. (1997). *Virtual Heritage.* Glasgow, University of Strathclyde.

Groat, L. and Wang, D. (2002). *Architectural Research Methods.* New York, John Wiley & Sons.

Grossman, F. (Undated). *Bruegel: The paintings.* London, Phaidon Press.

Halper, N., Mellin, M. et al (2003*). Towards an Understanding of the Psychology of Non-Photorealistic Rendering.* Viewed August 2004. < wwwisg.cs.uni-magdeburg.de/graphik/pub/files/Halper_2003_TAU.pdf>.

Harbison, R. (1991). *The Built, the Unbuilt and the Unbuildable.* London, Thames & Hudson.

Heim, M. (1995). Crossroads in Virtual Reality. In *Understanding Images: Finding meaning in digital imagery*, F. T. Marchese (Ed). New York, Springer-Verlag. 265-280.

Holtorf, C. (2005). *The Portrayal of Archaeology in Contemporary Popular Culture: Opportunity or obstacle for professional archaeologists?* Viewed April 2005. <http://traumwerk.stanford.edu:3455/PopularArchaeology/9>.

Homer (1950 [?]). *The Iliad*, E.V. Rieu (Trans). London, Penguin Books.

Interview with Luyen Chou (undated). Viewed April 2005. <http://www.ruf.rice.edu/~macro/public_html/Macrocosm/Divisions/Editorial/website/pages/latestissue/luyen/luyen.html>.

Jalmain, D. (1990). De la Brie à la Beauce, du Passé au Présent. In *Aerial Photography and Geophysical Prospection in Archaeology: Proceedings of the*

Second International Symposium, C. Léva (ed). Brussels, Centre Interdisciplinaire de Recherches Aériennes. 155-162.

Jesse, R., Isenberg, T., Nettelbeck, B. et al (2004). *Dynamics by Hybrid Combination of Photorealistic and Non-Photorealistic Rendering Styles*. Viewed August 2004. < wwwisg.cs.uni-magdeburg.de/graphik/pub/files/Jesse_2004_DBH.pdf>.

Johnston, W.R (1991). Antiquitas Aperta: The past revealed. In *Empires Restored, Elysium Revisited: The art of Sir Lawrence Alma-Tadema*, J.L Lovett and W.R. Johnston (Eds). Williamstown, Massachusetts, Sterling and Francine Clark Art Institute. 30-35.

Kammermans, H., Verbruggen, M. and Schenk, J. A. (1995). Who Will Make the Drawings? In *Computer Applications and Quantitative Methods in Archaeology 1993*, J. Wilcock and K. Lockyear (Eds). Oxford, Tempus Reparatum. 127-132.

Kantner, J. (2000). *Realism vs. Reality: Creating virtual reconstructions of prehistoric architecture*. Viewed August 2004. <http://sipapu.gsu.edu/SAA00/ >.

Keen, J. (1999). The Ancient Technology Centre, Cranbourne, UK: A reconstruction site built for education. In *The Constructed Past: Experimental archaeology, education and the public*, P.G. Stone and P.G. Planel (Eds). London, Routledge. 229-244.

Kemp, D. (1995). Personal Computer-Based Three-Dimensional Modelling of Standing Buildings. In *Computer Applications and Quantitative Methods in Archaeology 1993*, J. Wilcock and K. Lockyear (Eds). Oxford, Tempus Reparatum. 249-254.

Kemp, M. (1990). *The Science of Art: Optical themes in western art from Brunelleschi to Seurat*. New Haven, Yale University Press.

Khemlani (1999). *Into 3D with formZ*. New York, McGraw-Hill.

Kostof, S. (1985). *A History of Architecture: Settings and rituals*. New York, Oxford Univerity Press.

Kubach, H. (1975). *Romanesque Architecture*. New York, Harry N. Abrams.

Lange, E. (1996). Development of an On-Site Digital Imaging System for the Documentation of Wall Paintings. In *British Museum Occasional Paper Number 114: Imaging the past,* T. Higgins, M. Main and J. Lang (Eds). London, British Museum. 1-11.

Leica Geosystems (2005). Viewed April 2005. <http://www.leica-geosystems.com/corporate/en/lgs_index.htm>.

Levy, R.M. (2001). Temple Site at Phimai: Modelling for the scholar and tourist. In *Proceedings of the Seventh International Conference in Virtual Systems and Multimedia, 25-27 October 2001, Berkley, California*, H. Thwaites and L. Addison (Eds). Los Alamitos, California, Institute of Electrical and Electronic Engineers. 147-158.

Lewin, J.S., Ehrhardt, M. et al (1997). *Not Just Another Pretty Face.* CAAD Futures 1997 Digital Proceedings. Viewed April 2005. <http://depts.washington.edu/dmgftp/publications/pdfs/cf97-ceren.pdf>.

Liu, J. (1999). Remote Sensing into the Study of Ancient Beiting City in North-Western China. In *Computer Applications and Quantitative Methods in Archaeology 1997*, L. Dingwall, S. Exon et al (Eds). Oxford, British Archeaological Reports International Series 750. On CD-ROM.

Lock, G. (2003). *Using Computers in Archaeology: Towards virtual pasts.* London, Routledge.

Lovett, J.L (1991). A Life Colored by Art. In *Empires Restored, Elysium Revisited: The Art of Sir Lawrence Alma-Tadema,* J.L. Lovett and W.R. Johnston (Eds). Williamstown, Massachusetts, Sterling and Francine Clark Art Institute. 9-29.

Lucet, G. and Lupone, C. (1995). A Computerised Register of Pre-Hispanic Architecture. In *Computer Applications and Quantitative Methods in Archaeology 1993*, J. Wilcock and K. Lockyear (Eds). Oxford, Tempus Reparatum. 145-148.

Lupone, C. and Lucet, G. (1995). A Methodology for Recording Pre-Hispanic Mural Paintings. In *Computer Applications and Quantitative Methods in Archaeology 1993*, J. Wilcock and K. Lockyear (Eds). Oxford, Tempus Reparatum. 245-248.

Masuch, M., and Strothotte, T. (1998). *Visualising Ancient Architecture Using Animated Line Drawings*. Viewed August 2004. < wwwisg.cs.uni-magdeburg.de/graphik/pub/files/Masuch_1998_VAA.pdf>.

Masuch, M., Freudenberg, B. et al (1999). *Virtual Reconstruction of Medieval Architecture*. Viewed August 2004. <wwwisg.cs.uni-magdeburg.de/graphik/pub/files/Masuch_1999_VRM.pdf>.

Mehta, M. (2001). Virtual Reality Applications in the Field of Architectural Reconstructions. In *Proceedings of the Seventh International Conference in Virtual Systems and Multimedia, 25-27 October 2001, Berkley, California*, H. Thwaites and L. Addison (Eds). Los Alamitos, California, Institute of Electrical and Electronic Engineers. 183-190.

Miller, P. and Richards, J. (1995). The Good, the Bad, and the Downright Misleading: Archaeological adoption of computer visualisation. In *Computer Applications and Quantitative Methods in Archaeology 1994*, J. Huggett and N. Ryan (Eds). Oxford, Tempus Reparatum. 19-22.

Orwell, G. (1938). *Homage to Catalonia*. London, Penguin Books.

Ozawa, K (1996). ASM: An ancient scenery modeller. In *British Museum Occasional Paper Number 114: Imaging the past,* T. Higgins, M. Main and J. Lang (Eds). London, British Museum. 109-118.

Preston, D. (2000). The Temples of Angkor: Still under attack. *National Geographic Magazine,* August. 8-22.

Radding, C. and Clark, W. (1992). *Medieval Architecture, Medieval Learning: Builders and masters in the age of the Romanesque and Gothic.* New Haven, Yale University Press.

Redfern, S. (1999). A PC-Based System for Computer Assisted Archaeological Interpretation of Aerial Photographs. In *Computer Applications and Quantitative Methods in Archaeology 1997*, L. Dingwall, S. Exon et al (Eds). Oxford, British Archaeological Reports International Series 750. On CD-ROM.

Reed, P. (2000). Structural Rationalism and the Case of Sant Vicenç de Cardona. In *Architectural History 43*. London, The Society of Architectural Historians of Great Britain. 24-41.

Reed, P (2002a). Professor Emeritus, University of Strathclyde, Glasgow. Personal communication.

Reed, P. (2002b). *Further Observations on Sant Vicenç de Cardona.* Unpublished draft.

Reilly, P. (1992). Three-dimensional Modelling and Primary Archaeological Data. In *Archaeology and the Information Age: a global perspective*, P. Reilly and S. Rahtz (Eds). London, Routledge. 147-173.

Riley, H. (1999). The Use of Global Positioning System Technology to Record and Interpret Archaeological Sites and Landscapes. In *Computer Applications and Quantitative Methods in Archaeology 1997*, L. Dingwall, S. Exon et al (Eds). Oxford, British Archaeological Reports International Series 750. 189-194.

Rheingold, H. (1991). *Virtual Reality.* London, Mandarin.

Ruskin, J. (1989 [1880]). *The Seven Lamps of Architecture.* New York, Dover Publications.

Ruurs, R. (1987). *Saenredam: The art of perspective.* Philadelphia, Benjamins / Forsten.

Ryan, N. (1996). Computer Based Visualisation of the Past: Technical 'realism' and historical credibility. In *British Museum Occasional Paper Number 114: Imaging the past,* T. Higgins, M. Main and J. Lang (Eds). London, British Museum. 95-108.

Ryan, N., Pascoe, J. and Morse, D. (1999). Enhanced Reality Fieldwork: The context aware archaeological assistant. In *Computer Applications and Quantitative Methods in Archaeology 1997*, L. Dingwall, S. Exon et al (Eds). Oxford, British Archaeological Reports International Series 750. 269-274.

Sabloff, J.A. (1989). *The Cities of Ancient Mexico.* London, Thames and Hudson.

Schmidt, M. (1999). Reconstruction as Ideology: The open air museum at Oerlinghausen, Germany. In *The Constructed Past: Experimental archaeology, education and the public*, P.G. Stone and P.G. Planel (Eds). London, Routledge. 146-155.

Seichter, H. (2003). Augmented Reality Aided Design. In *IJAC: International Journal of Architectural Computing 04,* A. Brown (ed). Brentwood, Multi-Science. 451-459.

Sheering, P. K . (1995). Rapid Prototyping Branches Out. In *Cadalyst Magazine.* April 4. Viewed April 2005. <http://cadence.advanstar.com/2003/0503/report0503.html>.

Sommer, U. (1999). Slavonic Archaeology: Gross Raden, an open air museum in a unified Germany. In *The Constructed Past: Experimental archaeology, education and the public,* P.G. Stone and P.G. Planel (Eds). London, Routledge. 157-170.

Stamp, G. and McKinstry, S. (Eds) (1994). Thomson's Architectural Theory. In *'Greek' Thomson,* Edinburgh, Edinburgh University Press. 63-72.

Steadman, P. (2001). *Vermeer's Camera: Uncovering the truth behind the masterpieces.* Oxford, Oxford University Press.

Stempel, P. (1983). *Alan Sorrell: Das alte Wales wiedergeschaffen.* Cardiff, National Museum of Wales.

Stone, P.G. and Planel, P.G (1999). Introduction to *The Constructed Past: Experimental archaeology, education and the public,* P.G. Stone and P.G. Planel (Eds). London, Routledge. 1-13.

Stotz, R. (1968). Inexpensive Graphics. In *Computer Graphics in Architecture and Design: Proceedings of the Yale Conference on Computer Graphics in Architecture,* M. Milne (ed). New Haven, Connecticut, Yale School of Art and Architecture. 52-54.

Streilein, A. (1996). *Digital Architectural Photogrammetry and CAAD – Project Description.* Viewed June 2001. Zurich, Eidgenössische Technische Hochschule. <http://www.geod.ethz.ch/p02/projects/dapcad/dapcad_project.html>.

Strothotte, C. and Strothotte, T. (1997). *Seeing Beyond the Pixels: Pictures in interactive systems.* Berlin, Springer-Verlag.

Strothotte, T., Puhle, M. et al (1999). *Visualizing Uncertainty in Virtual Reconstructions.* Viewed August 2004. <wwwisg.cs.uni-magdeburg.de/graphik/pub/files/Strothotte_1999_VUW.pdf>.

Tavernor, R (1995). Architectural History and Computing: Developing a new discipline. In *Computer Applications and Quantitative Methods in*

Archaeology 1993, J. Wilcock and K. Lockyear (Eds). Oxford, Tempus Reparatum. 255-257.

Tavernor, R. (1996). An Architect's Perspective on History and the Computer. In *British Museum Occasional Paper Number 114: Imaging the past,* T. Higgins, M. Main and J. Lang (Eds). London, British Museum. 149-158.

Terlingen, J.B.A. and Engelbregt, G.M.J. (1996). Herbouwd verleden. In *Bulletin KNOB 1995-2*. Amsterdam, Bureau KNOB. 41-52.

Thoreau, H. D. (1997 [1854]). *Walden*. Oxford, Oxford University Press.

Threat to World Heritage in Iraq, The (2003). Oxford, University of Oxford. Viewed April 2005. <http://users.ox.ac.uk/~wolf0126/>.

Toby's Film Stills (2002). Viewed April 2005. <http://filmstills.netfirms.com/index.html>.

TVfilm (2004). Viewed April 2005. <http://www.tvfilm.hu/>.

Van Den Berg, D. J. (2001). Spectators in Jerusalem: Urban narrative in the scenic tradition. In *Image & Narrative: Online magazine of the visual narrative*, J. Baetens and H. Van Gelder (Eds). Leuven, Instituut voor Culturele Studies. Viewed April 2005. <http://www.imageandnarrative.be/illustrations/dirkvandenberg.htm>.

Van Schalwyck, L.O. (1999). oNdini: The Zulu royal capital of King Cetshwayo ka Mpande (1873-1879). In *The Constructed Past: Experimental archaeology, education and the public*, P.G. Stone and P.G. Planel (Eds). London, Routledge. 269-282.

Virtual Babel Encyclopaedia, The (undated). Viewed August 2004. <http://www.towerofbabel.391.org/index.htm>.

Vranich, A. (2002). Seeing What is Not There: Reconstructing the monumental experience. In *Experimental Archaeology: Replicating past objects, behaviours, and processes*, J.R. Mathieu (ed). Oxford, British Archaeological Reports International Series 1035. 83-94.

White, J. (1957). *The Birth and Rebirth of Pictorial Space*. London, Faber and Faber.

Witcombe, C. (undated). *Stonehenge Restorations*. Sweet Briar, Virginia, Sweet Briar College. Viewed August 2004. <http://witcombe.sbc.edu/earthmysteries/EMStonehengeB.html>.

Wood, J. (1992). Three-Dimensional Computer Visualization of Historic Buildings – with particular reference to reconstruction modelling. In *Archaeology and the Information Age: a global perspective*, P. Reilly and S. Rahtz (Eds). London, Routledge. 123-145.

Wood, M. (1996). *In Search of the Trojan War*. London, Penguin Books/BBC.

Zarifis, N. (1999). Image Processing Techniques in the Study and Restoration of Byzantine Mural Paintings. In *Computer Applications and Quantitative Methods in Archaeology 1998*, J.A. Barcélo, I. Briz and A. Vila (Eds). Oxford, British Archaeological Reports International Series 757. 55-57.