Reconstructing Ancient Kellis

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Abstract: The possibilities offered by Virtual Archaeology generated a great deal of enthusiasm during the 1990s despite limitations of the technology. Today, with advances in computer graphics and processing power, 3D applications are increasingly used in furthering the documentation, conservation and preservation of ancient heritage. This paper examines the digital reconstruction of Ismant el-Kharab, ancient Kellis, Egypt based upon data from excavations carried out by Dr Colin Hope and Dr Gillian Bowen, Centre for Archaeology & Ancient History, Monash University. Presently ancient Kellis exists principally in data not immediately interpretable to the general public. In line with the growing emphasis on Virtual Heritage, comprehensive three-dimensional (3D) visualisations can significantly advance the awareness of historical sites normally inaccessible due to their location or fragile condition. Visualisations stretching across time and space can provide the possibility of visiting places that no longer exist or of viewing how places would have appeared at different times in their history. In the case of ancient Kellis, as in most archaeological excavations, a complete reconstruction is not possible as only a fraction survives. Several theories may compete to explain probable or possible reconstructions; a presentation of plural visualisations is the only way to obtain reasonable results. Interactive applications offer the ability to compare and contrast details of buildings and suggested reconstructions and choose between visualisations where temporal and spatial aspects can be explored. These techniques can significantly advance the archaeological interpretation of the site.

Introduction

The purpose of this article is to present an introduction to a new project: the Virtual reconstruction of ancient Kellis.1 To place this project within its context, an archaeological overview of the site and the structures that are currently being reconstructed by the 3D process, is provided by Gillian Bowen, Centre for Archaeology & Ancient History, Monash University and Deputy Director of excavations at Ismant el-Kharab. Although reports on excavations at the site have been published in various journals, this overview will introduce readers of Buried History to work currently undertaken in Egypt by a team of academics and students centred in Melbourne. The discussion of the Virtual Archaeology project and the work undertaken to date is provided by Thomas Chandler and Derrick Martin, Faculty of Information Technology, Monash University.

Ancient Kellis

Ismant el-Kharab (Ismant the ruined), ancient Kellis, is a Roman Period village situated in Egypt’s Dakhleh Oasis, some 800 km south-south-west of Cairo and about 280 km west of Assyut in the Nile Valley. The site falls within the concession granted to the Dakhleh Oasis Project (DOP) in 1977. It was surveyed by the Project during the 1981-82 field season at which time limited excavation was undertaken and a detailed plan of the site was begun (Mills 1982: 99-100; Knudstad and Frey 1999). Small-scale excavation continued in the 1982-83 field season and, following the completion of the survey of historic sites, Ismant el-Kharab had shown sufficient potential to warrant closer examination (Hope 1988: 160). In the 1986 season a more extensive excavation programme was embarked upon under the directorship of Dr Colin A. Hope (Hope 1985: 114-25). The work is on-going.

The settlement was built upon a low terrace of Nubian clay with wadis to the southeast and northwest (Figure 1). It covers an area 1050 m northeast-southwest and 650 m northwest-southeast (Knudstad and Frey 1999: 189). The remains of the village are visible above the surface of the site and are extremely well preserved with some structures surviving to a height of over eight metres above the surface (Hope 1990:43; Knudstad and Frey 1999: 188). Knudstad and Frey (1999: 912) note that in the central, south and west sections of the site, most of the vaults and domes are to a large extent preserved, indicating that the structures are in the early stages of erosion. Kellis was built almost entirely of mud brick, with sandstone and limestone reserved for some formal structures and some tomb chambers. The village was surrounded with field systems, traces of which are visible today. Two major cemeteries are located outside the village: one in the low escarpment across the northwest wadi and comprises rock-cut tombs that contained pagan burials, whilst the second, which developed in the northeast, consists of pit graves uniformly cut into the bedrock on an east-west axis; bodies were placed in a supine position with their heads to the west (Birrell 1999: 38-41; Bowen 2003), which conforms to early Christian burial practice and the cemetery was clearly established for members of this section of the population. A series of freestanding mausolea form a line along the north-western edge of the site and a further group is to be found in the extreme south.

In the northernmost sector of the village, to the east of the mausolea, are three large complexes spanning an area of approximately 240 m north-south and 100 m east-west.
They occupy a sector of the site designated Area B (Hope 1988: 163). The most southerly of these complexes forms a single unit, which had undergone at least three extensions. In its final stage it contained no fewer than 216 rooms and is presumably civic in nature (Hope 1988: 163). The complexes to the north are essentially residential with small domestic units dispersed between large, well-constructed villas, with elaborately decorated walls (Hope 1988: 163-64; 1990: 43; Hope et al 2005: 37-40). A test was conducted in one of the latter in the 2005 field season: B/3/1. The extent of the structure has not yet been determined but it comprises numerous rooms around a large central hall with substantial columns and piers; the structure, which predates the fourth century, attests the affluence of some members of the Kellis community (Hope et al 2005: 37-40). The sector designated Area C is contiguous with the east side of Area B; it extends to the easternmost boundary of the site. Area C comprises domestic and light industrial structures, including potters kilns and evidence of blacksmithing (Hope 2002: 174; Hope et al 2005). This area has witnessed more deflation than the remainder of the site; there is no evidence of occupation during the fourth century. The central residential sector, designated Area A, lies immediately to the south of Area B. This sector extends to the southern limits of the site, and includes the Large and Small East Church that were built...
on the south-eastern periphery of the village overlooking the south-east wadi (Knudstad and Frey 1999: 168; Hope 1988: 165; 1990: 44; Bowen 2002: 65). Houses within Area A were built in the late third and fourth centuries; occupation of the village in the fourth century might well have been largely restricted to Area A and sections of Area D (Hope 1997: 12). The houses in Area A include both single- and double-storey structures (Hope 1997: 11). A major east-west thoroughfare leads west from the churches and intersects some 100 m west of the Large East Church with a north-south street, which runs in front of the outer temenos wall of the Temple of Tutu. A bathhouse has been identified in the south eastern corner of this intersection (Knudstad and Frey 1999: 205). The north-south street marks the boundary between the residential Area A and the formal religious complex to the west. Four contiguous enclosures occupy the south-western sector of the site, which is designated Area D. The largest and most southerly of these, Enclosure 1, houses the Temple of Tutu with its associated shrines and ancillary structures; it occupies a sizeable portion of the entire village. By the mid-fourth century the formal cult practice in the temple had ceased and the structure was used for secular purposes. The limited excavation that was undertaken in Enclosure 2 revealed domestic structures; no excavation has been undertaken in Enclosure 3. Enclosure 4 contains the West Church and a small Christian cemetery to its east. Two pre-existing classical-style, stone tombs located to the immediate east of the church were incorporated into the enclosure when the church was built (Hope and McKenzie 1999).

**Period of Occupation**

The site was occupied from the late Ptolemaic Period, as determined by the discovery of burials and demotic inscriptions from that period (Schweitzer 2001: 270; Hope 2002: 205); it was abandoned in the closing years of the fourth century (Hope 2001). The latest text that can be dated is a horoscope drawn up in the year 392 (Hope and McKenzie 1999), the West Church and tombs (Hope and McKenzie 1999), the Large and Small East Churches (Bowen: 2002). The research objective adopted for Kellis by the director was to glean as comprehensive a picture as possible of life in a provincial settlement. With this in mind specific areas were targeted for excavation. As the village spanned the transitional period from paganism to Christianity, excavation would naturally include the Temple of Tutu and at least one, if not all of the churches. Selective house units within various areas of the site would also be included, as would a representative selection of the monumental tombs. Areas excavated to date include:


Area B: Test trenches in the south of B1, the entrance room to a series of niched chambers in the west, B2 (Hope 1999: 65), and four rooms in one of the villas, B3 (Hope 2005: 37-40).


Area D: the Temple of Tutu, room 1 of Shrine 1, Shrines 2 and 3, minor clearance in one room of Shrine 4, the rear of the temple, and structures to the north west of the inner temenos, D/8 (Hope 2002: 178-206), the classical tombs (Hope and McKenzie 1999), the West Church and the Enclosure 4 cemetery (Bowen 2002: 75-84; 2003: 175-77).
Mausolea: one tomb in the South Tomb Group, and seven tombs, and one room of an eighth in the North Tomb Group (Hope 2003: 244-86; 2004: 19-41). The Christian and pagan cemeteries are excavated under the supervision of the physical anthropologists under the leadership of J. Eldon Molto.

Houses 1-3

Structures chosen for Virtual Archaeology reconstruction include Houses 1-3 (Figures 1 and 2). These are located at the north of the Area A residential sector. The houses are bounded by an east-west street in the north that separates the residential sector from the Large Building (B1) and another east-west street in the south that separates the block from other house units. At the rear of the houses are two other structures that are associated with the houses: the North Building that is situated to the north of the courtyards of Houses 1 and 2, and an unexcavated, rectangular enclosure north of the courtyard of House 3 (Hope 1997: 6). The houses differ in plan but have similar architectural features. All are single-storey with a staircase giving access to the roofs. The larger living rooms are flat roofed or open to the sky but the majority of the rooms are barrel vaulted. Each of the living areas have niches and open cupboards with shelves built into their walls; these features were highlighted with a band of white plaster, presumably to indicate their presence in what must have been gloomy rooms. A band of white plaster was also painted across some vaulted ceilings. On abandonment of the houses, the occupants removed most of the wooden fittings although not all were taken away; several door lintels were found in the corridor of House 1. Many of the rooms were filled with windblown sand before any appreciable erosion or collapse had taken place and consequently they are remarkably well preserved.

House 1 (Figure 2; Plate 1), the most westerly, is approached through a single door in the opening off the street to the south in room 9, which, in turn gives access to a corridor (room 8) that runs the width of the house and opens onto the courtyard with animal mangers. The main living areas (rooms 1-6) are to the west of the corridor; these include a kitchen (room 1). Across the corridor is a walk-in cupboard (room 10), the staircase to the roof, with ten preserved steps, with its under-stairs cupboard (room 11). The largest room in the house is an L-shaped dining area (room 7) located in the east. Access to this room is via a door in its west wall, which opens directly onto a courtyard. Peculiar to this room is a mud-brick, plastered, horseshoe-shaped feature set within a solid platform; this occupies the southern section of the room. The remains of a circular feature were found in the north of the room. It would appear that the north section of this room was unroofed (Hope 1987: 74-83). Shelves and niches in the rooms were highlighted by a band of white plaster and a similar band was painted across the vaulted ceilings (Hope 1986: 74-83).

House 2 (Figure 2), the central residence in the block, is accessed from the south street via a double-roomed entrance system (rooms 5-6). Room 6 opens into interconnecting living rooms (rooms 2-3). Room 1 in the north, is accessed via room 2, room 8 in the south is accessed through room 3, as is room 4 in the west. A short corridor (room 7) in the south gives access to the stairs, an under-stairs cupboard, and the kitchen, which, like that in House 1 was a late
addition. All rooms were vaulted with the exception of the interconnecting living rooms, which were flat; they were constructed of palm trunks topped with palm fronds and covered with a thick coat of mud. The extensive courtyard is not approached directly from the house but from the street (Hope 1987: 157-66; 1997: 6-7). From the artefactual remains found within the house, we know that during the last phase of occupation a carpenter was conducting his business from here; amongst other items, he manufactured the leaves for wooden codices (Hope 1987: 163-6).

House 3 (Figures 3 and 4), to the east of House 2, is the largest of the three houses. The door, which opens from the south street, had been raised some 0.80 m during the later stages of occupation. A semi-circular wall of mud brick was erected in the street, on the level of the original sill, to the east of the door in an effort to prevent a build-up of chaff and debris (Hope 1993: 3-4). The entrance (room 1) was down a short flight of steps; the room opens directly into a corridor, which extends the length of the house. A suite of nine rooms opens off the corridor to the east (Hope 1991: 41-3). The access room (room 6) was open to the sky. Rooms 2-3, 5 and 7-9 open directly off the central room; room 4 is accessed through a door in the south wall of room 5, whilst the entrance to room 10 is in the north wall of room 9. The staircase and under-stairs cupboard is to the north-west of the central room. The corridor opens into a courtyard with animal mangers and flimsy structures, presumably animal pens; two ovens are built into the north-western corner of the courtyard. The courtyard is also accessible from a compound to the north. Another room opens off the courtyard to the east (room 11). Rooms 2 and 3 each had a small window set high above the door in the north wall some three metres above the floor. This presumably served to let in light from the open-roofed room 6. A small textile business was conducted from this house (Bowen 2001: 24-6).

The houses bear a striking resemblance in plan and appearance to the older sections of modern villages in Dakhleh such as Balat, Bashendi and the Islamic town of Qasr. The architecture of these desert settlements has changed little over the centuries. Houses, shops and small industrial areas cluster together and in some instances they are indistinguishable from each other when viewed from the narrow, covered streets and lanes. The structures are built of mud brick, an ideal medium in a harsh environment; palm trunks, covered with fronds and mud-plaster are used for the roofs. Doors and their fittings remain unchanged. Rooms interconnect and are dark; windows are few. Whitewash is used on some of the internal walls but this is a rarity, and more often than not the walls are simply coated with mud plaster. As with the structures at Kellis, the floors in these older houses are made of earth.

The Small East Church

The second area of the site chosen for a Virtual Archaeology study is the Small East Church. The structure is located within a large enclosure, overlooking the south-east wadi (Figure 1). It is part of a larger ecclesiastical complex that includes the Large East Church, a purpose-built basilica that dates to the first half of the fourth century (Bowen 2002: 81). The enclosure is imprecisely mapped due, in part, to the degree of preservation of the walls, which makes
it impossible to locate buried doorways, and because the structures within the enclosure have undergone extensive alteration (Knudstad and Frey 1999: 205). The structure occupied by the church was not originally built as such but was modified for Christian use by setting an apse and side chambers against the east wall of the enclosure, ten metres north of its south-eastern corner, in an already existing room.

The church is a two-roomed, mud brick structure: the church in the south, room 1, and an adjoining room on the north, room 2 (Figure 5). The overall dimensions of the complex are 10.5 m north-south and 9.5 m east-west. The area to the south has not been excavated but it does not provide direct access to the church. To the immediate north of the complex is a narrow vaulted corridor, 1.00 m wide that separates the Small East Church from the narthex of the Large East Church. A door in the north wall of Room 2 once gave access to the structure from this corridor but was blocked in antiquity, possibly with the modification of the building. Access to the church was through two small vaulted rooms to the west. These rooms, which preserve their vaults and are in a somewhat dangerous state, have not been excavated and so the entrance system cannot be determined. It has been established, however, that the entrance door was set in the south-western corner of room 1.

The access room to the church (room 2) is barrel-vaulted. The vault had collapsed on to the floor and a decision was made not to excavate this room entirely. A small window set high in the west wall was exposed. This was presumably the sole light source for the room. The church itself (room 1) was preserved to a height of four metres in the west (Figure 6); its flat roof had disappeared and the entire structure was filled with windblown sand. The church comprises a nave, with an apse and two side chambers built against the east wall of the enclosure (Plate 2). Access was via two doors, which communicate with room 2: a narrow one in the west and a large central door. A low bench was built against the north, south and west walls of the nave and cupboards were built into the south, west and north walls; these were once closed off with wooden doors. The floor was once gypsum-coated and all walls were painted with white plaster. A solitary window in the west wall had been blocked with the modification of the building. The apse and side chambers are slightly elevated from the floor of the nave and were framed by mud-brick arches, the stumps of which survive (Figure 7). The side chambers were barrel-vaulted and

Figure 5: Ismant el-Kharab: Plan of the Small East Church (drawing by J. Dobrowolski and B. Rowney)

Figure 6: Ismant el-Kharab: Small East Church, east-west section (AA) through the centre of the church looking north through room 2 (drawing B. Rowney).
the apse was roofed with a cupola, which commenced 1.72 m from the floor. Both side chambers functioned as storage rooms. That on the north (room 3) measures 1.20 m x 1.18 m, and comprises a large wall bin and an open cupboard built into the north wall for the full length of the room, leaving a space of only 0.80 m between the bin and the apse wall. The room was closed off from the nave by a door. The south chamber (room 5) is 1.20 m x 1.50 m. It is devoid of features. A wall was constructed to block this room off from the nave and access was gained through a narrow doorway placed 0.35 m above the nave floor. The doorway is 0.63 m high and 0.45 m wide. Both chambers, including the bin, were coated with white plaster.

A narrow sandstone step gives access to the apse (room 4); the floor was similarly lined with sandstone, most of which were removed in antiquity. The maximum dimensions are 1.87 m north-south and 1.32 m east-west. The lack of bonding between the apse and the exterior wall, together with an insubstantial foundation for the apse has caused the latter to slump, creating two large cracks. Two niches, each framed by a sunken arch and painted red and yellow, were built into the north and south sides of the apse; these were once fitted with doors. The apse was elaborately decorated. An engaged half column was set on the rear wall, slightly north of centre; its capital comprised three-pointed leaves rising and spreading from a horizontal moulding. It was painted yellow and red. Two painted columns were placed either side of the engaged half-column; their shafts are painted red and they are set upon yellow plinths. Between the engaged half-column and the painted columns are two painted frames with representations of panelled double-leaf doors. These comprise a series of eight rectangles decorated with stylised palm fronds. Below the niches are painted squares divided into four alternating red and yellow triangles. In the centre of each square is a small crux ansata, the Christian adaptation of the Egyptian ankh, which for Christians symbolised eternal life. Both faces of the pilasters are painted with geometric designs. The front to the sanctuary, facing the nave, was elaborately painted to represent columns set upon pedestals with geometric designs.

**Preservation and conservation of the monuments**

Preservation and conservation of the monuments is a priority. Some of the excavated structures are sound, their mud-brick walls being strong enough to withstand the weight of the sand surrounding them; others are precarious and have large cracks in the walls caused, in part, by the removal in antiquity of their wooden fittings. The practice adopted in relation to all structures is to draw up detailed architectural plans and sections, to photograph, and then to backfill as many as possible at the end of the excavation, thereby returning them to their
pre-excavation condition. The internal walls in some of the formal structures are decorated with wall paintings executed upon a thin plaster wash. The paintings are fragile and the conservation strategy developed is to consolidate those paintings that remain on the walls and to collect all pieces of painted plaster that have fallen to the ground for reconstruction and consolidation in the workroom (Kaper 1999, 2002). Paintings that remain on the walls are drawn and photographed in careful detail; following this a wall, reusing ancient mud bricks, is built about 30 cm from each of the decorated walls and the intervening space filled with clean sand. The remainder of the room is subsequently backfilled. No wall paintings that are in situ anywhere on the site will remain exposed. The intention is to reproduce the decorative schemes in line drawing and photographic displays. It is here that Virtual Archaeology offers enormous potential.

Virtual reconstruction as a tool for archaeology

Virtual archaeology is the ideal medium for examining ancient Kellis. The technology will give the archaeologists a variety of reconstruction options for structures that have suffered the ravages of time and choices for the placement of objects that were found within the structures. It offers the potential to visualise the village as a whole and the individual structures within it. Many of the buildings have undergone modification over time; these include the Temple of Tutu and the Small East Church. Virtual Archaeology gives the opportunity to visualise these monuments in the various stages of their evolution. The visualisation of the Small East Church is of particular significance as it is the earliest church so far attested in Egypt; its modification as such dates to the early years of the fourth century. Furthermore, this new technology will facilitate a comparison of the architecture of Kellis with contemporary architecture in Dakhleh and in the Nile Valley. An invaluable aspect of Virtual Archaeology for Kellis is its role in the preservation of the site. The fragile nature of the structures renders Ismant el-Kharab a dangerous site for tourists to visit. Numerous buildings are preserved beneath the sand; the tops of some vaults and stairwells are visible from the surface, others are hidden and can collapse should the unwary tourist venture across the site. Moreover, tourists walking upon the walls and roofs of such structures pose a threat to the monuments themselves. Virtual Archaeology can address this problem and make Kellis widely accessible to the general public in a comprehensible form.

Introduction to Virtual Archaeology

The terms 3D reconstruction and 3D modelling can be a misleading. Though they can refer to physical 3D scale models made from, for example, clay or balsawood, increasingly the terms refer to virtual reconstructions built with the aid of computer programs. Conceptually and visually however, the concept of modelling 3D objects on a computer is the same as physical modelling, with the advantage of being more flexible and plastic. Digital 3D models, like clay, are ‘soft’ and plastic; they can be resized, reshaped and remodelled in countless ways (Novitski 1998: 15). Today, 3D technologies are employed for a multitude of purposes: the visualisation of architecture before final construction; in prototyping industrial designs; in animation for major movies and in creating convincing virtual worlds for computer games.

The application of 3D technologies for archaeological visualisation is similarly well established. Many people are familiar with spectacular special effects in televised historical documentaries and museum exhibitions, but digital reconstruction and visualisation regularly aid archaeological research at a more operational level. The recreation of daily life and domestic structures based upon floor plans and sections, textual descriptions, photographs and material textures has assisted archaeologists in visualising the possible appearance of historic buildings and how people organized household activity and organised storage and work spaces (Simmons, cited by Novitski; 1997: 35). These digital reconstructions, whether intended for public display or for specific academic purposes, have come to be classified under the rather general term Virtual Archaeology.

There have been several valid criticisms of Virtual Archaeology. In the early stages where 3D technologies were adopted, particularly in the 1990s, 3D focused archaeological projects too often served as “vehicles for demonstrating advanced graphics techniques with any archaeological considerations playing a less important role” (Ryan 1996: 107). 3D technologies have matured considerably in the last decade, but continual improvements in hardware, visualisation software and the compelling nature of images and video means that the preoccupation with demonstrating novel graphic capabilities over and above archaeological method and enquiry is an ongoing problem. Another criticism is that the initial information upon which reconstructed models are based is not made “transparent” and offers ‘a peremptory single reconstruction without offering alternatives’ (Forte 2000: 249).

In a study of the documentation and validation of Virtual Archaeology, Ryan (2001: 2) emphasizes the key role that visualisation methods bring to the archaeological process 'in providing interfaces to data sources that help to identify uncertainty and enable the exploration of alternative interpretations'. To ensure that the building of virtual models does not end with definitive visual representations, interactivity presents researchers with the ability to choose and manipulate presented digital images.

Where reconstructions are presented not as static images but as interactive spaces the possibilities for visualisation and interpretation become more complex and rich. This study examines and describes some of the ways forward for 3D reconstruction, using specific structures that have been excavated at ancient Kellis. Researchers in archaeological
visualisation have pointed to the necessity of a sequence of images to explore alternatives; archaeological visualisations ideally should involve digital reconstructions of several interpretations of the data, of not just of one 3D model but of lengthy sequences of models (Novitski 1990: 58).

Though the digital reconstruction of a range of buildings at Kellis is underway, this paper focuses upon several buildings specifically: Houses 1, 2 and 3, and the Small East Church. The images presented in this paper reveal the iterative process guiding the digital reconstructions and are subject to further alterations as new discoveries are made and new interpretations are brought to light. Rather than concluding the research process, virtual reconstructions should be regarded as a continuous evolutionary process in which 3D models experience constant refinement (Mausch 1999: 1). It is important not only to communicate the archaeological basis upon which these reconstructions rely, but also the methodological approaches of the 3D technologies that have been employed.

It is hoped that the inherent flexibility of the modelling process and the interactive ways in which it can be communicated will provoke discussion of possibilities and techniques in future research.

The Reconstruction of Houses 1-3 and the Small East Church; Archaeological Data and the 3D Reconstruction Process

The 3D recreation of architecture relies upon accurate information regarding the size and placement of the building walls, doors, windows and other features. The exceptional state of preservation of many structures at Kellis facilitated the production of comprehensive plans and sections (Hope 1990: 48; 1991: 41; Knudstad & Frey 1999: 202-6; Bowen 2002: 76). These plans, together with photographs of the structures, provided accurate information upon which to base the images presented in this paper.³

The process of modelling begins with digitising the floor plan to create a reference image and template for the 3D placement of walls and door openings. Once the base was defined the plan was extruded along an axis to recreate the walls. Doors and windows were cut through the model’s walls, and a roof was added to complete the external geometry. This process is illustrated in Figure 8 where the Small East Church plan is used as the template. Although the reconstructions shown depict the Small East Church as a free-standing building, it did in fact adjoin other structures and was part of a larger enclosure.

As the upper portions of the buildings at the site have not survived, the building profile diagrams and floor plans were studied for information regarding the correct height and placement of walls, floors, niches and doors (Figures 5-7). Although the diagrams provided information about some non-existing features (for example, Figure 7 shows the architect’s reconstruction of the arches that frame the sanctuary), certain architectural features needed to be added without the direct archaeological information. As with other virtual heritage projects (Sanders 2005), the accurate modelling for these parts of the building rely on expert advice, comparison to similar sites and comparison with modern buildings constructed with identical materials. In the case of the church and houses detailed in this study, these analyses allowed wall features (shelves, niches, cupboard doors), ceilings and roofs to be completed for the models.

The inherent flexibility of the 3D model means that several different versions of building features can be created. This modular approach allows flexibility and future proofing; if future research indicates that different geometry was present, a more accurate model may be swapped into the reconstruction.

Once the geometry of the building was modelled, appropriate ‘textures’ were applied over the 3D model surfaces. Digital textures have two roles in 3D architectural visualisation; they render the surface colours and they recreate surface irregularities, or ‘bumpiness’. Surface colours for the Kellis visualisation were partially based on surviving plasterwork from the site, both internal and external (Bowen 2002: 159; Hope 2002: 235). The digital recreation of textures and colours for Houses 1-3 and Small East Church were important in communicating a number of peculiarities by way of surface treatment. For example, the walls of the houses are known to have

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been treated with a mud coating. This has been eroded from the external walls leaving the mud brick structure exposed. The mud plaster has survived on many of the internal walls. It should be noted here that a band of white plaster was painted around the features, presumably to highlight their position. This indicates poor light source. Colours are similarly important in faithfully rendering details of the Small East Church, where the external wall on the east was mud plastered but the internal walls were white (Figure 9). The painted decoration in the apse and the façade of the sanctuary was rendered in various ochres found in the surrounding desert. The apse decoration is largely intact but the two large cracks in the rear wall caused by the slumpage of the apse wall have damaged a section of the design. The design on the façade is more fragile. Large portions of plaster were dislodged from the wall in antiquity and some colours have faded considerably making it difficult to determine the pattern. This requires a degree of interpretation.

The reconstruction in this study extracted textures from photographic references to create generically accurate textures. These textures are generated so that the small sample may be repeated across each surface, without noticeable ‘tiling’ or obvious repetition. Unique textures are placed on the surface above the base colour. For example, the barrel ceilings in Houses 1, 2 and 3 had paint outlining the roof-wall juncture and the arc of the roof. This paint is placed separately to the plaster colour for the ceilings (Figure 10). For mud brick construction, the colour of the local sand determines brick colour. In determining the correct colour, lighting conditions of the reference photography varied from white to pink, yellow and brown based on the time of day the photograph was taken. Eyewitness review was necessary to accurately recreate the true colour of the mud brick walls. The commencement and ongoing research into surface texture recreation and restoration has presented a number of interesting questions, particularly where specific coloured decorations are concerned. How reliable are the photographs by way of colour considering the colours have faded since they were produced in antiquity? How is it at all possible to recreate them in detail? The presentation of several variations is necessary to explore these uncertainties.

The reconstruction of the surface treatment of Houses 1-3 and the Small East Church was carried out with the aid of photographic documentation from past excavations. Ideally, 3D texture reconstruction favours photographic images taken at right angles so that they can be painted
or ‘stuck’ onto flat surfaces on a virtual model. While many photographic references were appropriate for this method, it should be stressed that the existing photography was primarily intended for archaeological documentation long before a 3D reconstruction of the site was proposed (and before 3D technologies were capable of rendering detailed and coloured surfaces). An entirely accurate 3D recreation of the surface textures of the building would require the photographic textures sourced from every part of the building at specific angles and with specific lighting considerations. Though this is technically feasible, it would involve considerable effort and expense and is often not possible given excavation timelines and considerations for the state of the preservation of the buildings involved.

The second role of textures in 3D recreations is to provide surface depth details (bumpiness). This is typically done using ‘bump mapping’, where the surface has an artificial unevenness or roughness applied. For this study there was often no need to exactly recreate existing bumpiness. Only when the surface appearance was significant and unique to a particular location did precise data become required. One example of such unique surface information exists in the two large cracks in the apse of the small East Church mentioned above. Modelling these structural fault lines would require considerable time, however the application of digital textures and virtual lighting renders the surface quickly and creates an illusion of depth. (Figure 11).

It should be noted that a technique exists to duplicate surface protrusions and indentations using a single camera and four lights (Einarsson 2004). This method generates an exact recreation of the surface detail and can be applied to 3D geometry as a texture. This technique was not employed here, as it requires physical access to the site and specialised equipment, though it may prove useful in capturing the surface details of structures excavated in the future.

**Specialised techniques: Visualising Interiors, Exteriors and Internal Architectural Structure**

One of the important parts of this 3D visualisation is the need to be able to ‘see’ inside the buildings. There were several possible methods for visualising the interior of the structures.

The two most obvious methods were to make the entire structure semi-transparent, or to remove parts of the digital geometry to reveal the structures within. These methods were simple
to implement, but suffered several different restrictions. In making the structure semi-transparent, the colour and surface detail of the architecture become less obvious. When removing geometry, the removal must be done manually and is destructive to the virtual model; that is, the original version of the structure must be kept separate in order to be able to go ‘back’ to the complete version.

An alternative method involves the interception of graphics as they are displayed to the screen (Niederauder 2003) but because the removed geometry must align in a particular direction it was incompatible with the buildings addressed in this paper.

A more suitable approach was to simulate a ‘cutaway’ visualisation for the generated images which removes irregularly shaped ‘slices’ of the reconstructed model. The result is very similar to traditional technical illustrations used in architecture and industrial design, with the advantage of offering the viewer/computer user many angles of view simultaneously. For the visualisations shown in Figure 12, a method was constructed using light intensity from a light within the virtual environment that cast no shadows or lit any of the 3D geometry. Instead, the intensity of the light was used to ‘cut through’ the 3D geometry and make it transparent, leaving the rest of the digital model intact but invisible.

This method proved very flexible because the cut-away section could be moved over the model by moving the light in the 3D environment. This technique also permitted animations to be created where the cut-away section moves into the building, showing increasing amounts of the interior over time. The programming of this visualisation technique into an interactive interface is currently being investigated, which will allow researchers to examine the entirety of the structure, internal and external, by moving the mouse over the model.

One limitation to this technique lies in the fact that all virtual geometry is filled with empty mathematical space. Although a virtual wall may appear solid from all sides its interior is in fact hollow, so cutting through building walls reveals empty space instead of the internal structure of the wall (Figure 13, left). In order to create the illusion of solidity, it was necessary to apply a single colour to the inside faces of any geometry being cut. (Figure 13, right). Since white is the only colour applied to these spaces within the walls, improvements need to be made that reveal the materials (bricks, plaster and mortar) from which the wall is made. Beyond the visualisation of reconstructed architecture, this technique shows potential for further archaeological visualisation applications such as the interactive display of site stratigraphy.

Figure 13: The internal structure of the virtual model

Figure 14: An interactive environment
Future Developments and Research

This study details the reconstruction of architecture through digital geometry and surfaces and examines several of the ways in which these structures can be visualised in computer rendered images. The procedures and techniques outlined here constitute only the foundations of more extensive digital reconstruction work in the future. Absent from these images of reconstructed architecture are the many elements suggestive of a lived in space such as baskets, pottery, weaving looms, storage jars, people and animals. Even once all these elements are assembled and placed in context, the rendered images portrayed remain only as snapshots to the past. Interactive visualisations that offer the researcher a choice of differing reconstructions have already been alluded to, though ultimately richer visualisations still would include animation and sound and allow virtual visitors to the site to navigate through the reconstructed virtual environment at will. The creation of these ‘immersive’ environments with the latest computer game technology considerably advances the possibilities for exploration and interpretation within a reconstructed space. Being able to ‘walk through’ ancient Kellis, pick up objects and move through doorways and corridors will engage the virtual visitor in ways which static reconstructed images never can. Although these interactive environments are currently being investigated (Figure 14), their creation nevertheless depends upon the groundwork of the cumulative research work detailed above.

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Endnotes

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2 A team from Columbia University under the directorship of Roger S. Bagnall is currently excavating another Roman period site: Amheida, in the west of Dakhleh.

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