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The visual consumption of mural painting in Late Bronze Age Akrotiri (Thera, Greece):

A computational approach to visibility analysis in three-dimensional built environments

by

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Thesis for the degree of Doctor of Philosophy

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To my parents

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

SCHOOL OF HUMANITIES

ARCHAEOLGY

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The devices used for the communication of meaning in mural painting often pervade pictorial space to reach out into actual space. This fact is often acknowledged in interpretations of Theran wall paintings that have been occasionally concerned with aspects of human experience and engagement with the decorated spaces. However, the reception of Theran murals within their original architectural context has been neither thoroughly nor systematically studied. This is mainly due to the lack of formal methodologies by which human engagement with ancient and partially preserved built environments could effectively be explored.

This thesis investigates aspects of the visual experience of Theran wall-painting, and more particularly, the visibility of the murals and its relationship firstly to the iconographic meaning of the painted scenes, and secondly to the social function and significance of the paintings. It introduces a new method of visibility analysis that integrates 3D modelling and spatial technologies (GIS) to take account of the nature of human experience in the built environment which is essentially three-dimensional. The suggested approach also formally addresses the problems of uncertainty and incomplete data in the archaeological record along with their impact on archaeological interpretations. Finally, it discusses the issue of human movement which is strongly linked to the visual experience of built space and introduces an agent-based approach that aims to investigate aspects of mobility in populated spaces within the social context of movement in the past.

The above methodology is employed to explore the reception of mural decoration in a visually complex ritual space (building Xeste 3), examining the relationship between visual emphasis in pictorial space and the visual exposure of individual elements of a composition in actual space. In this way, it highlights meaningful patterns in the archaeological record that would have otherwise remained unobserved. The results of the analysis are also suggestive of movement and circulation during ritual performances that could have taken place in the building. Furthermore, the same methodology is used to investigate whether pedestrians traversing the street network could have seen, through open windows, the wall paintings that embellished the interiors of elaborate private houses. The application of visibility analysis offers insights into the social significance and functions of Theran murals, illuminating their possible symbolic role in establishing power relations in the prehistoric society of Akrotiri.

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Introduction

Few artefacts have shed as much light on so many diverse aspects of life in an Aegean Late Bronze Age (LBA) town, as the Theran murals have. The wall paintings unearthed at Akrotiri are a rich source of unique evidence for economic and social activities in the Aegean Bronze Age providing valuable information on prehistoric architecture, flora, fauna, ship building, clothing, jewellery, weaving, basketry, and armour equipment. It is not surprising therefore that, since 1967, when the first fragments of painted plaster were discovered at Akrotiri, the wall paintings of Thera have been among the most well-studied and discussed finds of Aegean prehistory.

The paintings embellished the town houses of a coastal urban settlement (fig. 1-1) located at the south of the Greek island of Thera, which was buried by an immense volcanic eruption sometime during the Late Bronze Age. Since the site's discovery in 1967, an area of 12 acres has been excavated, estimated to be a relatively minor part of the original settlement (cf. §2.2). This small sample outlines a picture of a town that consisted of multi-storeyed buildings with indented façades and flat roofs, which were accessible via a well-organised road network. The preservation of the unearthed buildings is unique, as the volcanic material that penetrated the rooms after the eruption prevented the complete collapse of walls and floors, ensuring in some cases even the preservation of upper storeys. Within these buildings many hundreds of square metres of wall-paintings have been discovered, mostly in fragments, but occasionally *in situ*. Their themes vary from ornamental, floral and geometric, to landscape scenes, and from miniature frescoes to almost life-size human representations.

To date, most published works on Theran mural painting have mainly been concerned with the iconographic interpretation of the paintings. Emphasis has been given to the identification of the painted theme, the particular ways in which it is rendered and organised in pictorial space, and the understanding of conventions used in the representation of space and time. However, within the last forty years, there has been a growing awareness of the need to consider and incorporate aspects of human experience and engagement with the decorated spaces into the frameworks used to interpret the meaning and social functions of the murals. Such a tendency is motivated by the acknowledgement, that when painting adorns mural surfaces the architectural context of a pictorial composition should also be considered, as the form and functions of the wall paintings are strongly related to the form and functions of the rooms they embellish, and the devices used for the communication of meaning often pervade pictorial space to reach out into actual space. Recent studies of the paintings have more or less tacitly acknowledged that the investigation into the modes in which the murals were received in their original environment could give indications regarding the hierarchy of meaning in a composition, highlighting the intentions of the painters or those who commissioned the painted themes. More importantly, however, it has been suggested that the issue of visual access to the murals could be associated with aspects of social order in the prehistoric community, indicating the existence of different group identities and strategies of social recruitment and exclusion; in that case the examination of possible social functions of the Theran murals could offer a rare opportunity to illuminate some aspects of the Late Bronze Age society, for which there is only scanty evidence, despite the exceptional preservation of the site. Nonetheless, apart from some general and sporadic observations, the visual reception of the paintings has not been thoroughly studied. This is partly due to the state of preservation of the site, which does not enable the encounter with the frescoes in their initial architectural context, and as a result the acts of 'seeing' and 'moving' within the decorated spaces are difficult to appreciate. More importantly, however, a systematic approach to these issues is hindered by the general lack of formal methodologies that can effectively explore human engagement with ancient and partially preserved built environments.

Within this framework this work examines the factors affecting the visual experience and communicative impact of Theran murals in building interiors and in the townscape of LBA Akrotiri, and investigates the different modes in which the visibility of the paintings could be related to their iconographic interpretation and social functions. It develops and employs new formal computer-based methodologies that aim to establish a human-centred approach to the investigation of visual experience and movement in past environments. It introduces for the first time a method of visibility analysis that integrates 3D modelling and spatial technologies (GIS) to take account of the nature of human experience in the built environment, which is essentially three-dimensional. The suggested approach also attempts to address archaeological concerns regarding visibility in past built spaces and more particularly the problems of uncertainty and incomplete data in the archaeological record and their impact on archaeological interpretations. Finally, this research looks at the issue of movement in the built environment, which is strongly linked to the visual experience of mural painting, and introduces an agent-based approach that aims to investigate aspects of mobility in populated spaces within the social context of movement in the past.

These ideas are further developed in the following chapters:

Chapter 1 firstly (§1.1) discusses interpretations of Theran murals that have been concerned with the visual experience of the paintings, as well as the objectives, merits and limitations of these works. It then goes on to address the particular aims of this research (§1.2) and to identify the factors that affect visual perception in the built environment (§1.3), and especially the visibility of painted wall surfaces. These will be discussed throughout the thesis.

Chapter 2 is a background chapter that presents information on the environment, settlement and society at prehistoric Akrotiri. A variety of evidence regarding the uses of space and human activities including land cultivation, animal husbandry, seafaring, trade, craftsmanship and ritualised expression in the settlement are discussed. Besides introducing the site, this chapter aims to inform and support the interpretations suggested in subsequent chapters. Evidence for the economic and social life in the settlement presented here is later utilised in discussions in Chapter 6 and 7.

Chapter 3 is a methodology chapter. It reviews, firstly, the current computing approaches to the study of visual space with particular reference to the disciplines of archaeology and urban studies. After a short discussion on Virtual Reality (VR) and 3D modelling in archaeology it argues that experiential approaches, although in many ways informative, are subject to methodological limitations when used to investigate the visual experience of past environments (§3.1). Following this, more formal computer-based methodologies that aim to analytically examine visibility in space are reviewed. Firstly, the development of archaeological GIS-based visibility analysis in the context of landscape research is discussed and certain issues of the archaeological problematic concerning visual perception in past environments are highlighted. Subsequently, various methods of visibility analysis, mainly applied to two - dimensional spaces, which have been developed in the field of urbanism are examined (§ 3.2). It is concluded that in many ways the limitations of the above approaches restrict the lines of inquiry that can be pursued in the interpretation of past built environments, especially because they fail to take into account the 3D nature of space that the archaeologists wish to interpret.

In the final section of this chapter (§3.3) a new methodology that integrates 3D modelling and GIS functionalities and can take into full account the 3D nature of past built spaces is developed. A number of methods for recording visibility information and performing spatial mapping and analysis are presented, with particular reference to the visibility of mural surfaces. The proposed methodology also suggests ways of considering uncertainty in the archaeological record, by propagating probability, fuzziness and error in the outcomes of the analysis.

Chapter 4 discusses the visual consumption of wall paintings in Xeste 3, a building that is believed to have been used for public gatherings and ceremonies in Late Bronze Age. Firstly, the architecture and wall decoration of Xeste 3 are introduced (§4.2, §4.3). Emphasis is given to indications in the material record of devices used to control physical and visual access to the east wing of the building, which was embellished with mural paintings of ritual-symbolic significance. Ritual practices that could have taken place in Xeste 3 are then discussed (§4.4), as they are inextricably linked with movement and action in the decorated spaces, and consequently, with the visual consumption of mural decoration. Then the methodology presented in Chapter 3 is employed to investigate the visual access to the wall-paintings of the Adorants, the male scene and the Crocus Gatherers that decorated spaces 3a and 3b on the ground and first floors of the building (§ 4.6). Uncertainty in the reconstruction of the spaces under study is considered and formally assessed with the application of sensitivity analysis and error propagation. The results of visibility analysis presented at the end of this chapter (§ 4.7) raise interesting issues regarding three interrelated study areas: a) the relationship between the reception of individual pictorial elements and the hierarchy of meaning in painted scenes, b) the reconstruction of ritual practices that could have taken place in Xeste 3, and c) the painting process.

Chapter 5 investigates potential social functions of wall painting by exploring whether and to what degree Theran murals embellishing interiors of first floor rooms could have been exposed to pedestrians traversing the street network of the prehistoric town. The visibility of wall decorations in Rooms B1 of Beta South, Room 5 of the West House, and the first floor room above the Gate at Delta West from the open public spaces of the town is examined via the application of visibility analysis. This approach takes into account visual angular ranges related to the ease with which the paintings could have been seen and alternative reconstructions regarding the form of the window openings. The outcomes of the analysis are discussed together with other factors that would have affected the visibility of the murals, such as illumination, distance, colour and scale of the painted features.

Visual access to the painted scenes from the open public spaces of Akrotiri would also be greatly depended on patterns of pedestrian mobility in the street network. For this reason **Chapter 6** shifts the focus from visibility to movement in past built spaces. Its first part (§6.2) is methodological and discusses models of human mobility in the built environment, as well as the factors that influence movement in built space. Various aggregate and individual-level modeling approaches are presented. Special emphasis is given to agent-based models of pedestrian movement that can be applied to fine spatial and temporal scales. In the end the potential and caveats related to the application of these approaches in archaeological investigations are discussed. The second part of Chapter 6 (§6.3) explores the social context of movement in prehistoric Akrotiri and discusses aspects of mobility in the settlement at medium spatial scales. It then presents an agent-based simulation of pedestrian movement employed at the micro-scale. The model is applied to investigate tendencies in the movement of pedestrians traversing the Mill House Square in opposite directions that would have determined the degree to which the wall-paintings of Room Beta 1 could have been visible from the street network. The chapter concludes with the evaluation of the model and a discussion on the modes in which the observed patterns of movement could have affected the visibility of the paintings from the square.

Chapter 7 firstly (§7.1) summarises and combines the conclusions of chapters 3 to 6, mainly focusing upon the implications of the use of the suggested methods and technologies in this work. Then (§7.2) building upon the results of visibility and movement analyses of Chapters 4, 5, and 6, it discusses possible social functions of Theran mural paintings in Late Bronze Age Akrotiri, and attempts to explain the circumstances that encouraged the production of wall paintings in the settlement. The last part of this chapter (§7.3) proposes some promising future directions of research and discusses their potential to contribute to a wider academic context.

Chapter 1
The visual experience of Theran mural painting: Introduction and problem definition

1.1 The reception of Theran mural painting: Current non-computational approaches

Prehistoric painting mirrors the beliefs, lifestyle and aesthetics of the society in which it was produced, shedding light onto the ways past peoples thought and conceptualised different aspects of their life. Nevertheless, the student of ancient painting has a very difficult task to perform when s/he attempts to decode the iconographic notation of works of art created thousands of years ago. The arrangement of the individual components of a theme in pictorial space is one of the most important indicators of meaning. This applies for all painted artefacts: murals, pottery, easel painting, etc. When it comes to wall painting, however, architectural form and pictorial space are strongly linked, and as a result, part of the meaning of a painted theme rests in the mode it has been developed in a particular mural setting. Unfortunately, Aegean Bronze Age wall paintings are usually found in fragments, often in secondary contexts, and they may not be appreciated within the spaces they aimed to embellish. Thus, a basic aspect of their visual structure and significance eludes us. For this reason Theran murals are a very important source of information on Aegean painting, as in Akrotiri almost complete mural decorations are sometimes discovered *in situ*, or have fallen in fragments in close association to the walls they used to adorn (cf. Introduction), offering a unique opportunity to explore the visual structure of Aegean paintings in their original architectural context.

Up to now many hundred square metres of painted plaster have been unearthed from public and domestic spaces and some have been restored, giving an impressive sample of ornamental and figural compositions (Doumas 1992a). In many occasions the restoration of the surviving painted fragments indicates the original dimensions of a painting and of the wall(s) it used to adorn, which are usually no longer present. Thus, even if the reconstruction of some paintings is disputed, as applies to the Miniature fresco (pls. 1-7) or the murals recovered in the House of the Ladies (fig. 1-1; Peterson Murray 2004; Doumas 1992a), the best-preserved examples of Theran painting form in most cases rare evidence of the ways a theme was developed and received within the Late Bronze Age built environment (table 1-1).

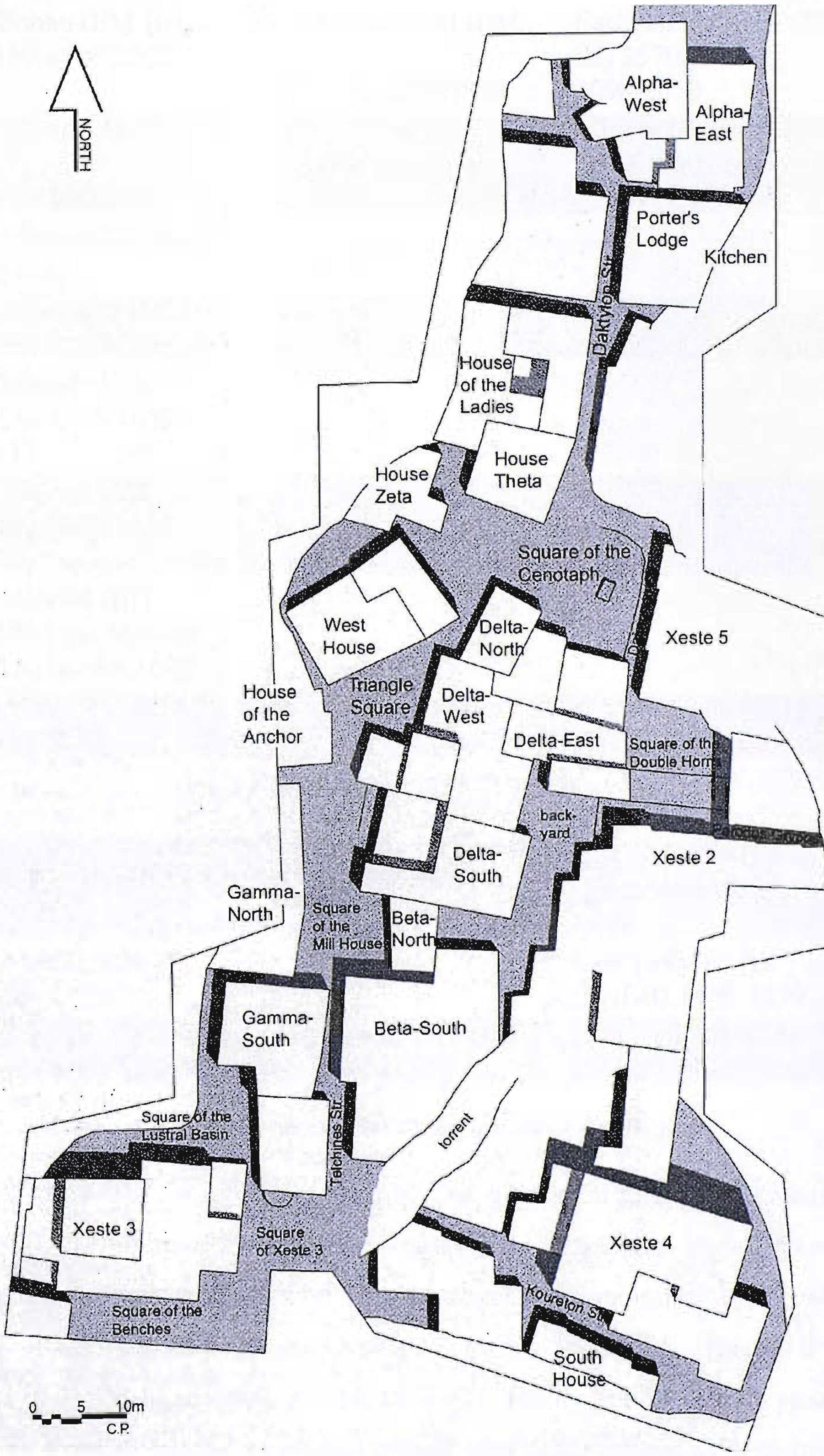

Figure 1-1: Building units unearthed at Akrotiri (form Palyvou 2005a, p. 30)

CRETE	CYCLADES	MAINLAND
Early Minoan I (EM I) 3650/3500- 3000/2900	Early Cycladic (EC I) 3500-2900	Early Helladic I (EH I) 3600-2900
Early Minoan II (EM II) 2900-2300/2026	Early Cycladic II (EC II) 2800/2700-2400/2300	Early Helladic II (EH II) 2900-2570/2410
Early Minoan (EM III) 2300/2150-2160/2025	Early Cycladic III (EM III) 2400/2300-2050/1950	Early Helladic III (EH III) 2570/2410-2090/2050
Middle Minoan IA (MMIA) 2160/1979-20th cent.	Middle Cycladic 2050/1950 onwards	Middle Helladic (MH) 2090/2050 onwards
Middle Minoan IB (MM IB) 19th cent.		
Middle Minoan II (MM II) 19th cent.-1700/1650		
Middle Minoan IIIA (MM IIIA) 1700/1650-1640/1630		
Middle Minoan IIIB (MM IIIB) 1640/1630-1600		
Middle Minoan IIIB (MM IIIB)/Late Minoan IA (LMIA) border 1600		
Late Minoan IA (LMIA) 1600/1580-1480	Late Cycladic I (LCI) from 1600	Late Helladic I (LHI) 1600-1510/1500
	Theran Eruption ca 1550-1530	
Late Minoan IB (LMIB)1480/1425	Late Cycladic II (LC II) from 1500/1480	Late Helladic IIA (LHIIA) 1510/1500-1440
Late Minoan II (LM II) 1425-1390		Late Helladic IIB (LHIIB) 1440-1390
Late Minoan III AI (LM III A 1) 1390-1370/1360	Late Cycladic III (LCIII) from 1390	Late Helladic IIIAI (LH III AI) 1390-1370/1360

Table 1-1: Indicative chronological framework (Warren and Hankey 1989, p.169).

All examples of figurative painting that have been found in Akrotiri are dated to the last phase of the settlement, namely the period that started 50 to 75 years before the volcanic eruption that destroyed the prehistoric town, which occurred around the end of Late Cycladic I period (table 1-1; Doumas 1981; 1992a, p.30-31; Morgan 1988, p.5-10; cf. §2.2). The beginning of this phase is marked by a major seismic event that caused significant rebuilding activities in the settlement, after which the town network and houses took the form seen in the extant archaeological record. Murals with figural themes firstly appeared in Akrotiri at some point after this last reform of the settlement and provide evidence of the ways pictorial compositions were developed in architectural space in the Late Cycladic I period (table 1-1).

During this phase there are mainly two ways in which the painted surface is demarcated by architecture (Cameron 1972, p.205; Immerwahr 1990, 12-13; Palyvou 2000). In the first case the limits of pictorial space are defined by architectural features, such as cross beams in the timber framework of the wall, windows and door frames. These divide the different themes of a pictorial program into friezes and panels. A good example of such an arrangement can be observed in the West House (fig. 1-1, 5-6, 5-7, 5-8), presently the best excavated and published building in Akrotiri. The 'Miniature fresco' (pls. 1-7) was developed in four friezes directly above the windows and door lintels of Room 5 on the first floor (pl. 4, Doumas 1992a, fig. 26-48). The limited space below the windowsills was decorated with marble imitations (pl. 5; Doumas 1992a, fig. 14-17), while the two wall paintings of the 'Fishermen' (pl. 1) formed panels that were fitted into the only locations on north and west walls that were not pierced by window openings (Doumas 1992a, fig.18-25). Finally, the 'Priestess' (pl. 2; Doumas 1992a, fig.24-25) was probably placed at the left jamb of the door that connected rooms 4 and 5 (Doumas 1992a, p. 47; Televantou 1994).

In the second case, a single theme is developed within the boundaries of an entire wall, and sometimes pervades them so as to extend to an adjacent mural surface. In all-wall decoration architectural limits such as window and door frames, are often ignored and covered with painted plaster. There are a number of examples of all-wall decoration in both private and public houses unearthed in Akrotiri (fig 1-1). The frescoes of 'Crocus Gatherers' in Xeste 3 (fig. 1-1, 4-1, 4-2, pl. 14-16; Doumas 1992a, fig.116-130) and the 'Monkeys' in Beta 6 (pl. 20; Doumas 1992a, fig. 85-90) were developed on two adjacent walls. The 'Spring fresco' in Delta 2 (pl. 17; Doumas 1992a, fig.66-76) is the only instance in Akrotiri where a nature scene is illustrated uninterrupted in three walls (Doumas 1992a, p100).

The surviving associations of painted themes with architectural space have up to now encouraged sparse observations regarding human engagement with the decorated spaces and interpretations concerned with the pictorial meaning and the social significance of Theran murals. These interpretations, which acknowledge the importance of the visual experience of the mobile and stationary observer in the painted rooms, have been made on a largely intuitive basis and are discussed below. Broadly, they can be divided to two categories: those that consider the visibility of the paintings in real space in order to support a particular iconographic interpretation, and those that explore visual access to the painted scenes so as to discuss the identity of the potential consumers and social functions of the murals.

1.1.1 Visibility and pictorial meaning

Iconographic interpretations of Theran frescoes have often aimed to identify those elements of a composition that form the visual focus in pictorial or actual space, because these presumably are 'important' for understanding the painter's intentions behind a theme or narrative. In a painted scene individual components can be given more weight by means of their colour, size, form, shape and positioning within pictorial space. Moreover, it has been tacitly acknowledged that pictorial emphasis and hierarchy of meaning in a composition are related to the ease by which a painted element is viewed by someone standing or moving in the decorated spaces (Marinatos 1984; 1993; Televantou 1994; Shaw 2000). Such an assumption is especially made when it comes to visually complex architectural contexts, and where the theme of the fresco extends on more than one wall of a room, as for example in Xeste 3 and the West House (fig.1-1).

Xeste 3 (fig. 4-1, 4-2, 4-3, 4-4) is a building that apparently had a public ceremonial function, as suggested by its architectural form and elaborate mural decoration (cf. § 4.2, 4.3). At the area of the *adyton*[1] (Room 3a) on the ground floor of the building the north wall is embellished with the wall painting of the 'Adorants', depicting three female figures (pl. 13), while the east wall was adorned by an altar topped with horns of consecration (pl. 12). Marinatos (1984,

[1] The "Lustral basin" or *adyton* is one of the most characteristic architectural features of Minoan architecture and is found in palaces and buildings unearthed in Crete. It is a small, square room with its floor at a level lower than that of surrounding rooms. Rooms of this type were once believed to have been "baths" but their connection to water has been questioned. Spyridon Marinatos, who excavated the Room 3a, preferred the word "*adyton*" ("holy of the holies") to describe such a structure (Marinatos 1976, p.23). Frequently "lustral basins" are considered to be of ritual/religious significance.

p.74; 1993, p. 206) observes that the women of the north wall would have been "on the direct axis of vision" of the viewer in Room 3, but she notes that the altar is the focal point for the person descending into the *adyton*. As she explains '...*The reason is the hypothetical person would have to turn eastwards by necessity following the direction of the stairs, and would thus be facing the altar.*' Besides the potential viewer, the movements and gestures of the painted girls were also orientated towards the altar (Morgan 2000), further supporting the assumption that this is the focal point in this scene. A similar observation has been expressed, regarding the male scene (pl. 8, 9, 10), which embellished space 3b of the same room. The scene is composed of three different panels that depict four male figures (cf. §4.3). Marinatos notes that the most important panel would be that of the seated man with the jug (pl. 9) which "would be on the line of vision" of the spectator standing outside the door openings that gave access to the decorated room (Marinatos 1993, p. 209). Again in this case, the three other male figures of the scene appear to be walking towards the seated man.

A similar line of argument has been followed in the interpretation of the Miniature Fresco (pl. 4, 7). It has been suggested that the four friezes of Room 5 of the West House form a unified theme, a narrative of a long sea voyage in which the owner of the building participated (Doumas 1992a, p. 49; Televantou 1994). If this is true, the sequence of events that are recited is far from obvious. Televantou (1994) suggests that the narrative of the Miniature Fresco starts from the west frieze because this is what someone would see upon first entering the room. Here, the observer's facial orientation is the sole argument on which interpretation is based. Maria Shaw (2000, p. 271) on the other hand questions whether the east frieze is part of the narrative using a similar reasoning: She observes that the frieze would be at the back of an observer entering the room adding "...*The artists deliberately encapsulated scenes with causal or temporal connections, that is the plot of the story, on the three walls, south, west and north, that could be seen at once by a visitor entering the room.*' (Shaw 2000. p.271).

Another factor often considered to affect the reception of mural painting is the vertical position of pictorial elements on the painted surface. Palyvou (2000, p. 419) rightly notices that in many cases the iconographic horizon in life-sized representations would correspond to the actual horizon of an individual standing in the decorated rooms. Thus the observer would have been able to experience the picture with ease and even have an eye to eye contact with the painted human figures. This effect would have perhaps made the viewer feel like a participant in the illustrated scenes (cf. Renfrew 2000, p. 140). On the other hand, representations that required the viewers to raise their heads in order to appreciate a theme may have created a sense of subordination (Palyvou 2000, p. 419). However, the latter are quite rare in Aegean painting and it is not surprising that the sole instance of such figure in Akrotiri is the 'Goddess' (pl. 14) from Xeste 3, who is depicted seated on a stepped structure, and placed higher from the visual horizon of a standing observer.

It is characteristic that in all the above interpretations factors that define ease of view are assumed to have affected the rendering of a painted theme and to have played an important role in communicating meaning. One can reasonably wonder at this point whether such approaches in the study of Late Bronze Age mural painting express a contemporary understanding of the experience of space that perhaps would not have been shared by the beholder in prehistory. Recent works in the fields of archaeology and anthropology (Tilley 1993, 1994, 2004; Thomas 1993a, 1993b; Hamilakis *et al.* 2002) have often expressed a concern about interpretations of past spaces that reflect modern perceptions of space, mainly focusing their criticisms upon the prioritisation of vision at the expense of other senses. When it comes to the interpretation of objects that were created to be seen, however, such as Theran murals, such critiques are perhaps less applicable. Nonetheless, there do remain aspects of the visual experience that are culturally specific, for instance the perception of depth in images (Bloomer 1990, p.18), and for this reason the alleged common visual understandings of past and modern viewers should be justified whenever possible.

Having this in mind it is noteworthy that ways of thinking and engaging with mural art such as those discussed above were by no means unknown to prehistoric people. In the Assyrian palaces, for example, representations which are undeniably "important", like the royal figure, are displayed in strategic points both in pictorial and actual space, for example on axis in the throne room, or opposite the doorway, namely locations that enable maximum visual exposure (Winter 2000, p.748). Far more examples of similar arrangement of symbolic features in architectural space can be found in later periods in prehistory and history. These similar perceptions of space are not surprising, of course, as they are related to biological processes, such as the function of the human visual system, which is common to both us and the viewers in the past. It is known for example that a human visual field ranges approximately 180 degrees at the horizontal and 160 degrees at the vertical level (Bloomer 1990, p. 37)[2]. Nonetheless, a viewer cannot perceive information within these ranges with the same degree of clarity. The preferential processing of some items within the field of view to the detriment of others is linked with the functions of foveal and peripheral vision. The information that one gets from the centre of the eye, that is the fovea, is of much higher acuity than information that is received from areas away from the central regions. Experiments have shown that objects seen with foveal vision are recognised quickly and without difficulty, while recognition deteriorates in the parafovea and periphery (Findlay and Gilchrist 2003, p. 135, 137-138). Acute vision over a wide angle is achieved through rapid smooth and saccadic eye movements (Bruce et al. 1997, p. 21), while head and body movements are also necessary to direct foveal vision towards objects not placed at the front of the observer.

The above apply to the modern viewer, as well as the observer in the past. The bodily and facial orientation of the onlooker entering a room embellished with frescoes will naturally lead foveal vision to be focused at the area opposite the entrance, which is more likely to attract attention at first. The acute viewing of features which are not faced naturally would necessitate additional eye, head, and body movements. It would require, therefore, more effort. So the emphasis in archaeological interpretations on ease of viewing as an important factor that defines the reception and communicative impact of the paintings does have a solid basis on the physiology of the human visual system.

That said, one also has to bear in mind that accessibility in LBA Aegean built space is complex and there are often many entrances and ways of accessing a room, that could have affected in different ways the ease of appreciating pictorial compositions. In addition, besides ease of viewing, there are other factors that could have determined the positioning of a pictorial element in architectural space, like the dimensions and suitability of the available mural

[2] According to Gibson (1979, p. 206) a human visual field ranges 140 degrees at a vertical level.

surface for the execution of the desired theme. For these reasons arguments that aim to support the significance of a pictorial element by focusing upon the experience of the observer within the painted rooms are more persuasive when they are supported by additional evidence, especially iconographic.

On the other hand, if ease of viewing is accepted as an important parameter that influences the rendering or reception of a composition, then it has to be acknowledged that it is defined by factors that have rarely been discussed or are very little understood. For example, it has been observed that illumination would have affected the reception of the paintings by enhancing or hindering the comprehensibility of a theme, or in the case of ritual performances, by affecting the viewer's emotional state (Immerwahr 2000; Palyvou 2000; Marinatos 1984, p. 84; Marinatos and Hägg 1986, p. 60; Doumas 1987, p. 157-157). Nonetheless, the precise relationship between pictorial meaning and light qualities or distribution patterns is difficult to conceptualise and examine. More importantly, however, a factor that would have often influenced the visual experience of the frescoes, namely the occlusive effects of other architectural elements on the decorated wall surfaces, has been greatly overlooked in the existing iconographic interpretations of Theran murals. On many occasions the onlooker in the past would not have the opportunity to appreciate a view of the entire painted theme, since decorated surfaces were often obstructed by intervening built structures, such as the door jambs of pier-and-door partitions (*polythyra*)[3] (Palyvou 2000). The paintings of Xeste 3, for example, would have been seen through a series of door openings, whose frames in most cases would not have permitted the visual exposure of entire compositions. Nonetheless, the ways in which intervening doorjambs[4] might have affected the ease of visual access to individual painted elements and the mechanisms in which pictorial meaning was communicated to the viewer have not been considered. On the contrary, visual access to the painted scenes has received much attention in discussions that focus on the intended consumers and social functions of the murals.

[3] The term "*polythyron*" or "pier-and-door partition" is ambiguously used in different publications on Minoan architecture (Palyvou 1999, p.343-344). Sometimes it is utilised as exact synonym of "Minoan Hall". Other researchers use it to describe a room with many pier-and-door partitions. In this thesis, the term is defined, as suggested by Palyvou (1999, p. 343-344): a structure that consists of three or more door openings in a row.

[4] Marinatos has considered the occlussive effects of the doors of pier-and-door partition in Xeste 3 (Marinatos and Hägg 1986; Marinatos 1984)

1.1.2 Visibility and the social meaning of mural painting

It can hardly be questioned that Aegean wall painting was imbued with symbolic meanings, which were communicated to the members of prehistoric society that encountered the paintings. Obviously the messages of the murals would have been received solely by those individuals or groups that were allowed in the spaces permitting visual access to the decorated wall surfaces. But who were the intended consumers of the murals and who were excluded from receiving their messages? Answers to such questions are of great interest for the student of Aegean prehistory, as they could elucidate aspects of social order within Late Bronze Age societies. Visual access to wall paintings has been discussed regarding both public and domestic spaces in published literature.

The issue of visibility/non-visibility of the painted surfaces was firstly considered by Marinatos (1984, p. 73, 81), and later by Marinatos and Hägg (1986, p. 60). They suggested that activities during ritual performances in Xeste 3 were to a great extent determined by the physical and visual access to the main foci of attention in the building, the wall paintings and the *adyton*, which were controlled by pier-and-door partitions. Marinatos (1984, p. 73) noted that the spatial structure of the decorated spaces in the vicinity of the *adyton* indicates that during rituals only a restricted number of people would have been able to see the murals and the performed events. She also observed (Marinatos 1987, p. 32) that male and female representations do not mix and sexes appear segregated 'spatially and symbolically'. Gesell (2000, p. 950) further built upon the idea of sex segregation and related the occlusive function of the doors of pier-and-door partitions on the ground floor of Xeste 3 with the existence of separate male and female rituals which required the concealment of the paintings in the main initiation areas from members of the opposite sex. Thus, in this case restrictions to the visibility of the frescoes support the assumption that social needs and customs demanded the existence of distinctive male and female ceremonies.

The visual access to paintings decorating domestic spaces has also been discussed, but this issue has been appreciated quite differently in published works. Chapin (2004) examined the consumption of Cretan and Theran landscape paintings and maintained that visual access to murals embellishing public and private buildings is associated to the establishment of elite identities and social strategies of exclusion. She notes:

'...frescoes were available on an everyday basis only to those who habitually worked or resided in the rooms bearing the frescoes. These few people, then, were the principle consumers of the art. Moreover, they probably controlled access to the images, since everybody else presumably needed permission to be allowed into the rooms. This likely situation applies equally to private residences, such as the House of the Frescoes at Knossos or Complexes Beta and Delta at Akrotiri, as to buildings with probable public use, such as Xeste 3 at Akrotiri, and to villas with a likely mix of public and private functions, such as at Ayia Triada. In each instance, the archaeological record suggests that somebody outside the building only viewed landscape art if he or she was permitted access to the decorated interior room. Landscape art, then, was not only an element in the display of prestige and wealth- it was also an art of exclusion.
...But if the average Minoan received an invitation to appear at the residence or seat of government of his or her local civic and religious leader, then landscape art could have been used to make a powerful psychological impact on the non-elite visitor.' (Chapin 2004, p. 60-61)

With the above comments Chapin describes some plausible modes of engaging with Aegean wall painting, not necessarily restricted to landscape art. Contrary to her view, however, Doumas (2005) has recently maintained that, at least as far as Akrotiri is concerned, wall paintings in private houses, would have been exposed through windows to a passer-by outside the buildings. According to Doumas the visual exposure of wall paintings to individuals situated in the street network was intentional and aimed to reinforce the social status of the proprietor of the building by communicating a message of prestige to those pedestrians who saw the paintings.

If in Akrotiri wall paintings were indeed visible from the street network, then they had a much larger potential to convey ideas of social recruitment or exclusion, and were consumed by a significantly larger proportion of Theran society than previously suggested – that is to say any pedestrian that would pass outside the houses as opposed to a limited number of individuals that were allowed in the decorated rooms. This possibility might clarify one puzzling and yet unresolved issue in BA Aegean painting studies, namely why wall painting appears to have been such a popular art form in Akrotiri, being attested in almost every house in the excavated part of the settlement. This picture contradicts the general impression one gets from other Aegean Bronze Age urban settlements, where in most cases one or two buildings seem to have had mural decoration (cf.

§ 5.1). Ultimately, the questions of who were the intended viewers of the paintings and how the murals were consumed are implicit in the wider issue of the functions of wall painting at Akrotiri that has provoked a lot of debate in the past (cf. §5.1).

Nonetheless, it is clear from Doumas' and Chapin's interpretations that there is no agreement regarding the modes in which the Theran paintings were seen, and that different assumptions are made about the visual access to the murals. These different understandings also relate to the fact that the degree of visibility of mural painting from the public street network cannot be assessed with certainty given the state of preservation of the site. Wall paintings used to decorate rooms of the first floor and were partly occluded by the wooden frames of windows that are no longer preserved. Understanding how much of a painted wall surface could have been exposed to the viewer is important in order to define whether the themes of the murals were comprehensible, and whether the visibility of the paintings was intentional, as opposed to epiphenomenal. The extent to which the paintings were visible from the open public spaces of the settlement is however still open to debate.

1.1.3. Objective difficulties and limitations of the current approaches

From the above it is obvious that in recent years issues of visual perception have received much attention in archaeological interpretations of Theran murals. Nonetheless, they have been neither sufficiently nor systematically explored, especially when it comes to visually complex contexts. This is partly because the remains of the prehistoric settlement allow the modern viewer to have only a vague impression of how it appeared in the past. The picture that the archaeological site presents today is much different from the one suggested by the archaeological record: murals have been removed from the walls of the buildings they adorned, door leaves have disintegrated, floors and roofs have collapsed. As a result, the physical engagement with the site as it is today cannot provide sufficient answers concerning the reception of Theran murals. Often, insightful but unverified statements on the appearance of decorated interiors are made. The review of the relevant literature (cf. §1.1.2) indicates that researchers have not always been able to conclude about what would or would not have been observable in the past and sometimes they seem to comprehend differently the visual phenomena in a given architectural context. The different understandings of the modes in which wall paintings were received are to a great extent due to insufficient knowledge regarding the exact form, location, or dimensions of architectural elements no longer preserved, such as door jambs and window frames. The existence of these structures can often be safely deduced from their remains, and it is certain that in some instances they would have affected the visibility of mural painting. Uncertain features make the study of visual phenomena at Akrotiri even more intricate.

Given the above difficulties, the main visual aids that have traditionally been used by archaeologists willing to explore visibility in the built environment, namely paper reconstruction drawings, appear to be limited. Drawn reconstructions do not always accurately reproduce the geometry of space and show only single or limited views of the study area. As a result, interpretations are usually constrained to a similarly restricted number of viewpoints. Because of these limitations interesting questions may escape attention; one may ask, for example, how the ease of visual access to mural decoration changes for a variety of different locations or during the course of movement. As the built environment of Akrotiri offers many possibilities of accessing a decorated space such inquiries may significantly enhance our understanding of how the murals were received in the past.

It is noteworthy that aspects of visibility in Aegean Bronze Age environments have also been explored with the application of non-computational two-dimensional analyses, although these approaches have not been applied to the study of wall paintings. For example, Sanders (1990) plotted sightlines on the ground plan of the Early Bronze Age settlement of Myrtos to calculate the visible area from a limited number of "decision-making" locations, mainly corresponding to the positions of door entrances. On the other hand, Letesson and Vansteenhuyse (2006) examined aspects of the visual experience in Minoan palaces by using simple trigonometry to identify those locations on the ground plan of their study area at which the beholder could have seen the target object (a "window of appearance") within predetermined visual angles, possibly related to the onlookers′ impression of monumentality (cf. §1.3). Such analysis has been discussed and used in the past by other authors in non-Aegean contexts (Märtens 1890; Higuchi 1983; Moore 1996). The above approaches, however, are founded on two-dimensional representations of space that offer limited possibilities to explore the reception of vertical architectural elements, such as painted surfaces, in visually complex contexts. For example, the visibility of Theran murals through the open first floor windows of domestic buildings cannot be investigated by these analyses; Sanders' approach takes into account solely what can be seen at the horizontal plane corresponding to the eye level of the viewer, while in Letesson and Vansteenhuyse's approach the target object is conceived as a point in space, which is a crude description of a wall surface or pictorial element. Impressions created to the viewer in three-dimensional space are hard to investigate by these means.

1.2 Aims and purpose of this research

This thesis argues that computational methods can enable a better understanding of the visual perception of murals by describing and analysing what could be seen by a viewer in 3D space. It maintains that 3D digital reconstructions of the decorated spaces can significantly enhance our understanding of how the paintings were received in the past. It emphasizes, however, that the usefulness of these models could extend far beyond their merely descriptive use. More specifically, this work hopes to demonstrate that the study of visibility issues in spatially complex and partially preserved built spaces has a lot to gain with the application of a formal methodology that combines 3D modelling methods with GIS-based spatial analysis. Because current computational approaches do not allow the coupling of these techniques in a meaningful way (cf. Chapter 3), the aim of this research is, firstly, to develop a new methodology that permits the description and formal investigation of impressions created by navigating 3D digital reconstructions of past environments. The proposed methods should be able to examine the factors that influence the reception of painted wall surfaces, such as the occlusive effects of architectural elements on the paintings and certain visual angles possibly related to the reception of the murals. They should also permit the formal consideration of incomplete and uncertain information in the archaeological record in the cases where it can significantly affect the validity of archaeological interpretations.

This methodology will be used to investigate human engagement with the decorated spaces in Late Bronze Age Akrotiri, and more specifically to examine those issues that have raised controversy in the currently proposed interpretations of Theran murals. The focus will be upon aspects of the visual experience of mural painting that have not been discussed before in a thorough way and are hard to appreciate solely by the inspection of the remains or the ground plans of buildings. These usually relate to the reception of painted wall surfaces within architecturally complex built environments (cf. §1.1.1, §1.1.2). More specifically this research aims:

A) to investigate the reception of pictorial compositions in Xeste 3, a public space, apparently used for communal gatherings and ritual performances. A number of murals that have been discovered in this building, have already been restored. For this reason Xeste 3 offers more opportunities to explore possible associations between the visibility of painted surfaces and the iconographic meaning of the murals than other buildings in the settlement. Moreover, Xeste 3 provides a unique chance to investigate the ways in which murals could have guided Late Bronze Age communal ritual practices in built interiors, illuminating the possible social functions of wall painting during public gatherings.

B) to examine the visibility of the wall paintings from the open public spaces of the settlement, and discuss the degree to which the murals could have been exposed to a viewer situated in the street network. Were the paintings visible enough for a pedestrian to distinguish a particular theme, and is there any evidence to suggest that their exposure to pedestrians was intentional rather than just epiphenomenal? What kind of messages the murals would have communicated when seen from the street network? Ultimately, this research aims to examine the identity of the potential viewers and possible symbolic meanings of the paintings in the Theran townscape.

The above case studies investigate the reception and visual experience of Theran murals under totally different conditions, namely in building interiors and in the townscape of Akrotiri, and could, therefore, shed light onto the diverse modes in which the messages of the paintings could have been communicated to the prehistoric viewer. Finally, although the case studies are associated to more specific questions of a different nature, their combined examination could help illuminate the social functions of mural painting in the prehistoric settlement, perhaps suggesting some plausible reasons why they became such a popular art form in Akrotiri.

1.3 Defining ease of viewing

Ease of viewing will be a recurring subject in interpretations proposed in this thesis. This is a concept both obvious and yet obscure, if not explicitly

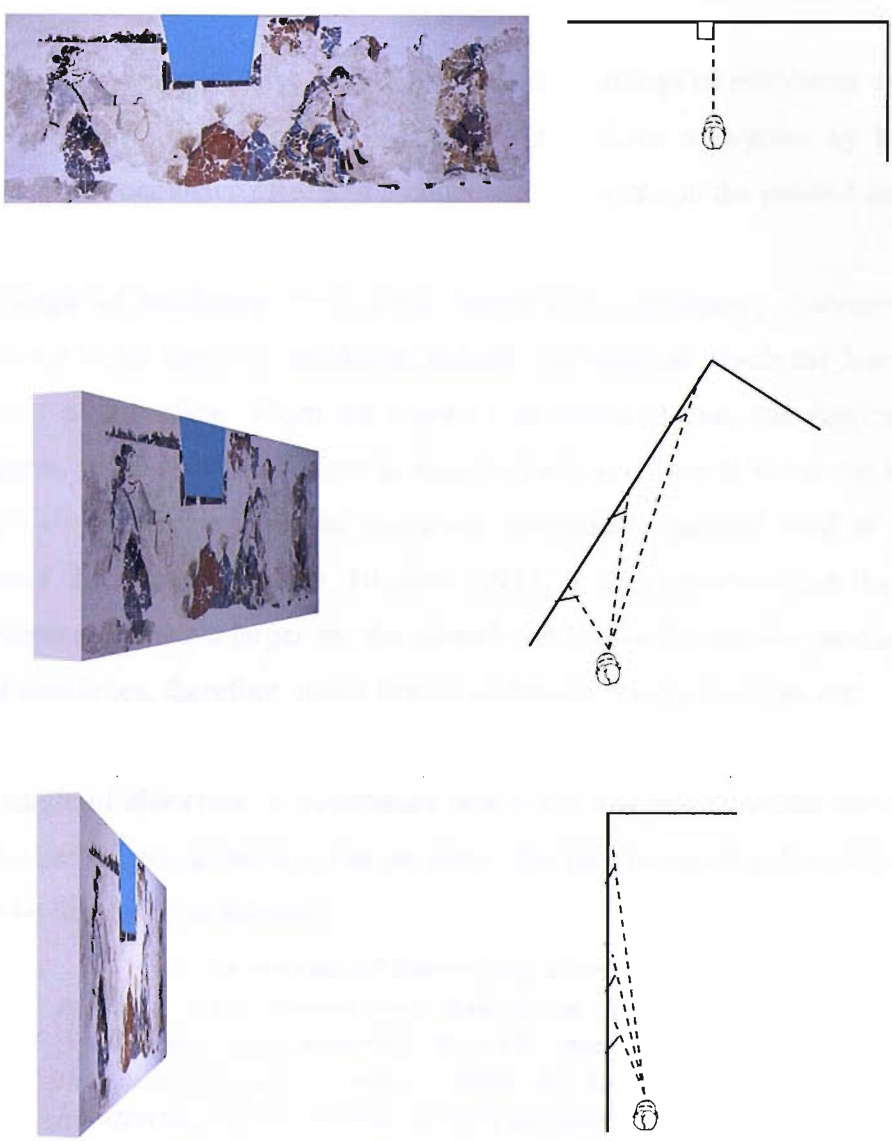

Figure 1-2 : Varying angles of incidence for a wall surface. Frontal surfaces are always easier to see.

defined. Some of the indices that have been utilised in the past by Higuchi (1983) to investigate the visual structure of landscapes are used here to identify and examine the factors that determine the ease of viewing of painted wall surfaces. Higuchi (1983) proposed a set of formal criteria to describe the visual and spatial structure of landscapes, some of which he adopted from earlier works on the visual experience of built space. As himself notes (1983, p. 4) all the indices he discusses are applicable to the study of built environments. In the following chapters six factors affecting the visual experience of painted wall surfaces are examined:

1) Visibility/ invisibility: This defines which paintings or individual elements of a composition can or cannot be seen from a given viewpoint by taking into account the occlusive effects of architectural elements on the painted surfaces.

2) Angle of incidence: One of the factors that significantly determine ease of viewing is the angle of incidence, namely the angle at which the line of vision strikes each surface. When the angle of incidence reaches the maximum of 90 degrees, the surface of interest is seen frontally and lays at about the horizon of the viewer. As the angle of incidence decreases a painted wall is seen with greater difficulty (fig. 1-2). Higuchi (1983, p. 26) observes that the angle of incidence is always larger for the frontal rather than for the longitudinal planes, and concludes, therefore, that a frontal surface is always easier to see.

3) Angle of elevation: It determines how many degrees above the horizon of the onlooker the target surface can be seen. The physiological effect of looking up can be described as follows:

> *'...the process of looking up at an object tends to limit the mobility of the human body and to cut off the line of vision at a point above the horizontal. With the most stable line of vision for the average person being about 10 to 15 degrees below the horizontal, it follows that the very process of looking up involves a certain amount of stress. Presumably this is why the term 'look up to' connotes the idea of paying respect or reverence. 'Looking up to' someone or something requires a visual effort.'* (Higuchi 1983, p. 46)

The angle of elevation was also a factor used by Märtens (1890) to formally describe visual impressions related to monuments. Märtens (cited in Higuchi 1983, p. 47) suggested three visual ranges at 18, 27 and 45 degrees at which the impact of the monument on the viewer changes significantly. He noted that at 18 degrees a building starts to be conceived as monumental, at 27 it fills the viewers range of vision, while at 45 degrees it can be seen with more clarity (the viewer can distinguish small details of the building as well as see the structure as a whole).

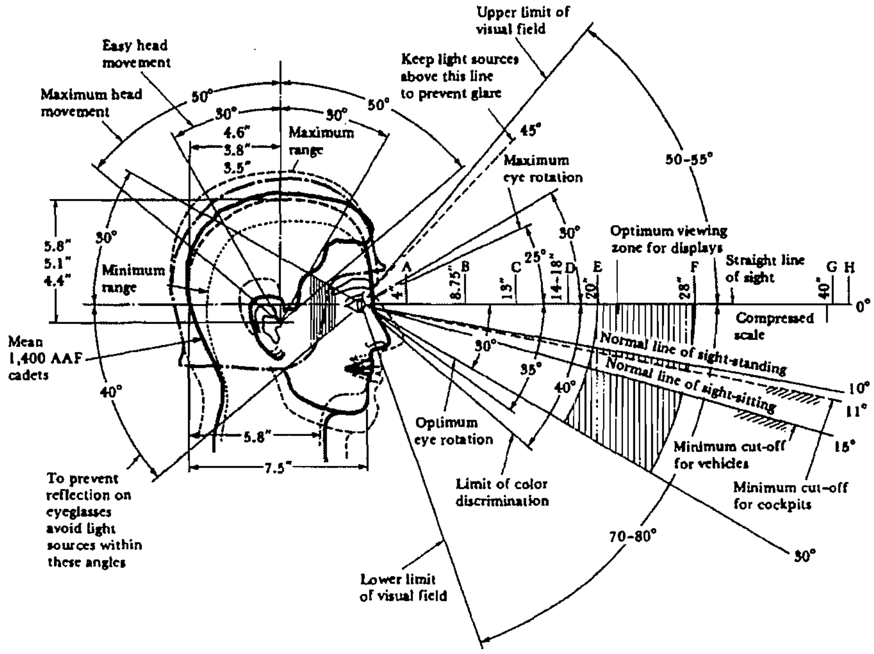

Figure 1-3: Henry Dreyfuss (1959) basic data on vision. From Higuchi (1983, p. 40)

Although nothing in the built environment of Akrotiri aspires to monumental, the vertical angle from which a painted surface can be seen may be related to the communicative impact of the paintings. As it was noted above, Theran murals were often placed on locations corresponding to the viewer's eye level and were seen with ease by a viewer in the decorated rooms. However, this would not necessarily have been the case if certain paintings, such as painted friezes in rooms of the first floor, were seen by an onlooker situated in the public spaces of the settlement, as suggested by Doumas (2005). If the paintings were placed high above the viewers' eye level and beyond the angular range of maximum eye rotation (that is more than 25 degrees above the visual horizon of the onlooker according to Dreyfuss (1959)[5] (fig. 1-3)), then pedestrians would not have been able to see the paintings without upward head movement, which may have disrupted or restricted the mobility of the body. Pedestrians traversing the street network would have perhaps to slow their pace or stop walking altogether in order to see the paintings. Such behaviour also suggests a conscious intention to look inside the building interior that cannot be always easily assumed or justified for a pedestrian in the past (cf. §5.3). If, on the contrary, the paintings were located within such visual ranges at which they could be seen solely with eye movements, then pedestrians traversing the street network would have more opportunities to effortlessly encounter the painted scenes, regardless of whether they intended to do so. In this respect, examining the vertical angle from which the paintings were appreciated could elucidate the communicative potential and impact of the paintings in the townscape of LBA Akrotiri.

4) Distance:

When it comes to the issue of visual clarity in the built environment and the degree to which a particular object can be distinguished and recognised, the distance of the onlooker from the object of interest is an important factor that needs to be considered. Märtens (1890 cited in Higuchi 1983, p.9) suggested that the maximum distance in which a person's face can be identified is twenty-five metres (the nasal bone then occupies an angle of 1 minute in the field of vision). Hall (1966), on the other hand, considers a maximum distance of 12 metres in which human communication through sight and other senses is enabled. In any case the maximum distance in which mural painting would have been distinguishable cannot be as easily defined. As it will be argued again in Chapter 3 and 5, the visual clarity of a painted element depends not only in its distance from the viewer, but also on the scale of representation, colour, texture, contrast with the background and illumination which are particular to each painted scene. For these reasons the effects of distance to the ease of viewing of the painted themes will be examined separately for each case.

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[5] Cousin (1980) has proposed alternative angular ranges that determine ease of viewing, namely an ellipse of vision that extends 54 degrees horizontally and 37 degrees vertically (14 degrees above the horizontal and 23 degrees below it) (Letesson and Vansteenhuyse 2006).

5) Illumination

Besides architectural form, an important element in the definition of built space is illumination. Light plays a fundamental role in the perception of shape, colour and texture of surfaces that create the visual impression of the environment. As applies for distance, illumination is a factor that affects the comprehensibility of a painted theme, together with other parameters (e.g. distance, scale, colour etc.), and its influence to the reception of painted walls has again to be discussed individually for each different context.

6) Human mobility

The function of the human visual system and the perception of the environment are greatly depended upon the mobility of the body (Gibson 1979, p. 223). Stasis and movement through space would have determined the spatial relationship of the observer's body with the painted scenes, affecting the mode in which the paintings were experienced. The boundaries between the two states are rather fluid as suggested by Gibson (1979, p. 75):

> *"When the moving point of observation is understood as a general case, the stationary point of observation is more intelligible. It is no longer conceived as a single geometrical point in space but as a pause in locomotion, as a temporarily fixed position relative to the environment."* Gibson (1979, p. 75)

The observer of the paintings can be assumed to have been stationary or mobile. It is often the case, however, that at times one state of the body prevails over the other depending on the nature of human practices that are performed in the built environment. For example, during rituals such as those that have been suggested for Xeste 3 (cf. Chapter 4), certain individuals may have attended the events, as well as the painted scenes, from fixed points for long durations of a ceremony. Stasis in space would have restricted visual access to the paintings by allowing partial but lasting views of a composition (cf. Chapter 4). On the contrary, pedestrians traversing the street network may have encountered the murals within the course and pace of their movement, which would have shaped a momentary and essentially different experience of the painted scenes.

It chapters 3 and 6 methods that could formally approach and measure all the above factors in computer generated three-dimensional spaces are introduced.

Chapters 4, 5, 7 discuss the ways in which the above criteria would have affected the visibility of Theran murals.

Chapter 2
Akrotiri: Environment, settlement and society

2.1 Thera: LBA environment and settlement patterns

The archaeological site at Akrotiri (fig. 1-1, 2-4) is located at the south part of the Greek island Thera (Santorini) (fig.2-1, 2-2, 2-3) at a distance of about 500m from the modern village Akrotiri. It was discovered in 1967 by the archaeologist Prof. Spryridon Marinatos, who began excavations on the island hoping to find evidence to support his theory that the decline of the Minoan civilization in Crete was the result of a catastrophic eruption of the Thera volcano in Late Bronze Age (Marinatos 1939). Marinatos started his excavation from Akrotiri, as he thought that the location provided more advantages for agricultural exploitation and maritime activities in prehistory than other sites that had been identified on the island (Doumas 1983, p. 11). Although the findings at Akrotiri never offered Marinatos the proof he had hoped for, they were especially rewarding, as excavation revealed the remains of an exceptionally well-preserved Late Bronze Age settlement, buried under a thick layer of volcanic ash and pumice[6].

The prehistoric town is situated on a low hillock just 200-250 metres from the south coast of the island (fig. 2-1). The landscape that surrounds the settlement today (fig. 2-3) has mainly been formed after the prehistoric eruption, and is covered to a great extent by thick layers of volcanic deposits. The rocky hills that can still be seen at the west of the excavated area would have been,

[6] Main published works on Akrotiri: Marinatos (1968, 1969, 1970, 1971b, 1972, 1974, 1976) and Doumas (1981, 1983) made the first observations on the archaeological finds discovered in the settlement. Town planning, architectural form and construction techniques have been investigated by Palyvou (2005a, 1990a, 1986, 1999). The use and function of the first floor have more systematically been studied by Michailidou (2001a), while Nikolakopoulou (2002) has focused on the storage facilities. The small finds of the West House have been recently published in Doumas (2007c). Televantou's (1994) and Morgan's (1988) published PhD thesis on the wall-paintings of the West House and Doumas's 'The wall-paintings of Thera' (Doumas 1992a) are the most comprehensive publications on Theran mural painting. Significant contributions to the study of the prehistoric settlement of Akrotiri have also been made in the four international conferences that have been organised since 1967: 'Acta of the 1st International Scientific Congress on the Volcano of Thera' (1971a), Thera and the Aegean World II (Doumas 1978-1980), Thera and the Aegean World III (Hardy *et al.* 1990; Hardy and Renfrew 1990)and the 'The wall paintings of Thera: proceedings of the first international symposium' (Sherratt 2000). Many articles on research in Akrotiri between the years 1967-1987 are included in Doumas (1992b).

however, part of the Bronze Age scenery, since the volcanic material has been washed out from these parts of the terrain (Palyvou 2005a, p. 21). The coastline at the north of the settlement, which is shaped by the caldera cliffs, has also changed very little since prehistory (Heiken *et al.* 1990). In contrast, the seascape at the north of these cliffs, part of which are today the islands of Aspronisi, Therasia, Palaia Kameni, and Nea Kameni (fig. 2-1), is believed to have been quite different in the past. McCoy and Heiken (2000, p. 64) have suggested that at the time just before the prehistoric eruption Thera, Therasia, and Aspronisi belonged to a single island, with a flooded depression at its south (cf. Heiken *et al.* 1990). According to Druitt and Francaviglia (1990) a second volcano island would have existed at the area occupied today by Palaia Kameni, and Nea Kameni.

The region at the south of the settlement has also significantly transformed after the eruption. This is due to the amassing of large quantities of volcanic deposits that covered the prehistoric shoreline, which would have been further inland than it is today (Doumas 1983, p. 55). It has been suggested in the past that one or perhaps two Late Bronze Age harbours would have existed, either at the south-west, where the modern valley of Hagios Nikolaos (Doumas 1983, p. 55, fig. 2-3) lies, or further closer to the town, at its immediate south and east (Shaw and Luton 2000). A harbour in close proximity to the town is also suggested by recent findings from the rescue excavation of 1999[7] (Doumas 2002); these confirm that the terrain below the excavation area slopes abruptly at the east and south. It seems likely that the south part of the town would have been located on a small peninsula in the past, which would have permitted anchorage on either side of the promontory depending on seasonal winds (Doumas 2003, p. 169). This type of "twin harbour" seems not to have been uncommon in the Aegean, as it is also attested at Pseira and Ayia Irini (Chryssoulaki 2005, p. 82).

The pre-eruption landscape of the Santorini island group seems to have been well-populated in Late Bronze Age. Besides Akrotiri, a number of sites belonging to the period just before the volcanic eruption have been identified on

[7] The excavation was restricted at the areas around the supporting pillars of the new shelter of the site. The pits that were dug for this purpose have been named after the number given to the pillars (fig. 2-3) e.g. pillar pit 24.

Thera and neighbouring islands to date (at Archangelos, Ftellos, Mavromatis quarries, Balos, Kokkino Vouno, Alaphouzos quarry, Ayios Nikolaos, Exomiti, Cape Koloumvos, Katsases, Oia quarry, Profitis Ilias). These have been described as mainly of rural character, such as hamlets and farmsteads (Sperling 1973; Davis and Cherry 1990).

Figure 2-1: Thera and its neighbouring islands.

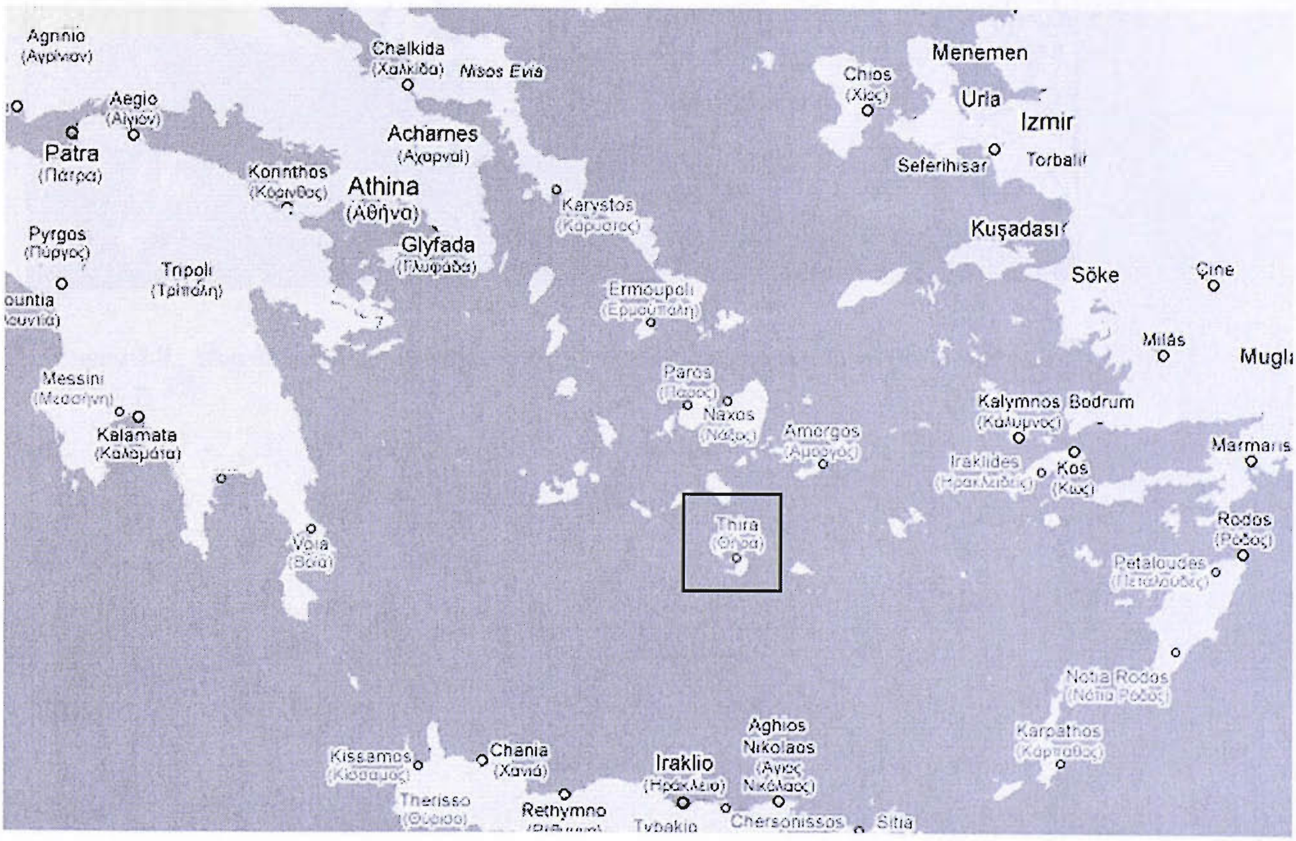


Figure 2-2: Thera in the Aegean. From Google Map

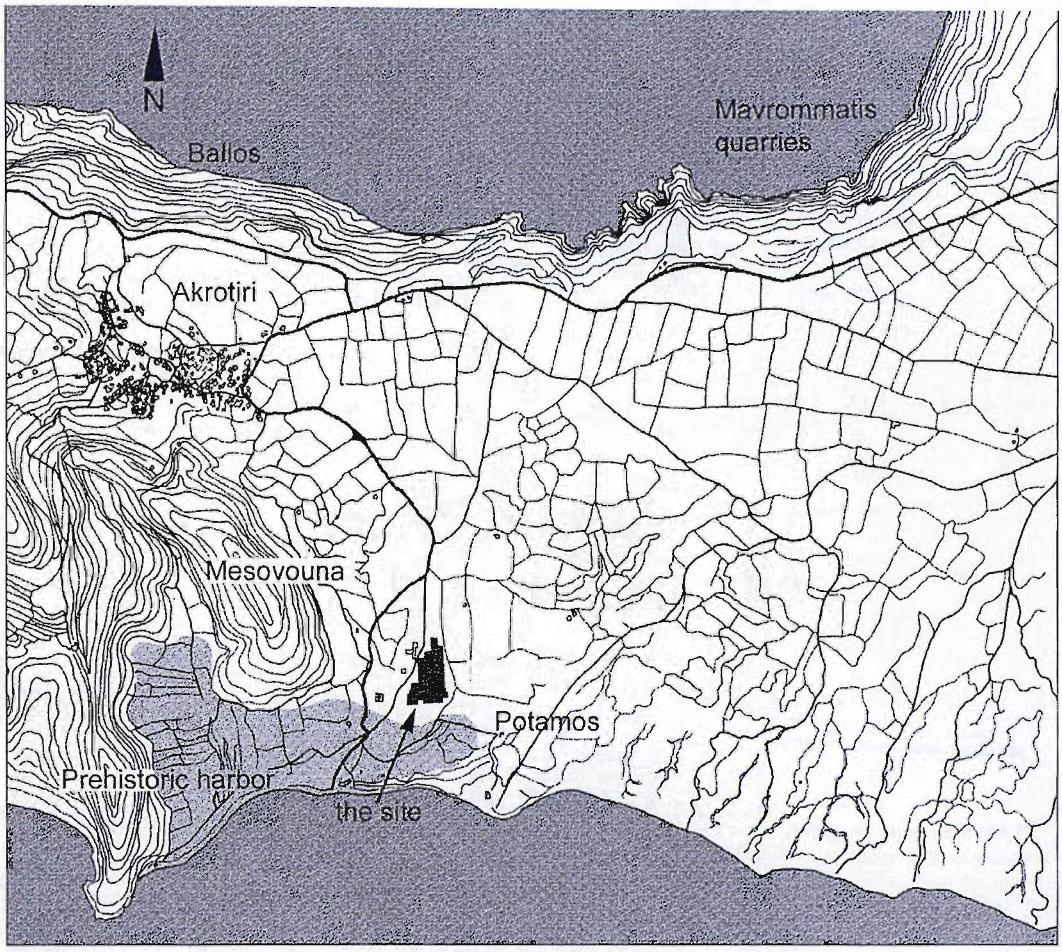


Figure 2-3: Map of the modern landscape that surrounds the excavated area (from Palyvou 2005a, p. 20)

Figure 2-4: Topographic plan of Akrotiri (from the excavation archive)

2.2 The prehistoric town at Akrotiri

Akrotiri was the largest prehistoric settlement on the island of Thera and has provided evidence of continuous occupation since the Late Neolithic (Sotirakopoulou 1990). The Early Bronze Age (table 1-1) remains consist of underground chambers cut in the rock, which would have been used as tombs in Early Cycladic period (Doumas 2003, p.170) and rectangular structures built on the bedrock (Palyvou 2005a, p.15). From the Early Cycladic until the Late Cycladic period the settlement gradually expanded, acquiring an urban form. During this long sequence of habitation many phases of seismic destruction and rebuilding have been attested (Doumas 2003, p. 169). At about the end of Middle Cycladic or at the beginning of the Late Cycladic period, a major earthquake destroyed a large part of the town (Doumas 1983, p. 43-44). It seems, however, that the town houses were quickly rebuilt after that to obtain their final form. As already mentioned (cf. §1.1.1) this major seismic episode, which is conventionally referred to in the published literature and in this thesis as *seismic destruction*, is believed to have occurred just 50-75 years before the volcanic eruption that buried the settlement (Doumas 1981; 1992a, p. 30-31; Morgan 1988, p. 5-10). The absolute date of the later ultimate catastrophic event is still an open and hotly debated issue. Given the evidence provided by Egyptian chronology the eruption would have occurred between 1560 and 1480 B.C the latest. Radiocarbon dates, dendrochronology, and ice-cap dating, however, suggest an earlier date, between 1650 and 1643 B.C. (Hardy and Renfrew 1990; Warren and Hankey 1989; Manning 1999; Wiener 2003, p. 364).

Up to now an area of 12 acres has been excavated that is thought to be solely a small part of the prehistoric settlement (fig. 1-1, 2-3). The estimations for the original size of the town range from 100,000 square metres (Palyvou 2005a, p. 27) to 300,000 (Doumas 1983, p. 45; Doumas 2001, p. 91). The larger estimate is based on the hypothesis that the sites at Balos and Mavromatis quarries (fig 2-2) that have been discovered at the northwest and northeast of the excavated area may have been the suburbs of the town. Nonetheless, the density of habitation between the unearthed urban core and these sites is not known, and consequently estimations on the original size of the settlement can neither be verified nor rejected. The size of the town in human terms is also a matter of conjecture. Taking into account suggested estimations regarding the settlement size and the number of inhabitants per hectare (from 150 to 400 persons per hectare), 1,500 to 9,000 people could have dwelled in the town in Late Bronze Age (Palyvou 2005a, p. 29). Nikolakopolou (2002, p. 198) has estimated only the inhabitants of the excavated area to have been between 300 and 450, considering both the number of dwellers per built unit and suggested density estimations for Late Bronze Age Aegean towns.

The form of the urban tissue at the unearthed part of the town is fairly clear. Two main roads with N-S and E-W orientation provide access to the 35 buildings that have been identified up to now (Palyvou 2005a, p. 45). The latter are either arranged in complexes (e.g. Beta, Gamma, Delta etc.) or form separate units (e.g. Xeste 3, West House, House of the ladies etc.). The town network also consists of secondary roads, as well as narrow and blind alleys that were used for drainage, ventilation and illumination (Palyvou 1986, 2005a). Some open broad areas in the street network have been identified as public squares, such as the Triangle Square, the Mill House Square and the Square of the Cenotaph (fig. 1-1). A public sewage system also ran through the settlement suggesting that the prehistoric community was highly organised.

Most buildings are only partially excavated and up to now only ten have been adequately investigated (Palyvou 2005a, p. 45). They usually have a second and, in some cases, a third floor and are made of stone, wood, and clay. The ground floor of some of the buildings is below the street level. This is the result of the rebuilding of the town after the seismic destruction. During this major reform of the settlement the town inhabitants (Doumas 2000) laid the debris of the ruined built structures on the open public spaces. As a consequence, the street pavement rose up to 1m to 2m above the earlier street level and many of the ground floor rooms became semi-basements (Palyvou 1984; 2005a, p. 177-178). The artificial layer that consists of the re-used building materials has been identified in many areas of the town. Following the modifications in the open public spaces, the entrances of some of the houses were rebuilt, so as to correspond to the new street level.

The degree of preservation of most of the houses is unique, as the volcanic material that penetrated into the rooms after the eruption prevented the complete collapse of walls and floors, enabling in some cases the preservation of upper storeys until today. Least well-preserved are the structures that were found in the course of the ravine (fig. 1-1) that runs through the settlement from north to south, which was created by torrential water and storms that followed the volcanic eruption (Palyvou 2005a, p. 5, 19). Parts of the complexes Beta and Delta were badly eroded because of the torrent. In most cases, however, the houses that have been unearthed are in an exceptionally good level of preservation, as the pumice and tephra that filled their interior after the eruption acted as "packaging" material. In this way thousands of complete vessels, hundreds of square-metres of wall-paintings and a great number of stone tools and utensils survived. Imprints and sometimes complete negatives in the thin volcanic ash provide evidence about the existence and form of architectural structures and movable objects made from perishable materials, such as wood, leather, textile, and reeds, which have left no organic traces (fig. 2-5). These have provided invaluable information on building technology — for example on the timber reinforcement of the walls (Doumas 1983; Palyvou 2005a, p. 112) — and house equipment (wooden furniture, baskets, rope, etc.).

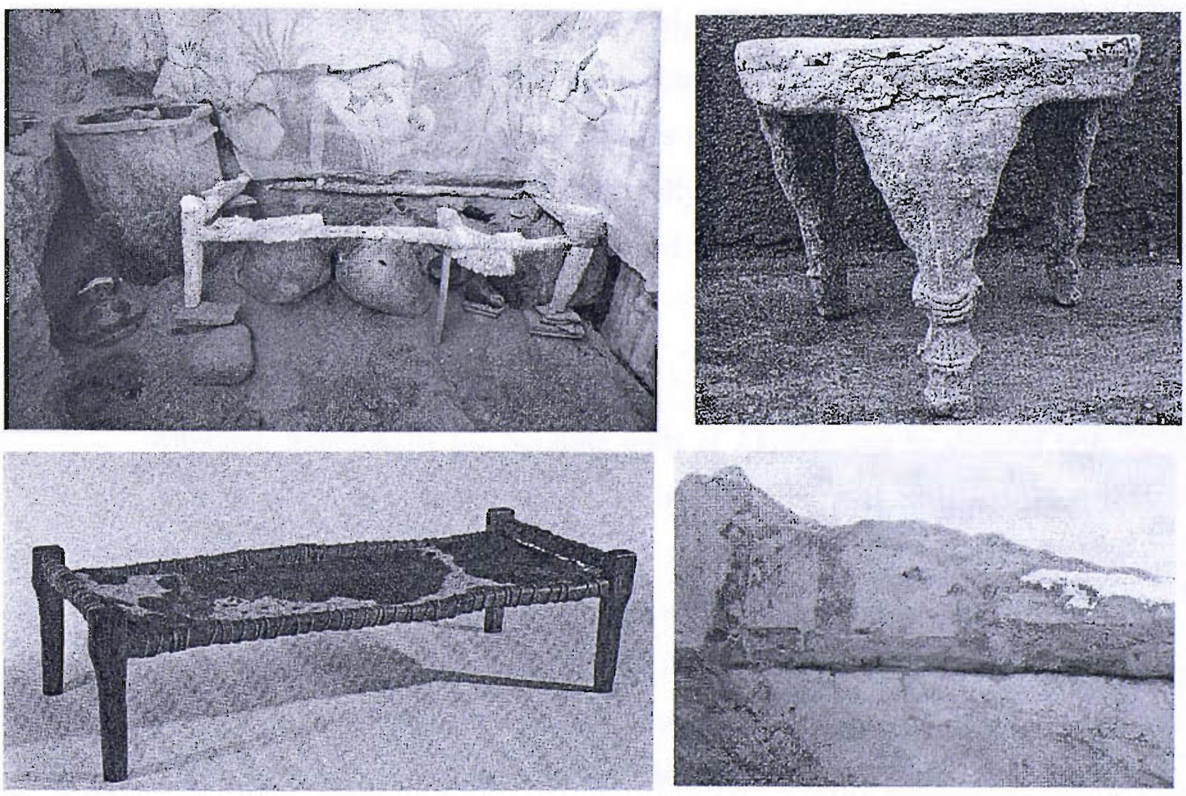


Figure 2-5: Top left: The gypsum cast of a bed found in Delta 2. It was created by pouring plaster-of-Paris in the imprints left in the ash. From the excavation archive. Bottom left: A reconstruction of the bed (Doumas 1999, p. 59). Top right: The gypsum cast of a wooden table. From Doumas 1983, pl. 84. Bottom right: Imprint of the pier-and-window partition of Room 5 of the West House (first floor) (Palyvou 2005a, p. 50).

On grounds of architectural form and find assemblages some buildings have been identified as either private or public. A typical Late Bronze Age Theran private house (Palyvou 1990a; 2005a, p. 46-53) is of medium size and has only one entrance which, as a rule, is accompanied by a window. Directly opposite the entrance there is a staircase that leads to the upper storeys and the roof. The rooms of the ground floor, which were used as ancillary areas for food preparation or workshops, are quite small and their walls and floor are made of beaten earth (Michailidou 2001a, p.427-428). They are illuminated by small openings which once were blocked by wooden lattices, as imprints in tephra indicate. On the other hand, rooms of the upper storeys are more spacious and elaborate and are characterised by typical Minoan architectural features, such as central columns or pier-and-door partitions[8]. They were well-illuminated by large windows, had paved or plastered floors and their walls were often embellished with wall-paintings. The great majority of the buildings that have been discovered in Akrotiri are variations of the above described architectural type.

By contrast, buildings that are considered to be of communal or public function, such as Xeste 3 and Xeste 4, differ significantly as far as size, spatial articulation and quality of construction are concerned (Palyvou 2005a, p. 29, 35). They are much larger as a whole, have facades made of ashlar blocks, and both their ground and upper storeys are internally arranged with pier-and-door partitions. Public buildings were embellished with mural decoration at the ground floor as well as in upper storeys.

2.3 Society in LBA Akrotiri

Although functionally the building units at Akrotiri can be divided into public and private, they share many similar features and give no direct indications of group division. Nonetheless, if their architectural idiom is to be interpreted within the wider context of Aegean urban architecture of the Late Minoan IA/Late Cycladic I period (table 1-1), it is apparent that they express the affluent life style and aesthetics of the elite. Most buildings were already incorporated in the urban tissue in the late Middle Cycladic period, but were significantly modified after the seismic destruction that occurred at the beginning

[8]Cf. note 3.

of the Late Bronze Age. In this phase they are characterised by a number of built forms (room with the central column, lustral basin, pier-and door partitions, extensive use of ashlar masonry) and building technologies (vertical timber reinforcement of stone walls) that are well known from the Late Bronze Age Cretan urban centres (Palyvou 2005a, p. 179-188). Some of the new architectural features, such as the pier-and door partitions, the lustral basin, ashlar masonry, and frescoed walls, are typical of large Cretan mansions (McEnroe 1982; Palyvou 1999, p. 445; 2005a, p. 185). Nonetheless, the size and spatial organisation of the majority of the buildings, are characteristics of more common town houses (McEnroe 1982; Palyvou 1999, p. 445 ; 2005a, p. 185). As Palyvou notes, however, even the smallest buildings "are by no means poorer than the rest" (Palyvou 2005a, p. 185). Furthermore, Linear A tablets, which are associated with the palaces and elaborate private houses in Crete (Schoep 2004, p. 290) have been found in sector Delta (Boulotis 1998). Their presence at the houses of Akrotiri suggests the existence of organised private administration that, as applies for the Cretan finds, perhaps is associated with "successful mercantile activities, possession of land and /or higher status of some household" (Schoep 2001, p. 97). It is noteworthy that excavations in other Cycladic sites, such as Ayia Irini and Phylakopi have not revealed as many affinities to Cretan architecture and material culture as the town of Aktrotiri. This fact supports the suggestion that Theran houses were the residences of a "Minoanising" elite that had a special, although yet undefined, relation to Crete, and more specifically to Knossos (Doumas 1983, p. 129-131; Boulotis 1992, p. 89; 2000, p. 849; Palyvou 2005a, p. 181).

Despite the fact that the buildings unearthed up to now do not give clear indications for social differentiation, archaeological finds, such as archaeobotanical and faunal remains, the pottery, stone tools, metalwork, and iconography suggest the presence of diverse specialised human activities including land cultivation, animal husbandry, seafaring, trade, craftsmanship etc. These finds form the sole – indirect – evidence regarding different aspects of social life in the Late Bronze Age town.

2.3.1 Agricultural production and animal husbandry

In Akrotiri the unusual taphonomic conditions of the settlement have enabled the preservation of large quantities of archaeobotanical remains from within the buildings. The study of flora residues, which have been collected from storage vessels, sewage system and floors, testifies that crops were an essential part of the diet of the town residents at the period just before the volcanic eruption (Sarpaki 1992, p. 222-223). The specimens that have been identified belong to cereals and legumes (e.g. barley, lentils and peas), as well as fruits (dried figs, grapes) and olive.[9]

These species are common in the Aegean and could have been produced on the arable fields of Thera, while at least, as far as olive is concerned, Sarpaki (1987, p.155-156) provides evidence that this was indeed the case[10]. This is also further supported by evidence for the existence of a population living on the island and the neighbouring islets that was occupied in agricultural activities; clusters of buildings and constructions of agricultural character, often described as farmsteads and rural houses, were discovered at Balos, Archangelos, Kamara, Katsades and Alaphouzos Quarry (Sperling 1973). Some of these structures (e.g. at Balos and Alaphouzos) have been used for storage of crops in large quantities[11] and one of the buildings in Alaphouzos Quarry at Therasia was also equipped with an olive press. Doumas (1983, p. 129) and Sarpaki (1987, p. 104) have suggested that the immediate surroundings of the town at the north would have been used for the cultivation of crops, serving the town dwellers needs for agricultural products, as the settlement of Akrotiri would have been located within the largest plain on the island in Late Bronze Age.

Animal products were also part of the diet of the town inhabitants, as is evidenced by the osteoarchaeological material that has been collected from outdoor areas in the settlement. These were apparently food residues, and indicate the consumption of domesticated animals, mainly sheep, goats, pigs and

[9] The analysis of the species sampled from the West House has shown that lentils (lens culinaris), peas (pisum sativum), six-row and two-row barley (hordeum vulgare and hordeum distichum), einkorn (triticum monocorum) were consumed. In addition, the samples coming from the sewage suggest also the consumption of figs (ficus carica), olive (olea europa) and grapes (vitis vinifera) (Sarpaki 1992).

[10] Sarpaki has presented evidence for the local cultivation of olive (Sarpaki 1987). Also Boulotis (1998) mentions the presence of the ideogram for oil on the fragments of Linear A tablets that were found in sector Delta.

[11] Within the buildings unearthed at Alaphouzos quarry grains had been stored in heaps (Sperling 1973, p. 39, 56-61; Davis and Cherry 1990, p.190).

cattle (Trantalidou 1990; 2000; 2001; Gamble 1978) Nonetheless, it is generally accepted that meat was only occasionally consumed in Late Bronze Age Aegean; in Akrotiri sheep and goats were mainly raised for milk, milk products, and wool, while cattle would have been used for traction as suggested by the fact that most specimens belong to adult animals (Gamble 1978; Trantalidou 2001, p. 200). Animal stalling took place outside the settlement (Trantalidou 2000, p. 723), however, as none of the spaces unearthed so far seem to have been used for keeping animals. To this Akrotiri is no different than other Aegean Bronze Age urban centres. On the other hand, stock-raising should have occurred in close proximity to the town. At Balos, 1km north of the excavated area, sheep and goat bones were found in an enclosed yard. Sarpaki (1987, p. 120) has suggested that the hills surrounding the prehistoric town would have been used for grazing.

Since the excavated houses at Akrotiri are of undeniably urban character (Palyvou 2005a; Tzachili 1997, p. 25-26), lacking spaces suitable for animal stalling or installations that would clearly point to agricultural occupations, such as oil presses, it is probable that not all the residents of the town were directly involved in the cultivation of the land or pastoral activities (Sarpaki 1987, p. 103). Although the discovery of milling installations suggests that some food processing would have taken place in the houses (Devetzi 1990, p. 19), Sarpaki (1987, p. 206) notes that in Late Bronze Age crops had been transported into some buildings after they had been coarse-sieved[12], indicating that their primary processing took place elsewhere. According to Sarpaki (1987, p. 206) this enforces the possibility that crops were traded goods at the period before the volcanic eruption and that certain buildings were "consumer" residential units, whose inhabitants would have been occupied in non-agricultural activities. Indeed craft production, trade, seafaring and even priesthood are some occupations that the residents of the urban core appear to have been involved in (cf. § 2.3.3, §2.3.4, §2.3.5).

The fact that the subsistence of the households at the excavated area of the settlement was dependent on the procurement of foodstuffs that were apparently produced either at the outskirts or even out of the limits of the town, signifies perhaps the existence of important socio-economic relationships and

[12] Sarpaki (1987, p.206) refers specifically to finds coming from the West House and Xeste 3.

dependencies between the urban and rural populations of Thera, and sophisticated power dynamics that are rather expected for an urban port (cf. Branigan 2001b, p. 38). At the moment, however, the exact nature of these relationships can only be conjectural given the existing evidence. A public building with a form and function similar to that of Cretan or Mycenaean palaces has yet to be unearthed. In addition, Nikolakopoulou (2002, p. 249) has concluded that at least in the excavated houses subsistence storage was organised at household level and finds no evidence, for example a communal storeroom, to support the existence of a central authority that would manage the storage and redistribution of agricultural produce in Akrotiri. Moreover, as is often noted, neither the extent of the arable land nor the climatic conditions seem to have favoured the production of considerable surplus in agricultural products that would give rise to a palatial administrative system as is the case in Crete (Doumas 2001, p. 92). It is possible, then, that a regulated exchange network existed between the dwellers of the urban core and the rural population, or that some of the inhabitants of the excavated buildings were indeed involved in agricultural production along with other occupations (Branigan 2001b, p. 48; Dickinson 1994, p. 96) or were somehow able to control it at the level of private administration. On the Linear A tablets that were found in sector Delta the ideograms for oil and sheep have been identified (Boulotis 1998, p. 409), suggesting involvement of the residents of the building to agricultural activities and animal husbandry.

2.3.2 Fishing

The sea would have fulfilled to a certain extent the subsistence needs of the residents of the coastal town. This is attested by ichthyofaunal material recovered from the settlement, as well as iconography. Fish bones in Akrotiri are often found in water-sieved assemblages (storage jars, sewage pipes, hearths and floors) (Mylona 2001, p. 189) and provide evidence that fish, mainly of small size, were consumed (Gamble 1978; Trantalidou 1990; 2000; Mylona 2000, 2001). These would have been caught with nets and traps operated from the shore, while fishing in shallow waters with boats might also have occurred (Mylona 2000, 564; 2001, p. 191). Molluscs and shells were also part of the diet, as is indicated by the amount of shells that came from the areas outside the buildings. These served not only as food or bait, but also as ornamental objects, and floor decoration (Palyvou 1999, p. 195; 2005a, p.127). A ritual function for some specimens has also been suggested (Karali-Yannacopoulou 1990; Karali 2001). Karali (2001, p. 185-186) also notes that Murex shells that have been found in large amounts in Akrotiri would have been used for the production of porphyry, the famous purple-red dye that had been manufactured in the Aegean already since the Middle Minoan period. This would have been used for the dyeing of textiles, but also as purple pigment in wall decoration (Chrysikopoulou 2005, p. 78).

It eludes us how many of the inhabitants of the prehistoric town were actually involved in fishing, or whether it was a full-time or a part time occupation. Rose (1994, p. 184) notes that fishing in the Bronze Age Aegean was labour intensive, time consuming, and probably of low productivity; thus he maintains that it constituted a secondary and opportunist activity, that could, however, be pursued throughout the year. Mylona (2001, p. 191) referring to Akrotiri in particular, mentions the existence of evidence suggesting that fishing was an organised as well as a part-time occupation. Whatever the case, it seems to have been an important male activity, associated with social beliefs and ritual activities, which would have not merely aimed to fulfil the practical needs of everyday subsistence; in the well-known paintings of the fishermen that decorated Room 5 of the West House (pl. 1) the young males are represented holding bundles of large fish identified as dolphinfish and tunnies (Economidis 2000; Mylona 2000; Trantalidou 2000). Both these species are hardly represented in the archaeological assemblages of Akrotiri (Mylona 2000, p. 564). Therefore, it has been rightly observed, that the rarity of the fish depicted probably aims to emphasize the skills of the young fishermen and the difficulty of their accomplishment which might signify a "rite of passage" (Papageorgiou 2000; Mylona 2000, p. 565; Doumas 1987, 2000a; 2005; Boulotis 2005, p. 68). If fishing was indeed related to initiation rituals in Theran society, it should have been a basic and required skill of the male population of the town, and an occupation that could have been practiced even occasionally by a considerable number of the town dwellers.

2.3.3 Craft production and intra-site exchanges

The inhabitants of LBA Akrotiri – and perhaps those living at the other sites on the island – were the consumers of artefacts produced by small scale local industries, as is attested to by the finds that most commonly make up the household equipment, such as pottery vessels and stone tools. As far as pottery is concerned, the large number of shapes and the standardisation in the production of vessels, whose various sizes sometimes appear to conform to fractional measures of capacity, has been considered a testimony for the existence of full-time potters (Doumas 1983, p. 124-125; Doumas and Constantinides 1990; Katsa-Tomara 1990). Similarly, the presence of specialised lapidaries on the island (Doumas 1983, p. 125; Devetzi 1990; 2001, p. 145) is suggested by the amount of mill stones, mortars and oil lamps made of local rock that have been found in the excavated houses. Metal objects, such as vessels, tools, daggers, hooks, jewellery[13] (beads) etc, are less often discovered, and thus are found in smaller quantities; nevertheless, their variety and distribution throughout the settlement, as well as the apparent economic affluence of the town according to Michailidou (2001b, p. 165) would justify the presence of craftsmen on the island. Moreover, the imprints of elaborate furniture (stools and chairs, tables and bed) that have survived in the volcanic material that buried the settlement suggest the existence of specialised craftsmen (Polyxronakou-Sgouritsa 2001, p. 138). Regardless of the plethora of finds indicating local craft production, however, no lapidary, pottery or metallurgy workshop has yet been unearthed. On the contrary, in some of the excavated buildings there is substantial evidence for the organised production of textiles, namely the type of workshop, whose finished products are least likely to be preserved.

Weaving activities are indicated primarily through the discovery of loom weights (fig. 2-6). An unusually large number of these artefacts, four hundred and fifty, have come from Room 3 of the West House[14]. Tzachili (1990, p. 386; 1997, p. 192) notes that at least five looms could have been used simultaneously requiring the labour of ten people (two for each loom), that may have not been

[13] The inhabitants probably took with them all the valuable possessions they could carry, including jewellery, before they abandoned the settlement (Michailidou 2001a, p. 164).
[14] The number of loom weights coming from the West House is very unusual. It is characteristic that from the whole settlement of Ayia Irini 185 loom weights have been reported (Tzachili 1990, p. 381).

residents in the house. Loom weights have also been found in large numbers in Sectors Alpha, Delta, and Beta, while they appear to be totally absent from other buildings in the settlement, a fact that perhaps suggests the presence of specialised weavers in the above houses (Tzachili 1990, p. 385). The preliminary publication of the few fragmentary Linear A tablets that have been found in Room Delta 18α also seem to support that in the building textiles were produced in large numbers (Boulotis 1998). The clay fragments that belong to at least 2 tablets, record a great amount of textiles (200 units), and quantities of sheep (46), which were perhaps raised for wool. Other finds that might be related to weaving activities are lead weights (fig.2-6) serving the weighting of wool or linen that were discovered in relatively large numbers in the West House and Sector A (Michailidou 1990, p. 418; Boulotis 1998, p. 410). It has been suggested that all the above buildings would have housed textile workshops (Michailidou 1990, p. 418; Boulotis 1998, p. 410).

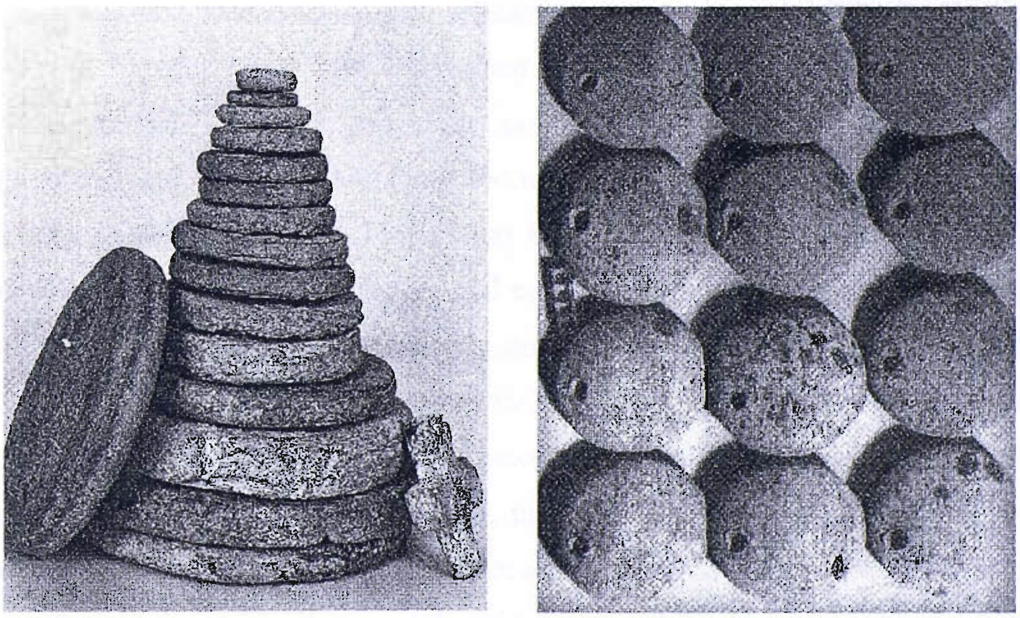


Figure 2-6: Left: Lead weights, from Doumas (1983, pl. 73), Right: Loom weights. From Tzachili (2001, p. 163).

As items made of cloth are hardly ever preserved, it is not known exactly what sorts of products were manufactured in the buildings mentioned above. Tzachili (1990, 2001) notes that these might have ranged from elaborate dresses of an undeniable social significance, such as those depicted on the wall paintings of Xeste 3 (§4.3), to more modest clothing and items that would be part of the common household equipment, such as bed covers or wall hangings. Furthermore, items that are related to the gear of a number of other occupations would have been produced by the loom; sails for boat building and seafaring, sacks used for the storage and transportation of crops and nets for fishing (Tzachili 2001). The great number of finished products that was recorded in the Linear A tablets found in Delta 18α suggests that these were intended to be exchanged. According to Boulotis (1998) the existence of systematic archives, the great quantity of registered textiles, and the presence of imported precious objects in Delta East indicate that the owner of the building was involved in overseas trade. If this was indeed the case then one would expect that the textile workshop in Delta East aimed at the production of items that would have been valued exports within a network of inter-regional exchanges. Concerning this it is noteworthy that Aegean textiles seem to have been highly valued items in Egypt in Bronze Age (Barber 1992, p. 311-357).

Weaving at the scale that appears to have occurred at the excavated houses at Akrotiri would have contributed to the economic and social life of the settlement not only by providing products of obvious socio-economic significance but also by encouraging and motivating a variety of other activities. Products of the loom, made of wool, may have been further processed after their weaving. Fulling, the strengthening and consolidation of the fabrics by soaking and agitating the finished products in water for many hours, was an activity that according to Linear B tablets was performed by men in Aegean Bronze Age (Tzachili 1997, p. 291). Moreover, weaving would have encouraged animal husbandry for the production of wool, the manufacture of dyes, which might have been related to the gathering of crocus from the hilly landscape of Thera or the collection murex shells (Tzachili 2001; Karali 2001), and even seafaring and trade, if the finished products were indeed traded overseas. Thus, the buildings that housed textile workshops besides private residences were significant economic units, the destination of raw materials coming from the hinterland, the source of finished trade goods, and a likely place of meeting and interaction for people that were involved in a variety of occupations and possibly belonged to different social rankings.

It has been suggested that other kinds of exchange among the town dwellers, such as the trade of processed food, might have taken place in Sector

A. The ground floor of the Alpha East consists of three rooms (A1, A2, and A3) all of which had been used for storage (Nikolakopoulou 2002, p. 208-209), forming the largest storeroom that has been discovered in Akrotiri up to now. The exterior east wall of A1 is pierced by a tripartite large opening and has a low sill (about 1m high) paved with slabs that faces the public space at the north-east fringe of the excavated area (Marinatos 1968, p. 21; Palyvou 1999, p. 207-208). The size of the opening in this case is quite uncommon for a ground floor room; as a rule in Akrotiri windows in close proximity to the street level are characterised by their small dimensions and the wooden lattice that often blocks their opening. The window of A1 obviously deviates from this norm, although it is not the only one. The House of the Anchor and Room Delta 16 also have large windows at the ground floor, facing the Triangle Square and the Telchines Road respectively[15]. It has been observed that such windows would have enabled communication with the public spaces outside of the buildings (Palyvou 2005a, p. 83, 86; Marinatos 1984, p. 16) and that perhaps functioned as "counters" or "shop-windows" (Doumas 1983, p. 51). Such interpretation would explain the unusual form of the windows, but is supported by little other evidence. Finds from the ground floor of Alpha East, such as scales, lead weights, cooking pots, a hearth, a stone basin, and grinding stones (Marinatos 1968, p. 16-34; Michailidou 2001a, p. 281) may have served the needs of a domestic unit. Nonetheless, Sarpaki (2001a) notices that the sampling of substances coming from Sector A suggests the storage of large quantities of flour. Given the fact that flour has a low storage life she considers the results of sampling as an indication for the consumption of processed food in quantities that would exceed the needs of an individual household. Consequently, she proposes that distribution or exchange of food for other services might have taken place at Alpha East. Despite, however, the evidence that suggest exchanges in Akrotiri, for example the standardised pottery shapes and capacities (Katsa-Tomara 1990; Doumas and Constantinides 1990), as well as the lead weights (Michailidou 1990), very little is known about buildings that would have functioned as trading units in the Late

[15] Xeste 3 had also four large windows at the ground floor (Palyvou 1999, table Δ, p. 419). There is evidence, however, that those at the east façade were blocked with lattices (Palyvou 1999, p. 400, fig. 223). In addition to these, large windows (Type C) at the ground floor have been identified in Rooms A2, D20 (the room was filled with debris after the seismic destruction) and the Sunk House (Alpha West) (Palyvou 1999, table Δ, p. 419).

Bronze Age. Therefore, their existence should perhaps be left an open issue at the moment, pending further evidence.

2.3.4 Seafaring and overseas exchanges

Besides the indirect evidence for intra-settlement exchanges mentioned above, the archaeological record provides plentiful indications for the existence of overseas trade networks. It has long been maintained that Akrotiri became prosperous due to seafaring and transit trade, as it is unlikely that the limited arable land and the mainly small scale industries would have created the necessary surplus for the accumulation of wealth that is witnessed in the excavated part of the town (Schofield 1982, p. 19; Buchholz 1990; Doumas 1983, p. 119; Doumas 2001, p. 93). The archaeological assemblage also testifies to the cultural communications of the Late Cycladic town, which can be seen in the numerous imports (pottery, ostrich eggs, stone, metal etc) and the apparent external, mainly Cretan, cultural influences in the manufacture of local artefacts (potttery, stone vesssels, wall painting, architecture, metal artefacts, etc.)[16]. The finds from Akrotiri attest to the close relation of Thera with Crete, but also exchanges with other islands and peoples, the Dodecanese, and mainland Greece as well as Egypt, Syria and Palestine. To these, one should add the Theran exports (for instance nippled jugs and 'swallow' jugs) and influences on iconography and art that have been attested in many of the aforementioned locations (Warren 1979a; Doumas 1983, p. 132; Barber 1984, p. 181; Morgan 1988, p. 171; Doumas 2001, p. 90). Generally, the quantities of imported pottery are not many if compared to the finds of Theran origin (Nikolakopoulou 2002, p. 98), and the amount of exports is relatively limited as well. Nikolakopoulou (2002, p. 97) maintains that exchanged vessels should be considered a "by-product" of the overseas communication between Therans and other peoples rather than an indication of "directional trade of bulk commodities".

Seafaring activities in the Late Bronze Age settlement are further suggested by iconography. The Flotilla frieze (pl.4, fig.2-7) that adorned Room 5

[16] A great number of published works refer to overseas exchanges and influences in the archaeological record of Akrotiri (Warren 1979a; Doumas 1983, p.119; Wiener 1984; Hood 1984; Stos-Gale and Gale 1984; Laffineur 1984; Devetzi 1990, p. 21- 22; Papagiannopoulou 1990; Stos-Gale and Gale 1990; Cadogan 1990; Gillis 1990; Hood 1990; Poursat 1990; Wiener 1990; Marthari *et al.* 1990; Morgan 1990; Sakellarakis 1990; Televantou 1990; Vanschoonwinkel 1990; Koehl 1990; Marinatos 1990; Kilikoglou *et al.* 1990; Marthari 1990; Vaughan 1990; Buchholz 1990; Doumas 2001, p. 93; Devetzi 2001, p. 144; Nikolakopoulou 2002).

of the West house (cf. §5.2.1) is often believed to have depicted the town and harbour of Akrotiri (Arrival town-Town V) (Marinatos 1974, p. 55; Televantou 1994, p. 337; Doumas 1992a, p. 49; Marinatos 1984, p. 54; Shaw and Luton 2000). It shows seven large vessels arriving at an urban port of which some are manned with approximately, two dozen people judging from the number of paddles, and perhaps twice as many, if one accepts that the paddlers only of one side of the vessel have been represented (Televantou 1994, p. 285). Such craft would have been suitable for long distance[17] travelling (Doumas 1983, p.119; Buchholz 1990, p. 227). If the vessels are indeed part of a Theran fleet, the number of crew members suggests that considerable labour was invested in seafaring, and that perhaps a significant amount of the inhabitants of the island would have been seamen at least during the sailing season. The arrival of the vessels in Town V has mainly been interpreted either as the return of the Theran fleet following a long voyage overseas or as a Theran nautical procession that took place during a local festival or ceremony (Morgan 1988, p. 145), whereas some readings of the painting incorporate both these possibilities (Boulotis 2005, p. 66). In any case, it is obvious that the events represented in the Flotilla scene and the maritime activities that they imply were of particular importance for the inhabitants of the "Arrival town" that had gathered at the harbour to watch the advent of the fleet.

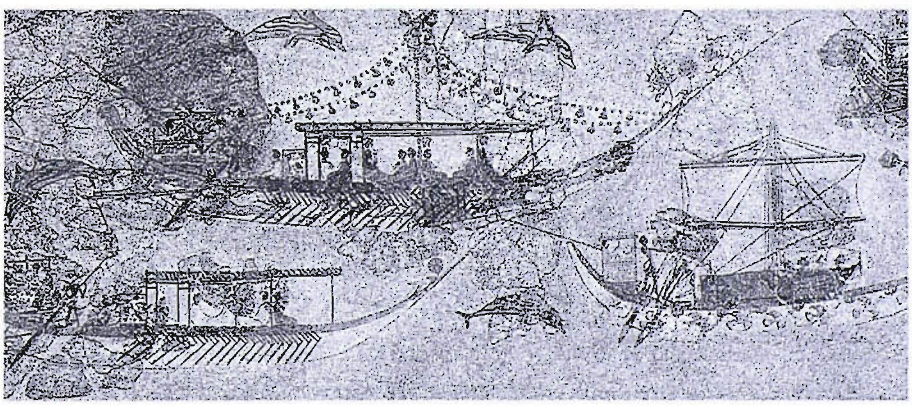


Figure 2-7: Detail from the Flotilla frieze (Room 5, West House). From Doumas 1992a, fig.35.

It has also been suggested that Akrotiri would have been an ideal port of call for trading sea vessels, as it is in a convenient location between Crete, Greek mainland and East Mediterranean (Schachermeyr 1978; Davis 1980; Schofield

[17] Although Morgan (1988, p. 141) maintains that in the Flotilla frieze the ships depicted are equipped for a particular occasion and would not have been travelling over a long distance.

1982, p. 19; Cherry and Davis 1982; Doumas 1982; Doumas 1983, p. 119; Stos-Gale and Gale 1984; Buchholz 1990; Morgan 1988, p. 171-172; Stos-Gale and Gale 1990). If this is true, the harbour of Akrotiri might have served not only the needs of local economy but also those of inter-regional trade, being a mid-journey stop for non-Theran boats and fleets that would be in need for anchorage and supplies.

In the absence of documentary evidence the exact mechanisms of inter-regional exchange in LBA Aegean remain unknown. It has been suggested that trade in the Aegean would have operated within a framework of diplomatic links with independent merchants perhaps involved in the process (Schofield 1982, p. 22; Cherry and Davis 1982, p. 340; Sherratt and Sherratt 1991, p. 365), and it is most probable that traded items were subject to some sort of taxation (duties on exports, imports, harbour-dues)(Schofield 1982). Perhaps the procession scene of Xeste 4 could be interpreted in the context of this kind of diplomatic relations. The participants in the procession, which starts at the entrance of the building and goes up to three storeys, appear ascending the staircase carrying ritual symbols and "gifts" (Doumas 1992a, p. 176; 2000b, p. 20; Boulotis 2005, p. 31). The scene aims to mark the use of the staircase that would have been the passing point of a real procession of men. It is characteristic that Boulotis (2008) has recently suggested that the gift-bearers represented in the scene are from Crete. He has also identified a small model of "ship cabin" among the participants of the procession (Boulotis 2005, p. 34). This feature could signify the occupation and position of the gift-bearers, who could be involved in maritime and seafaring activities, perhaps agents appointed by the palaces to the organisation of inter-regional trade. The evidence for religious symbolism that has also been identified in the painting does not contradict such an interpretation, as gift exchanges or trade agreements could have been sealed with religious/ritual ceremonies (cf. Cline 1995, p. 149). The suggestion that Thera was a port of call further justifies the affluence of the settlement at Akrotiri, and enhances the socio-economic significance of the harbour, which in the past might have been a cosmopolitan crossroad, a place where people of various origins would meet and exchange goods and ideas.

2.3.5 Ritual and religious expression

In Late Bronze Age Akrotiri, ritualised expression seems to have embraced all aspects of everyday life, pervading both the public and private spheres. Wall-paintings frequently form the most eloquent evidence for such an expression in domestic contexts. In some houses, the most formal rooms were adorned with murals with ritual-symbolic content. The "Fishermen" (pl. 1), the "Priestess" (pl. 2) and the "Boxing Boys" (pl. 18) are characteristic examples of murals that have been given such interpretations (Marinatos 1984, p. 109; 1987, p. 31; 1993, p. 201-220; 2005; Papageorgiou 2000; Mylona 2000, p. 565; Doumas 1987, 2000a; 2005; Boulotis 2005, p. 68; Michailidou 2001a, p. 468). Michailidou (2001a, p 425-427) has maintained that the first floor rooms which the above paintings adorned, Room Beta 1 of Beta Complex, and Room 5 of the West House (fig. 1-1), were multifunctional private rooms: the space where tenants would gather, consume food, and sleep, as well as the stage of domestic rituals, which would have been an inseparable part of daily life (Michailidou 2001a, p. 427). It is quite probable, given the themes of some of the paintings, that social practices related to milestones in the cycle of life (childbirth, entering adulthood, marriage, death), commonly referred to as "rites of passage", would have taken place in these rooms (Boulotis 2005, p. 63). Perhaps the enactment of such practices would have involved group gatherings and small-scale drinking and feasting episodes, evidenced in the large number of cups stored in close proximity to the decorated rooms, as well as in the cooking utensils discovered in large amounts in some buildings[18] (for example in West House and Beta 1) (Papagiannopoulou 1995; Boulotis 2005, p. 63). It is also reasonable to assume that the decorated rooms, which are the most formal and elaborate rooms in the houses, would have been the settings of encounters of the residents of the dwelling with important visitors on many other occasions.

A ritual function has also been suggested for decorated spaces associated with purely preserved contexts, such as Room 1 of the House of the Ladies (fig. 1-1, Doumas 1992a; Peterson Murray 2004). The function of this building is not

[18] These had been taken as evidence by Marinatos (1984, p. 20-21) that many of the houses at Akrotiri were public shrines allegedly associated with the preparation of cultic meals. This interpretation has faced a lot of criticism (see Doumas 2000b; Boulotis 2005, p. 40-42) in the past. Furthermore, it has been argued in recent years that in Late Bronze Age the collective consumption of food and feasting episodes would have not been solely related to religion (Hamilakis 1996, 2002).

clear, as its ground plan does not conform to the model of a typical Theran house (Palyvou 2005a, p. 83-85); it is relatively large and its mural decoration, which includes a scene depicting female dressing has potentially a ritual symbolism (Marinatos 1984, p. 100, 104; Doumas 1992a, p. 35; Doumas 2005, p. 78; Boulotis 2005, p. 49; Murray 2004). Moreover, a pair of horns of consecration, a typical Minoan religious symbol, has been discovered in association with this building (Boulotis 2005, p. 34). Other spaces in the settlement decorated with nature scenes, such B6 (pl. 20) and Delta 2 (pl. 17), have also been considered to have formed the background of rites and acts of worship (Marinatos 1984; Hägg 1985, p. 211), although neither the iconography nor the finds unearthed in these rooms explicitly suggest ritual action (Doumas 1992a, p. 100).

Ritualised expression is not necessarily a manifestation of religious beliefs and it is now well-acknowledged that the distinction between the secular and the sacred in prehistoric cultures is not always possible, meaningful, or even useful (Frankfort 1949; Doumas 1992a, p. 100; Chapin 2004, p. 51; Boulotis 2005, p. 22; Bradley 2005, p. 33-35). To date, Xeste 3 is the only building for which there is wide agreement that it had a public/cult function due to its architectural features (lustral basin), spatial arrangement and wall-paintings with undeniably religious significance (cf. §4.3). Xeste 4 (fig. 1-1) also appears to have had a communal character, although its exact use is not known at the moment; it would have been a public building, a fact that is suggested by its elaborate façades constructed with ashlar blocks, its size, and the impressive wall painting of the procession scene that decorated the main staircase (Doumas 1992a, p.176; Doumas 2005). It has been proposed that Xeste 4 possibly had an administrative use (Doumas 2005), whereas Boulotis (2005, p. 31, 34) has identified quite a few instances of religious symbolism in the wall-painting of the procession (cf. § 2.3.4).

Besides private or public buildings, ritualised performances would have taken place in outdoor spaces, which were either embedded in the urban tissue or lay within the mountainous and coastal landscape of Thera (Boulotis 2005). The existence of such places is to a great extent deduced by iconography. The ritual activities depicted in the murals of the Adorants (pl.13) and the Crocus gatherers of Xeste 3 (pl. 14, 15, 16) are performed in the countryside, probably in the hills surrounding the archaeological site of Akrotiri, where saffron grows in the present day (Tzachili 1994, p. 21-23; Katsipis 2001; Sarpaki 2001b; Palyvou 2005a, p. 21-22). The Crocus gathering scene, that has a strong religious symbolism, as it includes the representation of a goddess (cf. §4.3), offers evidence about various aspects of Theran society. It suggests, for example, that the picking of plants, as in many traditional cultures, might have been a female occupation (Dickinson 1994, p. 91). Crocus would have been a highly valued product in LBA (Sarpaki 2001b, p. 180-181; Boulotis 2005; Davis 1979, p. 147), and according to Boulotis (2005) the offering of the stamens to the goddess indicates that its collection was probably under the control of the priesthood.

Furthermore, the painted scenes of the West House (cf. §5.2.1) indicate that the harbour would have also been a setting for important communal festivities and ritual practices. In the scene that unfolds at the coastal landscape of the Arrival town a procession of men is heading towards the harbour (Morgan 1988; Boulotis 2005). Among the men a bull is depicted that is apparently intended to be sacrificed (fig. 2-8). Sacrifice rituals in the context of public gatherings would have been associated with conspicuous consumption and display, as suggested by the lavishly decorated sea vessels that approach the harbour in the Flotilla scene (pl. 4); it is apparent that varying social ranks distinguish those on board the vessel, the paddlers, the passengers and the persons in the ship cabins (Morgan 1988, p. 116; Televantou 1994, p. 287-288). The latter appear to be at the top of the hierarchy. Such expressions of conspicuous display during public events might have aimed at reinforcing the prestige of certain town dwellers and at establishing power relationships in the LBA society.

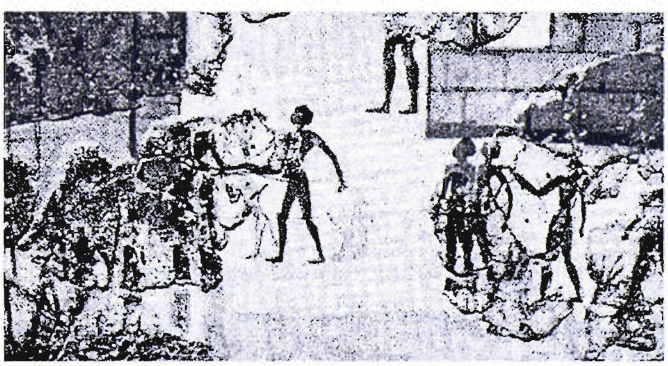


Figure 2-8: Procession of men in the Arrival Town. A bull is depicted among the participants (Miniature fresco, south frieze). Detail from Morgan 1988, pl. 105.

Despite the abundance of iconographic details that suggest the performance of communal rituals in open spaces, it is rare that the presence of such loci is verified directly by excavation evidence. In this sense we are very lucky that the pillar pit that was dug at the area of the House of the Benches revealed undisputable traces of ritual practices (fig. 1-1, 2-3, at the immediate west to the Square of the Benches). Remains of sacrificed animals, that consist of hundreds of pairs of animal horns belonging to sheep, goats and bovines, have been found arranged in a heap above the debris of buildings. These manifest the use of space for communal performances shortly before the abandonment of the settlement (Boulotis 2005, p. 44). A gold ibex figurine was also discovered in this area; it was kept inside a wooden casket which had been deposited within a clay larnax (Doumas 2002, p. 173). Evidence for ritual deposition of objects has also been reported regarding the Square of the Cenotaph: a construction similar to an Early Cycladic grave which contained 7 marble Early Cycladic figurines (Doumas 1995, p. 184) has been discovered in this area. It is possible, as has been suggested, that communal ritual activities related to the worship of ancestors took place at the square (Doumas 1995; Boulotis 2005, p. 43; Palyvou 2005a, p. 37).

2.3.6 Conclusion

The finds from this final phase of the prehistoric settlement piece together an image of a prosperous and bustling harbour town. Despite the abundance of archaeological information that has come to light in Akrotiri, however, the social structure of Theran society remains elusive. Although the apparent variety of occupations of town inhabitants implies the existence of different social groups and a sophisticated social organisation, the exact nature of societal relationships, their hierarchical or perhaps heterarchical[19] character, is less easy to be assumed, especially because only a small area of the settlement has been unearthed. The affluence of the excavated houses suggests that perhaps a number of the town inhabitants living in the urban core had access to important resources. This however, would not be necessarily true for all the inhabitants of the settlement

[19] Heterarchy is defined after Crumley (1995, p. 3) as "the relation of elements to one another when they are unranked or when they possess the potential for being ranked in a number of different ways".

and its hinterland. Evidence on economic and social activities may be suggestive about diverse aspects of social relationships within the settlement. For example, it is possible that some of the inhabitants of Akrotiri have profited by the production of textiles in large quantities that could have been valued items within interregional exchange networks. Sherratt and Sherratt (1991, p. 359) have suggested that in Late Bronze Age the concentration of the textile production in urban centres rather than in farms or villages would have benefited elite members capable of distributing the manufactured items. This situation entails the potential of social conflict (Sherratt and Sherratt 1991) and may require the establishment of power relationships through the production of material culture artefacts aimed at conspicuous consumption and display (cf. §7.2); In the following chapters is going to be argued that the study of the social and symbolic functions of mural decoration could be instructive regarding social relationships in Theran society (cf. Chapter 1). Social aspects of the reception of Theran murals will be discussed in Chapters 4 to Chapter 7. Chapter 3 that follows is concerned with the methods in which aspects of the visual experience of the paintings can be investigated.

Chapter 3
Methodology: Visibility analysis in fully 3D spaces

3.1 3D modelling and Virtual Environments

3D digital reconstruction is a necessary first step to the investigation of visual experience in partially preserved and visually complex archaeological environments such as that of Akrotiri. The advantages of using solid modelling and animated 3D graphics in archaeology have been identified as early as the 1980s (Reilly and Shennan 1989, p. 157; Reilly 1990, p. 133). Especially in recent years, however, computer based 3D modelling techniques have been widely utilised for the visualisation of 3D spaces or even the creation of 'virtual' environments, and have become well established tools for the reconstruction of elements that once defined the appearance of archaeological sites and monuments. Computer-assisted 3D modelling can indeed proved useful for the investigation of the visual properties of space, as it enables the creation and exploration of high-quality digital reconstructions that take into account the physical properties of real world features and environments (for instance texture, illumination, and atmospheric effects) which are essential to the shaping of visual perception. Digital models that can be viewed via pre-rendered walkthroughs or enable real-time interaction have additional advantages over computer-generated stills, as they give an impression of movement within the reconstructed spaces. Such an impression is created at the very least via the continuous alteration of the point of view from which the model is observed, a process which, it can be argued, offers a sense of what Gibson terms 'visual kinesthesis' (Gibson 1979, p. 183). This could be defined as the experience of the changes in an individual's optical flow that occur during his/her movement in the environment, which is constitutive of the sense of the moving self (egolocomotion) (Gibson 1979, p. 123, 183). However, a 3D model can offer much more than that depending on the system in which it is viewed. Such a system can be projected (the image fills the viewer's field of vision), desktop or table-top (Fernie and Richards 2002). The various systems differ in the level of immersion, physical movement and natural vision they provide users. For example, projected systems that enable interaction with the virtual world by means of natural movement, such as head movements in the case of head-mounted displays, are considered immersive in contrast to systems that allow navigation solely through a keyboard and/or a mouse. It is interesting to note that despite significant differences among the various systems on which a 3D model is viewed, some first experiments have shown no apparent discrepancies between the ways people navigate in desktop virtual environments and immersive systems (Ruddle *et al.* 1998; Ruddle *et al.* 1997; Ruddle *et al.* 1996).

For the needs of archaeological research, the use of a desktop system is most often the preferred option. Archaeological interpretations are constructed through interaction with the virtual environment, and meaning is constructed within a framework of inference that is similar to that used in physical encounters with archaeological remains. Space and the objects of interest are approached from many different viewpoints and emphasis is given to human-scale perspective and the observation of phenomena such as illumination and movement. It is true that desktop virtual reality cannot offer the users the complexity (auditory, olfactory, tactile etc.) and depth (intensity of stimuli) of real experience. In addition, there are differences between the visual perception of an environment that surrounds the perceiver and the visual inspection of images projected on a computer screen, for example regarding foveal and peripheral vision (cf. § 1.1.1). Nonetheless, the computer-based method has profound benefits over the natural engagement with historic and prehistoric sites in cases where the present appearance of the object of study is substantially different from that it has had in the past. On these occasions, a 3D model can bring the observer one step closer to human-scale experience of the environment and facilitate the formation of subjective, intuitive, and qualitative statements about human perception in space. It should be noted, however, that a walk-through or even immersion in a VR model does not necessarily entail a better interpretation of the past. It has been noted that meaning is an internalised understanding, culturally embedded, which is essentially different from the experience of interacting or even being immersed in a VR world (Lock 2003, p. 261). Of course, if one is going to suggest, as archaeologists do, that past meanings can be mediated by the study of material remains, then it has also to be assumed that something of that meaning can be revealed in the reconstruction and exploration of the material circumstances that used to be associated with past human practices. Nonetheless, in this case the knowledge and preconceptions of the archaeologist for the culture under study are what in the end contributes to a meaningful interpretation of what is seen in virtual space. Therefore, the utility of a VR model heavily depends on what is already known about the people that inhabited the spaces being reconstructed.

The contribution of VR models to the understanding of past ways of thought and action is also subject to many of the methodological limitations that can be attributed to physical encounters with historic or prehistoric spaces as means of interpreting the past. For instance, a virtual walk-through can lead to vivid and insightful observations concerning the visual impact of Theran wall paintings within their original setting. It is obvious, however, that whatever insights derive from this approach depend on the user's arbitrary decisions on how to experience the virtual environment, which involve choices regarding the speed of movement, stopping behaviour and the selection of viewpoints from which the different scenes are appreciated. One could argue that arbitrary decisions concerning how to move in a digital reconstruction leave a lot of space for biases that can seriously undermine the validity of the interpretation; subjective choices regarding which viewpoints should be recorded and discussed are likely to reflect preconceptions of the researcher, while perceptions from alternative locations might remain completely unnoticed and unregistered. Furthermore, as has already been suggested (cf. §1.3), movement in space is embedded in everyday human practices. Visual impressions derived via a walkthrough that does to consider the social context of movement in the past do not necessarily conform to the visual experience of an individual in prehistory.

Finally, interpretations based on the exploration of a virtual environment are likely to be related to subjective understandings of what is seen, and the use of descriptive terms with often vague and ambiguous meanings, such as, 'monumental, 'spacious', 'private', 'isolated', 'prominent' etc. Ultimately, the lack of rigour in such descriptions limits the level of explanation and interpretation that can be offered by 3D computer-based representations, and consequently their research potential. It would be of great interest, for instance, if subtle and yet meaningful variations in the visual qualities of space that encourage certain behavioural responses were systematically and precisely defined and recorded. Such possibility could permit a more comprehensive investigation of the visual experience in past environments that will consider comparisons between distinct built forms and the effects of transformations in architectural configuration through time. Eventually, these lines of inquiry might permit a gradual distillation of some basic causal factors that would have shaped human behaviour in historic and prehistoric space. Considerations of this kind have motivated the development and use of computing methodologies that can analytically approach aspects of visual perception.

3.2 Analytical approaches to visual perception

3.2.1 GIS-based visibility analysis

Computer-based analytical approaches to the visual perception of past environments have mainly been applied in a landscape context and are based on the use of Geographical Information Systems (GIS.). These hardly ever refer to urban spaces which is the main focus of this research. Nonetheless, GIS-based approaches have often been concerned with the visibility of built structures situated in the landscape and they are discussed here since they mirror theoretical and procedural concerns regarding the visual experience in past environments.

GIS were introduced into the investigation of the visual experience in past landscapes at the beginning of the 1990s, because they enabled the easy calculation of 'line-of-sight', 'field-of-view' and 'intervisibility' from several points of interest in a digital terrain representation. Such concepts and similar heuristics were already being used in a number of non-computational archaeological works (Renfrew 1979; Fraser 1983; Drewett 1982; Devereux 1991; Fraser 1988) that aimed to explore the cultural formation of prehistoric space by laying emphasis upon the visual experience of individuals situated in the landscape. Using a similar interpretive framework GIS-based studies sought to explain in a formal way the relationship between visual perception in the natural environment and the spatial distribution of sites and archaeological remains, such as watchtowers, funerary mounds or monumental architecture (Gaffney and Stancic 1991; Wheatley 1995, 1996; Lock and Harris 1996). In these approaches, the visibility, non-visibility or intervisibility of landscape features are considered of possible significance for the choice of location on which built structures were erected and the constitution of places that were redolent with symbolic meaning. It is noteworthy that, in parallel with the first applications of visibility analysis, the importance of vision and sight for the formation of cultural landscape was acknowledged by the exponents of phenomenology in archaeology, although they disputed the benefits of computer-based analysis in the interpretation of past environments (Thomas 1993a, 1993b; Tilley 1993, 1994, 2004).

The calculation of *viewshed,* that is, the area visible from a certain location in a landscape, is nowadays a standard procedure in GIS software packages. It requires mainly a digital representation of the landscape under study (Digital Terrain Model-DTM) and a point in that model that represents an individual's position. A GIS can then calculate the viewshed of the given location by interpolating a line (line of sight) from the observer's point at eye level to every other cell in the digital terrain model. Depending on whether this line is obstructed by the height of landscape features or not, the different areas of the DTM are classified as non-visible or visible respectively, and results are presented in a binary map (viewshed) (fig. 3-1a). The estimation of intervisibility between locations is implemented in a similar manner, although the viewer's height is considered for all locations of interest so as the reciprocity of results to be ensured. GIS-based analyses of visibility and intervisibility are presently routinely used in archaeological investigations.

Following the widespread adoption of viewshed analysis by archaeologists, many of its limitations have been highlighted over the years (Conolly and Lake 2006, p. 228-233; Lake and Woodman 2003; Wheatley and Gillings 2000; Wheatley and Gillings 2002, p. 214-216; Van Leusen 2002; Fisher 1991, 1993). The development of visibility analysis from the beginning of the 90s until today has more or less aimed at addressing some of these shortcomings with various levels of success:

a) Uncertainty in viewshed analysis

Since the early 90s a number of criticisms have focused upon the limitations of binary viewsheds which produce an undifferentiated field of view that does not conform well to the real-life experience of seeing within a landscape (Fisher 1994, 1992; Wheatley and Gillings 2000). Concerns about the accuracy of DEM models that are greatly dependent upon the scale and resolution of the represented topographic information, have repeatedly been expressed. In addition, there has been an increased awareness about the existence of factors that can significantly determine the visibility or non-visibility in natural environments that are not considered by line-of-sight calculations. Vegetation, for example, could have completely obstructed the visibility of archaeological features in the landscape, while atmospheric conditions, distance, as well as the colour and texture of landscape features, might have impeded object recognition in a natural environment. It is by now well established that any estimation of visible areas in the landscape that is grounded on viewshed analysis embodies a certain degree of uncertainty, a fact that should be made explicit in interpretations.

More importantly however, probability and fuzziness can be made evident in viewshed representations. Fisher has suggested ways of incorporating uncertainty in the outcomes of the analysis, such as the probable and fuzzy viewshed (Fisher 1991, 1992, 1993, 1994, 1995, 1996). The former is a raster grid that expresses the probability with which each cell in the viewshed is visible from the observer's location. It aims to allow for uncertainty caused by errors in the DEM and discrepancies between different visibility algorithms. Fuzzy viewsheds, on the other hand, purport to deal with the issue of visual clarity of objects in a landscape by applying formulas that take into account the effects of distance decay, weather conditions, and atmospheric haze (Fisher 1994). Wheatley and Gillings (2000), following the work of Tadahiko Higuchi (1983), also dealt with the issue of visual clarity and recommended ways of determining distinct visual ranges in a binary viewshed (Higuchi viewshed) (fig. 3-1c).

b) Quantitative and inferential rigour

Given the amount of uncertainty that exists in viewshed calculations and the debatable significance of visibility as a factor that determines the locations of past monuments, means of testing the significance of the results of visibility analysis have been suggested. Notwithstanding its limitations, the binary viewshed has remained a useful heuristic, forming the basic unit of advanced products of analysis that encompass considerable inferential rigour, such as *cumulative* (Wheatley 1995, 1996) and *total viewsheds* (Llobera 2003; Llobera *et al.* in press). These form summary maps of the visual characteristics of a group of sites and the entire terrain respectively. A cumulative viewshed (fig. 3-1b) indicates the number of specified locations that can be seen from each cell within the study area and can be utilised for the interpretation of the distribution of one group of sites in relation to the visibility characteristics of another. The meaning of the resulting spatial patterns in this case can be assessed not solely with visual inspection, but with statistics as well, which can explore the probability of occurrence of the observed spatial distribution and determine whether a proposed association is 'random' or not. Wheatley (1995, 1996) used cumulative viewsheds and statistical testing to investigate the distribution of Neolithic funerary monuments in the Avebury and Stonehenge regions concluding that many of the Stonehenge barrows were situated in locations from which other barrows are visible. On the contrary, statistical testing did not allow the rejection of the hypothesis that barrows in Avebury area were randomly distributed (Wheatley 1995, 1996). Fisher et *al.* (1997) and Lake *et al.* (1998) also evaluated the results of cumulative viewshed analysis for site locations on the island of Mull and in Rhinns of Islay respectively by means of statistics.

c) The visual properties of the entire terrain

Recently, the calculation of the *total viewshed* of the study area has permitted an even more rigorous validation of cumulative viewsheds. In total viewsheds visibility is considered from all locations in the landscape, namely from each cell in the raster that defines the study area. In the final outcome of the analysis the value of each grid unit represents the number of locations (cells) that can be seen from it (or from which it can be seen, depending on the location of the viewer). In this way total viewsheds (Lee and Stucky 1998; Llobera 2003; Llobera *et al.* in press; Llobera 2006) summarise the visibility characteristics of the population of the area of interest against which the significance of the results of cumulative viewsheds can be tested.

Besides enhancing the inferential rigour of viewshed analysis, total viewsheds are useful analytical products *per se* expressing a shift of interest from the visibility of sites to the visual structure of the whole environment. They are indicative of locations that have similar visual characteristics, and can be further analysed to produce additional information on the visual qualities of the study area, such as topographic prominence, as it has been demonstrated by Llobera

(2003, 2005). Given the fact that they take into account this information for each location in continuous space, they can also be suggestive of the visual experience from the point of view of a mobile observer, if, for example, they are intersected with possible walking paths (Llobera 2003, p. 36). The latter is a promising development in visibility analysis, as the consideration of mobility has often been a concern of archaeological investigations in past landscapes.

d) The experience of the mobile observer

Real-life encounter with natural environments has since long encouraged scepticism regarding the "static" approach to visual perception implicitly adopted in most applications of visibility analysis, which focus upon the visual impact of landscape features as seen from a limited number of discrete viewpoints. These approaches ignore the constantly changing visual impressions of the individual moving in the landscape. Gibson's ecological approach to visual perception, and his emphasis on the importance of movement in the shaping of visual experience, further motivated an interest on the issue of mobility in the studies of past environments (Gibson 1979).

As a consequence, some studies have attempted to develop a line of inquiry that links visibility with the experience of a moving individual. Issues of interest in this case include the role of the perception of monuments in forming patterns of movement in a landscape or the social significance of the emergence of new features in relation to existing paths or wider areas of human activity and practice. One of the most comprehensive archaeological studies in this area was curried out by Llobera (2000) who built on the theoretical works of Pred (1986) and Hägerstrand (1970). Llobera uses the concept of constraint as defined by Time-Geography to create raster maps in which each cell indicates the probability of an individual moving into or through that cell. In the determination of the probability values presented in these maps, the visibility of built forms, which would have attracted or repelled movement, is essential.

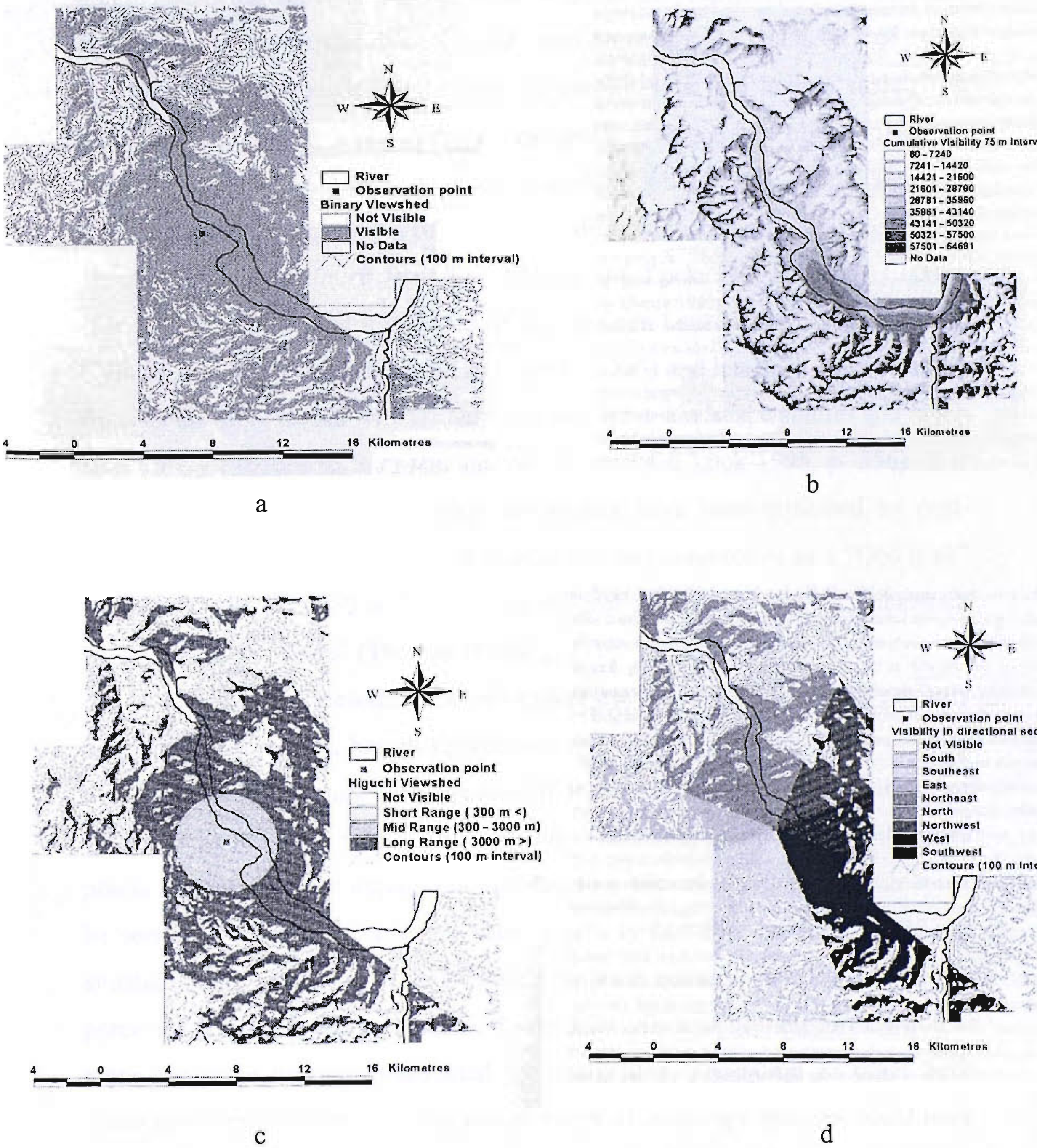


Figure 3-1. Visibility around the River Danube, Iron Gates Gorge, from an observation point near the prehistoric site of Vlasac. (a) A simple binary viewshed, (b) A cumulative viewshed, (c) A Higuchi viewshed showing short, mid and long ranges in all directions, (d) A directional viewshed showing binary visibility in eight directional sectors. From Lock (2003, fig.5.3).

e) Moving beyond two-dimensionality

While a number of criticisms concerning viewshed analysis have been successfully addressed by recent methodological and technological advances, others have been less so. Perhaps the most often discussed shortcoming of the method, and the most difficult to deal with, is the dependence of viewshed analysis on the reductionistic and two-dimensional character of GIS representations that significantly limit its usefulness at the human scale. It is obvious that a reduced and abstract description of space can only provide an equally restricted understanding of visibility within the study area. In archaeological applications of GIS two-dimensionality has always been identified as a significant limitation (Harris and Lock 1995, p. 355; Claxton 1995; Gillings and Goodrick 1996; Gaffney and van Leusen 1995; Wheatley and Gillings 2002, p. 241; Harris and Lock 1996, p. 307) and has been considered by some as the main reason why GIS use is restricted to landscape studies and much more rarely expands to intra-site analysis (Harris and Lock 1995, p. 356). It is also one of the main reasons why GIS studies have been criticised by post-processual theorists that generally disregard the map perspective as a "God trick" (Haraway 1991, p. 189) and "a picture of past landscapes that the inhabitant would hardly recognise" (Thomas 1993a, p. 25).

The fact that viewshed analysis makes use only of 2 ½D [20] does not only raise theoretical issues, but also pragmatic concerns. The effects of the absence of the third dimension are made apparent if one needs to consider the visibility of built structures in the natural environment. The representation of buildings as points forces a Boolean inquiry into the data (e.g. the object of interest can either be seen as a whole or cannot be seen at all). In real life, however, buildings situated in the landscape are never seen in their entirety, as they are always perceived from a certain perspective that reveals only part of their form, while in most occasions they are obstructed by topography, vegetation or other built structures. Nevertheless, even the partial views of landscape features could have a symbolic significance, and their gradual revelation to the viewer is essential in shaping the experience of space and place. Good examples are the large Andean ceremonial complexes, whose presence, according to Moore (1996), mirrored the

[20] Here the shorthand '2 ½D' is used to refer to the common practice of using attribute data to represent the third dimension within an essentially 2-dimensional data structure.

exercise of power within Andean societies, or buildings in Mayan towns (Hohmann-Vogrin 2005, p. 287). If one is going to investigate the symbolic significance of such structures, it would be important to know for example which parts (e.g. façade, side walls, architectural details and decorations etc) of a building are visible from the surrounding urban and natural environment. Such inquiries could determine which features of the buildings were meant to be seen and the possible intentions of those who built these structures.

At this point, it would be useful to clarify that, although recent versions of GIS offer more opportunities for 3D visualisation, they are still based on 2D or 2 ½D data structures (Wheatley and Gillings 2002, p. 241; Harris and Lock 1996, p. 307) that significantly limit the usefulness of visibility analysis. GIS software still cannot differentiate between two points which have the same x and y coordinates, but different heights and does not permit the representation of complex built structures or building interiors. Furthermore, since a viewshed is a 2D raster grid representing space as seen from the top, visibility analysis is essentially restricted to two dimensions. This can be demonstrated if one considers the extreme example of a GIS representation of near vertical walls. In this case, when the results of visibility analysis are visualised in 3dimensions by draping the viewshed on Triangulated Irregular Network (TIN) of the space under study, quantisation errors could be observed on the faces of the walls (fig. 3.2), a consequence of the fact that a viewshed calculation represents as a line what in real world is a surface.

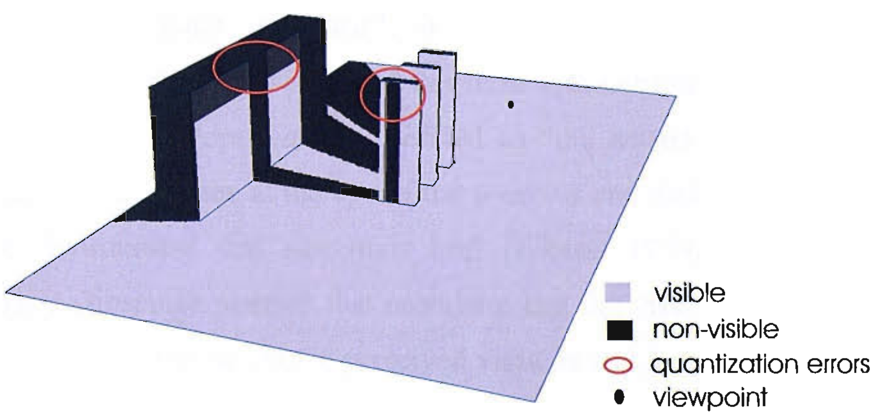


Figure 3-2. Quantisation errors in GIS-based visibility analysis that is applied on almost vertical walls.

To conclude, five basic trends can be noted in computer-based archaeological visibility analysis over the years: a) the realisation and explicit representation of the uncertainties inherent in viewshed calculations, b) an interest in developing analyses with an increased quantitative and inferential rigour, c) the consideration of visibility from all locations in the study area d) an emphasis on investigating the experience of a mobile observer and, e) the demand for a less reductionistic and more human-centred approach to past environments. Although these trends have been eminent in the study of past landscapes, they are indicative of an archaeological reasoning that might also profit the investigation of visual experience in past urban spaces. On the other hand, computer-based visibility analyses specifically aimed at the study of built spaces have been developed in the field of architecture and urbanism, mirroring primarily the research interests of those disciplines.

3.2.2 Visibility analyses in urban spaces

The development of visibility analysis within the fields of architecture and urbanism differs from that of archaeological GIS-based methods in two respects: firstly, visibility analysis in built environments has always focused upon the visual properties of spatial configuration rather than the visibility of individual objects situated in built space; secondly, it was from the very start created to investigate the experience of a mobile observer. The first attempts at a formal analysis of the visual qualities of built environments were made by Benedikt (1979), who introduced the concept of the *isovist,* the set of all points visible from a vantage point in space[21], into the study of architectural configurations (fig. 3.3a). Benedikt associated this term with Gibson's ecological optics and the notion of an '*optic array*', defined as "the nested complex of visual angles that have their apex at the eye of the observer and their base at the surfaces of the environment that surrounds her" (Gibson 1979, p. 65-71). Following the basic Gibsonian premise that postulates that the visual experience of the environment is constituted via the perceived variants and invariants in the changes of the optic array, which occur due to the observer's movement (Gibson

[21] Although the isovist as initially discussed by Benedikt (1979, p. 52), was defined as either a 3dimensional or a 2dimensional entity, isovist analysis is based on the production of two-dimensional isovists.

1979, p. 73-75), Benedikt aimed to investigate the interplay in the isovist properties among contiguous points in space. He suggested, therefore, a spatial analysis based on the examination of *isovist fields* (fig. 3.3b), which are scalar fields, similar to topography contour lines, indicating various isovist properties (area, perimeter, occlusivity, variance, skewness and circularity). It was argued that these measures were significant in the formation of certain perceptions and behaviours related to the concepts of privacy, surveillance, prominence, visual access and exposure (Benedikt 1979, p. 52). Benedikt and Burnham (1985), later managed to experimentally demonstrate that isovist properties affect human perception, but they were not able to generalize their results. More recently, Conroy (2001, p. 207) in her investigations of movement within virtual environments also observed correlations between large isovist areas and pedestrian stopping behaviour. At the same time, Batty (2001) further extended isovist analysis regarding simple geometric measures (distance, area, perimeter, compactness and convexity), in order to study the visibility characteristics of different building and city types, which could allegedly influence the perception of individuals moving in those spaces.

In addition to isovist analysis, Turner et *al.* (2001) drew on the theoretical framework developed by Benedikt, as well as on social theories of networks, such as those proposed by Hillier and Hanson (1984) and Watts and Strogatz (1998), and proposed a graph approach to the investigation of visual perception in urban space, known as *visibility graph* analysis (VGA). A visibility graph is a set of edge connections that link locations in space that are mutually visible (fig. 3.3c). This type of representation has the advantage over isovists that it can be analysed with local and global graph measures (e.g. neighbourhood size, clustering coefficient, and mean shortest path length) which could potentially be related to decision-making while navigating in the built environment (Turner *et al.* 2001, p. 118). For instance, Turner has suggested that visually integrated areas in urban space (fig. 3d), that is, areas for which the mean shortest path to all other location is low, offer better opportunities for pedestrian congregation. He also proposed that the clustering coefficient of a visibility graph is indicative of the amount of visual accessibility that will be gained or lost in the course of the observer movement and may be associated

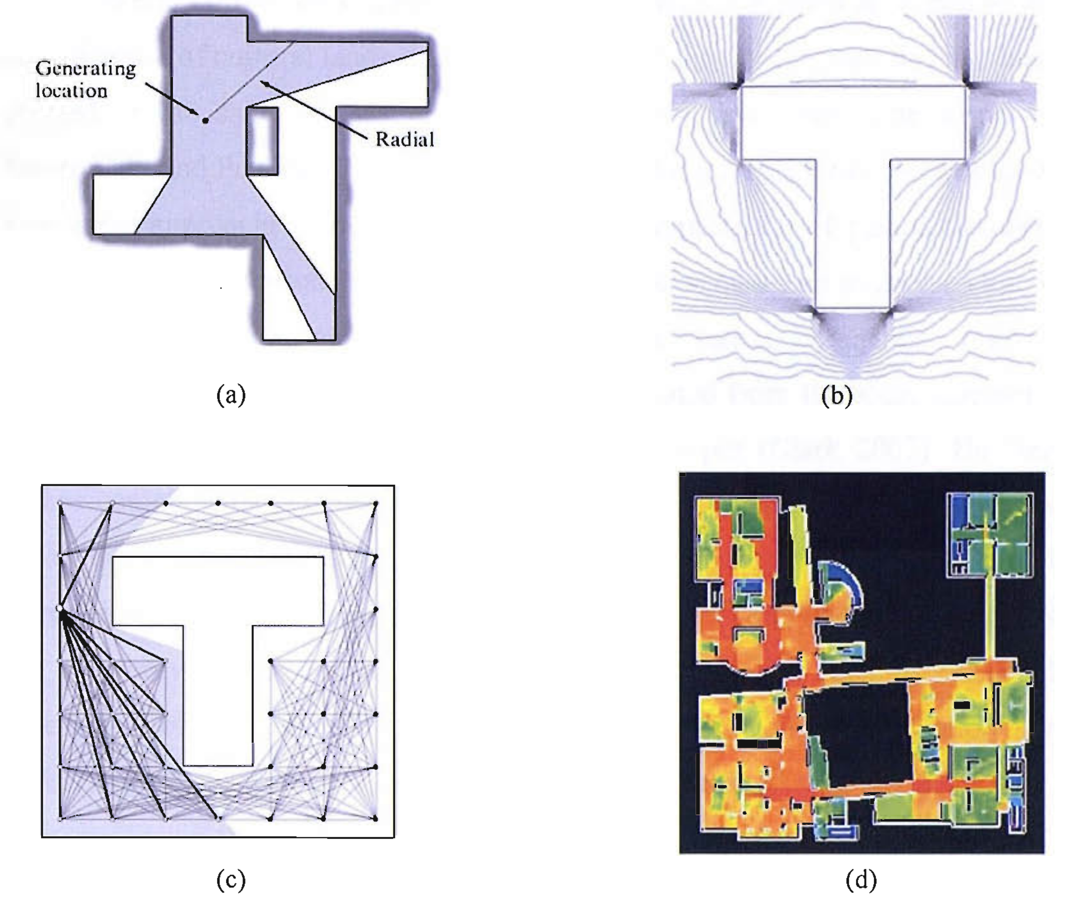


Figure 3-3. Visibility analysis in urban space. (a) An isovist (from Turner et *al.* 2001, fig 1), (b) An isovist field of equal area (isolines connect points in space from which equal area can be seen, from Turner et *al.* 2001, fig. 4, (c) A visibility graph, from Turner et *al.* 2001, fig. 3, (d) Visually integrated areas in built space (analysis performed with Depth Map) from http://www.vr.ucl.ac.uk/research/vga/ accessed March 2006.

with way-finding in complex spatial configurations. Turner and Penn (Turner and Penn 2002) and Turner (2003) have further attempted to investigate the relationship between VGA and locomotion with the application of agent-based modelling. In the model they propose, agent movement is guided by the viewable area that is computed for each point of a dense grid visibility graph. After applying their methodology in a region of the City of Westminster in London, they find that the agents' behaviour correlates well with observed patterns of pedestrian movement indicating that visible area is a factor that could determine individuals behaviour in the built environment.

Isovist and Visibility Graph Analysis in archaeology

While GIS-based visibility analysis is a well established approach to the investigation of cultural landscape, isovist and visibility graph analysis have been utilised in the study of past built spaces in only few cases. The works of Stavroulaki and Peponis (2005) and Clark (2007) form characteristic examples of how these approaches can be applied for the interpretation of past ecclesiastic spaces. Clark's investigation of visibility in Byzantine churches in Jordan (fig. 3-4) considers the measures of spaciousness (area), openness (isovist perimeter2/area) and complexity of isovists calculated from the altar, assembly, ambo and precider's chair for six distinct church types (Clark 2007). He then makes comparisons between the respective values of each location through six subsequent time phases and forms statements regarding the level of visual integration of these features and the relationships between assembly members and the clergy. It is characteristic, however, that Clark neither attempts a detailed description of what exactly would have been visible from each location nor makes a precise estimation of the suggested measures. As he notes: "Often,

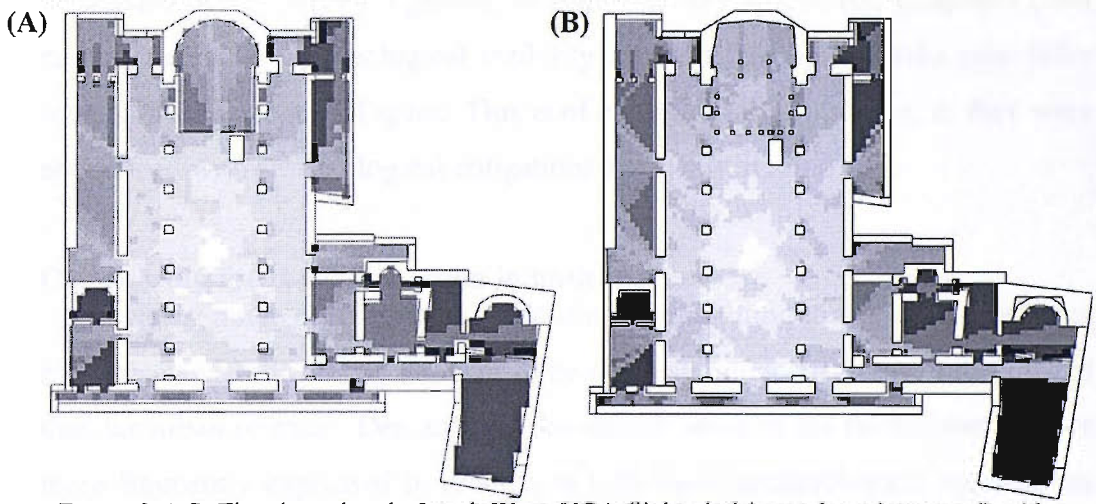


Figure 3-4. St Theodore church, Jerash West, VGA (light–dark/most–least integrated) with chancel screen. B. St Theodore church, Jerash West, VGA (light–dark/most–least integrated) without chancel screen (from Clark 2007, p. 98)

screens, ranging from 0.80m to 1.30m in height, and chancel post-collonettes often 2m in height, with or without balustrades or architraves, impeded the assembled view *without totally blocking it*" (Clark 2007, p. 86, original emphasis). VGA does not permit the consideration of occlusive effects of these features, even if they are represented in a very abstract way. As it produces solely a two-dimensional slice of visible space at the eye level of the viewer, it cannot allow for the possibility that one can see beyond obstacles that would have partially hindered visibility below or above the horizontal. In that sense, VGA offers a rather crude description of visibility in built space.

The adoption of isovists and VGA for archaeological purposes is not unproblematic. Although it has been proposed that these methodologies could possibly reveal social and aesthetic aspects of the visual experience of space (Turner *et al.* 2001; Batty 2001), it has been rightly argued that some of the statistical measures they suggest cannot always be interpreted in a meaningful way (Llobera 2003, p. 27-28). Furthermore, there are still few empirical studies[22] of how exactly isovist and visibility graph measurands can be associated to human behaviour and perception of the environment. Agent-based models that aim to explore the links between VGA and pedestrian movement at fine spatial scales similar to those mentioned above seem promising and could potentially motivate new lines of inquiry into the experience and social significance of past environments. However, in many situations the 2dimensional nature of VGA and isovist analysis does not meet in the most efficient way neither existing demands of archaeological inquiry regarding visibility in built spaces (cf. Chapter 1), nor current trends in archaeological visibility analysis that aim to take into fuller account the 3D nature of space. This is of course hardly surprising, as they were not created with archaeological obligations and goals in mind.

Considering the third dimension in built spaces

It is noteworthy that the two-dimensional limitations of the existing methods of visibility analysis seem to be of greater concern to the archaeologist than the urban scientist. Demands for the consideration of the third dimension are more frequently expressed in relation to GIS-based archaeological applications (Llobera 2003; Gillings and Goodrick 1996) rather than analytical approaches to visual perception developed within the field of urbanism. This is probably mainly[23] due to the fact that visibility analyses employed in the built environment have focused on the study of unoccupied space among buildings and walls which

[22] For example, such as those carried out by Benedikt and Burnham (1985), Conroy (2001) and Franz and Wiener (2005).
[23] Computation and time constraints related to the 3dmodeling and analysis of very large data sets (e.g. town plans) have also been issues of concern.

is seen as potential for movement (Benedikt 1979; Hillier and Hanson 1984, p. 272).

That said, in recent years there have been attempts by urban scientists to develop analytical approaches that can be applied in 3D spatial representations. Consistent with these trends is the idea that the analysis of the 3D visual properties of urban or natural landscapes is essential for the understanding of human perception of the environment. It has been also maintained that 3D methods coincide better with Gibson's definition of the optic array and Benedikt's original description of the isovist as a 3D entity (Benedikt 1979). The description and analysis of 3D isovists has until now been attempted with the development of spherical analyses that mainly aim to examine open urban spaces.

Fisher-Gewirtzman and Wagner (2003) introduced a metric tool that was developed using the JAVA programming language and VRML modelling in order to calculate a Spatial Openness Index (SOI), which they defined as "the volume of open space potentially seen from a given point" (ibid, p. 39). The method is based on the count of visible voxels (cube units) of open space that fill up a sphere around the observation point. Fisher-Gewirtzman et *al.* (2003) have attempted to demonstrate via a preliminary test that SOI is correlated to "perceived density" in urban space which they suggest is an important indicator for environmental quality. It is characteristic however, that this test, which involves comparisons between a number of alternative spatial configurations, tends to approximate spatial openness measurements with two dimensional viewing angles estimated from horizontal and vertical sections, rather than calculate the visible volume for each observation point, as the latter would be "extremely complex" (Fisher-Gewirtzman *et al.* 2003, p. 581). Another spherical tool created by Yang et al (2007) as an extension for GIS software is similarly aimed at the creation of 3D indices that are allegedly closely related to the sense of spatial enclosure (ibid. p. 989). Their technique, however, works only with 2 ½D data and it cannot deal with real 3D objects. As a result, its applicability is limited to exterior open spaces and does not extend to building interiors (ibid. p. 975). Teller (2003) has also demonstrated a method that permits the measurement and analysis of spherical projections of visible sky area as seen from specific viewpoints in a 3D model of an urban environment.

Despite the fact that spherical metric tools, such as those described above, have been primarily created for the study of modern environments, they could also be useful for archaeological investigations. In the past, aesthetic aspects of prehistoric built spaces have been explored by measuring and analysing urban open space. Palyvou (2000), for example, comments on the proportionality of mass (built space) versus void (open space) in Minoan Architecture noting that the latter exceeds the former in Neopalatial buildings. It should not be precluded that spatial openness measures may also be associated with social aspects of space. For instance, an urban area with large visible open space volume would give more opportunities for visual access to the surrounding natural or built environment enhancing the communicative impact of features of symbolic significance situated within it. Similarly, concepts analogous to sky openness have been associated with archaeological interpretations in past landscapes; Lake and Woodman (2003, p. 695), for instance, maintained that the placement of prehistoric stone circles may have been determined by the amount of visible far horizon seen from these sites, which could have contributed to the shaping of an impression of 'circularity' that is echoed in the configuration of the monuments. Although spherical metric tools could potentially benefit archaeological interpretations of past environments, they are only useful in the case when the visibility of surfaces, rather than that of open space, is of interest.

On the other hand, a fully 3D technique that focuses upon the visual perception of objects within their surrounding environment has been suggested by Groß (1991), who proposed the analysis of rendered scenes derived from a 3D model. His approach was later enhanced by Bishop et al (2000; also Bishop 2003), as a completely automated method for visual impact assessments in a landscape context, although it could be equally used for urban space analysis. The application of this methodology requires, as a first stage, the creation of a 3D model and the allocation of discrete colours to the objects or features of interest. In a second stage, the amount of visibility of individual features is estimated by calculating the counts of the colour-coded pixels in a number of rendered camera views. Depth-information that indicates the distance of visible objects from the camera is also extracted from the images. Bishop's methodology offers an effective approach into the investigation of the visual properties of objects within their surrounding environment for a finite number of observer viewpoints. Far from being restricted to Boolean operations, it can determine how much of the object is visible or how much it cuts the horizon. Furthermore, according to Groß (1991, p. 408) and Bishop (2003, p. 685), it has the potential to take into account atmospheric conditions that could affect the perception of objects, although no applications have been presented in this area. Nevertheless, contrary to some GIS-based approaches, Bishop does not attempt to estimate this information for all locations within the area of interest or map it back in space, because this "would require prohibitive computing time" (Bishop 2003, p. 686). This restricts the usefulness of his approach, as the spatial component of the data cannot be subjected to further analysis and interpretation.

3.3 A new approach to visibility analysis in fully 3D spaces

The above review of current methodologies of visibility analysis in the fields of archaeology and urbanism reveals a lack of approaches that can effectively take into account and analyse the visual properties of complex 3D spaces and objects. It is now well established that computer-based analysis in archaeology should not be restricted by the functionality of existing systems that were not designed to serve archaeological goals, and that new methods which meet the particular requirements of archaeological research in a more efficient way should be developed (Gillings and Goodrick 1996; Moore 1996, p. 228; Lake *et al.* 1998; Wheatley and Gillings 2000, p. 24; Lake and Woodman 2003, p. 69; Wheatley and Gillings 2002, p. 237). Besides being motivated by theoretical concerns, the move towards methodologies that aim to investigate space from a human-scale and three-dimensional perspective emanates from the nature of inquiry related to the meaning and experience of past environments, especially when built structures situated within urban contexts or landscapes are considered.

The problematic that was developed concerning the Theran wall paintings is a good example. The reconstruction of the decorated spaces is a necessary first step in any approach of assessing their communicative impact. However, the mere descriptive use of 3D models, although in many ways illuminating, is of limited utility, mainly due to the lack of methodological rigour in the users' interaction with the 3D model and the ambiguity of terms used in interpretations. On the other hand, it is also true that the study of human cognition cannot be restricted to observations derived from abstract representations, and statistical and physical measurements. In the past, the synergy of visibility analysis and 3D modelling has been described as promising, as has the potential to make use of the benefits that both approaches have to offer (Gillings and Goodrick 1996). In practice however, the integration of such diverse technologies (Table 3-1) in a meaningful way entails obstacles, as quite often visual impressions that are derived from a 3D and human-scale perspective of space cannot be explored in a meaningful way with the established methods of spatial analysis that are restricted to 2 and 2 ½ dimensions.

3D modelling approaches:	**Spatial analysis (GIS, urban studies):**
Aim to explore visual space through virtual interaction with 3D models	Aim to explore properties of space through products of analysis (viewsheds, calculation of intervisibility, isovists, visibility graphs, statistics)
Seek to study visual space in an experiential mode and are interested in the direct impressions that space creates the observer	Investigate and measure the properties of space, which are implicit in the form and structure of the built environment and may not be immediately perceivable
Look into visibility issues from a human-scale perspective	Adopt a Cartesian/2dimensional view of space
Facilitate the formation of subjective, intuitive, and qualitative statements about human perception in space	Enable formal and quantitative approaches to the study of visual experience

Table 3-1 Comparison between 3D modelling and analytical approaches to visibility.

For example, in the investigation of the visual experience of the wall paintings, it is obvious that the faces of the walls, rather than their 2D footprints, are of interest. Furthermore, the research questions of this work focus upon the visibility of painted features that would be seen through architectural elements, such as door openings and windows. In this case a visibility analysis in fully 3D spaces is required that conforms better to the impressions created by looking at the 3D model, allowing for the fact that an observer is able to see above obstacles such as furniture, through windows or below door lintels.

In order to approach these issues this research proposes new methods of visibility analysis in fully 3D spaces that couple 3D modelling and GIS functionalities. These methods explore visibility in 3D computer-generated representations of space and permit the consideration of uncertain knowledge regarding the geometry of space, and of certain factors that affect visual experience, such as the angle of view, distance and illumination. A basic premise that underlies this work is that 3D models and 3D modelling software can have more than a descriptive use in archaeological investigations, also forming useful analytical tools.

3.3.1 Visibility recording and analysis in 3D digital environments

Benedikt (1979), in his seminal article on isovist analysis, attempted to visualize the behaviour of an isovist along a path by moving a point light source across a 3D model of an environment. He defined the set of illuminated points in 3D space as the isovist calculated from the location of the light source. Although Benedikt did not further build on this association, and went on to describe the isovist as a 2D entity, the comparison is particularly instructive. The connection between point-source illumination and visibility in a 3D digital environment makes sense, as in computer graphics views of virtual scenes are produced by simulating the propagation of light (Bittner and Wonka 2003). Figures 3.5b and 3.5c show this association clearly; if a light source emitting rays in all directions is positioned at the observer's location at eye level, the illuminated and shadowed areas in the model will correspond to the visible and non-visible surfaces seen from a camera positioned at the same location as the illumination source (Paliou and Wheatley 2007).

It is, therefore, possible to develop a visibility analysis of virtual scenes based on simulations of light propagation. It has to be noted that although information on the visibility of features can apparently be derived from the camera view (cf. §3.2.2), in the way that has been suggested by Bishop et al (2000) and Bishop (2003) for example, the simulation and recording of light distribution offers greater opportunities for spatial mapping and analysis, as it will be demonstrated later in this chapter.

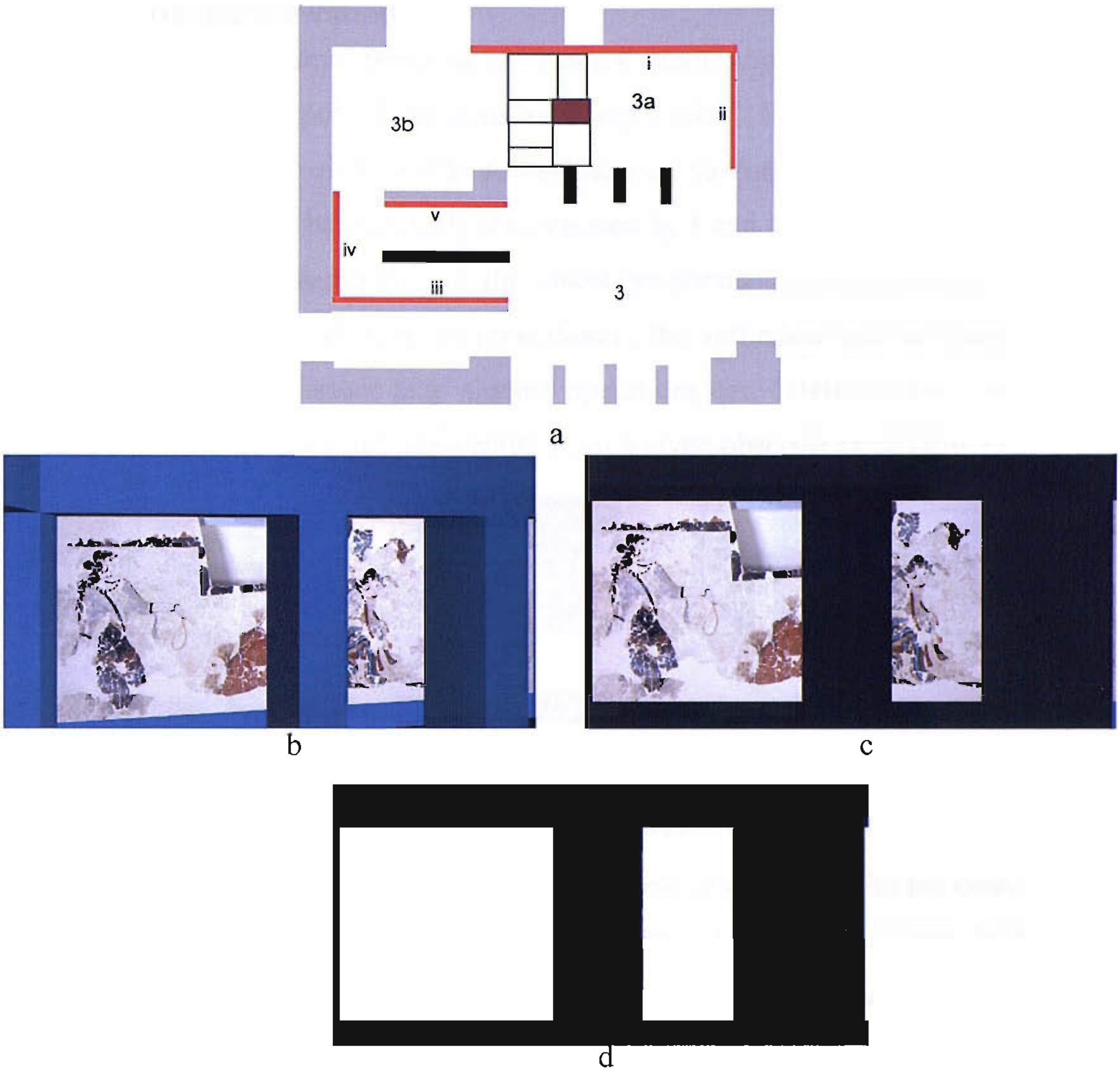


Figure 3-5. a) Room 3 of Xeste 3 on the ground floor. b) A view of the wall painting of the Adorants (fig. 3-5a i) from a camera positioned in Room 3 (fig. 3-5a, 4-2, 4-3, 4-4) c) A light source has been positioned at the location of the camera and an image is rendered by a second camera positioned perpendicularly to the wall. d) The binary viewshed from the same observer point.

As is the case with camera views, information about the illumination of a surface can be extracted by rendering as raster image. For single flat objects such as wall surfaces, illumination maps can be created by placing a camera perpendicular to the target object and using it as vantage point for the recording of light distribution on the surface of interest. Alternatively, if the visibility of the entire environment is of interest, the textures of all wall surfaces with information on illumination can be extracted as lighting or shadow maps, as has been suggested by Earl (2005). The latter process is the only option if non-flat objects are of interest.

3.3.2 The binary viewshed

Illumination maps, being raster images containing spatially referenced information, can be imported and analysed using a GIS[24]. For example, they can be turned into a binary viewshed by reclassification so that the visible areas (all areas that a ray of light has reached) are indicated by 1 and non-visible areas by 0 (fig. 3.5d). For the investigation of the visual properties of wall paintings this process is particularly useful, as the projection of the outlines of painted features on the viewshed and further map algebra operations can determine the visible area (in cell count or per cent) of an entity from a given observer point (Fig 3.6).

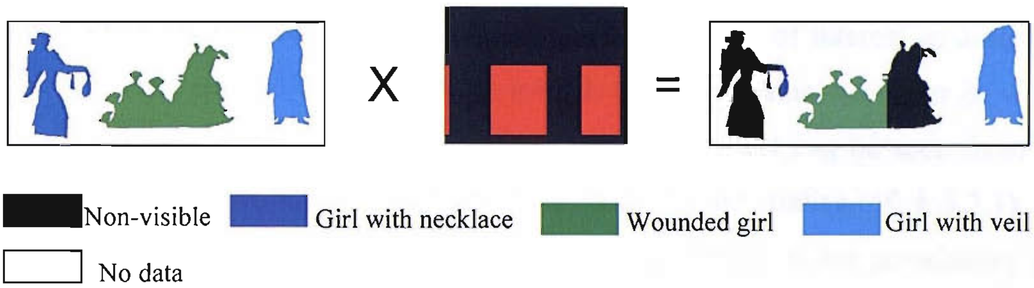


Figure 3-6. The calculation of the viewable area for each feature of interest.

This process can be repeated for each viewpoint of interest. In the context of this research the suggested operations are performed for every location in the study area, as long as all locations can be potentially occupied by an observer. In each case the space in which the observer may have been located is sampled at regular intervals defined by a grid, whose centroids mark possible viewer's positions. It is important that the resolution of the grid is fine enough to describe changes in the visibility of the features of interest to the detail that the research problem requires. If the analysis is performed at the appropriate resolution, the produced viewsheds will provide the population, rather than just a sample of visibility measurements. For visually complex interior spaces, such as Xeste 3, it was discovered that a fine grid of 20x20cm is more suitable to describe rapid changes in visibility that could occur due to the observer's movement than a 50x50cm or a 1x1m grid, that are often used for visibility analyses in built spaces (cf. Turner *et al.* 2001).

A great number of single viewsheds will reveal that visibility changes constantly in many cases depending on the observer's location. The question that

[24] 3D modelling and spatial analysis in this research were implemented using 3ds Max (versions 8, 9 and 2009) and ArcGIS (versions 9.1, 9.2).

rises at this point is, which features will be more frequently within a viewer's field of view, and therefore more likely to be seen? The invariants of the visual experience in built spaces can be shown up by summarising the visibility information incorporated in individual viewsheds.

3.3.3 'Times seen'

'Times seen'[25] (fig. 3-8) can help identify parts of the target object (in this case a painted wall) that are less obstructed by other objects or architectural features and therefore have greater potential to be seen. These are maps created by summing up binary viewsheds (equation 1, fig. 3-7) with map algebra operations. If viewsheds are recorded from all locations of interest as described above, their sum will correspond to a total viewshed, namely a raster in which each cell indicates the number of times the target object can be seen from the study area. As applies to total viewsheds in landscape studies (cf. § 3.2.1), the raster created in this case determines the characteristics of the population, and hence statistical testing for the evaluation of the significance of the observed patterns is not necessary.

(1)
$$y_{ij} = \sum_{c=1}^{m} x_{ijc}$$

where y is a cell at row i and column j and m is the number of binary viewsheds (x) to be combined.

The projection of the outlines of individual painted elements on the total viewsheds permits comparisons between the visibility of different elements of a composition (fig. 3-8). The amount of visual exposure of each feature can be determined with the application of zonal statistics, as well as visual inspection. Total viewsheds can describe the likelihood that a particular painted feature will be encountered by a viewer moving in the space of interest (less obstructed features are more likely to be seen). They can also help to identify invariants in the divergent perspectives of multiple observers standing in space during public gatherings (cf. Chapter 4). Moreover, 'times seen' can be created by summing up

[25] The term 'times seen' is used by Fisher (1994, p.169) to define simply "the sum of all binary viewsheds". In this research unless otherwise stated, 'times seen' are synonyms to total viewsheds, as they are the result of the summation of binary viewsheds derived from all location in the study area.

only viewsheds from locations that intersect a walking path. This could enable the creation of useful visual summaries that can reveal the most exposed features in the course of particular routes (Earl 2005).

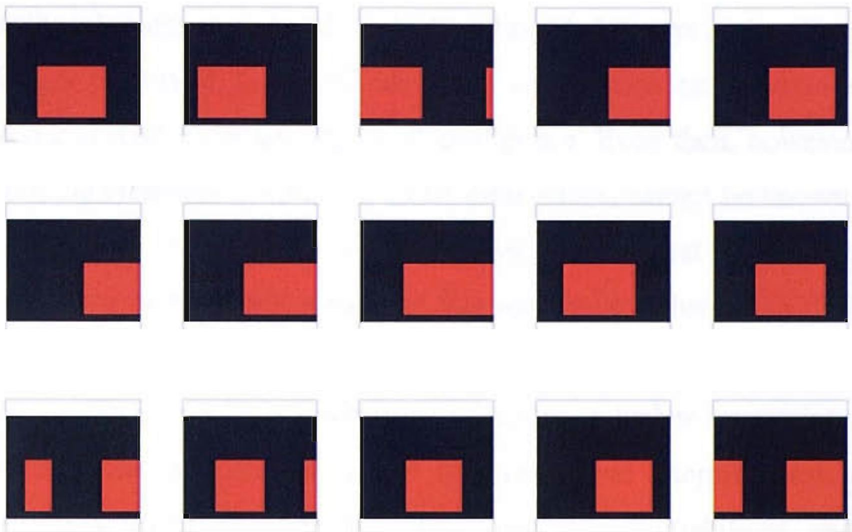


Figure 3-7: Some of the binary viewsheds that were added to create the total viewshed of the wall surface of the Adorants.

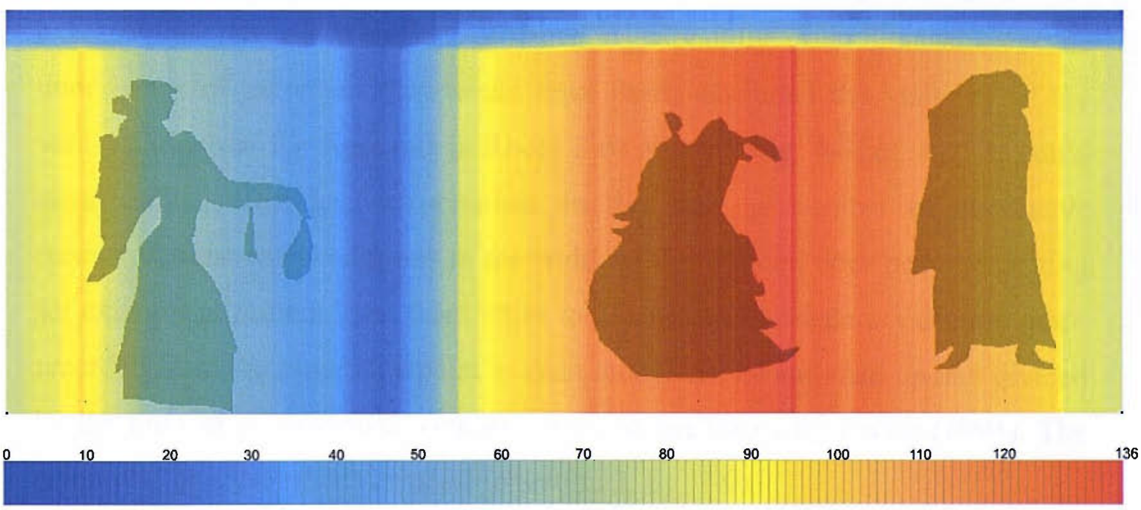


Figure 3-8: Cumulative map that was created by summing 213 individual viewsheds. It indicates the relative differences in the visual exposure of the three female figures of the wall painting of the Adorants from Room 3 of Xeste3.

3.3.4 Managing uncertainty and error: probable and fuzzy viewsheds

It cannot be overemphasized that, as in the case of landscape visibility studies, in most situations there is some degree of uncertainty as to whether a target feature is visible or not from a particular location. This lack of confidence in the results of the analysis is caused by possible errors in the reconstructed geometry of the digital model of the built space under study. Errors in a proposed reconstruction are likely to be caused by imprecise recording of the extant built features on site, or during the digitisation process (e.g. when calibrating site plans). The main source of uncertainty, however, is the partial preservation of the archaeological record and the lack of knowledge concerning features that are no longer preserved. On some occasions assumptions can be made regarding such features with a certain degree of confidence. Even then, however, details of the missing elements, such as the exact dimensions, cannot be known with precision. Ultimately, it has to be acknowledged that a great deal of detail about the geometry of past built structures that may have influenced visibility in space is simply unknowable.

That said, it is important to establish whether uncertainty in a particular context can substantively affect statements and interpretations concerning the visibility of the features of interest. For that, probabilistic viewsheds can be created that aim to show the likelihood that a certain feature is exposed to the viewer, and the propagation of possible error in the analysis outputs. For example, one may ask if the lack of knowledge about the exact dimensions of the door jambs of *polythyra* that would have partly occluded the visibility of the wall-paintings of the Adorants in Room 3 of Xeste 3 (fig. 4-3, cf. §1.1.1) could significantly affect an interpretation. In this case, a number of alternative reconstructions with variations in the width of the wooden door posts (changing for example at ordinal level from 18cm to 25cm) can be created. Visibility maps recorded from the same viewpoint in each model can be summed up and divided by the number of proposed reconstructions as suggested by Fisher (1994). The result will be a probable viewshed (equation 2, fig. 3-9).

$$(2) \qquad p(x_{ij}) = \frac{\sum_{k=1}^{n} x_{ijk}}{n}$$

where $p(x_{ij})$ is the probability of a cell at row *i* and column *j* in the raster image being visible, and x_{ij} is the value at the cell of the binary coded viewshed in realization *k* such as that *k* takes values 1 to *n*.

Figure 3-9. A probable viewshed

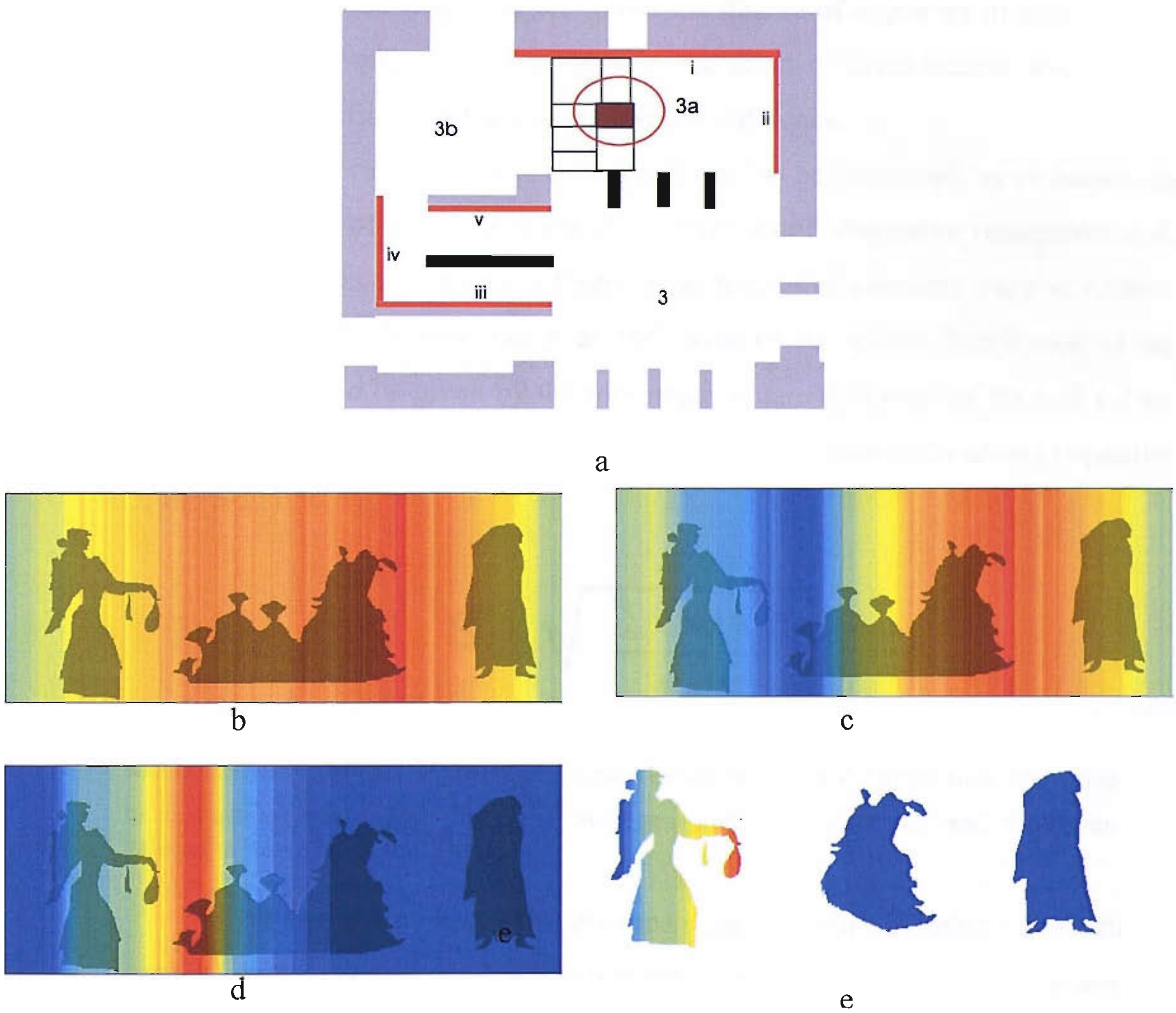


Figure 3-10 a) Detail plan of the ground floor of Xeste 3 with indication of the position of the pier (in red ellipse) reconstructed by Palyvou (2005a, p. 120, fig.166) in Room 3a. The wall painting of the Adorants was located on the north wall of the room (i) b, c) The visibility of the wall-paintings of the Adorants with (c) and without (b) the wooden pier (fig. 3-10a) (blue-low visibility/red-high visibility d) the range of difference between the two maps (blue areas are not affected by possible errors/red areas are those that are most affected e) The range of difference between maps b and c within each individual class (feature) is indicative for the effects of uncertainty for individual painted elements (blue-areas are not affected by possible errors/red areas are most affected. The visual exposure of the figure at the left is more affected by the presence of the pier.

3.3.5 Propagation of error in 'times-seen'

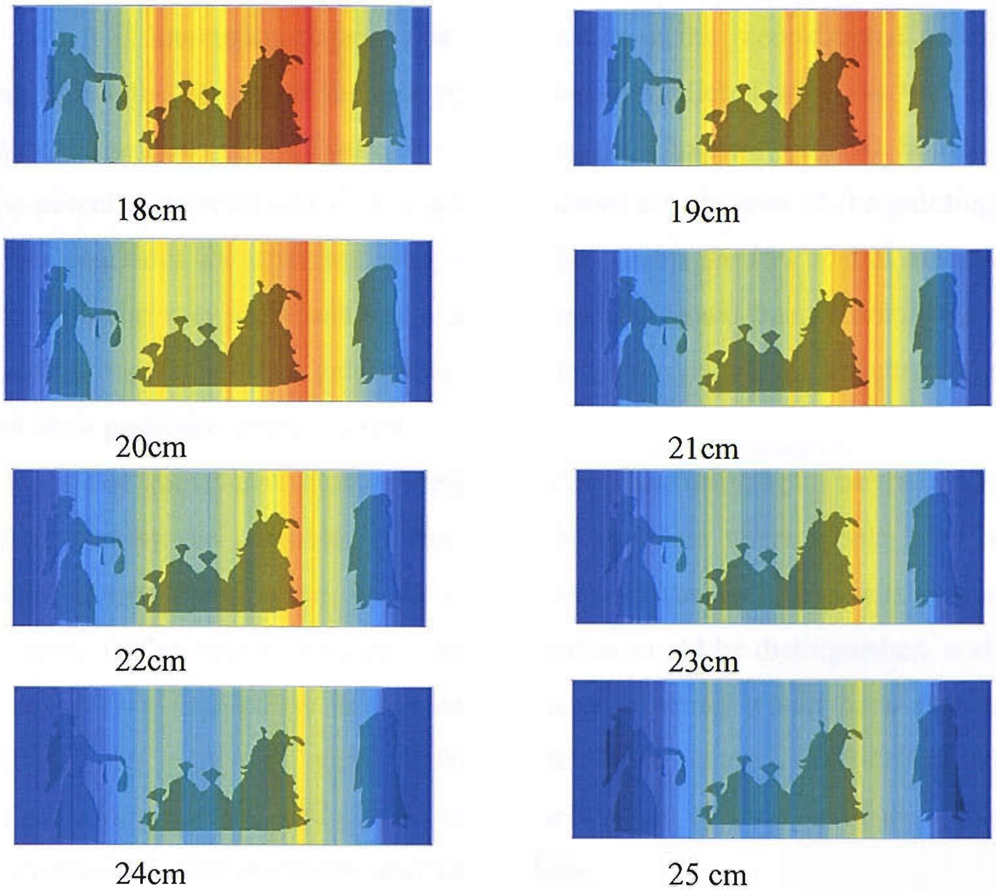
As long as interpretations are based on visual summaries, such as 'times seen', it would be more useful if uncertainty and error propagation were discussed in relation to these more complex products of analysis. In this case measures of dispersion can be used to assess the degree in which error in a particular situation is substantive or not. In the simplest situation between total viewsheds created from two alternative reconstructions, the error can be described as the range of difference between the absolute values displayed in the two maps. For example, in figure 3-10d the degree of exposure of areas whose visibility is not affected by changes in the form of architectural space (blue areas), can be defined with a high degree of confidence.

Often more than two outcomes will need to be compared, as on occasions when a number of visibility maps are derived from alternative reconstructions, among which the dimensions of certain architectural elements vary at ordinal level (cf. § 3.3.4). In such cases, an indication of the spatial distribution of the possible error can be given by the root-mean-square deviation of the cell values of the different possible outcomes from the mean (standard deviation) (equation 3, fig. 3-11):

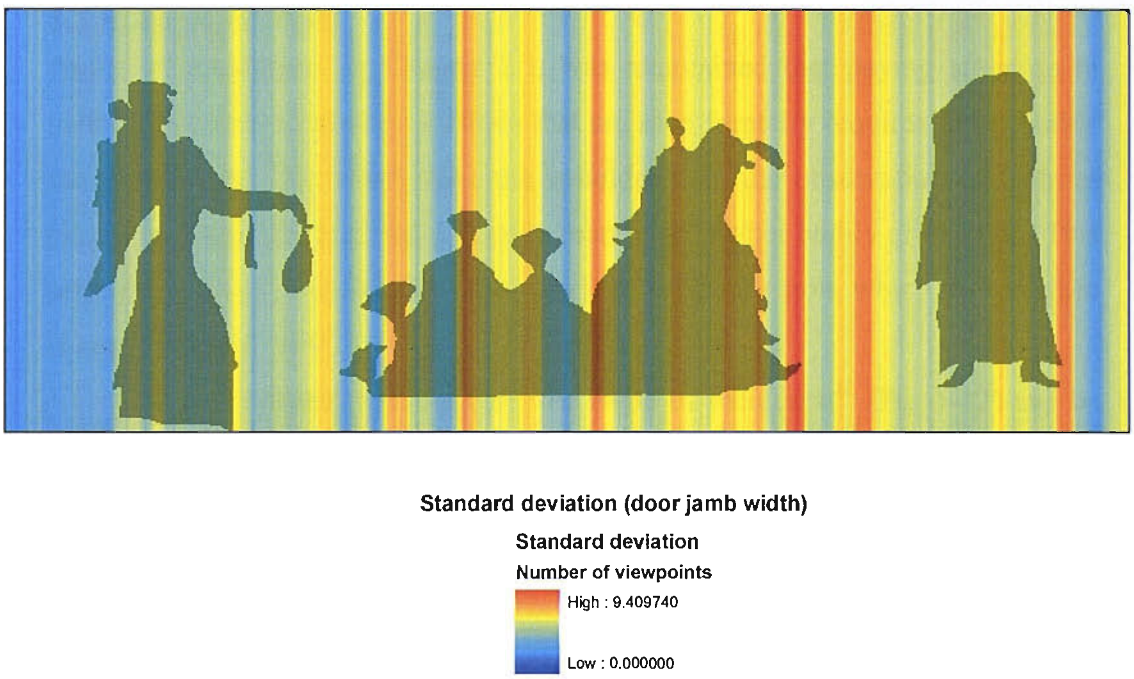
$$S = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}} \qquad (3)$$

standard deviation of the cell values of a number *(n)* of 'times seen' derived from alternative reconstructions, where x is a 'times seen' based on a probable reconstruction and $\bar{x}$ the mean cell value of n 'times seen' considered.

This process averages the discrepancies between a number (n) of 'times seen' (fig. 3-11a) that are based on a set of alternative and equally plausible reconstructions using the standard deviation of the samples. The result will be a raster (fig. 3-11b) whose cell values indicate a plus or minus error in the "times-seen" value expressed by each cell in the map. In addition, the probability could be normally distributed around the most likely value, if the latter is known, for example by sampling and statistical analysis of the dimensions of similar features that are preserved. This procedure provides an estimation of the range of the possible error, as well as its spatial distribution.



a



b

Figure 3-11: a) Total viewsheds (213 viewpoints) derived from 8 alternative reconstructions in which the door post width of *polythyra* in Room 3 changes at ordinal level from 18cm to 25cm. b) Standard deviation among the cell values in the total viewsheds shows a small maximum error of +/- 9 viewpoints (red areas). N.B. The occlusive effects of the wooden pier in the adyton of Xeste 3 (see fig. 3-10) and of the lintel of *polythyra* are not taken into account in the above analysis

It is interesting to note that uncertainties in the reconstructed geometry can affect the results of the analysis in quite unpredicted ways, as was found through the study of the Theran wall-paintings (cf. Chapters 4 and 5). Sometimes the potential error is small but distributed across a wide area of the painting. In other situations the estimated error is high but affects smaller spatial extents. In the end, the way in which the research questions have been formulated in a specific context is what determines whether the possible error is substantive or not for a particular interpretation.

The above methodology determines the possibility that a target feature is obstructed by the geometry of the scene. Nonetheless, there would have been other factors affecting the ease of viewing of wall surfaces, as it was argued in Chapter 1. The degree to which a painted feature could be distinguished, and the visual effort required by the viewer to attend a theme, would have also been affected by angle of view, distance and illumination. Considering these parameters regarding visibility in built spaces could be thought of as a way of introducing fuzziness to viewshed calculations.

3.3.6 Angle of view

Angle of incidence: In Chapter 1 it was maintained that paying attention to painted elements located on surfaces that are seen frontally requires fewer bodily movements and less effort from the beholder than the observation of features placed on walls that are longitudinal in relation to his/her bodily orientation. This phenomenon is a consequence of the angle of incidence from which each surface is seen (Higuchi 1983).

In a 3D digital environment, the angle of incidence[26] (Fig 3-12) can be derived by the intensity values in the lighting maps of a white surface that is illuminated by a single standard light which does not attenuate with distance. The more a surface inclines away from the light source, the less light it receives and the darker it appears. As a result high HSV (Hue, Saturation and Lightness) values (approaching 255) correspond to areas that can be seen from a maximum convenient angle (90 degrees-frontally), while low values (approaching to 0) to surfaces that can be appreciated with more visual effort. Such differences in the

[26] In the user manual of 3ds Max an angle of incidence is defined as the angle between a ray of light and the face normal of a surface. This is angle is complementary to what Higuchi terms angle of incidence. Here the term is used according to Higuchi (cf. Chapter 1).

reception of painted elements belonging to the same context can potentially be edifying for pictorial emphasis in a scene, at least in the case where large differences in angle of incidence can be observed.

It has to be noted, however, that in built environment frontal and longitudinal surfaces with respect to the position of a viewer situated in a given space can in many situations easily be identified from ground plans and, therefore, the relative differences in angle of incidence for individual wall surfaces is not always necessary to be calculated computationally.

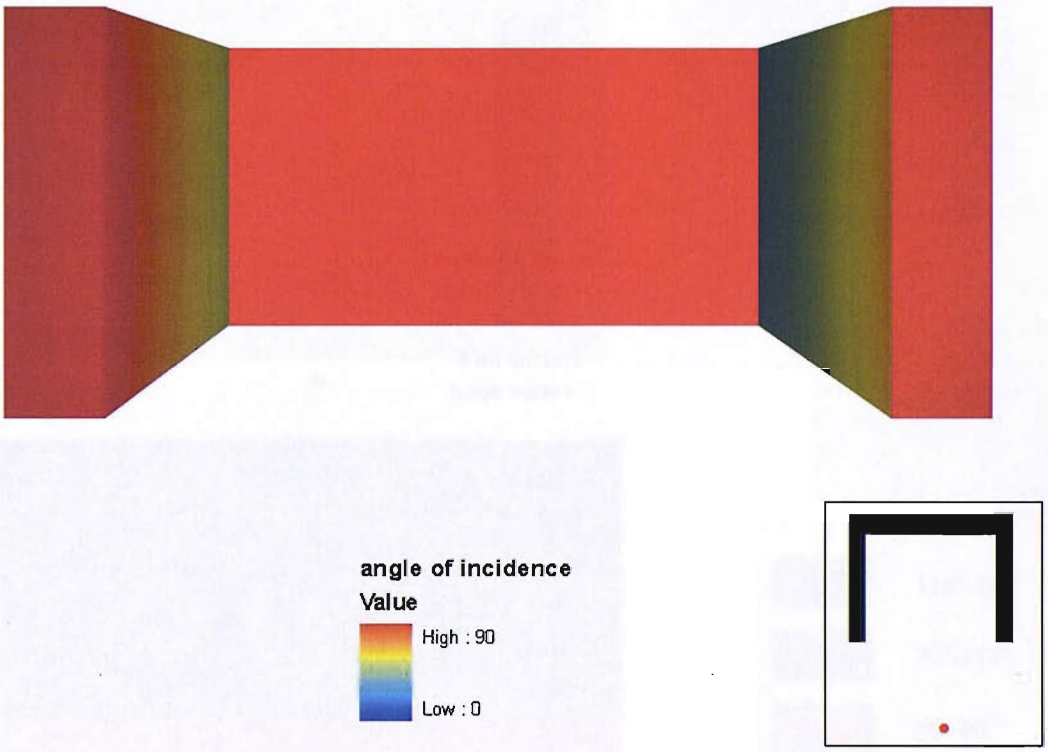


Figure 3-12. The angle of incidence for frontal and longitudinal surfaces.

Angle of elevation: Another factor thought by Higuchi (1983) to affect the perception of objects in space is the angle of elevation, which is determined by the height of the perceived feature above the horizon of the viewer. As has been argued, this angle might have been important in shaping the experience of a mobile observer (cf. §1.3); an angle of elevation over 25 degrees, that is above the maximum eye rotation, would perhaps require a viewer in a cluttered environment to stop walking in order to pay attention to an object. Illumination maps created by an omni-directional light source are not indicative for the angle of elevation. Nonetheless, thresholds such as those suggested by Märtens (1890, cf. §1.3) can be determined by considering the propagation of light distributed by a photometric light source. A photometric light casts rays within a fixed set of horizontal and vertical angles defined by the user and it can be utilised for the creation of lighting maps in the same way as an omni-directional light (fig. 3-13). In this case, areas in 3D scenes that are not within the angular range specified by the user will receive no light and will be allocated a null value in binary viewshed calculations. The resulting lighting map can complement those created by standard point source illumination, defining different levels in the visual effort needed to observe the target object.

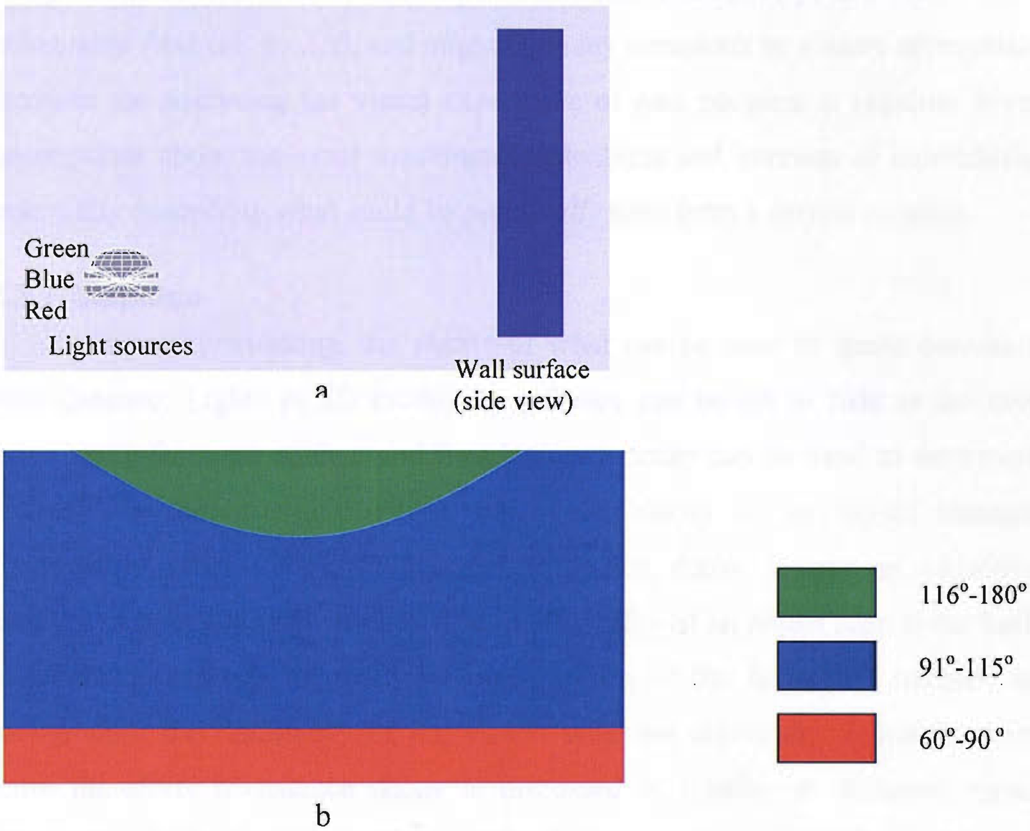


Figure 3-13: a) A wall surface in 3ds Max illuminated by three photometric lights placed at the same location that cast rays within three different vertical visual angle ranges (side view). b) Light distribution on the wall surface (front view): 0 - 30 degrees below the horizontal (red), 0 - 25 degrees above the horizontal (blue), and 26 – 90 degrees above the horizontal (green). The first two ranges define the areas of optimum and maximum eye rotation.

Physiologically constrained field of view: As mentioned in Chapter 1 the physiologically constrained field of view, that is the angular extent of the observable world that is seen at any given moment, is approximately 180° in the horizontal plane and 160° (Bloomer 1990, p. 37) in the vertical. This means that people see space in an ellipse in which the clarity of the viewer's sight varies within the ranges of foveal and peripheral vision. The physiologically constrained field of view can be simulated with the use of photometric lights. Defining a precise ellipse of vision might be a useful method of recording visibility in the context of hypothesis testing, for example regarding the visual experience of people moving along a path, and when assumptions can be made about the focus of an individual's attention. Nonetheless, when it comes to the interpretation of past environments assigning so accurate thresholds for focal and peripheral vision may not always be desirable. The use of a 360° field of view that surrounds the observer, such as the one defined by omni-directional lights, brings in mind Gibson's ambient optic array (Gibson 1979, p. 65) which is an unbounded field (cf. §3.2.2), and might on many occasions be a more appropriate heuristic for analysing the visual experience of past peoples; it requires fewer assumptions about the exact movements, intentions and interests of individuals, essentially describing what could be *potentially* seen from a certain location.

3.3.7 Distance

Generally speaking, the clarity of what can be seen in space decreases with distance. Lights in 3D modelling software can be set to fade as the rays move away form the source, and thus intensity decay can be used to determine distance thresholds within which the visual clarity of an object changes significantly (Earl 2005). Nonetheless, distance decay is not an objective measure of visual clarity in space. The intelligibility of an object seen in the built environment depends on many factors: the size of the feature of interest, its background, the familiarity of the viewer with the object etc. It makes more sense therefore, if distance decay is discussed in relation to different visual ranges in which the clarity of a certain feature, or the effort required by an individual to observe a particular object, can change significantly. The exact thresholds that mark substantive changes in the visibility of an object are context dependent, and thus hard to define in an objective way, but at least they can be discussed on the basis of arguments that are made explicit. As has been suggested on other occasions (Conolly and Lake 2006, p. 231), visual ranges can be determined with experiments that consider similar targets under comparable real life conditions.

By setting the light's attenuation to thresholds specified by the user, three visual ranges (foreground, middleground, background) can be determined, according to context-specific requirements (fig. 3-14):

a) Foreground: a spherical region around the viewing location in which an object can be seen with ease.
b) Middleground: a range in which the clarity of the object starts to decrease.
c) Background: a range in which the object, although within the observer's field of view, is not intelligible.

Such an approach is similar to the one used in the creation of fuzzy viewsheds in the context of landscape research (Fisher 1994; Wheatley and Gillings 2000). Visibility within a single visual range (for example, foreground, middleground, or background) can be calculated using a light source whose intensity decreases to zero after a specified distance. In this way binary viewsheds can be created in which null values will be given also to those locations that do not fall within the desired threshold. Information for foreground, middleground, and background can be incorporated into a single map by summing up binary viewsheds that express these visual ranges with map algebra operations (cf. Earl 2005).

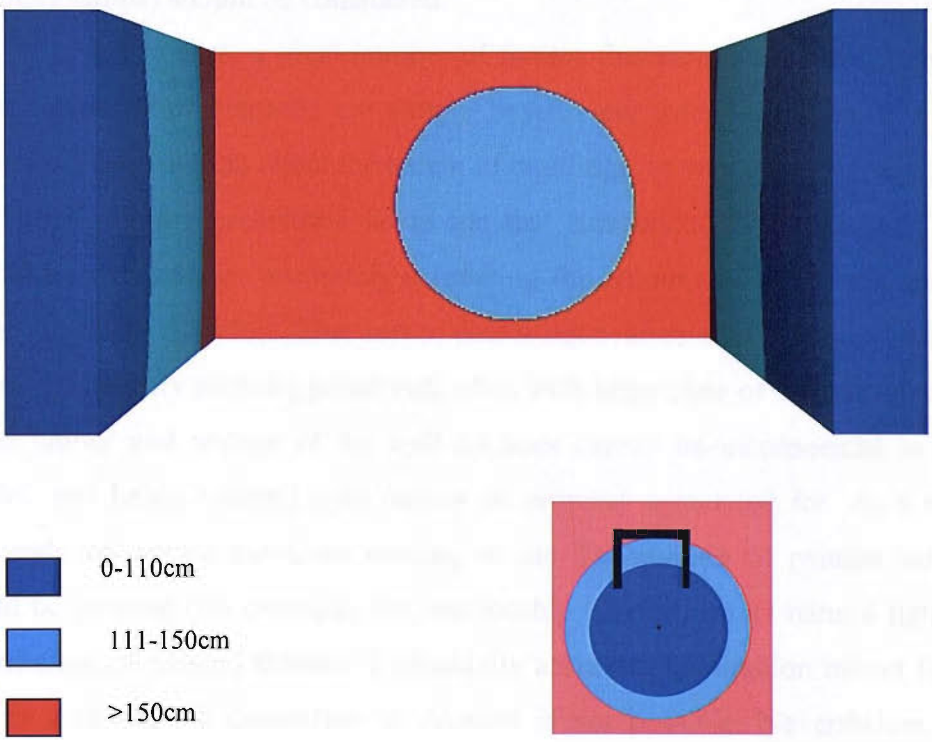


Figure 3-14: Three arbitrary visual ranges: 0-110cm (dark blue), 111-150cm (light blue/green), >150cm (red).

3.3.8 Illumination

Illumination plays a fundamental role in the perception of shape, colour and texture of surfaces that shape the visual impression of the environment. In a virtual scene, natural illumination can be simulated with a light system that follows the geographically correct angle and movement of the sun over the earth at a given location. In this way sunlight interaction with built forms can be modelled with accuracy and areas that are more likely to be illuminated by direct daylight can be identified. Illumination maps that take into account the true illumination of 3D environments can be used for showing possible differences in the visual clarity of objects in a scene. In theory these can be sampled at regular time intervals throughout a day or year, and then averaged, so that the surfaces receiving more light within the specified period can be identified.

Nevertheless, there are a number of pragmatic issues to be considered if this approach is to be used for the interpretation of past environments. A realistic illumination of a virtual environment requires also that indirect illumination, the light that bounces off surfaces, is also taken into account. For the creation of a physically accurate illumination model, the physical properties of a surface should be known, such as reflectivity, transparency and colour. Furthermore, on some occasions the possibility that spaces were illuminated by artificial light (for example lamps) should be considered.

In most cases, a great number of factors that would have influenced the illumination of past spaces are simply beyond our knowledge. Akrotiri is no exception; information about the height of buildings, as well as knowledge of the topography of the prehistoric landscape that surrounded the prehistoric town, would be required for accurately estimating the amount of direct sunlight that passes through a window. That sort of data is not available. Furthermore, as wall-paintings are only partially preserved, often with large parts of them missing, the exact colour and texture of the wall surfaces cannot be incorporated in a 3D model, and hence indirect light cannot be properly accounted for. As a result, although interesting questions relating to the illumination of painted surfaces could be pursued (for example, the relationship between direct natural light and distribution of painted themes) a physically accurate illumination model for the rooms with painted decoration in Akrotiri is not possible. Nevertheless, it is noteworthy that the suggested methodology of visibility recording has the potential to consider the effects of illumination in archaeological contexts, when there are suitable datasets to permit the physically accurate illumination of 3D scenes.

3.3.9 Mapping information back onto space

The spatial relationship between the human body and the painted scene can be much better understood, if information about the visibility of each feature of interest is mapped back onto the study area. This can include, for example, the proportion of a painted element or a set of painted elements that are visible from each observer point considered in the analysis (fig. 3-6, 3-15). The recording of this information for all observer locations in the space of interest results in a scalar field that shows the changes in the visibility of painted features that could occur due to the observer's locomotion (fig. 3-15). The distribution of values mapped within the study area could be further explored with simple histograms or pie charts. Probability and error propagation can be incorporated into the analysis with map algebra operations as it was described in §3.3.4 and §3.3.5. Moreover, the mapping of visibility data onto the study area could enable other types of analysis. For instance, it could be used for the implementation of least-cost path calculations that are determined by visibility information, as suggested by Lee and Stucky (1998). This process could perhaps reveal cases where the distribution of painted elements was determined by particular ways of accessing the decorated spaces.

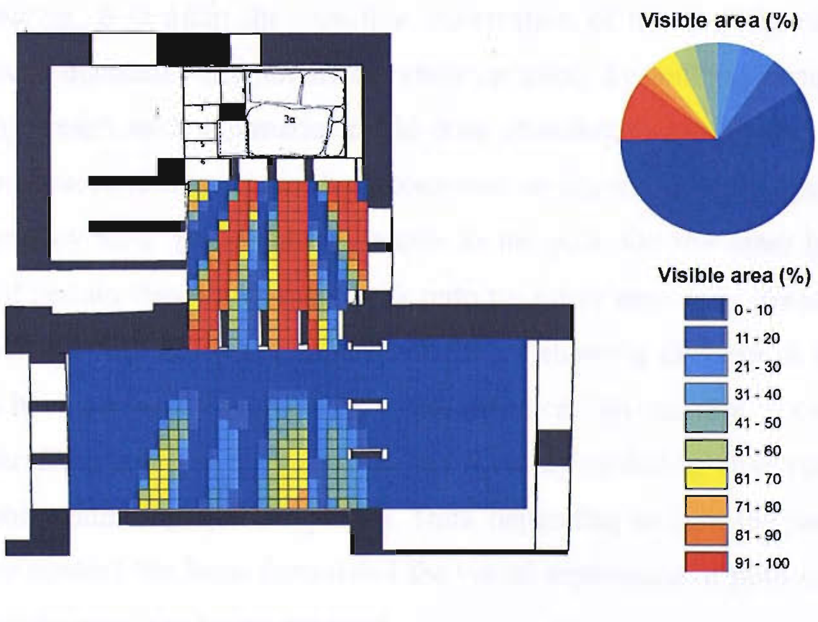


Figure 3-15. Mapping back onto space the percentage of the visibility of the middle figure of the wall-paintings of the Adorants.

3.4 Summary and Conclusions

Visibility analysis in fully 3D representations of space, far more than other methods of visibility analysis, such as GIS-based viewshed analysis, isovist and VGA analysis, meets archaeological demands for a less reductionistic and more human-centred approach to the visual experience of space. Although it can be applied at various geographic extents, it has significant advantages over other methodologies, especially when it comes to very fine spatial scales, since it has the potential to accurately represent the 3D geometry, as well as other physical properties of the features that archaeologists wish to study. A basic benefit of the methodology over experiential approaches to visual experience, (for example physical encounter with archaeological remains or walk-through in a digital environment) is that it permits the *recording* of the visual properties of the objects of interest for a great number of observer locations in space; visibility analysis can be performed at very fine resolutions that could virtually include all locations at the eye level of the viewer within the study area. For this reason is a more robust methodology that leaves less space for potential research biases deriving from a restricted selection of observer locations based on the preconceptions of the researcher.

The outcomes of the analysis can be presented in the form of visual summaries that can illuminate aspects of the visual experience in built environments. On the one hand, total viewsheds ('times seen') can highlight areas in space that are more visually exposed, and hence more likely to be seen by an observer. It is often the case that information of this kind is subtle and relational and therefore does not always show up solely by walking through a 3D model. As a result such summaries could draw attention to some basic qualities of space, unobserved otherwise, whose conscious or unconscious recognition and knowledge may have guided human action in the past. On the other hand, the mapping of certain visual properties back onto the study area, (e.g. percentage of area visible of a feature) is particularly useful for showing changes in visibility that could have occurred in the course of an observers' locomotion. It could also indicate the differences in the perception of standing or sitting observers in the case of public gatherings (cf. Chapter 4). Thus, depending on how the problem in a particular context has been formulated the visual experience of both stationary and mobile observer can be investigated.

Furthermore, the proposed methodology introduces new formal methods for considering uncertainty in the archaeological record and its influence on suggested interpretations. Although formal ways to manage uncertainty in GIS-based visibility analysis have been proposed (cf. §3.2.1), similar suggestions have not be made in the context of built environments until now. The methods presented in §3.3.4 and §3.3.5 aim to encourage new directions of research and to respond to purely archaeological concerns related to incomplete data and alternative reconstructions-interpretations of past built spaces. The formal assessment of uncertainty regarding visibility in built spaces and the propagation of possible errors in the outcomes of the analysis has the potential to profit archaeological interpretations by helping to define the level of confidence with which certain statements are made.

The suggested methodology permits also the consideration of other factors that affect visibility in built spaces, such as distance, angle of view and illumination. These could be common concerns in the fields of archaeology and urban studies. So in various others aspects, the contribution of the suggested methodology could extend beyond the particular aims of this research and the more specific demands of archaeological inquiry, having a value of multi-disciplinary nature. Despite the fact that in the presented examples emphasis was given to the description of painted features and wall surfaces, the methodology could be used to describe the visual characteristics of any 3D object. It could also be utilised to analyse the visual properties of entire building interiors (Earl 2005) or even larger spatial configurations, enabling the description and analysis of entities similar to the 3D isovist originally suggested by Benedikt (1979). There is no reason why the same methodologies could not be applied in a landscape context. Their benefits become particularly apparent, when the visual characteristics of complex built structures situated in the natural environment are considered. In this case not only the visibility of the entire structure but also that of individual architectural features can be recorded and analysed. The products of the proposed methods of analysis generally fit Llobera's definition of the concept of visualscape (Llobera 2003, p. 31-32), as they can describe the visual structure of space in both 'natural' and urban 3D environments.

A shortcoming of the methodology is that it is computationally expensive, since it aims to consider all viewpoint locations of a given study area.

Nonetheless, the computation time required depends on the resolution of the spatial sampling, and is not prohibitive in most cases, being comparable to other methodologies that seek to consider visibility from all locations in the space of interest, such as total viewsheds in landscape studies. Besides the resolution of the analysis, an issue that needs to be considered if the methodology is to be applied for the investigation of visibility within complex large scale environments, is the detail with which the environment is modelled. Reduced computation times require that the built space of interest is composed from as few entities as possible. The implementation of the different stages of the analysis can be significantly facilitated and speeded up with the use of scripts and batch processes (fig 3-16, Apendix I).

It is generally anticipated that the above methodology can enhance the research potential of 3D models in the disciplines of archaeology, geography, and urban planning, by encouraging their analytical, besides their merely descriptive use. The benefits of this approach for archaeological investigations will be demonstrated in the following Chapters 4 and 5 through the implementation of intra-building and intra-site visibility analysis.

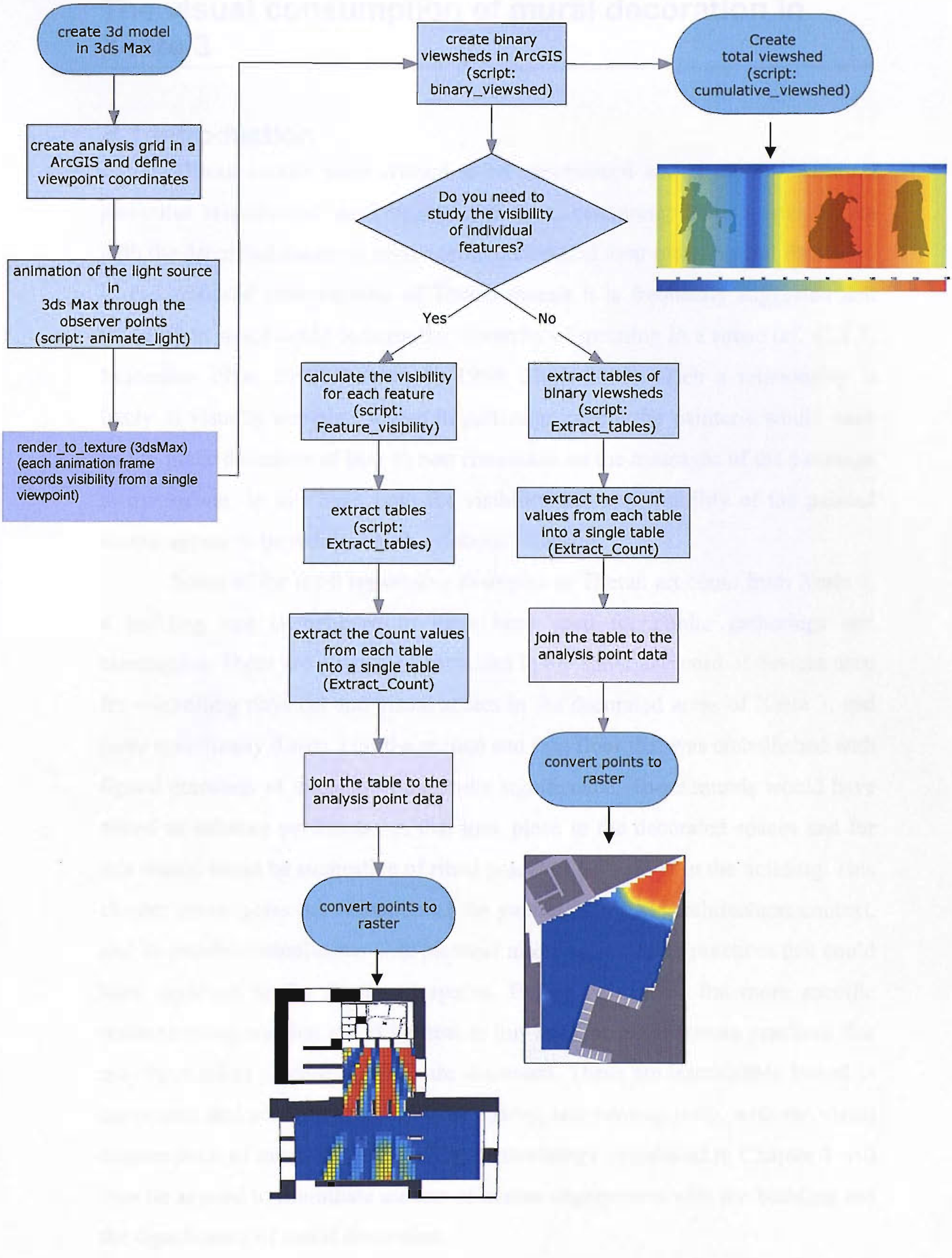


Figure 3-16: Flow chart of the steps of the analysis used in this research.

Chapter 4
The visual consumption of mural decoration in Xeste 3

4.1 Introduction

Theran murals were created to be experienced and consumed within a particular architectural environment and thus, examining human engagement with the decorated spaces is important to understand their meaning and functions. In the proposed interpretation of Theran murals it is frequently suggested that visibility in space could indicate the hierarchy of meaning in a scene (cf. §1.1.1, Marinatos 1984; 1993; Televantou 1994; Shaw 2000). Such a relationship is likely in visually complex spaces in particular, where the painter/s would have had to make decisions of how to best communicate the messages of the paintings to the viewer. In this case, both the visibility and non-visibility of the painted scenes appear to be redolent with symbolic meaning.

Some of the most impressive examples of Theran art come from Xeste 3, a building that is believed to have been used for public gatherings and ceremonies. There are plenty of indications in the material record of devices used for controlling physical and visual access in the decorated areas of Xeste 3, and more specifically Room 3 on the ground and first floor that was embellished with figural paintings of undeniably symbolic significance. These murals would have aimed to enhance performances that took place in the decorated spaces and for this reason could be suggestive of ritual practices performed in the building. This chapter investigates the reception of the paintings in their architectural context, and its possible associations with pictorial meaning and ritual practices that could have occurred in the decorated spaces. Before examining the more specific research questions that are of interest in this case, possible human practices that may have taken place in Xeste 3 are discussed. These are inextricably linked to movement and action in the decorated spaces, and consequently, with the visual consumption of mural decoration. The methodology introduced in Chapter 3 will then be applied to illuminate aspects of human engagement with the building and the significance of mural decoration.

4.2 Architecture

Figure 4-1: Rooms 2 an 4 of Xeste 3. A view from the east. Photograph from the excavation archive.

4.2.1 Description

Xeste 3 (fig. 4-1, 4-2), one of the largest units that have been found so far at Akrotiri, is situated at the south west edge of the excavated settlement. The building, discovered in 1971, is distinguished by its elaborate construction, as the greater part of its exterior walls was coated with hewn stones. Only the ground floor and parts of the first storey are extant, however, evidence[27] indicates that there should have been a second storey above the western wing. The plan of the building (fig. 4-2) is almost the same for the ground and first floor[28], but space articulation differs significantly from the west to the east. The western part mainly consists of rectangular spaces that communicate via door openings. On

[27] Bases of *polythyra* that connected probably Room 10 with Room 13, and Room 9 with Room 10 on the second floor have been found (Palyvou 1999, p. 352; Michailidou 2001a, p. 339).

the other hand, in the east wing an area of about $80m^2$ is divided into smaller rooms by *polythyra*[29]. When the doors of the pier-and-door partitions were open these rooms formed a single large hall suitable for public gatherings (Palyvou 2005a, p. 61). The public use of the building is also attested by the low quantity of domestic shapes of pottery (Papagiannopoulou 1995, p. 209-215). The spatial arrangement, distinctive architectural features, and mural decoration of Xeste 3 suggest that the east wing was the focus of communal activities, while the west wing is more likely to have had mainly a service function (Marinatos 1984, p. 72, fig. 51; Marinatos and Hägg 1986, p. 59).

The east wing

The entrance to Xeste 3 is located at its south east corner. It leads into a relatively large vestibule (Room 5) with benches along the walls and a broad staircase, which enabled access to the upper storey. On the ground floor a wooden wall (Palyvou 1999, p. 178) used to separate the vestibule from Room 4. Admission to the latter was provided via an opening at the west of this partition. Room 4 was surrounded from the west, east and north by *polythyra*, whose doors lead to Rooms 2, 7, 3 respectively. The upper storey had a similar arrangement the only difference being that Rooms 4 and 7 were connected by a door opening instead of a pier-and-door partition. A paved corridor connected the auxiliary staircase, Room 8, with Room 3, which had a special function; in this room two perpendicular *polythyra* gave shape to the two narrow spaces 3a and 3b, which housed the most distinctive features of the building, the lustral basin (*adyton,* Room 3a)[30] and wall paintings imbued with ritual symbolism (fig. 4-2, 4-3, 4-4 pl. 8-16).

The *adyton* of Xeste 3 is the only example of this characteristic Minoan structure that has been found in Akrotiri. It has a paved floor, 80cm lower than the ground floor level, and is accessible by five steps "placed at right angles round a built podium or small wall of hewn stones" (Marinatos 1976, p. 25). Marinatos (1976, p. 25) had initially suggested that the latter might have served as an altar. Although this suggestion has yet to be verified, the connection of the

[28] All rooms of the ground floor repeat on the first floor with the exception of Room 1 which appears to be a later addition to the building (Michailidou 2001a, p. 335).
[29] Cf. note 3.

adyton with cultic activities is hard to question, as it is surrounded by wall-paintings whose themes are obviously religious in nature.

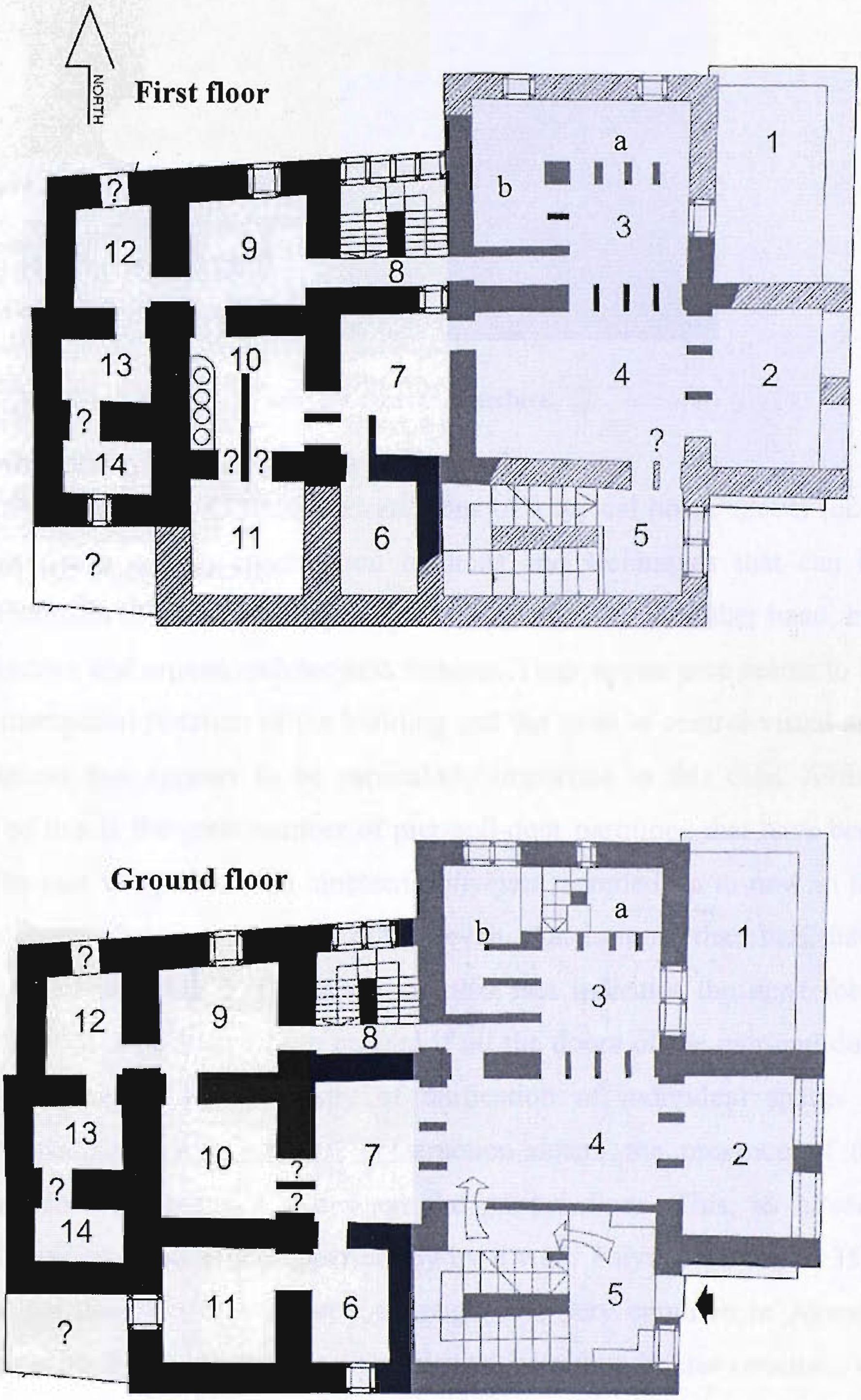


Figure 4-2: Plan of Xeste 3 (based on Palyvou 2005, p.55). The east wing of the building is indicated with light grey.

[30] Cf. note 1.

Figure 4-3: The adyton. Photograph from the excavation archive.

4.2.2 Visual and physical access in Xeste 3

Most buildings in Akrotiri are variations of a typical house model (cf. § 2.2) and evidence certain construction methods and techniques that can be repeatedly attested in the archaeological record. Xeste 3, on the other hand, has many distinctive and unique architectural features. Their appearance seems to be related to the special function of the building and the need to control visual and physical access that appears to be particularly important in this case. A first indication of this is the great number of pier-and-door partitions that have been found in the east wing: from the nineteen *polythyra* recorded up to now in the whole settlement (Palyvou 1999, p. 344), eleven, that is more than half, have been discovered in Xeste 3. On one hand, this fact indicates the need for a unified space that would have been created if all the doors of the pier-and-door partitions were open. The necessity of unification of individual spaces is suggested especially by an unusual construction detail, the presence of the *polythyron* between Rooms 4 and 7 on the ground floor. This, as already mentioned, was replaced at the upper storey by a wall. Palyvou (1999, p. 351) notices the peculiarity of this feature; although it is very common in Akrotiri walls of the ground floor to support a *polythyron*, namely a lighter structure, on the floor above, the opposite is only attested in this example of Xeste 3. It is likely that in this occasion it was the need to expand the unified east wing of the building that dictated the construction of the *polythyron* between spaces 7 and 4.

At the same time attempts to enable communication between the rooms of the east wing are combined with an effort to control physical and visual access in this area. The vestibule with benches at the main entrance is the first indication of the public function of Xeste 3 and was apparently intended for people who were not allowed admittance to the building, at least at certain times or occasions. Nonetheless, it is again a unique feature that most eloquently suggests the need for controlling movement and visibility in the east wing, namely the wooden or clay wall[31] that once existed between the vestibule and Room 4 (Palyvou 1999, p. 176-179). This wall constituted the limit between Room 5 and Room 4 on the ground floor. It was located 70cm northern of the wall that marked off the area of the staircase at the upper storey. In this manner, the north part of Room 5 on the ground floor and the anteroom which provided access to the important spaces of the east wing broadened. The structure had an opening at its western limit that provided access to space 4. There are two main consequences of the existence of this architectural feature: firstly, the weight of the superstructure was transferred northward, on the wooden beams of the partition, which might constitute a 'daring' (Palyvou 1999, p. 179), but apparently necessary solution from the point of view of the constructors; secondly, a person entering Room 4 from the opening at the west of the wooden wall would not have direct visual access to the *adyton*, as it would have been the case if there had been no partition seperating Rooms 5 and 4. Palyvou suggests that the latter was created to reduce the visual exposure of the *adyton* and its surrounding area (Palyvou 1999, p. 179). The doors of the pier-and-door partitions within the main building, when closed, would also have served the same purpose through the isolation of the individual rooms.

In addition, some further architectural details might have been aimed to control visibility in Room 3. It is notable that the pier-and-door partition that connects Rooms 4 and 3 has a very low lintel (about 1.40m). Although it is probable that the presently observed height of this feature is a result of the destructive consequences of the volcanic eruption on the building, the possibility

[31] The structure was either a wooden wall consisting of vertical and horizontal beams, or a clay partition supported by vertical beams. The indications for the existence of this partition are the post holes found on the ground floor between Rooms 4 and 5, which were made by wooden beams (tree trunks cut in half) that stepped on slabs sunken in the ground (Palyvou 1999, p. 178).

that this is an attribute of the original construction cannot be excluded. In this case, the low lintel was meant to mark a liminal area and hinder the visibility of events occurring in Room 3. In addition, the eastern openings of the pier-and-door partition in front of the wall paintings of the *adyton* seem to have served to control visual rather than physical access. Descent to the *adyton* was only enabled from the westernmost opening of the *polythyron*, and then through the stairs. The two remaining doors were followed by a 80cm vertical gap and their existence can only be justified if they acted as screens, concealing or revealing the murals and the events that took place in the *adyton* from viewers located in Room 3.

The various means for controlling physical and visual access in Xeste 3 have supported the theory of successive admittance to the ceremonies performed in the building, as well as the existence of separate male and female rituals that could have taken place in adjacent spaces at different occasions (Doumas 1987; Gesell 2000, p. 950)(cf. §1.1.2, §4.4). They also indicate there was careful consideration of issues of visibility from the constructors of Xeste 3 who did not hesitate to apply uncommon construction solutions, so as to create a spatial form that satisfied the uses and functions of the building.

4.3 Wall decoration of Xeste 3

4.3.1 Description

Xeste 3 has provided some of the finest and best studied examples of Aegean mural decoration, although a great part of the wall paintings unearthed in the building still need to be restored and published. Fragments of mural decoration were discovered at both the ground and first floor of Xeste 3 in Rooms 2, 3, 4, 5, 8 and 9 (Doumas 1992a, p. 128). Of these only those from rooms 3, 4 and 5 have been restored, at least partially. The visitor of the building would have first encountered the wall paintings of the vestibule (Room 5) that embellished the south wall and the two sides of both flights of the staircase (Doumas 1992a, p. 128). The themes of these paintings, which are only partially preserved, include a mountainous landscape, three male figures that have been identified as "huntsmen" and animals (bull and goat)(Marinatos 1976, p. 23;

The wall in question is unique in Akrotiri and appears to be very rare in Aegean architecture (Palyvou 1999, p.179).

Doumas 2007a, p. 113-114). Room 4, being marked off by three pier-and-door partitions, would not have offered many opportunities for wall decoration. Nonetheless, some wall painting fragments were indeed discovered in this room and have been attributed to the horizontal bands directly above the *polythyra*[32] (Marinatos 1976, p. 25, 27; Doumas 1992a, p. 128). These give an idea of the subject of the illustrated scenes, which seems to have been inspired from nature: swallows are depicted feeding their young as well as blue monkeys holding a harp and a sword (Doumas 1992a, p. 128, fig. 95-99).

The wall paintings that were unearthed in Rooms 3a and 3b represent human figures, females and males respectively. In Room 3a the decorated areas were located on the east and north walls just above the *adyton.* The wall-paintings were poorly preserved when they were first discovered, laying in fragments in the fill of the *adyton* (Marinatos 1976, p. 27). Their restoration took many years, but nowadays their position in space is certain. On the east wall of Room 3a an architectural construction topped with horns of consecration was depicted (pl. 12), probably an altar or shrine of Minoan type (Marinatos 1976, p. 27; Marinatos 1984, p. 74; Boulotis 2005, p. 29, fig.6). Red drops, representing blood, are dripping from the horns (Doumas 1992a, p. 129). The three female figures that are depicted on the north wall of the *adyton* appear to face towards the altar (pl. 13). The first figure on the left represents a woman with elaborately dressed long hair, rich jewellery, and variegated Minoan garments. In her extended left hand she holds a necklace made of rock crystal beads, which has been interpreted as an offering in association with the altar of the east wall. The middle figure is seated in a rocky landscape. Her left hand touches her forehead while the right hand holds her foot, from which blood is trickling. The gestures of the woman and her half opened lips have been interpreted as expressions of pain (Marinatos 1984, p. 79; Doumas 1992a, p. 129)[33]. She also has luxurious appearance created by her sophisticated coiffure, elaborate jewellery and distinctive clothes. The last figure on the right, dressed in a Minoan bodice and skirt, is wholly covered in a transparent veil with the exception of her face and part of the head. Her body is turned towards the left, where the other two females

[32] Marinatos (1976, p. 25) mentions that these paintings belong to Room 2 instead of Room 4 probably by omission (cf. Doumas 1992a, p.128).

are located, but her face looks in exactly the opposite direction, where the altar is depicted. Her head is shaved except for two long locks at the back and one smaller above her forehead. This kind of hair style has Egyptian parallels (Marinatos 1984, p. 62; Davis 1986; Doumas 1987, p. 153) and indicates the young age of the woman. The exact meaning of the scene is ambiguous, and especially the posture and gesture of the figure in the middle. It is widely accepted, however, that the female figures represented above the *adyton* are participating in initiation rites that also involved acts of worship to a deity whose presence is implied by the depiction of the altar (Marinatos 1984, 1993, 1987; Marinatos and Hägg 1986; Doumas 1992a, 1987; Morgan 2000; Gesell 2000; Boulotis 2005). For this reason the whole scene has been known as the 'Adorants' (Doumas 1992a, p. 129).

The wall decoration of Room 3b on the ground floor consists solely of male figures (pl. 8, 9, 10). This room has a rather intricate spatial arrangement, since it is divided by thin clay partitions into narrow spaces or corridors. Fragments of murals discovered in this area have been attributed to the southern half of the west wall, as well as the south wall of the middle and the north wall of the north corridor (Doumas 1992a, p. 130)[34]. On the west wall of Room 3b a man is depicted holding a large jug. Contrary to the other three figures in the scene, which are completely naked, he wears a white Minoan loincloth (zoma) and he is seated. Towards him moves a male figure that is illustrated in the north corridor. This is a young man with partially shaved head carrying in both hands a large open bowl. The last two figures that complete the scene are depicted on the south wall of the middle corridor. The older of the two represents a young man that holds a garment with variegated stripes. He also moves towards the man on the west wall, though his head faces the opposite direction. He is being followed by a very young boy with completely shaved head who holds a small bowl. The paintings have been interpreted by Doumas as an initiation scene involving the ritual dressing of a male who is going to 'achieve manhood' (Doumas 1990, p.

[33] Contrary to this interpretation, Morgan (2000, p. 932) maintains that the touching of the forehead is a ritual gesture denoting "adoration".

[34] Originally, Doumas had suggested that both the figures of the man with the jug and the boy with the bowl were located on the west wall (Doumas 1990, p. 208). Later, he (1992a, p. 130) and Marinatos (1993, fig. 211, 215; 2005, fig. 9.15) suggested that the boy with the bowl was probably painted on the north wall of the north corridor. Palyvou (2000, p. 428, fig. 13) and Morgan (2000, p. 929, fig.2) adopted Doumas' original interpretation in their reconstructions.

208; 1987, p. 157; 1992a, p. 130). The idea that ceremonies related to the initiation of males are represented has also been supported by Morgan (2000), and Gesell (2000). Marinatos (1993, p. 210-211), on the other hand, has suggested that the males are marginal participants in ceremonies, 'assisting the girls during initiation'.

Room 3a on the first floor of Xeste 3 was embellished with the murals of the 'Crocus gatherers' (pl. 14, 15, 16). These paintings are distinguished by their unique narrative theme and quality of execution. The scene is represented on the north and east wall of the room. A female figure is represented on the middle of the north wall, seated on a stepped structure. Like the other females described so far she wears luxurious Minoan garments and rich jewellery. However, there are plenty of indications that this is not a representation of an earthly figure, but rather a depiction of a goddess. Even aside from the fact that she is illustrated at a prominent position on the wall at a higher level than the rest of the human figures, she is flanked by exotic and imaginary animals, a blue monkey and a griffin. For this reason she has been identified as the Mistress of Animals or the Great Goddess of Nature (Marinatos 1984; Boulotis 2005). The monkey stepping on the built structure on which the goddess is seated offers her a handful of crocus flowers. The picking and offering of crocuses are also the activities, the rest of the depicted figures, all of them female, are involved in. At the left of the north wall a young woman looking at the goddess empties her basket full of crocuses into a larger pannier on the ground. At the opposite side of the same wall, exactly at the east of the large window that interrupts the scene, another woman is depicted carrying a basket on her shoulders and walking towards the stepped structure (pl. 15). Two more young females are illustrated picking up crocuses within a rocky landscape on the east wall (pl. 16).

The wall paintings discovered in Room 3b of the first floor are only partially preserved. Mural decoration has been attributed to the west wall of the room that was embellished with an aquatic landscape. In addition, four 'mature' females, who have their hair bound up in a bun and wear elaborate dresses, are attributed in pairs to the walls of the corridor that connected Room 3b with the staircase 8 (Vlachopoulos 2003, p. 511). More wall painting fragments that belong to decorative themes have been discovered in spaces 8 and 9[35].

4.3.2 Meaning of mural decoration and programmatic parallels

A number of studies have been concerned with the meaning, function and painting technique of the wall paintings of Xeste 3 (Marinatos 1984, 1987, 1985; Marinatos and Hägg 1986; Karageorghis 1990; Gesell 2000; Rehak 1999, 2004; Doumas 1983, 1987, 1992a, 2000a; Birtacha and Zacharioudakis 2000; Chryssikopoulou *et al.* 2000; Shaw 2003; Niemeier 1992; Davis 1986; Vlachopoulos 2000, 2003; Morgan 2000; Tzachili 1994). More often discussion has revolved around the murals of the Adorants, and the Crocus Gatherers, and less frequently the male scene, while some relatively recent publications are concerned with the newly restored wall paintings of Room 3b of the first floor (Vlachopoulos 2000, 2003). As already mentioned, it is generally accepted that the wall paintings of Xeste 3 represent rites of passage, and more specifically puberty rites, and probably acted as 'sign posts' or mnemonic for activities that took place inside the building or outdoors. Nevertheless, opinions may vary on the exact meaning of individual compositions and representations. It is uncertain, for example, which of the human figures are already initiated, before or at the stage of initiation, the precise significance and symbolism of their expressions and gestures (Morgan 2000, p. 932), or their age (Laffineur 2000, p. 898). Furthermore, with the exception of the depiction of the goddess that can reasonably be considered the focal point in the crocus gathering scene, the relative significance of the other human representations performing ritual acts is not immediately clear. As a result interpretive statements concerning pictorial emphasis in a composition are often depended on the intuition and individual understandings of the researcher.

It is noteworthy, however, that some programmatic parallels that enable a more formal assessment of meaning can be observed among the wall paintings of the 'Adorants', the male scene, and the 'Crocus Gatherers' (table 4-1). All three consist of representations of human figures that are engaged in ritual acts and are located in the most highly controlled spaces of the building (Michailidou 2001a,

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[35] These consist of colourful bands painted on white background (Room 8) and an impressive decorative pattern that combines relief bands with painted rosettes (Room 9) (Michailidou 2001a,

p. 394)[36]. Morgan (2000) has convincingly argued for the existence of analogies regarding the posture and gesture of individual figures [37] in these three compositions. She notes that the orientation of the gestures of the figures mainly converge towards a single *seated* human representation, which acquires in this manner an advantageous focal position within the individual compositions (cf. Doumas 2005, p. 74). This also implies a parallel significance among the figures in question (Morgan 2000, p. 925). As far as the wall paintings of the 'Adorants' is concerned, the focal point is the wounded girl at the center of the north wall. Although all three female figures face to the east where the altar is depicted, the gestures and bodily orientation of the women with the necklace and the veil converge toward the location of the wounded girl. In the painted scene in Room 3b again the naked males are moving towards the seated man with the jug[38]. Finally, in the wall painting of the Crocus Gatherers the directional flow of the figures' movement clearly guides the eye of the observer towards the goddess[39].

Furthermore, the wounded girl, the man with the jug and the goddess, are distinguished by other attributes, such as hairstyle, clothing and jewelry (Davis 1986; Doumas 1987, 2000a; Morgan 2000; Laffineur 2000): the man with the jug is the only one in the male scene that has fully grown hair and is dressed. The goddess, besides the fact that she is flanked by uncommon and mythic animals, wears two necklaces with ducks and dragonflies which are distinctive among the elaborate jewelry of the crocus gatherers. Finally, the costume of the wounded girl has been characterized as 'unique in Aegean iconography' (Rehak 2004, p. 88). Morgan also notes that the goddess and the man with the jug distinguish also by scale and position, as they are larger and are placed higher than other figures (Morgan 2000, p. 934).

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p. 342).

[36] This is confirmed also by the results of access analysis that Michailidou (2001a, p. 394) performed in the building.

[37] Parallels between individual figures of the wall paintings of the 'Crocus Gatherers' and the 'Adorants' have also been noted by Marinatos (1985, p.226).

[38] This applies to both suggested reconstructions of the painted scenes (cf. note 34)

[39] Morgan (2000, p. 936) also notes sub-scenes of opposite directional flow; in the male scene the boy that holds the cloth turns his head backwards, while walking towards the man with the jug. Moreover, the two crocus gatherers of the east wall of Room 3a (first floor) face each other but both their bodies are oriented towards the Goddess.

Figure	Wall painting	Location	Posture	Pictorial position
Wounded girl	Adorants	3a, ground floor	seated	Focal point
Man with the jug	Male scene	3b, ground floor	seated	Focal point
Goddess	Crocus Gatherers	3a, first floor	seated	Focal point

Table 4-1: Iconographic parallels in the three scenes.

The above observations draw attention to some important cues that could suggest pictorial emphasis in individual compositions, shedding light onto the devices used by the painter(s) to communicate meaning. Nevertheless, although in easel paintings the visual structure of a composition is shaped solely by the relationships among its various pictorial elements, in mural painting the focal point in a theme is determined also by what can be seen by a viewer situated in the decorated rooms. This should also be considered in the interpretations of the paintings. As mentioned in Chapter 1 none of the scenes would have been seen as a whole, as in most cases they would have been occluded by the door-jambs of *polythyra*. Focal areas within the painted scenes would have also been determined by the spatial relationship between the murals and the bodies of individuals that would view the paintings in the course of performances enacted in the building.

4.4 Communal performances in Xeste 3

The exact nature of communal activities that would have taken place in Xeste 3 cannot be positively known given the existing evidence and any discussion on this issue is a matter of speculation. Nonetheless, the architectural form, mural decoration and find assemblage could provide some indirect indications of the human practices performed in the building. Space articulation in the east wing would have simultaneously created large unified and isolated spaces, liminal and boundary areas, a fact that suggests there must have been rituals that would have involved public display and the communication of symbols, as well as ceremonies that were either hidden from view or revealed to a limited number of observers. Paintings of ceremonial significance, such as representations of ritual acts ('Adorants', the 'male scene', the 'Crocus Gatherers') are located in rooms with restricted area that would have been accessed by a limited number of people, perhaps the initiates and some selected few. On the other hand, these rooms are not completely isolated from their surrounding spaces. In front of the wall-painting of the Adorants a pier-and-door partition was built, rather than a wall with a door opening, suggesting the paintings and events that took place in the *adyton* were intended to be seen from viewers located in Room 3, and perhaps other adjoining rooms. The restricted area of Rooms 3a and 3b also implies that only a few people at a time would have been the main actors in the ceremonies, while other individuals would have been observers to the occurring events.

The wall paintings themselves are also suggestive of certain aspects of the practiced rituals. The latter would have been closely related to the presence of the deity which was induced to the viewer by the depictions of the goddess and the altar. Ritual acts associated with these representations and symbols are illustrated in the painted scenes. These involve the offering of precious objects (woman with the necklace) or crocuses (Crocus Gatherers), veiling or unveiling (woman with the veil), and sacrifice (altar with blood) (cf. Marinatos 1984; 1986). Other gestures, postures and movements of the painted figures are harder to interpret, such as those of the seated girl from the wall paintings of the Adorants (cf. §4.3.2). The latter suggest that the infliction of pain and bleeding may have been also linked to the performed rituals (Marinatos 1984, p. 81; Gesell 2000). The male scene, although lacking religious symbols, is of apparent ritual character, and alludes to nudity at least for males (nude males) and ritual dressing (Doumas 1992a, p. 130). It is also likely that ceremonies in the building were associated with the pouring of liquids. Evidence for this is provided again in the wall paintings of the males in which the represented figures carry pouring vessels. In addition, the pottery assemblage of Xeste 3 also concurs to the same conclusion, as it consists in its greater part of pouring shapes (mainly jugs of different shape and size among which the nippled jug is often encountered) contrary to what applies to other buildings in the settlement (Papagiannopoulou 1995, p. 214). Similarly, the two bathtubs found in Room 2 seem to indicate that fluids, and perhaps the idea of purification, were not irrelevant to the function of the building. The painted scenes clearly suggest that the above acts would have been carried out by young people, the principal performers in the activities in question that are most frequently identified as the initiates in the rites of passage. Music could also have been part of the rituals (monkey with harp).

Detailed reconstructions of the movement patterns and performances in Xeste 3 have been attempted by Marinatos and Gesell. Marinatos (1984, 1987; 1993, p. 203-211; Marinatos and Hägg 1986) suggested that female rituals focused on the area of the *adyton* mainly took place in the building. She maintained the principal performers in these events were a group of females at the stage of initiation that gathered at the area before the *adyton* in Room 3. She then conjectured that a successive visual revelation of the painted females (Marinatos 1984, p. 81; Marinatos and Hägg 1986, p. 60) and deposition of offerings in the *adyton* would take place. Besides the principal performers in the ceremonies, many other people would indirectly participate in these events, from rooms 3, 4, 2, 7. Of them, only those situated in Rooms 3 and 4 would have direct visual access to the area of the *adyton* (Marinatos 1984, p. 73). Nonetheless, individuals located in Rooms 2 and 7 would be involved in the rituals by other means, "by hearing, or by smelling incense, perfume, the odour of flowers etc." (Marinatos and Hägg 1986, p. 60). According always to Marinatos (1984, 1987, 1993) the wall paintings of Room 3b suggest that males would have acted as marginal participants in the events "assisting the girls during initiation" (Marinatos 1993, p. 210-211). She also assumes a parallel ceremonial function for the first floor of Xeste 3, which was accessible by the two staircases located in Room 5 and 8; the former was intended to be used by the public viewers of the events while the latter by the initiates or the personnel of the building.

Gesell (2000), on the other hand, attempts a thorough reconstruction of separate male and female rituals that would have taken place perhaps at different times of the year. As already mentioned (§4.3.1), the idea that male rituals would have also been performed in the building had been proposed earlier by Doumas

(Doumas 2001, p. 157)[40]. According to Gesell the participants in the ceremonies, namely groups of either males or females, would proceed in an organized and controlled way to Rooms 3a and 3b. They would firstly gather in the anteroom of the building (Room 5) and then in Room 4 (and possible Rooms 7 and 2) that would be at first physically and visually separated from Room 3 through the closed doors of pier-and-door partitions. Eventually, however, the doors would open and the initiates would enter Room 3, and subsequently the *adyton* (females) or Room 3b (males), one at a time to perform certain ritual acts individually. The female performances would end on the first floor that the participants would access through the staircase of space 8, while the male performances would have been restricted to the ground floor.

Although the above detailed accounts of the events that could have taken place in the building can neither be verified nor rejected, the proposed reconstructions of ceremonies reasonably suggest that the practice of rituals would have been very closely linked with the visibility of the paintings. This agrees with the architectural context of the decorated spaces and the devices that have been used to control physical and visual access to the decorated spaces. Some observations regarding the manner in which the spectator was positioned in relation to the paintings have already been discussed; a person descending to the *adyton* would have to face the altar, as the women represented on the north wall do, while an individual walking through the decorated spaces would often find themselves moving in the same direction as the surrounding painted human figures[41]. Most of the time the wall paintings would be seen in parts, however, through the door jambs of pier-and-door partitions, which would have significantly interrupted the represented scenes. Initiates and more active participants in the events would have appreciated the depicted scenes from a variety of viewpoints while moving, and in the pace of the performed acts. While ritual performances would have been restricted mainly to spaces 3a and 3b, it is likely that other individuals would be present in Room 3 and perhaps Room 4, 2 and 7. These individuals (initiates waiting their turn to participate more actively in the performances, marginal participants, or members of the community that

[40] Morgan (2000, p. 941) also maintains the parallels in the female and male scenes indicate analogous performances.

would observe the events) would have to stand in space, having a more or less fixed view of the wall paintings for great parts of the ceremony, and would thus have experienced the murals as a combination of exposed and hidden painted surfaces. Their experience would have been as important for the fulfilment of the purpose of the rituals as that of the main participants in the events: rites of passage, although private in nature, aim to the social cohesion of the community by perpetuating the existing social status; the presence of indirect participants to the ceremonies would have been crucial, even if they merely observed the unfolding scenes. The viewing of paintings depicting rites of passage would have elicited a host of associations to the onlooker, both at the level of personal and collective memory (Papageorgiou 2000, p. 967).

In all cases the visual experience of the paintings would have been significantly determined by how easy or difficult they were to view. As discussed in §1.1.1, on many occasions pictorial features that were seen with ease in space had an added symbolic meaning and formed significant components of a scene or narrative. Still, ease of viewing in Xeste 3 is very little understood given the visual complexity and state of preservation of decorated spaces. Especially the occlusive effects of the door jambs of the *polythyra* on the wall-paintings give rise to a number of issues regarding the reception of the paintings, its relationship to iconographic meaning and ritual practices performed in the building. The remainder of this chapter aims therefore to examine:

a) The modes in which the reception of the painted scenes is affected by the presence of pier-and-door partitions.

b) The extent to which individual pictorial elements are visible and whether there are any features that are likely to be more exposed to the mobile or stationary viewer.

c) The ways in which the visibility of the wall-paintings changes for the various spectators (watchers in the rituals) positioned at different locations in space.

d) The relationship between ease of viewing and the suggested hierarchy of meaning in the depicted scenes (§4.3.2). In what ways visibility in 3D space might have affected the visual

[41] This applies for the younger figures of the male scene and the mature women that embellished

structure of the paintings and the rendering of individual themes?

e) Whether the visibility or non-visibility of the paintings could provide evidence regarding plausible ritual practices performed in the building.

The above issues are discussed in relation to the wall paintings of the Adorants, the male scene and the Crocus Gatherers that decorated spaces 3a and 3b on the ground and first floor of Xeste 3, since these scenes were the focus of attention in the building. Reconstruction of the decorated spaces and visibility recording and analysis are necessary for the investigation of the phenomena and relationships that need to be examined in this case.

4.5 The reconstruction

The process of digitally restoring the paintings in their original architectural context entails difficulties, even though it is facilitated by the numerous ground plans and sections that record in detail the state of the building during various stages of excavation and conservation (Palyvou 1999, 2005a), as well as publications that argue over the exact location of the paintings in Xeste 3 (Doumas 1992a). The sources that were used for the reconstruction are: a) ground plans and sections of Xeste 3 from the excavation archive b) detail drawings from the excavation archive[42] c) the restored wall-paintings that give indications of the dimensions of walls that have collapsed. The creation of the digital 3D model was substantially based upon small scale plans of the space upon which the analysis focuses, namely Room 3 (Fig 4-4, Appendix II, Plan 1 and Plan 2). For the reconstruction of the walls of Rooms 4 and 2, generic plans of the ground and first floor of Xeste3 were used.

The height of architectural elements was occasionally derived from sections. For instance, the height of the lintel of the pier-and-door partition connecting Room 3 and 4 (about 1.40m) was calculated from section Z-Z (Appendix II, Plan 3) that includes the imprints of the wooden frame of the structure in the volcanic material (nowadays this pier-and-door partition has been restored by pouring cement in the place of the missing timber frame (Doumas

the corridor that connected room 3b with Room 8 on the first floor (cf. §4.3.1).

1984, p. 265). Information of this kind, however, is usually not available, because in most cases the walls and pier-and-door partitions are not preserved at their original height.

In addition, the dimensions of the decorated wall surfaces were partly deduced from the restored wall-paintings, some of which preserve their outer limits. The male scene indicates the original height of Room 3b at about 1.93m., as the restored wall-paintings of the two boys and the man with the jug include both their upper and lower limits (Athanasiou 2008; Vlachopoulos 2008). It is reasonable to assume that space 3a had the same height as space 3b, given the fact that both form compartments of the same room. This means that the upper limit of the wall-paintings of the Adorants that is preserved (Athanasiou 2008; Vlachopoulos 2008) would have been located at about 1.93m above the floor of Room 3. It is interesting to note that the positioning of the wall-painting at this height suggests once more that it was created to be seen from Room 3, as the viewer standing in that space would have an "eye to eye" contact with the painted figures as has been observed in other cases in Akrotiri (Palyvou 2000). On the contrary, the Adorants were placed above the eye level of the observer standing in the *adyton*, who would not have been able to observe the scene with ease (fig. 4-20).

Although the murals that were unearthed in the fill of the *adyton* (the Adorants and the Crocus Gatherers) were discovered in fragments (Marinatos 1976), there seems to be little present doubt regarding their location in space (fig. 4-4). The latter is testified by "the dimensions and shape of the restored parts" of the paintings (Doumas 1982, p. 295). The reconstructions that were created for the needs of this research take into account the already proposed distribution of the paintings in spaces 3a and 3b of the ground and first floor. In the digital reconstruction the Adorants (1,43m X 3.91m)[43] embellish the north wall above the *adyton* on the ground floor, while the altar is depicted on the east wall of the same space. The crocus gathering scene adorns Room 3a on the first floor; the offering of crocus to the goddess (2.30m X 3.22m) can be seen at the west part of the north wall, while the girl with the basket (2.17m X 0.69m) at the easternmost

[42] All plans and sections that were used for the reconstruction have been created by Clary Palyvou.
[43] All dimensions are given in Doumas 1992a.

part of this wall, immediately following the large window that interrupts the scene. The two remaining crocus gatherers (2.44m X 2.66m) are located on the east wall of Room 3a. This scene extends the limits of space 3a, covering the eastern door jamb of the *polythyron* that marks the south extent of this room, as well as the northern part of the east wall of space 3.

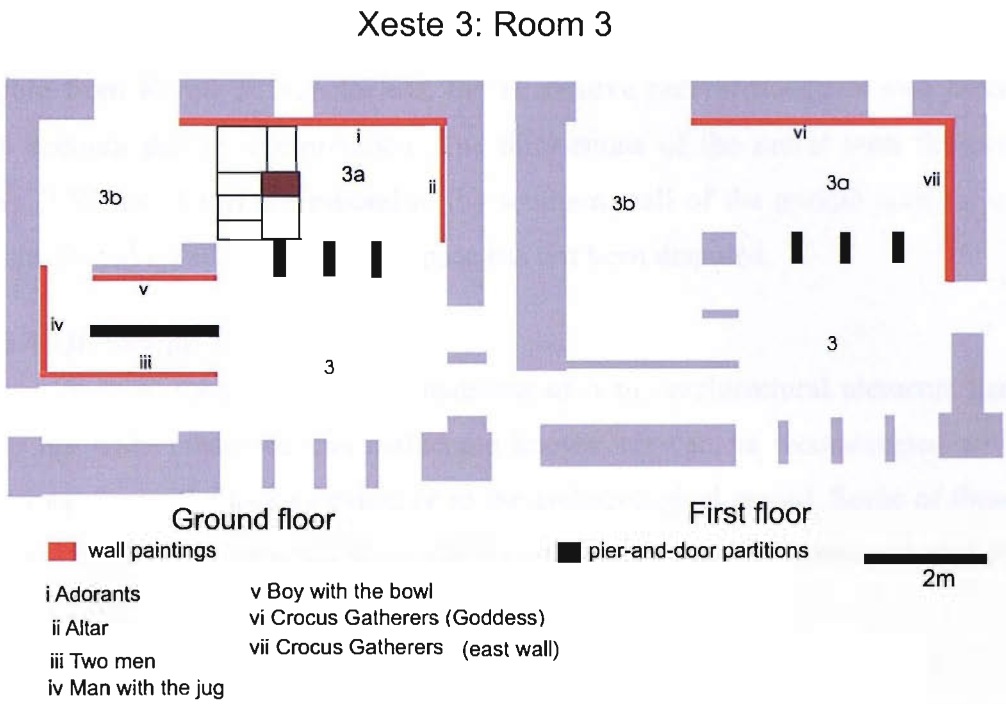

Figure 4-4 : Plans of the ground and first floor of Room 3 in Xeste 3 with indication of the position of the restored wall paintings in the room.

The location of the paintings in Room 3b is less certain and two different reconstructions have been suggested. Originally, Doumas (1987, p. 156) proposed that the man with the jug (1.93mX1.82m) and one of the nude boys (1.75x1.24) would have been depicted in adjacent locations of the west wall of space 3b, the former occupying the south part of that wall. Later, however, he attributed the boy with the bowl to the north wall of the north corridor (Doumas 1992, 130) an interpretation that has also been adopted by Marinatos (1993). This is a likely reconstruction as the dimensions of the restored wall-painting seem to agree well with those of the corridor. The reconstructions of Palyvou (2000, p. 428, fig. 13) and Morgan (2000, p. 929, fig. 2) represent the boy with the bowl on the west wall, as originally suggested by Doumas, matching the yellow ochre band that appears to run along the preserved left limit of the painting to the similar band that is depicted at the right of the man with the jug. It is difficult to be conclusive about which of the two alternatives is more plausible, as the wall-painting is incomplete, and neither its left limit, nor fragments connecting to the man with the jug have been restored. The reconstruction of space 3b that was used in this case was based on the assumption that the boy with the bowl would have been located in the northern corridor, and that would have been partly visible from Room 3. Nonetheless, the alternative reconstruction is also taken into account during interpretation. The dimensions of the mural with the two boys (1.92mX1.93m) correspond to the southern wall of the middle corridor of Room 3b and its allocation to this space has not been disputed.

4.5.1 Uncertain features

In most cases the exact dimensions of many architectural elements that have not been preserved can neither be known nor can be reconstructed with certainty due to the lack of evidence in the archaeological record. Some of these features could have affected the visibility of the paintings of Rooms 3a and 3b and are listed below:

1) **Height of the lintel of pier-and-door partitions:** Pier-and-door partitions are usually identified from their stone bases, often found in situ. As a rule their upper structure that was supported by a wooden frame has not survived, and therefore details of their construction, including the height of the lintel are in most cases unknown. Luckily, three pier-and-door partitions in Xeste 3 have left their negative impressions on the volcanic material that filled the building after the volcanic eruption (Palyvou 1999, p. 346) giving some indications for the dimensions of their upper structure (fig. 4-5). Overall on the ground floor of Xeste 3, five pier-and-door partitions have been identified; these were located at the north, west and south limits of Room 3 and between spaces 7 and 4, and 4 and 2 (Palyvou 1999, p. 351-352). The first three would have occluded the painted scenes that embellished spaces 3a and 3b. Of these only those located at the south and west of Room 3 have left a full imprint (Palyvou 1999, p. 351) from which the height of the door opening can be derived. As mentioned above, the door openings of the south *polythyron* of Room 3 was about 1.40m. Even in

this case it is not certain if this was the original elevation of the upper structure as it may have subsided (the imprints are deformed, cf. Doumas 1984, p. 265) due to the effects of the eruption on the building. From the north pier-and-door partition of Room 3 on the ground floor only the foundation is preserved, just above the level of the ground floor (Palyvou 1999, p. 351). On the first floor, the bases of the door jambs of the *polythyra* at the west and south of Room3 can be seen in situ, but no evidence exists for the form of their upper structure.

2) **Precise location of the pier and door partitions:** The bases of the pier-and-door partitions of both the ground and first floor of Xeste 3 have been found in situ and have been carefully recorded in plans and sections. The only exception seems to be the basis of the door jambs of the north *polythyron* of Room 3 on the first floor (Palyvou 1999, p. 352). Palyvou mentions that these were removed from the building, just before the excavation of the ground floor rooms, but their original position was unfortunately not recorded (Palyvou 1999, p. 351-352). However, at least two of the door jambs of the *polythyron* (the two westernmost) can be seen in plans created by S Iakovides in 1973 (Appendix II, plan 4; published in Michailidou 2001a, p.240, fig. 250). Still, the base of the easternmost door jamb does not appear in this plan and therefore cannot be known with accuracy.

3) **Width of the door jambs of pier-and-door partitions.** The width of the wooden door posts of exterior doors that have been restored ranges between 18cm and 26 cm (Palyvou 1999, p. 313). The width of the door posts of the pier-and-door partitions of Xeste 3 might have been towards the lower values in this range, as they belonged to interior doors, which as a rule were of smaller dimensions (Palyvou 2005a, p.141). It appears that the open door leaves of *polythyra* would not have further decreased the width of the door openings, as they would have often been placed within a "Γ"-shaped encasement carved in the wooden door post[44] In any case, the exact dimensions of the doorjambs are not known.

[44] Palyvou (1999, p. 333, 481; 2005a, p. 142) notes that door jambs with a stone base at the shape of "Γ"would probably have wooden door posts with a cross-section forming an encasement for the wooden doors leaves (0.02-0.025 m thick).

In the 3D model of Xeste 3 the reconstruction of the elements that were not preserved, such as those mentioned above, is tentative, as far as their dimension and position are concerned. Nonetheless, the effects of uncertain features were considered in the suggested interpretations using the methods described in §3.3.4, §3.3.5 (cf. §4.6).

Figure 4-5: The restored pier-and-door partition between spaces 3 and 4 (ground floor). The *adyton* can be seen in the background. Photograph from the excavation archive.

4.5.2 The 3D model

A solid model of the spaces of interest was firstly created in AutoCad, and was later imported into 3ds Max. Some basic textures and materials were added to the reconstructed built structures. The materials were included in the model so as to make the different architectural elements more comprehensible to the viewer and were not aimed to create a photorealistic impression, as this does not serve the purpose of modeling at this stage, namely the investigation of the reception of the murals from space 3 and 4.

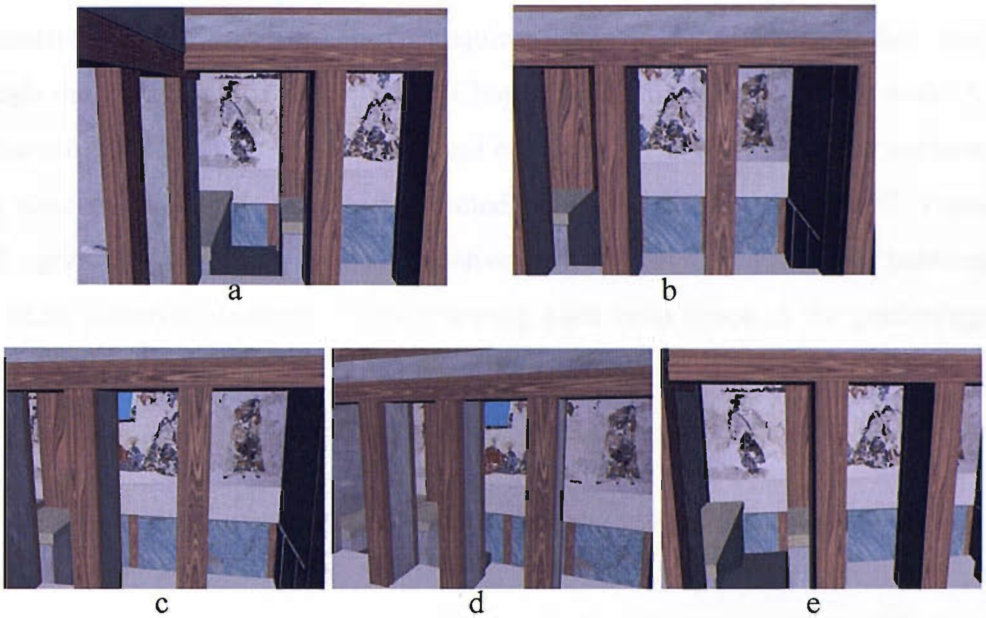

Figure 4-6: The door jambs of the pier-and-door partitions seem to frame the figures, when someone gazes at them frontally (a, b), while the significantly obstruct the viewing of the painting when they are seen from an oblique angle, that is in most cases (c, d, e).

The viewing of this basic model enables a quick appraisal of the occlusive effects of the architecture on the wall-paintings. From Room 3 it is apparent that the wall-paintings are significantly occluded by the door jambs of the pier-and-door partitions. Although from certain viewpoints the latter appear to frame the human representations (fig. 4-6 a, b), in most cases these are seen from an oblique angle, and as a result they hinder a great part of the decorated wall surfaces (fig. 4-6 c, d, e). The rapid shifting of points of view in the model or the mere visual appraisal of many dozens of rendered images that often present subtle variation in the visibility of individual painted features can hardly provide conclusive answers to the questions raised above.

As expected, the model also suggests that the theme of the Adorants can only be seen with difficulty from Room 4 because of the low lintel of the pier-and-door partition between spaces 3 and 4.

4.6 Visibility analysis

A more formal approach to the investigation of the visibility of the paintings would require the recording of the occlusive effects of the door jambs of *polythyra* from all locations in space 3 and 4[45], their quantification and

[45] The paintings would not have been visible form spaces 2 and 7.

cumulative evaluation. The above requirements were fulfilled in this case through the methodology described in Chapter 3 and more specifically with: A) the recording of the visually exposed and occluded areas of the painted surfaces from observation points evenly distributed in space, B) the creation of "times seen" giving indications of the relative differences in visibility between individual pictorial elements C) the mapping back onto space of the percentage of visible area for each pictorial element of interest.

"Times seen"

"Times seen" were created with the method described in Chapter 3. In all cases space in Rooms 3 and 4 was sampled using a 20x20cm grid. A fine resolution is necessary in this case to efficiently describe the occlusive effects of pier-and-door partitions on the paintings, which cause significant changes to the visibility of the individual elements of a composition, when moving from one viewing location to another. From each grid centroid (viewpoint) a viewshed was calculated that records the parts of the wall surface that the observer could see from that location by moving their eyes, or head, or even turning their body. The eye level of the viewer was set at 1.55m for the analysis, since the average height of an individual in the Aegean Bronze Age, as derived from human bone samples, appears to have been around 1.61m (McGeorge 1988; Dickinson 1994, p. 89).

4.6.1 The wall paintings of the ground floor

A) The Adorants

'Times seen'

Figure 4-7 presents the "times seen" of the wall painting of the Adorants from 213 viewpoints in Room 3. It clearly suggests that the wounded girl is the most visually exposed figure of the scene, as it is placed at that location of the wall whose visibility is less obstructed by the door jambs of the pier-and-door partitions and the wooden pier that has been reconstructed by Palyvou in the area of the *adyton* (2005a, p. 120, fig. 166)[46]. The estimation of the mean visibility of each entity, again suggests that the wounded girl was more visible than the other two women.

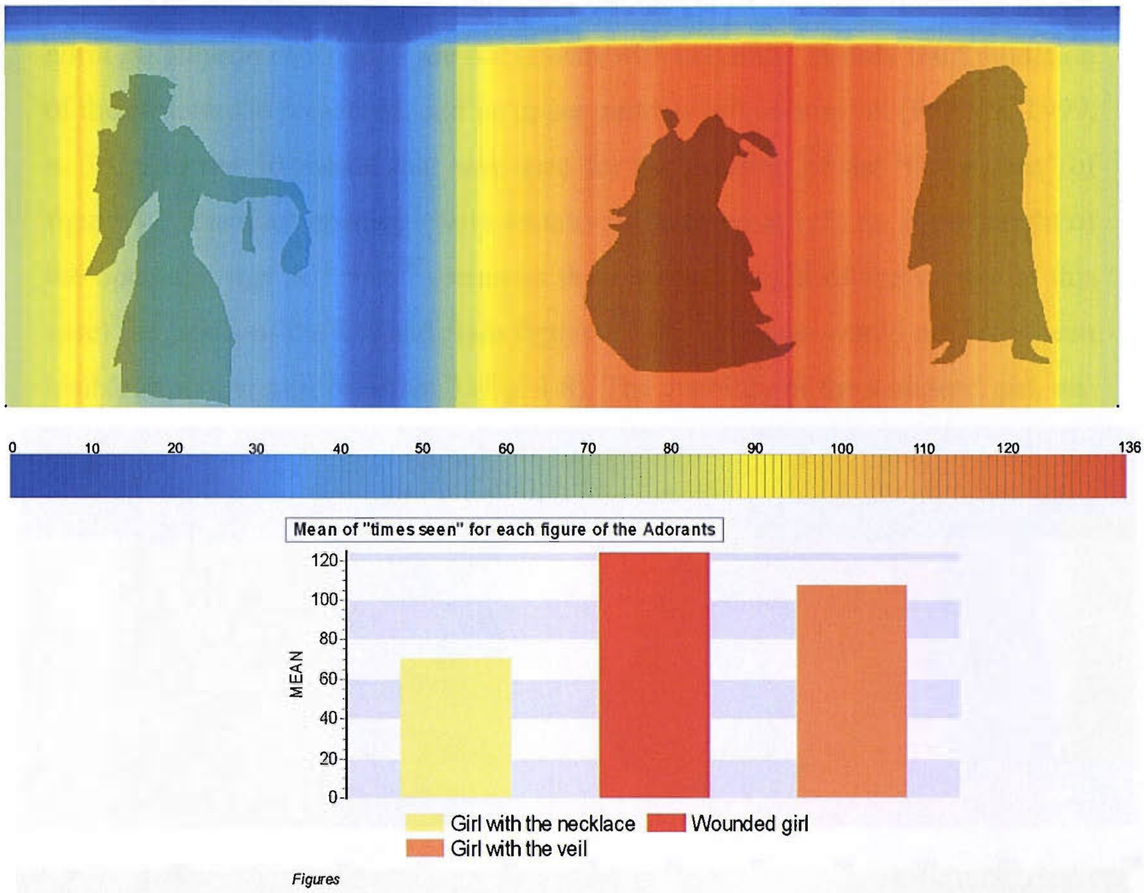

Figure 4-7: Times seen of the Adorants from 213 viewpoints in Room 3 (ground floor, Xeste 3).

The degree that the painted wall surface is obstructed by the lintel of the north *polythyron* in Room 3 depends on the distance of the observer from the painted surface, a phenomenon that can also be experienced by the change of viewpoint in the 3D model; the greater distance one stands away from the painting the more the visibility of its upper outline is obstructed. The effects of the presence of the lintel are mirrored in the "times seen" in the form of a narrow horizontal band whose colour changes gradually from blue to yellow. This suggests that the visibility of the painting gradually increases from top to bottom till the point where the lintel ceases to be an obstruction to the viewing of the painting.

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46 It is interesting to note that even in the absence of the latter the wounded girl would still be

The effects of uncertain features on the visibility of the paintings

The dimensions of the lintel and the height of the door openings of the north *polythyron* of Room 3 are not known with certainty, as only the foundation of the structure is preserved, and its upper part has left no imprint (Palyvou 1999, p. 352). In the 3d model that was used for the creation of the 'times seen' of figure 4-7, the door openings were tentatively restored at 1.70 m. If the height of the openings was at 1.55m[47] (same as the assumed height of the viewer in this case) the heads of the left and right figures of the Adorants would not have been visible from a viewer in Room 3 (fig. 4-8). The visibility of the wounded girl, on

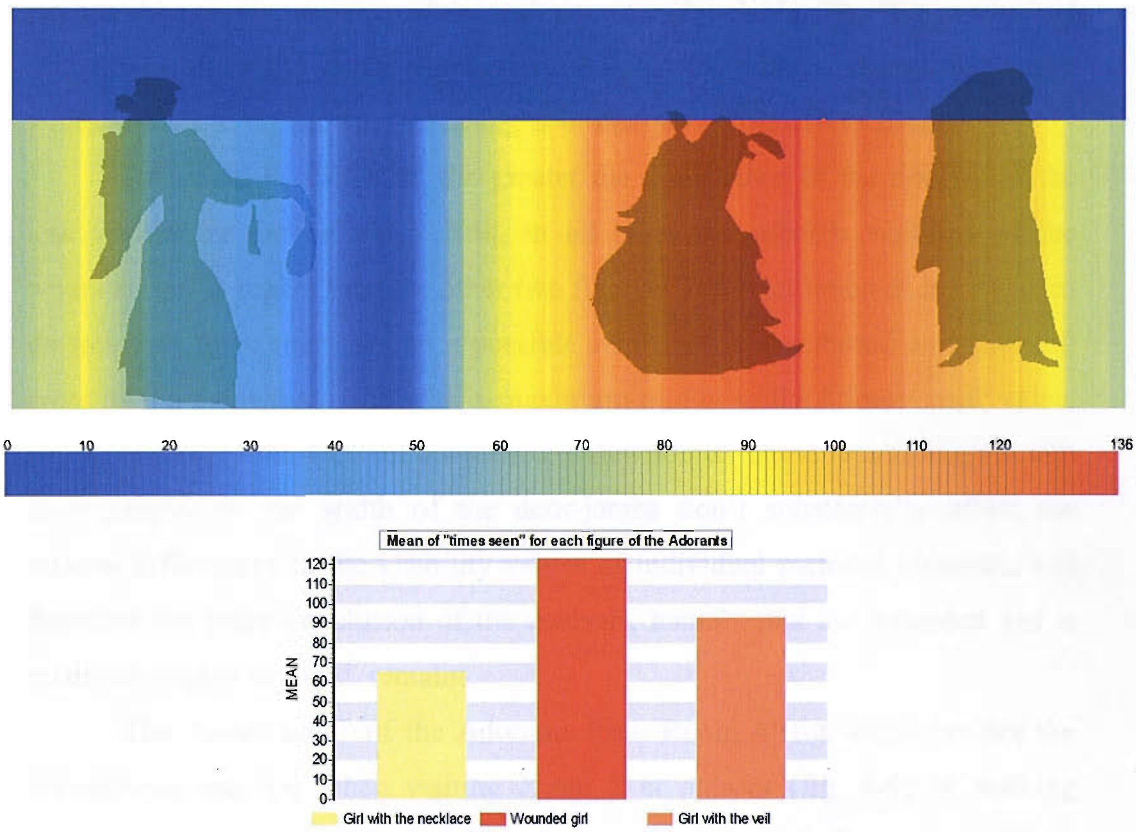

Figure 4-8: Times seen of the Adorants from 213 viewpoints in Room 3 when the height of the door openings of the north pier-and-door partition is 1.55m (Xeste 3, ground floor).

the other hand, is hardly affected by reconstructing the lintel at 1.55m, as it is placed lower than the other two figures, therefore it remains the most visually exposed among the female representations of space 3a. Nonetheless a further reduction to the height of the opening would have significantly influenced the

more visible than the other two figures as indicated in fig. 3-10b.

[47] The height of preserved internal doors of ground floor rooms in Akrotiri is between 1.40-1.60 (Palyvou 2005, p.142, 143, table 3).

visibility of the wounded girl. In any case it appears that the visibility of the wounded girl is favoured by its placement on the wall surface and that the figure is more visually exposed to a viewer standing in Room 3 than its accompanying human representations.

The width of the door jambs of the pier-and-door partitions in the reconstruction was tentatively restored at 20cm. Uncertainty regarding the exact width of these elements, however, does not seem to influence the interpretation of cumulative visibility maps. This fact is suggested by the results of a sensitivity analysis that was carried out with the aim of exploring the effects of various door jamb widths on the visibility of the wall painting (fig. 3-11). The "times seen" of figure 3-11 show the visual exposure of the painting when different door jamb widths are set in the model, increasing at ordinal level form 18 to 25cm.

As would be expected, the greater the dimensions of the doorjambs the less visible are the paintings. Still, in all cases the relative visibility of the wounded girl is higher than the other two figures. The calculation of the standard deviation of these maps shows a possible error that is distributed on almost all areas of the painted surface with a maximum of +-9 in the "times seen" value, corresponding to the 4.2% of the sampled viewpoints. These results suggest that discrepancies in the width of the door-jambs don't substantially affect the relative differences in the visibility values of individual pictorial elements, and therefore the basic conclusion of the analysis, namely that the wounded girl is relatively highly exposed, remains.

The "times seen" of the Adorants from Room 4 (fig. 4-10) verifies the impressions one has when visiting Xeste 3 at present (fig. 4-9) or walking through the 3D model of the building: the standing viewer in Room 4 would not have a good view of the paintings due to the low lintel of the *polythyron* between spaces 3 and 4. Here, the effects of the lintel on the visual exposure of the Adorants appear quite significant, as it occludes the upper body of all three figures, even if the viewer is standing in those locations that offer optimum visibility to the painting. It is interesting to note, however, that even in this case the part of the wall that corresponds to the location of the wounded girl is the most visually exposed.

Figure 4-9: The *polythyron* between spaces 3 and 4. A view from the west (Xeste 3, ground floor). Image by the author.

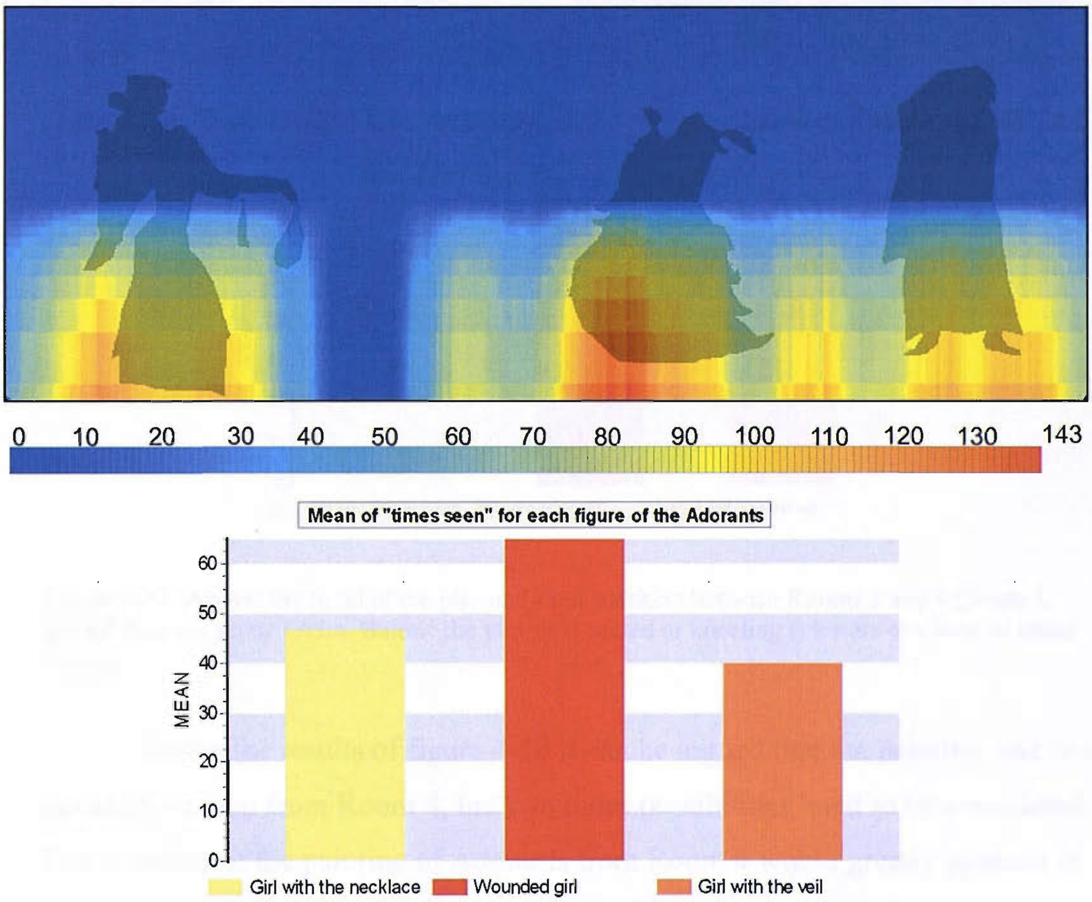

Figure 4-10: The "times seen" of the Adorants from Room 4 out of 447 observations (Xeste 3, ground floor).

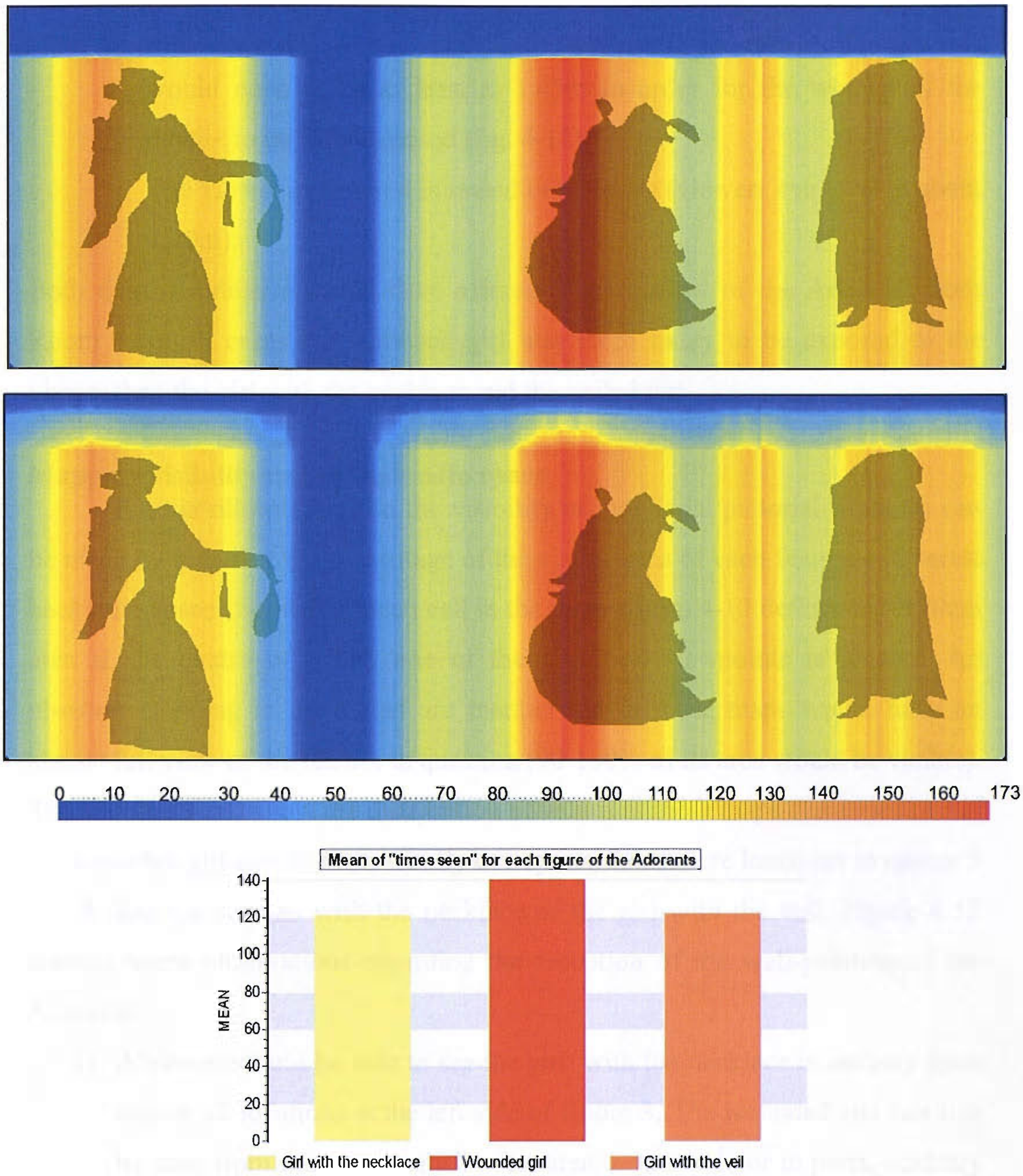

Figure 4-11: Above: the lintel of the pier-and-door partition between Rooms 3 and 4 (Xeste 3, ground floor) is set to 1.65m. Below: the viewer is seated or kneeling (viewers eye level at about 1.20m).

Seeing the results of figure 4-10 it can be argued that the painting was not meant to be seen from Room 4, but two more possibilities need to be considered. The visibility of the painting of Adorants from Room 4 would greatly increase if:

a) The original height of the lintel of the *polythyron* between Rooms 3 and 4 was higher than it appears to be from its imprint in the volcanic material. The possibility that the feature may have subsided following the volcanic eruption has already been mentioned. However, the lintel would need to be at least at 1.65m in order for the women of the *adyton* to be fully exposed (fig. 4-11).

b) The viewer in Room 4 is seated or kneeling (viewers eye level at about 1.20m).

Both these conditions would have offered a better view of the Adorants from Room 4. In all cases the wounded girl was more likely to be exposed to the viewer than the girl with the necklace and the veiled girl.

Mapping visibility values back onto space

Further observations on the visibility of individual pictorial elements can be made by mapping the percentage of the visible area of each feature of interest back onto space (fig. 4-12). Each cell in the maps of fig. 4-12 defines a 20x20cm area at the centre of which one of the specified viewpoints is located. An observer standing in areas that are marked red in these maps would have an almost full view of the feature in question (90-100% of its area would be visible). The pie charts that show the distribution of values in these maps demonstrate that the wounded girl can be seen, wholly or in parts, from more locations in spaces 3 and 4 than the woman with the necklace or the girl with the veil. Figure 4-12 enables some observations regarding the reception of the wall-painting of the Adorants:

1) A viewer would be able to see the girl with the necklace in entirety from almost all locations at the left side of Room 3. The wounded girl can also be seen from most locations in that area, as a whole or in parts, contrary to the girl with the veil who is much less visually exposed.
2) If the spectator was standing at the central area of the room s/he would have a full view of the wounded girl and mostly partial views of the other two figures. The girl with the necklace is the feature that is less visible from that part of the room.
3) An observer standing at the right side of Room 3 could easily see the woman with the veil, and great percentage of the seated girl. The girl with the necklace is almost non-visible from that space.

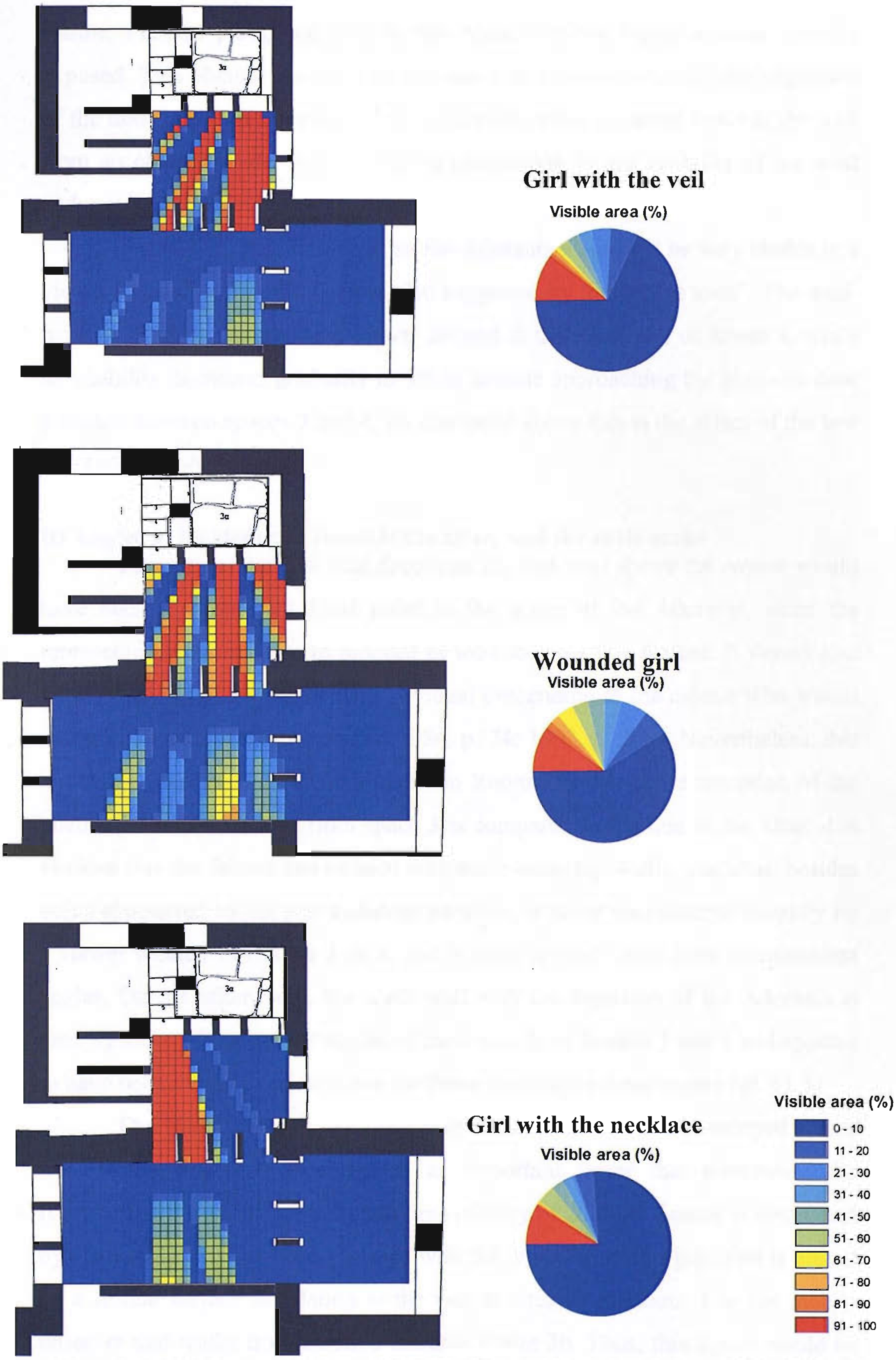

Figure 4-12 : Visible area in % for each individual figure of the Adorants (ground floor, Xeste 3).

In a few words, the depiction of the wounded girl would in most cases be visible, even in parts, and it is in that sense that the figure is more visually exposed. This phenomenon can be explained as a consequence of the alignment of the door jambs of the pier-and-door partition when a viewer looks at the wall from an oblique angle, mostly causing obstruction to the visibility of the west and east limits of the painted surface.

Figure 4-12 also suggests that the Adorants would not be very visible to a viewer located in Room 4, as was also suggested by the "times seen". The wall-painting is more exposed to a viewer located at the south end of Room 4, while its visibility decreases gradually to 0% to anyone approaching the pier-and-door partition between spaces 3 and 4. As discussed above this is the effect of the low lintel of the *polythyron*.

B) Angles of incidence in Room3: the altar, and the male scene

The altar: The altar that decorated the east wall above the *adyton* would have been an important focal point in the scene of the Adorants, since the represented females seem to proceed or look towards this feature. It would also be the focus of attention for the individual descending to the *adyton* who would naturally face the altar (Marinatos 1984, p. 74; 1993, p. 206). Nevertheless, this is not the case for the viewer situated in Rooms 3 or 4; if the reception of the visibility of the Adorants from space 3 is compared to the one of the altar, it is obvious that the former can be seen with more ease (fig. 4-20). The altar, besides being obstructed by the pier-and-door partition, is never encountered frontally by a viewer located in Rooms 3 or 4, and is seen in most cases from inconvenient angles. On the other hand, the north wall with the depiction of the Adorants is seen by more advantageous angles of incidence from Rooms 3 and 4 and appears to have been the focus of attention for those standing in these rooms (cf. §1.3).

The male scene: In the male scene where the theme is developed across three walls, angle of incidence is an important factor that determines the reception of the paintings; although the visibility of all three figures is obstructed by the middle clay partition, the man with the jug is the only figure that is placed on a frontal surface in relation to the viewer situated in Room 3 or the mobile observer that walks from Room 3 towards Room 3b. Thus, this figure would be seen from a convenient angle; the other three figures would be viewed foreshortened and from small angles of incidence, and therefore would not have been viewed with ease. It is also clear that the person walking through the north or the middle corridor of room 3b would have no view either of the wall painting with the two males or of the mural with the young boy with bowl, although s/he would have been able to see the man with the jug on all occasions.

4.6.2 The wall-paintings of the first floor

A) North wall: offerings to the Goddess

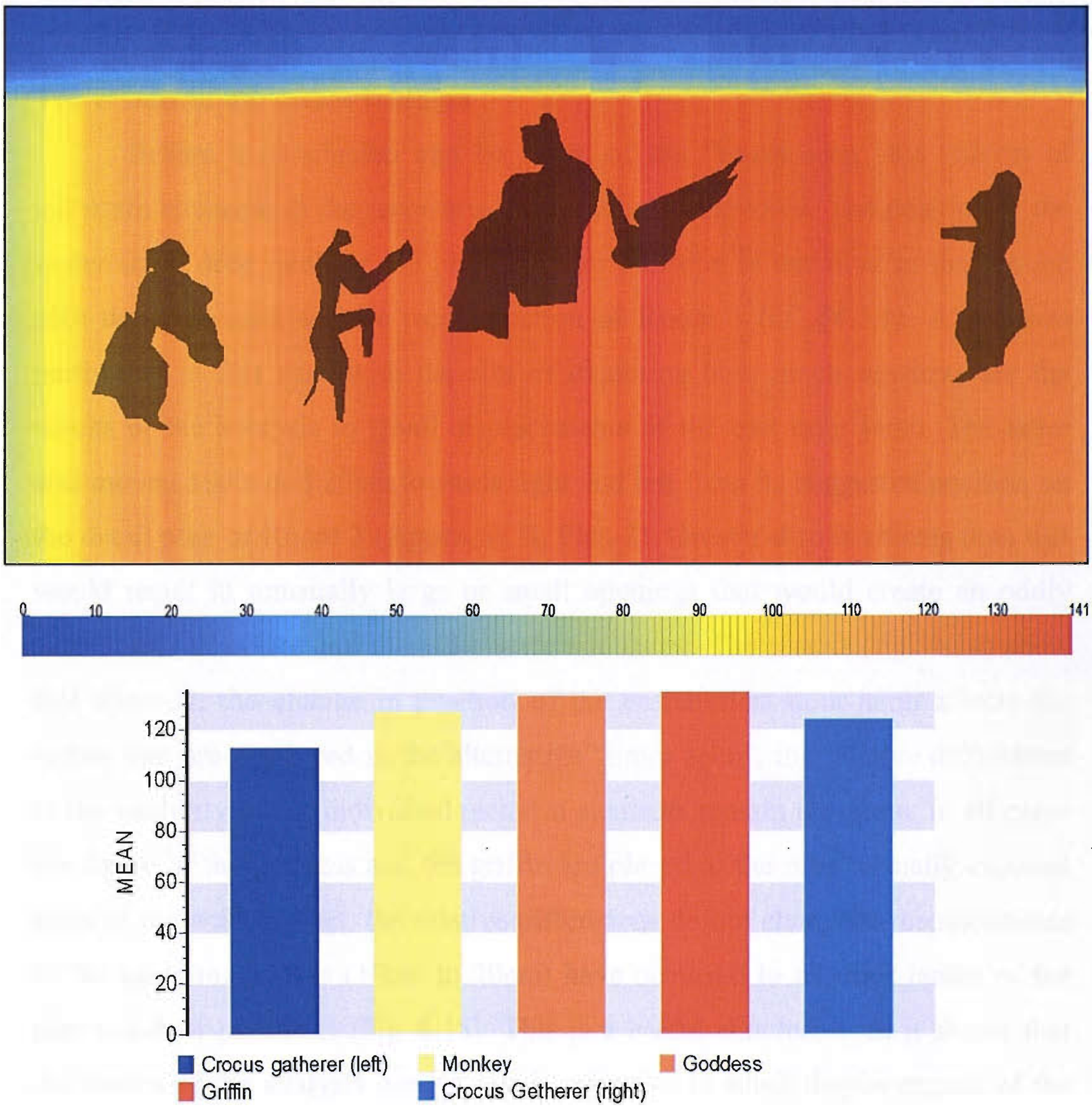

Figure 4-13: The "times seen" of the Crocus Gatherers (north wall) from 218 viewpoints in Room 3 (Xeste 3, first floor).

The "times seen" of the north wall of Room 3a on the first floor (fig.4-13), which sums up the results of 218 observations from room 3, suggests that the goddess and the figure of the griffin were placed at the most visually exposed areas of the wall surface. The figures have been depicted in close proximity to each other and in fact create a unified meaning, as the presence of the griffin is essential for the identification of the goddess as the "Mistress of animals". Thus, they should be considered together in the interpretation. The monkey approaching the Goddess to offer her flowers has also been represented in highly exposed locations of the wall surface. In this way the act of offering to the Goddess acquires particular emphasis. On the contrary, the figures of the Crocus gatherers that are represented on the same wall are positioned on areas of the wall surface that are less visible.

The effects of uncertain features

Before a conclusion can be made of the "times seen" the effects of uncertain elements in the reconstruction need to be explored. The position of the easternmost door jamb of the pier-and-door partition is tentative in the ground plan that was used for the reconstruction of Room 3 (cf. §4.5.1). A test was performed in this case with the aim of exploring how much sensitive are the results of the analysis to small displacements of the east door jamb. The latter was moved 10cm and 20cm towards right and left from its suggested position on the detail plan of Room 3 (Appendix II, Plan 2). Greater displacements than this would result in unusually large or small openings that would create an oddly asymmetric structure and therefore were not tested. The results (fig. 4-14) show that although the change in position of the easternmost door-jamb affects the values that are displayed in the alternative "times seen", the relative differences in the visibility of the individual pictorial elements remain the same. In all cases the figure of the goddess and the griffin are placed at the most visually exposed parts of the wall. In fact, the relative differences do not change if displacements of the same magnitude (10cm to 20cm) have occurred to all door jambs of the pier-and-door-partitions (Fig 4-15). This is a useful conclusion as it shows that the results of the analysis are not overly sensitive to small displacements of the door jambs that may have occurred due to the effects of the volcanic eruption on the building, errors in the recording of the position of architectural elements on site[48], or during the digitisation process.

[48] The estimated error in the plans is 0.5% (Doumas 1982, p. 399).

The height of the lintel of the pier-and-door partition at the north of room 3 is not known, since the upper structure of the *polythyron* has not been preserved. In the 3D model upon which the analysis was based it was set at a height of 1.70m taking into account the fact that Room 3 on the first floor would have been more spacious that that of the ground floor, being at least 2.30m high (the preserved height of the wall painting with the goddess). This is a plausible suggestion, since the preserved height of door openings on the first floor sometimes exceeds 1.70m (Palyvou 2005a, p.143, table 4).

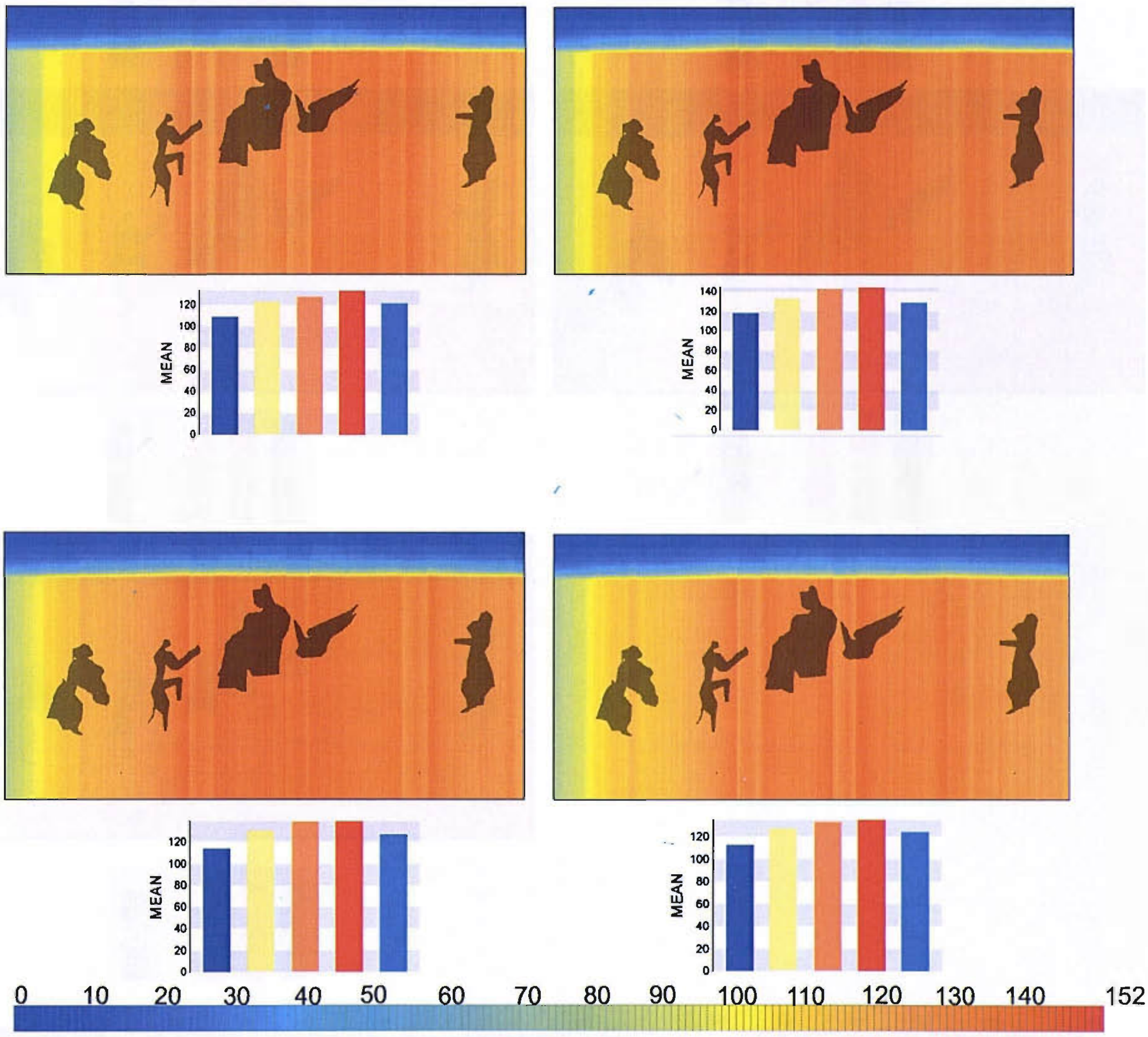

Figure 4-14:'Times seen' based on alternative reconstructions that differ in the positions of the eastern most door post of the north pier-and-door partition of Room 3 (Xeste 3, first floor).

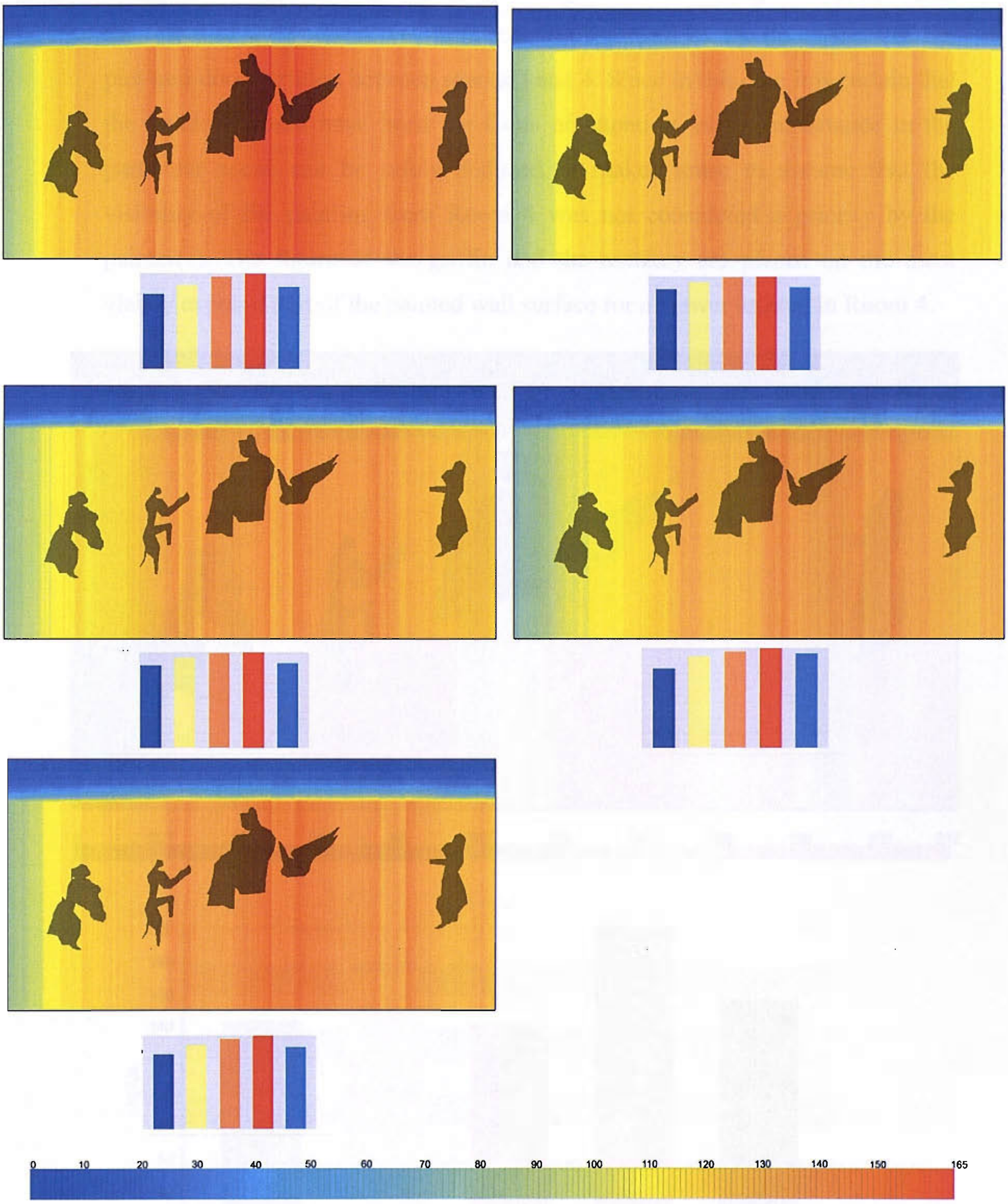

Figure 4-15: "Times seen" based on alternative reconstructions that differ in the positions of all door posts of the north pier-and-door partition of Room 3 (Xeste 3, first floor).

Room 4

The "times seen" of the wall-painting from Room 4 (fig.4-16) reveals that the figure of the goddess was significantly obstructed by the door jambs of the pier-and-door partition between spaces 3 and 4. Since in this case it is certain that the goddess would have been the focus of attention, as its importance in the particular scene can be safely deduced, it makes sense to assume that the visibility of the painting from Room 4 was not considered a priority by the painter(s). The figure of the griffin and the monkey are placed on the most visibly exposed part of the painted wall surface for a viewer located in Room 4.

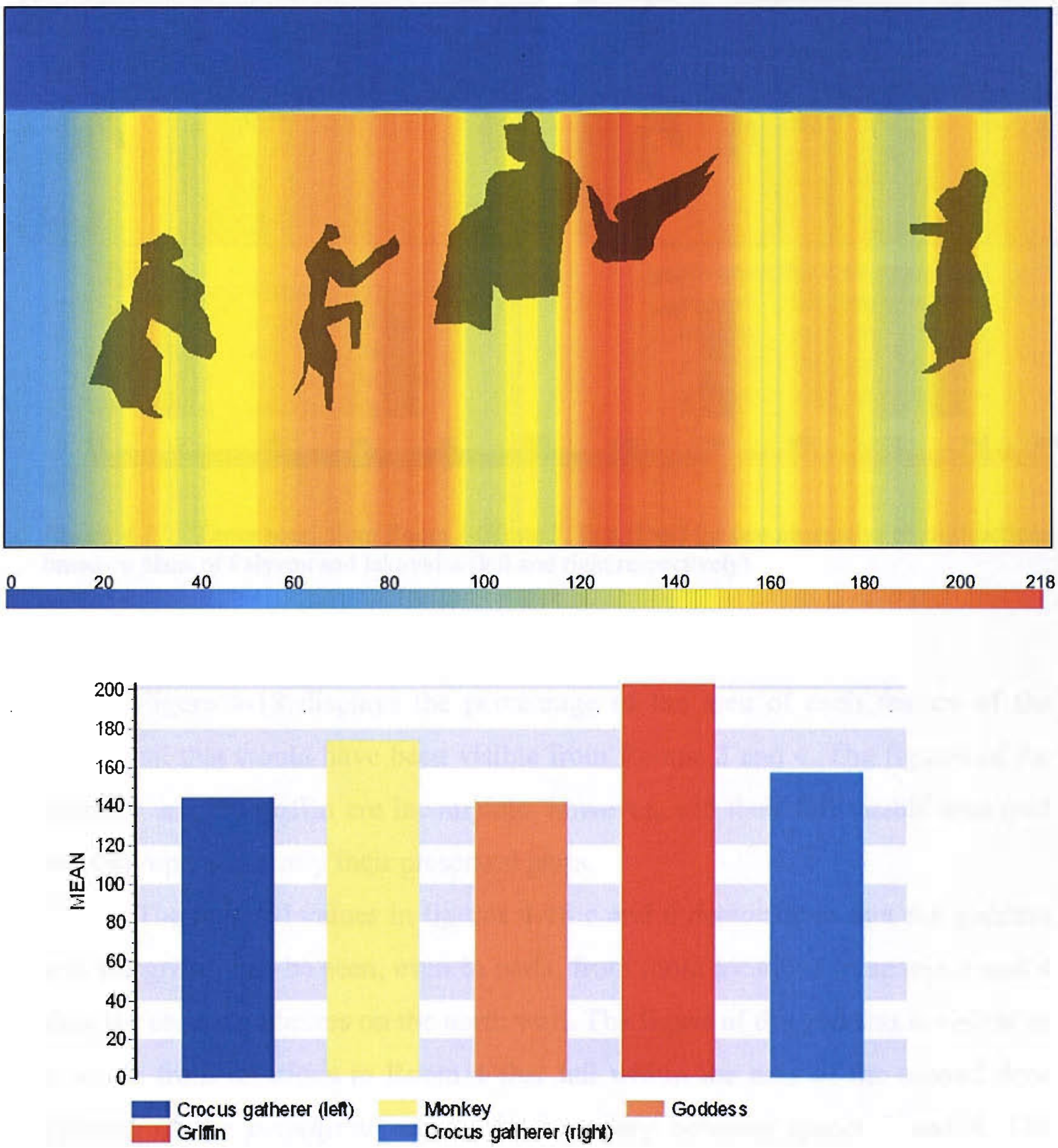

Figure 4-16: The 'times seen' of the wall painting with the goddess from Room 4 (Xeste 3, first floor).

Uncertain elements

The visibility of the wall painting was examined using two alternative 3D reconstructions. One was based on a ground plan created by Palyvou (Appendix II, Plan 2) and the other on a ground plan drawn by Iakovides (Appendix, Plan 4). The two plans differ on the exact location of the door jambs of the pier-and-door partition between spaces 3 and 4. In both cases the figure of the Goddess appears to be significantly obstructed by the door jambs (fig. 4-17).

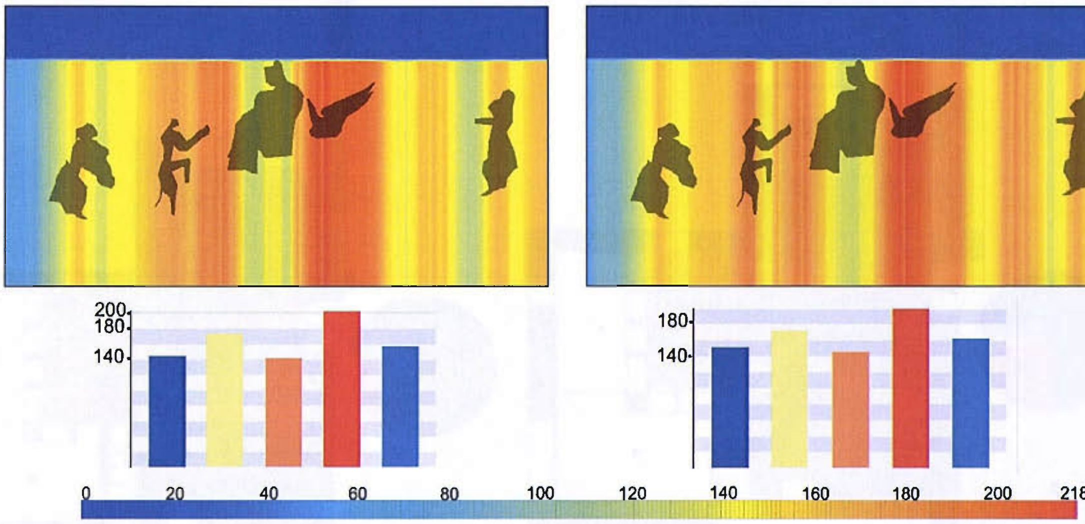

Figure 4-17: 'Times seen' from Room 4 (Xeste 3, first floor) for two alternative reconstructions based on plans of Palyvou and Iakovides (left and right respectively).

Mapping visibility values back in space

Figure 4-18 displays the percentage of the area of each feature of the north wall that would have been visible from Rooms 3 and 4. The figures of the monkey and the griffin are incomplete, however, and their full visible area (red values) represents only their preserved parts.

The mapped values in figures 4-18 c and d demonstrate that the goddess and the griffin can be seen, even in parts, from more locations in spaces 3 and 4 than the crocus gatherers on the north wall. The figure of the goddess is visible as a whole from locations in Room 4 that fall within the axis of the second door opening of the *polythyron* setting the boundary between spaces 3 and 4. The greater part of the figure is, however, hidden for the viewer who is not situated

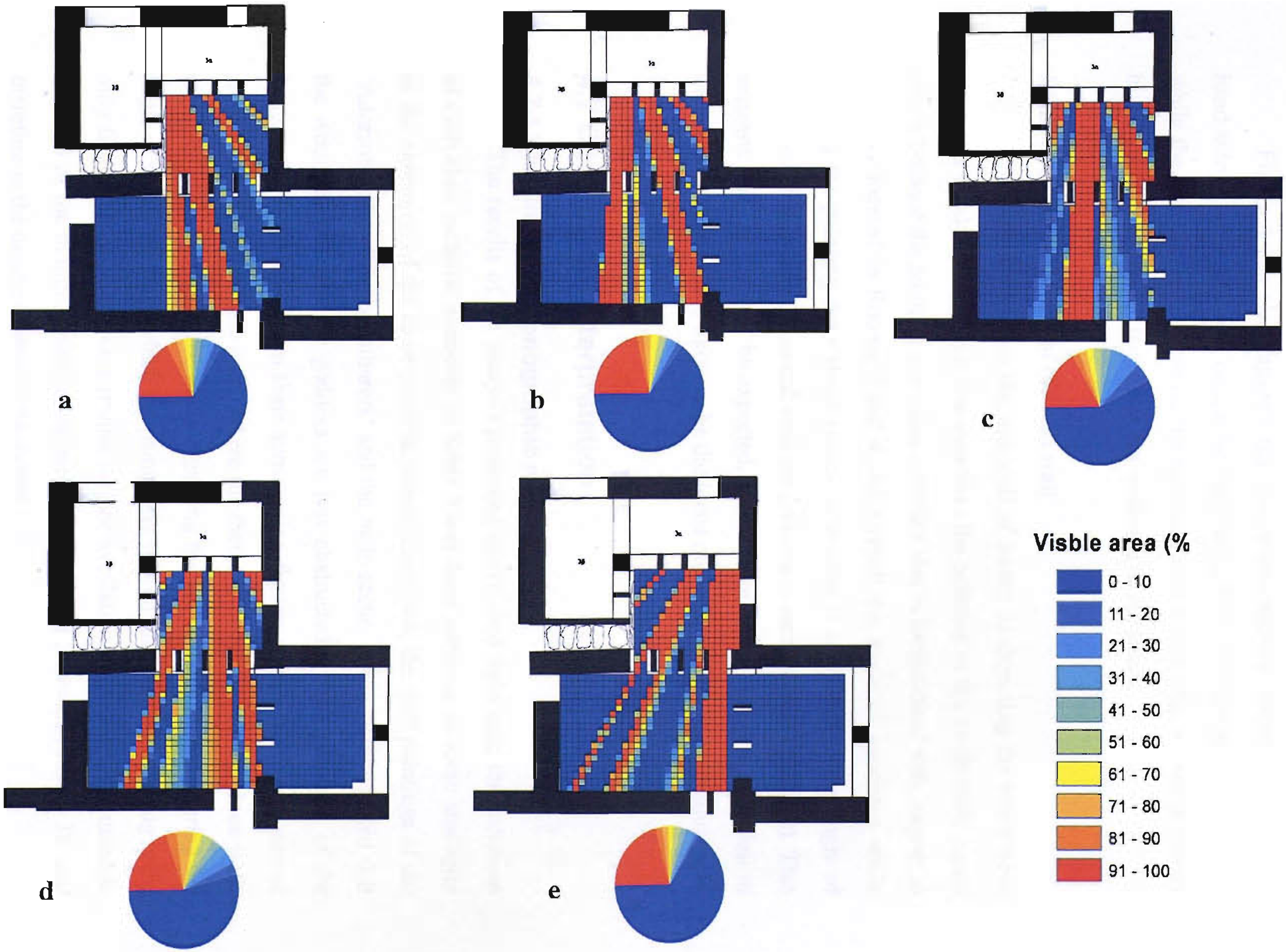

Figure 4-18: a) Crocus Gatherer (left) b) the Monkey c) the Goddess d) the griffin e) Crocus gatherer (right).

within this axis.

Figure 4-18a also suggests that the crocus gatherer depicted on the left hand side of the north wall cannot be seen easily from the east side of Room 3, while the one that is depicted on the right end of the wall (fig. 4-18e) is mostly hidden from the viewer standing at the west side of the room.

B) The crocus gatherers of the east wall

The wall painting on the east wall of Room 3a depicting the two crocus gatherers would be seen with less ease than the painting of the north wall. Again this is because the painting decorates a surface that is longitudinal with respect to a viewer located in Rooms 3 and 4. As a result the angle of incidence while viewing the painting from these spaces is smaller if compared to the angle of incidence from which the mural with the goddess is seen (a frontal surface). This suggests that, as it would be expected, it is the north wall with the depiction of the goddess that is more likely to be the focus of attention for a viewer situated in Room 3.

4.7 Conclusion/ Interpretation

4.7.1 Visibility and iconographic meaning

The results of the analysis presented above shed light onto the reception of individual pictorial elements in Xeste 3 and draw attention to some analogies in the execution of the three pictorial scenes examined, the wall paintings of the 'Adorants', the 'Crocus gatherers' and the male scene. It was demonstrated that the wounded girl and the goddess are less obstructed by the presence of the jambs of the *polythyra* than their surrounding figures, especially when viewed from Room 3. In the male scene where the theme is developed across three walls a similar observation can be made regarding the seated man by considering the angle of incidence from which the painting is viewed; the man with the jug is the only figure that is placed on a frontal surface in relation to the viewer situated in Room 3 or the mobile observer that walks from Room 3 towards Room 3b, and therefore is the most exposed to the viewer.

Results of the analysis in this case are interesting if they are considered together with contextual evidence and proposed formal iconographic interpretations of the murals of Xeste 3 that were discussed in § 4.3.2.

Figure	Wall painting	Posture	Pictorial position	Relationship to viewer
Wounded girl	Adorants	seated	Focal point	Most visually exposed
Man with the jug	Male scene	seated	Focal point	Most visually exposed
Goddess	Crocus Gatherers	seated	Focal point	Most visually exposed

Table 4-2: Correspondence of visual emphasis in pictorial space with visual exposure in actual space.

It appears that there is a correspondence in all three scenes between visual emphasis in pictorial space and visibility in actual space, which should be considered neither accidental nor without significance. Redundancy of visual cues is a key to understanding hierarchy of meaning in prehistoric painting and the importance of each figure in individual themes is verified not only by their place in composition, their posture, hairstyle and dressing, but also by their location in real space. The results of the analysis confirm that the examination of visibility or non-visibility of Theran murals in their original context can be indicative of pictorial emphasis in a composition.

The above relationship also suggests that the painter(s) of the iconographic program of Xeste 3 had taken into consideration visibility issues during the painting process. In the case of the wall paintings of the Adorants and the Crocus gatherers, the occluded and exposed surfaces of the north wall of Room 3a would have been perceivable by an individual, if s/he moved, stopped, and looked at the wall from different locations in space. The painter could have observed the working surface in this way before making decisions on how to illustrate the theme of the frescoes. It has been demonstrated in other cases, as well, that there was considerable planning involved in the rendering of Aegean murals (Cameron 1972; Birtacha and Zacharioudakis 2000; Shaw 2003); incised lines covered by colour that would have been visible only to the painter were often used to mark the position of pictorial elements on the wall before the application of the color pigments (Cameron 1972; Shaw 2003). It is noteworthy that such lines were applied to delineate the forelock and locks of the goddess (Shaw 2003, 183)[49], the most exposed feature to the onlooker situated in Room 3. This fact further supports the suggestion that the placement of the figure on that location was the result of careful consideration.

4.7.2 Visibility and ritual performances in Xeste 3

The reconstruction of ritual practices in prehistoric spaces is undeniably a difficult and ambitious endeavour. To the extent, however, that the paintings were aimed to be seen during ritual practices, some comments can be made here about stasis, movement and circulation during ceremonies. Generally we accept that ritual performances related to separate male and female rituals would have taken place in the building, as has been maintained by Doumas (1987), Gesell (2000) and Morgan (2000) (cf. §4.4). The male scene does not seem to be related to the female representations and clearly occupies a separated area of space 3. It is also held that both active and indirect participants would have taken part in the rituals, as the architecture and spatial arrangement of the building (vestibule with benches, size) suggest the gathering of a number of people in the east wing of Xeste 3.

The themes of the Crocus gatherers and the Adorants have been executed in a way that permits the maximum exposure of the goddess and the wounded girl respectively to the viewer in Room 3. This may be taken as an indication for the presence of individuals in that space during rituals (cf. §4.4). As proposed already, these could be indirect participants-viewers to ceremonies, or initiates that would not have been allowed access in Rooms 3a and 3b at least initially. Neither the wall-painting of the Adorants nor that of the figure of the goddess are conveniently seen from Room 4, a fact that suggests that during public gatherings, the pier-and-door partition between spaces 3 and 4 defined a liminal area that perhaps marked a change in the use and function of space or signified successive admittance to the decorated spaces. As far as the wall-painting of the Adorants is concerned it is the reconstructed low lintel of the *polythyron* in

[49] Incised lines were used for the delineation of the curls of two of the crocus gatherers, as well. However, these were intended to be visible, as they were made on a dry pigment and aimed to

question that obstructs the visibility of the mural. The height of the door openings in this case perhaps mirrors the destructive effects of the volcanic eruption on the building, rather than the original form of the *polythyron*. With the existing evidence, however, one has to conclude that unless the onlookers were seated or kneeling (fig. 4-11), they would not have been able to observe the painting with ease. Moreover, the figure of the goddess seems to have been significantly hidden from a viewer located in Room 4, due to the occlusive effects of the door jambs of the *polythyra* in spaces 3 and 4. Taking the above into account it appears that on both floors of the building the paintings were primarily created to be seen by someone situated in Room 3 and that the performances that took place in Room 4 were less likely to be associated with the exposure of the painted scenes.

The above mainly concern the experience of the individuals that would stand or sit in Rooms 3 and 4 during the performed rituals. For the mobile observer the engagement with the painted scenes would be different. The most active participants in the ceremonies would have focused their attention and movements on the performance of ritual acts, not necessarily involving or enabling on all occasions the viewing of the paintings, contrary to what applies for the standing participants that would have more opportunities to observe both the paintings and the performed events. Moreover, in the course of movement[50] occluded and exposed surfaces alternate in a rapid rate, and for this reason no part of the wall painting would have been perceived as hidden from view, although again individuals would have limited visual access to some of the painted features, if their actions were controlled and restricted only to certain parts of room 3.

For example, if one had to enter Room 3 from the westernmost opening, s/he would have the opportunity to appreciate more views of the woman with the necklace and the wounded girl, rather than the girl with the veil (fig. 4-12). Figure 4-19 shows the percentage of the visible area for all three figures of the Adorants, suggesting that the theme as a whole would have be seen with more ease from locations close to the two westernmost openings of the pier-and-door

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accentuate the hair style of the represented figures (Shaw 2003, p. 184).

[50] Differences in the visual experience of the mobile and standing observer in cluttered environments have been verified experimentally by Gibson (1979). He notes: '...Hence probably a pause in locomotion calls attention to the difference between the hidden and the unhidden,

partition that connected Rooms 3 and 4 (fig. 4-20). If decisions concerning the placement of pictorial elements were made by taking into account the experience of the mobile observer, it can be argued that individuals would enter Room 3 from that side. The two westernmost openings are also those that offer the most direct in terms of physical distance access to the steps that lead to the *adyton*, as well as to the corridor that connects to the auxiliary staircase of Xeste 3 (space 8, fig. 4-2). These openings, then, would have been frequently used by the inhabitants of the buildings and participants to the rituals; the fact that the all three figures can be seen from locations close to these doors is likely not to be a coincidence.

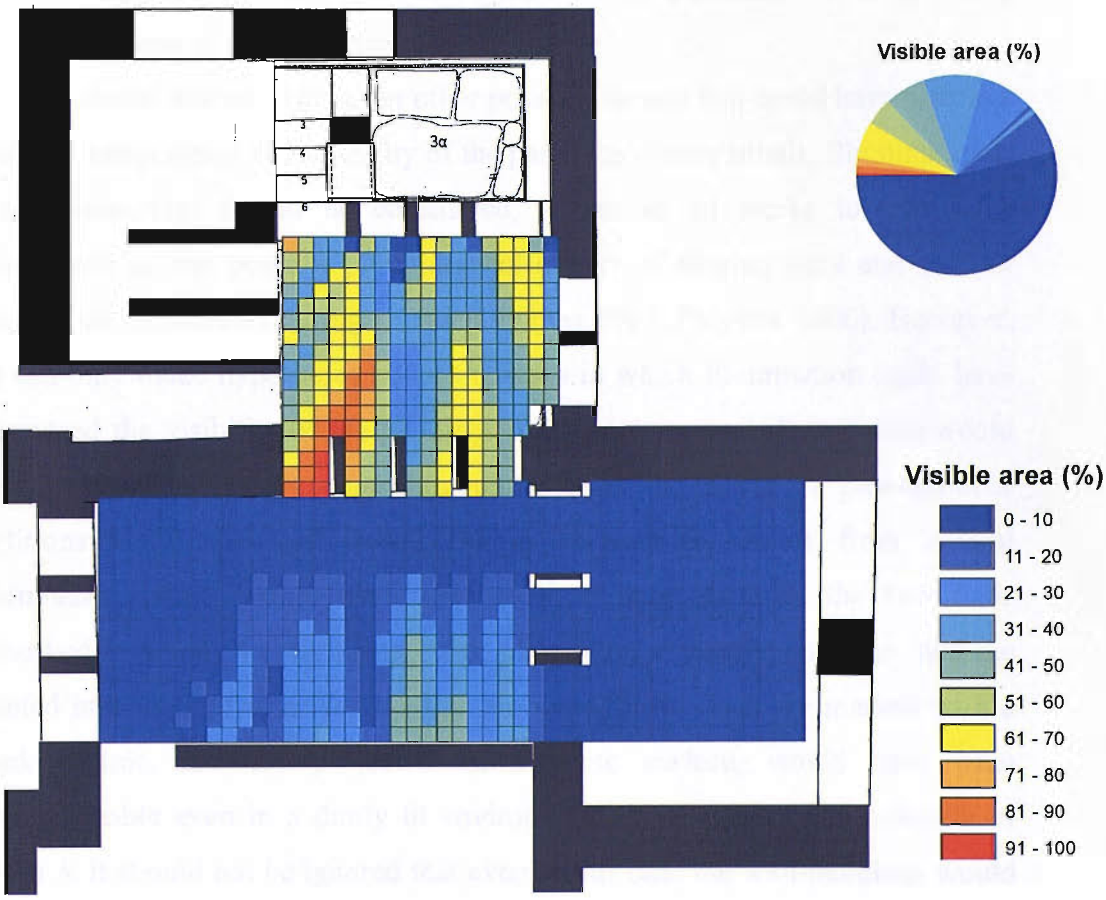

Figure 4-19: The areas from which all three figures of the Adorants (Xeste 3, ground floor) would have been visible (red areas).

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while locomotion makes evident the continuousness between the hidden and unhidden...' (Gibson 1979., p. 89).

The male scene appears also to have been rendered with respect to the mobile viewer in mind. The figures placed on the walls of the narrow corridors that lead to space 3b would not have be seen in an optimum way from space 3 and seem to have aimed primarily to guide movement through space. As already mentioned, the man with the jug could be appreciated from a more convenient angle by a viewer situated in Room 3, but especially by someone approaching space 3b through the corridor. It appears that the male rituals performed in the building were not aimed to be exposed to the indirect participants of the events in Room 3. This impression is also supported by the fact that generally space 3b would not have been visually accessible from a viewer situated in that room. All the above indicate that the male and female rituals performed in the building would have been of different nature.

Finally, one must consider other possible factors that could have affected, although temporarily, the visibility of the paintings during rituals. Illumination is a parameter that should be considered; a number of works to date have commented on the possible psychological impact of altering light and shadow patterns on individuals during rituals (Doumas 1987, Palyvou 2000). However, we can only make hypotheses about the ways in which illumination could have influenced the visibility of the paintings in Xeste 3; natural illumination would have changed constantly depending on whether the doors of pier-and-door partitions were open or closed during ceremonies. Apart from natural illumination lamps would have been used, as suggested by the two finds unearthed in Room 4 (Marinatos 1976, plate 54β). It seems, however, that the painted human figures in Xeste 3 that are almost life sized, are marked with a black outline, and are projected on a white surface, would have been distinguishable even in a dimly lit environment, especially by the onlooker in Room 3. It should not be ignored that even in this case the wall-paintings would not have be seen with ease on all occasions, as their visibility would have been obstructed by the bodies of other individuals participating in the rituals. The degree to which views of the painted scenes could have been obstructed by the presence of other people is difficult to appreciate without knowing the number of individuals gathered in Room 3. The body of a person located in the *adyton* would not have significantly hindered the visibility of the Adorants, as this occupied an area about 1,40m high immediately below the ceiling of Room 3, while an individual would have been located 80cm below the floor of that room (fig 4.20). A 3D impression in populated space suggests, however, that few of the participants would be able to see the descendent to the *adyton*, while the wall paintings would still be exposed to most of the viewers. This observation further enlightens the social importance of wall paintings during the performance of communal rituals in Xeste 3, as it seems that often murals would have been the main focus of visual attention during the enacted ceremonies, promoting social cohesion by perpetuating culturally shared codes and messages.

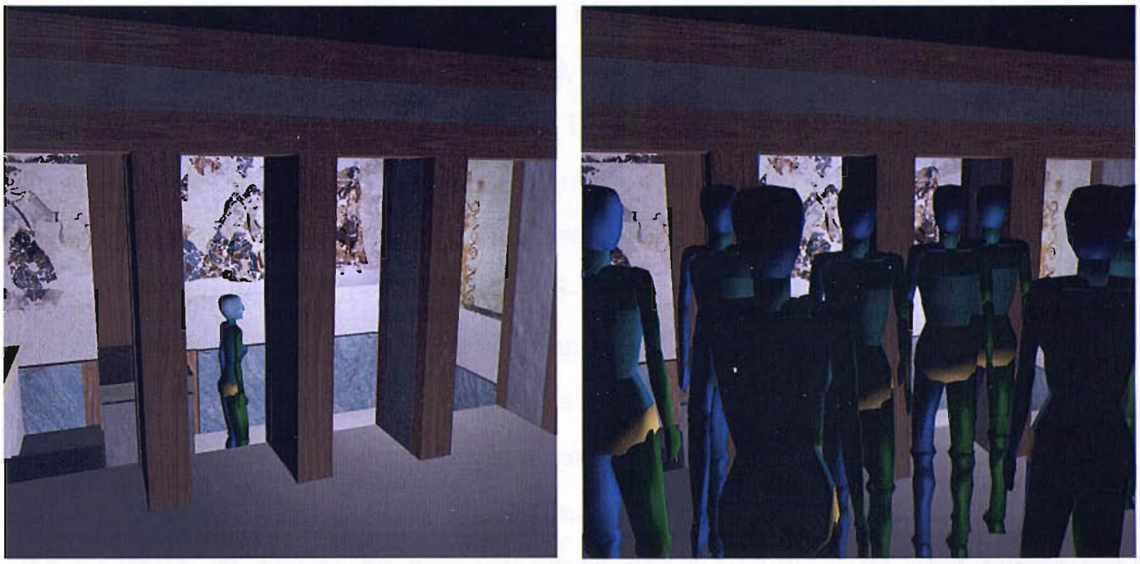

Figure 4-20: Left: The body of the person in the *adyton* would not have obstructed the painted scenes. Right: In populated space the viewer could still be able to observe the painted scenes. By the author.

The above application of visibility analysis aimed to shed light onto the function of wall-paintings in a building used for public gatherings. The consideration of human practices and possible mobility patterns in Xeste 3 was essential for interpreting the results of the analysis. The social context of human engagement with the decorated spaces would have been different as regards private houses, however. Aspects of human engagement with the wall-painting in private buildings are discussed in the remainder of the thesis.

Chapter 5
The wall paintings in the townscape

5.1 Introduction

The wall paintings are perhaps the most striking feature of the houses that were unearthed at Akrotiri and are a testament to the prosperity of the town inhabitants. Aegean mural art in Late Cycladic I/Late Minoan IA period (table 1-1), regardless of the precise messages it aimed to communicate on each occasion, was undeniably an expression of the ideology and aesthetics of socially privileged classes (Blakolmer 1995; 2000, p. 403; Boulotis 1992, 2000; Chapin 2004; Gates 2004). The wall-paintings of Thera were created some time between the seismic destruction and the volcanic eruption that destroyed the settlement. It is believed that these two events define a relatively short time span of about fifty to seventy-five years (Morgan 1988, p. 5-10; Doumas 1992a, p. 30-31) during which Theran mural painting flourished and the first figurative themes appeared (cf. §1.1, §2.2). Painted plaster fragments dating to an earlier period have also been found, illustrating decorative, linear and abstract patterns (Marinatos 1971b, p. 33; Televantou 1994, p. 129-130; Doumas 1992a, p. 185). In Late Bronze Age the repertoire of Theran painters was much richer including life-sized human figures, miniature paintings, and nature scenes, as well as a great number of decorative and geometric motifs (Doumas 1992a). The quantity of pictorial fragments that have been unearthed, the probable existence of local workshops of Theran painters (Doumas 1983, p. 124; Televantou 1992; Morgan 1990; Boulotis 2000), the repetition and similar rendering of the same decorative and geometric themes in different buildings (Vlachopoulos 2007), have supported the idea that wall painting in Akrotiri was a popular trend adopted by an affluent society (Boulotis 1992, p. 89; 2000, p. 853).

In connection to this the wide distribution of wall-paintings in the settlement is particularly telling. Within the area of the excavation, which is slightly larger than one hectare, whole compositions or fragments of wall painting have thus far been reported in relation to 15 buildings. These include Xeste 3, Xeste 4, Xeste 2, Xeste 5 (pillar pit 68), Beta South, Delta West, Delta East, Delta north (Xeste 1), West House, House of the Ladies, the building that housed the "Porter's Lodge" and the "Kitchen", Gamma South, Gamma North[51], the newly excavated building north east of sector A (at the area of pillar pit 72), and the building at the area where pillar pit 70 is located at the north east area of the site (Vlachopoulos 2007). To these should be added some fragments with mainly linear motifs coming from spaces excavated west and northwest of Xeste 3 that have been mentioned recently by Vlachopoulos (2007). In many of the buildings with mural decoration more than one room is embellished with wall-painting. In addition, one cannot exclude the possibility that many of the other identified buildings in the settlement also had wall paintings, as most of them are not excavated.

The diffusion of mural decoration in the buildings of Akrotiri is particularly impressive, especially when compared to the number of known contemporary town houses that have had mural decoration in Crete and the Cyclades. According to Immerwahr's (1990) catalogue most examples of wall painting in Late Minoan IA are restricted to one or two buildings at each site, although some of the settlements are much larger than Akrotiri (cf. Branigan (2001b) and Whitelaw (2001) for settlement size) and have been excavated to a greater extent. An exception to this rule is the town of Knossos, where besides the palace five houses in close proximity to it are reported to have had mural decoration (House of the frescoes, South House, Southeast House, Caravanserai, and Unexplored mansion) (Immerwahr 1990; Driessen and Macdonald 1997). According to Immerwahr (1990) other Cretan settlements that have given pictorial fragments dated to Late Minoan I are Amnisos, Ayia Triadha, Chania, Mallia, Palaikastro, Pseira, Kommos and Tylissos, while buildings with frescoes have also been excavated at sites close to Knossos, for example at Katsamba, Nirou Chani, Prasa and Vathypetro. It is noteworthy that not all Minoan towns had houses with frescoed walls and that few only fragments have been discovered in palaces such as Phaistos or Zakros[52]; More recently some fragments with iconic subjects similar to those found at Knossos and Akrotiri and dated to the Late Minoan IA have been discovered in the so-called "Minoan villa of Epano Zakros" (Platon 2002), while other fragments have been reported from

[51] According to Vlachopoulos (2007), fragments that were found in Room 10 of Gamma North originally belonged to Room 7 of Gamma South.
[52] No fragments have been reported from the palace at Mallia .

the palace at Galatas and the nearby Building 1 (Rethemiotakis 2002, p. 73); no wall paintings have been reported from the town houses of sizeable urban settlements, such as Gournia (Soles 2002, p. 125). In the Cyclades painted fragments have been found in the towns of Ayia Irini (Kea) and Phylakopi (Melos). At these sites that have a comparable size to the excavated area at Akrotiri, 7,500 and 18,000 square metres respectively (Palyvou 2005a, p. 26), a few spaces decorated with murals have been unearthed (Immerwahr 1990).

The above are based on the reported preserved fragments of mural painting, but even if one takes into consideration the exceptional taphonomic conditions at Akrotiri and the problems of preservation in other Aegean sites, it is obvious there was a remarkable investment in wall decoration by the inhabitants of the Theran town (Boulotis 1992, p. 89; Blakolmer 2000, p. 399; Palyvou 2005a, p. 184). This conclusion inevitably raises the questions of the function and significance of mural decoration in Theran society, the reasons behind their wide diffusion throughout the settlement, and the identity of their consumers.

To date, discussion on the function of Theran painting has focused on whether it had a primarily religious or secular character. Especially after the first discovery of Theran murals it was suggested that Aegean wall painting had a religious significance (Cameron 1972; Marinatos 1984, 1985; Hägg 1985; Niemeier 1992), and the rooms they embellished were considered to have been shrines, rooms where paraphernalia were kept or places of temporary house cult (Niemeier 1992, p. 103-104). Although it was later strongly questioned whether the purpose of mural decoration was solely to serve the cult needs of the Late Bronze Age society, the religious connotations of at least some wall paintings, for example those of Xeste 3, is widely accepted. In the context of religious practices it has been suggested that wall paintings acted as 'sign posts' (Cameron 1970, 1972) used to guide movement in space, images that perpetuated ritual scenes and acts (Hägg 1985, p. 211) or 'attention focusing devices' (Renfrew 1985).

The 'sign post' function has been proposed mainly regarding procession scenes depicting life-sized males or females walking in line and bearing offerings (e.g. vessels, flowers, wooden boxes, idols etc). Procession scenes are very frequent in Aegean wall painting[53] (Kontroli-Papadopoulou 1996; Immerwahr 1990, p. 114). When there is evidence of their original location in space, it reveals their association to staircases, corridors or vestibules (Immerwahr 1990, p. 88, 114-118). The most characteristic example of painted procession adorned the walls of the Grand Staircase in the palace of Knossos "directing the onlooker from the less important rooms on the lower or ground floors towards the very important rooms situated on the upper storeys" (Cameron 1970, p. 165). In Akrotiri processional figures attributed to a staircase have been discovered in Xeste 4 (cf. §2.3.4, Doumas 1992a, fig. 138-141; 2000b, p. 20). They represent men ascending on both sides of the staircase and continue up to three storeys. As discussed in Chapter 4, wall paintings that apparently aimed to guide movement and action in space also embellished Xeste 3. It has also been suggested that some nature scenes without narrative content, such as those that have been found in Room Delta 2 and the House of the Ladies at Akrotiri, could have functioned as backdrops for ceremonies (Marinatos 1984, 1985; Hollinshead 1989; Foster 1995; Peterson Murray 2004).

Nonetheless, many reservations have been expressed to date about the attribution of a primarily religious significance to all decorated spaces. The architectural context of mural decoration and associated finds suggest at least some of the buildings embellished with wall paintings were domestic units. On this basis some murals have been ascribed a secular function and are seen as a symbolic expression of the privileged social position of individuals or groups (Blakolmer 2000, p. 403; Doumas 2005, p. 78-79; Televantou 1994; 2000, p. 832). According to some of the advocates of this interpretation painted images of young males or females, like the Fishermen (pl. 1) and the Priestess (pl. 2) from the West House, and the Boxing Children (pl. 18) from Beta 1, depict family members of the building owner, while the scenes illustrated in the Miniature Fresco are deemed to be representations of the commercial and economic activities of the proprietor (Doumas 2005, p. 79; Televantou 1994).

Despite the different interpretations regarding the function of the decorated spaces that have been proposed in the past, at present it is widely accepted that in most cases it is very difficult to argue for a merely religious or

[53] Kontroli-Papadopoulou (1996) mentions twenty-four paintings from eight sites at: Knossos, Ayia Triadha, Akrotiri, Ayia Irini, Mycenae, Tiryns, Pylos, and Thebes.

secular character of Bronze Age murals. Lack of evidence, insufficient understanding of the modes in which the sacred and the profane were signified in the Aegean Bronze Age, but mainly the often indiscernible boundaries between religious and secular life in prehistoric societies (Frankfort 1949), are indicative of the difficulties that the process of interpretation entails. The more recent theories about the function of Theran wall painting explicitly express this ambiguity. As Blakolmer (2000, p. 399) has maintained, wall paintings representing rites of passage were probably linked to social ceremonies with a religious background rather than cult in a narrow sense. Such interpretation seems plausible not only for the wall paintings that decorated the private houses at Akrotiri, but also for Xeste 3, despite the strong religious symbolism of the murals discovered in the building, mainly expressed in the depictions of the altar and the goddess (cf. §4.3, pl. 12, 14). Furthermore, it has been noted that at least some of the Aegean, and especially Cretan murals, could have been created to serve the interests of an 'oligarchy with a theocratic orientation' (Gates 2004, p. 41) or have had a religious symbolism which was used to reinforce the privileged social status of the elite class (Chapin 2004, p. 54). Ultimately, however, and in spite of the various and often contradicting interpretations, the present knowledge regarding Bronze Age Aegean societies is very fragmentary and the social functions of mural painting remain obscure.

Since Theran murals aimed to be consumed by the members of the society in which they were created, the issue of visual access to the painted wall surfaces could provide important clues for their purposes and functions. The obvious consumers of the paintings were of course those who had or were allowed access to the decorated rooms, the inhabitants and visitors of the buildings. If these were the only individuals that could access the paintings, the viewing of Theran murals would have been restricted only to few selected individuals and groups (cf. Chapter 1), as Chapin maintains in her discussion on the consumption of Aegean landscape paintings (Chapin 2004, p. 60). Doumas (2005), however, has drawn attention into the less apparent aspects of the visual consumption of Theran frescoes. He maintains that, as a rule, wall paintings, at least in the private houses of Akrotiri, would have been visible through windows by passers-by outside the buildings, unlike what seems to be the case for buildings of public use (Doumas 2005). He, then, acknowledges the existence of a social logic in the distribution of the wall paintings in the settlement and the choice of decorated areas. As far as private buildings are concerned, this logic reveals the intention of the owner to communicate a message of prestige to pedestrians that could potentially encounter the paintings. On the contrary, according to Doumas, in public buildings of religious or secular significance, for example Xeste 3 and Xeste 4 respectively, wall paintings aimed to address their messages to particular groups who had the privilege to access the decorated spaces; a person situated outside these buildings could not have visual access to their mural decoration.

The possibility that frescoes, at least in private houses, could be seen by pedestrians traversing the street network in the course of their daily activities could precipitate new insights into the identity of the potential viewers of the paintings and the social significance of mural decoration; at the very least it implies frescoes were consumed by a much greater proportion of Theran society than usually imagined. However, such an assumption is more easily made than confirmed. Even though it is true that some of the decorated rooms had large windows that faced the squares and streets of the prehistoric town, in most cases it is hard to define the degree to which a painted theme would have been exposed to a viewer located in the public spaces of the settlement. One should take into account the fact that windows used to have wooden frames and were partly blocked with vertical or horizontal beams that are not preserved today (Palyvou 1990b; 1999, p. 406-407; 2005b, p. 196). Furthermore, frescoes mainly embellished rooms of the first floor and, hence, the likelihood of a pedestrian encountering the paintings was greatly determined by the location, distance and viewing angle that the paintings would have been visible (cf. §1.3). Finally, patterns of pedestrian movement within the settlement should also be considered, when discussing the degree to which views of the paintings were enabled from outdoors, or the extent to which they were part of the everyday experience of the townscape; the presence of pedestrians in the exterior open spaces of Aegean urban settlements is not self-evident, as the latter were distinguished by different levels of privacy. In some cases access to the public was unrestricted, and open spaces seem to have been used by all members of the community; on other occasions passage was more or less controlled and their use limited to particular groups (Palyvou 2004). Additionally, as is known from common experience even at present, some parts of a public street network, e.g. main thoroughfares, tend to be more widely used than others.

Within this framework a number of questions concerning the visual experience and social meaning of mural decoration can be raised: For instance, how much visible were the wall-paintings from the public spaces of Akrotiri? Were they visually exposed to the degree whereby one could distinguish particular themes? Were they seen with ease from a passer by or did their view require the intentional effort of the beholder? Who were the pedestrians or social groups that could have encountered the paintings and in which conditions did they experience the painted scenes? Were the murals visible from those locations of the street network where a pedestrian was more likely to pass through? Was the visual exposure of the paintings towards the street network intentional or merely an epiphenomenon? All these issues are possibly related to the function of the paintings and their consideration could potentially explain the wide distribution of these artefacts in the prehistoric settlement.

Without doubt, it is difficult to answer these questions, not only because we have solely an incomplete image of the Late Bronze Age town, but also because the evidence concerning the most important factor, the human presence in the street network, is limited and indirect. In the following chapters the issues raised above will be discussed using the available data. Firstly, by following the methodology of visibility recording and analysis described in Chapter 3 the areas of the street network from which mural decoration would have been visible will be outlined, and the degree of exposure and ease of view of the painted scenes will be examined. The issue of pedestrian movement in the prehistoric settlement is discussed in chapter 6.

Windows in rooms with mural decoration

A necessary condition for the paintings to be visible from the street network is the existence of windows in the decorated rooms opening towards public spaces. Despite the fact that fragments of painted plaster indicate the presence of wall-paintings in a great number of buildings, the exact architectural context of mural decoration is in most cases more[54] or less unknown due to

[54]In some cases the architectural context of mural decoration is unknown. The fragments found in Xeste 2 were discovered piled up in a small Room located at the area of the West façade of the

incomplete excavation or poor preservation. Quite often windows in rooms with painted decoration have been identified or their existence can be assumed, but the spaces towards which these windows face are frequently unexcavated.

Up to now 85 windows have been identified at the excavated buildings of Akrotiri and have been classified by Palyvou (1990b, 1999; 2005a, p.145-152) into four distinct types. Openings belonging to Type A (fig. 5-1) are small (0,50sq m) with rectangular shape and are found always at the ground floor. Type B (Palyvou 2005a, p.147-148) comprises of windows which are longer on the vertical axis and have a surface area of 1sq m. Such windows can been observed at both ground and first floors, as applies for the windows of Type C (Palyvou 2005a, p.148-149). The latter are large and longer on the horizontal axis (fig.5-2, 5-5), with a surface area varying between 1.43 sq m and 4.35sq m. Openings of Type C often have one or two intermediate supports. Finally under Type D are listed the pier-and-window partitions (fig. 2-5), which are multiple windows usually divided in four parts, occupying almost the entire wall (Palyvou 2005a, p.149).

We can positively say that at least in three cases rooms with painted decoration had large windows at the first floor (Type C or D) (Palyvou 2005a, fig. 216) looking over public spaces: Space Beta 1 of **Beta South**, room 5 of the **West House**, and the first floor room above the Gate at **Delta West** had large openings that faced towards the Square of the Mill house, the Square of the Ship Procession, and the Triangle Square respectively (fig. 1-1). The existence of windows in rooms with frescoes has been verified in a number of other occasions; the areas towards which these openings face are, however, unexcavated and their character remains obscure. We can imagine that the latter were mainly public open spaces, but the case of Delta 2 which had a window opening towards an interior space suggests that such assumption should be treated with caution. In Xeste 5 (pillar pit 68), wall-paintings have been found *in situ* in a room with a large window facing east (Vlachopoulos 2007), but nothing has been reported as yet concerning the space outside this opening. The same applies to the newly excavated Room 2 located east of Sector A (area pillar pit

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building (Vlachopoulos 2007) and apparently used to embellish another space in the past. Furthermore, the architectural context of the fragments recently discovered at the area of pillar pit 70 (Vlachopoulos 2007) is currently unknown.

72). In this case, mural decoration embellished the wall between two windows (Vlachopoulos 2007). Finally, a pier-and-window partition facing east (Palyvou 1999, p. 420, 388, fig 210γ) used to illuminate the space known as **"Kitchen"**, in which a great number of fresco fragments were discovered (Marinatos 1972, p. 15-16, pl. 14a ; Doumas 1992a, p.146; Palyvou 2005a, p. 86).

Despite the fact that as a rule all rooms in Akrotiri have at least one window (Palyvou 2005b, p. 196), in a number of cases the presence of windows in spaces with painted decoration can neither be affirmed nor ruled out from the available material evidence. Many unexcavated or poorly preserved rooms with frescoes adjoin exterior spaces and could have windows facing outdoors. The partially excavated architectural context of Gamma 7 (**Gamma South**), in which fragments depicting rosettes were discovered (Vlachopoulos 2007), has been recently reconstructed by Palyvou (2005a, 69, Fig.86) as a square room with a column in the centre with a probable large window on its west wall. The open space that lay to the west of the suggested window has only partially been revealed. The recently restored frescoes of the **Porter's lodge** (Marinatos 1969, p. 28) are comprised of two friezes, however, not much is known regarding the form of the first floor room that these paintings adorned. It has been observed, however, that painted friezes may suggest the existence of *polythyra* or pier-and-window partitions (Cameron 1976, note 17; Palyvou 2005a, p. 184) and it is possible that these paintings were in a room with a large window facing towards the street. Wall-paintings that have been discovered in the area of Room Gamma 1 (**Gamma South**) depict spirals and floral motifs (Marinatos 1970, p. 39-40), and some of them according to Doumas (1992a, p. 146) perhaps decorated a frieze. As Gamma 1 is delineated on its three sides by exterior walls, one can imagine that at least one window facing outdoors would have existed. In addition, the existence of windows in the flights of the staircase of **Xeste 4**, whose walls were decorated with the procession scene, should be rather expected (Doumas 2005), since these would have provided the necessary amount of natural light for those ascending or descending the stairs. Room B6 of **Beta South,** that used to house the wall-painting of the monkeys (pl. 20), was greatly damaged by torrential waters and its architectural form at the first floor can only be conjectured. The room had a floor covered with volcanic slabs that collapsed together with the decorated wall surfaces (Michailidou 2001a, p. 287). Fragments of murals have been found mainly along the north wall. Marinatos (1971b, p. 45) has attributed the restored parts of the wall-painting on the north and west wall, while Doumas (2005) on the west and south. Doumas (2005, p. 76) assumes the existence of a window on the long north wall of the room. A window positioned in the middle of this wall, above the two small windows of the ground floor, would conform to the typical arrangement of windows at Akrotiri (Palyvou 2005b, p. 196); nonetheless, the presence of an opening in the east wall of this room cannot be ruled out, either. The few fragments of mural decoration that have been found in **Delta North** were also unearthed in spaces that had at least one exterior wall. Those coming from Room Delta 17 (Marinatos 1976; Doumas 1992a, p. 146; Michailidou 2001a; Palyvou 2005a, p. 82) have been attributed to a missing upper floor of the building (Michailidou 2001a, p. 312)[55]. Some fragments have also been found in the area of room Delta 4 (ibid.) that is preserved at the ground floor level.

The above suggests there may have been a great number of cases in which a pedestrian traversing the street network would have been able to see the coloured surfaces of building interiors. As mentioned above, however, the possible presence of windows looking out onto public spaces would not have necessarily enabled the viewing of frescoes from outside the building. Regarding spaces 1 of the **House of the Ladies** and Delta 2 of **Delta East** it can be confidently stated that this was indeed the case. Delta 2 has a window that faces the roofed ground floor space Delta 21, while Room 1 of the of the House of the Ladies on the second floor had a window with dimensions 0.47x0.47m, too small to allow visual access to the mural decoration that adorned the room (Doumas 2005, p. 74). Relative small openings pierced also the walls of Room 4 of the West House; Room 4 had a window of Type B facing onto the narrow alley at the west of the building (87x127), and another opening of a similar size (87x132) facing onto the Triangle Square (Palyvou 1999, p. 419). It is unlikely that openings of this size at the first floor would have permitted visual access to the interior of the house. In addition some paintings in Room 3B of Xeste 3 (pl. 8, 9,

[55] Nevertheless, Palyvou (2005a, p.82) notes that Delta 17 did not have an upper floor, since the room had a spout at roof level.

10) could also have been visible from the Square of the Lustral Basin through the large window at the north wall of the room. It is most probable, however, that this window was blocked by a dense wooden lattice, as applies for other ground floor windows (Room 2) of this building (Palyvou 2005a, p. 150, fig. 229). Such a feature would have obstructed the viewing of the paintings of Room 3B from outside the building. The presence of lattices blocking the windows should be considered possible even regarding first floor rooms, as suggested by excavation evidence.

Wooden lattices

Urban representations in Aegean iconography and architectural remains suggest that windows had wooden frames that were blocked on many occasions by wooden lattices (Morgan 1988, p. 79-81; Palyvou 2005a, p.150; 2005b, p. 196; 1999, p. 396-400). In Akrotiri imprints of these lattices on the volcanic material are in some cases preserved, and indicate that such features were associated with openings of all four types that have been identified in Akrotiri (Palyvou 2005b, p. 196). In small windows of Type A and B at the ground floor the lattices were dense and often consisted of two or three horizontal boards that left only narrow (up to about 10 cm) gaps between them (Palyvou 1999, p. 397-399; 2005a, p. 150) (fig 5-1). The imprints of lattices associated with large windows of types C and D[56] (Palyvou 1999, p. 396-397; 2005a, p. 151)

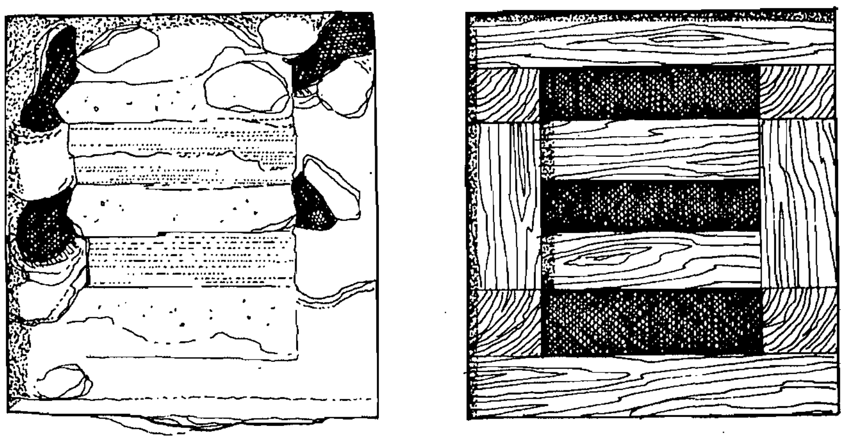


Figure 5-1: A window of Type A with a wooden lattice Left: the imprint of the window as recorded during excavation, Right: a reconstruction of the window. From Palyvou (1999, p. 398).

[56] Namely the windows with a long horizontal axis and pier-and-window partition respectively (see typology at the beginning of subchapter).

Figure 5-2: The imprint of a wooden lattice of a first floor window (Xeste 2). From the excavation archive

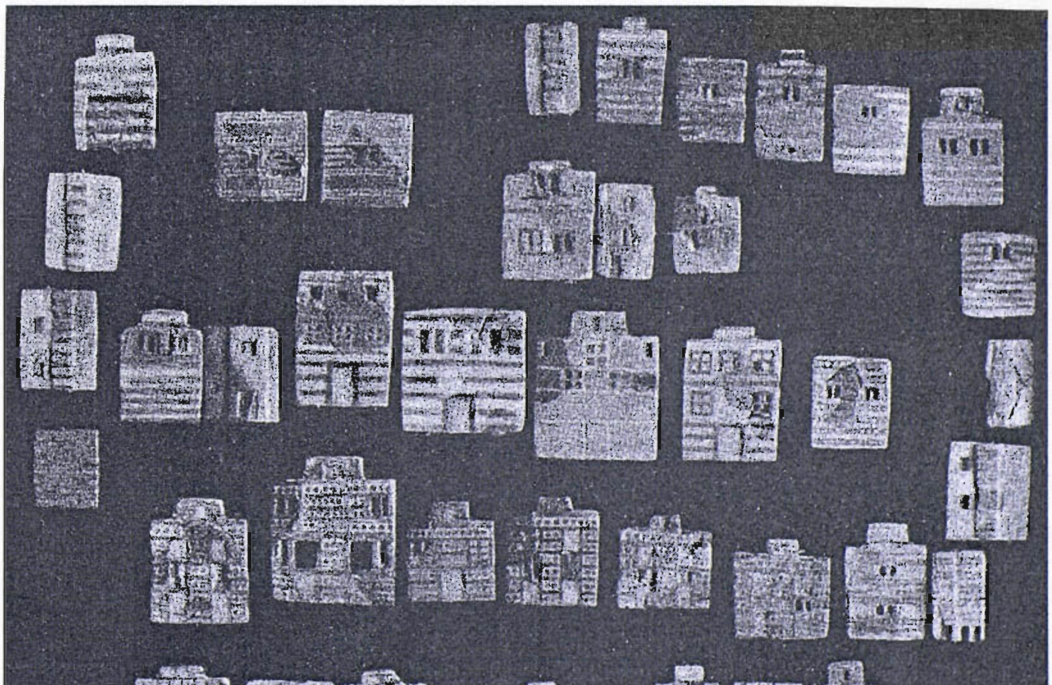


Figure 5-3: The town mosaic. From Evans (1921, fig. 223).

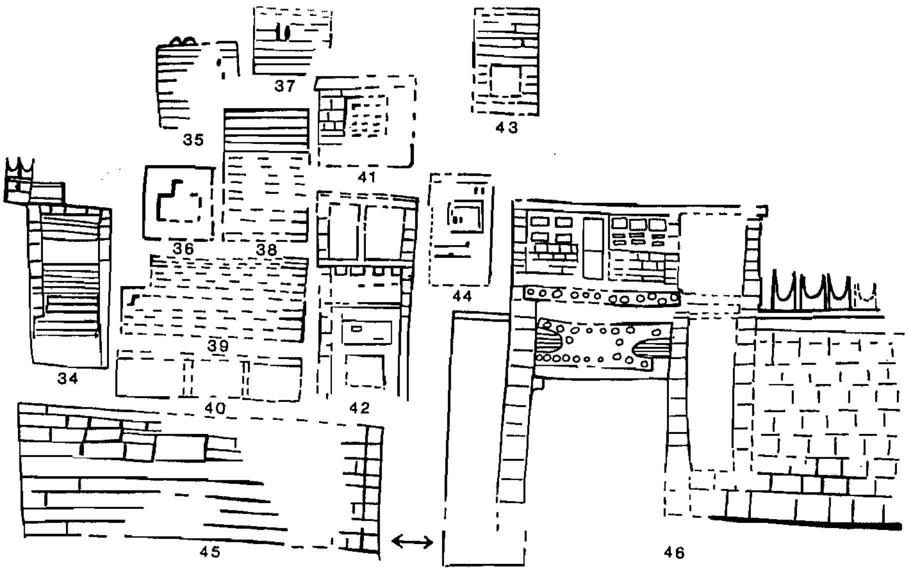


Figure 5-4: Drawing of the buildings of the Arrival town (Room 5, West House). From Morgan (1988, pl. 106)

are rarely preserved. The only example mentioned by Palyvou (1999, p. 396-397) comes from the first floor of the north façade of Xeste 2, belonging to a window with a long horizontal axis and dimensions of about 1.80x1.25m; this seems to have been blocked by one horizontal and three vertical wooden beams placed in the middle of the window (fig. 5-2). It appears, then, that the lattices of large windows on the first floor were not as dense on the horizontal axis, as those of smaller windows of Types A and B on the ground floor, which apparently aimed to prevent intruders from entering the house (Palyvou 2005a, p.150). This is also verified by architectural representations in Aegean art (fig. 5-3, 5-4) where in many occasions large windows seem to be divided into four or six panes (Morgan 1988, pl. 106, 111).

However, iconography also suggests that not all windows had horizontal boards blocking their opening. Many windows at the Town Mosaic from Knossos (fig. 5-3), the Miniatures of Akrotiri (fig. 5-4) and Ayia Irini, and the Archanes house model show rectangular or square windows that are either simple or are vertically divided in two, three or more lights (Morgan 1988, p. 79-80). These windows lack horizontal wooden beams. The imprint of the window of A1 does not support the existence of horizontal boards although vertically it is divided into three parts (fig. 5-5).

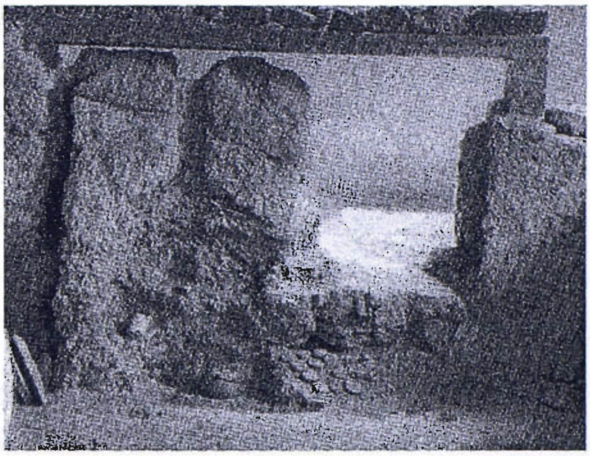


Figure 5-5: Imprint of window from sector Alpha. From the excavation archive.

Neither iconography[57] nor excavation evidence[58] provide any clues for the presence of shutters (Marinatos 1970, p. 33; Palyvou 1999, p. 406-407). According to Palyvou their existence can be ruled out, if windows had lattices. It has been reasonably suggested that parchment, mat, or cloth may have been used to control weather conditions when that was necessary (Palyvou 1999, p. 406-407). These would also have obstructed the visibility to the interior of the houses. However, one has to consider that these features would have been used to control the amount of light and air coming into the room according to the ephemeral needs of the residents, having only transient effects on the visual exposure of mural decoration from the street. Generally, it is believed the climate in the Late Bronze Age Aegean was not notably different than it is today, while air temperatures would have been slightly warmer (McCoy 1980, p. 96). It is also obvious that on certain occasions, openness is the prevailing concept behind the architectural form of rooms embellished with murals. For example, in Room 5 of the West House, or the first floor room above the Gate, the great number of window openings exceeds the requirements of any practical function. In these cases, one can imagine that pier-and-window partitions would have been used to allow for the maximum amount of light and air into the rooms, when the weather conditions allowed for it.

[57] Laurence (1973, p. 27) has suggested, however, that the red windows in the Town Mosaic might represent solid shutters.

[58] Palyvou (1999, p. 407) convincingly argues against the possibility that the imprints of thin wooden boards found in front of the north wall of Room 5 of the West House (first floor) belong to shutters.

5.2 The visibility of Theran murals from the open public spaces

Inevitably, computational recording and analysis of the visibility characteristics of mural decoration can only be implemented when there is enough evidence to reconstruct the architectural form of the decorated spaces, and only when something positive can be stated about the location of frescoes. The cases of room B1 of **Beta South**, room 4 and 5 of the **West House,** and the first floor room above the Gate at **Delta West** fulfil these criteria, even if the level of confidence in the reconstructions of these spaces differs. Although the sample is small, these rooms are distinguished by common features of Theran architecture, such as pier-and-window partitions and Type C windows, painted friezes, and entire wall decoration. Therefore, the investigation of the visibility of wall paintings from these spaces aims, besides exploring the communication impact of the murals in question, to illuminate and draw attention to the general conditions under which Theran painting could have been visible.

5.2.1 The West House

The most thoroughly investigated building in the prehistoric settlement, the West House (fig. 1-1, 5-6, 5-7), is located at the north edge of the Triangle Square, at the west of the excavated area. It is a medium-sized free-standing structure, surrounded by three open spaces: the "Square of the Ship procession" at the northwest, the "Square of the Cenotaph" at the northeast, and the Triangle square at the southeast (fig. 1-1). The "Square of the Ship procession", which was named after the famous fresco that decorated Room 5 of the West House on the first floor (Doumas 1997, p. 158), is partly covered by the remains of a collapsed building (Palyvou 2005a, p. 39, 46), and therefore its exact extent is not known. A narrow alley running along the southwest outer wall of the West House separates it from the other buildings that lay in this area (Palyvou 2005a, p. 46).

Figure 5-6: A view of the West House from the south. From the excavation archive.

The West House having three storeys, the third extending only to its eastern wing, follows the model of a typical Theran house (Palyvou 1990a). It has only one entrance facing the Triangle Square which gives direct access to the main staircase of the building. As in most houses of Akrotiri, the eight rooms of the ground floor, which are relatively small, dimly lit and have no mural decoration, would have been used in the past for storage, food preparation and other workshop activities (Michailidou 2001a, p. 428, 467, 469). These rooms had small windows piercing the outer walls of the building at a height close to the level of the Triangle square. In fact, the floors of most of the rooms of the ground floor lay up to 1.80 m lower than the street level, and were essentially semi-basements (Palyvou 2005a, p. 46). As already mentioned (cf. § 2.2) this is mainly the result of the accumulation of debris in the open spaces of the settlement after the LBA seismic destruction, which caused a significant increase to the street level.

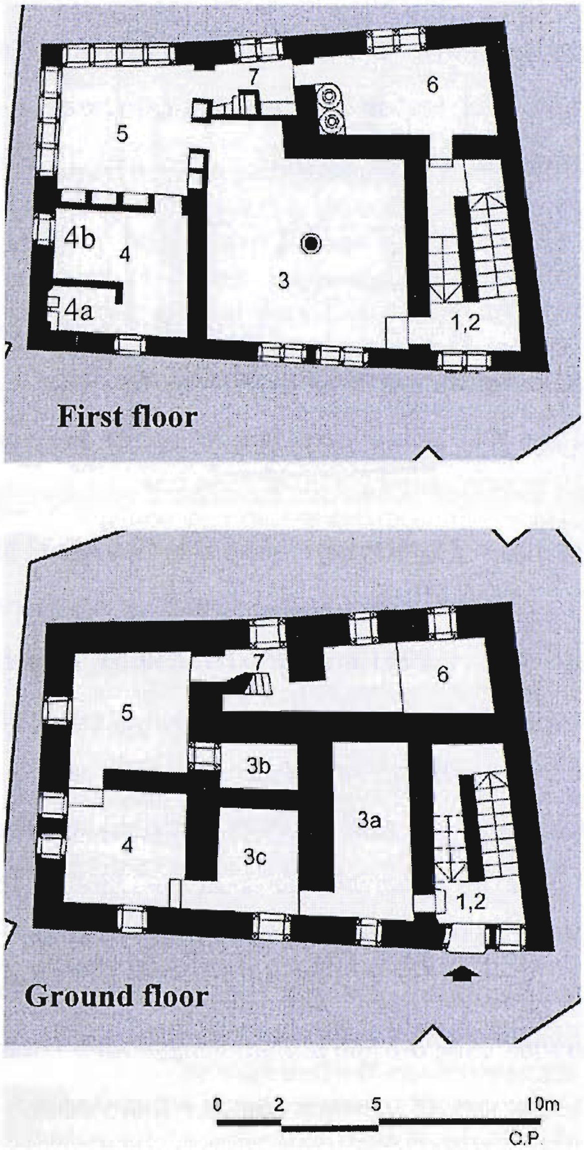


Figure 5-7: Plans of the ground and first floors of the West House (from Palyvou 2005a, p.47)

In comparison to the ground floor, the second storey of the house has a much more sophisticated appearance. Here, rooms are spacious and well illuminated, especially those in the south west wing, which is embellished with mural decoration. This part of the house, which consists of Rooms 4, 4a, 4b and 5, is accessible via the main staircase and Room 3, or through the auxiliary staircase of Room 7. Room 3, one of the largest rooms discovered so far, is distinguished by the great number of loom weights (450) that have been found in it, which indicate that it used to accommodate weaving activities. A large window is presently restored in the south wall of the room[59] that would have provided the appropriate amount of day light for weaving. Room 3 has no mural decoration, and its walls were covered with white plaster. At the northwest end of this space a door opening provides access to Room 5, certainly the most elaborate room of the house judging by its architectural form and mural decoration.

The southwest wing: architecture

Space 5 had a total of eight windows arranged in two pier-and-window partitions, placed at the north and west walls. The east and south sides of the room were delimited by a series of cupboards and door openings. The two doors at the east side led to rooms 3 and 7 respectively, while the one in the south wall gave access to space 4. Room 5 was paved with large volcanic slabs, whose interstices had been painted red (Palyvou 1999, p. 207-208), a construction detail that further added to the luxurious appearance of this room.

Room 4 was only accessible through Room 5 and was divided by thin mud-brick partitions (Palyvou 1999, p. 165) into three smaller spaces. The one at the south-west (Room 4a) housed a lavatory installation, and its walls were painted with yellow-ochre plaster (Doumas 1992a, p. 49). On the other hand, rooms 4 and 4b were embellished with wall paintings and were illuminated with two medium sized windows facing the narrow alley between West House and the House of the Anchor, and Triangle Square respectively. In Rooms 4 and 4b the mural decoration consisted of a series of variations of the well-known motif of the Ship Cabin (pl. 3, Doumas 1992a, fig.49-62). The jambs of the window in Room 4 were also embellished with painted flower pots (Doumas 1992a, fig. 63-64).

The wall paintings of Room 5

As already discussed in §1.1, in Room 5 all available wall surfaces were covered with wall paintings (pl. 1-7, fig. 5-8). Painted imitations of variegated marble alternating with wood were represented below the window sills (pl. 4, 5). Above them at the southwest and northeast corners of the room, the two famous

[59] Palyvou (2005a, p. 47, fig. 46) has lately reconstructed two double windows at that location.

paintings of the fishermen were depicted (pl. 1). They formed two panels, each one representing a nude young male holding fish arranged in bunches. Televantou (1994, p. 173-174) has convincingly argued for the positioning of the "Priestess" (pl. 2) at the east door jamb of the opening that connects rooms 4 and 5. Finally, one of the most impressive examples of Theran art, the Miniature Fresco (pl. 4, Doumas 1992a, fig. 26-48), expanded into four friezes located at the upper part of all four walls of the room, namely the areas above the window and door openings. This mural is a complex pictorial composition 16m long and is perhaps the most often discussed example of Theran mural painting, not only because it provides unique information about various aspects of life in the prehistoric Aegean, but also because it has fostered contentions and controversial interpretations.

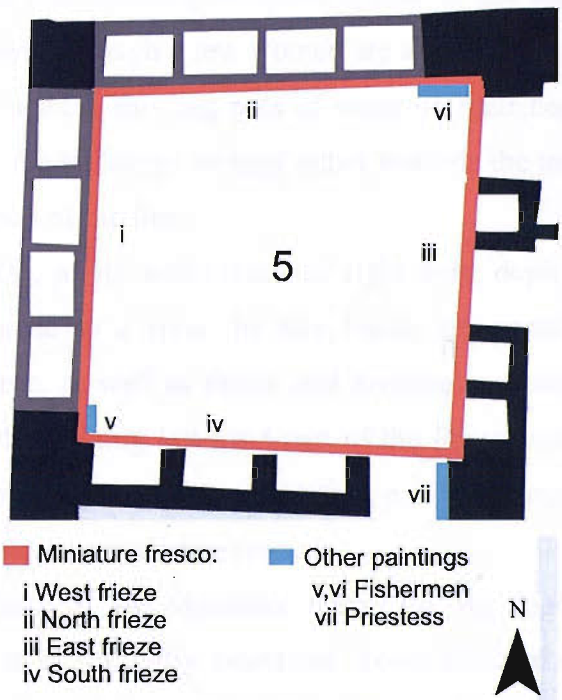


Figure 5-8: The location of mural decoration in Room 5 (first floor) of the West House.

Considering what is apparent from currently restored fragments (1994), the four friezes depict five towns in their surrounding landscape. The scenes are populated with about 321 human figures, while domestic, exotic and mythic animals, including plants that are characteristic of each location are also represented (Televantou 1994, p. 201). Some of the friezes, and especially those attributed on the west and north walls, are poorly preserved. The West frieze has been almost wholly perished except from two fragments showing buildings with characteristic black triangular projections on their roof. According to Televantou (1994, p.201) these belonged to the depiction of a town (Town I).

The north frieze is much better preserved, with almost half of the original painting surviving (Televantou 1994, p. 171), and although it was discovered in many fragments, most of its scenes have now been restored. It depicts a large and densely populated coastal town (Town II) that is protected by a wall and is situated at the top and slope of a hill. From the harbour and the countryside that surround the town only parts have survived. In this setting a number of scenes unfold: a meeting of men upon a hill, pastoral scenes of herds-men leading bulls, goats and sheep, a procession of soldiers with Aegean weaponry moving towards the town. At the bottom of the frieze a fleet of ships can be seen. In their vicinity dead naked men and their floating weapons appear in the water. Most of the human figures are men, although a few women are also represented: two of them are walking close to a well, carrying pots of water on their head. More women stand on the roofs of the buildings looking either towards the meeting on the hill or towards the direction of the fleet.

The east frieze, at its well-preserved right part, depicts a sub-tropical landscape situated close to a river. Its two banks are populated with reeds, papyrus and palm trees, as well as exotic and mythical animals (griffin, jackal, wild ducks etc). At the missing left hand part of the frieze another town (Town III), has been restored by Televantou (1994, p. 198), suggesting that this landscape was also related to an urban scene.

The south frieze of the Miniature fresco (pl. 4), depicting two towns (Towns IV and V), is almost fully preserved. Town IV, at the left side of the frieze, is a riverside, as well as a coastal town that is the departure point of the large fleet that occupies the greater part of the scene, in the middle of the wall. It consists of seven large vessels that are lavishly decorated with emblems on the hull, prow, and stern. Six of the ships have sheltered passenger compartments under which men with long robes are sitting (Morgan 1988, p. 117). Above the heads of the men spears and helmets appear to be attached. Apart from them 18-20 paddlers are depicted in each vessel. Most of the large vessels have a small ship cabin at the stern, similar to the life-sized ship cabins that adorned Room 4.

A single male figure is seated in each cabin. The fleet approaches Town V whose inhabitants have gathered at the harbour to watch its arrival.

A great number of diverse opinions have been expressed about the meaning of the scenes of the Miniature Fresco. These form a quite extended body of literature that has been very well summarised by Televantou (1994) in her PhD thesis discussing the reconstruction and interpretation of the paintings of the West House. According to one group of scholars (Marinatos 1974, p. 38-60; Televantou 1994, p. 321-349; Doumas 1992a, p. 47-49; Page 1976; Davis 1983) the scene depicts real and continuous events, a long overseas voyage of an Aegean fleet, the ports of call during the journey, peaceful meetings and war conflicts with the local population, and finally the return of the fleet to the home town. Many suggestions have been made about the identity and possible location of the Towns II, III, IV which according to the authors mentioned above were located either in Africa or the Near East. Other interpretations suggest, however, that all towns are Aegean (Warren 1979b), while some, have argued that the scenes of the north and south friezes depict peaceful events, religious or social ceremonies and seasonal public festivals, rather than a long journey and war scenes (Sakellariou 1980; Morgan 1988; Marinatos 1984; Gesell 1980). In many of the above interpretations Town V is usually, but not always, identified as Akrotiri itself (Marinatos 1974, p. 55; Televantou 1994, p. 337; Doumas 1992a, p. 49; Marinatos 1984, p. 54; Shaw and Luton 2000).

It has been proposed that the owner of the West House was an active participant in the represented events (Marinatos 1974, p. 43; Doumas 1992a, p. 49; Televantou 1994, p. 349), as either the admiral leading the Aegean fleet, or a priest in the ceremony, depicted in the south frieze inside the ship cabin of the flagship (Marinatos 1974, p. 43). The suggestion that the proprietor of the house played a leading role in the illustrated scenes is mainly supported by the depiction of life-sized ship cabins on the walls of Rooms 4 and 4a, that probably aimed to denote participation in sea-faring activities and the high social status of the owner of the house (cf. §2.3.5).

The reconstruction

Since the West House is the best investigated and published building in Akrotiri up to now, there is much evidence for a detailed reconstruction of Room 5 (Televantou 1994, p. 165-172). The restoration of the paintings, some of which were found *in situ*, has enabled the reconstruction of the dimensions of the few wall surfaces of the room. The marble imitations that decorated the space below the window sills at the north and west wall (dimensions 0,45x4.10 and 0.45x3.70 respectively (Doumas 1992a, p. 50), were found at their original position (Televantou 1994, p. 52-53). The fisherman of the northwest wall (1,17x0,69) was detached from the wall surface it used to decorate, and had slipped on the floor just below it (Televantou 1994, p. 54), while the fisherman of the southwest wall (1,20x0,55) was recovered in fragments close to the southwest corner of the room (Televantou 1994, p. 57). Both wall-paintings have been restored to their initial height of about 1,20m. This should have been also the height of the openings of the pier-and-window partitions. The Miniature fresco was placed above the wooden lintel of the windows, the north and south frieze at approximately +- 1,836-1,846m and the east and west at about +- 1,952-1,972m above the floor of the room (Televantou 1994, p. 171). The exact vertical dimension of the paintings is known after the restoration of the surviving fragments: 0.43 for the south frieze, 0.45cm for the north, and about 20cm for the east (Televantou 1994, p. 170). Twenty centimetres is also the suggested height for the west frieze (Televantou 1994, p. 169), although, as mentioned above, it has almost completely perished.

Details of the form of one of the *polythyra* can be seen in a photograph that shows its imprint on the volcanic materials; the vertical divisions of the opening can clearly be distinguished, but there is no evidence that the window had a dense lattice (Palyvou 2005a, fig. 225). In the reconstruction that was used for the analysis horizontal wooden boards with a width of 15cm were added at about half the height of the openings, as it is proposed in the published paper reconstruction of Room 5 (Palyvou 2000, p. 418, fig. 4; 2001, p. 128, fig. 2).

The height of the window from the public spaces was derived from the plan of the north elevation of the building (Appendix II, Plan 5). The lower limit of the opening was to be found at about 2.85m above the street level.

Visibility recording and analysis

The visibility of the Miniature Frieze was recorded for about 2500 viewpoints defined by a 20x20cm grid laid at the areas northwest and west of the building. As applies to all implementations of visibility analysis presented here, the viewer's eye level was taken into account, and was set at 1.55 m. The space at the northwest of the West House has been identified on the topographic plan of the excavated area (fig. 1-1, 2-4), as the Square of the Ship Procession. Although, as mentioned above, Palyvou (2005a, p. 39) notes that the exact shape of the area is uncertain because it is partly covered by the debris of building Z (fig. 2-4), remains belonging to a third built structure have yet to be identified in this area. The pillar pit 24A at the northwest of the West House verified the existence of an open space in this part of the site, which probably dates to the beginning of the LC period (Georma 2008). So, the existing evidence suggests that the area among the building Zeta, the West House and the western limit of the excavation was a public square.

The area to the southwest of the West House is marked as a broad open space on the general topographic plan of the site (fig 2-4). The House of the Anchor is located in close proximity to this space, but the building has not been unearthed, and its northern outline is unclear. Palyvou (2005a, p. 35), mentions, however, that "a very narrow alley" separates the West House from other buildings at the west (Palyvou 2005a, p. 46). Since the form of this public space is ambiguous, it is not included in the analysis.

The visibility of the south, west and east frieze was, therefore, recorded from locations in the Square of the Ship Procession only. It is apparent that the North frieze would not have been visible from the square. The analysis was repeated twice; the first time no angle restrictions were set, while the second time only the visible wall surface that could be seen between 30 degrees below and 25 degrees above the viewer's horizon were recorded. As discussed in Chapter 3 this is the angular range between maximum and optimum eye rotation. Within these limits wall-painting would have been visible with ease by the moving observers, namely without necessarily having to lift their head upwards or stop to see the paintings.

Results

The results of visibility recording (fig. 5-9, 5-10) suggest that the South Frieze, depicting the return of the Fleet, would have been more visible from the Square of the Ship Procession. The visual exposure of the painting from that space reaches up to 86%. On the contrary, the east and west friezes seem to be much less visible from the square (up to 51%), and are generally seen from fewer viewpoints. These results refer to the area of the painted surface that was exposed to a viewer located in the street network, and not to the degree that the theme was discernible. The later issue will be discussed in the conclusions of this chapter. It is also noteworthy that the great majority of the locations from which the paintings are visible fall in most cases at least 4 metres away from the walls of the buildings. This observation is important and its significance will also be examined in §5.3.

Generally the results of the analysis with the angle restrictions show that from almost all locations that would have enabled the visual exposure of the paintings the murals were seen within the specified angular range, meaning that the paintings would have been appreciated with ease. Exceptions form the locations closest to the walls of the buildings from which the west and east friezes would have been visible (fig. 5-10). The recording of the visibility with the angular restrictions suggests that the viewer in all cases should be at least 3m away from the wall of the house and in the case of the south frieze 4m, so as to see the murals with ease.

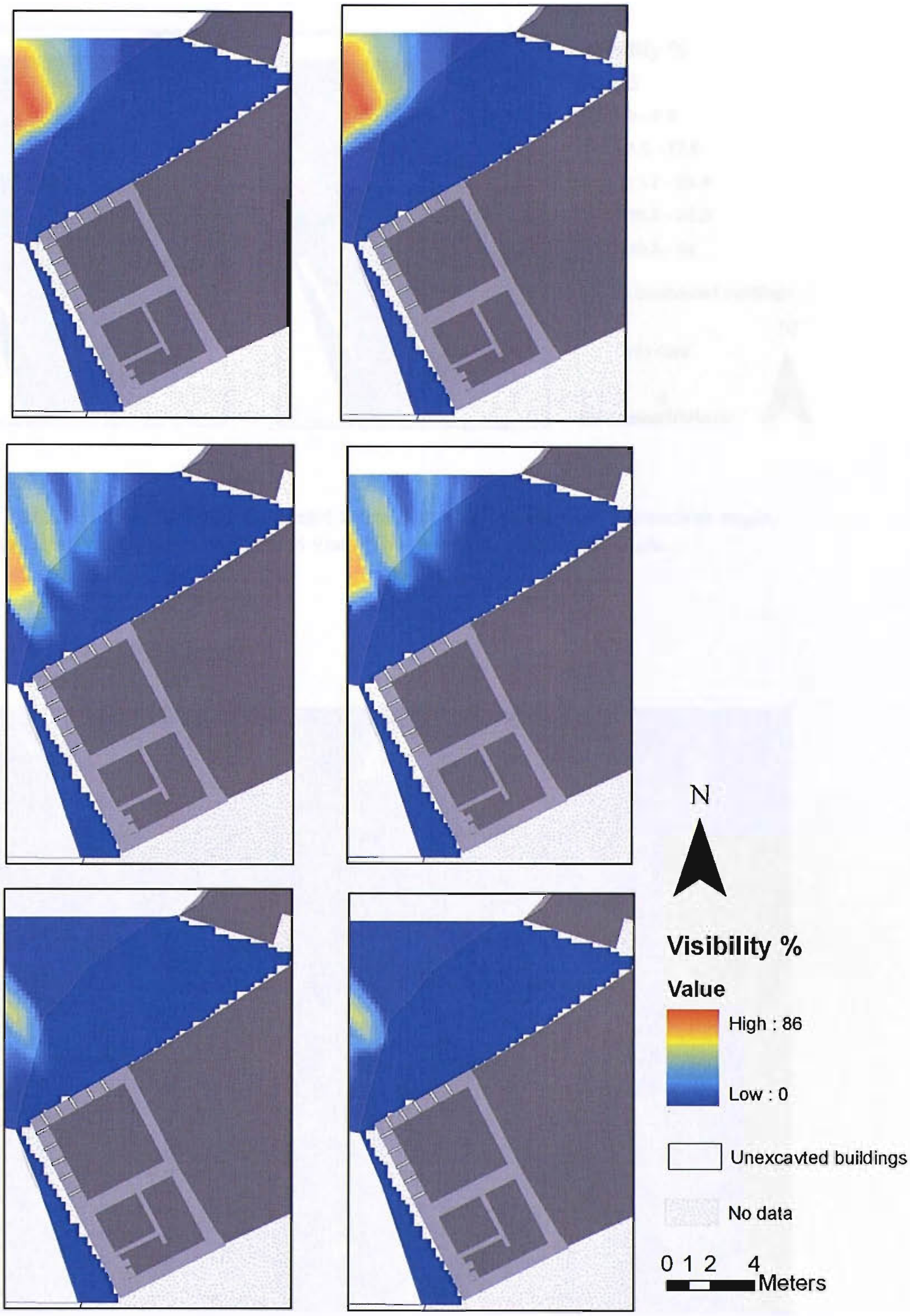


Figure 5-9: Top: The visibility of the south frieze from the square without (left) and with angular restrictions (right). Middle: The visibility of the west frieze from the square without (left) and with angular restrictions (right). Bottom: The visibility of the east frieze from the square without (left) and with angular restrictions (right).

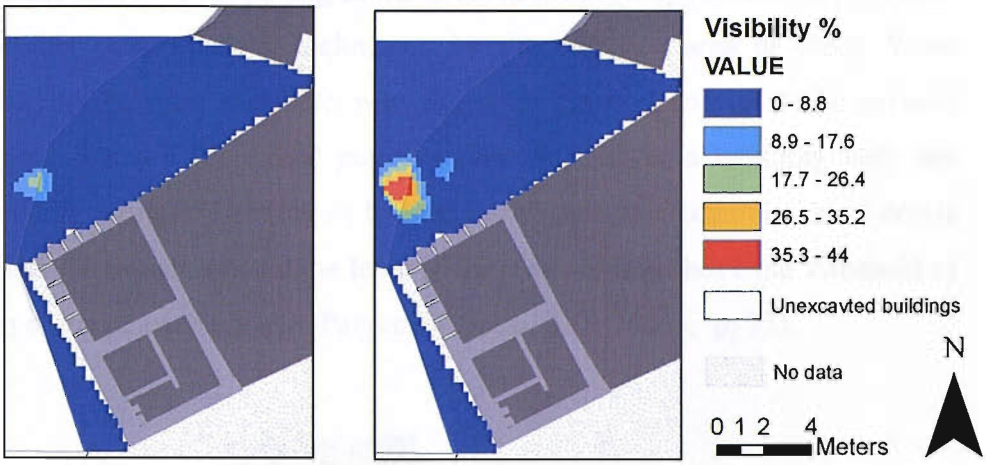


Figure 5-10: Left: the areas from which the east frieze is visible but not from convenient angle. Right: the areas from which the west frieze is visible but not from convenient angle.

5.2.2 Delta West: The Gate

Figure 5-11: The gate: A view from the south. From the archive of excavations at Thera.

The Gate (also known as Pylon) (fig. 1-1, 5-11, 5-12) is a built structure at the south of the Triangle square protruding from the west façade of Delta West. It is composed of a wall at its west side and two large openings at its north and south. The latter create an unconstrained passageway for the pedestrians traversing the Triangle Square, as indicated by the fact that the floor below the

Gate has the same cobble paving as the street network (Palyvou 2005a, p. 75). At the east this passageway is delineated by the entrance area of Delta West. According to Palyvou the Gate was added to the building after the seismic destruction; it has a functional purpose, namely to form a retaining wall and prevent the flooding of Delta West by rainwater, since the accumulation of debris in the Triangle Square caused the level of the plaza to rise above the threshold of the main entrance of the house (Palyvou 1999, p. 323; 2005a, p. 75).

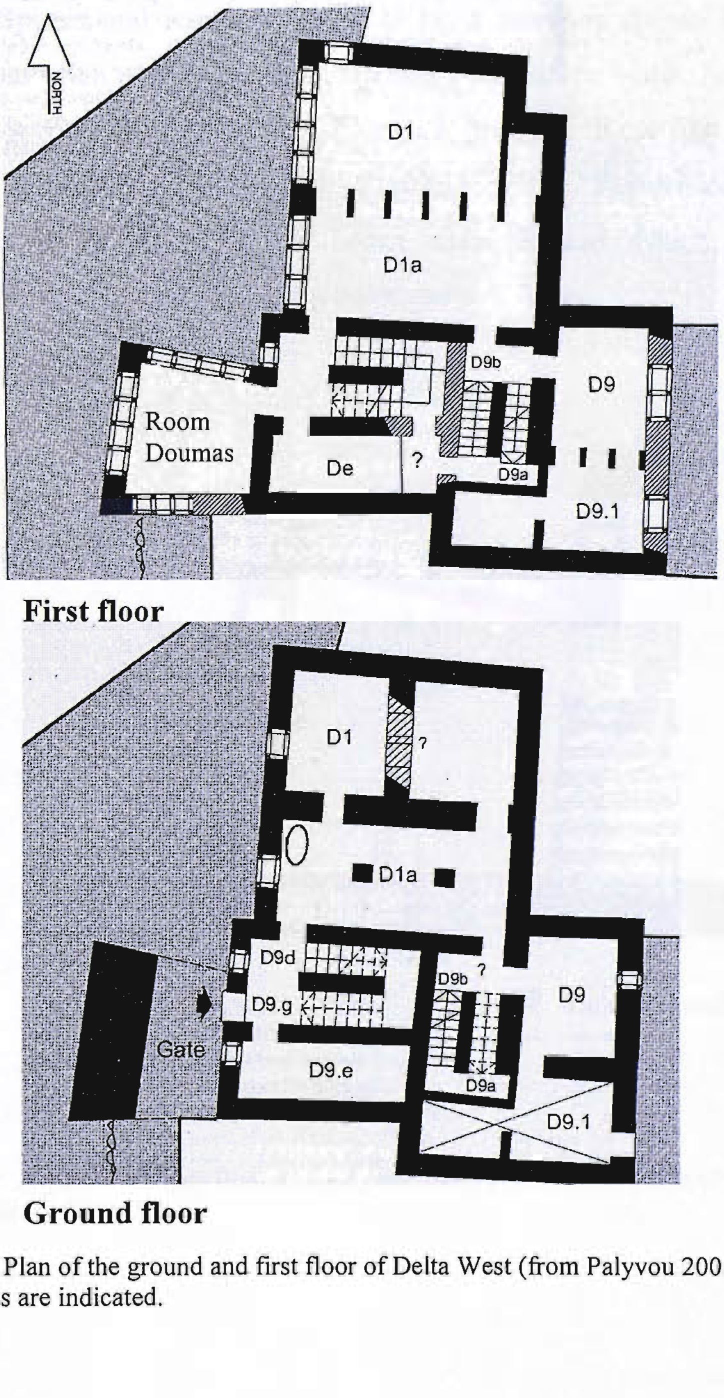


Figure 5-12: Plan of the ground and first floor of Delta West (from Palyvou 2005a, p.76). Hatched walls are indicated.

The first floor room above the Gate, which has been named after Doumas (Vlachopoulos 2007), was accessed through the main staircase of the house. The fragments of frescoes recovered in this area depict spirals and rosettes, but the compositions have yet to be restored (Marinatos 1974, p.18; 1976, p.16). Immerwahr's (1990, p. 188) catalogue lists fragments of rosettes coming from the area of the Gate, noting that belong to a frieze. Palyvou (2005a, p. 80) who has reconstructed three pier-and-window partitions at the west, north and south wall of "Room Doumas", also suggests that the surviving fragments embellished a frieze. Spirals and rosettes appear to be a common theme in Theran wall painting and often used to decorate the upper part of the walls. Friezes of spirals and rosettes embellished Room 2 of Xeste 3, probably at the first floor (Doumas 1992a, p. 128, 132, fig.93-94). The rosettes found in "Room Doumas" are very similar to those recovered in sector Gamma and which, according to Vlachopoulos (2007) also probably belonged to a frieze.

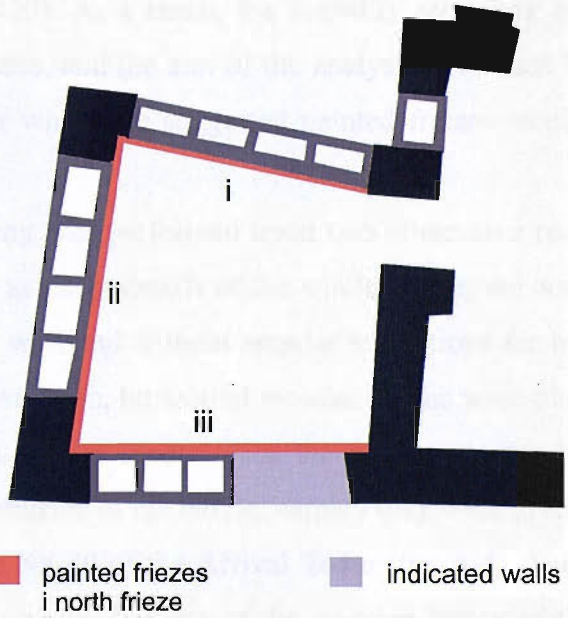


Figure 5-13: A plan of the gate (based on Palyvou 2005, p.76). The location of the suggested friezes is indicated in red.

The reconstruction

The reconstruction of the Gate was based on the elevations and plans created by Palyvou (fig. 5-12, Appendix II, Plan 6). If the fragments belonged to friezes, as it has been reasonably suggested, then the mural decoration could be attributed to the north, south or west walls of the room above the three pier-and-window partitions, although it cannot be excluded that more than one or all walls had murals, as is often the case in Akrotiri. For the needs of this research a recording of the visibility of the wall surface above the windows was performed. That part of space was given a tentative height of 45cm that conforms to the dimensions of the north and south friezes of the Miniature fresco of the West House (Doumas 1992a, p. 66). Nonetheless, one has to bare in mind that the areas above the window lintels may not have had the same height, as applies to Room 5 of the West House, where the east and west friezes were half the height of the south and north. The height of the window openings is also uncertain; a vertical dimension of 1m was given in this case, a plausible suggestion if one takes into account available data from better preserved contexts in Akrotiri (Palyvou 1999, p. 418-420). As a result, the visibility recording can only give tentative values in this case, and the aim of the analysis is to shed light into the general conditions under which the suggested painted friezes would have been visible.

Visibility recording was performed upon two alternative reconstructions of the building that vary as far as details of the window form are concerned. The analysis was carried out with and without angular restrictions for both cases. In the first proposed reconstruction, horizontal wooden beams were placed at about half the window height. In the second case the windows were reconstructed without the horizontal elements of the lattice, namely they were given a form that is similar to the opening No 40 of the Arrival Town (fig. 5-4). The aim was to investigate the degree to which features of the wooden lattice of the windows, such as horizontal beams, would have affected the visibility of the wall-paintings.

Results

The analysis was performed from 2637 points for the south, 2909 for the north and 2727 for the west frieze. The results show that the friezes would have been visible in the west up to 70% (fig. 5-17), the north 52% (fig. 5-16), and the south 76% (fig. 5-14), although due to the uncertainty regarding the exact location and dimensions of the friezes the outcomes of this analysis should be interpreted qualitatively. It is enough to say in this case that wall decoration on the upper part of the walls of "Room Doumas" would have been visible to a great extent.

In the cases where the horizontal wooden beams were added to the windows the percentage of each painted wall exposed was reduced for some of the observer locations, although not for all. Few viewpoints from which the south, and north frieze (at least up to the area of Delta 15) of the Gate are visible are affected (fig.5-15, 5-16), while in the case of the west frieze the effects of the wooden beam appear to be more substantive. For most of the locations from which the mural is visible the visibility values are decreased and in some cases the decline of the visible area reaches up to 20 % (fig. 5-17, 5-18). Generally, however, the results of the analysis suggest that a wooden frame of that form would have obstructed, but in most cases not significantly, the visibility of the paintings.

When examining the spatial distribution of the locations that permit the viewing of the paintings, it is noteworthy that the south and north frieze appear to have been visible from areas at least five metres away from the walls of the buildings, while the frieze of the west wall can be seen from areas that are up to 2 metres close to the wall. The recording of visibility with angular restrictions suggests, however, that the west frieze would only have been seen with ease from those locations that are again at least 5m (fig. 5-17b, d, 5-18) distant from the Gate. Regarding the south and north friezes the wall-paintings would have been seen with ease for almost all locations than enable the visibility of the respective painted surfaces (fig. 5-14, 5-16).

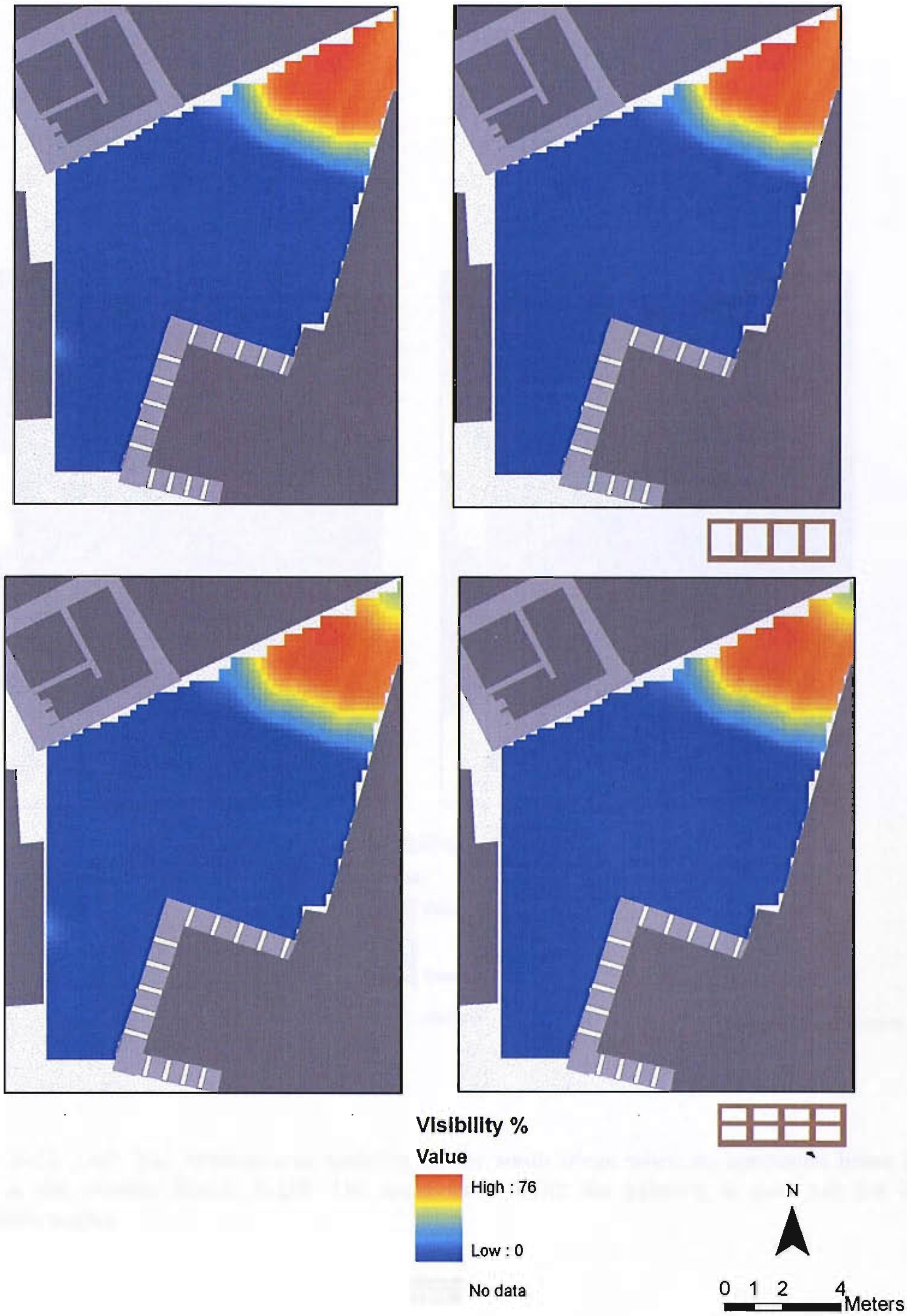


Figure 5-14: Top: The visibility of the south frieze of the gate without (left) and with (right) angular restrictions. Bottom: Alternative reconstruction of the wooden frame with the addition of one horizontal beam. The visibility of the painting without (left) and with (right) angular restrictions.

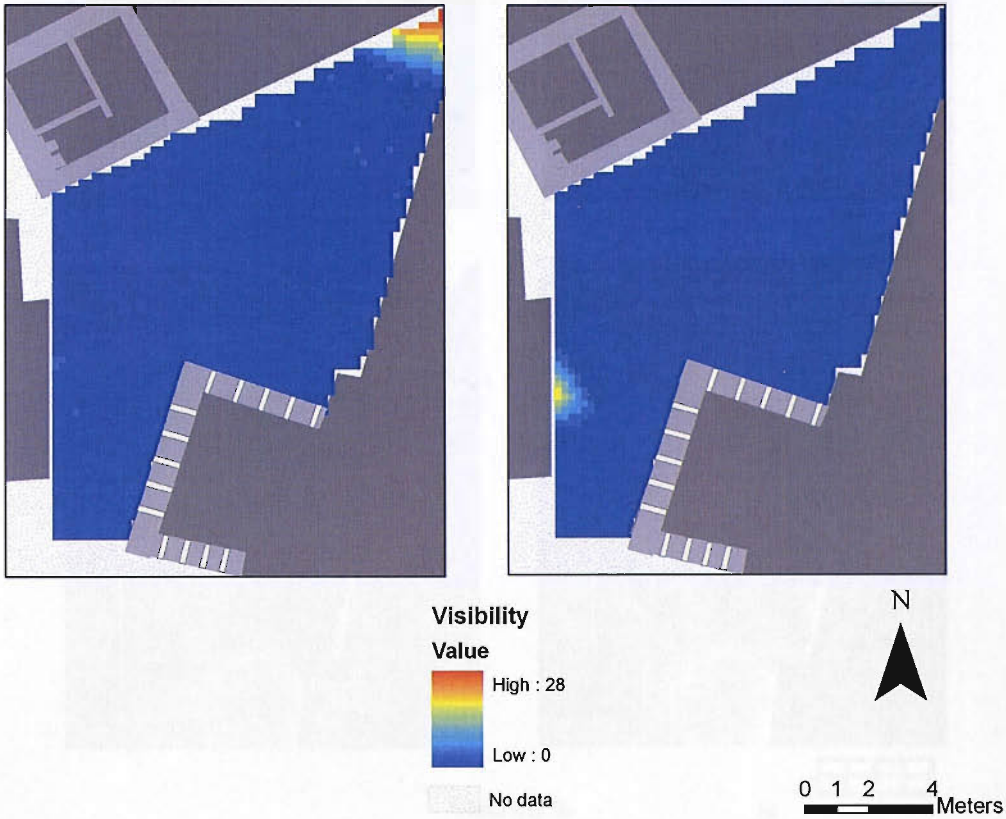


Figure 5-15: Left: The difference in visibility of the south frieze when an horizontal beam is added at the window frame. Right: The areas from which the painting is seen but not in convenient angles.

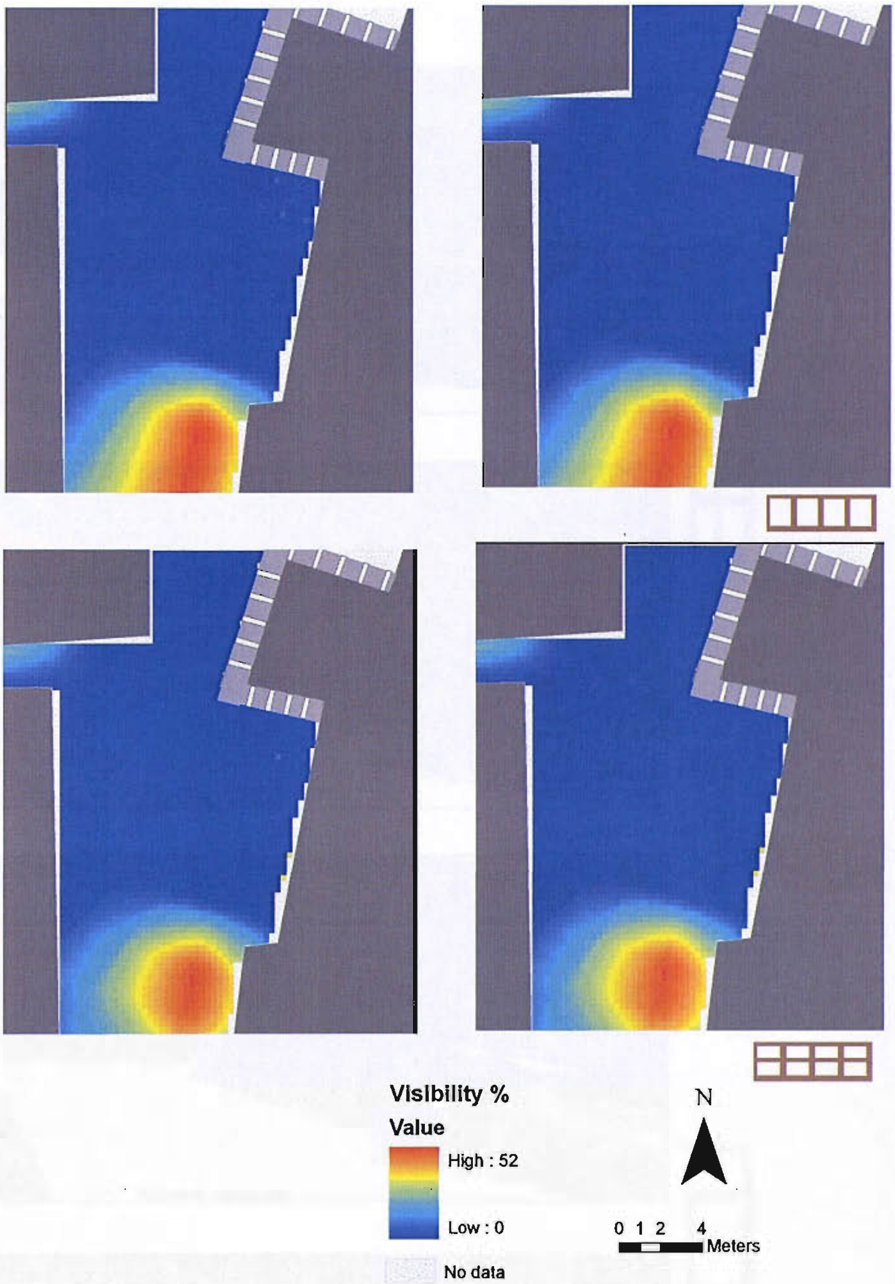


Figure 5-16: Top: The visibility of the north frieze of the gate without (left) and with (right) angular restrictions. Bottom: Alternative reconstruction of the wooden frame with the addition of one horizontal beam. The visibility of the painting without (left) and with (right) angular restrictions.

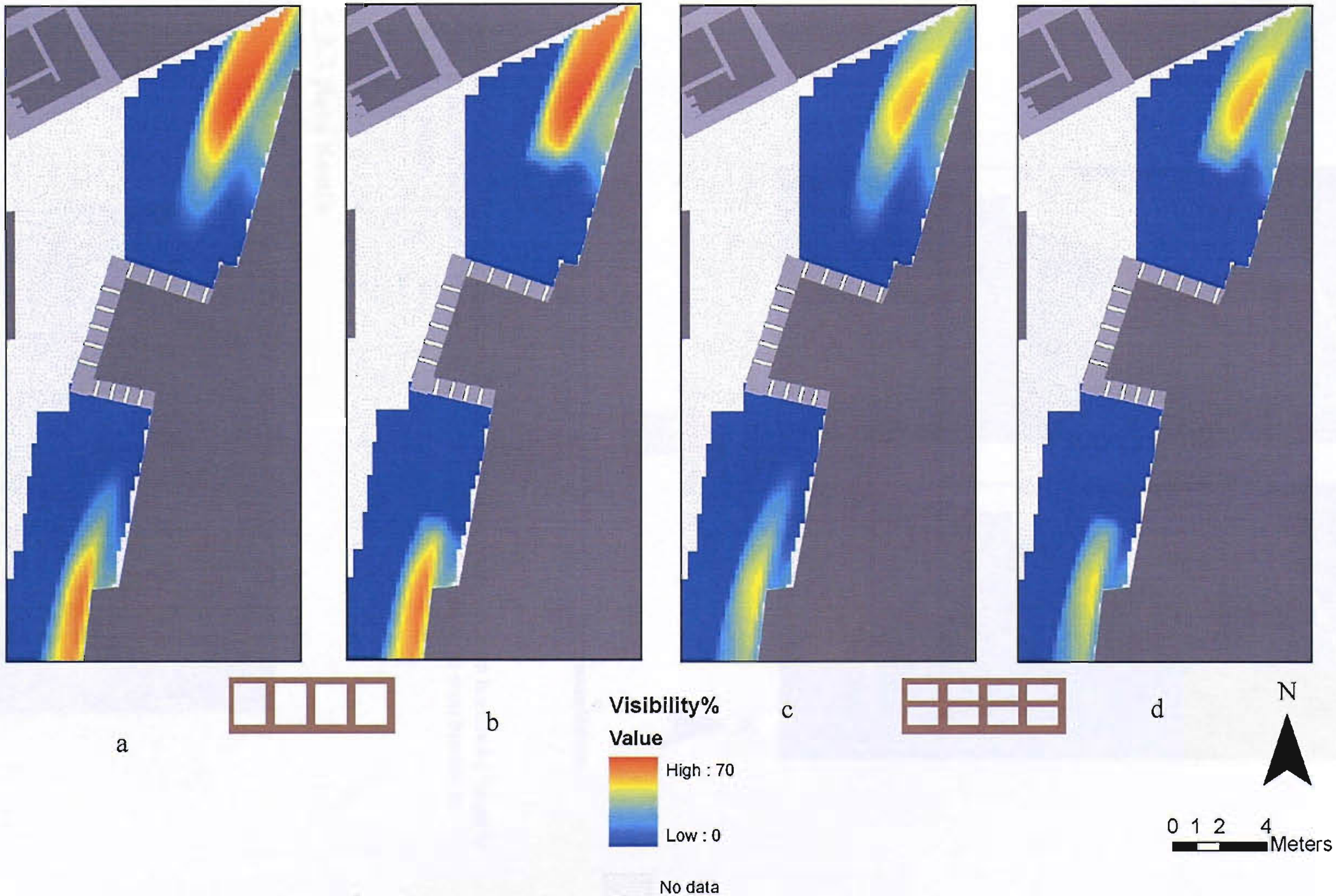


Figure 5-17: From left to right: The visibility of the west frieze of the gate without (a) and with (b) angular restrictions. (c, d) : Alternative reconstruction of the wooden frame with the addition of one horizontal beam. The visibility of the painting without (c) and with (d) angular restrictions

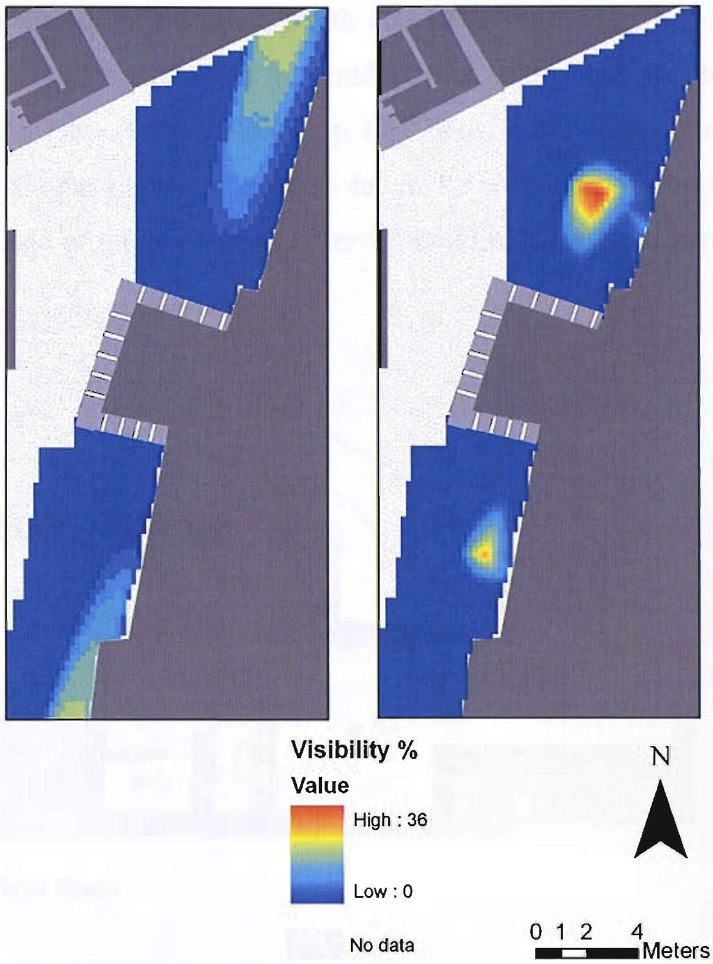


Figure 5-18: Left: The difference in visibility of the west frieze when an horizontal beam is added to the window frame. Right: The areas from which the painting is seen but not in convenient angles.

5.2.3 Beta South

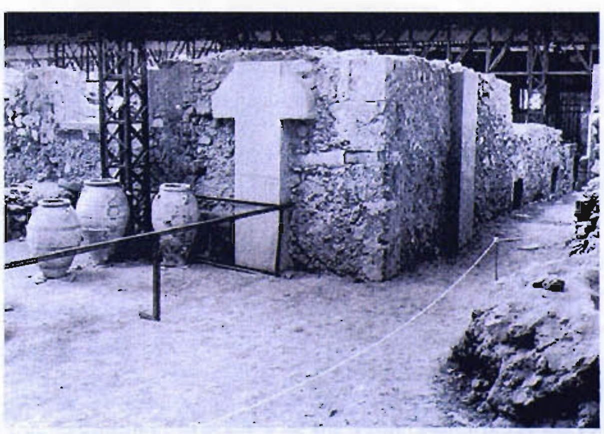


Figure 5-19: Beta South. A view from the North. From the excavation archive.

Passing through the Gate and moving further to the south one encounters sector Beta which consists of Beta North and Beta South (fig. 1-1, 5-19, 5-20). Beta North is a building of an as yet unidentified nature and use, being a later addition to sector Beta (Palyvou 2005a, p. 68). Beta South, on the other hand, is a rather typical Theran house, at least as far as its west part is concerned. It is, unfortunately, one of the least well preserved buildings that have been unearthed

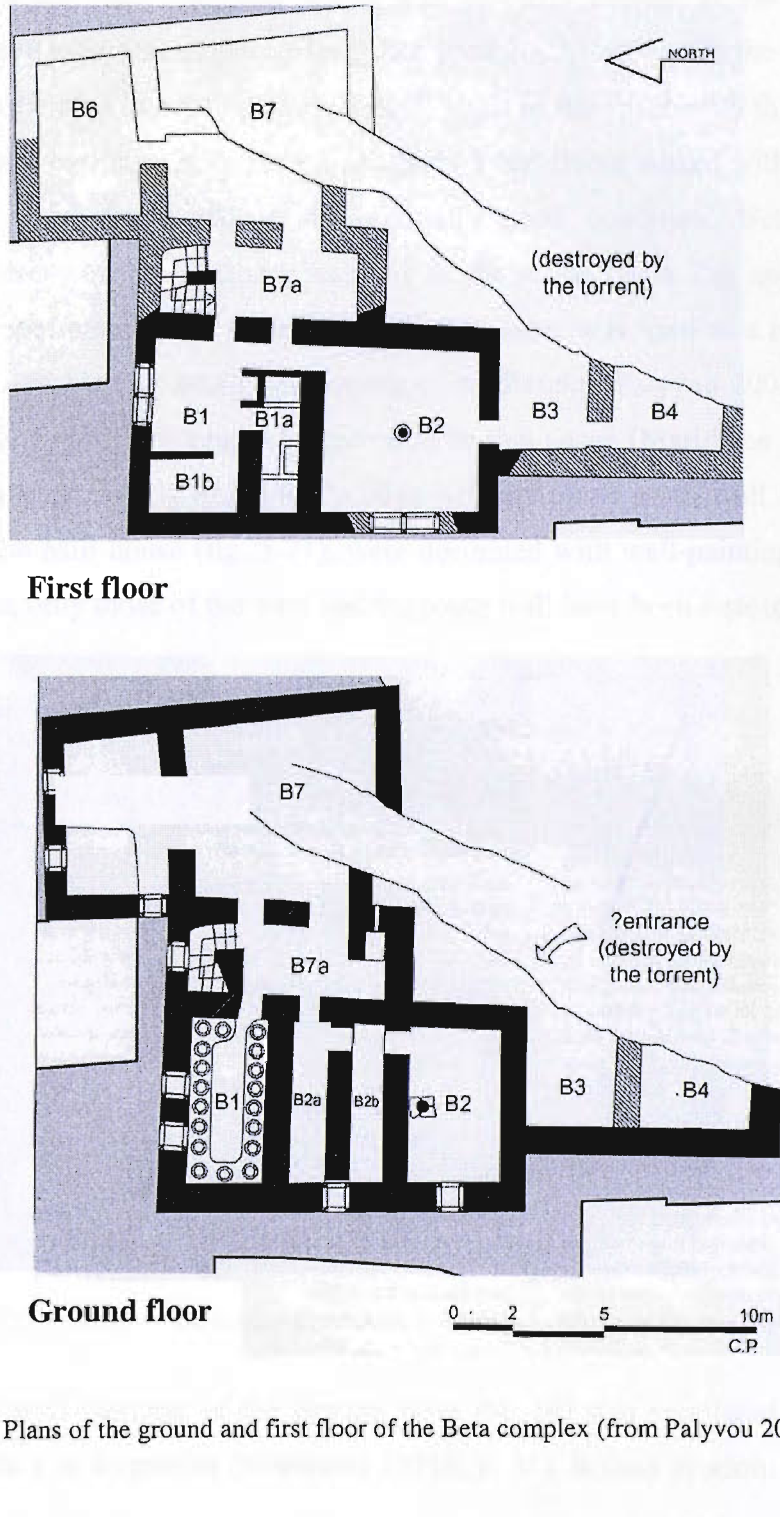


Figure 5-20: Plans of the ground and first floor of the Beta complex (from Palyvou 2005a, p. 64)

in Akrotiri, as its eastern part has been damaged by the torrent (cf. § 2.2). Two rooms of Beta South, Beta 1 and Beta 6 were embellished with wall paintings.

The spatial arrangement of the building at the western wing, where Beta 1 is located, is similar to that of the West House; the ground floor consisting of small-sized rooms was used for storage and cooking while the upper floor accommodated the most elaborate spaces of the house. These would have been accessed by the main staircase, which was probably located at the presently collapsed southeast part of the building (Palyvou 2005a, p.65). On the first floor a large room with a central column (Beta 2) leads to the space with the frescoes (Beta 1) via a corridor. Both Beta 1 and Beta 2 had floors coated with volcanic slabs that were discovered in an unusually good condition. Beta 1 also communicated with the auxiliary staircase of the house (Beta 7a), and the two smaller compartments Beta 1a and Beta 2b. The latter was used as a repository, as is suggested by four small cases made of mudbricks (Palyvou 2005a, p. 66) and other finds (pottery vessels) discovered in this space (Marinatos 1971b, p. 29). All walls of Beta 1, which had a large window on its north wall facing the Square of the Mill house (fig. 5-21), were decorated with wall-paintings (fig. 5-22). To date, only those of the west and the south wall have been restored.

Figure 5-21: The window on the north wall of Beta 1. From the archive of excavations at Thera.

The wall painting of the Boxing boys (pl. 18) was recovered from the floor of Beta 1 in fragments (Marinatos 1971b, p. 31). It used to adorn the south wall at the space between the two door openings that gave access to Beta 1a and Beta 1b (Doumas 1992a, p. 110). It depicts two children performing a kind of boxing game or competition. They have shaved heads except for two tresses and two locks at the back and the top of the head respectively, and they are both dressed in loin cloths. Their bodies are depicted with red pigment, as it is the rule in male representations, and are delineated with dark outlines. The whole scene is projected on a white background. Regarding the exact significance of the wall paintings of Beta 1 only hypotheses can be made. Doumas (2005) and Schachermeyr (1978) have suggested that the "Boxing Boys" depict family members of the owner of the house. On the other hand, Marinatos (2005) maintains that the painting together with the Antelopes that embellished the adjoining walls, aims to suggest ideals of manhood without representing specific individuals.

The Antelopes that used to decorate the west wall (pl. 19) are portrayed solely with black outlines of varying thickness on a white background. Fragments of wall-paintings that represent parts of animals were found in situ on the east and north wall, (Marinatos 1971b, p. 29, 33) suggesting that the whole room was embellished with murals (Doumas 1992a, p. 110). More specifically, a pair of Antelopes has been attributed to the east wall, and two more animals to the north, at the west and east (left and right) of the window opening (Marinatos 1971b, p. 33).

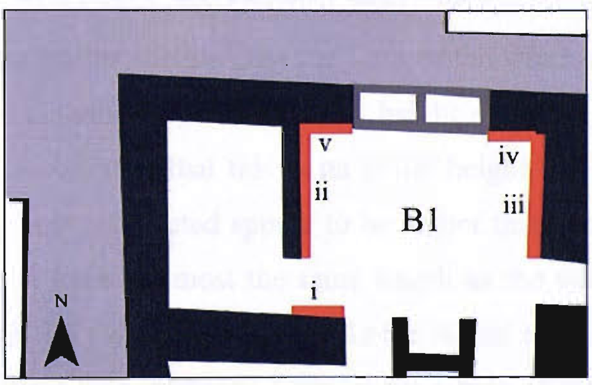


Figure 5-22: The location of wall paintings in Beta 1. Based on Palyvou 2005, p. 64.

Room Beta 6 of the first floor was adorned with the wall-painting of the Monkeys (pl. 20). As mentioned above the architectural form of the room is not clear today because the area was badly damaged by torrential waters and for this reason a visibility analysis of the Monkeys was not performed.

The reconstruction

The reconstruction of Beta 1 was based on the published elevations and plans of the building (Palyvou 1984, p. 138, fig 2; 1999, p. 87, fig 28; 2005, p. 65, fig 77, p. 68, fig. 85). To a great extent the original form of the interior of B1 can be reconstructed with a high degree of certainty, as the wall-paintings have been restored to their original dimensions. Although Beta 1 is a room of the upper storey the level of its floor is only 0,9-1,00m higher than the level of the Square of the Mill House outside the building, while the lower limit of the opening on the north wall is about 1.50m above the street (Appendix II, Plan 7). This is because Room Beta 1 of the ground floor belongs to the phase before the seismic destruction that occurred at the beginning of Late Cycladic I period (cf. §2.2); after the catastrophic event this space ended up as a semi-basement, because the level of the public open space outside the building was raised for about 1.20-1.50 m due to the accumulation of debris (Palyvou 1984, p. 136). The first floor of the building was rebuilt after the seismic destruction right above the room of the ground floor, which has a low height of 1.90m (Palyvou 2005a, p. 67).

Although excavation has revealed many details of the construction of Beta 1, there is uncertainty concerning the form of the window in the north wall of the room. The opening is preserved to a height of 93cm (Palyvou 1999, p. 419), however it is doubtful that this is its initial height. All other windows of Type C that have been excavated appear to be higher than this- for example the window of Delta 7, having almost the same length as the window of Beta 1, is about 150 cm high (Palyvou 1999, p. 419). In the digital reconstruction of Beta 1 the window was given its preserved height, so the results of the visibility analysis are rather towards the conservative side.

There is also some uncertainty concerning the wooden frame of the window. Palyvou notes that windows of Type C were either simple or multiple, and that some of the restored windows, especially those of large dimensions, had intermediate divisions that were not identified during restoration in the first years of excavation (Palyvou 1999, p. 383). Although the window of Beta 1 is not listed with the known cases where an intermediate partition was not recognised, in the most recent published plans of the building the window has been reconstructed with an intermediate partition (Palyvou 2005a, fig. 76). In this research the visibility of the decorated wall surfaces of the room is considered also for the case where the window would have had an intermediate division. Since the first floor room of Beta 1 is obviously very close to the street level, the application of analysis with angular restrictions was not necessary.

Results

In this case, the visibility of the "Boxing Boys", as well as the "Antelopes" of the west and east walls were investigated. The Antelopes of the north wall would not have been visible from outside the building. The analysis was performed from about 3000 locations mainly falling within the Square of the Mill House. In the area outside the window of Beta 1 the wall-painting of the 'Boxing Boys' would have potentially been exposed to up to 75% - 78% (fig. 5-23, 5-24). The Antelopes of the west wall and the wall-painting of the east wall, which is badly preserved and has not been restored, would have been visible up to 64% and 59% respectively.

Looking at the spatial distribution of the areas that enabled the visibility of the paintings some interesting observations can be made:

a) In the case where the window is reconstructed without an intermediate partition (fig. 5-23): While the east wall, embellished with the theme of the Antelopes, could be seen from the greater part of the Square of the Mill House, the paintings of the south and the west wall (Boxing Boys and Antelopes respectively) would only have been visible from the area immediately outside the window. A greater part of the east wall is also more exposed to a viewer situated in this area.

b) The visibility recording and analysis based on the alternative reconstruction of the window (fig. 5-24) with an intermediate partition suggests that this form of the opening would have significantly obstructed the visibility of the east wall of the room from the Square of the Mill House. Figure 5-25 shows the areas that are most affected by possible errors in reconstruction. The visibility of the east wall of Beta 1 decreases significantly for locations that correspond to a large proportion of the Mill House Square, hence, the degree to which the painting was visible to someone located in the plaza cannot be defined with certainty. Even in this case however, the east wall would be more visible from the area outside the window. Although, the visibility of the Boxing boys is also affected by the existence of an intermediate partition (fig. 5-24, 5-25) the paintings would have still been visually exposed to a great extent to someone located outside the window.

In conclusion we can say that a great part of the painted wall surfaces of Beta 1 could have been visible from the public area outside the building. Nevertheless, such statement can be made with confidence only regarding a few locations of the Mill House Square located close to the window of Beta 1.

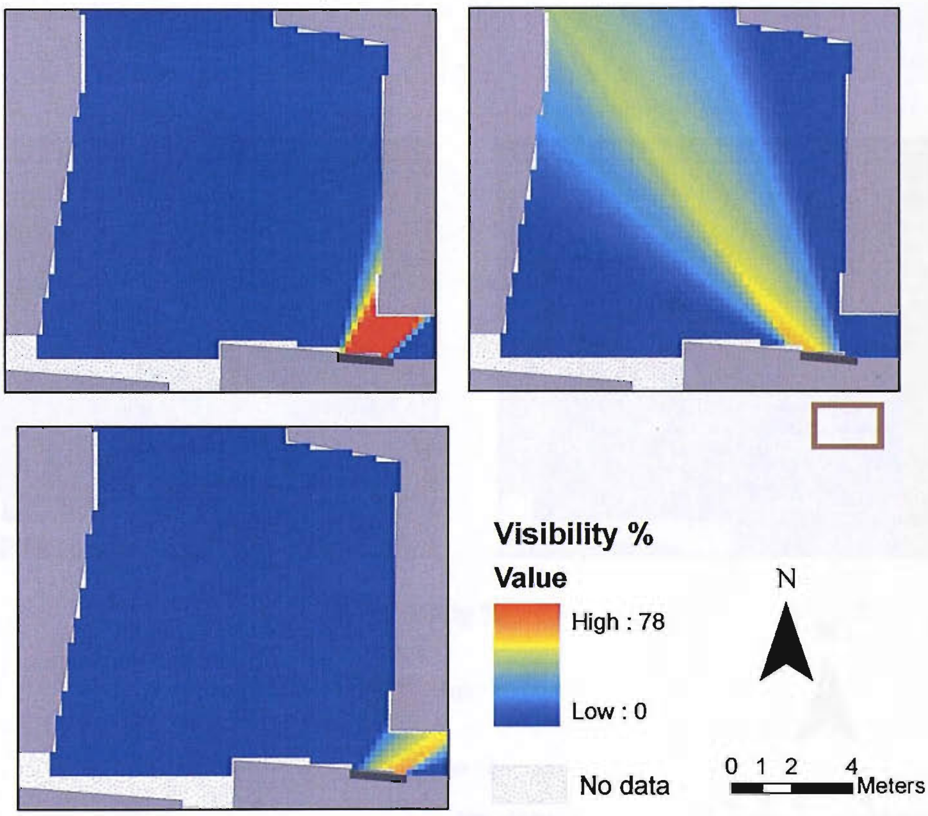


Figure 5-23: Top: The visibility (%) of the Boxing Boys (left) and the Antelopes of the East wall (right), Bottom: The area visible of the Antelopes of the west wall. The window is reconstructed without intermediate division.

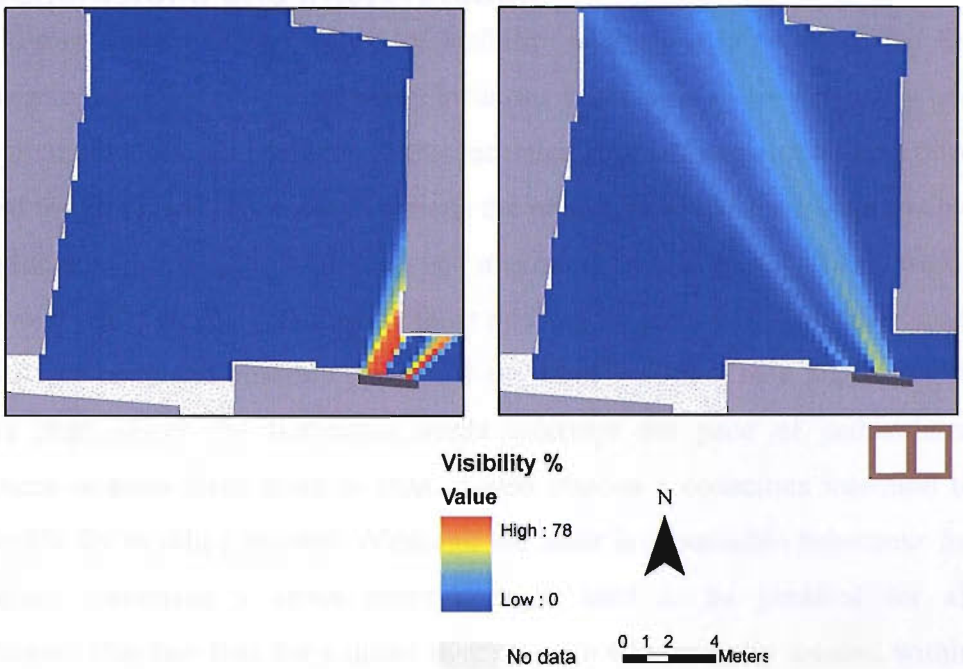


Figure 5-24: The visibility of the wall paintings of B1 based upon an alternative reconstruction. Left: Boxing boys. Right: The Antelopes of the east wall. The window is reconstructed with intermediate division.

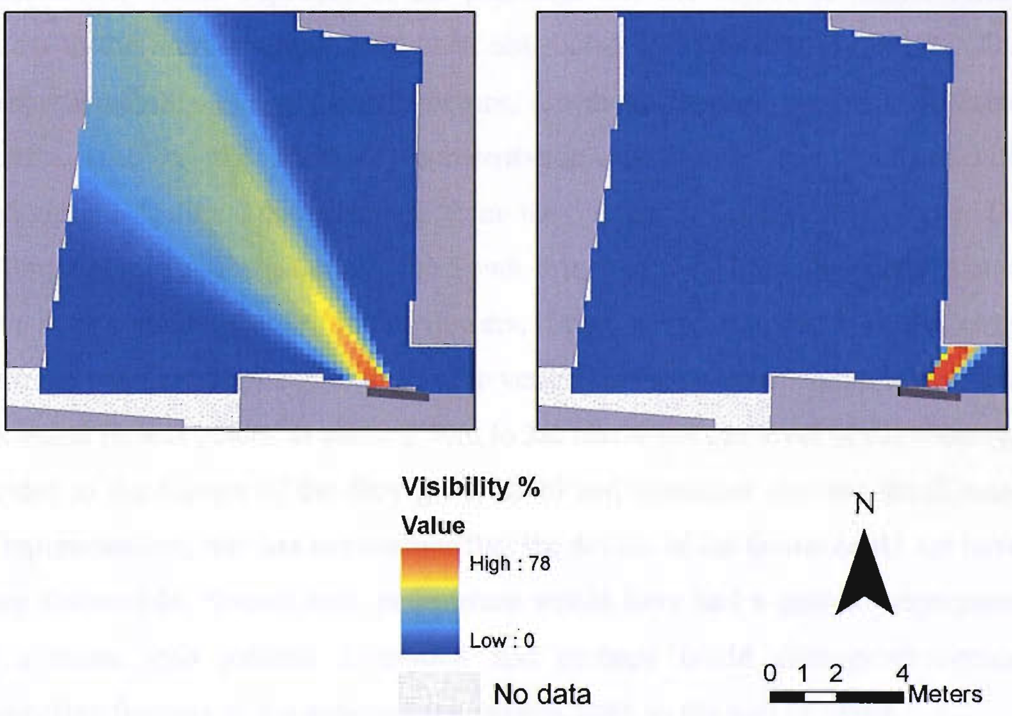


Figure 5-25: The difference in visibility of the east wall (left) and south wall (right) of Beta 1 when an intermediate division is added to the window frame.

5.3 Conclusions and interpretation

From the above application of visibility analysis it is deduced that the wall-paintings were visible from many locations in the public street network and that a great percentage of the area of the decorated wall surfaces could have been exposed to the viewer. On most occasions the paintings would have been visible within the angular ranges of optimum and maximum eye rotation, in other words the viewers could see the paintings without necessarily having to raise their head. In a densely built and possibly populated environment, such as a public street, looking high above the horizontal might interrupt the pace of pedestrians' movement or even force them to stop. It also implies a conscious intention to look inside the building interior. Although the latter is a plausible behaviour for individuals traversing a street network, it is hard to be justified for all pedestrians. The fact that the painted themes were conveniently located within the visual field of the onlooker would have reinforced the communicative potential of the paintings, and perhaps would have encouraged their viewing even when it was not originally intended.

The concepts of visibility and ease of view are mainly used here to describe the visual exposure of the paintings and the degree to which visual access to the murals would have been obstructed by architectural features. The comprehensibility of the painted themes, however, depends on many different factors, such as the scale of representation, the colour and contrast with background features, the distance from the viewer (cf. §1.3), and varies for different contexts. For example, the South Frieze of the Miniature Fresco would have been visually exposed to the viewers, if they were located at least 9m away from the painting. If one adds to this the vertical distance between the viewer and the mural (it was placed at about 2.50m to 3m above the eye level of the observer located in the Square of the Ship procession) and considers also the small scale of representation, one has to conclude that the details of the theme could not have been discernible. Nonetheless, pedestrians would have had a general impression of a room with painted decoration and perhaps could distinguish certain distinctive features of the depicted sea vessels, such as the hull or masts.

However, the visibility of the murals from the public street network would have been imbued with meaning even if the theme was not distinguishable (cf. §7.2). Wall paintings in LBA Aegean were elite architectural features, and as such they marked the residences of those town dwellers that probably had a high position in the social hierarchy. The mere knowledge of the existence of a room with frescoes could have conveyed ideas of social order to the viewers, as is discussed in more detail in §7.2. In addition, the more precise significance and messages of the paintings could still be communicated to those individuals who may had been occasionally allowed in the decorated rooms (cf. §2.3.5, §7.2) and were already familiar with the contents of the painting. In this case the frequent or even daily encounter of the decorated surface in the course of movement through the street network would have acted as a mnemonic perpetuating the messages of the murals.

The same could apply to Beta 1, nonetheless, the wall-paintings of this room would have been received differently than those of the West House by the viewers situated in the public open spaces. The murals of Beta 1 would have been mainly exposed to individuals located in areas close to the window and would have been viewed from a short distance. Since the paintings depict figures that are three-quarter life-sized with black outlines projected on a white background, the beholder standing close to the window could have easily comprehended the represented theme. On the other hand, the wall-paintings of the Gate would have been experienced in very similar conditions to those of the West House, as they form painted friezes that would have been visible from a distance by pedestrians traversing Telchines/Daktylon axis. The theme of the paintings in this case may have been easy to discern and understand by the passer by, even if it was partially exposed, because it consists of repetitive motifs. It is interesting to note that the wall-paintings of the Gate constitute the only frescoes that have been discovered in Delta-West, a house that generally follows the "Theran house model" (Palyvou 2005a, p. 80). Room Delta 1 at the first floor had the longest pier-and-door partition that has been found in Akrotiri. Despite its formal appearance, Delta 1 was probably used for weaving, since loom weights were found in the room, and has no mural decoration (Marinatos 1971b, p. 19; Michailidou 2001a, p. 324; Palyvou 2005a, p. 79-80). The fact that they decided to decorate the room above the Gate, which is not a typical room of Theran houses, is likely not to be without significance. The Gate used to house part of the public open area and was in a conspicuous position within the street network. A pedestrian traversing the Telchines/Daktylon axis would have to face toward the direction of the Gate and the painted friezes. It seems that in this case the paintings were intended to be consumed by those traversing the street network, as well as by the residents of Delta West.

Illumination is an important factor that would have affected the degree to which a particular theme would be discernible. In §3.3.8 the difficulties of carrying out a physically correct illumination model and analysis for Akrotiri were discussed. Although illumination changes constantly within a day, and over the year and depends on weather conditions etc., one can imagine that in quite a few occasions rooms with many windows, such as the first floor of the Gate and Room 5 of the West House would have received adequate light for the paintings to be seen by a viewer located outside the buildings. The visual experience of neoclassical houses in Greece that also have painted decorated friezes verifies that murals are visible and sometimes their themes are discernible through windows, even when the interiors of the houses appear dark. Beta 1 would not have been as well lit as the other two rooms examined, but still it has a large window on its north wall that would have provided plenty of light in the room. The fact that the viewer should have been close to the window to see most of the murals also suggests that illumination would not have hindered the visibility of the wall paintings. Nevertheless, the lack of natural light would not always be disadvantageous for the visibility of the paintings. At dusk, if the residents were using lamps to illuminate the decorated rooms, such as the portable and table lamps discovered at the West House (Devetzi 2007, p. 119-121), coloured walls could still have been visible, even if the themes of the paintings would not have been distinguishable on all occasions. In the dimly lit or dark townscape illuminated spaces with mural painting may have been quite prominent.

Perhaps the most interesting conclusion from the application of the above analysis derives from examining the spatial distribution of the areas from which the paintings would have been visible. For the West House and the Gate the murals could be seen with ease when the viewer was located at least more than 3 and in most cases 5 m away from the walls of the building. Taking into account that the main roads in Aegean Bronze Age towns, including Akrotiri, often reach up to only 2 m., one has to conclude that the likelihood that a pedestrian would encounter painted friezes decorating rooms of the first floor greatly increases when s/he is located in wider areas of the street network, such as the so-called squares of Akrotiri. It has to be noted that these wide public spaces are a distinctive feature of the prehistoric town. As a rule, other Cycladic and Cretan towns seem to have much more densely built urban layouts (Palyvou 2005a, p. 29; McEnroe 1979), in which comparable open spaces are less often encountered. Although it cannot be precluded, that other spatial configurations would have also enabled the visibility of the wall-paintings (for example open urban public space broadens usually at street junctions) it seems that the visibility of painted friezes in first floor rooms would have been favoured by the spatial configuration of the prehistoric town.

Palyvou (2005a) notes that the squares of Akrotiri may have been the result of an infill process, where no more built structures could be erected without violating commonly accepted rules regarding the resident's rights to access, light and air. Furthermore, one could add that the creation of such open areas in Akrotiri could have been motivated by seismic stress. It is now known (Doumas 2003, 2002) that the town inhabitants would often have to cope with the destructive consequences of seismic events. Since in the excavated buildings there are no open areas within the houses, as applies to some of the LBA buildings unearthed in Crete, openings in the street network would have been necessary for the protection of the inhabitants from falling building materials during earthquakes. Other social factors could also have determined the form of the street network. It is characteristic, however, that many of the "plazas" are dated to the beginning of LC I period and belong to the modifications that occurred in the settlement after the major seismic destruction (Georma and Sofianou 2007). In many cases the squares were created over destroyed buildings that were not rebuilt after they had collapsed.

It is also noteworthy that the rebuilding activities in the open public spaces at the beginning of LC I created the necessary conditions that permitted the visual exposure of the paintings of Beta 1 from outside the building. The window is positioned relatively close to the level of the Square of the Mill House, and the great exposure of the murals from outside this opening is due to this fact. As already mentioned, the rising of the street level in that area is the result of the accumulation of building debris. Accumulated debris have been found in other areas of the street network (cf. § 2.2), so Beta 1 might not have been the only case of a decorated first floor room which ended up close to the street level. So, in the case of Akrotiri, environmental factors seem to have greatly influenced the form of the urban tissue and may have played an important role in shaping those particular human-environment relationships that permitted the visibility of Theran murals from the open public spaces. As it will be argued in Chapter 7 the wide dispersal of mural decoration in the prehistoric town may have been encouraged as much by these relationships as by certain social circumstances.

Of course, the likelihood that a pedestrian would have encountered the paintings in the past is also determined by patterns of pedestrian movement in the settlement. It should be examined then how much integrated where the locations that allowed the visibility of the paintings within the urban network. The possible identity of the viewers of the paintings and the conditions under which the murals would have been appreciated need also to be discussed. These issues are approached in Chapters 6, 7.

Chapter 6
Human movement in the urban network of LBA Akrotiri

6.1 Introduction

Visual perception, as applies to all other perceptual systems, has a symbiotic relationship with movement through space. This fact has been plainly phrased by Gibson:

> *'Locomotion is guided by visual perception. Not only does it depend on perception but perception depends on locomotion inasmuch as a moving point of observation is necessary for any adequate acquaintance with the environment. So we must perceive in order to move, but we must also move in order to perceive' (Gibson 1979, p. 223)*

What an individual sees or perceives, of course, greatly depends on his/her mobility within space. However, movement, besides shaping and being shaped by perceptual processes, is also a social activity embedded in the everyday human practices, projects and tasks, as it has already been noted in a considerable number of works in the fields of social theory, anthropology and geography (Giddens 1984; Bourdieu 1977; Ingold 2000, p. 189-208; Pred 1986; Goffman 1969, 1972; Hägerstrand 1970). People move for a reason. In modern cities they traverse the street network to go to work, do their shopping, meet each other and socialize, activities that are essential for the shaping of social relationships. These everyday tasks determine the daily routes that individuals take in the urban network. In a similar way the everyday paths through the prehistoric town of Akrotiri would have been shaped by social and economic aspects of daily life in the Late Bronze Age.

Moreover, movement is deemed a social process because it involves human interaction. People in daily encounters attend to each other and are inclined to adjust their behaviour through space in the mere presence of other individuals, even if this is expressed simply as an intention to avoid collisions with other pedestrians (Goffman 1972, p. 26; Helbing *et al.* 2001). Walkers can also function socially in a number of other ways (Goffman 1972, p. 28), for example they can be engaged in a conversation with other pedestrians, move in groups, or work on common tasks with other people, like transporting bulky objects or other goods.

Currently, the movement of visitors within the street network of the prehistoric town has been organised by signs in a single direction along a predetermined path. The entrance to the archaeological site is located at the south east of Xeste 3 (fig. 1-1). Starting from this point the visitor's path then moves east of Sectors Beta and Sector Delta until it reaches the Square of the Cenotaph, and then takes a turn towards the south, traverses the Triangle square, and ends up at the exit south of the House of the Anchor. For a great part of the first half of the tour through the eastern side of the excavated area visitors have to move along the modern narrow walkways that are raised above the prehistoric street network and sometimes above unexcavated areas. However, one can still wander around the Square of the Cenotaph and the Triangle Square, as well as move through Telchines Road. Since entrance into the buildings is not allowed, tourists tend to walk along the walls of the houses, often stopping outside the door and window openings to look at their interior (fig. 6-1, 6-2). An archaeologist investigating the visibility of mural painting from the public spaces of the settlement, either by engaging with real space or walking through its virtual representation, is tempted to do the same. However, this is an unlikely behaviour for pedestrians in prehistory, and totally devoid of the social context of movement in the past.

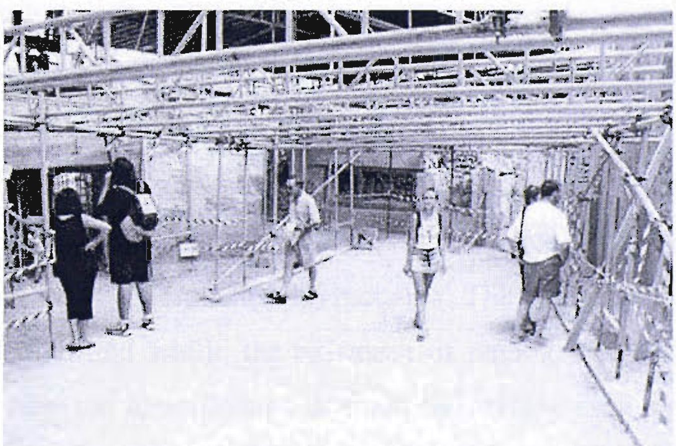
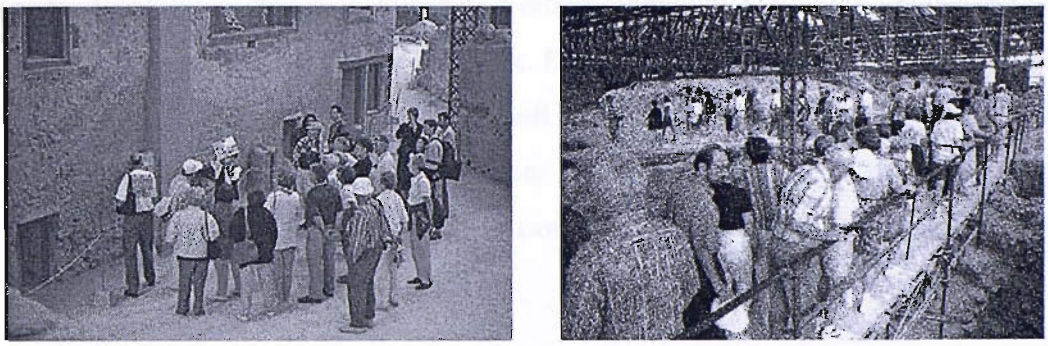


Figure 6-1: Pedestrian movement in Akrotiri today. Image taken from **http://community.iexplore.com/photos/journal_photos/akrotiri1_prefRes.jpg**



a

Figure 6-2: Groups of pedestrians in Akrotiri today. a) Image taken from **http://www.stuartfrew.com/Barefootin/Santorini/akrotira.jpg**, b) from Doumas (2007b, fig. 13).

That said, a visit to the archaeological site does lead to interesting observations concerning the process of walking in a built environment. Even nowadays one has the chance to watch people wandering around the site sometimes individually or in pairs, other times organised into groups. Some walk faster than others as they are in a hurry to keep up with a busy daily schedule, others move at a slower pace chatting to each other. At peak times on busy days the pace of movement in narrow passageways slows down significantly, as they get crowded and pedestrians try to keep distances from each other; the broader open spaces offer, however, opportunities for some people to pull away from the main stream of movement, pause temporarily, or wait for other group members (fig. 6-2). It is obvious that nowadays the patterns and speed of movement through the site are greatly determined by spatial form as well as pedestrian presence and interaction.

But can we really know something about the process of movement in the prehistoric town during the Late Bronze Age? The archaeological record offers only indirect indications about human mobility patterns. The form of the excavated street segments, their length and width, the existence of paving, the location of building entrances can all help the identification of main and widely used streets in the urban network. Evidence on the use of space derived from the study of archaeological finds (pottery, loom and lead weights, microfossil remains, cf. Chapter 2) provide some indications about the nature of human practices and interactions in the built environment, as well as the mobility patterns associated with them. Moreover, the modes of transport and movement in the context of specific tasks can be illuminated by the study of Aegean Bronze Age art and iconography (cf. § 6.3.2). Finally, some inferences regarding human mobility in past environments can be made via the use of formal analytical and computational methods. Before delving into the issue of human mobility in the settlement of Akrotiri it will be instructive to discuss the formal approaches that have been used up to now to investigate human movement on medium and small spatial scales, and the various factors that shape mobility patterns in the built environment.

6.2 Formal approaches to the study of movement in built environments

6.2.1 Aggregate models

As of now numerous formal methods of studying movement through the built and natural environment have been developed within the fields of urban studies and geography, and some have been applied to historic and prehistoric space. The existing methodologies differ significantly in the exact modelling method used, the scale, the specific aspect of movement they seek to investigate, as well as the assumptions they make about the main generators of movement patterns. In archaeology human mobility has mainly been investigated at large scales and within the context of landscape studies, while only relatively few applications have aimed to look into aspects of movement in built spaces. For the study of human mobility through past landscapes both GIS-based raster models and network representations have been used. A detailed description of the methodologies employed for large geographic extents is beyond the aims of this study, but the interested reader can refer to a great number of published works on this issue (Van Leusen 2002; Wheatley and Gillings 2002, p. 151-159; Conolly and Lake 2006, p. 151-159; Llobera 2000; Bell and Lock 2000; Bell *et al.* 2002; Gaffney and Stancic 1991; Harris 2000; Madry and Crumley 1990; Savage 1990).

When it comes to the study of human mobility in past built environments, at the scale of streets and buildings, graph-theoretic models, and in particular space syntax methodologies, have almost exclusively been used. Space syntax is an influential theoretical trend in the field of urbanism, which maintains that the configurational structure of built space is the most important generator of movement (Hillier and Hanson 1984; Hillier *et al.* 1993). According to space syntax accessibility, which is defined as topological distance (i.e. the number of spaces needed to be traversed to reach a destination) constitutes a major indicator for patterns of human mobility. Since accessibility, and hence movement, in the built environment is facilitated or hindered by spatial form, it follows that spatial arrangement could encourage or discourage respectively human encounters, and participate in the process of social reproduction (Hillier and Hanson 1984, p. 140-142). The most frequently applied space syntax approach is access analysis, a graph based methodology that aims to enable inferences about social structures through the investigation of the spatial organisation of buildings (Bonanno *et al.* 1990; Chapman 1990; Cutting 2006, 2003; Grahame 2000; Laurence 1994, p. 115-121; Michailidou 2001a, p. 387-398; Van Dyke 1999; Fairclough 1992; Foster 1989; Moore 1996, p. 184-205; Thaler 2005). In Akrotiri this method has already been utilised by Michailidou (2001a, p. 387-398) to examine possible circulation patterns in private and public buildings, leading to the identification of spaces that were potentially used mainly by those dwelling in the buildings, as well as rooms more likely accessed by both visitors and inhabitants.

The application of space syntax methodologies for the investigation of movement through ancient urban street networks, which are the main focus of this research, are relatively limited (see for example Potter 1998; Kaiser 2000; Ferguson 1996 ; Robb 2007; Craane 2007). At the scale of settlements, a graph-based method, known as axial analysis, is employed. Axial analysis aims to identify the most "accessible", and therefore most widely used street segments within an urban network (Hillier and Hanson 1984, p. 82-142; Hillier *et al.* 1993). The term "axial" refers to the first stage of the analysis in which the built environment is represented in terms of axial lines. These are the longest and fewest lines of sight that traverse each outdoor space in a continuous urban plan. At the second phase of the analysis axial lines are represented as nodes, and their intersections as links in a graph (Hillier and Hanson 1984, p. 82-142; Conroy 2001, p.12). The average distance (number of steps) of a node to all other nodes in the graph is then calculated and an index with the degree of integration of each axial line in the system is created. Street segments that correspond to axial lines which are of a small average distance to other lines in the spatial configuration are termed "integrated", or, if the opposite is the case, "segregated". Integrated and segregated street segments are considered indicative of the distribution of traffic volumes in the network with the former signifying the most frequently used passageways.

To date it has been demonstrated that in modern built environments there is a good correlation between integration indices and pedestrian movement counts (Hillier *et al.* 1993; Conroy 2001, p. 12; Turner 2003). Most successful predictions of traffic volumes are derived when only lines that are three steps away ("radius three integration") are considered in the analysis (Conroy 2001, p. 12). Nonetheless, it has to be recognised that correlation indicates association and not necessarily causality, and in this sense it cannot be precluded that patterns of mobility have been shaped under the influence of factors other than spatial form, which are not taken into account in space syntax approaches.

A main problem with the application of axial analysis in archaeology is that it requires the urban networks under study to be continuous and complete (all spaces must be described in terms of axial lines) which is hardly the case for the great majority of past urban spaces, including Akrotiri. Perhaps in the future this can be less frequently a problem considering the advances in remote sensing technologies that in many situations can give a fairly good impression of past road networks (cf. Branting 2004). Furthermore and most importantly, however, the premise that spatial configuration is the main factor that determines pedestrian movement should be treated with scepticism (Haklay *et al.* 2001, p. 344-345; Steadman 2004). It has to be noted here that access and axial analyses are not the only formal approaches that acknowledge a primary role to spatial configuration in shaping patterns of human mobility. Such an assumption is also implicit in isovist and visibility graph analysis (cf. §3.2.2) which maintain that there is a relation between the visibility of architectural configuration and human movement (Turner 2003; Turner *et al.* 2001). As already mentioned, such analyses have hardly been applied in archaeology, and when they have, they focus upon aspects of visibility rather than movement (Clark 2007).

The problem with all the above approaches is that they do not take into account that human mobility through an urban network could be influenced by a great number of other factors besides spatial form, such as the use and function of space, the location of attractors of movement in the urban network, the modes of transport, the size and quality of the street segments, physiological parameters of human locomotion, pedestrian interaction, as well as culturally specific social perceptions of space (Haklay *et al.* 2001; Helbing *et al.* 2001; Steadman 2004). It is characteristic that up to now in the field of urbanism the axial map has not been the most popular graph theoretic representation for the study of human movement in urban spaces. Transportation networks in which junctions are represented as nodes and street segments as links (Steadman 2004; Fischer 2003), have more commonly been used. The analysis of transportation networks aims to investigate the movement of humans, vehicles and goods, assuming that people primarily move in a way that enables them to conserve effort, time and expense (Steadman 2004, p. 484), parameters determined by Euclidian distance rather than topological proximity. In terms of graph theory a transportation network is a valued graph. Contrary to pure networks that focus on topological measures, a transportation network also allows for flow characteristics, taking into account the direction of movement, capacity constraints (the maximum amount of material that can flow between nodes), and link cost functions (Fischer 2003, p. 2; Conolly and Lake 2006, p. 236-238). Cost in this context can be determined by a variety of factors such as metric distance, time, metabolic energy expenditure or expense, etc.

The analysis of transportation networks is the object of study of a newly developed and rapidly growing area of research that uses transportation Geographic Information Systems (GIS-T) for the investigation of movement in geographically referenced networks (Thill 2000; Fischer 2003). Up until now, GIS-T approaches had few applications in archaeology, although they have the potential to offer a much more sophisticated approach to movement through open urban spaces, incorporating a great amount of contextual information related to the use of space and socio-economic aspects of transportation. Branting's (2004) study of Iron Age pedestrians at Kerkenes Dağ is one of the few applications of GIS-T methodologies to prehistoric data. The aim of his model is to identify patterns of movement and co-presence of individuals that belong to six different groups of age and sex. The model takes into account physiological aspects of human locomotion; for each pedestrian group different length, energy and time costs are assigned to each segment of the network that corresponds to a single human stride. Nonetheless, this GIS-T application does not allow for additional factors which are usually considered in transportation network analysis, like uses of space and other socio-economic data, because of the lack of relevant information at the time the analysis was undertaken. This is also indicative of the implications related to the employment of transportation network analysis in archaeological contexts, when socio-economic data about the population under study are not available.

CSA, Space Syntax and GIS-T approaches can be called aggregative, as they are concerned with the estimation, and analysis of aggregate measures and behaviours (e.g. integration or cost values assigned to street segments in the urban grid) to investigate aspects of pedestrian movement. Such approaches are better suited for describing collective patterns of human mobility or predicting the distribution of traffic volumes in medium and large geographic extents, rather than the independent movement of individuals along streets. For example, they are not suitable for answering questions like what side or which locations along a street an individual is more likely to traverse (Haklay *et al.* 2001). Studies in the sociology of movement (Goffman 1972, p. 23-40), as well as empirical observations of pedestrians (Helbing *et al.* 1994; Helbing *et al.* 2001) in urban environments in the last thirty years, suggest, however, that human mobility is not solely affected by spatial configuration, energetic or time expenditure; interactions among pedestrians are also important in determining the modes in which people move in urban space, especially at very fine temporal and spatial scales (Helbing *et al.* 2001; Batty 2003). Aggregative approaches completely neglect spatio-temporal dynamics of pedestrian movement and are not suitable to investigate the formation processes of mobility patterns at small spatial scales. In recent years the shortcomings of aggregative approaches have given rise to the development of individual-level (or disaggregate level) models, that is the more recent trend in the study of pedestrian movement.

6.2.2 Individual-level models: The agent-based paradigm

Individual-level modelling is founded upon the function of discrete processing units, known as automata. In the field of urban simulation two classes of automata, cellular automata (CA) and agent-based models (ABM), have known wide applicability (Torrens 2003, p. 62). In CA models each automaton occupies a fixed space, which is called a cell, within a lattice structure composed of connected automata. Within the boundaries of a cell every CA can have a finite number of predefined states which indicate different properties of the system (e.g. land use, capacity, population density etc.). During a simulation run the state of CA changes following simple local rules, which take into account the preceding state of each cell and the properties of its neighbours. CA models are used for the simulation of a variety of spatial processes such as epidemics dispersion, urban growth, land-use change and traffic dynamics, where global order is believed to arise ("emerge") from local rules (Batty 2005, p. 68). Although they have also been used to simulate pedestrian behaviour they are generally not considered the best tool for this purpose. This is because each CA is constrained within the limits of a single cell, and hence movement in a CA model can only be approximated by diffusion (Torrens 2007, p. 63), a process that does not describe effectively the dynamics of real-life pedestrian mobility. On the other hand, individual agents in ABM are mobile entities and therefore can represent pedestrian behaviour in more efficient ways.

6.2.3 Agent-based models (ABM) of pedestrian movement

Agent-based modelling is a paradigm and a mindset rather than a specific methodology (Bonabeau 2002; Castle and Crooks 2006) which has been adopted by many different disciplines (economics, biology, social sciences, ecology, urbanism etc) to the study of complex systems. The term basically refers to the case when a system is described at the microscopic level and with the emphasis being placed on its constituent units (Bonabeau 2002). Due to the versatile use of ABM there is no generally accepted definition of the word "agent". In models of pedestrian movement, in particular, agents most often represent mobile individuals that at a rudimentary level are "autonomous" and "goal-directed", meaning they behave according to a set of tendencies or individual goals rather than a user's commands (Ferber 1999, p. 9). Agents exist within an *environment* in which they can "sense" and "act" or even "communicate", "learn" and "adapt" depending on the level of cognition that has been programmed into them. The environment in ABM can be at the very least a network of interacting agents (Gilbert and Terna 2000), but when it comes to simulations of pedestrian behaviour, agents are usually situated in an environment representing a physical space, a real or plausible setting. Agents can have different levels of spatial awareness; they can be "reactive", that is they can merely respond to stimuli in their surroundings and adapt to a certain extent, or "cognitive", meaning that they have knowledge of the model of their world, according to which they act, as opposed to responding solely to local information (Schelhorn *et al.* 1999, p. 4).

Contrary to aggregative models that are based on a top-down approach, simulations of pedestrian movement that focus on agent interactions aim to study mobility processes from the bottom up, by examining the non-linear formation of collective patterns of movement that emerge as a result of interactions among individuals. A non-linear phenomenon can be understood as a complex system in which the whole is more than the sum of its independent components. As such it is difficult to predict and can even be counter-intuitive (Bonabeau 2002). ABM that consist of agents representing pedestrians are particularly useful for studying complex phenomena of human mobility, as they can be used for exploratory purposes as "miniature laboratories", where pedestrian interaction and behaviour can be studied by repeatedly altering the parameters of the model (Castle and Crooks 2006, p. 11).

6.2.4 ABM in the field of urbanism

Agent-based models of pedestrian mobility have been traditionally employed in the field of urbanism for studying movement in the built environment at various spatial scales. At the micro-scale, they aim to predict the behaviour of pedestrians that usually walk along a predetermined direction, and close to certain spatial formations of the street network, such as crossroads or bottlenecks (Haklay *et al.* 2001; Helbing *et al.* 2001). These models aim to simulate common walking strategies, for example obstacle and collision avoidance. One of the most comprehensive and influential studies on the factors that shape pedestrian behaviour at very fine scales has been carried out by Helbing (1992). He has maintained through a number of papers (Helbing 1992; Helbing and Molnár 1995; Helbing *et al.* 1994; Helbing and Vicsekz 1999; Helbing *et al.* 2001) that under certain conditions collective patterns of human movement are predictable because they are the result of self-organised phenomena caused by "automatic" reactions of pedestrians. These phenomena are similar to observed animal behaviours associated with the formation of flocks, herds and schools (Reynolds 1987). Helbing et al. (2001) supported this suggestion with a number of empirical observations of pedestrian movement (direct observations, time-lapse photography and videos) collected by researchers in the field of urbanism in the last thirty years. These reveal that although individuals generally can move in quite unpredicted ways, their behaviour often shows certain regularities, especially in medium and high pedestrian densities. Such regularities exist because pedestrians tend to adopt an optimal behaviour while walking, which is the result of learning "by trial and error" (Helbing *et al.* 1994; Helbing and Vicsekz 1999; Helbing *et al.* 2001). Helbing et al. (2001) described this behavioural strategy in terms of simple rules and incorporated them in a single model inspired by gas-kinetics, known as the *behavioural or social force model*. At the conceptual level the model is simple. It states that a pedestrian's position, orientation and velocity in any given moment is determined by a behavioural force. This is an acceleration force that is the sum of several force terms that express internal motivations of the individual: his/her wish to walk towards a certain direction, to keep a desired walking speed, to maintain a distance from obstacles and other individuals in the environment, or move together with other pedestrians. The mathematical description of this model (fig. 6-3) also takes into account variations in the behaviour of pedestrians caused by deviations from the optimal way of acting, with the addition of a random factor in the formula ($\xi_\alpha\,(t)$). Such deviations aim to reflect real life situations in which pedestrians have different impulses or strategies of how to move on.

$$f_a(t) = f_a^0(\upsilon_a) + f_{aB}(\boldsymbol{r}_a) + \sum_{\beta(\neq\alpha)} f_{a\beta}(\boldsymbol{r}_a, \upsilon_a, \boldsymbol{r}_\beta, \upsilon_\beta) + \sum f_{ai}(\boldsymbol{r}_a, \boldsymbol{r}_i, t) + \xi_a(t) \qquad \text{(i)}$$

(Helbing et al. 2001)

$$\begin{bmatrix}\text{new}\\ \text{position}\end{bmatrix} = \begin{bmatrix}\text{old}\\ \text{position}\end{bmatrix} + \begin{bmatrix}\text{desired}\\ \text{position}\end{bmatrix} + \begin{bmatrix}\text{geometric}\\ \text{repulsion}\end{bmatrix} + \begin{bmatrix}\text{social}\\ \text{repulsion}\end{bmatrix} + \begin{bmatrix}\text{social}\\ \text{attraction}\end{bmatrix} + \varepsilon \qquad \text{(ii)}$$

(Batty 2003)

Figure 6-3: (i) A mathematical description of the social force model (Helbing et al. 2001, p. 366), where $f_\alpha^0(U\alpha)$ is an acceleration force, $f_{\alpha\beta}\,(r_\alpha)$ repulsive effects due to boundaries, $f_{\alpha\beta}\,(r_\alpha,\ v_\alpha,\ r_\beta,\ v_\beta)$ repulsive interactions with other pedestrians β, and $f_{\alpha i}\,(r_\alpha,\ r_i,\ t)$ attraction effects (ii) A similar conceptual model suggested by Batty (2003).

It has been demonstrated that the social force model, despite its conceptual simplicity, can form the foundation of multi-particle and multi-agent micro-simulations of human crowds which are able to successfully describe and predict life-like phenomena of pedestrian movement (Helbing and Molnár 1995; Helbing *et al.* 2001; Helbing *et al.* 1994; Turner and Penn 2002, p. 476; Batty 2003). Such phenomena occur at the micro-scale, usually at junctions and at the entrance of narrow passages. For example, it has been observed that on occasions where a number of oppositely moving pedestrians attempt to traverse the entrance of a narrow passage (bottleneck), stream-like patterns and deadlock situations alternate between the two walking directions (fig. 6-11). Computer simulations following the social force model are often used to replicate pedestrian movement under these conditions in the planning of emergency evacuation scenarios (Bonabeau 2002). Furthermore, assumptions similar to those utilised in the social force model have been incorporated into the conceptual modelling of a number of agent based applications in urban studies (fig. 6-3, Batty 2003; Kerridge *et al.* 2001), that aim to simulate movement in a wider range of situations than those originally described by Helbing et al. (2001).

Nonetheless, pedestrian interactions are not the sole factor affecting the movement of individuals in built environments, especially at the scale of street networks. The simulation of pedestrian movement during large-scale full trips requires agents with advanced cognitive abilities (e.g. memory, knowledge of the environment, clearly defined aims, vision) and a well-defined course-determining mechanism. Broadly speaking, as far as the latter is concerned, the agent-based approaches that have been suggested up to now can be classified into two categories. The first includes ABM in which agents are programmed to act with respect to cost-benefit functions. These models often make use of predetermined activity schedules based upon land use distribution and other socio-economic data. In order to achieve their goals agents tend to select the shortest route (distance, energy or time minimising) to their destination. The STREETS model suggested by Haklay et al. (2001) is a good example of this approach. Kurose et al. (2001) also use a cost minimising logic in the determination of agent route choices modelling pedestrians that are guided by local rather than global knowledge of the environment (namely agents choosing the shortest path from shop to shop). On the other hand, ABM have also been suggested in which agents' behaviour is driven by configuration properties of the built environment, such as the longest line of sight, the minimum angle towards a destination (Penn and Dalton 1994) and the visual field (Jiang and Gilbert 2002), rather than cost and activity plans. In these models movement, especially at a microscopic level, is merely seen as a human spatial variable, (Turner and Penn 2002, p. 477), while socioeconomic factors are not considered. For instance, Turner and Penn (2002) have introduced an "active walker" model inspired by Gibson's theory of direct perception where individuals' movements are guided by "vision"; they introduce agents with an "exosomatic" visual system that is based upon the pre-calculation of dense-grid visibility graphs, which define the urban areas that afford "walking" (Turner and Penn 2002, p. 478). Turner, later compares the results of the simulation with real pedestrian counts and finds that "the technique performs considerably better in predicting human-movement patterns than the use of raw visibility-analysis values based on visibility graph methods". Generally such methods can be useful for predicting the movement of individuals at small spatial scales and low pedestrian densities, where the presence of other individuals would not have influenced significantly the behaviour of a walker. From the above it is obvious that ABM of pedestrian movement share similar assumptions and heuristics as aggregate models, not excluding some of their weaknesses and uncertainties.

6.2.5 ABM of pedestrian movement in archaeology

Simulations that aim to model the behaviour of mobile individuals in non-urban contexts have appeared in archaeological research since the 90's. Aldendelfer (1998) and Lake (2001) review a number of ABM applications in archaeology that have been employed at large geographic scales. In these applications the focus is often upon primate societies where individuals form alliances (Doran *et al.* 1994) or exchange information to procure resources in the landscape. The mobility of the agents representing pedestrians is often essential for the formation of the observed social phenomena, but the models in most cases do not primarily aim to simulate the process of movement *per se*.

The applications of ABM in archaeological urban environments are more recent. They consist of a few simulations of crowd movement that have been developed to populate virtual reconstructions. These should not be confused with animations of non-autonomous virtual humans whose exact movements are defined by a series of user commands. One of the first models that aimed to model pedestrian behaviour was employed by Heïgeas et al (2003) who programmed a particle system to simulate emergent properties of crowd movement, such as flowing, avoiding, jamming and collapsing, in the ancient agora of Argos. In this model mobility is determined by avoidance rules; pedestrians simply aim to keep away from buildings and other individuals in their surrounding environment. The objective of the simulation, however, is again to increase the realism of the scene, rather than face archaeological considerations. Nevertheless, besides aiming at the creation of more compelling computer graphics, ABM of crowds have been recently utilised to test hypothesis concerning the ergonomics of ancient public buildings including the building's capacity and circulation mechanism (Shao and Terzopoulos 2006; Gutierrez *et al.* 2005). Gutierrez et al's (2005) initial results of the study on circulation patterns in the Colleseum of Rome indicate that human movement in the stadium was not as efficiently organised as originally suggested, while Shao and Terzopoulos (2006) with their model question the previously suggested capacity of the Theatre at Petra. Interpretations derived by both these models depend heavily on the investigation of interactions among agents at micro-spatial scales, which are determined again mainly by the intention of the agents to avoid collisions with other individuals.

ABM in archaeology: Benefits and caveats

Perhaps the most obvious benefit of the use of autonomous agent approaches to the study of human mobility in past environments is that they encourage archaeologists to think about human practices, experience and the processes of socialisation and movement in inhabited space, as opposed to unpopulated environments. Human interactions, such as those of mobile individuals, are hard to conceptualise within a framework that takes into account aspects of social life in the past without the aid of computer simulation. ABM of pedestrian movement have the potential to form a robust and theoretically informed methodology for the exploration of various possibilities of moving through the built environment that is capable of producing repeatable results. In this sense they do have advantages over other approaches to the experience and action in space, such as phenomenology or virtual walkthroughs, which usually depend on the subjective and individual response of the researcher towards an environment devoid of human interaction.

Of course, there are some caveats regarding ABM applications that must be borne in mind. To date, there has been much discussion about the level and nature of knowledge that can be offered by ABM, and in particular whether they can be used for accurate quantitative analysis, interpretation and prediction, or only to inform qualitatively research on human phenomena (Bonabeau 2002, p. 7287; Batty and Torrens 2001; Castle and Crooks 2006, p. 15; Gilbert 2004; Kerridge et al. 2001; Helbing and Molnár 1995; Torrens 2003, p. 78). The current debate has focused on the application of ABM to the investigation of social phenomena in modern human societies, but for the needs of this research the particular implications of their use in archaeological practice should also be emphasised.

A basic problem of all ABM applications, utilised for the study of either contemporary or past societies, is that human behaviour can be complex and unpredictable (Bonabeau 2002, p. 7287) and cannot be easily understood, justified or quantified. Furthermore, the parameterisation of ABM requires a variety of socioeconomic data for the population under study (Kerridge *et al.* 2001), which are often difficult to obtain and not always available even regarding modern societies.

This problem appears on a much larger scale when the aim of the modelling is to investigate past human phenomena. It should always be recognised that the behavioural trends of pedestrians in the past could have been different than those observed nowadays. Even "automatic" reactions of individuals while walking (Helbing and Molnár 1995) can be culturally specific. For example, in Germany pedestrians prefer to turn towards the right-hand side to avoid an obstacle (Helbing *et al.* 2001, p. 364-365). In American downtown streets, and perhaps in other contemporary societies, males take often the road side when passing females, while women perhaps in the anticipation of such behaviour wait longer before yielding to an oppositely moving male individual (Goffman 1972, p.31, note 12). In addition, in most societies there are traffic rules that regulate the interactions (e.g. priority) between pedestrian and wheeled vehicles. Similar regulations or non-discursive strategies would have shaped the behaviour of individuals and patterns of movement in past societies in ways that on most occasions cannot be anticipated. In only a few cases, there is evidence about human movement and transportation in the archaeological record. A good example is the case of Pompeii where the study of the rutting and marks on kerbstones, stepping stones and other street features has enabled not only to conclude that traffic in the Roman town was systemised, but also to identify two-way and one way streets, as well as the side on which cart-drivers used to drive (right-hand side) (Tsujimura 1991; Poehler 2006). Finally, the validation of an ABM model employed in past environments is quite problematic. Validity in ABM is usually ascertained by comparing the output of the model with comparable data of a real-world system (Castle and Crooks 2006, p. 37), presumably similar to the one under study. The validation of ABM that use archaeological data therefore entails difficulties as past systems cannot be the object of direct observation and are often very different to those that can be examined today. Moreover, the validation process also requires the calibration of the model, namely to assign values to the model parameters that reflect a real world system. The calibration of an ABM that investigates human movement in the past could be partly based on values obtained from a modern system, but this is not always possible.

The above caveats do not aim to imply that ABM cannot or should not be applied to past environments, but merely that their results should be appreciated from a critical stand. The degree of accuracy and completeness in the model inputs should determine (Castle and Crooks 2006, p. 15) the inferential framework in which the output of the model should be interpreted. On certain occasions ABM are better seen as useful "tools to think with" (Batty and Torrens 2001), which enhance our understanding of past space-time dynamics otherwise little understood, rather than models that provide an accurate prediction of an alleged past reality.

Considering the above one has to conclude that human behaviour is difficult to be understood let alone be predicted. Analytical and computational models of pedestrian movement cannot offer a complete explanation of why people move, nor embrace all of the possible factors that could have influenced the behaviour of individuals. Nonetheless, such approaches have proved successful in developing and employing theoretical and methodological frameworks that can be used for the "prediction" of movement patterns observed in real world situations. From the factors that affect human mobility mostly spatial configuration, socio-economic uses of space, and pedestrian interactions were discussed above. Physiological factors of movement related to energy, time and cost expenditure, other modes of transport besides walking, the quality of the street network, as well as social perceptions of space should also be considered, however, as parameters occasionally affecting human mobility in built environments. Although the issue of which factor has a primary role in shaping patterns of human movement is still a matter of debate, on most occasions the answer depends on the scale of analysis and on the particular way the problem is framed. Furthermore, the fitness of an ABM is greatly depended on the availability of the datasets that are necessary to inform the model parameters. This fact greatly restricts the aspects of human mobility that can be formally investigated in historic and prehistoric built spaces that are only partially preserved and excavated. In the case of Akrotiri, for example, the application of a formal approach that seeks to investigate movement phenomena at medium spatial scales through the examination of the spatial configuration of the street network (i.e. axial analysis or ABM with a route choice mechanism), could have suggested the most widely used streets in the settlement, indicating the degree of integration of those public areas from which the paintings would have been visible. The urban tissue of the prehistoric town is, however, only partially known and the application of such an approach is not possible. Nonetheless, there is plenty of evidence for the use of space in the excavated area (cf. Chapter 2) that give an indirect indication of the significance and character of the excavated street segments and human movement within them. On the other hand, movement at fine spatial and temporal scales in the urban network of the prehistoric town can be studied with formal methods. Within the unearthed part of the town an agent-based approach could help the investigation of patterns of movement at the micro-scale, illuminating those occasions when visual access to the painted scenes could have been determined by pedestrian interaction. Such a case is investigated below. Before presenting the model evidence for movement through the street network at medium spatial scales should be discussed.

6.3 Human mobility in LBA Akrotiri

6.3.1 Pedestrian movement at medium spatial scales

Studies on pedestrian movement within contemporary environments can take into account a vast amount of socio-economic data obtained by direct observation of the population under study using video cameras, time-lapse photography, as well as interviews and questionnaires (Kerridge *et al.* 2001). Unfortunately, these options are not available for the archaeologist who seeks to investigate movement in past built environments and the reconstruction of life in Late Bronze Age towns is a difficult task based on an inevitably incomplete archaeological record.

In Akrotiri, although a small part of the settlement is excavated, the exceptional degree of preservation of the site, and the unique information that can be derived by individual contexts enable important insights into aspects of the everyday life of the prehistoric town inhabitants including food procurement, craft production, exchanges, and social/ritual performances (cf. §2.3). Communication and interaction among the town dwellers were essential in all the above situations, and were accomplished via movement through the urban network. Besides forming passageways between places, the streets and public open spaces would have been the stage of both random and purposeful encounters among the town dwellers or visitors. Most human interactions, however, would have taken place along the thoroughfares of the street network, which channelled movement through the settlement and essentially shaped the human experience and engagement with the townscape.

In Aegean Bronze Age towns main thoroughfares are often the outcome of a slow formation process that mirrors the long-term use of space rather than elaborate planning. This is especially true for settlements that have a long history of habitation such as that at Akrotiri (cf. § 2.2). In this case the main streets of the town are often shaped by the accumulation of buildings along routes that had been long used for human movement and transportation in the course of everyday life (Palyvou 2005a, p.

31; Chryssoulaki 1990). In this sense major roads within the urban network already suggest the most persistent and enduring patterns of pedestrian movement within a settlement.

Although the layout of Aegean Bronze Age towns is hardly ever completely preserved or excavated, major roads can be identified partly because of their form. In Aegean Bronze Age urban centres, where streets as a rule are up to a couple of meters wide, main roads form the most spacious pathways within the town network. They are also likely to be the longest street segments, because they essentially channel movement through the town, serving the needs of the community rather than those of individual households. Sometimes, they stand out from secondary passageways because of the details of their construction, for example the existence of paving or the fact they are delimited by elaborate building facades (Palyvou 2005a, p.29, 31). Primarily, however, major roads are distinguished because they offer access to places of public interest, namely important buildings, open spaces and loci that were significant for the daily life of the town dwellers (Chryssoulaki 1990, p. 372) forming a fundamental link between the private and public sphere.

Telchines/Daktylon St. and Koureton St. (fig.1-1), which traverse the unearthed part of Akrotiri from north to south and east to west respectively, have many of the characteristics of major roads. Telchines/Daktylon St. is about 2.00-2.20m wide and over 120m (Palyvou 2005a, p. 29) — the widest and longest road that has been excavated so far — and seems to extend further to the north and south, probably reaching as far as the coast (Palyvou 2005a, p. 65). Parallel to the Telchines/Daktylon St axis runs another minor street with a north to south orientation, which has been named Daimonon Street. This is about 1.20-1.70m wide and it does not traverse the settlement, as it was interrupted at the area between Xeste 2 and Delta 19 by a retaining wall (Palyvou 2005a, p. 29). Koureton St. (1.60-2.00m wide), on the other hand, has an east-west orientation and at least according to Palyvou,[60] expands beyond the excavated area at both ends, forming the second known major passageway of the street network (Palyvou 2005a, p. 31). That said, one has to consider that the greatest part of the town still remains to be excavated, and if we are to discuss the significance of these roads within the prehistoric town network, or the degree to

[60] Doumas (1998, p. 132) notes that the southeast end of the road is blocked by the walls of Xeste 4 and the building ΙΔ that appear to meet at this point. Palyvou (2005a, p. 43, note 14) on the other hand, argues that the road is blocked only by building debris, and that Koureton St. would have extended further to the east.

which they would have determined patterns of movement in the settlement, it is important to consider the connections they establish among important loci in the life of the community.

Evidently, significant places for the dwellers of the LBA port town were those associated with essential everyday economic-productive and social activities, namely arable fields, pastures, the harbour and the coast. As discussed in § 2.3 the subsistence of the households at Akrotiri would have depended on communication between two spatially segregated urban and rural districts and the transportation of people and foodstuffs from the northern limits of the town, the hinterland, and possibly neighbouring islets towards the urban centre. The need for communication with the "producing" sites in the north would have been served mainly by the major routes that ran through the settlement. Telchines/Daktylon St., having a north to south orientation, certainly appears to be one of them. Sea transport of products coming from the northern parts of the island or the neighbouring islets cannot be excluded either. In this case, goods could have been imported into the town from the harbour (cf. § 2.1), subsequently following the aforementioned north-south thoroughfare. Telchines/Daktylon Street would have been used by the community in many other occasions when connection to the coast was necessary. As already mentioned (cf. §2.1, §2.3.2, §2.3.5), the harbour was also one of the daily destinations for those town inhabitants involved in the procurement of sea products and seafaring activities, as well as one of the important termini in the course of communal ritual performances.

It is also noteworthy that Telchines/Daktylon Street and Koureton Street connect important loci within the geographic extent of the excavated area. They offer access to public buildings, such as Xeste 3 and Xeste 4 and traverse open spaces such as the Square of the Benches and the Square of the Cenotaph (fig. 1-1) that may have been used for social/religious ceremonies, apparently of public character (cf. § 2.3). Furthermore, Telchines/Daktylon Street enabled access to buildings that appear to have been textile household workshops (West House, Complex Delta, Sector A), serving the needs of those involved in textile production, as well as the transportation of raw materials and possibly finished trade goods. The presence of public buildings, the affluence of the excavated houses, the proximity to the coast and the harbour, all form evidence that the unearthed part of the town would have been located at the centre or close to the centre of the settlement. Thus, Telchines/Daktylon and Koureton Streets, by establishing connections between loci and termini that are important for the social and economic life of the community, appear to have been multi-functional thoroughfares and main channels of human movement in the Late Bronze Age.

The possibility that somebody traversing the street network could have encountered the painted walls of the Gate, the West House and Beta South can be discussed at this point. The wall-paintings of the Gate could have been viewed by those walking along Telchines/Daktylon axis, since the paintings were visible as soon as someone approached the Gate from the north or south. For the wall-paintings of the West House we cannot be conclusive, as the area to the west of the building is unexcavated and there is no evidence suggesting the degree to which this part of the town was integrated in the daily routes of the inhabitants of Akrotiri. The only thing that can be said in this case is that if pedestrians reached the Square of the Ship Procession, they would probably see the painted friezes since they were highly visible from the square. The extent to which the murals of Beta 1 were exposed to pedestrians is also not evident, however, despite the fact that the Square of the Mill House is fully excavated. Figures 5-23 and 5-24 demonstrate that although the wall painting of the east wall could have been viewed even partially from many location in the square, the south and the west walls (the "Boxing children" and the "Antelopes") would have been visually accessed only from a small area at its south east corner, just outside the window of Beta 1. It is noteworthy that this area does not fall exactly within the main traffic axis that traverses the public open space from north to south (Fig 6-4a). Furthermore, as already mentioned, the narrow passage outside the window of Beta 1 which used to separate Beta North from Beta South is a blind alley aimed to meet the ventilation and illumination needs of Beta complex, and therefore is not connected to other pedestrian routes; the windows of Beta 7 and Beta 6 face towards this space (Palyvou 2005a, p. 34). On the other hand, the alley at the west of Telchines Street is only partially excavated, but it has been described as "very narrow" (Palyvou 2005a, p. 69) a fact that suggests that it may have had a similar function to the alley passing along the north façade of Beta complex. Pedestrians rarely change course without a reason (Helbing et al. 2001), and one can argue that individuals walking along Telchines/Daktylon Street having a southerly orientation would not have moved towards the area of the window and, consequently, they would not be in position to see neither the "Antelopes" of the west wall nor the "Boxing Children". Such a statement appears to make sense in the case when an individual would traverse the square in absence of other people. However, in the most likely situation of inhabited space, the interactions among pedestrians must also be taken into account before any persuasive suggestion regarding pedestrian movement along Telchines/Daktylon Street can be made.

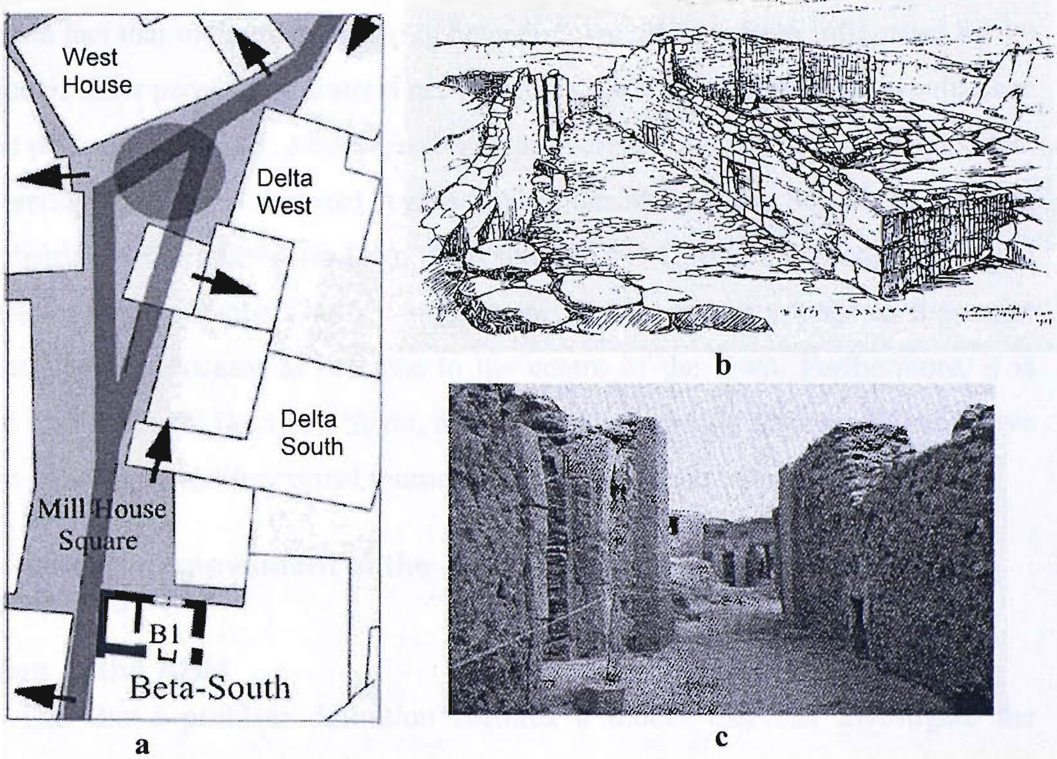


Figure 6-4 a) Telchines Daktylon Street traffic axis at the area of Mill House square (based on Palyvou 2005a, p. 32) b) Telchines Street; view from the south: artist impression (form Michailidou 2001a, p.283 cited Marinatos (1970). c) Telchines Street view from the south (from Palyvou 2005a, p.33). The gate is in the background.

In order to examine the relationship between the locations that could have enabled the visibility of the wall paintings and possible patterns of pedestrian movement at the area close to the window of Beta 1 an agent-based micro-simulation was carried out. Two points should be made before describing the model. Firstly, it is necessary to acknowledge that any successful approach to the experience and movement in past environments should take into account — or at least attempt to discuss — the possible activities that would have occurred in the spaces in question. Regarding the nature of practices within the public spaces of Late Bronze Age Akrotiri many suggestions have been made (cf. Chapter 2), including public gatherings of social/religious significance, processions, and trade, although these activities are very difficult to reconstruct in a convincing way given the existing evidence. On the other hand, it can be reasonably argued that at a rudimentary level streets and squares would have acted as passageways channelling human movement. The suggested model is therefore aimed to investigate tendencies in the mobility patterns of oppositely moving pedestrians along the axis of Telchines and Daktylon Streets, and especially at the area around Beta South complex, by taking into account the simple fact that individuals' walking behaviour would have been influenced by the presence of other people in the street network. It is also held that this area would have been, at peak times at least, a busy passing point. Perhaps it is difficult to imagine that the presently ruined and deserted region around the Mill House Square was once a lively district of the prehistoric town. Nonetheless, our current knowledge about the settlement seems to support such a suggestion. The square, as applies to the entire excavated area, is located at or close to the centre of the town. Furthermore, it is crossed by Telchines/ Daktylon Street, a road which as already discussed would have been an important multifunctional thoroughfare within the street network.

6.3.2 Pedestrian movement at the micro-scale: an autonomous agent-based approach

Purpose of the ABM

The above problem definition requires a model that can investigate the behaviour of mobile individuals at very fine spatial and temporal scales. The conceptual framework of Helbing's social force model appears to be suitable in this case, as it describes some very basic modes of pedestrian action and interaction at the micro-scale. Pertinent to the employment of this approach is the following discussion on modes of transport of people, animals and goods in the Late Bronze Age Aegean. This is necessary for shedding further light onto the context of practices related to movement in the prehistoric town and for defining the basic elements of the system modelled.

Elements of the model: means of land transport in Aegean Bronze Age

Evidence of movement and transport in the Late Bronze Age, involving pedestrians, human porters, pack and ridden animals, and wheeled vehicles is sparse and indirect, and comes mainly from iconography. The miniature paintings of Thera, Kea, Tylissos and Crete (Immerwahr 1990, p. 63-75) constitute rare source materials on human activities and movement, sometimes situated in the built environment[61]. Yet, at least as far as the paintings from Thera, Kea and Crete are concerned, the illustrated events relate to festivities and communal gatherings (Morgan 1988, 1998), rather than productive/economic aspects of daily life, which are, as a rule, rarely represented in Aegean art. From the Tylissos fresco (Shaw 1972) too few fragments survive and the exact theme of the painting is not clear.

The procession scene from the miniature fresco of the West House (fig. 6-5) offers some insights into characteristic modes of human movement during public festive events, where a large number of pedestrians would walk in an organised manner in the same direction. In the miniature friezes of Kea and Tylissos, however, movement of pedestrians is sometimes linked to the transportation of heavy goods, which would have been a common activity in the course of everyday life in Late Bronze Age. The paintings from the North East bastion at Ayia Irini (Morgan 1998; Coleman et al. 1973; Abramovitz 1980) depict men walking in opposite directions, some of them carrying pots suspended on poles. Transportation of goods by groups of men is also illustrated in a hunting scene that comes from the same room; it shows a man carrying a deer slung on a pole, whose other missing end was apparently supported by a second individual (Morgan 1998, p. 204). A surviving fragment from the Tylissos fresco (fig 6-6), which possibly depicts the transport of amphorae (Shaw 1972), also shows a man bearing a pole on his shoulder upon which an amphora is attached (Shaw 1972, p. 186). Finally, women carrying pots on their heads are depicted in the miniature frescoes of Thera and Kea (Morgan 1998; Doumas 1992a, fig. 28).

Figure 6-5: Procession of men from the south frieze of the Miniature fresco. From Doumas 1992a, fig.46.

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[61] This can be maintained with certainty for the miniature paintings of Thera and Kea. Only very few fragments survive from the painting found at Tylissos; one of them (no 12) depicts part of a building (Shaw 1972, p.178).

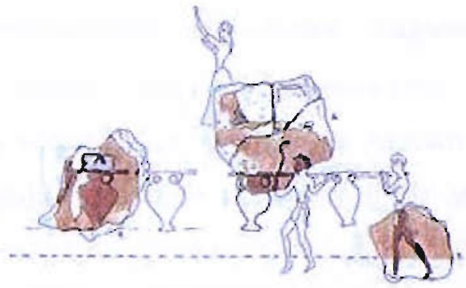


Figure 6-6: Man carrying a pole from which an amphora is suspended (from Shaw 1972, fig 13)

Besides these few scenes illustrating pedestrians and human carriers, transportation of people and goods in the Late Bronze Age is also attested in a few clay and painted representations of pack and ridden animals identified as horses, mules or asses (fig. 6-7). Most of these artefacts are discussed by Crouwel (1981) in his thorough treatment of transport in Late Bronze Age Greece and date after the volcanic eruption that destroyed Akrotiri, the earlier belonging in Late Minoan III and Late Helladic III (Crouwel 1981, p. 44). However, the study of osteo-archaeological evidence in Bronze Age settlements confirms that asses, which would have been used as carriers for land transport, appear already in Lerna in the Early Helladic II period (Crouwel 1981, p. 35), whereas the presence of horses is first confirmed on mainland Greece slightly later in the Middle Helladic period (Crouwel 1981, p. 33). Among the bones unearthed in Akrotiri, one specimen belonging to an equid has been reported (Gamble 1978; Trantalidou 1990), although the exact species could not be identified. It is interesting, however, that Nikolakopoulou (2002, p. 87) observes that the morphological characteristics of certain Theran pottery vessels, such as size, shape, handles and crescent lugs, would have enabled the use of strings for their easy and secure transport on a carrier.

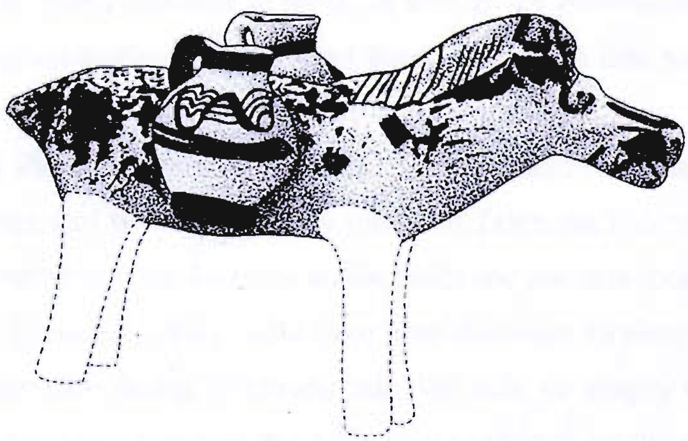


Figure 6-7: Pottery vessel from Phaistos representing an equid carrying a pair of jugs (LMIIIC) from Crouwel 1981, pl. 50.)

Since both types of wheeled vehicles, wagons and chariots, have been associated with some Aegean Bronze Age towns prior to or at the period of the eruption of the Theran volcano, their presence in Akrotiri cannot be excluded either. Wheel marks that would have been the most direct and apparent indication for wheeled traffic (Tsujimura 1991; Poehler 2006) are yet to be reported. Nonetheless, in Akrotiri there was a network of roads with cobbled paving and some of them, such as Telchines/Daktylon traffic axis, could have been suitable for wheeled traffic; it is wide enough for small vehicles, slopes gently towards the south, and passes through many open public spaces that would have been adequate for pulling over vehicles. Such wagons may have served occasional needs for the transportation of heavy goods like imported or local wood and stone, used for building activities, or large quantities of farm produce. The existence of chariots in Akrotiri can less easily be assumed, as they were prestige items (Morgan 1998, p. 204), usually associated with Knossos. Seal impressions showing the representation of a chariot have been found in Akrotiri, but they are of a non-local clay, possibly originating form Crete (Crouwel 2005). Nonetheless, as already mentioned, a chariot is represented close to the harbour of the prehistoric settlement at Ayia Irini, and the presence of such a prestige item in Akrotiri, which appears to have been larger and more affluent, cannot be precluded. In any case, however, the presence of wheeled vehicles in the streets of the prehistoric town should have been rare; the transportation needs of humans and goods were more likely to have been covered with pack and/or ridden animals, as was the case in the Greek mainland and islands until modern days.

The elements of the model

Bearing the above evidence in mind, as well as the socio-economic character of Telchines/Daktylon traffic axis, the agent-based simulation that was implemented in this case allowed for the presence in the street network of:

A) Mainly single pedestrians or human carriers. These represent individuals of varying age and sex that would have daily traversed Telchines/Daktylon St. to reach the coast and the harbour at the south, or arable fields and pastures located at the north of the settlement. In addition they could have been the town dwellers residing in the houses with an entrance facing Telchines/Daktylon axis, or simply individuals that were involved in economic activities that have been suggested for these houses.

B) Groups of pedestrians walking together or taking part in a common task, for example transportation of heavy goods. Human carriers could have carried bulky objects suspended from poles, as represented in the miniature scenes of Tylissos and Kea (fig. 6-6). One can imagine that groups of human carriers would not have been an uncommon sight in this area that was close to the coast and probably to the port of the town. Groups of people in the model do not permit other individuals to move through them.

C) Pack and ridden animals used for the transportation of humans and goods. The transportation of raw materials and finished products to and from the buildings housing textile workshops (West House, Sector Alpha, Sector Delta) could have be made by these means.

D) Small wheeled vehicles, such as wagons or carts. These could have been used for the transportation of building materials or large quantities of farm produce to the storage facilities of the buildings accessed through Telchines/Daktylon street (Nikolakopoulou 2002), for example the West House, Sector A, Delta West, Delta South, Delta North, Sector Gamma, House of the Anchor, House of the Ladies, Xeste 3. As mentioned above, wheeled vehicles should have been rare in the street network of Akrotiri, for this reason they are included in only some simulation runs.

The model environment and rules of agent interaction

The agent-based model was implemented with the Crowd simulation engine of 3ds Max 8 which enables the creation of autonomous software objects with cognitive abilities and behaviours, called delegates. Delegates are capable of "sensing" obstacles in the environment and other agents in their surroundings, acting according to a predefined set of goals and rules. They can also change their behaviour in the course of a simulation solution following scripted conditions, demonstrating a form of artificial intelligence. During a simulation run the delegates' intentions are expressed as repulsive or attractive forces that ultimately determine each agent's position and velocity. A force is conceived as a sphere around the delegate that defines the distance in which the influence of attraction or repulsion starts to be exerted. At the conceptual level it may, as well, be understood as the agent's intention to avoid or reach something. In this respect, the simulation engine of 3ds Max seems to be particularly fitted for the employment of the concepts of the social force model. It is noteworthy that the exact specification[62] of this model requires that the repulsive forces are "asymmetric", because pedestrians "rarely react to situations behind them", and "anisotropic" as individuals "need more space in the walking direction than in directions perpendicular to it" (Helbing et al. 2001, p. 366). Helbing et al. (2001, p. 366) conclude, however, that "all of this is not essential for the resulting self-organization phenomena". Forces in 3ds Max crowd simulations are symmetric and isotropic, as they are diffused within the boundaries of a sphere, this, however, should not significantly affect the emergence of collective patterns of human movement.

Figure 6-9: The ABM environment: agents moving towards the south are indicated in green and those heading towards the north in red. The blue object stands for group of pedestrians, pack or ridden animals. Forces of avoidance (hard and repel radii) are indicated with light blue.

[62] The concrete mathematical specification of the force terms, is discussed in detail in Helbing and Molnár (1995) and Helbing (1996, 1997).

The behaviour of agents was set following the principles of the social force model. All agents aimed to keep a distance from boundaries in the environment and other individuals, animals, and vehicles, while moving in a north or south orientation within the Telchines/ Daktylon traffic axis, and more specifically between the area of the Gate and the south end of Telchines street. In the model delegates are represented by default with a pyramid shape (the point of the pyramid indicates the forward direction of the agent), and most of the time represent individuals (fig. 6-9). Larger elongated objects attached to delegates were used to represent pack or ridden animals, vehicles and groups of pedestrians or human carriers. All delegates were set to act following two basic behaviours that are built-in the simulation engine of 3ds Max:

a) Avoid behaviour: Agents were set to avoid other agents and wall boundaries. The Avoid behaviour works as follows: The object to be avoided is environed by a bounding sphere (hard radius) that agents cannot penetrate. In order to keep away from an obstacle delegates can steer, slow down or even stop. In addition to the hard radius, the object to be avoided is encircled by a second sphere with a larger diameter within which a repelling behaviour is sensed, making the agent start evading the obstacle in question. This sphere only expresses a tendency of avoidance and it does not have determinative effects on the delegate's behaviour, meaning the agent can still approach the object, if another behaviour or tendency overpowers the repelling behaviour.

While creating the model, the description of a building as a single object representing an obstacle appeared to be problematic, as the repelling force is always expressed as a bounding sphere that has its centre at the pivot point of the modelled object. As buildings in Akrotiri are not spherical, on most occasions the influence of the force either does not reach the wall boundaries, meaning the agents could penetrate walls, or far exceeds them, and as a consequence the delegates cannot approach close to the building. The latter significantly hinders the modelling of the scenario that needs to be examined here, since agents traversing Telchines Street in opposite directions need to approach in close proximity to the walls of Sectors Gamma and Beta. For this reason smaller box-shaped objects whose bounding sphere better matched the original building borders were used to make pedestrian evade walls (fig. 6-9).

b) Seek behaviour: Agents were made to follow a constant direction either up or down the Telchines/Daltylon traffic axis by seeking targets. A first target was set at the north end of Telchines Street so as to make the agents orientate towards the path. Another target was placed at the south end of the study area and two more at its north end (one at the north of the Gate and the other further west) pointing at the destination of the agents. The agents were programmed first to seek the target on Telchines Street. After they reached this they would seek a second target either to the north or south following their original orientation. That sort of behaviour was enabled with scripted conditionals.

Parameterisation of agent's behaviour

During the iterative running of the simulation the values of the parameters of the agents' behaviour were altered many times. Self-organisation phenomena were observed in medium and high pedestrian densities and are described in detail below. Generally, it was found that the emergence of observed collective patterns of movement was not sensitive to small, or even sometimes to large changes of certain parameter values (for example, the speed of movement, agent's starting position, or repel radius). This seems to agree with Helbing's et al. (2001, p. 367) observations who note that the generic patterns of crowd movement that emerge with the employment of the social force model are not very sensitive to the exact specification of the model parameters, as applies for the forces. In the end however, certain values were preferred, as they formed a better match to real world data. In cases where such data were not available the model was parameterised using plausible random values. The effects of altering the parameter's values on the observed general patterns of movement were again examined through iterative simulation runs. Below the most important variables of the model are described:

Number of agents: One of the parameters of the model that significantly influences the results of the simulation is the number of agents that interact each time. This factor greatly affected the pedestrian densities in the study area, and more specifically the main areas of interest close to the window of Beta 1. On most occasions, when there were less than 10 agents, no collective patterns of movement emerged and delegates managed to reach their destination without approaching the area in question. On the contrary, it was found that self-organising patterns of movement emerged when at least 12 interacting agents standing for single pedestrians were distributed more or less equally in both directions of movement. On the occasions when a greater number of pedestrians, and when agents representing groups of people, ridden and pack animals or vehicles were included in the simulation, the observed collective phenomena of movement were made even more apparent.

The presence of 12 to 14 pedestrians in the study area is considered plausible for peak times, if one takes into account suggested population estimates for the unearthed part of the town (300-450 according to Nikolakopoulou (2002, p. 198; cf. §2.2) and that Telchines/Daktylon axis would have been a main thoroughfare, used by many other town inhabitants or visitors.

Personal space that a pedestrian wishes to maintain: This is defined by the specification of hard and repel radius in the Avoid behaviour. The fact that the widest routes in the prehistoric town were up to 2.20m (the north entrance at Telchines Street is about 1.70m), while narrower streets were 1.20m-1.70m (Palyvou 2005a, p. 29) means that pedestrians would not have kept great distances to each other while traversing the street network. Furthermore, the personal space an individual wishes to maintain is also dependent on pedestrian density, with pedestrians keeping smaller distances in high densities (Helbing *et al.* 2001). In this case the repel radius of the avoid behaviour for single individuals was set at 1m and the hard radius at 50cm, as these values would enable agents to move in opposite directions along a street at the same time. In the squares of the prehistoric town pedestrians would have kept greater distances to each other, but since the model mainly aims to investigate the behaviour of individuals while approaching or walking along a street segment the above values were considered adequate for the modelling of the particular scenario.

Speed of movement: Observations of pedestrians in modern environments suggest that human walking speed on a level surface can be relatively standard approaching 1.5m/s (Sutherland et al. 1994; Turner and Penn 2002). However, in many real-life situations pedestrian speed varies according to the activities the walkers are involved in, their age or gender (Kerridge et al 2001, p. 330). People carrying loads and older individuals move slower than young people or pedestrians that do not bear weight. In the ABM simulation delegates representing humans were given various speed values that deviate from the average walking speed, so as to allow for the possibility that individuals of different ages and pedestrians that were potentially involved in different activities (e.g. walking, transportation of goods etc.) were traversing the street network. Speed of movement was allocated for each agent randomly before each simulation run.

There are no real life data available regarding the speed of movement of wheeled vehicles, pack and ridden animals in a built environment such as that of Akrotiri, although one can imagine that speed would have varied depending on parameters such as the amount of load carried, the slope of the street segment, etc. For the requirements of the simulation animal and vehicle speed was set randomly around the average walking speed of pedestrians. With iterative simulation runs it was found that changes in the speed values do not affect the emergence of the observed generic patterns of movement. It has to be noted, however, that, generally the presence of pack or ridden animals and vehicles was not assumed in all simulation runs, as it is not possible to determine given the existing data the frequency in which animals or vehicles would have been encountered in the streets of the prehistoric town. In the great majority of cases each delegate stands for either a pedestrians or a group of pedestrians. The presence of vehicles at least, as noted above, would have been rare. In the cases where animals or wheeled vehicles were included in a simulation run, they where represented by no more than one delegate. This, as far as animals are concerned, might be a rather conservative assumption for certain situations in the past, when, for example, the transportation of a considerable amount of goods could require the use of more than one animal.

Starting position: The starting position of agents within the study area was altered using random number seeds before each simulation run. This process aimed to allow for the possibility that pedestrians would approach the locations of interest from different directions. One has to take into account that pedestrians would have entered the Square of the Mill House in a north or south orientation following the main traffic axis. Some may have come, however, out of the main building entrances, while others may have moved in the square in ways we cannot predict nowadays and in the course of activities that are hard to envisage. A random starting position accounts for all the above possibilities. In any case, it was found again that changes in the starting position of the agents do not affect the observed collective patterns of movement that occur close to the area of the window of Beta 1.

Solving the simulation

As already mentioned, when the presence of less than 12 agents was assumed in the model, they tended to follow the main Telchines/Daktylon axis and did not approach the area from which the wall paintings of Beta 1 would have been visible. In medium and high pedestrian densities, however, which could have occurred in the area at peak times, self-organisation phenomena were observed, resulting in a tendency of the agents to move close to the window of Beta 1 (fig. 6-10, 6-11, 6-12). This was mainly due to encounters and repulsive interactions among oppositely moving individuals that would have occurred near the entrance of the narrow passage at the west of the Beta South complex. More specifically, individuals walking towards the south would often have to move away from the main road when they approached Telchines Street, slowing down or even stopping close to the window of Beta 1 (fig. 6-10), in order to allow pedestrians coming from the opposite direction to enter the Mill House square. The patterns of movement that emerge in this case are similar to oscillations of the passing direction that are often observed at bottlenecks in real life (fig. 6-11, Helbing et al. 2001, p.370).

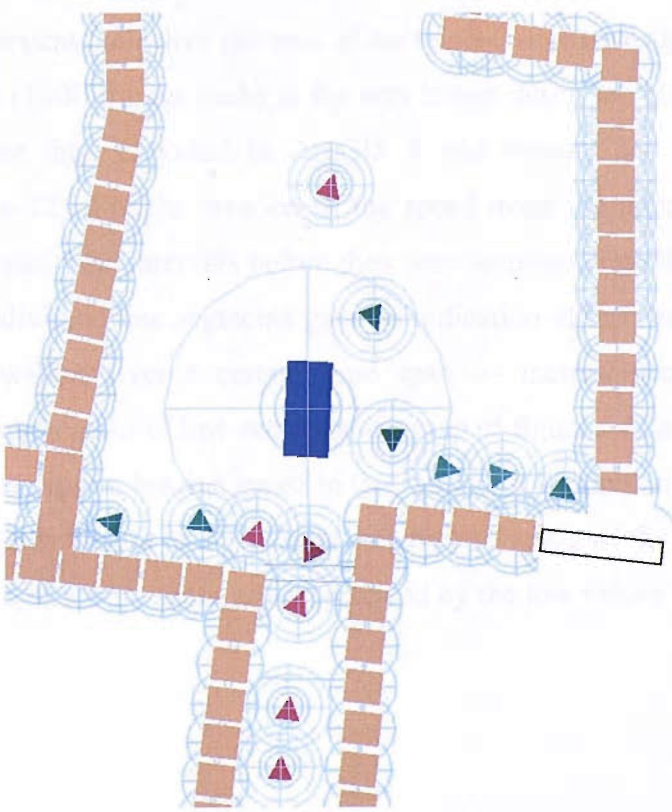


Figure 6-10: Interactions of pedestrians close to the area of the window of Beta 1.

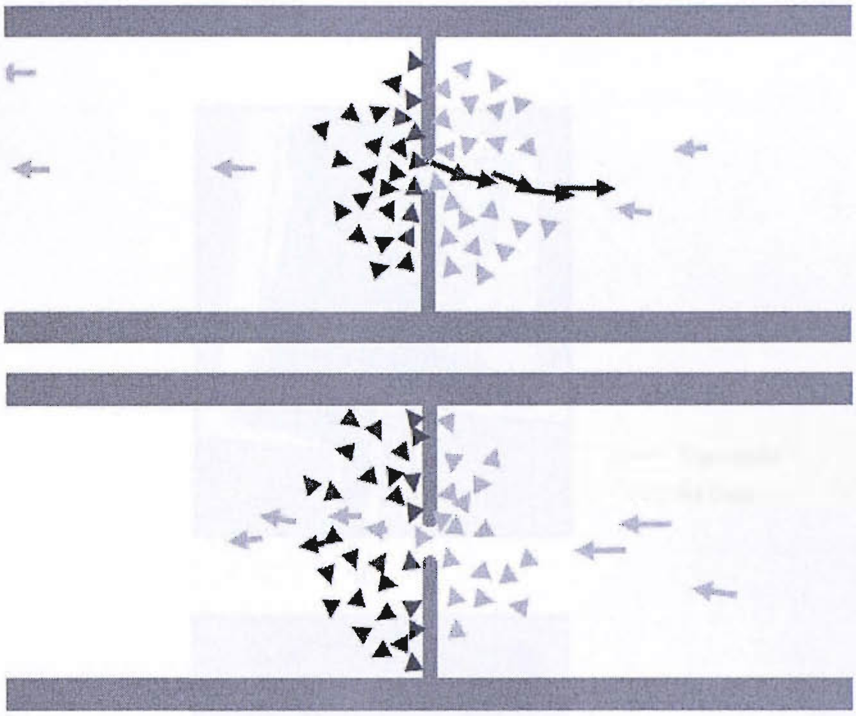


Figure 6-11: 'At narrow passages one finds an oscillation of the passing direction. When a pedestrian is able to pass through the door, normally another pedestrian can follow him or her easily (above). However, the pedestrian stream arising in this way will stop after some time owing to the pressure from the other side of the passage. Some time later, a pedestrian will pass through the door in the opposite direction, and the process continues as outlined before' Helbing et al. (2001, p.370, fig.7).

The emergent collective patterns of movement were investigated with iterative simulation runs (1000 frames each) in the way it was described above. The delegates trajectories were then exported in ArcGIS 9 and density and speed maps were produced (fig. 6-12). For the creation of the speed maps the agent trajectories were segmented in equal time intervals before they were imported into the GIS. In this way the length of individual line segments gave an indication of the velocity of movement (e.g. distance walked over a certain time span — metres/ second in this case). Following the application of line statistics, the map of figure 6-12c was created which illustrates the average pedestrian speed in the square for 40 simulation runs. The areas in which the agents tended to slow down or stop as a result of the geometry of space and the presence of other agents, are represented by the low values (light blue-blue).

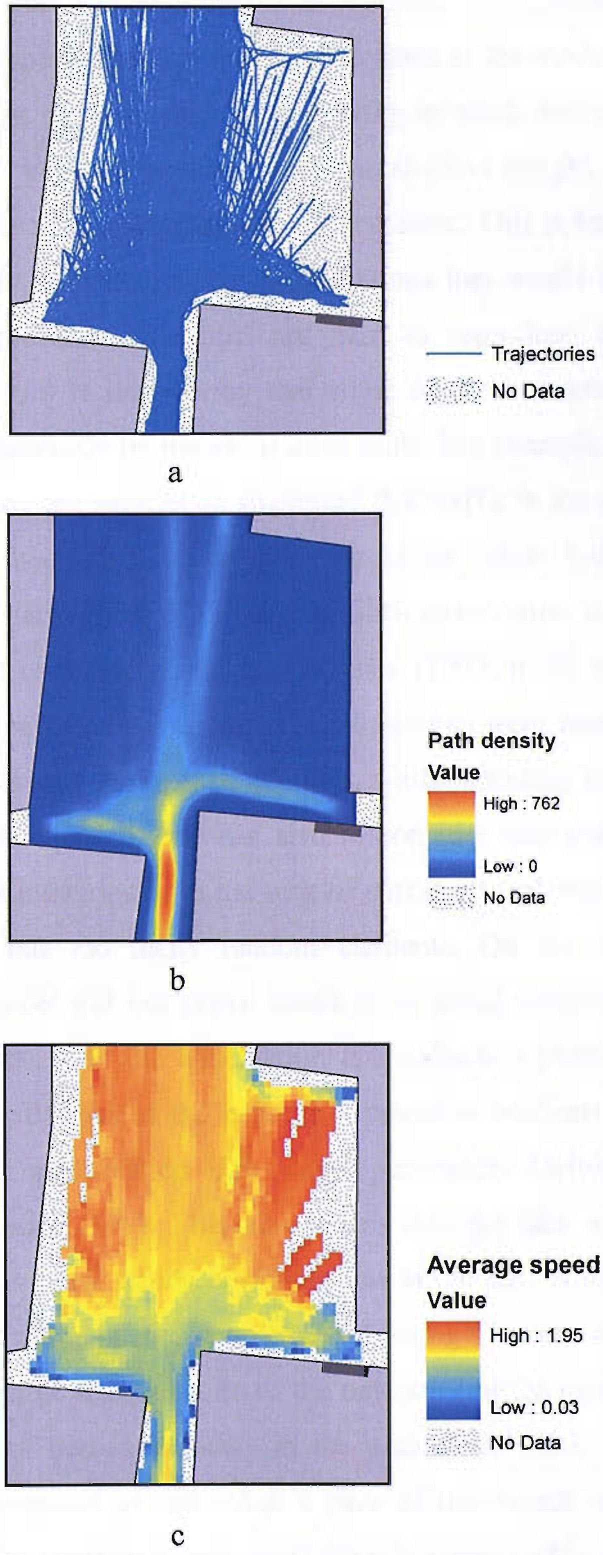


Figure 6-12: a: Agent trajectories derived from 40 simulation runs. b: Path density. c: Average pedestrian speed.

Interpretation

The results of multiple simulation runs presented in figure 6-12 suggest that pedestrian interactions in the study area could on certain occasions bring individuals close to the window of Beta 1 making the visual exposure of the paintings more likely than it would initially appear. The fact that the outcomes of the model seem to reflect real-world situations (fig. 6-11) is promising. Having in mind, however, the caveats mentioned in §6.2.5, the model should be used for qualitative insight, that is as "a tool to think with", rather than accurate quantitative prediction. This is because the model outputs cannot be easily validated, since the conditions that would have determined mobility patterns in prehistoric Akrotiri are hard to reproduce in modern built environments. However, it is noteworthy that some of the outcomes of the model seem to be supported indirectly by the excavation finds. For example, the observation of colliding agents during the simulation suggested that traffic in the street network of Akrotiri should have been difficult at peak times or when bulky goods were transported, due to the narrowness of the streets. Such observation is corroborated by excavation evidence: it is characteristic that Palyvou (1999, p. 90-91; 2005a, p. 31) notices that the lower part of several corners of buildings were rounded in order to facilitate traffic and to avoid damage. In addition, whilst deciding how the results of the model should be interpreted, one has also to consider that some of the model parameters were not calibrated, due to the lack of sufficient real-world data, and as a result the simulation has too many random elements. On the other hand it is noteworthy that the model did not prove sensitive to small variations in stochastic processes. This conforms with the observation that collective phenomena of crowd movement, such as oscillations of the passing direction at bottlenecks, are not very sensitive to the concrete specification of the model parameters (Helbing *et al.* 2001, p. 367; Helbing and Vicsekz 1999). This also means that the lack of knowledge for culturally specific behavioural trends of pedestrians in the past is less likely to have affected the emergence of the phenomena observed during the simulation.

Even the qualitative interpretation of the outcomes of the simulation enhances our understanding about human mobility in the prehistoric town. The intention to avoid collisions can interrupt an individual's pace of movement and even cause a pedestrian or group of pedestrians to pull away from the main traffic axis. At the north end of Telchines Street pedestrians or human carriers, with a south orientation might have chosen to give priority to individuals, groups of individuals or pack animals coming from the narrow passage at the south by stopping on the much wider open space in Mill House Square in the area close to the window of Beta 1. This behaviour would have only temporarily interrupted their pace of movement but it cannot be precluded that it would have motivated other kinds of pedestrian behaviour and interaction, e.g. human carriers could pause to rest for a while by putting down their load, and individuals could engage in conversations or other types of interaction. On many of the above situations pedestrians traversing the Mill House Square could have the opportunity to come upon the painted walls of B1. As it was demonstrated in §5.2.3 in the area outside the window of Beta 1 the wall-painting of the 'Boxing Boys' could have been exposed to the degree that one could distinguish the theme of the paintings. But even quick glances on the partly occluded painted walls could have communicated a variety of messages to the viewer (cf. Chapter 7). The outcomes of the ABM application further reinforce the possibility that the paintings would have been seen from outside the building, as they suggest pedestrians may have slowed down or even stopped close to the window (fig 6-12c). Speed maps such as that of figure 6-12c are thus instructive about the temporality of the human experience in built space and the pace in which the painted scenes could have been appreciated, complementing interpretations derived by the application of visibility analysis.

6.4 Summary and conclusions

The visibility of wall paintings from the open public spaces of Akrotiri would have been very much dependent on pedestrian movement through the prehistoric urban network. A discussion on human mobility in the open streets and squares of the prehistoric town is, however, a difficult undertaking, because they are only partially unearthed and even indirect evidence on human movement in the settlement is scanty. Some statements regarding mobility patterns at the settlement level can be made by taking into account the form of the excavated street segments, the presence of paving, the location of the main building entrances, the identification of public loci, and evidence for the use of space; all these indicate that Telchine/Daktylon St. was a main thoroughfare in the prehistoric town. This street would have channelled traffic through the settlement in Late Bronze Age shaping the mobility patterns of human walkers and carriers, pack and ridden animals and perhaps occasionally wheeled vehicles.

The application of an autonomous agent approach to investigate pedestrian movement and human-environment interactions in the preserved parts of the prehistoric network highlighted some plausible mobility patterns close to the window of B1. The social force model offered a useful and theoretically informed framework for discussing human behaviour in populated open public spaces, taking into account certain social factors that could have influence mobility through space in the past. Of course, the possibilities of moving through the street network are not limited to the outcomes of the model; depending on the human practices that could have taken place in these spaces in the past movement patterns could have been shaped in ways that are hard to predict, and the context of experiencing the murals would have changed accordingly.

From the above study and discussion on pedestrian mobility in LBA Akrotiri it appears that the paintings of the West House, Gate and Beta South would have been occasionally features of the townscape and elements of the public stage on which social interactions would have taken place. Murals seen from the street network would have embodied a variety of messages whose precise content probably depended on the social background of the onlooker. The identity of the potential viewers and the social consumption of mural decoration in Late Bronze Age Akrotiri are discussed in Chapter 7 that follows.

Chapter 7
Summary and Conclusions

The final chapter of this thesis serves three purposes: firstly, to summarise the outcomes of visibility and movement analyses and to examine the implications of the use of the suggested methods and technologies in this work. Secondly, to draw upon the conclusions of Chapters 4 to 6 and discuss the possible social functions of Theran murals in the prehistoric society of Akrotiri. Thirdly, to propose ways in which this work can further be developed within a wider academic framework.

7.1 Visibility analysis in fully 3D spaces: A summary of the methodology

A basic conclusion of this research is that 3D modelling and spatial analysis methods can be effectively combined for the investigation of visibility in partially preserved past spaces. Visual impressions derived from a 3D and human scale perspective of space can be explored and analysed by extracting information from 3D scenes. This has been accomplished in this research by simulating and analysing the effects of point source illumination produced by a single light source in a 3D digital environment. When the light source is placed at the height of the viewer's eye level illuminated and shadowed areas in a 3D model correspond to visible and non-visible surfaces respectively. Information on visibility within a scene can then be obtained by extracting the textures of 3D objects that include information on illumination. These textures provide useful data regarding visibility and non-visibility, angle of incidence and simulated 'natural' or artificial illumination in the 3D environment (cf. §3.3). Moreover, by changing the parameters determining the way light is distributed in the virtual scene various variables affecting ease of view, such as angle of elevation and distance, can be measured.

Visibility information extracted for a great number of locations in the study area can be summarised via the creation of 'times seen'. 'Times seen' highlight areas in space that are more visually exposed, and hence, more likely to be seen by an observer (cf. §3.3.3, §4.6). Furthermore, it is possible to map visibility information (for example percentage of visible area) derived from individual binary viewsheds back onto the study area. This sort of mapping is particularly useful for showing the changes in visibility that could have occurred in the course of an observers' movement (cf. §3.3.9, §4.6, §5.2). Alternatively, it could indicate the differences in the perception of standing or sitting viewers in the spaces of interest, for example during public gatherings (cf. §4.6). Thus, depending on how the problem in a particular context has been formulated, the visual experience of both the stationary and mobile observer can be investigated.

An important benefit of the above methods over experiential approaches to the investigation of past built spaces (for instance physical encounters with the remains of historic and prehistoric buildings or walk-through in digital models), is that they can be applied at very fine resolutions enabling the *recording* of the visual properties of the object of interest for virtually all locations in the study area. For this reason they form a more robust methodology that is not restricted to a potentially limited selection of observer locations based on preconceptions of the researcher. Moreover, visual summaries are valuable for examining the visual structure of built environments, as they can highlight visual properties of the spaces under study that are often subtle and relational, and do not just show up solely by walking through a 3D model. These visual qualities may have encouraged certain behavioural responses to the viewers in the past that could be manifested in the archaeological record (cf. §4.5). In comparison to textual descriptions of space that often use ambiguous terms, visibility recording and analysis enables the precise definition and investigation of certain factors that may have shaped visual experience in past environments. Ultimately, the proposed methods could permit comparisons between distinct built forms and the investigation of the effects of transformations in architectural configuration through time.

Visibility analysis applied in this research is performed in 3D representations of space that can accurately represent the 3D geometry of built environments and objects within them. In this respect it has benefits over other methods of visibility analysis employed in 2D or 2.5 D representations of space, such as isovist, visibility graph analysis, and GIS-based analysis, when the visual structure of fully 3D environments needs to be considered. If compared to other methodologies that explore visibility using 3D models, such as those suggested by Groß (1991) and Bishop (2003) (cf. §3.2.2), the methods proposed in this research have the advantage that they do not solely create indices of visibility values, but permit the spatial mapping and further analysis of these indices through the creation of visual summaries. For this reason, they are more suitable for identifying and exploring spatial patterning and relationships in the archaeological record.

The proposed methodology also allows for the consideration of uncertain knowledge regarding the spaces under study. The lack of accurate information on the exact dimensions or position of built structures could significantly affect the results of the analysis and interpretive statements. Even though the precise appearance of past spaces is in most cases beyond our knowledge, it is important to establish whether possible data inaccuracies in a particular context are significant enough to question the validity of proposed interpretations. Maps that show the propagation of probable errors are particularly useful heuristics in formally assessing the effects of uncertainty upon the suggested interpretations. Measures of dispersion can be used to determine whether estimated errors are substantive. In the simplest situation between total viewsheds, or other mapped data that were created from two alternative reconstructions, the error can be described as the range of difference between the absolute values displayed in the two maps. In the case that more than two outcomes need to be compared, for example when a number of visibility maps are derived from an equal number of alternative reconstructions, an indication of the spatial distribution of the possible error can be made by the estimation of the standard deviation among the values in all maps. The consideration of uncertain knowledge is useful for defining the degree of confidence with which statements about the visual experience in past environments are made; the propagation of possible errors can help the identification of areas that could have been visible (or non-visible) in all proposed reconstructions and locations that are greatly affected by incomplete information. In the latter case it should be made explicit that proposed interpretations should be treated with caution.

7.1.2 The visibility and non-visibility of mural painting in Xeste 3

The above methods proved to be particularly useful for examining the relationship between iconographic meaning and the visual exposure of individual pictorial elements in three different painted scenes in Xeste 3: the wall painting of the Adorants, the Crocus Gatherers and the male scene. Through the creation of total viewsheds and maps showing the changes in visibility of each pictorial feature within the study area it was demonstrated that there is a correspondence between visual emphasis in pictorial space with visibility in actual space in all three scenes. It was established that the figures of the wounded girl, the man with the jug, and the goddess are the most emphasised features both within individual compositions and in real space, since these are the most exposed painted components of each scene to a viewer situated in Room 3. The existence of uncertain elements in the reconstruction was also discussed and their effects on the suggested interpretation were formally assessed by estimating the distribution of the possible errors in the analysis outputs. Error propagation demonstrated that variations in the width and the position of the door jambs of *polythyra*, namely the features that would have mainly hindered visual access to the paintings, would still cause the same relative differences in the visibility of individual elements of a composition. This is an important finding because if the analysis was overly sensitive to these variations interpretations could be flawed.

The mapping of visible area indices for each painted figure upon all observer locations in the east wing of Xeste 3 highlighted possible activity and circulation patterns during public gatherings that could have taken place in this part of the building, and illuminated aspects of the visual experience of mural decoration for stationary and mobile observers. The results of the analysis (times seen) on both floors suggested that from Room 4 visual access to the wall paintings of the Adorants and the goddess was to a great extent obstructed by the presence of intervening architectural elements. As far as the ground floor is concerned, the application of the analysis merely confirmed what one suspects when visiting the building today: the lintel of the presently reconstructed *polythyron* between spaces 3 and 4 would have significantly hindered visual access to the Adorants, providing that the height of the door openings was about the same in the past. The application of the analysis, however, on the first floor of the building revealed a visual pattern that could not have been observed otherwise: the alignment of the door jambs of the *polythyra* at the north and south of Room 3 would have considerably obstructed the visibility of the figure of the goddess, the main focus of the Crocus Gathering scene. This conclusion was derived after the iterative application of the analysis in alternative reconstructions with small variations in the exact position of the doorjambs of the *polythyra* (cf. § 4.6), which in this case is uncertain. If the wall paintings were the main foci of attention during ritual performances in Xeste 3, then the difficulty of seeing the Adorants and the figure of the goddess from Room 4 implies that the threshold between spaces 3 and 4 was a liminal area that defined a different use and function of space. It seems likely that individuals in Room 4 were not supposed to have visual access to events in Room 3 and that there would have been probably successive admittance from Room 4 to Room 3 during ritual performances. This finding seems to support a reconstruction of ritual practices similar to that suggested by Gesell (2000) (cf. §4.4), while it raises doubts regarding the proposal of Marinatos (1984; Marinatos and Hägg 1986) that there would have been individuals in Room 4 watching the events. Furthermore, the mapping of visibility values in space 3 of the ground floor also suggested that the areas situated close to the two westernmost openings of the *polythyron* between spaces 3 and 4, afforded the best view of all three figures of the Adorants. These openings would have enabled the most direct access to the *adyton* and the auxiliary staircase of the building in terms of Euclidean distance; thus, it is likely that they would have been often used by the residents of Xeste 3, and perhaps provided access to Room 3 and the *adyton* during ritual performances. The outcomes of the analysis in this case suggest that circulation patterns in Xeste 3 probably played a role in determining the rendering of the painted scenes.

The above application of visibility analysis was instructive for three reasons: firstly, because it formally supported the importance of certain figures within individual compositions. The significance of the wounded girl and the man with the jug is obscure to the modern viewer. In the absence of written sources that would illuminate the exact content of the scenes it has been argued that hierarchy of meaning is indirectly indicated by the placement of each figure in pictorial space, posture, hairstyle and dressing. The study of the visual structure of the murals within their architectural context provided additional evidence regarding hierarchy of meaning in the paintings, and established that considering redundancy of visual cues in both pictorial and real space is essential for deciphering the messages of mural painting. Secondly, the results of visibility analysis shed light into the painting process. They suggested that visibility issues in actual space did affect decisions regarding the rendering of the painted theme and that there was considerable planning behind the execution of the paintings; it appears that the positioning of pictorial elements in architectural space was carefully thought and aimed to better communicate the intentions of the painter or those who commissioned the paintings. This finding confirmed that the visibility or non-visibility of Theran murals is imbued with meaning and encouraged the further investigation of the various modes in which these artefacts would have been received in the past. Thirdly, the employment of the proposed methodology in Xeste 3 demonstrated that it has the potential to highlight meaningful visual patterns that could not have been identified otherwise. In addition, it established that formally considering possible errors in archaeological data can strengthen archaeological interpretations in partially preserved contexts.

7.1.3 The wall paintings in the LBA townscape of Akrotiri

The proposed analysis proved to be as applicable for intra-settlement as for intra-building analysis, when it was utilised to investigate the visibility of mural painting from the open public spaces of Akrotiri. The visibility maps presented in §5.2.1 showed that the painted friezes of Room 5 of the West House would have been visible from the Square of the Ship Procession, whilst suggesting that the south frieze was more likely to be seen by the onlooker situated in the square. The return of the fleet, regardless its exact meaning, is often considered to have been the most important scene of the fresco (§5.2.1). Its visual exposure to the viewer in the square is likely to have had a symbolic significance, even if the details of the theme were not distinguishable. The room above the Gate was rather tentatively reconstructed, but after alternative representations of the window openings were considered, it was concluded that painted friezes in that space would have probably been highly exposed to pedestrians traversing the surrounding public spaces. On the other hand, it was discovered that the visibility of the murals that embellished Room Beta 1 from the Square of the Mill House varied considerably. Visibility analysis suggested that statements regarding the visibility of the Antelopes of the east wall should be made with caution, since the degree to which the painting would have been exposed to pedestrians traversing the square significantly depends on the exact form of the window of Beta 1, which was only partly preserved. On the other hand this painting, the Antelopes of the west wall, as well as the Boxing Boys, would have been easily seen from those areas located outside the window (cf. 5.2.3).

Generally, it was found that a great percentage of the area of the decorated wall surfaces could have been exposed to the viewer. The results of the analysis need not necessarily mean that the viewers were able to distinguish particular themes on all occasions, as the comprehensibility of a theme would have also been depended on the effects of illumination, the distance between the viewer and the paintings, as well as the scale of representation (cf. §5.3). The application of visibility analysis within pre-defined angular ranges also established that the murals would have been viewed within the angles of optimum and maximum eye rotation, namely 30 degrees below and 25 degrees above the horizon of the viewer that suggests that pedestrians could see the paintings without necessarily having to raise their head or move in a way that would disrupt their walking pace. This analysis outcome is particularly significant as it implies that painted walls could have been seen with relative ease and that their viewing would not have required the conscious effort of the prehistoric onlooker; pedestrians could have come across the painted scenes even without intending to do so. In other words, wall paintings had rather high potential in communicating messages to a viewer situated in the public street network.

The systematic recording and mapping of visibility values in the open public spaces under study offered new insights into the various modes in which the murals were consumed, as it drew attention to a basic condition for the visual exposure of the paintings to pedestrians traversing the streets and squares. It became evident that normally painted friezes decorating first floor rooms were visible, only if pedestrians were situated a few metres away from the walls of the buildings (usually 3 to 5m). Given the fact that most main roads in Late Bronze Age Aegean towns were frequently no more than 2 metres wide, painted walls on the first floor of the building would not, as a rule, have been easily seen from open public spaces. However, in Akrotiri plenty of broad openings in the street network existed, usually identified as plazas or squares, contrary to what seems to be the rule in Cretan and Cycladic towns (§ 5.3). Besides permitting movement through locations that made possible the viewing of the paintings, plazas were likely to have allowed ample of light in the decorated spaces on many occasions; hence, they would have significantly enhanced the visual exposure and communicative impact of paintings embellishing first floor rooms from the street network. It is quite possible that painted interiors were a distinctive feature of the townscape of Akrotiri, at least in the excavated area.

The issue of pedestrian mobility in the prehistoric town was also discussed, since it is indissolubly related to the likelihood that individuals traversing the street network would have encountered the paintings. The examination of the excavation evidence (form and configuration of the excavated street network, archaeobotanical and faunal remains, loom and lead weight distributions etc, cf. §2.3) suggests that Telchines/Daktylon Street was a multifunctional thoroughfare related to important socio-economic aspects of the life of the town inhabitants and, thus, would have been a widely used passage in Late Bronze Age (cf. §6.3.1); as a consequence, it was argued that the paintings of the Gate would be highly exposed to pedestrians, since it is situated upon the main axis of this thoroughfare. As far as the West House is concerned, this thesis did not reach a conclusion, as the area around the house has not been excavated and it is not yet clear how the locations permitting the visibility of the Miniature fresco were accessed in the past. The results of visibility analysis for the paintings of Beta 1 showed, however, that the locations from which most of the paintings were seen, were to be found right outside the window of the room and did not fall within the main Telchines/Daktylon traffic axis. Moreover, the narrow blind alley that passes from west to east outside the window of Beta 1 was mainly used for ventilation and not to channel traffic, therefore it is unlikely that it would have attracted pedestrian movement in the past. Nonetheless, there are many factors that could have influenced human mobility and engagement with the built environment, which are worthwhile examination; the agent-based model presented in §6.3.2 aimed to illuminate further plausible human-environment interactions in the area close the window of Beta 1. The application was conceptually based upon the behavioural force model suggested by Helbing et al. (2001) which takes into account pedestrian interactions assuming very basic human behaviours in populated spaces, such as the wish to walk in a certain direction, to keep a desired walking speed, to maintain a distance from obstacles in the environment and other individuals, or move together with other pedestrians. The iterative running of the simulation suggested that agents walking towards the south would often have to move away from the main traffic axis when they approached Telchines Street, slowing down or even stopping, sometimes close to the window of B1, in order to allow pedestrians coming from the opposite direction enter the Mill House square. The model offered useful qualitative insights into possible movement patterns within the area of interest, suggesting that the paintings of the Boxing Boys and the Antelopes of the east wall were more likely to be exposed to a pedestrian than it would initially appear.

The agent-based model in this case proved to be valuable because it enabled the exploration of possible mobility patterns in a populated street network, also taking into account certain socio-economic factors that are likely to have influenced mobility in LBA (uses of space, functions of the street network). In this sense it had a significant conceptual contribution to the examination of the issues that this thesis aimed to tackle, as human behaviour and aspects of experience in *inhabited* past spaces are difficult to investigate with non-computational approaches. The dynamic nature of ABM simulations also offered opportunities to appreciate the pace of human visual experience within the built environment by suggesting locations in the street network at which pedestrians could have slowed down or stop. In this way it complemented the viewshed approaches that were already employed, as the latter lack a temporal component. Generally, the computer simulation showed that agent based models of pedestrian movement can offer useful qualitative insights into spatio-temporal dynamics in past built environments.

The discussion on pedestrian mobility in LBA Akrotiri at medium and small spatial scales suggested that the paintings of the West House, the Gate and Beta South would have been occasionally features of the townscape and elements of the public stage on which social interactions would have taken place. This realisation sheds new light on possible functions of wall painting at Akrotiri, perhaps explaining why murals embellished so many houses in this prehistoric settlement. In order to elucidate the symbolic significance of the paintings in the townscape, the functions of Theran murals and the social identity of those who commissioned and consumed the paintings need to be discussed.

7.2 The functions and consumption of Theran wall paintings

There is no doubt that the functions and consumption of wall painting in the LBA settlement were related to activities that took place in the decorated spaces. The scanty surviving evidence, however, do not speak for themselves, and, although a number of suggestions can be made for the use of these rooms, they do remain conjectural. In domestic buildings spaces embellished with wall paintings, such as Room 5 of the West House and Beta 1 of Sector Beta, could have been on occasions the stage of domestic rituals given the frequently ritual-symbolic themes of the murals. These rooms are also likely to have housed a number of other everyday activities, including sleeping and dining (cf. § 2.3.5). Moreover, being the most elaborate spaces in the residence they were probably the rooms where the inhabitants of the houses received important guests. Feasting episodes with the participation of a small group of people could also have occasionally occurred in the decorated spaces of the West House and Complex Beta, as is suggested by the great number of drinking and cooking vessels that have been found in the houses, and sometimes in the vicinity of the rooms (Boulotis 2005). On all the above occasions the represented scenes would have communicated messages associated with the interests, beliefs, ideologies and social identity of the proprietors of the buildings; the themes of the paintings mostly express ideas of manhood (boxing children, fishermen, war scenes), an interest in seafaring and the promotion of maritime symbols, and a reverence for nature. The latter is perhaps associated with a disguised 'religious' symbolism, as has been suggested by some authors (Marinatos 1984; Peterson Murray 2004) , or more generally to the proprietors' particular understandings and perceptions of the world. The obvious receivers of these messages would have been the residents of the building and those visitors that were occasionally allowed in the decorated rooms. Given the character of the excavated area, which consists mostly of structures of elaborate construction, the consumers of the paintings should have been elite members, although it cannot be precluded that on some occasions non-elite visitors were also allowed in the decorated rooms (cf. Chapin 2004).

The above does not necessarily apply for all painted rooms embellishing domestic spaces. Making convincing suggestions regarding the functions of Room 1 in the House of the Ladies, Delta 2 in Delta East and Beta 6 in Sector Beta is a particularly difficult task because of the poorly preserved or problematic archaeological contexts of these spaces. Regarding Room 1 and Delta 2, it has been proposed that they could have housed ritual performances or been used as repositories for sacred paraphernalia (Marinatos 1984, 1985; Hollinshead 1989; Foster 1995; Peterson Murray 2004). Such a suggestion seems to be supported by more evidence in the case of Room 1 that was embellished with scenes of ritualised female dressing (Doumas 1992a, p. 33-44; Peterson Murray 2004), rather than Delta 2, whose wall decoration does not seem to have an explicitly ritual content and where a number of artefacts have been found in a secondary context (Doumas 1992a, p. 100). Due to the great ambiguity regarding the use of these rooms any hypothesis regarding the conditions in which the paintings were received appears to be particularly problematic. The decorated spaces are small-sized, however and, if they were indeed the background of ritual practices, they were probably used for private performances, in which the residents of the buildings would have participated.

The consumption of wall paintings in an apparently public building, Xeste 3, was also discussed in Chapter 4. The spatial configuration of the building and the themes of the paintings strongly suggest that the murals in Xeste 3 would have guided action in space during public ceremonies. The visibility analysis, as well as the 3D reconstruction of Room 3 (cf. §4.7.2, fig. 4-20), indicated that viewing the vivid representations of ritual acts could have been an important aspect of the experience of the performed events, which was probably shared among many participants; viewers in that space would have many opportunities to see the painted scenes and receive their messages, even when murals were partly hidden by the bodies of individuals partaking in the events. On the contrary, rituals performed in the *adyton*, the area often considered to have been the main focus of attention during ceremonies, would have been difficult to observe under these conditions (fig. 4-20). The above suggest that the representation of ritual acts on the walls of the building would have played a vital role in perpetuating collective values of the community and promoting social cohesion during communal performances. Xeste 4 is still not yet fully excavated and the exact character of this public building is not clear. Nonetheless, the procession that decorated the staircase seems to have aimed to impress the visitors of Xeste 4 as soon as they entered the building.

The above concerns the possible modes in which the paintings were received by individuals situated in the painted rooms. A more careful examination of human-environment relationships in the settlement of Akrotiri shows, however, that those allowed access in the decorated spaces would not have been the sole consumers of wall painting. From the results of visibility and movement analysis presented in Chapters 5 and 6 it is deduced that individuals situated in public open spaces would have many opportunities to encounter the painted scenes that decorated the interior of domestic buildings. In some cases they could have been able to distinguish particular themes, while other times they would have only briefly come across the coloured walls during the natural course of their movement. However, even when pedestrians would not be in a position to see the whole paintings and discern the depicted subject or the details of a composition, the murals would not have totally abolished their communication potential and impact. In fact, wall-painting are likely to have elicit multiple meanings to the observer in the past that would operate at a variety of levels, and go beyond the decipherment of their iconography; this suggestion is based on the understanding that mural painting is an inseparable part of the built environment and, as such is implicated in the versatile, and often subtle, meanings of built space. The existence of such meanings has been recognised by a number of authors (Moore 1996). Characteristic is the schema suggested by Rapoport (1990), who distinguishes three levels of meaning in the built environment:

a) *"High-level" meanings related to, for example, cosmologies, cultural schemata, worldviews, philosophical systems, and the sacred.*

b) *"Middle-level" meanings, those communicating identity, status, wealth, power, and so on – that is, the latent rather than the instrumental aspects of activities, behaviour and settings.*

c) *"Low-level" everyday and instrumental meanings: mnemonic cues for identifying uses for which settings are intended and hence the social situations, expected behaviour, and the like; privacy, accessibility, penetration gradients; seating arrangements; movement and way-finding; and other information which enables users to behave and act appropriately and predictably, making co-action possible."*

(Rapoport 1990, p.221)

The distinction between various levels of meaning, such as those proposed above, is in most cases ambiguous; features of built spaces, including wall paintings, could have incorporated all the above dimensions – either consciously or unconsciously – in past viewers perceptions. Ideologies suggested by the represented themes would have been inseparable from social aspects of the built spaces and actions within them. To the modern viewer meanings related to the cosmology and worldviews of past people (high-level) are frequently obscure and difficult to identify and interpret, although they were absolutely comprehensible to the viewers in the past. Middle- and low-level meanings also followed cultural codes, but their significance can sometimes be deduced by studying the archaeological record, as they often function within a system of contrasting visual cues.

Visually explicit codes of this kind can be observed in the built environment of Akrotiri. One does not necessarily have to traverse the impressive thresholds of Xeste 3 or Xeste 4 to understand that these were "important" buildings. This is suggested by their size and impressive façades distinguishing them from the surrounding structures. Their special character is further enhanced through the use of colour (Palyvou 2000). All four walls of Xeste 4 are made of ashlar blocks. The material used for their construction, tuff, is distinctive for its white-cream colour that differs from the dark red-brown ignimbrite used for the construction of the façades of other ashlar buildings (Palyvou 2005a, p. 116, 168). In addition, the south façade of Xeste 3 was covered with a yellow-orange pigment (Palyvou 2000, p. 431) that would stand out from the rubble walls of other buildings that were not plaster coated. In the interior of Xeste 3 and 4 the relatively large number of pier-and-door partitions, and the extensive application of wall decoration would signify the importance of the building. As already mentioned these features are also attested in the private houses in Akrotiri, although they are encountered less often and are usually restricted to the most elaborate rooms of the first floor. The presence of the same features in domestic and public buildings shows a connection between the private and public sphere, and suggests that these architectural elements were aimed for conspicuous consumption.

This conclusion is corroborated by the fact that *polythyra* and mural painting were also distinctive architectural features of the palaces and the most lavishly constructed buildings in Crete during the same period (Late Minoan IA, cf. §2.3). Theran murals, being a part of this wider symbolic architectonic system, would have denoted high status in the social hierarchy and participation in elite groups, regardless of the particular messages they aimed to communicate on each occasion. It is characteristic that other expressions of material culture in Akrotiri are redolent with visual codes that have a cultural specific significance. The hairstyle, clothing and jewellery of the painted human representations of Xeste 3, the West House, the House of the Ladies, and Beta South, seem often to signify the differing occupations, age, degree of socialisation, and social status among the represented figures, mirroring the existence of distinctive group identities (Marinatos 1984, p.62; Morgan 2000, 1988; Davis 1986; Doumas 2000a; Laffineur 2000; Doumas 1987; Rehak 2004). One can imagine that these material expressions made an important contribution to the shaping of social life in the LBA settlement, and their mutually shared meaning(s), would have determined human behaviour and interactions in daily situations. The human representations in Theran murals are also the sole testimonies for the existence of prestige artefacts that are absent from the archaeological record in Akrotiri, such as lavish garments and jewellery[63], confirming the affluent life-style of the town dwellers living in the urban core.

Considering the great number of houses that are distinguished by elite architectural features, and also the lack of evidence so far regarding the presence of a centralised authority, it appears that in Akrotiri a considerable number of town dwellers had access to resources, and a privileged social position in the period before the volcanic eruption. This implies the existence - if not of an egalitarian polity– at least of a negotiable social hierarchy. In that case, the image of prosperity pieced together by the archaeological finds could mask a climate of social competition. Political conditions of this kind partly might explain why in Akrotiri the investment in mural decoration appears to be very intensive – if not exceptional – when compared to other Minoan or Cycladic towns. An intensification in the production of elaborate material culture artefacts is

[63] The inhabitants had probably taken their valuables with them when they abandoned the settlement (cf. note 13).

characteristic of social structures in which power dynamics are constantly negotiated (Hamilakis 2002; Schoep 2002). Of course, an increase in luxurious products (architecture, art and crafts) is a phenomenon that is generally observed at the beginning of Neopalatial period (Middle Minoan III-Late Minoan IB, table 1-1) in Crete (Driessen and Macdonald 1997); nonetheless, the great number of painted walls that have been uncovered in Akrotiri is unattested in other Aegean urban centres. Even if this is partly due to the exceptional preservation of the site, the special interest of the town inhabitants in the production of frescoed walls needs an explanation. The investigation into the less obvious ways in which the Theran paintings were consumed concluded that human-environment relationships in Akrotiri, often determined by the existence of the so-called squares, would have enhanced the communicative impact of murals from the street network. This could have been one important reason why mural painting became so popular in the prehistoric town. But what kind of messages the paintings would have communicated to the individuals traversing the open public spaces?

When it comes to understanding the symbolic significance and function of the wall paintings within the Theran townscape, the question of who were the consumers of the paintings from the street network inevitably arises. The discussion on the social life in Akrotiri and evidence on the use of space (cf.§2.2) permit the formation of informed hypotheses regarding the identity of the viewers of the murals. These could have been:

A) Individuals living in the excavated area, namely the residents of the houses that surrounded the public places from which the wall paintings were visible. These would have frequently encountered the murals while traversing the street network, perhaps on a daily basis. Furthermore, given the character of the excavated buildings, at least some of the dwellers in this part of the town were members of the elite and could have been allowed access into the decorated rooms of neighbouring houses during social occasions and gatherings (cf. §2.3). Hence, they might have been familiar with the painted themes. The frequent encounter with the paintings from the public spaces of the settlement would have then acted as mnemonic for these social occasions (cf. §5.3) perpetuating the messages of the paintings.

B) Those who were involved in activities related to suggested functions of the buildings (for example in weaving and perhaps in supporting industries such as animal husbandry, fulling and dyeing). If organised large-scale production of textiles occurred in some of the houses as suggested by the Linear A tablets found in sector Delta and the large number of loom weights, discovered in the West House (Boulotis 1998, cf. §2.3), then it would have involved the participation of people with different roles in the manufacturing and distribution of textiles, probably belonging to various social groups; consumers of the paintings may have also been dependent labourers of lower social ranking participating in the production of textile, who may have accessed the houses embellished with murals on many occasions, for example during the transportation of raw materials and finished products, or even to enter the spaces in which weaving would have taken place. These individuals might not have been allowed in the decorated rooms but they would still be able to see the paintings from the street network.

C) As Telchines/Daktylon was a main thoroughfare serving the needs of the community, potential viewers of the paintings were also inhabitants of the prehistoric town and its hinterland, daily traversing the street network to reach the coast, the arable fields and pastures; namely people of various occupations and perhaps of different social statuses.

D) The visitors to the settlement, mainly residents of other Cycladic islands, Crete or the Near East, mariners, freelance traders and agents appointed by the palaces or other administrative centres with which the inhabitants of Akrotiri could have developed contacts and communication. The presence of non-locals in the settlement is a natural consequence, if Akrotiri was indeed a port of call. It is hard to define the exact relationships of these individuals with the local population due to the lack of written sources that could shed light on the nature of inter-regional exchanges in Cyclades in the Late Bronze Age. One can imagine, however, that permission of anchorage and the procurement of water or food supplies, which are necessary for long-distance travelling by sea, would have encouraged exchanges between the mariners and the locals. If ships had to stay longer to the harbour due to bad weather conditions (cf. Cline 1995, p.149-150) these exchanges could have lasted several days. During this period shelter and even lodging for sailors could be provided in the town houses (cf. (Betancourt 1995).

Murals seen from the street network could have communicated a variety of messages to the above groups. As symbols of high status they would have been very efficient agents in strategies of recruitment, social negotiation and competition among elite members. Moreover, they would have been involved in tactics of exclusion; an organised system of textile production in Late Bronze Age was likely to have functioned for the benefit of the elite members capable of distributing the finished products (Sherratt and Sherratt 1991, p.359). This kind of situation entails the possibility of conflict (.ibid); in this case power relationships could have been established and regulated through the use of symbols, conspicuous consumption and display. People of lower social ranking contributing to the manufacturing of textiles may not have had the right to access the decorated rooms, but while traversing the street network they would be aware of the existence of mural painting, denoting ideas of both power and exclusion.

We can imagine that non-local visitors would be impressed by the townscape of Akrotiri and the often prominent elaborate decorated rooms of Theran houses. The viewing of wall paintings from the street network could have then induced an image of prosperity that would be reflected to the local elite members, some of which (for example those residing in the West House and Delta West) appear to be involved in mercantile and/or seafaring activities (Boulotis 1998, cf. Chapter 2). A prosperous port of call could serve more effectively sailors in need of supplies whilst perhaps providing a clientele interested in acquiring luxurious items, which might have motivated trade in LBA in the first place (Sherratt and Sherratt 1991). In this respect the impression of affluence suggested by the elaborate interiors of the town houses could have contributed in securing the place of Akrotiri within the inter-regional network of exchanges and the towns dwellers' access to substantial resources.

If wall paintings are understood as features of the townscape, it is clear that their symbolic function and involvement in power relationships could have been much stronger than that assumed by Chapin (2004; cf. Chapter 1), who postulates that murals were consumed only by those that had access in the decorated rooms. Ideas of group cohesion, power and exclusion, would have been communicated not only during the few special cases that non-residents in the house were allowed into the spaces embellished with murals; such messages would have been induced to pedestrians traversing the street network perhaps on everyday basis, in the course of their daily activities and interactions.

The above suggested functions of mural decoration do not contradict and could operate in parallel with other possible uses of the paintings, for example their use as setting in practices that could have taken place in the decorated rooms. As a rule we can say that when paintings were encountered by individuals in these spaces, they would have been implicated in all three levels of meaning proposed by Rapoport (1990, p. 221). On the other hand, the visibility of murals from the street network may have been related mainly to more subtle middle and low level meanings, since it is likely that the painted themes and the more specific messages they express were not distinguishable and understandable on all occasions, when seen from the street network.

An issue that still needs to be tackled is to what degree the visibility of the wall paintings from the open public spaces determined the choice of decorated areas. In other words, was the visual exposure of the painted walls to pedestrians traversing the street network intentional, as has been suggested by Doumas (2005), or merely an epiphenomenon? Given the existing evidence is hard to give a definite answer to this question. On some occasions at least Doumas suggestion is plausible. The often accepted as most important scene of the Miniature frieze, the Ship Procession, has been depicted on the south wall of Room 5 of the West House. This wall surface is the most exposed to the viewer located in the Square of the Ship procession (cf. Chapter 5). Moreover, the first floor room above the Gate, which was pierced by windows on three sides, would have offered ample opportunities for the exposure of paintings embellishing the areas above the window openings. Only assumptions can be made regarding the use of this space, whose form is unique among the presently excavated rooms in Akrotiri. The great number of windows suggests, however, the idea of communication with the public space at the vicinity of the Gate and, in that sense, the murals in "Room Doumas", might have been aimed to be consumed by the residents of Delta West, as well as by pedestrians passing outside the building. The same may be argued regarding the flowerpots that used to decorate the windowsills of the West House. These were placed in an area that defines the boundary between the interior and the open public space outside the building. As already mentioned the form of the latter is not yet very clear to us, but it cannot be precluded that this painting would have been visible from the public street network[64] (cf. Palyvou 2005a, p.169).

On the other hand, the distribution of the painted scenes in Beta 1 does not show a similar intention for the exposure of the paintings to those traversing the Mill House Square. The Antelopes of the east wall could have been partly viewed from the square, but it is usually the theme of the Boxing Boys, representing human figures, which is considered to carry greater symbolic significance (cf. Marinatos 1971b, p.47). This was visible only from a limited number of locations in the Mill House Square and, although it could have been encountered by pedestrians on certain occasions (cf. Chapter 6), there is no evidence to suggest that this was intentional. It is obvious that in this case the choice of theme was largely affected by the size of available pictorial space, as the subject of the Antelopes was suitable for the longer walls of the room, while the Boxing Boys were more appropriate for the much narrower north wall.

The above support the idea that there were a number of criteria that led to the determination of decorated areas. The availability of the painted surface for the depiction of the desired theme is one such factor. Another would be the uses of decorated spaces. According to the existing evidence, wall-paintings in public buildings, e.g. Xeste 3 and Xeste 4, were not likely to be visible from outside the buildings (Doumas 2005), implying the paintings were meant to be seen only by those who were permitted into the decorated rooms. Also the wall paintings at the House of the Ladies and Room Delta 2 could not have been viewed from outdoor spaces, and apparently this was not necessary for the fulfilment of the special functions of these rooms. Taking into account the variety of represented themes, the diversity of archaeological contexts related to the painted rooms and the many modes in which the murals were received, it makes sense to suggest that in Akrotiri wall paintings were created to serve a range of different functions.

One could argue therefore that in some cases the visibility of the paintings from the street network was desirable and intentional, and not merely an epiphenomenon, yet it would not have always determined the choice of

[64] The paintings might have been partially hidden by the horizontal beam of a window lattice.

decorated areas. Nonetheless, intentional or not, even the momentary visual exposure of murals to pedestrians traversing the street network could have evoked messages of power and prestige, inducing the idea that wall painting was a desired art form. These conditions could have generally encouraged an investment in mural decoration, which probably served a variety of functions (ritual, decorative, etc.), even when the visibility of the paintings from the street network was not necessary, desirable or possible.

The above attempt to explain the consumption and wide diffusion of mural decoration in the houses of Akrotiri was inevitably based on the examination of a relatively small number of murals in relation to the great amount of painted fragments that have been unearthed in the settlement. The restoration of the pictorial compositions in the coming years is necessary for a better understanding of the spatial associations of Theran murals, and of the modes in which they were consumed. And luckily, the prehistoric town is still protected to its greater extent by a mantle of volcanic materials, whose removal in the future promises to bring to light new evidence regarding the presence or absence of painted rooms in the prehistoric town, further illuminating the social functions of the paintings within the Late Bronze Age society.

7.3 Future directions of research

The methodologies that were suggested in this thesis are promising, and their application in the built environment of Akrotiri showed they have the potential to enhance archaeological interpretations both conceptually and methodologically. That said, the case studies examined here should be seen, as a starting point for continuing research. Visibility analysis was used in this thesis to examine aspects of the visual experience within a prehistoric built environment that was preserved in an exceptional condition. Following the progress of excavation and conservation at Akrotiri the same methodology could be applied to new archaeological contexts in the future. In the light of new evidence it would be interesting to investigate, for example, whether there is any relationship between the quality of execution and the visibility of the paintings from the town's streets and squares, or whether figural themes were generally more likely to be exposed to the viewer in open public spaces, as opposed to non-figural paintings. The use of a similar approach in other Aegean prehistoric settlements entails difficulties, as evidence on both architecture and mural decoration is very fragmentary. Nonetheless, it is anticipated the suggested methodologies have the potential to prompt new research questions in a variety of other historic and prehistoric contexts.

An area that is likely to benefit from the application and further development of these approaches is the archaeology of buildings. Visibility analysis could be used to investigate human experience in built environments that are partially preserved or still extant. For example, it can help examine social and symbolic aspects of Mesoamerican built structures, such as large ceremonial complexes, pyramids and towns. In this case interesting research questions could be pursued for instance, how much of the façades of a building or other symbolic features could be seen from the surrounding built and natural environment. This line of enquiry could shed light onto the modes in which territories and boundaries were demarcated in these spaces, and the ways in which political power and group identities were manifested through the use of visual symbols.

Moreover, the application of visibility analysis to extant buildings could be valuable, as the results of the analysis can be assessed and discussed by considering human engagement with real environments. In that case a quantitative analytical approach can be combined with qualitative statements regarding the experience of these sites. Empirical observations in actual space could also help to better understand and describe certain parameters that affect visibility in natural and built environment, which could be taken into account while performing the analysis; for instance, they could facilitate the identification of visual ranges or distances in which the visual perception of an object changes significantly (cf. Chapter 3).

A potentially exciting research direction would be the integration of visibility and acoustic mapping; acoustic data derived from extant historic buildings can be visualised as scalar fields, similarly to visual data (Durvilli et al 2007; Knight and Tronchin 2008). The integration of visual and acoustic datasets could allow new heuristics to be developed that take into account the synergistic relationship between the senses, and meet better the demands of contemporary archaeological theory (Hamilakis *et al.* 2002). One way these data can be combined is through data fusion methods (data sum, Boolean intersection) performed with a GIS.

Another interesting area of research could be the incorporation of vegetation information in viewshed calculations performed in digital landscapes, as originally suggested by Groß (1991) and Bishop (2003). In recent years 3D modelling software has become more effective in rendering vegetation and the topography of the terrain. The accurate representation of topographic features is an issue that needs to be considered in this case, however the effects of errors in topography or lack of knowledge regarding palaeo-vegetation could be considered with the application of uncertainty methods similar to those proposed in Chapter 3. Visibility analysis that takes into account the occlusive effects of vegetation in a fully 3D environment could be an alternative to GIS-based analyses suggested by Dean (1997) and Llobera (2007). The benefit of this approach is that the visual structure of buildings in the natural environment could be more precisely represented and analysed. Moreover, the effects of other factors that influence visibility in landscapes, such as atmospheric conditions or natural illumination, could be modelled and formally investigated.

The above suggestions for future work involve the visibility analysis methods that were proposed and applied in this thesis. Agent-based modelling in built spaces could also provide fertile ground for new developments. Depending on the research interests and the suitability of archaeological datasets that are available in each case various aspects of movement in populated past spaces could be illuminated. Most ABM applications in archaeological built spaces have been used up to now for intra-building analysis, nonetheless agents with advanced cognitive abilities that are able to make route choices in a known urban network could be used to facilitate hypotheses regarding movement and mobility patterns in past settlements. Such analysis could lead to the identification of certain social factors that determined the formation of urban spaces and shed light upon dynamic processes that shaped the archaeological record.

Another possibly interesting research direction is to explore how agent-based models could further contribute to a more theoretically informed modelling of the behaviour and interactions of virtual people in populated 3D reconstructions of past environments. The strength of using ABM for this kind of modelling lies in the fact that the trajectories and pace of movement of avatars in a 3D model would be informed by certain physical (e.g. obstacle avoidance) and social factors (pedestrian interaction) that influence locomotion, and assumptions that are made explicit, rather than be determined by the modeller's arbitrary decisions. Direct impressions of the experience of a mobile individual in the 3D digital environment could then be derived by animating cameras at the eye level of virtual people along the agents' paths.

The research methodology of this work has greatly benefited from drawing upon theoretical frameworks and scientific practice that have long since been developed in the fields of geography and urban studies. It was found that such frameworks can greatly enrich the theoretical basis and research rigour of 3D visualisations of past environments. On the other hand, it is anticipated that visibility analysis methods that were introduced in this thesis could prove useful analytical tools for research within the fields of geography and urbanism. Besides encouraging the already discussed directions in landscape research, the methodology proposed in this thesis could be utilised to describe the visual characteristics of fully 3D built spaces, potentially permitting the analysis of isovists in three dimensions, as originally envisaged by Benedikt (1979). It is hoped that in the future this work will be further developed towards this direction, encouraging multi-disciplinary research on the ways humans engage with their environment.

Plates

Plate 1. The fisherman of north wall (room 5, West House). From the excavation archive.

Plate 2. The 'Priestess' (room 5, West House). From the excavation archive.

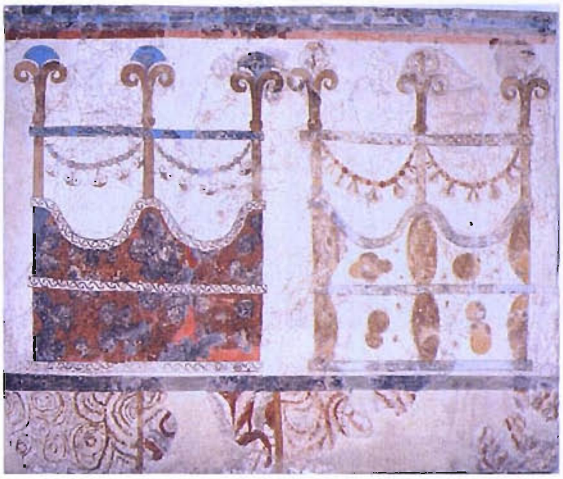


Plate 3. Ship cabin (room 4, West House). From the excavation archive.

Plate 4. The south frieze of the Miniature fresco (room 5, West House). From the excavation archive.

Plate 5. Marble imitation (room 5, West House). From the excavation archive.

Plate 6. Reconstruction of Room 5 (West house)- view of the west wall (Paliou 2002).

Plate 7. Reconstruction of Room 5 (West house)- view of the south wall (Paliou 2002).

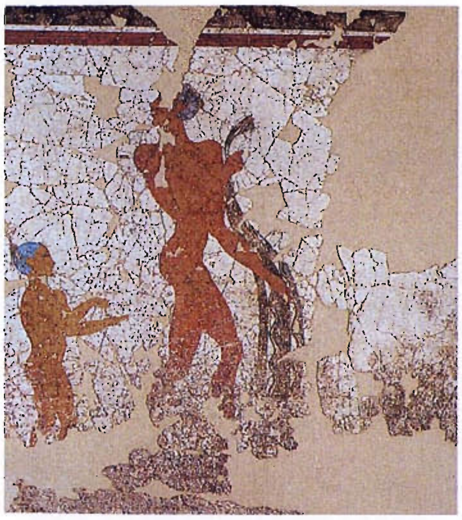


Plate 8. The males of the south corridor. (Xeste 3, ground floor, Room 3b). From the excavation archive.

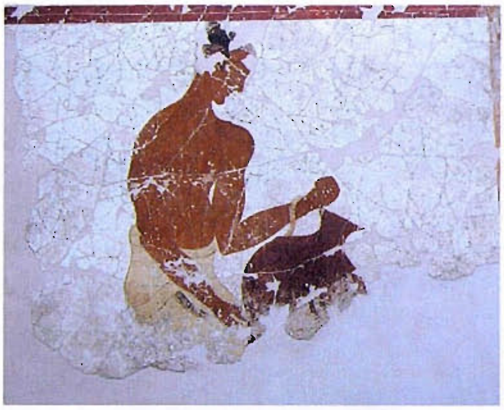


Plate 9. The man with the jug (Xeste 3, ground floor, Room 3b, west wall). From the excavation archive.

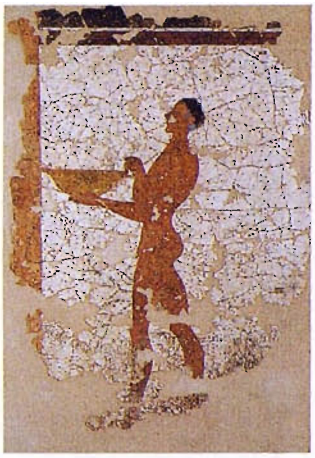


Plate 10. The male figure of the north corridor (Xeste Room 3b, ground floor). From the excavation archive.

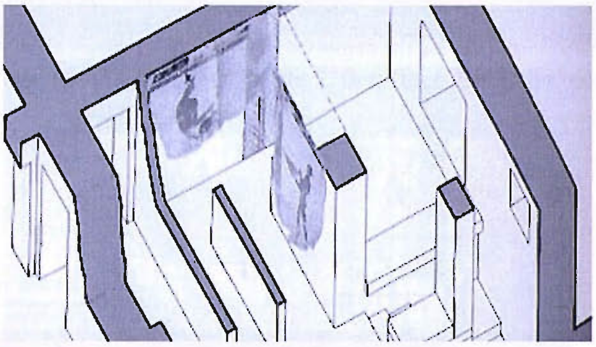


Plate 11. The location of the man with the jug and the young male with the bowl (Xeste 3, Room 3b, ground floor). By Clairy Palyvou (Palyvou 2005, fig.245)

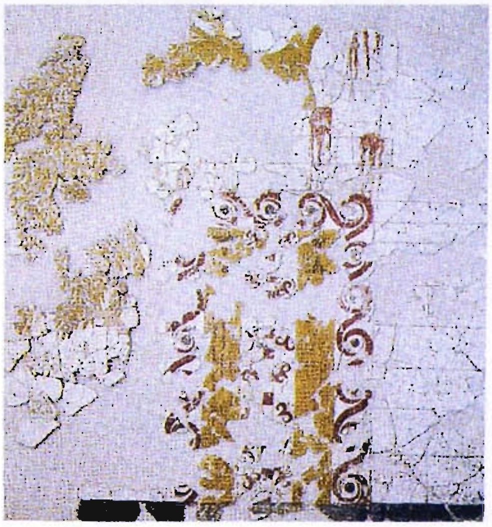


Plate 12. The altar of the east wall (from Boulotis 2005, p.29)

Plate 13. The wall painting of the Adorants (Xeste 3, Room 3a, ground floor, north wall). From the excavation archive.

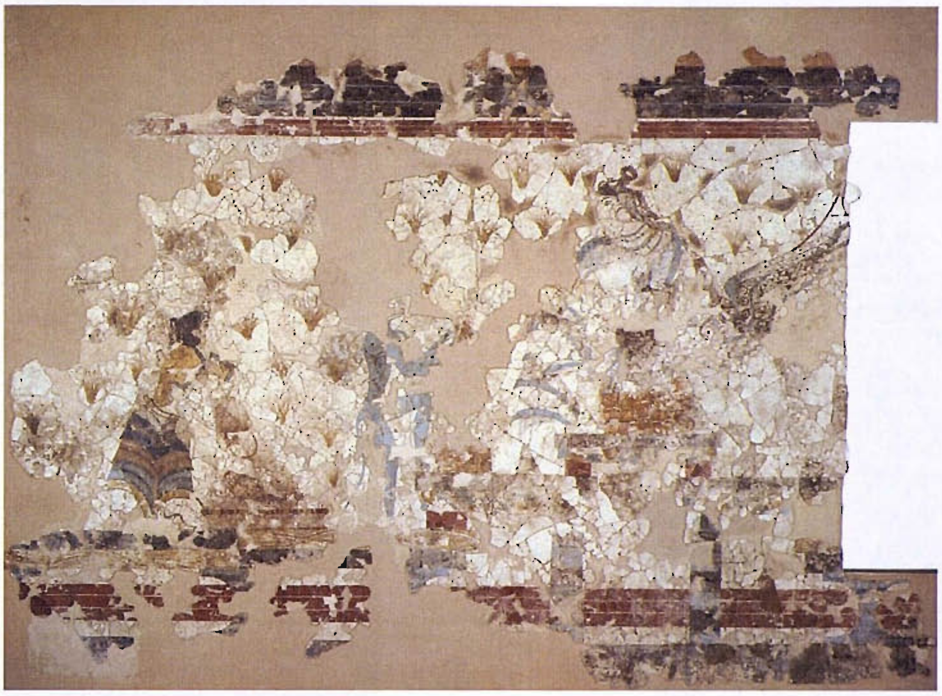


Plate 14. The Goddess (Xeste 3, first floor, Room 3a, north wall). From the excavation archive.

Plate 15. Crocus Gatherer (Xeste 3, first floor, Room 3a, north wall). From the excavation archive.

Plate 16. The Crocus Gatherers of the east wall (Xeste 3, first floor, Room 3a). From the excavation archive.

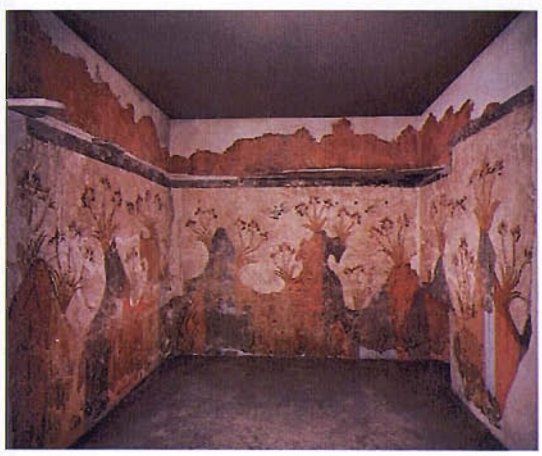


Plate 17 .The Spring fresco as displayed in the National Museum of Athens (sector D, room 2). From the excavation archive.

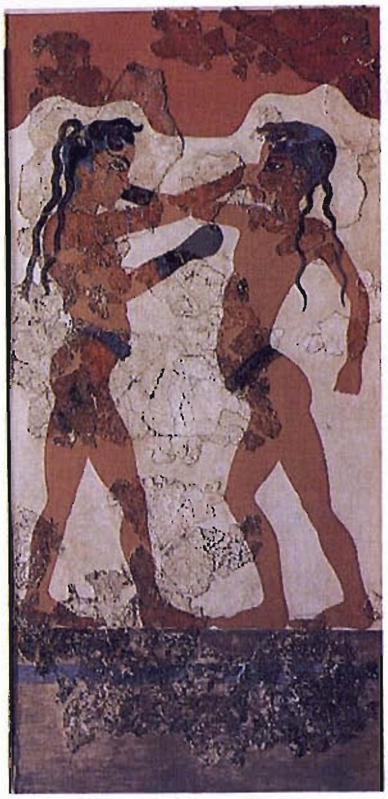


Plate 18. The boxing boys. From the excavation archive.

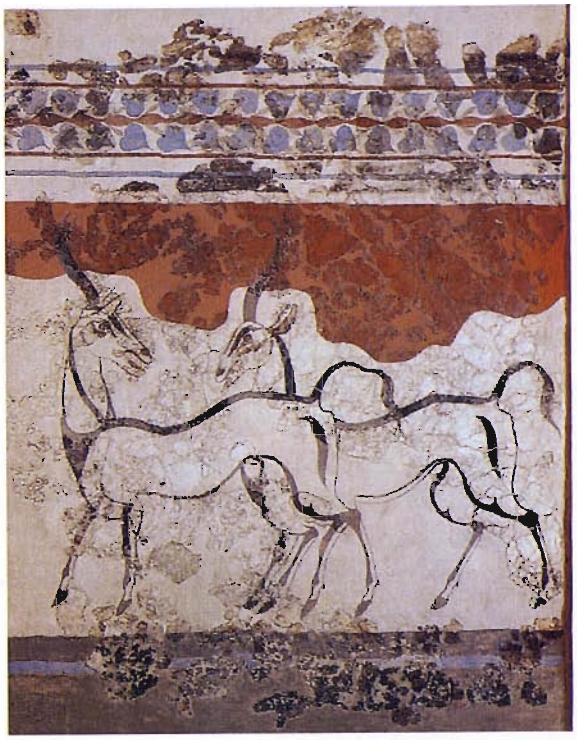


Plate 19. The Antelopes of the west wall of Beta 1. From the excavation archive.

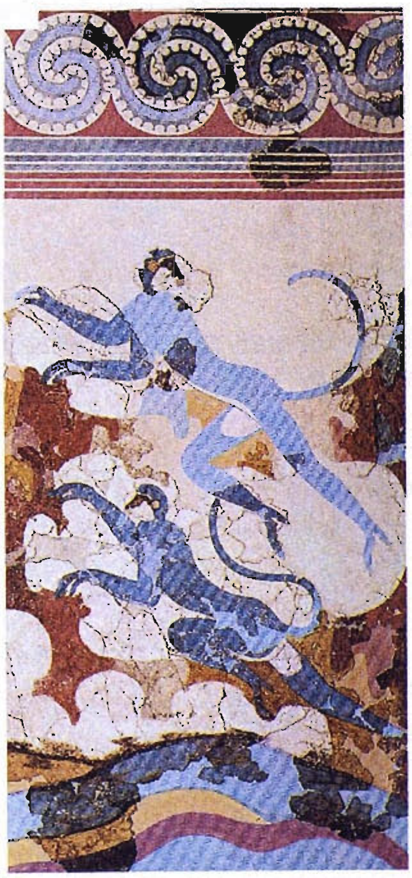


Plate 20. Details of the monkeys (Room Beta 6). From the excavation archive.

Appendix I: Scripts

I. Script: animate_light.ms

Description

This script, written in MaxScript, automates the process of visibility recording in a 3D environment created in 3dsMax. It animates a light source through a specified sequence of locations whose coordinates are listed in a text file. After the keys of the animation have been defined, the Render to Texture function in 3dsMax extracts the texture of the target object with information on illumination (visibility) for all keys (viewpoint locations) of the animation. Each animation frame then contains information on visible (illuminated) and non-visible (shadowed) areas of the target object from a specified viewpoint location.

Code listing

```
# -------------------------------------------------------------------------
# animate_light.ms
# Description: Animates a light source through a specified sequence of locations
# whose coordinates are listed  in a text file
# Requirements: 3ds Max, Version 8-
# Author: Eleftheria Paliou, University of Southampton, UK
# Date: 25/1o/2006
# -------------------------------------------------------------------------

l= $Omni01                          # Select the light source
fs = openFile "E:\\xyz.txt"         # Open text-file with viewpoint coordinates
seek fs #eof
numbervalues = (filePos fs)/13      # Find the number of lines in the file (number
N = (numbervalues - 1)              # of viewpoint coordinates)
fs = openFile "E:\\xyz.txt"
while NOT eof fs do                 # Loop: If you have not reached the end of file
(animate on                         # move the light source to the next viewpoint
        (for i= 0 to N do           # location
                (at time i l.pos = readvalue fs)
)
)
```

II. Script: binary_viewshed

Description

The creation of 'times seen' requires that textures with information on illumination (visibility) are converted into binary viewsheds in which illuminated areas are given the value of 1 and non-illuminated areas the value of 0. This script, written in Python, generates a batch process in which the input data files are textures maps stored in a single directory and the outputs are binary viewsheds corresponding to the input texture maps. Binary viewsheds are stored in a second (output) directory.

Code listing

```
# --------------------------------------------------------------------------
# binary_viewshed.py
# Description: Lists textures maps that are stored in a specified directory, and
# reclassifies illuminated and shadowed areas in each map to convert it to a binary
# viewshed. All binary viewsheds are stored in a second
# specified directory
# Requirements: Spatial Analyst license, ArcGIS 9.2
# Author: Eleftheria Paliou, University of Southampton, UK
# Date: 13/11/2006
# --------------------------------------------------------------------------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Obtain the parameters
InWorkspace = sys.argv[1]      #Directory with texture maps
OutWorkspace = sys.argv[2]     #Directory for the output viewsheds

# Check out any necessary licenses
gp.CheckOutExtension("Spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst
Tools.tbx")


# Useful functions: Identify the rasterID value from the filename
#=============================================================
def get_id_from_filename (stemlength, filename):
   cPos = stemlength
   rasterID = ""
   while len(filename) > cPos:
      rasterID = rasterID + filename[cPos]
      cPos = cPos + 1
```

```
    return rasterID

# Main Program
#===================================================================
# Set the workspace. List all of the .tif files
gp.Workspace = InWorkspace
rasters = gp.ListRasters("texture*",".tif")

# Reset the enumeration to make sure the first object is returned
rasters.Reset()


# Get the Rasters' name
raster = rasters.Next()

print ("")
while raster: # While the raster name is not empty

    #Get hold of the current rasterID value from the filename
    rasterID = get_id_from_filename (7, raster)

    #Get full filename of raster file
    RasterfileName = InWorkspace+"\\texture"+str(rasterID)

    #Set up output filenames
    OutRasterName = OutWorkspace+"\\Rec_text"+str(rasterID)

    #Process: Reclassify the  raster
    gp.Reclassify_sa(RasterfileName, "Value", "0 0;0 255 1", OutRasterName,
"DATA")


    raster = rasters.Next()
---------
```

III. Script: cumulative_viewshed

Description

This script generates a 'times seen' using a set of individual binary viewsheds. The script, written in Python, sums up binary viewsheds that are saved in an input directory one by one. The outputs are stored in a second directory. The last output saved after the script is finished is the sum of all viewsheds stored in the input directory, namely the 'times seen' for the specified set of viewpoints.

Code listing

```
#------------------------------------------------------------------------
# cumulative_viewshed.py
# Description: Sums up individual binary viewsheds that are saved in a single
# directory one by one. The outputs are stored in a second directory. The last output
# saved after the script is finished is the sum of all viesheds stores in the input
# directory.
# Requirements: Spatial Analyst license, ArcGIS 9.2
# Author: Eleftheria Paliou, University of Southampton, UK
# Date: 18/11/2006
# ------------------------------------------------------------------------


# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Obtain the parameters
InWorkspace = sys.argv[1]       #Directory for input rasters
OutWorkspace = sys.argv[2]      #Directory for output rasters

# Check out any necessary licenses
gp.CheckOutExtension("Spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst
Tools.tbx")



# Useful functions: Identify the rasterID value from the filename
#==========================================================
def get_id_from_filename (stemlength, filename):
```

```
    cPos = stemlength
    rasterID = ""
    while len(filename) > cPos:
        rasterID = rasterID + filename[cPos]
        cPos = cPos + 1
    return rasterID

# Main Program
#==================================================================
# Set the workspace. List all of the .tif files
gp.Workspace = InWorkspace
rasters = gp.ListRasters("Rec_text*", ".tif")

# Reset the enumeration to make sure the first object is returned
rasters.Reset()


# Get the first raster name
raster = rasters.Next()


print ("")

OutNum= 1
while raster: # While the raster name is not empty

    #Get hold of the current rasterID value from the filename
    rasterID = get_id_from_filename (8, raster)

    #Get full filename of raster file
    RasterfileName = InWorkspace+"\\Rec_text"+ str(rasterID) +".tif"

    #Set the name of the output rasters,and the map algebra expression.
    Outputmap= OutWorkspace+ "\\cum_text" + str(OutNum)
    Expression= Outputmap + "+" +RasterfileName
    NewOutput= OutWorkspace+"\\cum_text" +  str(OutNum+1)

    #Process: Add raster
    gp.SingleOutputMapAlgebra_sa(Expression, NewOutput, "")
    OutNum = OutNum + 1
    raster = rasters.Next()

gp.AddMessage("All Done")
```

IV. Script: feature_visibility

Description

In some cases the visual exposure of individual pictorial elements from a given space is of interest. As pictorial elements are 2D entities, their outlines can be digitised and projected onto a raster representing the painted wall surface for which visibility information has been acquired. In an ArcGIS environment these outlines are described by polylines that can be converted into a raster using Spatial Analyst. This raster can then be multiplied by binary viewsheds of the wall surface with the use of map algebra operations. The result will be a binary raster whose cells are either 1 or 0 corresponding to the visible and non-visible parts of the painted feature respectively.
The feature_visibility script, written in Python, generates a batch process that automates the above procedure. It multiplies each binary viewshed from a set viewsheds stored in the same input directory by the raster representing the painted feature(s) of interest. Outputs are stored in a separate directory.

Code listing

```
#-------------------------------------------------------------------------
# feature_visibility.py
# Description: Multiplies each binary viewshed from a set of viewsheds stored in a
# single directory with a  raster whose values represent the painted feature(s) of
# interest. Outputs are stored in a separate directory.
# Requirements: Spatial Analyst license, ArcGIS 9.2
# Author: Eleftheria Paliou, University of Southampton, UK
# Date: 23/11/2006
# -------------------------------------------------------------------------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()


# Obtain the parameters
InWorkspace = sys.argv[1]      # Directory in which the viesheds are stored
OutWorkspace = sys.argv[2]     # Directory for the outputs
Figuregrid = sys.argv[3]       # Raster representing the painted feature(s) of interest

# Check out any necessary licenses
gp.CheckOutExtension("Spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst
Tools.tbx")


# Useful functions: Identify the rasterID value from the filename
#================================================
```

```
def get_id_from_filename (stemlength, filename):
   cPos = stemlength
   rasterID = ""
   while len(filename) > cPos:
      rasterID = rasterID + filename[cPos]
      cPos = cPos + 1
   return rasterID

# Main Program
#==============================================
# Set the workspace. List all of the .tif files
gp.Workspace = InWorkspace
rasters = gp.ListRasters("Rec_text*", ".tif")

# Reset the enumeration to make sure the first object is returned
rasters.Reset()


# Get the first raster name
raster = rasters.Next()


print ("")


while raster: # While the raster name is not empty

   #Get hold of the current rasterID value from the filename
   rasterID = get_id_from_filename (8, raster)

   #Get full filename of raster file

   RasterfileName = InWorkspace+"\\Rec_text"+ str(rasterID) +".tif"
   Expression= Figuregrid + "*" +RasterfileName
   OutRaster= OutWorkspace+"\\Feat_Vis" +  str(rasterID)

   #Process: Add raster
   gp.SingleOutputMapAlgebra_sa(Expression, OutRaster, "")

   raster = rasters.Next()
```

V. Script: extract_tables

Description

Mapping the visibility values back onto the study area could permit the identification of meaningful spatial patterning in the data. A visibility parameter that can be mapped onto space is the area visible of a feature of interest (e.g. entire wall surface or individual pictorial element). Information regarding the visible area of the target feature from a given viewpoint is stored in the Count field of the table of the binary viewshed calculated from that viewpoint. In order to map this kind of information upon all viewpoint locations in the study area, the values in the Count field for each binary viewshed created must be extracted and stored in a single table. This table can then be joined to the table of the point features representing the viewpoint locations.
This process can be automated with the use of two scripts, extract_tables and extract_count. Extract_tables extracts the table of each binary viewshed from a set of viewsheds stored in the same input directory. It saves the tables in a defined output directory.

Code listing

```
# ---------------------------------------------------------------------------
# extract_tables.py
# Description: Extracts the table of each raster from a set of rasters stored in a single
# directory. It saves the tables in a second defined directory.
# Requirements: Spatial Analyst license, ArcGIS 9.2
# Author: Eleftheria Paliou, University of Southampton, UK
# Date: 25/11/2006
# ---------------------------------------------------------------------------

# Import system modules
import sys, string, os, arcgisscripting

# Create the Geoprocessor object
gp = arcgisscripting.create()

# Obtain the parameters
InWorkspace = sys.argv[1]       # Directory of the input rasters
OutWorkspace = sys.argv[2]      # Directory of the outputs (tables)


# Check out any necessary licenses
gp.CheckOutExtension("Spatial")

# Load required toolboxes...
gp.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst
Tools.tbx")


# Useful functions: Identify the rasterID value from the filename
#==========================================================
```

```
def get_id_from_filename (stemlength, filename):
   cPos = stemlength
   rasterID = ""
   while len(filename) > cPos:
      rasterID = rasterID + filename[cPos]
      cPos = cPos + 1
   return rasterID

# Main Program
#=================================================
# Set the workspace. List all of the .tif files
gp.Workspace = InWorkspace
rasters = gp.ListRasters("Feat_Vis*", ".tif")

# Reset the enumeration to make sure the first object is returned
rasters.Reset()


# Get the first raster name
raster = rasters.Next()


print ("")


while raster: # While the raster name is not empty

   #Get hold of the current rasterID value from the filename
   rasterID = get_id_from_filename (8, raster)

   #Get full filename of raster file

   RasterfileName = InWorkspace+"\\Feat_Vis"+ str(rasterID) +".tif"

   #Set the output tables path and name
   OutTable= OutWorkspace+"\\Table" +  str(rasterID)

   #Process: Add raster
   gp.ZonalStatisticsAsTable_sa(RasterfileName, "Value", RasterfileName, OutTable,
"DATA")

   raster = rasters.Next()
```

VI. Script extract_count

Description

This script, written in Python, is the second stage of the process for mapping visibility data back onto the study area. It uses as input the outputs of the extract_table script. It extracts the values in the Count field from each table, and inputs all the count values in a single new table. The new table can then be joined to the table of the point features representing the viewpoint locations. In this way information on the visible area of the target object becomes a mappable attribute of the point features.

Code listing

```
# ---------------------------------------------------------------------------
# extract_count.py
# Description: Extracts the values stored in the Count field of each table from a set of
# tables in a single directory and stores all the count values in a single new
# table.
# Requirements: Spatial Analyst license, ArcGIS 9.1
# Author: Eleftheria Paliou, University of Southampton, UK
# Date: 28/11/2006
# ---------------------------------------------------------------------------

# Import system modules
import sys, string, os, win32com.client

# Create the Geoprocessor object
gp = win32com.client.Dispatch("esriGeoprocessing.GpDispatch.1")

# Obtain the parameters
Workspace = sys.argv[1]     # Directory for input and output


# Useful functions: Identify the table ID from the filename
#==================================================================
def get_id_from_filename (stemlength, filename):
   cPos = stemlength
   tableID = ""
   while len(filename) > cPos:
      tableID = tableID + filename[cPos]
      cPos = cPos + 1
   return tableID

# Main Program
#==================================================================
# Set the workspace.
gp.Workspace = Workspace
```

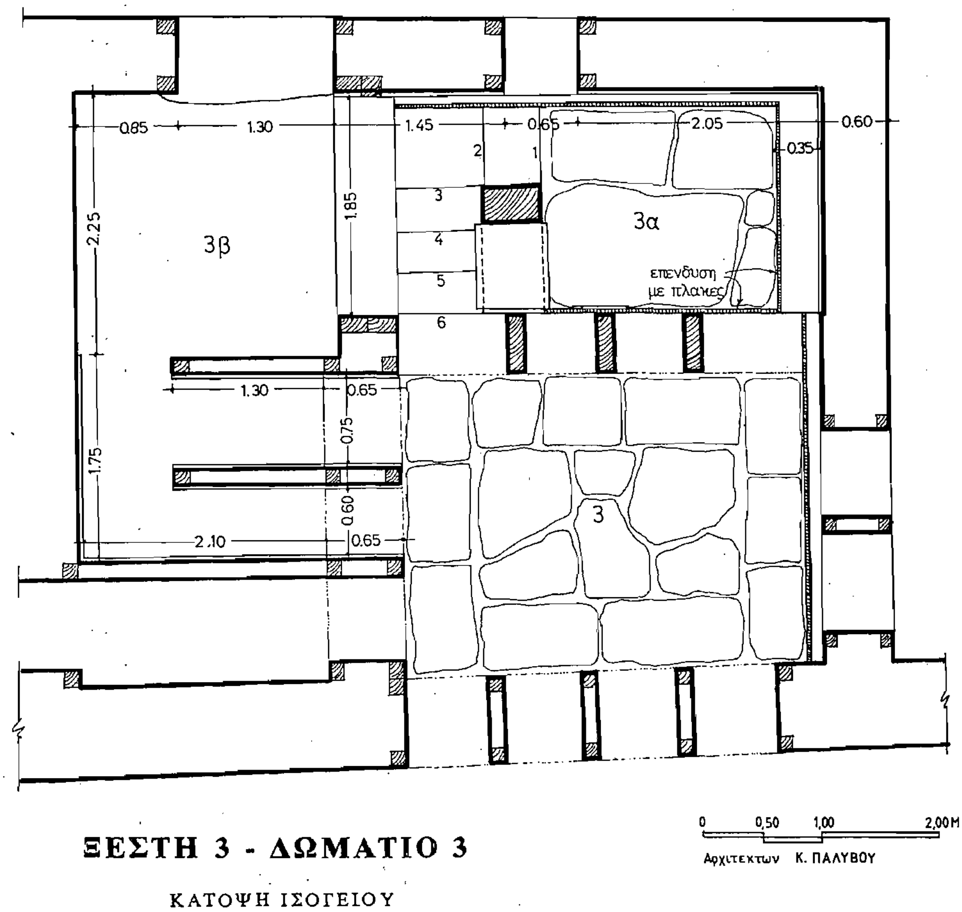
#Create a new table and add fields. The table created in this case stores the count value for three different features/classes (Feat1, Feat2, Feat3) that form three seperate rows in each of the input tables.

```
try:
   gp.CreateTable(Workspace, "pointvis")
   gp.addField ("pointvis.dbf","pointID","long")
   gp.addField ("pointvis.dbf","NoVis","long")
   gp.addField ("pointvis.dbf","Feat1","long")
   gp.addField ("pointvis.dbf","Feat2","long")
   gp.addField ("pointvis.dbf","Feat3","long")

except:
   #If an error occurred while running a tool print the messages
   print gp.GetMessages()

#List all the tables in the workspace

tables = gp.ListTables("Table*")

# Reset the enumeration to make sure the first object is returned
tables.Reset()


# Get the first raster name
table = tables.Next()

print ("")


while table: # While the table name is not empty

   #Get hold of the current tableID value from the filename
   tableID = get_id_from_filename (5, table)

   # Open insert cursor on the new table
   t_row = gp.InsertCursor(Workspace+ "\\pointvis.dbf")
   tnew_row = t_row.NewRow()


   # Create a search cursor on the table
   r_row = gp.SearchCursor(table)
   rnext_row = r_row.Next()

   while rnext_row <> None:

   # Create a new row for the new table and set the "pointID" to be the
   # same as the raster ID and set the "NoVis", "Feat1", "Feat2","Feat3" values to the
   # correwspondig counts in the raster table.
   # Values are returned using the field name as property of the row object
```

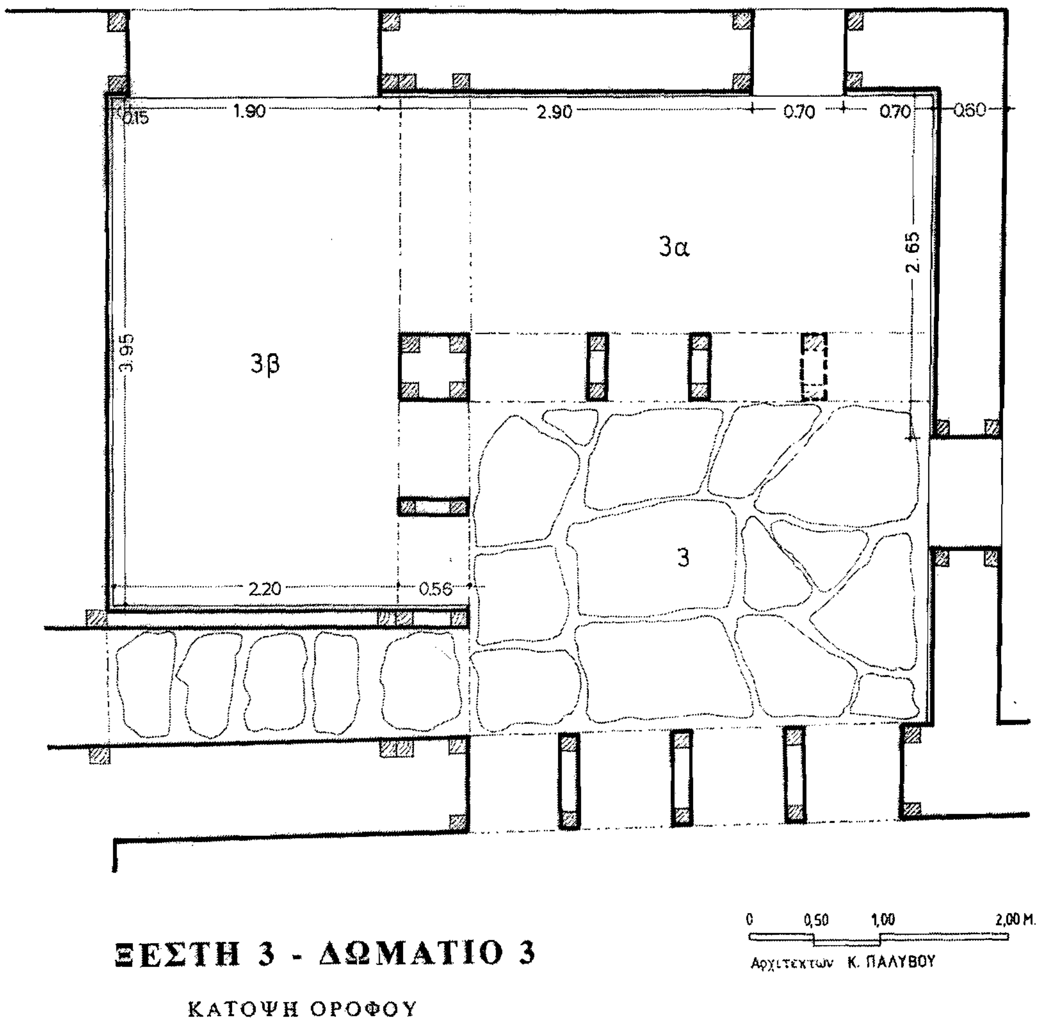
```
    tnew_row.pointID = int(tableID[:-4])
    if rnext_row.Value == 0:
        tnew_row.NoVis = rnext_row.Count
    elif rnext_row.Value == 2:
        tnew_row.Feat1 = rnext_row.Count
    elif rnext_row.Value == 3:
        tnew_row.Feat2 = rnext_row.Count
    elif rnext_row.Value == 4:
        tnew_row.Feat3 = rnext_row.Count

    rnext_row = r_row.Next()

# Insert the row into the new table
t_row.InsertRow(tnew_row)

table = tables.Next()
```

Appendix II: Data sources

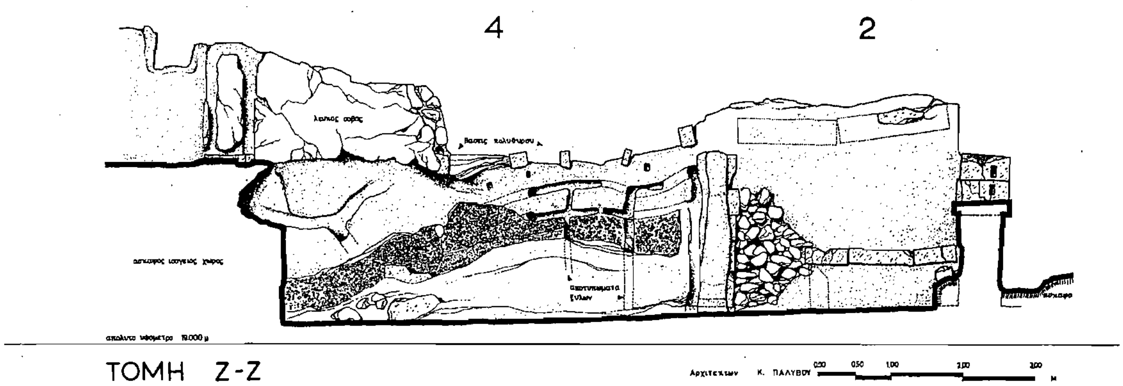
This Appendix contains some of the data sources used for the architectural reconstructions that are discussed in Chapters 4 and 5, and are not included in the main text of the thesis.



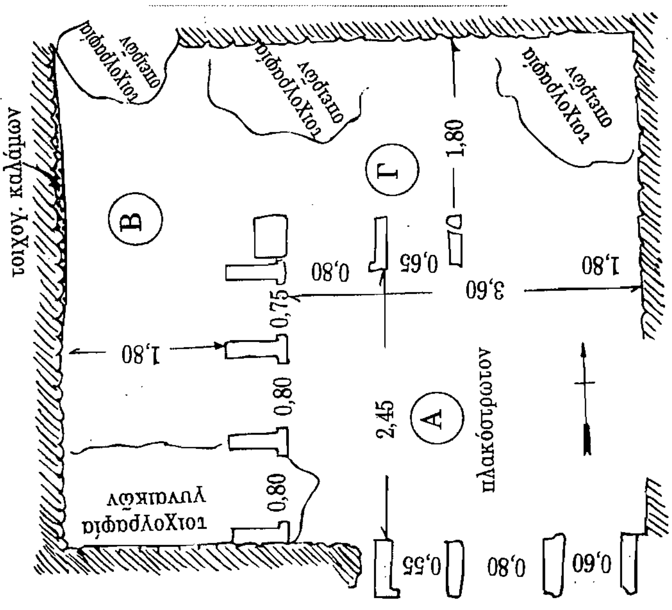
Plan 1: Room 3, Xeste 3. Plan of the ground floor (By Clairy Palyvou). From the excavation archive.



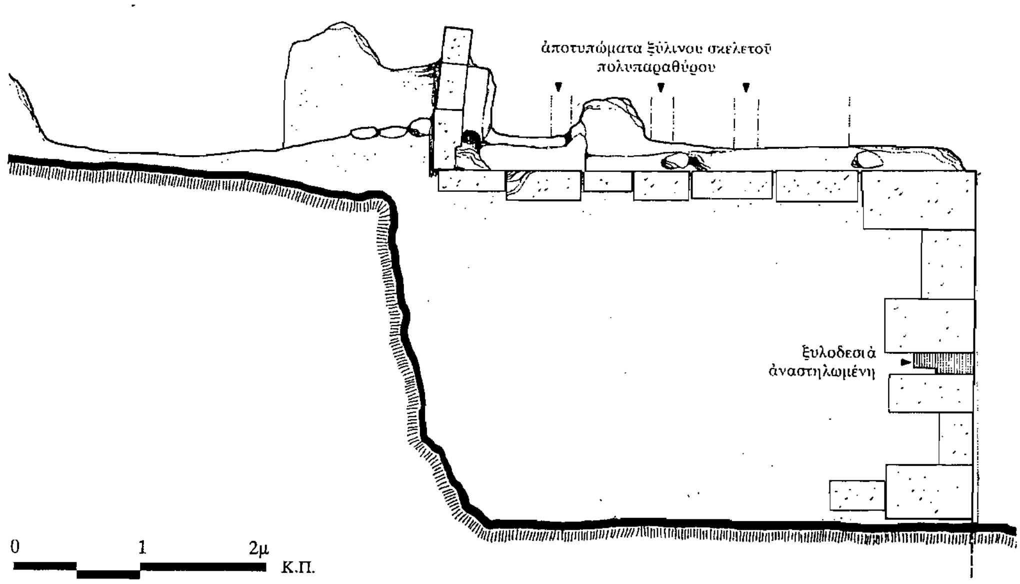
Plan 2. Room 3, Xeste 3. Plan of the first floor (by Clairy Palyvou). From the excavation archive.



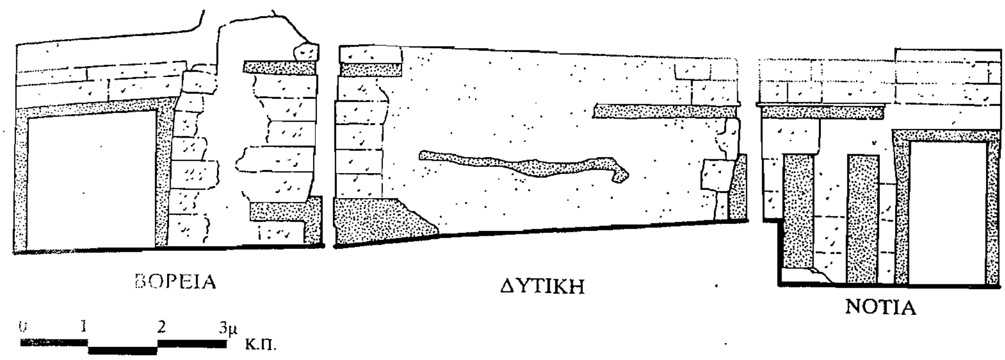
Plan 3. Section of Rooms 4 and 2 (Z-Z). (by Clairy Palyvou). From the excavation archive.



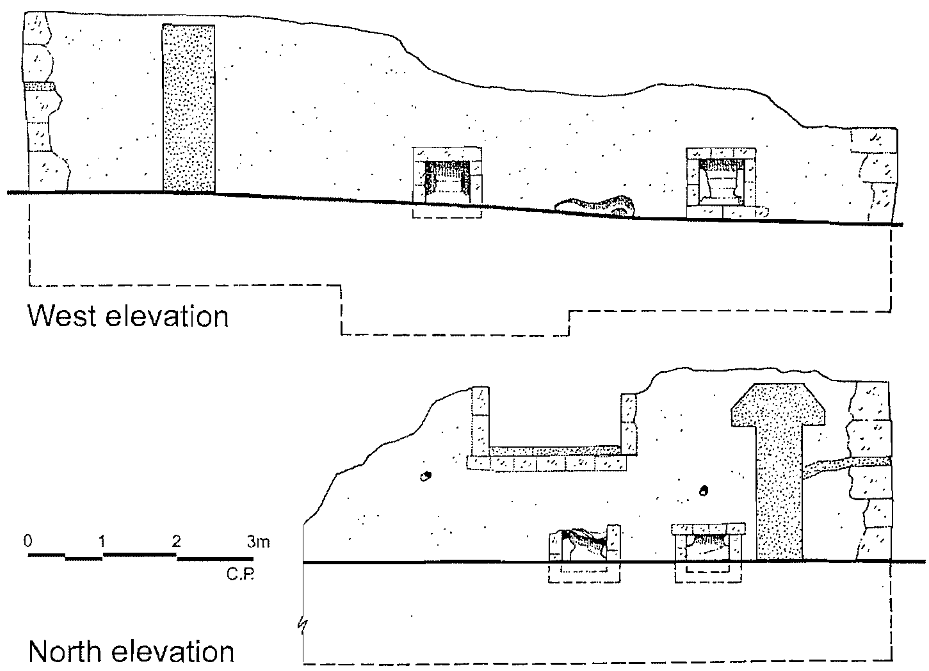
Plan 4. Room 3, Xeste 3, first floor (by S. Iakovides, from Michailidou 2001, fig.250).



Plan 5. The pier-and-window partition of the West House, north wall. By Clairy Palyvou (1999, fig.39).



Plan 6. Elevation of the Gate. By Clairy Palyvou (1999, fig.168)



Plan 7. Elevations of Beta South. By Clairy Palyvou (2005, fig. 77)

Bibliography

Abramovitz, K., 1980. "Frescoes from Ayia Irini, Keos. Parts II-IV", *Hesperia* 49 (1): 57-85.

Aldenderfer, M., 1998. "Quantitative methods in archaeology: a review of recent trends and developments", *Journal of Archaeological Research* 6: 91-120.

Athanasiou, K., 2008. *[E-mail]. (Personal communication 3 October 2008).*

Barber, E. J. W., 1992. *Prehistoric Textiles: The Development of Cloth in the Neolithic and Bronze Ages with Special Reference to the Aegean.* Princeton University Press.

Barber, R. L. N., 1984. "The status of Phylakopi in Creto-Cycladic relations", in *The Minoan Thalassocracy: Myth and reality. Proceedings of the Third International Symposium at the Swedish Institute in Athens, 31 May-5 June, 1982* R. Hägg and N. Marinatos, eds. Stockholm: 179 - 182.

Batty, M., 2001. "Exploring isovist fields: space and shape in architectural and urban morphology", *Environment and Planning B: Planning and design* 28(1): 123-150.

Batty, M., 2003. "Agent-based pedestrian modelling", in *Advanced Spatial Analysis: The CASA book of GIS.* P. A. Longley and M. Batty, eds. Redlands, California, ESRI Press: 81- 106.

Batty, M., 2005. *Cities and complexity: understanding cities with cellular automata, agent-based models, and fractals* London, MIT Press.

Batty, M. and P. M. Torrens. 2001,
. Modeling complexity: the limits to prediction. *Working paper 36* Retrieved 12 August 2007, from http://www.casa.ucl.ac.uk/working_papers/paper36.pdf.

Bell, T. and G. R. Lock, 2000. "Topographic and cultural influences on walking the Ridgeway in later prehistoric times", in *Beyond the map : archaeology and spatial technologies*. G. R. Lock, ed. Amsterdam ; Oxford, IOS Press: 85-100.

Bell, T., A. Wilson and A. Wickham, 2002. "Tracking the Samnites: Landscape and communication routes in the Sangro Valley, Italy", *American Journan of Archaeology* 106(2): 169-186.

Benedikt, M. and C. Burnham, A., 1985. "Perceiving Architectural Space: From Optic Arrays to Isovists", in *Persistence and Change-Proceedings of the first International Conference on Event Perception*. W. Warren, H. and E. R. Shaw, eds. Hillsdale, NJ, Lawrence Erlbaum: 103-114.

Benedikt, M., L., 1979. "To take hold of space: isovists and isovist fields", *Environment and Planning B: Planning and design* 6: 47-65.

Betancourt, P. P., 1995. "Pseira, Crete: The economic base for a Bronze Age town", in *Politeia: Society and state in the Aegean Bronze Age. Proceedings of the 5th International Aegean Conference / 5e Rencontre égéenne internationale, University of Heidelberg, Archäologisches Institut, 10-13 April 1994, Aegeum 12.* R. Laffineur and W.-D. Niemeier, eds. Liège: 163-167.

Birtacha, K. and M. Zacharioudakis, 2000. "Stereotypes in Theran wall-paintings: modules and patterns in the procedure of painting", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 1: 159-172.

Bishop, D., Ian, 2003. "Assessment of visual qualities, impacts, and behaviours, in the landscape, by using measures of visibility ", *Environment and Planning B: Planning and design* 30(5): 677-688.

Bishop, D., Ian, R. Wherrett, Joanna and R. Miller, David, 2000. "Using image depth variables as predictors of visual quality", *Environment and Planning B: Planning and design* 27: 865-875.

Bittner, J. and P. Wonka, 2003. "Visibility in computer graphics", *Environment and Planning B: Planning and design* 30(5): 729 - 755.

Blakolmer, F., 1995. "Komparative funktionanalyse des malerischen raumdekors in minoischen palästen und villen", in *Politeia: Society and state in the Aegean Bronze Age. Proceedings of the 5th International Aegean Conference / 5e Rencontre égéenne internationale, University of Heidelberg, Archäologisches Institut, 10-13 April 1994, Aegeum 12.* R. Laffineur and W.-D. Niemeier, eds. Liège: 463-473.

Blakolmer, F., 2000. "The Functions of Wall Painting and Other Forms of Architectural Decoration in the Aegean Bronze Age", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 1: 393-412.

Bloomer, C. M., 1990. *Principles of visual perception.* London, The Herbert Press.

Bonabeau, E., 2002. "Agent-Based Modelling: Methods and Techniques for Simulating Human Systems", *Proceedings of the National Academy of Sciences of the United States of America (PNAS)* 99(3): 7280-7287.

Bonanno, A., T. Gouder, C. Malone and S. Stoddart, 1990. "Monuments in an Island Society: The Maltese Context", *World Archaeology* 22(2): 190 - 205.

Boulotis, C., 1992. "Προβλήματα της Αιγαιακής ζωγραφικής και οι τοιχογραφίες του Ακρωτηρίου", in *Ακρωτήρι Θήρας: Είκοσι χρόνια έρευνας (1967 - 1987). Συμπεράσματα - Προβλήματα - Προοπτικές.* . Χ. Ντούμας, ed. Αθήνα, Η εν Αθήναις Αρχαιολογική Εταιρεία 81-93.

Boulotis, C., 1998. "Les nouveaux documents en linéaire A d'Akrotiri (Théra): remarques préliminaires", *Bulletin de correspondence héllenique* 122: 407-411.

Boulotis, C., 2000. "Travelling fresco painters in the Aegean Late Bronze Age: the diffusion patterns of a prestigious art.", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997*. S. Sherratt, ed. Athens, Thera Foundation. II: 844-858.

Boulotis, C., 2005. "Aspects of religious expression at Akrotiri", *Αλς. Periodical publication of the Society for the promotion of studies on Prehistoric Thera*(3): 20 - 75.

Boulotis, C., 2008. *Πομπή και κλιμακοστάσια. Η περίπτωση της Ξεστής 4. Paper presented at the conference "Ακρωτήρι Θήρας. Σαράντα χρόνια έρευνας (1967-2007)". 15-16 December 2007*. Athens.

Bourdieu, P., 1977. *Outline of a theory of practice*. Cambridge, Cambridge University Press.

Bradley, R., 2005. *Ritual and domestic life in Prehistoric Europe*. London and New York, Routledge.

Branigan, K. ed. 2001a. *Urbanism in the Aegean Bronze Age*. Sheffield Studies in Aegean Archaeology 4, Sheffield Academic Press.

Branigan, K., 2001b. "Aspects to Minoan Urbanism", in *Urbanism in the Aegean Bronze Age*. K. Branigan, ed., Sheffield Academic Press: 38-50.

Branting, S. A., 2004. *Iron Age pedestrians at Kerkenes Dağ: An archaeological GIS-T approach to movement and transportation*. PhD Thesis. The State University of New York at Buffalo.

Bruce, V., R. Green, Patrick and A. Georgeson, Mark, 1997. *Visual Perception: Physiology, Psychology and Ecology*. Psychology Press.

Buchholz, H. G., 1990. "Some observations concerning Thera's contacts overseas during the Bronze Age", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989*. C. Doumas, ed. London, Thera Foundation. 2: 227-240.

Cadogan, G., 1990. "Thera's eruption into our understanding of the Minoans", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989*. D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 93-97.

Cameron, M. A. S., 1970. "New Restorations of Minoan frescoes from Knossos", *BICS* 17: 163-166.

Cameron, M. A. S., 1972. *A General Study to Minoan Frescoes with Particular Reference to Unpublished Wall Paintings from Knossos, Ph.D. dissertation.* University of Newcastle upon Tyne.

Cameron, M. A. S., 1976. "Savaki's bothros: A minor sounding at Knossos", *BSA* 71: 1-13.

Castle, C. J. E. and A. T. Crooks. 2006. Principles and concepts of agent-based modelling for developing geospatial simulations. . *Working paper 110* Retrieved 12 August 2007, from http://www.casa.ucl.ac.uk/working_papers/paper110.pdf.

Chapin, A. P., 2004. "Power, Privilege and Landscape in Minoan Art", in *Charis: Essays in Honor of Sara A. Immerwahr [Hesperia Supplement 33]*. A. Chapin, ed., The American School of Classical Studies at Athens: 47-64.

Chapman, J., 1990. "Social Inequality on Bulgarian Tells and the Varna Problem", in *The social archaeology of houses*. R. Samson, ed., Edinburgh University Press: 49-92.

Cherry, J. F. and J. L. Davis, 1982. "The Cyclades and the Greek mainland in LC I: The evidence of the pottery", *American Journan of Archaeology* 86(3): 333-341.

Chryssikopoulou, E., V. Kilikoglou, V. Perdikatsis, S. Sotiropoulou, K. Birtacha and M. Zacharioudakis, 2000. "Making wall paintings: an attempt to reproduce the painting techniques of the Bronze Age Thera", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997*. S. Sherratt, ed. Athens, Thera Foundation. 1: 119-127.

Chrysikopoulou, E., 2005. "Use of murex purple in the wall-paintings at Akrotiri, Thera", *Αλς. Periodical publication of the Society for the promotion of studies on Prehistoric Thera*(3): 77- 80.

Chryssoulaki, S., 1990. "L'urbanisme minoen. A. Le réseau routier urbain", in *L'habitat égéen préhistorique [BCH Supplement 19]*. P. Darcque and R. Treuil, eds. Paris: 371-380.

Chryssoulaki, S., 2005. "The imaginary navy of Minoan Crete: Rocky coasts and probable Harbours ", in *EMPORIA. Aegeans in the Central and Eastern Mediterranean. Proceedings of the 10th International Aegean Conference : Italian School of Archaeology, Athens, 14-18 April 2004. Aegaeum 25.* . R. Laffineur and E. Greco, eds. Liège/Austin 77-89.

Clark, D. L. C., 2007. "Viewing the liturgy: a space syntax study of changing visibility and accessibility in the development of the Byzantine church in Jordan ", *World Archaeology* 39 (1): 84 - 104.

Claxton, J. B., 1995. "Future enhancements to GIS: implications for archaeological theory", in *Archaeology and geographical information systems : a European perspective*. G. R. Lock and Z. Stancic, eds. London, Taylor & Francis: 335-348.

Cline, E. H., 1995. " 'My Brother, My Son': Rulership and Trade between the Late Bronze Age Aegean, Egypt and the Near East ", in *The Role of the Ruler in the Prehistoric Aegean. Proceedings of a Panel Discussion presented at the Annual Meeting of the Archaeological Institute of America, New Orleans, Louisiana, 28 December 1992. Aegeum 11.* P. Rehak, ed. Liège: 143-150.

Coleman, K., L. J. Majewski and M. Reich, 1973. "Frescoes from Ayia Irini, Keos. Part I", *Hesperia* 42(3): 284-300.

Conolly, J. and M. Lake, 2006. *Geographical Information Systems in Archaeology.* Cambridge, Cambridge University Press.

Conroy, R., 2001. *Spatial Navigation in immersive virtual environments.* PhD thesis. University College London.

Cousin, J., 1980. *L'espace vivant: Introduction à l'espace architectural premier.* Paris, Editions du Moniteur.

Craane, M. L. 2007. Analysing Medieval urban space; a methodology. *Internet Archaeology* Retrieved 2 July 2008, from http://intarch.ac.uk/journal/issue21/craane_index.html.

Crouwel, J., 2005. "Early chariots in the Aegean and their Eastern connections", in *EMPORIA. Aegeans in the Central and Eastern Mediterranean. Proceedings of the 10th International Aegean Conference : Italian School of Archaeology, Athens, 14-18 April 2004. Aegaeum 25.* R. Laffineur and E. Greco, eds. Liège/Austin: 39-44.

Crouwel, J. H., 1981. *Chariots and other means of land tranport in Bronze Age Greece.* Amsterdam Allard Pierson Museum.

Crumley, C. L., 1995. "Heterarchy and the analysis of complex societies", in *Heterarchy and the analysis of complex societies.* R. M. Ehrenreich, C. L. Crumley and J. E. Levy, eds. Arlington, American Anthropological Association: 1-5.

Cutting, M., 2003. "The use of spatial analysis to study prehistoric settlement architecture ", *Oxford Journal of Archaeology* 22(1): 1-23.

Cutting, M., 2006. "More than one way to study a bulding: approaches to prehistoric household and settlement space", *Oxford Journal of Archaeology* 25(3): 225-246.

Davis, E., 1983. "The iconography of the Ship fresco from Thera", in *Ancient Greek art and iconography.* W. G. Moon, ed. Madison: 3-14.

Davis, J. L., 1979. "Minos and Dexithea: Crete and the Cyclades in the Later Bronze Age", in *Papers in Cycladic Prehistory.* J. L. Davis and J. F. Cherry, eds. Los Angeles, Institute of Archaeology, University of California: 143-157.

Davis, J. L., 1980. "Minoans and Minoanization at Ayia Irini, Keos", in *Thera and the Aegean world II: papers presented at the Second International Scientific Congress,* *Santorini, Greece, August 1978*. C. Doumas, ed. London, Thera and the Aegean World: 257-260.

Davis, J. L. and J. F. Cherry, 1990. "Spatial and temporal uniformitarianism in Late Cycladic I: Perspectives from Kea and Milos on the prehistory of Akrotiri ", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989*. D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 185-200.

Davis, N. E., 1986. "Youth and Age in the Thera Frescoes", *AJA* 90: 399-406.

Dean, D. J., 1997. " Improving the accuracy of forest viewsheds using triangulated networks and the visual permeability method", *Canadian Journal of Forest Research*: 969-977.

Devereux, P., 1991. "Three-dimensional aspects of apparent relationships between selected natural and artificial features within the topography of the Avebury complex", *Antiquity* 65: 894-898.

Devetzi, T. D., 1990. "The Stone Industry at Akrotiri: A Theoretical Approach", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989*. D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 19-23.

Devetzi, T. D., 2001. "Η παρουσία των λίθινων σκευών στον προϊστορικό οικισμό του Ακρωτηρίου", in *Σαντορίνη: Θήρα, Θηρασία, Ασπρονήσι, Ηφαίστεια*. Ι. Δανέζης, ed. Αθήνα, Εκδόσεις Αδάμ: 141- 149.

Devetzi, T. D., 2007. "Λίθινα σκεύη", in *Ακρωτήρι Θήρας-Δυτική Οικία. Τράπεζες, λίθινα, μετάλλινα, ποικίλα*. C. Doumas, ed. Αθήνα, Η εν Αθήναις Αρχαιολογική Εταιρεία: 102-160.

Dickinson, O., 1994. *The Aegean Bronze Age*. Cambridge, Cambridge University Press.

Doran, J. E., M. Palmer, N. Gilbert and P. Mellars, 1994. "The EOS project: modelling Upper Palaeolithic social change", in *Simulating societies*. N. Gilbert and D. J, eds. London, UCL Press: 195-221.

Doumas, C. ed. 1978-1980. *Thera and the Aegean world I-II. Papers presented in the second international scientific congress, Santorini, Greece, August 1978*. London.

Doumas, C., 1981. "Town planning and architecture in Bronze Age Thera", in *150 Jahre Deutsches Archäologisches Institut, 1829-1979 : Festveranstaltungen und internationales Kolloquium, 17.-22. April 1979 in Berlin*. Mainz, Deutsches Archäologisches Institut.: 95-98.

Doumas, C., 1982. "The Minoan thalassocracy and the Cyclades", *Archäologischer Anzeiger* 97: 5-14.

Doumas, C., 1982. "Ανασκαφή Θήρας", *Πρακτικά Αρχαιολογικής Εταιρείας 1980* 135: 289-296.

Doumas, C., 1983. *Thera, Pompeii of the ancient Aegean : excavations at Akrotiri 1967-79.* London, Thames and Hudson.

Doumas, C., 1984. "Ανασκαφές Θήρας", *Πρακτικά Αρχαιολογικής Εταιρείας 1982* 138: 263-266.

Doumas, C., 1987. "Η Ξεστή 3 και οι κυανοκέφαλοι στην τέχνη της Θήρας", in *Ειλαπίνη, Τόμος τιμητικός για τον Ν. Πλάτωνα.* Λ. Καστρινάκη, Γ. Ορφανού and Ν. Γιανναδάκης, eds. Ηράκλειο: 151-159.

Doumas, C., 1990. "Ανασκαφή Θήρας (Ακρωτηρίου)", *Πρακτικά Αρχαιολογικής Εταιρείας 1986* 141: 206-211.

Doumas, C., 1992a. *The wall-paintings of Thera.* Athens, The Thera Foundation.

Doumas, C., 1992b. *Ακρωτήρι Θήρας: Είκοσι χρόνια έρευνας (1967 - 1987). Συμπεράσματα - Προβλήματα - Προοπτικές.* . Αθήνα, Η εν Αθήναις Αρχαιολογική Εταιρεία

Doumas, C., 1995. "Ανασκαφή Ακρωτηρίου Θήρας", *Πρακτικά Αρχαιολογικής Εταιρείας 1992* 147: 176-188.

Doumas, C., 1997. "Ανασκαφή Ακρωτηρίου Θήρας", *Πρακτικά Αρχαιολογικής Εταιρείας 1994* 149: 155-166.

Doumas, C., 1998. "Ανασκαφή Ακρωτηρίου Θήρας", *Πρακτικά Αρχαιολογικής Εταιρείας 1995* 150: 127- 136.

Doumas, C., 1999. *Σαντορίνη - Οδηγός του νησιού και των αρχαιολογικών θησαυρών του.* Αθήνα, Εκδοτική Αθηνών Α.Ε.

Doumas, C., 2000a. "Age and gender in the Theran wall-paintings", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 2: 971-981.

Doumas, C., 2000b. "The Thera wall paintings as archaeological finds", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 1: 15-20.

Doumas, C., 2001. "Η Θήρα της Εποχής του Χαλκού: Πολιτιστικό σταυροδρόμι στην Ανατολική Μεσόγειο", in *Σαντορίνη: Θήρα, Θηρασία, Ασπρονήσι, Ηφαίστεια.* Ι. Δανέζης, ed. Αθήνα, Εκδόσεις Αδάμ: 87-98.

Doumas, C., 2002. "Ανασκαφή Ακρωτηρίου Θήρας", *Πρακτικά Αρχαιολογικής Εταιρείας 1999* 154: 155-202.

Doumas, C., 2003. "Ανασκαφή Ακρωτηρίου Θήρας", *Πρακτικά Αρχαιολογικής Εταιρείας 2000* 155: 169-172.

Doumas, C., 2005. "La Répartition Topographique des Fresques dans les Bâtiments d' Akrotiri à Théra", in *ΚΡΗΣ ΤΕΧΝΙΤΗΣ: L' Artisan Crétois. Recueil d'articles en l' honneur de Jean-Claude Poursat, publié à l'occasion de 40 ans de la découverte du Quartier Mu.* I. Bradfer-Burdet, B. Detournay and R. Laffineur, eds., Université de Liège, Histoire de l'art et archéologie de la Grèce antique; University of Texas at Austin, Program in Aegean Scripts and Prehistory. Aegeum 26: 73-81.

Doumas, C., 2007a. "Ανασκαφή Ακρωτηρίου Θήρας", *Πρακτικά Αρχαιολογικής Εταιρείας 2004* 159: 111-122.

Doumas, C., 2007b. "40 χρόνια", *Αλς*(5): 7-44.

Doumas, C. ed. 2007c. *Ακρωτήρι Θήρας-Δυτική Οικία. Τράπεζες, λίθινα, μετάλλινα, ποικίλα.* Αθήνα, Η εν Αθήναις Αρχαιολογική Εταιρεία.

Doumas, C. and A. G. Constantinides, 1990. "Pithoi, size and symbols: Some preliminary considerations on the Akrotiri evidence", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 41- 43.

Drewett, P., 1982. *The Archaeology of Bullock Down, Eastbourne, East Sussex: The Development of a Landscape.* Lewes, Sussex, The Sussex Archaeological Society.

Dreyfuss, H., 1959. *The measure of man: Human factors in design.* New York, Whitney Publication.

Driessen, J. and C. F. Macdonald, 1997. *The troubled island: Minoan Crete before and after the Santorini eruption.* Liège, Université de Liège and University of Texas at Austin.

Druitt, T. H. and V. Francaviglia, 1990. "An ancient caldera cliff line at Phira, and its significance for the topography and geology of Pre-Minoan Santorini", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, J. Keller, V. P. Galanopoulos, N. C. Flemming and T. H. Druitt, eds. London, Thera Foundation. 2: 362 - 369.

Durvilli, L., D. J. Knight, V. Tarabusi and L. Tronchin, 2007. "Sound Perception of Choral Music in San Vitale, Ravenna, Italy", Paper presented in the *International Symposium on Musical Acoustics (ISMA). 9th-12th September.* Barcelona, Spain.

Earl, G., P., 2005. *Texture viewsheds: Spatial summaries of built archaeological spaces derived from global light mapping.* Paper presented in the 11th International Conference on Virtual Systems and Multimedia, Ghent, Belgium VSMM (2005). October 2005.

Economidis, P. S., 2000. "The 'Little Fisherman' and the fish he holds ", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997* S. Sherratt, ed. Athens, Thera Foundation. II: 555-560.

Evans, A., J., 1921. *The palace of Minos at Knossos I.* London, Macmillan and Co., Limited.

Fairclough, G., 1992. "Meaningful constructions - spatial and functional analysis of medieval buildings", *Antiquity* 66: 348-366.

Ferber, J., 1999. *Multi-Agent Systems: An Introduction to Artificial Intelligence.* London, Addison-Wesley.

Ferguson, T. J., 1996 "Historic Zuni Architecture and Society: An Archaeological Application of Space Syntax", (Anthropological Papers of the University of Arizona) Tucson, University of Arizona Press 60.

Fernie, K. and J. D. Richards, 2002. *Creating and Using Virtual Reality: a Guide for the Arts and Humanities, AHDS Guides to Good Practice.* Oxford, Oxbow.

Findlay, J. M. and I. D. Gilchrist, 2003. *Active vision: the psychology of looking and seeing.* Oxfrord University Press.

Fischer, M. M. 2003. GIS and network analysis. *Handbook 5 Transport Geography and Spatial Systems* Retrieved 12 August 2008, from http://www.ersa.org/ersaconfs/ersa03/cdrom/papers/433.pdf.

Fisher-Gewirtzman, D., M. Burt and Y. Tzamir, 2003. "A 3-D visual method for comparative evaluation of dense built-up environments", *Environment and Planning B: Planning and design* 30(4): 575-587.

Fisher-Gewirtzman, D. and A. I. Wagner, 2003. "Spatial openness as a practical metric for evaluating built-up environments", *Environment and Planning B: Planning and design* 30: 37-49.

Fisher, P., 1991. "First experiments in viewshed uncertainty: the accuracy of the viewable area", *Photogrammetric Engineering and Remote Sensing* 57: 1321-1327.

Fisher, P., 1992. "First experiments in viewshed uncertainty: simulating the fuzzy viewshed", *Photogrammetric Engineering and Remote Sensing* 58: 345-352.

Fisher, P., 1993. "Algorithm and implementation uncertainty in viewshed analysis", *International journal of geographical information systems* 7(4): 331-347.

Fisher, P., 1994. "Probable and fuzzy models of the viewshed operation", in *Innovations in GIS: selected papers of the First International Conference on GIS research UK.* M. Worboys, F., ed. London, Taylor & Francis: 161-175.

Fisher, P., 1995. "An exploration of probable viewsheds in landscape planning", *Environment and Planning B: Planning and design* 22: 527-546.

Fisher, P., 1996. "Extending the applicability of viewsheds in landscape planning", *Photogrammetric Engineering and Remote Sensing* 62(11): 1297-1302.

Fisher, P., C. Farelly, A. Maddocks and C. Ruggles, 1997. "Spatial Analysis of Visible Areas from the Bronze Age Cairns of Mull", *Journal of Archaeological Science* 24: 581-592.

Foster, K. P., 1995. "A flight of swallows", *American Journal of Archaeology* 99: 409-425.

Foster, S., 1989. "Analysis of spatial patterns in buildings (access analysis) as an insight into social structure: examples from the Scottish Atlantic Iron Age", *Antiquity* 63: 40-50.

Frankfort, H., 1949. *Before philosophy: the intellectual adventure of ancient man - an essay on speculative thought in the ancient Near East.* Harmondsworth, Penguin.

Franz, G. and J. M. Wiener, 2005. "Exploring isovist-based correlates of spatial behavior and experience", in *Proceedings, 5th International Symposium on Space Syntax, Delft University of Technology.* A. Ness, ed. II: 503-517.

Fraser, D., 1983. *Land and society in Neolithic Orkney.* Oxford, British Archaeological Reports.

Fraser, D., 1988. "The orientation of visibility from the chambered cairns of Eday, Orkney", in *Records in Stone.* C. L. N. Ruggles, ed. Cambridge, Cambridge University Press: 325-337.

Gaffney, V. and Z. Stancic, 1991. *GIS approaches to regional analysis: a case study of the island of Hvar.* Ljubljana, Filozofska fakulteta.

Gaffney, V. and M. van Leusen, 1995. "Postscript- GIS, environmental determinism and archaeology: a parallel text", in *Archaeology and geographical information systems : a European perspective.* G. R. Lock and Z. Stancic, eds. London, Taylor & Francis: 367-382.

Gamble, C., 1978. "The Bronze Age animal economy from Akrotiri: A preliminary analysis", in *Thera and the Aegean world I. Papers presented in the second international scientific congress, Santorini, Greece, August 1978.* C. Doumas, ed. London: 745 - 753.

Gates, C., 2004. "The Adoption of Pictorial Imagery in Minoan Wall Painting: A comparative perspective", in *Charis: Essays in Honor of Sara A. Immerwahr [Hesperia Supplement 33].* A. Chapin, ed., The American School of Classical Studies at Athens: 27-46.

Georma, F., 2008. *[E-mail] (Personal communication 30 June 2008).*

Georma, F. and F. Sofianou, 2007. *Υπαίθριοι χώροι και αποχετευτικό σύστημα: διαχρονική προσέγγιση βάσει των νέων στρωματογραφικών δεδομένων. Paper presentation at the conference "Ακρωτήρι Θήρας. Σαράντα χρόνια έρευνας (1967-2007)". 15-16 Δεκεμβρίου 2007.* Athens.

Gesell, C. G., 1980. "The "Town Fresco" of Thera. A reflection on Cretan topography.", in *Procedings of the 4th Cretological Congress* Athens. 1: 197-204.

Gesell, C. G., 2000. "Blood on the horns of consecration?", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 2: 947-957.

Gibson, J., James, 1979. *The ecological approach to visual perception.* New Jersey, Lawrence Erlbaum Associates.

Giddens, A., 1984. *The constitution of society: Outline of the Theory of Structuration.* Cambridge, Polity press.

Gilbert, N. 2004. Agent-based social simulation: dealing with complexity. Retrieved 12 August 2007, from http://cress.soc.surrey.ac.uk/resources/ABSS%20-%20dealing%20with%20complexity-1-1.pdf.

Gilbert, N. and P. Terna, 2000. "How to build and use agent-based models in Social Science", *Mind & Society* 1(1): 57-72.

Gillings, M. and G. T. Goodrick. 1996. Sensuous and reflexive GIS: exploring visualisation and VRML. *Internet Archaeology* Retrieved 25 June 2005, 1, from http://intarch.ac.uk/journal/issue1/gillings_toc.html.

Gillis, C., 1990. "Akrotiri and its neighbours to the South: conical cups again", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 98 - 117.

Goffman, E., 1969. *The Representation of the self in everyday life.* London, Penguin Books.

Goffman, E., 1972. *Relations in public. Microstudies of the public order.* Harmondsworth, Penguin Books.

Grahame, M., 2000. *Reading space: Social interaction and identity in the houses of Roman Pompeii -A syntactical approach to the analysis and interpretation of built space.*

Groß, M., 1991. "The analysis of visibility-environmental interactions between computer graphics, physics and physiology", *Computers and graphics* 15(3): 407-415.

Gutierrez, D., I. Armenteros and B. Frischer, 2005. "Predictive Crowd Simulations for Cultural Heritage Applications", in *Proceedings of the 3rd international conference on Computer graphics and interactive techniques in Australasia and South East Asia, Dunedin, New Zealand, November 29 - December 02, 2005*, ACM: 109-112.

Hägerstrand, T., 1970. "What about people in regional science?", *Papers of the Regional Science Association* 24: 7-21.

Hägg, R., 1985. "Pictorial programmes in Minoan palaces and villas", in *L'iconographie minnoenne [BCH Supplement 11]*. P. Darque and J.-C. Poursat, eds. Paris: 209-217.

Haklay, M., D. O'Sullivan, M. Thurstain-Goodwin and T. Schelhorn, 2001. ""So go downtown": simulating pedestrian movement in town centres", *Environment and Planning B: Planning and Design* 28: 343 - 359.

Hall, T., Edward, 1966. *The hidden dimension.* New York, Doubleday.

Hamilakis, Y., 1996. "Wine, oil and the dialectics of power in Bronze Age Crete: A review of the evidence", *Oxford Journal of Archaeology* 15(1): 1- 32.

Hamilakis, Y., 2002. "Too many chiefs?: Factional competition in Neopalatial Crete", in *Monuments of Minos: Rethinking the Minoan palaces. Proceedings of the International workshop "Crete of the hundred Palaces?" held at the Université Catholique de Louvain, Louvain-la-Neuve, 14-15 December 2001*. J. Driessen, I. Schoep and R. Laffineur, eds., Université de Liège, Histoire de l'art et archéologie de la Grèce antique; University of Texas at Austin, Program in Aegean Scripts and Prehistory. Aegeum 23: 179-199.

Hamilakis, Y., M. Pluciennic and S. Tarlow eds., 2002. *Thinking Through the Body: Archaeologies of Corporeality*. New York, Kluwer Academic/ Plenum Publishers.

Haraway, D., 1991. *Simians, Cyborgs, and Women: the reinvention of nature.* London, Free Association Books.

Hardy, D. A., C. Doumas, G. Sakellarakis and P. Warren eds., 1990. *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989*. London, Thera Foundation.

Hardy, D. A. and A. C. Renfrew eds., 1990. *Thera and the Aegean World III: Vol. 3, Chronology: The Theran Event and its Global Impact. Proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989*. London, The Thera Foundation

Harris, T. M., 2000. "Moving GIS: exploring movement within prehistroric cultural landscapes using GIS", in *Beyond the map : archaeology and spatial technologies*. G. R. Lock, ed. Amsterdam ; Oxford, IOS Press: 116-123.

Harris, T. M. and G. R. Lock, 1995. "Toward an evaluation of GIS in European archaeology: the past, present and future of theory and applications", in *Archaeology* *and geographical information systems : a European perspective*. G. R. Lock and Z. Stancic, eds. London, Taylor & Francis: 349-365.

Harris, T. M. and G. R. Lock, 1996. "Multi-dimensional GIS: exploratory approaches to spatial and temporal relationships within archaeological stratigraphy", in *Analecta Preaehistorica Leidensia 28*. H. Kamermans and K. Fennema, eds. Leiden, Leiden University Press: 307-316.

Heïgeas, L., A. Luciani, J. Thollot and N. Castagné. 2003. A physically-based particle model of emergent crowd behaviors. *GraphiCon'2003, Moscow, September 5-10, 2003* Retrieved 12 August 2008, from http://artis.imag.fr/Publications/2003/HLTC03/crowd_Graphicon.pdf.

Heiken, G., F. McCoy and M. Sheridan, 1990. "Palaeotopographic and palaeogeologic reconstruction of Minoan Thera", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989*. D. A. Hardy, J. Keller, V. P. Galanopoulos, N. C. Flemming and T. H. Druitt, eds. London, Thera Foundation. 2: 370-376.

Helbing, D., 1992. "A fluid-dynamic model for the movement of pedestrians", *Complex Systems* 6(391 - 415).

Helbing, D., 1996. "Traffic modeling by means of physical concepts ", in *Traffic and Granular Flow*. D. E. Wolf, M. Schreckenberg and A. Bachem, eds. Singapore, World Scientific: 87-104.

Helbing, D., 1997. *Verkehrsdynamik*. Berlin, Springer.

Helbing, D. and P. Molnár, 1995. "Social force model of pedestrian dynamics", *Physical Review E* 51: 4282 - 4286.

Helbing, D., P. Molnár, I. J. Farkas and K. Bolay, 2001. "Self-organizing pedestrian movement", *Environment and Planning B: Planning and design* 28: 361-383.

Helbing, D., P. Molnar and F. Schweitzer, 1994. "Computer Simulations of Pedestrian Dynamics and Trail Formation", *Evolution of Natural Structures (Sonderforschungsbereich 230, Stuttgart)*: 229-234

Helbing, D. and T. Vicsekz, 1999. "Optimal self-organization", *New Journal of Physics* 1: 13.1-13.17.

Higuchi, T., 1983. *The Visual and spatial structure of Landscapes*. The MIT Press.

Hillier, B. and J. Hanson, 1984. *The social logic of space*. Cambridge, Cambridge University Press.

Hillier, B., A. Penn, J. Hanson, T. Grajewski and J. Xu, 1993. "Natural movement: or, configuration and attraction in urban pedestrian movement", *Environment and Planning B: Planning and design* 20(1): 29-66.

Hohmann-Vogrin, A., 2005. "Space syntax in Maya architecture", in *Proceedings, 5th International Symposium on Space Syntax, Delft University of Technology*. A. Ness, ed. II: 279-292.

Hollinshead, M., 1989. "The swallows and artists of Room Delta 2 at Akrotiri, Thera", *American Journal of Archaeology* 93: 339-354.

Hood, S., 1984. "A Minoan Empire in the Aegean in the 16th and 15th centuries B.C.?", in *The Minoan Thalassocracy: Myth and reality. Proceedings of the Third International Symposium at the Swedish Institute in Athens, 31 May-5 June, 1982* R. Hägg and N. Marinatos, eds. Stockholm: 33 - 38.

Hood, S., 1990. "The Cretan element on Thera in Late Minoan IA", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989*. D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 118 - 123.

Immerwahr, S., 1990. *Aegean Painting in the Bronze Age*. University Park.

Immerwahr, S., 2000. "Thera and Knossos: Relation of the paintings to their architectural space", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997*. S. Sherratt, ed. Athens, Thera Foundation. 1: 467-491.

Ingold, T., 2000. *The perception of the environment : essays on livelihood, dwelling and skil*. London, Routledge.

Jiang, B. and H. R. Gilbert, 2002. "An agent-based approach to environmental and urban systems within geographic information systems", in *Integrating Geographic Information Systems and agent-based modeling techniques for understanding social and ecological processes*. H. R. Gilbert, ed. New York, Oxford University Press: 171-190.

Kaiser, A., 2000. *The urban dialogue: an analysis of the use of space in the Roman city of Empúries, Spain* Oxford, Archaeopress.

Karageorghis, V., 1990. "Rites de passage at Thera: Some oriental comparanda", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989*. D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 67-71.

Karali-Yannacopoulou, L., 1990. "Sea Shells, Land Snails and other Marine Remains from Akrotiri", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989*. D. A. Hardy, J. Keller, V. P. Galanopoulos, N. C. Flemming and T. H. Druitt, eds. London, Thera Foundation. 2: 410-415.

Karali, L., 2001. "Θαλάσσιος κόσμος: διαιτολόγιο και αλιεία στο Ακρωτήρι", in *Σαντορίνη: Θήρα, Θηρασία, Ασπρονήσι, Ηφαίστεια*. Ι. Δανέζης, ed. Αθήνα, Εκδόσεις Αδάμ: 183-188.

Katsa-Tomara, L., 1990. "The Pottery-Producing System at Akrotiri: An Index of Exchnage and Social Activity", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 31-40.

Katsipis, S., 2001. "Οι κρόκοι της Θήρας", in *Σαντορίνη: Θήρα, Θηρασία, Ασπρονήσι, Ηφαίστεια.* Ι. Δανέζης, ed. Αθήνα, Εκδόσεις Αδάμ: 78 - 82.

Kerridge, J., J. Hine and M. Wigan, 2001. "Agent-based modelling of pedestrian movements: The questions that need to be asked and answered", *Environment and Planning B: Planning and design* 28: 327-341.

Kilikoglou, V., C. Doumas, A. Papagiannopoulou, E. V. Sayre, Y. Maniatis and A. P. Grimanis, 1990. "A study of the Middle and Late Cycladic pottery from Akrotiri", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 441 - 448.

Knight, D. J. and L. Tronchin, 2008. "The Acoustical Survival of San Vitale, Ravenna, Italy Through Two Millennia-Conference paper for the IOA ", Paper presentation in *the Institute of Acoustics Congress on Auditorium Acoustics. 3rd-5th October.* Oslo. Norway.

Koehl, R. B., 1990. "The rhyta from Akrotiri and some preliminary observations on their functions in selected contexts", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 350 - 362.

Kontroli-Papadopoulou, 1996. *Aegean Frescoes of Religious Character. SIMA 117.* Goteborg.

Kurose, S., A. W. J. Borgers and H. J. P. Timmermans, 2001. "Classifying pedestrian shopping behaviour according to implied heuristic choice rules", *Environment and Planning B: Planning and design* 28(3): 405 - 418.

Laffineur, R., 1984. "Mycenaeans at Thera: Further evidence?", in *The Minoan Thalassocracy: Myth and reality. Proceedings of the Third International Symposium at the Swedish Institute in Athens, 31 May-5 June, 1982* R. Hägg and N. Marinatos, eds. Stockholm: 133 - 139.

Laffineur, R., 2000. "Dress, hairstyle and jewellery in the Thera wall paintings", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 2: 890-906.

Lake, M., 2001. "The use of pedestrian modelling in archaeology, with an example from the study of cultural learning", *Environment and Planning B: Planning and design* 28(3): 385-403.

Lake, M. W. and P. E. Woodman, 2003. "Visibility studies in archaeology: a review and case study", *Environment and Planning B: Planning and design* 30(5): 689-707.

Lake, M. W., P. E. Woodman and S. J. Mithen, 1998. "Tailoring GIS Software for Archaeological Applications: An Example Concerning Viewshed Analysis ", *Journal of Archaeological Science* 25: 27-38.

Laurence, A. W., 1973. *Greek architecture, 5th edition.* Yale University Press.

Laurence, R., 1994. *Roman Pompeii: Space and Society.* London, Routledge.

Lee, J. and D. Stucky, 1998. "On applying viewshed analysis for determining least-cost paths on Digital Elevation Models", *International Journal of Geographical Information Science, 1998* 12(8): 891- 905.

Letesson, Q. and K. Vansteenhuyse, 2006. "Towards an Archaeology of Perception: 'Looking' at the Minoan Palaces ", *Journal of Mediterranean Archaeology* 19(1): 91-119.

Llobera, M., 2000. "Understanding movement: a pilot model towards the sociology of movement", in *Beyond the map : archaeology and spatial technologies.* G. R. Lock, ed. Amsterdam ; Oxford, IOS Press: 65-84.

Llobera, M., 2003. "Extending GIS-based visual analysis: the concept of visualscapes", *International journal of geographical information science* 17(1): 25-48.

Llobera, M., 2005. "The nature of everyday experience", in *Re-presenting GIS.* P. Fisher and D. Unwin, eds., John Wiley & Sons, Ltd.: 171-191.

Llobera, M., 2006. "What you see is what you get? Visualscapes, visual genesis and hierarchy", in *Digital Archaeology: bridging method and theory.* T. L. Evans and P. Daly, eds., Routledge: 148-167.

Llobera, M., 2007 "Modeling visibility through vegetation", *International Journal of Geographical Information Science* 21(7): 799-810.

Llobera, M., D. Wheatley, J. Steele, S. Cox and O. Parchment, in press. *Calculating the inherent visual structure of a landscape ('total viewshed') using high-throughput computing. International Conference Computer Applications and Quantitative Methods in Archaeology, Beyond the Artifact: Digital Interpretation of the Past, Prato, Italy, 13-17 April, 2004.*

Lock, G. R., 2003. *Using computers in archaeology : towards virtual pasts.* London, Routledge.

Lock, G. R. and T. M. Harris, 1996. "Danebury revisited: an English Iron Age hillfort in a digital landscape", in *Anthropology, space and geographic information systems.* M. Aldenderfer and H. Maschner, D.,G., eds. New York, Oxford University Press: 214-240.

Madry, S. and C. Crumley, L., 1990. "An application of remote sensing and GIS in a regional archaeological settlement pattern analysis: the Arroux River valley, Burgundy, France", in *Interpreting space: GIS and Archaeology* K. Allen, S. Green and E. Zubrow, eds. London, Taylor & Francis: 364-380.

Manning, S. W., 1999. *A test of time : the volcano of Thera and the chronology and history of the Aegean and east Mediterranean in the mid second millenium BC.* Oxford, Oxbow.

Marinatos, N., 1984. *Art and religion in Thera: reconstructing a Bronze Age society.* Athens, Mathioulakis.

Marinatos, N., 1985. "The function and interpretation of the Theran frescoes", *Bulletin de correspondance hellinique, Supplement XI, L'iconographie minoenne*: 219-230.

Marinatos, N., 1987. "Role and sex division in ritual scenes of Aegean art", *Journal of prehistoric religion* 1: 23-34.

Marinatos, N., 1990. "The rhyta from Akrotiri and some preliminary observations on their functions in selected contexts", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 370 - 377.

Marinatos, N., 1993. *Minoan religion : ritual, image and symbol.* Columbia, South Carolina, University of South Carolina Press.

Marinatos, N., 2005. "The ideals of manhood in Minoan Crete", in *Aegean wall painting: A tribute to Mark Cameron.* L. Morgan, ed., British School at Athens: 149-158.

Marinatos, N. and R. Hägg, 1986. "On the ceremonial function of the Minoan polythyron", *Opuscula Atheniensia* XVI: 57-73.

Marinatos, S., 1939. "The volcanic destruction of Minoan Crete", *Antiquity*(XIII): 425-439.

Marinatos, S., 1968. *Excavations at Thera I. First preliminary report (1967 season).* Athens.

Marinatos, S., 1969. *Excavations at Thera. II, (1968 season).* Athens.

Marinatos, S., 1970. *Excavations at Thera. III, (1969 season).* Athens.

Marinatos, S., 1971a. *Acta of the 1st International Scientific Congress on the Volcano of Thera : held in Greece, 15th-23rd September 1969.* Athens, Archaeological Services of Greece, General Direction of Antiquities and Restoration.

Marinatos, S., 1971b. *Excavations at Thera. IV, (1970 season).* Athens.

Marinatos, S., 1972. *Excavations at Thera. V, (1971 season).* Athens.

Marinatos, S., 1974. *Excavations at Thera. VI, (1972 season).* Athens.

Marinatos, S., 1976. *Excavations at Thera. VII, (1973 season).* Athens.

Märtens, H., 1890. *Optisches Mass für den Städtebau.* Bonn, Max Cohen & Sohn.

Marthari, M., 1990. "Investigation of the technology of manufacture of the local LBA Theran pottery: archaeological consideration", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 449 - 458.

Marthari, M., T. Marketou and R. E. Jones, 1990. "LB I ceramic connections between Thera and Kos ", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 171 - 184.

McCoy, F., 1980. "Climatic change in the Eastern Mediterranean area during the past 240,000 years", in *Thera and the Aegean World II.* C. Doumas, ed. London. 2: 79-100

McCoy, F. and G. Heiken, 2000. "The Late-Bronze Age explosive eruption of Thera (Santorini), Greece: Regional and local effects", *Volcanic hazards and disasters in Human Antiquity (Geological Society of America, Special Paper 345)*: 43-70.

McEnroe, J., 1982. "A typology of Minoan Neopalatial houses", *American Journal of Archaeology* 86(1): 3-19.

McEnroe, J. C., 1979. *Minoan House and Town Arrangement.* PhD thesis. University of Toronto.

McGeorge, P. J. P., 1988. "Health and diet in Minoan times", in *New aspects of archaeological science in Greece.* R. E. Jones and H. W. Catling, eds. Athens, British School at Athens: 47-54.

Michailidou, A., 1990. "The lead weights from Akrotiri: The archaeological record", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 407-419.

Michailidou, A., 2001a. *Ακρωτήρι Θήρας: Η μελέτη των ορόφων στα κτήρια του οικισμού.* Αθήνα, Η εν Αθήναις Αρχαιολογική Εταιρεία.

Michailidou, A., 2001b. "Ακρωτήρι: ευρήματα από μέταλλο και η περιπέτεια μιας χάλκινης υδρίας.", in *Σαντορίνη: Θήρα, Θηρασία, Ασπρονήσι, Ηφαίστεια*. Ι. Δανέζης, ed. Αθήνα, Εκδόσεις Αδάμ: 163-169.

Moore, D., Jerry, 1996. *Architecture and power in the ancient Andes-The archaeology of public buildings.* Cambridge University Press.

Morgan, L., 1988. *The miniature wall paintings of Thera : a study in Aegean culture and iconography.* Cambridge, Cambridge University Press.

Morgan, L., 1990. "Island Iconography: Thera, Kea, Milos", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 252-266.

Morgan, L., 1998. "The wall paintings of the North-East Bastion at Ayia Irini, Kea", in *Kea-Kythnos: History and Archaeology. Proceedings of an international symposium, Kea-Kythnos, 22-25 June 1994.* L. Mendoni and A. Mazarakis-Ainian, eds. Athens: 201-210.

Morgan, L., 2000. "Form and meaning of figurative painting", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 2: 925-945.

Murray, S. P., 2004. "Reconsidering the Room of the Ladies at Akrotiri", in *Charis: Essays in Honor of Sara A. Immerwahr [Hesperia Supplement 33].* A. Chapin, ed., The American School of Classical Studies at Athens: 101-130.

Mylona, D., 2000. "The 'Fishermen' frescoes in the light of the fish bone evidence", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. II: 561-567.

Mylona, D., 2001. "Μια αρχαιολογική αναζήτηση των ψαράδων της αρχαίας Σαντορίνης και της ψαριάς τους", in *Σαντορίνη: Θήρα, Θηρασία, Ασπρονήσι, Ηφαίστεια*. Ι. Δανέζης, ed. Αθήνα, Εκδόσεις Αδάμ: 189-192.

Niemeier, W.-D., 1992. "Iconography and context: The Thera frescoes", in *EIKΩN: Aegean Bronze Age Iconography: shaping a methodology, the 4th International Aegean Conference, University of Tasmania, Hobart, Australia, 6-9 April 1972.* R. Laffineur and L. Crowley, Janice, eds.: 97-104.

Nikolakopoulou, I., 2002. *Storage, storage facilities and island economy: the evidence from LCI Akrotiri.* PhD Thesis. University of Bristol.

Page, D., 1976. "The miniature frescoes from Akrotiri, Thera", *Πρακτικά της Ακαδημίας Αθηνών*: 135-152.

Paliou, E., 2002. *Virtual views of the West House: An interactive resource for archaeological research. Unpublished master's dissertation.* York, University of York.

Paliou, E. and D. Wheatley, 2007. "Integrating spatial analysis and 3D modelling approaches to the study of visual space: Late Bronze Age Akrotiri", in *The world is in your eyes - Proceedings of the XXXIII Computer Applications in Archaeology Conference. 21-24 March 2005.* Tomar, Portugal: 307-312.

Palyvou, C., 1984. "The destruction of the town at Akrotiri, Thera at the beginning of LCI : Rebuilding activities", in *The prehistoric Cyclades: Contributions to a workshop on Cycladic chronology.* J. A. MacGillivray and R.L.N. Barber. , eds. Edinburgh, Department of Classical Archaeology, University of Edinburgh: 134-147.

Palyvou, C., 1986. "Notes on the town plan of Late Bronze Age Akrotiri, Thera", *BSA* 81: 179-194.

Palyvou, C., 1990a. "Architectural design at Late Cycladic Akrotiri", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 44-56.

Palyvou, C., 1990b. "Observations sur 85 fenêtres du Cycladique Récent à Théra", in *L'habitat égéen préhistorique [BCH Supplement 19].* P. Darcque and R. Treuil, eds. Paris: 123-139.

Palyvou, C., 1999. *Ακρωτήρι Θήρας: Η οικοδομική τέχνη.* Αθήνα, Η εν Αθήναις Αρχαιολογική Εταιρεία.

Palyvou, C., 2000. "Concepts of space in Aegean Bronze Age Art and Architecture", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 1: 413-436.

Palyvou, C., 2001. "Μια αρχιτεκτονική της ευημερίας, ηλικίας 3500 χρόνων", in *Σαντορίνη: Θήρα, Θηρασία, Ασπρονήσι, Ηφαίστεια.* I. Δανέζης, ed. Αθήνα, Εκδόσεις Αδάμ: 125-132.

Palyvou, C., 2004. "Outdoor space in Minoan architecture: "community and privacy"", in *Knossos : palace, city, state ; proceedings of the conference in Herakleion organised by the British School at Athens and the 23rd Ephoreia of Prehistoric and Classical Antiquities of Herakleion, in November 2000, for the Centenary of Sir Arthur Evan's excavations at Knossos* G. Cadogan, E. Hatzaki and A. Vasilakis, eds., British School at Athens British School at Athens Studies 12: 207-217.

Palyvou, C., 2005a. *Akrotiri Thera: An architecture of affluence 3,500 years old.* Philadelphia, Pennsylvania, INSTAP Academic Press.

Palyvou, C., 2005b. "Architecture in Aegean Bronze Age art: façades with no interiors", in *Aegean wall painting: A tribute to Mark Cameron.* L. Morgan, ed., British School at Athens: 185-197.

Papageorgiou, I., 2000. "On the *rites de passage* in Late Cycladic Akrotiri, Thera: A reconsideration of the frescoes of the 'Priestess' and the 'Fishermen' of the West House.", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 2: 958-970.

Papagiannopoulou, A., 1990. "Some changes in the BA pottery production at Akrotiri", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 57 - 66.

Papagiannopoulou, A., 1995. "Xeste 3, Akrotiri, Thera: the pottery", in *Klados: essays in honour of J.N. Coldstream.* C. Morris, ed. London, Institute of Classical Studies: 209-214.

Penn, A. and N. Dalton, 1994. "The architecture of society: stochastic simulation of urban movement", in *Simulating Societies: The Computer Simulation of Social Phenomena.* N. Gilbert and J. Doran, eds. London, UCL Press: 85 - 125.

Peterson Murray, S., 2004. "Reconsidering the Room of the Ladies at Akrotiri", in *Charis: Essays in Honor of Sara A. Immerwahr [Hesperia Supplement 33].* A. Chapin, ed., The American School of Classical Studies at Athens: 101-130.

Platon, L., 2002. "The political and cultural influence of the Zakros Palace", in *Monuments of Minos: Rethinking the Minoan palaces. Proceedings of the International workshop "Crete of the hundred Palaces?" held at the Université Catholique de Louvain, Louvain-la-Neuve, I4-15 December 2001.* J. Driessen, I. Schoep and R. Laffineur, eds., Université de Liège, Histoire de l'art et archéologie de la Grèce antique; University of Texas at Austin, Program in Aegean Scripts and Prehistory. Aegeum 23: 145-155.

Poehler, E. E., 2006. "The circulation of traffic in Pompeii's Regio VI", *Journal of Roman Archaeology* 19: 53-74.

Polyxronakou-Sgouritsa, 2001. "'Επιπλα και επιπλουργία στον προϊστορικό οικισμό Ακρωτηρίου Θήρας", in *Σαντορίνη: Θήρα, Θηρασία, Ασπρονήσι, Ηφαίστεια.* I. Δανέζης, ed. Αθήνα, Εκδόσεις Αδάμ: 133- 139.

Potter, J., 1998. "The Structure of Open Space in Late Prehistoric Settlements in the Southwest", in *Migration and Reorganization: The Pueblo Period in the American Southwest.* K. A. Spielmann, ed. Tempe, Arizona State University: 137-153.

Poursat, J. C., 1990. "Craftsmen and traders at Thera: A view from Crete", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 124 - 127.

Pred, A., 1986. *Place, Practice and Structure: Social and Spatial Transforamtion of Southern Sweden.* Cambridge, Polity Press.

Rapoport, A., 1990. *The meaning of the built environment. A nonverbal communication approach. With a new Epilogue by the Author.* Tucson, The University of Arizona Press.

Rehak, P., 1999. "The monkey frieze from Xeste 3, Room 4: reconstuction and interpretation", in *Meletemata : studies in Aegean archaeology presented to Malcolm H. Wiener as he enters his 65th year.* P. P. Betancourt and M. H. Wiener, eds. Liège Austin, TX, Université de Liège. Histoire de l'art et archéologie de la Grèce antique ; University of Texas at Austin, Program in Aegean Scripts and Prehistory. III: 705-708.

Rehak, P., 2004. "Crocus costumes in Aegean Art", in *Charis: Essays in Honor of Sara A. Immerwahr [Hesperia Supplement 33].* A. Chapin, ed., The American School of Classical Studies at Athens: 85-100.

Reilly, P., 1990. "Towards a Virtual Archaeology", in *Computer Applications in Archaeology 1990.* K. Lockyear and S. Rahtz, eds. Oxford, British Archaeological Reports, International Series,. #565: 133-138.

Reilly, P. and S. Shennan, 1989. "Applying Solid Modelling and Animated Three-Dimensional Graphics", in *Computer Applications in Archaeology 1989.* R. Rahtz and J. Richards, eds. Oxford, British Archaeological, Reports, International Series: 157-162.

Renfrew, C., 1979. *Investigations in Orkney.* London, Society of Antiquaries.

Renfrew, C., 1985. *The archaeology of cult : the sanctuary at Phylakopi.* London, Thames and Hudson.

Renfrew, C., 2000. "Locus iste: Modes of representation and the Vision of Thera", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 1: 135-158.

Rethemiotakis, G., 2002. "Social and economic changes at Galatas and Pediada", in *Monuments of Minos: Rethinking the Minoan palaces. Proceedings of the International workshop "Crete of the hundred Palaces?" held at the Université Catholique de Louvain, Louvain-la-Neuve, I4-15 December 2001.* J. Driessen, I. Schoep and R. Laffineur, eds., Université de Liège, Histoire de l'art et archéologie de la Grèce antique; University of Texas at Austin, Program in Aegean Scripts and Prehistory. Aegeum 23: 55-69.

Reynolds, C. W., 1987. " Flocks, Herds, and Schools: A Distributed Behavioral Model", *Computer Graphics* 21(4 (SIGGRAPH '87 Conference Proceedings)): 25-34.

Robb, M. H. 2007. The spatial logic of Zacuala, Teotihuacan. *Proceedings, 6th International Space Syntax Symposium, Istanbul, 12-15 June, 2007* Retrieved 12 August 2008, from
http://www.spacesyntaxistanbul.itu.edu.tr/papers/longpapers/062%20-%20Robb.pdf.

Rose, M., 1994. *With line and glittering bronze hook: fishing in the Aegean Bronze Age*. Ph.D thesis. Indiana University.

Ruddle, R. A., S. J. Payne and D. M. Jones, 1997. "Navigating buildings in desk-top virtual environments: Experimental investigations using extended navigational experience", *Journal of Experimental Psychology: Applied* 3(2): 143-159.

Ruddle, R. A., S. J. Payne and D. M. Jones, 1998. "Navigating large-scale 'desk-top' virtual buildings: Effects of orientation aids and familiarity", *Presence: Teleoperators and virtual environments* 7(2): 179-192.

Ruddle, R. A., S. J. Randall, S. J. Payne and D. M. Jones, 1996. "Navigation and spatial knowledge acquisition in large scale virtual buildings: An experimental comparison of immersive and 'desk-top' displays", in *Proceedings of the 2nd International FIVE Conference*: 125-136.

Sakellarakis, J. A., 1990. "The fashioning of the ostrich-egg rhyta in the Creto-Mycenean Aegean", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989*. D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 285 - 308.

Sakellariou, A., 1980. "The West House miniature frescoes", in *Thera and the Aegean world II*. C. Doumas, ed. London. 2: 147-154.

Sanders, D., 1990. "Behavioral conventions and archaeology: methods for the analysis of ancient architecture", in *Domestic architecture and the use of space: An interdisciplinary cross-cultural study*. S. Kent, ed., Cambridge University Press: 43-72.

Sarpaki, A., 1987. *The Palaeoethnobotany of the West House, Akrotiri, Thera*. Ph.D thesis. University of Sheffield.

Sarpaki, A., 1992. "A Palaeoethnobotanical Study of the West House, Akrotiri, Thera", *BSA* 87: 219-230.

Sarpaki, A., 2001a. "Processed cereals and pulses from the Late Bronze Age Site of Akrotiri, Thera: Preparations Prior to Consumption: A Preliminary Approach to Their Study", *BSA* 96: 27-40.

Sarpaki, A., 2001b. "Ο κρόκος της ζαφοράς. Φυτό κατ' εξοχήν της Σαντορίνης", in *Σαντορίνη: Θήρα, Θηρασία, Ασπρονήσι, Ηφαίστεια*. Ι. Δανέζης, ed. Αθήνα, Εκδόσεις Αδάμ: 177-182.

Savage, S., 1990. "Modelling the Late Archaic social landscape", in *Interpreting space: GIS and Archaeology* K. Allen, S. Green and E. Zubrow, eds. London, Taylor & Francis: 330-355.

Schachermeyr, F., 1978. "Akrotiri: First Maritime Republic?", in *Thera and the Aegean World I. Papers presented at the Second International Scientific Congress, Santorini, Greece, August 1978*. C. Doumas, ed. London: 423 - 428.

Schelhorn, T., D. O'Sullivan, M. Haklay and M. Thurstain-Goodwin. 1999. STREETS: an agent-based pedestrian model. . *Working paper 9. Centre for Advanced Spatial Analysis UCL, London, UK.* Retrieved 12 August 2008 from http://eprints.ucl.ac.uk/267/1/streets.pdf.

Schoep, I., 2001. "Managing the Hinterland: the Rural concerns of Urban Administration", in *Urbanism in the Aegean Bronze Age*. K. Branigan, ed., Sheffield Academic Press: 87-102.

Schoep, I., 2002. "The state of the Minoan palaces or the Minoan palace-state?", in *Monuments of Minos: Rethinking the Minoan palaces. Proceedings of the International workshop "Crete of the hundred Palaces?" held at the Université Catholique de Louvain, Louvain-la-Neuve, I4-15 December 2001*. J. Driessen, I. Schoep and R. Laffineur, eds., Université de Liège, Histoire de l'art et archéologie de la Grèce antique; University of Texas at Austin, Program in Aegean Scripts and Prehistory. Aegeum 23: 15-33.

Schoep, I., 2004. "The socio-economic context of seal use and administration at Knossos", in *Knossos : palace, city, state ; proceedings of the conference in Herakleion organised by the British School at Athens and the 23rd Ephoreia of Prehistoric and Classical Antiquities of Herakleion, in November 2000, for the Centenary of Sir Arthur Evan's excavations at Knossos, British School at Athens Studies 12*. G. Cadogan, E. Hatzaki and A. Vasilakis, eds., British School at Athens 283-294.

Schofield, E., 1982. "The Western Cyclades and Crete: A "special relationship"", *Oxford Journal of Archaeology* 1(1): 9-25.

Shao, W. and D. Terzopoulos, 2006. *Populating reconstructed archaeological sites with autonomous virtual humans. IVA 2006, LNAI 4133*. Berlin / Heidelberg, Springer 420-433.

Shaw, J. W. and M. Luton, 2000. "The Foreshore at Akrotiri", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997*. S. Sherratt, ed. Athens, Thera Foundation. 1: 453-466.

Shaw, M. C., 1972. "The Miniature Frescoes of Tylissos Reconsidered", *Archäologischer Anzeiger*: 171-188.

Shaw, M. C., 2000. "The fleet fresco from Thera, and the punt reliefs from Egypt", in *The wall paintings of Thera: proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 1: 267-282.

Shaw, M. C., 2003. "Grids and other drafting devices in Minoan and other Aegean wall painting. A comparative analysis including Egypt.", in *Metron: Measuring the Aegean Bronze Age.* K. Foster, P. and R. Laffineur, eds. Liège, Université de Liège, Histoire de l'art et archéologie de la Grèce antique. Aegaeum; 24: 179-189.

Sherratt, A. and S. Sherratt, 1991. "From luxuries to commodities: The nature of Mediterranean Bronze Age Trading Systems", in *Bronze Age trade in the Mediterranean. Studies in the Meditteranean Archaeology.* N. H. Gale, ed. Jonsered. 90: 351-384.

Sherratt, S., 2000. *The wall paintings of Thera: proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* Athens, Thera Foundation.

Soles, J. S., 2002. "A central court at Gournia?", in *Monuments of Minos: Rethinking the Minoan palaces. Proceedings of the International workshop "Crete of the hundred Palaces?" held at the Université Catholique de Louvain, Louvain-la-Neuve, 14-15 December 2001.* J. Driessen, I. Schoep and R. Laffineur, eds., Université de Liège, Histoire de l'art et archéologie de la Grèce antique; University of Texas at Austin, Program in Aegean Scripts and Prehistory. Aegeum 23: 123-131.

Sotirakopoulou, P., 1990. "The earliest history of Akrotiri: The Late Neolithic and Early Bronze Age phases", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy and C. Renfrew, eds. London, Thera Foundation. III: 41-47.

Sperling, J. W., 1973. *Thera and Therasia, Ancient Greek Cities 22.* Athens.

Stavroulaki, G. and J. Peponis, 2005. "Seen in a different light. Icons in Byzantine museums and churches", in *Proceedings, 5th International Symposium on Space Syntax, Delft University of Technology.* A. Ness, ed. II: 251-263.

Steadman, P., 2004. "Guest editorial", *Environment and Planning B: Planning and design* 31(4): 483-486.

Stos-Gale, Z. A. and N. H. Gale, 1984. "The Minoan Thalassocracy and the Aegean metal trade", in *The Minoan Thalassocracy: Myth and reality. Proceedings of the Third International Symposium at the Swedish Institute in Athens, 31 May-5 June, 1982* R. Hägg and N. Marinatos, eds. Stockholm: 59 - 63.

Stos-Gale, Z. A. and N. H. Gale, 1990. "The Role of Thera in the Bronze age Trade in Metals", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 72-92.

Sutherland, D. H., K. R. Kaufman and J. R. Moitoza, 1994. "Kinematics of normal human walking", in *Human walking*. J. Rose and J. G. Gamble, eds., Williams and Wilkins, Baltimore, MD: 23-44.

Televantou, C., 1992. "Θηραϊκές τοιχογραφίες: οι ζωγράφοι", in *Ακρωτήρι Θήρας: Είκοσι χρόνια έρευνας (1967 - 1987). Συμπεράσματα - Προβλήματα - Προοπτικές.* . Χ. Ντούμας, ed. Αθήνα: 57-67.

Televantou, C., 1994. *Ακρωτήρι Θήρας: Οι τοιχογραφίες της Δυτικής Οικίας.* Αθήνα, Η εν Αθήναις Αρχαιολογική Εταιρεία.

Televantou, C., 2000. "Aegean Bronze Age Wall painting: The Theran Workshop", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 2: 831-843.

Televantou, C. A., 1990. "New light on the West House wall-paintings", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 309 - 326.

Teller, J., 2003. "A spherical metric for the field-oriented analysis of complex urban open spaces ", *Environment and Planning B: Planning and design* 30: 339-356.

Thaler, U., 2005. "Narrative and syntax: new perspectives on the Late Bronze Age palace of Pylos, Greece", in *Proceedings, 5th International Symposium on Space Syntax, Delft University of Technology.* A. Ness, ed. II: 323-339.

Thill, J.-C., 2000. "Geographic information systems for transportation in perspective", *Transportation Research Part C* 8: 3-12.

Thomas, J., 1993a. "The Politics of Vision and the Archaeologies of Landscape", in *Landscape, Politics and Perspectives.* B. Bender, ed. Oxford, Berg: 19-48.

Thomas, J., 1993b. "The Hermeneutics of Megalithic Space", in *Interpretative Archaeology.* C. Tilley, ed. Provedence/Oxford, Berg: 73-97.

Tilley, C., 1993. "Art, Architecture, Landscape [Neolithic Sweden]", in *Landscape, Politics and Perspectives.* B. Bender, ed. Oxford, Berg: 49-84.

Tilley, C., 1994. *A phenomenology of landscape: places, paths and monuments.* Oxford, Berg.

Tilley, C., 2004. *The Materiality of Stone: Explorations in Landscape Phenomenology: 1.* Oxford, Berg.

Torrens, P. M., 2003. "Automata-based models of urban systems", in *Advanced Spatial Analysis: The CASA book of GIS.* P. A. Longley and M. Batty, eds. Redlands, California, ESRI Press: 61-79.

Torrens, P. M. 2007. Behavioral intelligence for geospatial agents in urban environments. *Proceedings of the 2007 IEEE/WIC/ACM International Conference on Intelligent Agent Technology, p. 63-66,* Retrieved 12 August 2008, from http://delivery.acm.org/10.1145/1340000/1331636/30270063.pdf?key1=1331636&key2=4524751221&coll=GUIDE&dl=GUIDE&CFID=2932243&CFTOKEN=65815315.

Trantalidou, C., 1990. "Animals and Human Diet in the Prehistoric Aegean", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, J. Keller, V. P. Galanopoulos, N. C. Flemming and T. H. Druitt, eds. London, Thera Foundation. 2: 392-405.

Trantalidou, C., 2001. "Ζωοτεχνία και οικονομία στο Ακρωτήρι", in *Σαντορίνη: Θήρα, Θηρασία, Ασπρονήσι, Ηφαίστεια.* Ι. Δανέζης, ed. Αθήνα, Εκδόσεις Αδάμ: 193-204.

Trantalidou, C., 2000. "Animal bones and animal representations at Late Bronze Age Akrotiri", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. II: 709 - 736.

Tsujimura, S., 1991. "Ruts in Pompeii: Two traffic system in the Roman city", *Opusscula Pompeiana* 1: 58-86.

Turner, A., 2003. "Analysing the visual dynamics of spatial morphology", *Environment and Planning B: Planning and design* 30(5): 657-676.

Turner, A., M. Doxa, D. O' Sullivan and A. Penn, 2001. "From isovists to visibility graphs:a methodology for the analysis of architectural space", *Environment and Planning B: Planning and design* 28(1): 103-121.

Turner, A. and A. Penn, 2002. "Encoding natural movement as an agent-based system: an investigation into human pedestrian behaviour in the built environment", *Environment and Planning B: Planning and design* 29: 473 -490.

Tzachili, I., 1990. "All Important yet Elusive: Looking for Evidence for Cloth-Making at Akrotiri ", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 380-389.

Tzachili, I., 1994. "Αρχαίες και σύγχρονες κροκοσυλλέκτριες από το Ακρωτήρι της Σαντορίνης", in *Αριάδνη. Επιστημονική επετηρίδα της Φιλοσοφικής Σχολής του Πανεπιστημίου Κρήτης.* Ρέθυμνο, Πανεπιστήμιο Κρήτης. 7: 7-33.

Tzachili, I., 1997. *Υφαντική και υφάντρες στο προϊστορικό Αιγαίο. 2000-1000 π.Χ.* Ηράκλειο, Πανεπιστημιακές εκδόσεις Κρήτης.

Tzachili, I., 2001. "Η υφαντική στο Ακρωτήρι", in *Σαντορίνη: Θήρα, Θηρασία, Ασπρονήσι, Ηφαίστεια.* Ι. Δανέζης, ed. Αθήνα, Εκδόσεις Αδάμ: 163-170.

Van Dyke, R., 1999. "Space Syntax Analysis at the Chacoan Outlier of Guadalupe", *American Antiquity* 64(3): 461-473.

Van Leusen, M., 2002. *Pattern to process: methodological investigations into the formation and interpretation of spatial patterns in archaeological landscapes.* PhD Thesis. University of Groningen

Vanschoonwinkel, J., 1990. "Animal representations in Theran and other Aegean arts", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 327 - 347.

Vaughan, S. J., 1990. "Petrographic analysis of the Early Cycladic wares from Akrotiri, Thera", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 470-487.

Vlachopoulos, A., 2000. "The reed motif in the Thera wall paintings and its association with Aegean pictorial art", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 2: 631-656.

Vlachopoulos, A., 2003. ""Βίρα-μάινα": Το χρονικό της συντήρησης μιας τοιχογραφίας από το Ακρωτήρι (1973-2003)", in *Αργοναύτης : τιμητικός τόμος για τον καθηγητή Χρίστο Γ. Ντούμα από τους μαθητές του στο Πανεπιστήμιο Αθηνών (1980-2000)* Α. Βλαχόπουλος and Κ. Μπίρταχα, eds. Αθήνα, Καθημερινή: 505-526.

Vlachopoulos, A., 2007. *Η διασπορά των τοιχογραφιών στον οικισμό του Ακρωτηρίου. Τα δεδομένα μετά από τις προσφατές ανασκαφές.* Paper presented at the conference "Ακρωτήρι Θήρας. Σαράντα χρόνια έρευνας (1967-2007)*". 15-16 December 2007.* Athens.

Vlachopoulos, A., 2008. *[E-mail] (Personal communication 8 May 2008).*

Warren, P. and V. Hankey, 1989. *Aegean Bronze Age chronology.* Bristol, Bristol Classical Press.

Warren, P. M.a, 1979a. "The stone vessels from the LBA settlement at Akrotiri", *AEphem*: 82 - 113.

Warren, P. M., 1979b. "The miniature fresco form the West House at Akrotiri, Thera and its Aegean setting", *American Journan of Archaeology* 99: 115-129.

Watts, D., J. and S. H. Strogatz, 1998. "Collective dynamics of 'small-world' networks", *Nature* 393: 440-442.

Wheatley, D., 1995. "Cumulative viewshed analysis: a GIS-based method for investigating intervisibility, and its archaeological application", in *Archaeology and*

Geographical Information Systems: A European perspective. G. R. Lock, and Stancic Zoran, ed. London, Taylor & Francis: 171-185.

Wheatley, D., 1996. "The use of G.I.S. to understand regional variation in Neolithic Wessex", in *New methods, old problems: Geographic Information Systems in modern archaeological research.* H. Maschner, D.,G., ed. Carbondale, Illinois, Center for Archaological Investigations, Southern Illinois University at Carbondale: 77-103.

Wheatley, D. and M. Gillings, 2000. "Vision, perception and GIS: developing enriched approaches to the study of archaeological visibility", in *Beyond the map : archaeology and spatial technologies.* G. R. Lock, ed. Amsterdam ; Oxford, IOS Press: 1-27.

Wheatley, D. W. and M. Gillings, 2002. *Spatial technology and archaeology : the archeaological applications of GIS.* London, Taylor & Francis.

Whitelaw, T., 2001. "From Sites to Communities: Defining the Human Dimensions of Minoan Urbanism", in *Urbanism in the Aegean Bronze Age.* K. Branigan, ed., Sheffield Academic Press: 15-37.

Wiener, M. H., 1984. "The tale of the conical cups", in *The Minoan Thalassocracy: Myth and reality. Proceedings of the Third International Symposium at the Swedish Institute in Athens, 31 May-5 June, 1982* R. Hägg and N. Marinatos, eds. Stockholm: 17 - 26.

Wiener, M. H., 1990. "The isles of Crete? The Minoan Thalassocracy revisited", in *Thera and the Aegean world III : proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989.* D. A. Hardy, C. Doumas, G. Sakellarakis and P. Warren, eds. London, Thera Foundation. 1: 128 - 161.

Wiener, M. H., 2003. "Time Out: The Current Impasse in Bronze Age Archaeological Dating", in *METRON: Measuring the Aegean Bronze Age.* K. Foster, P. and R. Laffineur, eds. Liège/Austin Université de Liège, Histoire de l'art et archéologie de la Grèce antique. Aegaeum ; 24: 363-399.

Winter, I. J., 2000. "Thera Paintings and the Ancient Near East:The Private and Public domains of Wall Decoration", in *The wall paintings of Thera : proceedings of the first international symposium, Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997.* S. Sherratt, ed. Athens, Thera Foundation. 2: 745-762.

Yang, P. P. J., S. Putra and W. Li, 2007. "Viewsphere: A GIS-Based 3D visibility analysis for urban design evaluation", *Environment and Planning B: Planning and design* 34(6): 971-992.