The Kalavasos and Maroni Built Environments Project: Introduction and preliminary report on the 2008 and 2010 Seasons[1]

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Abstract

In this report we discuss the background and objectives of the Kalavasos and Maroni Built Environments (KAMBE) Project, as well as the preliminary results of its 2008 and 2010 field seasons. The primary aim of this project is to investigate the relationships between architecture, social interaction and social change in Late Bronze Age (or Late Cypriot; c. 1650-1100 BC) Cyprus. This period witnessed profound changes to both the island's built environment with the emergence of monumental architecture, new housing and tomb types, and the first urban centres, and its social fabric with the development and institutionalization of new sociopolitical structures. A growing body of research indicates that these processes were interrelated as the new urban environments played an active role as the contexts for social interactions through which Late Cypriot society was created, reproduced and transformed. These interrelationships have not been systematically investigated and understanding them requires more detailed knowledge

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The KAMBE Project is co-directed by Fisher, Manning and Rogers. The project would be impossible without the dedicated work of our field crew, many of whom also worked on data processing and analysis back at Ithaca College and Cornell University:
2008 Season: Kevin Hurley, Chris Hastings, and Charlie Simkin (Ithaca College); Jeffrey F. Leon, Rachel Kulick and Eilis Monahan (Cornell University); Seth Button (University of Michigan).
2010 Season: Jeffrey F. Leon, Katie Kearns, and Perri Gerard-Little (Cornell University); Kevin Hurley and Rebecca Grollman (Ithaca College).

of the anatomy of Late Bronze Age cities, i.e. how individual buildings were integrated into urban landscapes that structured social interaction.

Toward this end, the initial phase of the KAMBE project is undertaking survey using archaeological geophysics combined with the digital recording and 3D modeling of extant architecture at the partially-excavated sites of Kalavasos-*Ayios Dhimitrios* and Maroni (*Vournes*, *Tsaroukkas* and *Aspres*). The results from our 2008 and 2010 test seasons demonstrate the effectiveness of archaeological geophysics in detecting probable architectural features at both Kalavasos-*Ayios Dhimitrios* and Maroni-*Tsaroukkas*. In this report we discuss these results, as well as the specific survey methods and how we process and interpret the data. In addition to providing new insights into the social dynamics of Late Cypriot cityscapes, this work will form the basis for a GIS-based database of architectural and archaeological data from the two sites that will serve as a powerful research and cultural resource management tool for these sites and their environs.

I. Introduction

Cyprus stands out among its contemporaries in the eastern Mediterranean and Near East for the relatively late appearance of urbanism. Indeed, it was not until the transition to the Late Bronze Age ([LBA] or Late Cypriot [LC] period) c. 1650 BC that we see the rapid development of urban settlement on the island, long after cities had first appeared in the Levant, Anatolia and parts of the Aegean. The Late Bronze Age also witnessed the emergence of a number of other important innovations, including economic intensification and specialization, institutionalized of social classes, and the increasing integration of Cyprus into the politico-economic system of the eastern Mediterranean—innovations that revolutionized the way many Cypriotes lived their lives. Urbanism, along with other changes to the built environment, such as the appearance of monumental buildings and new types of domestic and mortuary architecture, have typically been seen as mere by-products of these processes. Current research suggests, however, that the new urban environments played an active and vital role in LBA social transformation as they became the primary arenas in which the island’s sociopolitical dynamics were played out.

Understanding the dynamics of this process is, unfortunately, greatly hindered by our inadequate knowledge of LC urban centers *in toto* (with the partial but not entirely satisfactory exception of Enkomi), and especially beyond the small relatively well-known elite components. The primary goal of the Kalavasos and Maroni Built Environments (KAMBE) Project is to shed light on the relationship between urban landscapes, social interaction and social transformation during the Late Bronze Age. Using a combination of archaeological geophysics, digital recording of extant architecture, and 3D modeling and visualization, we are investigating the two major LBA sites of Kalavasos-*Ayios Dhimitrios* and Maroni (*Vournes*, *Tsaroukkas*, and other localities) in south-central Cyprus in order to understand how the “urban revolution” transformed the social lives of people during this important period.

In the following report, we establish the rationale for the project, discuss its specific goals, and briefly summarize what we know of the two sites from previous excavation and survey work. Our work so far has focused on survey using archaeological geophysics, and the remainder of the report will address these methods and the results from the 2008 and 2010 field seasons. The preliminary results presented here demonstrate the potential for these methods to recover architectural data that can be used to reconstruct past urban landscapes.

II. Project Rationale and Objectives

In spite of excavations at a number of Late Cypriot sites, there has been little research into the social dimensions of their architectural remains and no field project has made such research the primary goal of its investigations. Until recently, most studies of ancient Cypriot architecture, informed by art-historical and culture-historical paradigms, have been descriptive rather than explanatory, focusing on issues such as stylistic classification and change, chronological considerations or the technical aspects of construction. Research in the 1980s-1990s, influenced by the processual archaeological paradigm, tended to see architectural change as reflecting the emergence and development of sociopolitical complexity, emphasizing the function of settlements within politico-economic systems. This is seen in attempts to model the complex web of production and exchange that linked different levels of LC regional settlement hierarchies: urban (usually coastal) centers, inland sanctuaries, and support settlements with copper mining or agricultural functions (Keswani 1993; Knapp 1986, 1997, ch. 5). Such approaches are important in highlighting the politico-economic functions and interconnections of Late Cypriot urban centers in a general sense but, in seeing urbanism as the inexorable result of processes of demographic growth and nucleation and politico-economic development, they ultimately fail to shed light on the far more significant social role that these cities played in revolutionizing the way many Cypriots lived and interacted.

The “spatial turn” in the social sciences that began in the late 1960s and early 1970s has brought recognition of the mutually-constituting relationship between space and society. Social theorists such as Giddens (1984), Lefebvre (1991[1974]), and Bourdieu (1977) argue that it is through actions and interactions of social agents in the course of daily practice that the structural properties of societies are produced and at the same time reproduced or transformed. Because social action and interaction take place in particular spatial contexts, the built environment plays a vital role in this process. As decades of research in environmental psychology demonstrate (e.g. Betchell and Churchman 2002; Hall 1966; Rapoport 1990; Stokols and Altman 1987), these contexts have a profound effect on the behaviour of people within them. More than just spaces, they are *places*: dynamic, socially-constructed and meaningful contexts of human action and experience imbued with identities and memories that make them both products and facilitators of social life (Feld and Basso 1996; Low and Lawrence-Zúñiga 2003; Preucel and Meskell 2004; Tuan 1977).While archaeology as a discipline has been slow to engage with these ideas (see Blake 2004), works by Manning (1993, 1998a), Bolger (2003) and Knapp (2003, 2008) take agent-centered approaches that see the Late Cypriot built environment as social space, imbued with meaning and memory and playing a significant role in creation and negotiation of individual and group identities. Fisher (2007, 2009a, 2009b) investigates LC built environments using an integrative approach that combines access analysis, as a way of figuring out how buildings structure movement and encounter, combined with a detailed study of how these buildings influence human behaviour and interaction through the nonverbal communication of meanings, which are perceived through vision as well as other senses (see Hillier and Hanson 1984; Rapoport 1990). He argues that LC elites created specific monumental urban buildings as contexts for social occasions, such as ceremonial feasts and other ritual activities, during which social status and identity were negotiated and displayed as a means of advancing their sociopolitical power. This work highlights how the strategic placement of architectural elements such as ashlar masonry was part of a deliberate program of place-making through which elites encoded and communicated messages meant to influence social action and interaction. The walls of buildings, elite or otherwise, were not just physical boundaries, but a materialization of social statements and practices integral to the formation and expression of individual and group identities during social interaction and various ritualized activities (both inside and outside/around these places of meaning and resonance).

These same dynamics were enacted at various levels of the urban landscape, from households, through neighbourhoods and other levels of urban community within which people were increasingly integrated during the Late Bronze Age. It is the dynamic cycle of acts of place-making at each of these levels that produced LBA cities (Fisher forthcoming). Based on the evidence from sites such as Enkomi and Kalavasos-*Ayios Dhimitrios*, it appears that by the Late Cypriot IIC period (beginning mid-14th c. BC) the general layouts of urban centers on Cyprus were, to a large degree, intentionally planned and the arrangement of buildings, streets, open spaces and fortifications had far-reaching effects on social interaction.

Whatever system of political authority was in place on the island at this time, we should see this as “top down” planning by ruling elites, materializing the large-scale appropriation of space into highly imageable urban landscapes (see Lynch 1960). As such, the new cities were, at least on one level, acts of elite place-making writ large. At the same time, the actions of lower order elite and non-elite individuals and groups in the construction and personalization of their houses, the formation of neighbourhoods, and the use of streets or other “public” spaces for private purposes, suggest that “bottom up” social action and resistance also took place (Fisher forthcoming). These too were acts of place-making and contributed to the creation of LC cities. LC urban landscapes, then, were not mere by-products of politico-economic processes, or an indication of social change, but rather intentional creations that served the interests of various individuals and groups and were catalysts for social transformation (see Cowgill 2004).

While the analysis of individual buildings can provide glimpses into these processes, we do not know enough about the spatial configuration of LC cities to understand how these processes worked at the landscape level. The difficulty with any conclusions about Late Cypriot urban environments is that, typically, much less than 5% of the estimated area of most of these sites has been excavated, and usually in discontinuous parts (see Iacovou 2007). In addition, some sites, such as Kition, are currently located in the midst of fairly dense modern urban development. With nearly 20% of its area excavated, much of it contiguous, one might expect that the site of Enkomi would play a more significant role in our understanding of Late Cypriot urbanism (Dikaios 1969-71; Courtois et al. 1986; Schaeffer 1971). The problem is that its potential is somewhat limited because of the incomplete publication of much of the site, controversies surrounding its phasing and chronology, extensive looting that has damaged many of its walls and doorways, and its location in the northern part of the island (see Fisher 2007, 120-2 for a summary).

Given the time and expense required, as well as the ethical and financial issues surrounding site preservation, it is impossible, if not undesirable, to excavate any ancient urban center to the extent necessary to obtain a satisfactory representation of its layout. Fortunately, advances in archaeological geophysics are allowing us to begin to address this issue, providing a far more complete look at the fabric of a Bronze Age city than was previously possible. One of our project's primary objectives, therefore, is to assemble relatively complete plans of substantive parts of the LBA urban centres of Kalavasos-*Ayios Dhimitrios* and Maroni. If we are ever to understand the relationship between the built environment and social change, it is necessary to place the small glimpses of urban planning we get from discrete excavation areas into a coherent picture of how these settlements structured social interaction. One need only look at the insights of spatial studies of Roman Pompeii (e.g. Grahame 2000; Laurence 1994) to see the potential social information that can be obtained from a relatively complete understanding of how the placement of private residences, industrial facilities, "public" buildings and infrastructure operate in concert to allow or discourage particular types of interaction. Such data can also shed light on the changing nature of the household (Bolger 2003), the emergence of communities (Fisher forthcoming; Knapp 2003, 2008) and the sociopolitical constitution and status of Late Cypriot urban centers. The plans generated from our work will guide targeted excavation work in a future phase of our project aimed at recovering detailed information on the use of space in various architectural contexts.

Having more complete urban plans would also help solve unanswered questions regarding the sociopolitical constitution and status of Late Cypriot urban centers. Based on the incomplete information currently available, Keswani (1996, 236) sees Kalavasos-*Ayios Dhimitrios* and Maroni as characterized by the presence of monumental ashlar buildings whose occupants had control over agricultural production and were "seemingly without institutional peers within their settlements at large". These sites were therefore dominated by centralized and hierarchical political structures.. By contrast, there is no single building or block at Enkomi that appears to have been the primary focus of administrative power. Rather, Keswani suggests that it is typified by a heterarchical sociopolitical organization with power dispersed among multiple nodes (see also Manning 1998a: 53). We need to test the validity of these assertions. More complete plans will also bring new data to bear on the thorny issue of how Late Bronze Age Cyprus was governed (most recently summarized in Knapp 2008, 144-53), allowing us to assess the degree of standardization in layout among the various cities that might be indicative of centralized or decentralized governance (Smith 2007). Ultimately, any attempts to understand the anatomy of these sites and explain the emergence of urbanism on Cyprus will require better data regarding their spatial configuration (as well as further exploration of the development, nature and scale of administrative practices, and so on).

Another major objective of the project is to develop a geographic information system (GIS)-driven database of spatial information on Late Cypriot built environments. This will involve the input into *ArcGIS* of new data from our survey, as well as the digitization of data from previous survey and excavation work at both sites. This process will include the digital recording of extant buildings, features and artifacts using 3D laser scanning and photogrammetry. These data will be used to (re)construct the urban environments of Kalavasos and Maroni using 3D modeling and visualization in an attempt to investigate the experiential qualities of movement and interaction. Ultimately, the creation of a GIS-based database will provide a valuable tool for the contextual and diachronic analysis of many aspects of LBA social life. This material will eventually be made available on the web for access by any interested parties. The database will also serve as an important management tool for the conservation and monitoring of these sites as cultural resources, particularly in light of the constant threat of development in the Kalavasos-Maroni region.

III. The Sites

Our project focuses on the LBA sites of Kalavasos-*Ayios Dhimitrios* and Maroni, which are situated in adjacent river valleys in south-central Cyprus, approximately 7 km apart (Figure 1). Both sites have been the subject of previous excavations that allow us to draw some tentative conclusions regarding their overall urban plans, but this work was conducted in only a few discrete areas of each site. We therefore have little idea as to how these were woven together into an overall urban fabric.

Kalavasos-*Ayios Dhimitrios* is located in the Vasilikos River valley about 3.5 km from the Mediterranean coast. It sits on flat and gently sloping terrain to the west of the river and is well situated for communication and trade, sitting astride the crossroads of the natural route that links central and eastern Cyprus with the western part of the island, and the north-south route that links the copper mines in the Troodos Mountains to the sea (South 1980, 23-6). Since 1976, this region has been the subject of survey and excavation work by the Vasilikos Valley Project, directed by Ian A. Todd (1977, 1986, etc.). Excavations by Alison South from 1979-1998 were initiated in advance of the construction of the (then) new Nicosia-Limassol highway and revealed an urban center dating to the Late Cypriot II period (c. 1450-1200 BC), reaching its zenith in the Late Cypriot IIC before being abandoned and destroyed (South 1980, 1988, 1997). Based on the extent of surface finds and architectural remains, the site likely covered about 11.5 ha (Figure 2). In spite of intensive earlier occupation elsewhere in the Vasilikos Valley (Todd 1996, 2004), significant occupation of this site can be traced back no earlier than the LC IIA:1. At this time it was at least used as a cemetery and, by the LC IIA:2/LC IIB, there is evidence for more extensive constructions (South 1997, 173).

Excavations were conducted in four discrete areas and recovered various buildings and roads that are largely oriented to the northwest, indicating that the city was probably laid out on a preconceived plan. This plan appears to consist of a system of parallel north-south streets and one or more transverse east-west streets. One such north-south street, 3.6 m wide, appears to extend at least 150 m through three separate excavation areas. Wright (1992, 115) argues that some form of zoning may also have been imposed in which the monumental administrative buildings were in the northeast, perhaps surrounded by a separate enclosure wall (see also South 1988, 223), with elite residences (some of which also contained industrial facilities) in the eastern and central parts of the city, and non-elite dwellings on the western outskirts. According to South (1995, 192) the plan exhibits symmetry and conformity, seen in the alignment of buildings on opposite sides of the street, and the possible existence of 'lots' demarcated by long stretches of wall.

Architecturally, the site is best known for Building X, a 30.5 x 37 m court-centered, monumental structure located in the northeast area. Building X and some of the surrounding buildings were initially erected some time after the LC IIA:2/IIB buildings noted above, and on a slightly different orientation. In mid-LC IIC Building X was monumentalized with the addition of impressive ashlar masonry (South 1997, 173). This building likely served as the site's administrative center and contained extensive evidence for the production and storage of olive oil as well as indications of elite feasting (Fisher 2007, 218-29; South 1995, 194; South 2008). The importance of Kalavasos-*Ayios Dhimitrios* is emphasized by Goren et al. (2003) who, based on petrographic analysis, consider it to be one of the most likely sources of the letters on clay tablets sent from the King of Alashiya to the Egyptian pharaoh and the King of Ugarit during the 14th and 13th centuries BC.

The nearby LBA site of Maroni is located in the Maroni (Ayiou Mina) River Valley, less than 3 km southwest of the modern village of Maroni (see Figure 1). Discrete areas of architectural remains dating mainly to the Late Cypriot II period have been recovered at the *Vournes*, *Tsaroukkas* and *Aspres* localities, while Late Cypriot tombs have been found in various parts of the site, a number of which were excavated by the British Museum in 1897 (Cadogan 1989, 1992, 1996; Johnson 1980; Manning 1998a; 1998b; Manning and Monks 1998; Manning and De Mita 1997; see Figure 3). In contrast to Kalavasos-*Ayios Dhimitrios,* a long Late Cypriot sequence is evident in the Maroni site area from LCIA to IIC. LCI onwards is known for example at Maroni-*Kapsalouhia* at the north of the overall site, at *Tsaroukkas* on the coast at the southern margin, and from a stratified series of horizons and structures from LCIA to LCIIC at *Vournes* (Cadogan 1996; Cadogan et al. 2001; Manning et al. 2002; 2006). Survey conducted by the Maroni Valley Archaeological Survey Project (MVASP; Manning 1998a; 42; 1998b; Manning et al. 1994; Manning and Conwell 1992; Manning and De Mita 1997) suggests an overall continuous, if dispersed, Late Cypriot urban area extending some 15-25 ha down to the shoreline.

Excavations of an elevated zone at Maroni-*Vournes* by Cadogan from 1982 to 1989 revealed a monumental building complex dating to Late Cypriot IIC that included the Ashlar Building, a 30.5 x 21 m tripartite structure constructed in part with ashlar masonry, and the four-aisled West Building, separated by a 4.5 m wide street (Cadogan 1984, 1992). The monumental buildings at *Vournes* were constructed over earlier structures and tombs, supporting Manning's (1998a) contention that the Late Cypriot IIC witnessed the emergence of a single, central figure who replaced earlier competing elite groups and ruled the Maroni region from these impressive structures. It is notable that the LCI architecture at *Vournes* is on a slightly different alignment to the subsequent LCII structures – if this pattern is a regular feature at the site, or in the area, then this may provide a basis to distinguishing LCI from LCII architecture in geophysical data (at least close to *Vournes*). *Vournes* appears the obvious candidate as the administrative focus of this region, although whether it formed part of a contiguous urban centre that included the other nearby LC sites is unclear—and this is one of the key questions this project will try to explore and address (cf. Iacovou 2007; 7). A few small sterile trial trenches along the eastern part of *Vournes* led Cadogan (1984: 2) to conclude that this administrative zone might have been physically separated from the settlement at *Tsaroukkas*, nearly 500 m to the southeast. The MVASP survey work has suggested perhaps discontinuous areas of major activity across the wider site, with a major debris area between *Tsaroukkas* and *Vournes* perhaps the likely locus for the main LBA settlement (Manning and De Mita 1997; Manning and Monks 1998; Manning 1998a; 1998b; Manning and Sewell, in preparation). Guided by pedestrian survey and a limited fluxgate magnetometer and resistivity survey, Manning undertook excavations at *Tsaroukkas* and *Aspres* from 1993 through 1997 (Manning and De Mita 1997, 124-126; Manning 1998b). At *Tsaroukkas* this work revealed LCIIC architectural remains of a more utilitarian nature belonging to a coastal port/production site, while a part of a large structure evidently with a storage role was recovered at *Aspres* (Manning and De Mita 1997; Manning 1998; Manning and Sewell, in preparation) (see Figure 10 for *Tsaroukkas*). Manning concluded that the greater or combined Maroni site was a Primary Coastal Centre that combined production, mobilization, administration and internal and external trade. The longevity of the Late Bronze Age occupation in the Maroni Valley and Manning's (1998a) account of the coalescence of power in this region underscore its importance in understanding Late Cypriot sociopolitical dynamics and the development of urbanism on the island.

Kalavasos-*Ayios Dhimitrios* and Maroni are excellent candidates for survey using archaeological geophysics. Much of the areas likely occupied by these settlements remain available as agricultural fields, albeit with increasingly intensive use and ploughing in some areas and the imposition of hothouses in some other places. British Museum search-pitting – as they looked for tombs (Johnson 1978; Cadogan 1992; Manning and Monks 1998) – and as recognized repeatedly in the excavations at *Vournes* and *Tsaroukkas*, will provide a complicating factor at Maroni (evident in the pits shown in the excavated areas at *Tsaroukkas* in Figure 10). Nevertheless, previous geophysical work was able to isolate LBA architecture successfully at *Tsaroukkas* and *Aspres* (Manning and De Mita 1997, 124-126; Manning 1998). Otherwise, both sites are situated on relatively level ground and without a great deal of permanent modern ground cover. A review of older aerial photos – for example, the 1963 set – indicates that many more olive and carob trees used to be in the area, and, again, the remains of these, especially if the stumps were burnt and/or removed, will provide a level of noise for any archaeological geophysics survey. The architectural remains at these sites are generally found within less than 0.5-1 m of the modern surface and their regular/rectilinear forms will produce signals that will be relatively easy to recognize.

Neither site area was occupied in any substantial way before or after the Late Bronze Age, thereby largely avoiding the problems of detecting multiple-period superimposed constructions. Earlier occupation of each valley occurred at discrete sites further inland and, although some Iron Age re-use or activity occurs at Maroni within the LBA site area, there is only modest or limited architecture in association on present knowledge. Except for the modern highway that runs through the middle of Kalavasos-*Ayios Dhimitrios*, and the (deeper) bulldozing associated with the paving of the former coastal track running across the *Tsaroukkas* site area in late 1990s (Manning et al. 2006), there is, at present, little other modern development directly on top of large areas of these sites, and there are no nearby power lines that might interfere with the instruments.

IV. Archaeological Geophysics Survey Methods

Archaeological geophysics is the examination of the Earth's physical properties using non-invasive ground survey techniques to reveal buried archaeological features, sites and landscapes (Gaffney and Gater 2003, 12). Its ability to detect subterranean features, precisely map them, and suggest interpretations based on their context, form and distribution (Kvamme 2005) makes it an ideal method for the initial phase of the KAMBE Project. A review of the use of archaeological geophysics in the Mediterranean written a decade ago (Sarris and Jones 2000) suggested that, while routinely used in northern Europe, it was still not regularly employed in Mediterranean contexts. Much has now changed. After the very early use of magnetometry at Enkomi (Aitken 1971), magnetic and resistivity survey at Hala Sultan Tekke (Fischer 1980; Linington 1977), and resistivity survey at Khirokitia (Hesse and Reminel 1978), archaeological geophysics has now become routine as part of many archaeological projects in Cyprus in the last decade or so. Some examples include: Kandou-*Kouphovounos* (Sarris et al. 2002), the Palaepaphos Urban Landscapes Project (Iacovou 2008), the Pyla-*Koutsopetria* Archaeological Project (Brown 2007; Caraher et al. 2007, 8-13), Hala Sultan Tekke (Fischer n.d.), and Maroni-*Tsaroukkas* and *Aspres* and Zygi-*Petrini* (Manning and De Mita 1997, 124-126; Manning 1998; Manning et al. 2000), among others. Considerable advancements in terms of the range, refinement, portability, battery-life and cost-effectiveness of instrumentation, combined with the ability to process data quickly in the field using powerful notebook computers have revolutionized the way archaeological geophysics is done. Large areas can now be quickly investigated for archaeological features at a relatively low cost. Preliminary investigations for this project adopted a multidimensional approach that tested a range of instrumentation (conductivity, resistivity, cesium magnetometry, fluxgate gradiometry, and GPR) resulting in GPR and magnetometry being identified as the most productive methods for imaging architectural features at Kalavasos-*Ayios Dhimitrios* and Maroni.

Ground-penetrating radar (GPR) uses a radio frequency antenna to actively transmit rapid radio pulses into the ground along a transect (see Conyers 2004a). When these radio waves encounter subsurface features with different physical, chemical, and dielectric permittivity properties, part of the radio wave is reflected back to the receiving antenna, while the remaining portion continues into the ground, possibly being reflected back by other subterranean features. This radio wave reflects more strongly when there is a large difference in the dielectric properties of adjacent materials. As the reflected waves arrive back at the receiving antenna the strength of the return radio wave and the time it took for the wave to travel down, reflect, and return are recorded. This allows one to estimate the depth of targets below the surface along a vertical section or "profile." The use of closely-spaced parallel transects also allows the data to be displayed in horizontal "time slices" where time is a substitute for depth (Kvamme and Ahler 2007). If the speed of the radio wave in the soils is known then the two-way travel time can be converted to depth, but using an "average soil" setting will give an approximate depth in meters. These time slices can enhance the interpretation of GPR data because archaeological features with regular shapes, such as the walls, roads and floors that our project would be looking for, are more easily recognized in plan view than in a vertical section (Conyers 2004a). We employed a Geophysical Survey Systems, Inc. SIR-3000 GPR with 400 and 900 MHz interchangeable antennae.

Magnetic surveying methods can detect and measure extremely small magnetic fields close to the ground surface associated with subterranean archaeological remains, based on the presence of weakly magnetized iron oxides. When materials are heavily-fired (usually > 600°C, although this depends on the material), they acquire a permanent magnetization associated with the direction of the earth's magnetic field within which they were allowed to cool (Gaffney and Gater 2003, 37). As such, archaeological features such as fired-clay hearths, kilns and metallurgical facilities can be detected using a magnetometer. Ditches and pits are also detectable since their construction involves the movement of soils, resulting in possible changes in iron oxide concentrations (e.g. Rogers et al. 2005; Rogers et al. 2006). Imported stone used in the construction of buildings or pavements might be more or less magnetic than surrounding soils and therefore detectable as well (Kvamme 2005).

Our preliminary investigations employed two types of magnetometer: a Geometrics G-868 Optically Pumped Cesium Vapour magnetometer and a Geoscan FM256 Fluxgate Gradiometer. Taken together, the complementary nature of these methods can potentially allow greater insight into the nature of subsurface archaeological features, since those not detected by one method may be visible to another (Clay 2001; Kvamme 2003). The effectiveness of each instrument to image features of interest varies due to different environmental conditions at each site. Our future surveys will provide a better understanding of how these instruments perform across a larger landscape.The archaeological geophysics survey units at both Kalavasos and Maroni were established using a Leica TRC 1105 total station. The existing archaeological grid systems at both sites provided primary and secondary site datums, and the archaeological geophysics grids were aligned within these systems. Typically, we employed a 20 x 20 m survey unit, although this was often adjusted to accommodate local topography, fencing and roads. The survey unit corners are identified by plastic stakes, which are non-ferrous and eliminate noise during magnetic surveys. Nylon survey tapes, which are also non-ferrous, are stretched between corner pegs to facilitate laying out transect lines used to guide instrument operators. Blaze orange, plastic, monofilament line – commonly used by hand-held weed-trimming tools – is stretched across the 20-meter-wide unit at 1 m intervals.All instruments used a bidirectional survey method in which the operator walks in one direction along the first transect, turns around, and walks back along the second transect. Data are collected at a transect spacing less than the one-meter-spaced monofilament lines by estimating the non-marked transects using the meter-spaced reference transects. As each instrument completes its unit, the data is immediately downloaded into a notebook computer for preliminary processing, allowing us to check the integrity of the data and detect significant instrument or other errors on-site. More detailed discussion of the data processing and its interpretation follows below.

V. The 2008 and 2010 Field Seasons

We carried out a two-week pilot season in June 2008 in order to assess the feasibility of using archaeological geophysics at both Kalavasos and Maroni in the summer period. The sites were largely bare of vegetation at this time. GPR, cesium magnetometer and fluxgate gradiometer surveys were conducted first at Kalavasos-*Ayios Dhimitrios.* Our work concentrated in the zone south of the Northeast (administrative) Area between the fence surrounding the excavations and the fence of the modern highway (Figures 2 and 4). This area was chosen for its high potential for buried architecture as indicated by the results of an unpublished resistivity survey conducted by John Hunt in April 2008, as well as the ability to compare the archaeological geophysics results with previously excavated features to the north and south of our units.

A ten-day-long field season was conducted from March 16-25, 2010 in order to test instrument responses under more moist soil conditions and to refine instrument settings and data collection methodology. Conyers (2004b) demonstrates that ground-penetrating radar reflections from subsurface features can be quite different between wet soils and dry soils. The survey areas at both Kalavasos-*Ayios Dhimitrios* and Maroni-*Tsaroukkas* were covered by c. 1 m tall cereals and grasses, which were flattened before work began. We again surveyed the area south of the Northeast Area at Kalavasos-*Ayios Dhimitrios*. Because the survey units were aligned to the extant architecture, we tried to assess whether any data patterning might be the result of this alignment. We therefore re-surveyed the two principal test units (Units 3 and 4), orienting them at 45º from the original units (Units 3 and 4 Diagonal) and found no significant difference in the data obtained. At Maroni-*Tsaroukkas*, the primary test focused on four 20 x 20 m units in the area between the excavations of Buildings I and II (Figures 5 and 9).

VI. Data Processing

Data gathered in the field during these two seasons include a number of signals that are not caused by the archaeology in question, and they must undergo several processing steps before archaeological interpretations can best be made. These processing steps are essentially a number of mathematical operations used to remove unwanted signals and to correct positional errors that can be caused during data collection. Basic processing steps are performed in the field in order to ensure that the parameters used for each instrument are correctly calibrated for the soil and survey conditions; more in-depth processing is undertaken in the laboratory after we return from the field.

Because the instruments measure different properties, different errors and unwanted signals need to be accounted for and removed, which, in turn, entails various processing steps for each instrument data set. During the survey process, slight differences in the start and end positions along survey transects cause each survey line to be slightly offset, necessitating a staggering correction. Magnetic data, which measures the strength of the magnetic signal in a given location, is affected by slight changes in the earth's magnetic field that are caused by the earth's location in relation to the sun at the time of surveying. These offsets must be corrected for. Additional large, anomalous signals can be caused by small metal objects (e.g. nails, old archaeological grid rebar, or other ferrous objects on the ground surface). These create "spikes" in the data where the magnetic signal is significantly larger than surrounding data points. De-spiking data enables us to remove these unwanted spikes in order to better detect the signals caused by the archaeology. In a similar vein, visualizing data becomes difficult if strong "wanted" signals (that is to say, signals potentially caused by archaeology) are significantly greater than weaker signals (i.e. with more than three standard-deviations difference). In these cases, we can filter the data by clipping these particularly strong signals at three standard deviations from the mean signal strength, so as to make sure weaker, but important, signals are more visible. Finally, we interpolate the survey data using a krigging method: a statistical algorithm that smoothes the data by estimating the probable value of an unknown point based on the measured values around it. This makes the signals easier to evaluate visually. Otherwise, the pixilated survey grids are difficult to interpret from an archaeological perspective.

For GPR, data processing takes a slightly different form. A small drift of the signal away from the data zero line (essentially the data mean) can be present in the data. This shift, called “DC drift” can be caused by localize electronics which use microwave pulses, and must be removed from the data (Goodman 2009). Moreover, as radio pulses from the radar antenna travel deeper into the ground, they lose strength, thus producing an artificial weakening of those signals returning from deeper reflectors. To correct for this (in order to make sure that deeper signals are given equal weight as shallow signals) artificial “gains points” are applied to the data that essentially multiply the data by a known factor, and boost the strength of these deeper signals. Although most commercial GPR units include shielding of the radar antenna in order to focus the signals into the ground, some radio waves can be reflected off the operator, the survey cart, the GPR control unit, or other localized surface reflectors. The signals that return from these unwanted reflectors, in addition to the signal caused by the coupling between the radar unit and the ground can be removed by using a “background” filter, which computes an average radar signal across each profile and removes it from the data, and in turn, does away with horizontal banding in the data.

Additional filters can be applied to both magnetic and GPR data to enhance or minimize particular signals. These include low-pass and high-pass filters, which allow signal strengths above or below defined amplitudes to “pass through” the filter, while unwanted signals are removed. Low-pass filters allow signals beneath a certain strength to pass through, while high-pass filters do the opposite, allowing signals above a given signal strength to pass. The ground penetrating radar data collected at Kalavasos- *Ayios Dhimitrios* and displayed here were gathered with a GSSI SIR 3000 instrument at a 0.5 m transect spacing, and an inline spacing of 0.02 m. Vertical sampling was set at 512 samples per scan with a time window of 30 nanoseconds (nS), meaning samples were taken at approximately every 3 - 4 mm in the vertical direction. Data were processed using GPR Slice software (for processing steps and parameters, see Table 1), which enabled us to run a background removal filter, grid the data at a 10 cm interpolation and create nine overlapping 2D time slices, each of which had an approximate thickness of 5 nS (see Figure 6).Magnetic data from Maroni-*Tsaroukkas* were collected using an FM256 Fluxgate gradiometer at a 0.5 meter transect spacing, and an approximate inline spacing of 0.125 m. Data were processed in Geoplot 3.0 software (for processing steps and parameters see Table 2), where the data were destaggered and despiked, and were processed using a zero mean grid and zero mean traverse algorithm. The grids were then edge mapped and the data were run through a high pass filter. Finally the data were interpolated in the X and Y directions using a sin x/x function. In what follows, we present preliminary results from the 2008 and 2010 field seasons based on data obtained by the most effective instruments.

VII. Results and Interpretation

Kalavasos-*Ayios Dhimitrios*

As noted above, the best results so far at Kalavasos were obtained using the GPR. Units 3 and 4, between the Northeast Area and the highway reveal a continuation of urban architecture compatible with expectations based on the excavated areas at the site. Figure 6 shows the results of a GPR survey from the 2010 season, represented as a series of time slices for Units 3 and 4 at gradually greater depths from the surface.

Figure 7 shows Time Slice 5 for Units 3 and 4 in context. The plot shows a number of linear features that are mostly on same alignment as the architecture in the neighbouring excavation areas. One of the most important features is what appears to be a continuation of the main north-south road that runs south from Building X through both the excavation area destroyed by the highway and the Southeast Area (see Figure 2; Feature R1 in Figure 8). This first appears in Slice 4 (Figure 6) as two parallel rows of relatively low intensity reflectors, approximately 4 m apart, running along the west side of Unit 3. These reflectors are most intense in Slice 5 where they align with two small sections of wall revealed by the excavation of a long narrow trench (no longer extant) that ran across Unit 3 at a 45º angle. The reflectors lose intensity in Slice 6 and are only partially visible in slice 7. On the east side of the road there are a number of high-intensity signals in Slice 5 in the northeast corner of Unit 3, possibly indicating a long, narrow rectangular structure, the west end of which seems to jut into R1. A feature of similar width and the same alignment appears directly across R1 (labeled W2 in Figure 8). A small, nearly square, structure with some internal partitioning (B1 in Figure 8) occupies much of of R1 at this point and may be a continuation of Feature W2. These features appear to indicate a deliberate attempt to restrict and control access to the Northeast Area. Features W1 and W2 could possibly be a continuation of the enclosure wall that South (1995: 194) suggests may have surrounded the Northeast Area, portions of which were excavated immediately north and east of Building X. This feature appears to continue to the west (W3 in Figure 8), though on a slightly more southerly alignment. If this is the case, then B1 may represent some form of gatehouse, controlling access to the administrative area.

South of W2 and bordering R1 on the west side is what appears to be a larger rectangular structure with internal partitioning (B2 in Figure 8). The southern extent of this structure is unclear, although it looks to be interrupted by an east-west street (R2 in Figure 8) running perpendicular to the north-south road. The southern limit of R2 appears as a line of reflectors, some of which are high intensity, running west from the north-south road along the 4975 m line of the y-axis of the geophysical grid. In any case, the line of the west wall of B2 appears to continue further southward, perhaps forming the west limit of another structure of the same width (B3). It is possible that a north-south laneway may have run along the west side of B2 and B3, ending at W3, although the western edge of such a feature is unclear. One last feature worth noting is the dense grouping of high-intensity reflectors recorded along the eastern edge of Unit 3, south of W1. These anomalies were caused by the presence of an olive tree and are clearest in Slices 5 though 9.

Maroni-*Tsaroukkas*

In 2010, a preliminary test was carried out in four units (Units 1-4) between and slightly to the north of the excavated areas of Buildings 1 and 2 at *Tsaroukkas*. For reasons we have not yet entirely resolved, GPR was not effective here in this test. The underlying signal was drowned by parallel linear features, which we assume to be plough marks. We hope that a different instrument setup combined with further analysis may be able to overcome this issue.

In contrast, the magnetometer survey produced promising results, consistent with previous good findings obtained using this method (see work by John Creighton reported in Manning and De Mita 1997, 124-126). Figure 9 shows the fluxgate survey of Units 1-4, revealing several rectilinear anomalies which appear present in the data and are on the same general alignment as the extant architecture of Buildings 1 and 2. The interpretation in Figure 10 suggests a number of possible architectural features. Of particular note is a complex or, more likely, two separate structures in the central part of Unit 1, both of which are roughly L-shaped. The easternmost structure bears some resemblance to the extant remains of nearby Building 2, while the western structure appears to show signs of internal partitioning. There is also some form of complex in the southeast of Unit 3. It is difficult to interpret the likely signals in Unit 4, while the large, broadly rectangular area in much of Unit 2 (and into southeast of Unit 4 and northwest of the structures in Unit 1) might as easily represent a relatively recent field division and use as Late Bronze Age archaeology (and are not dissimilar to some of the larger-scale rectilinear features noted by previous fluxgate survey in the area; see Manning and De Mita 1997, Figure 8). The successful identification of archaeology via fluxgate survey at Maroni – in contrast to poor results with this technique at Kalavasos – can be primarily explained by the different soils at the respective loci: Maroni in particular having more iron-rich soil.

VIII. Conclusions

In the initial phase of the KAMBE Project, we have spent two short seasons in rather different environmental conditions assessing the effectiveness of various archaeological geophysics instruments for detecting subsurface architectural features at Kalavasos and Maroni. It is apparent that, while resistivity can be an effective technique under certain specific conditions, the general dryness of the Cypriot landscape precludes effective use during late spring/summer field seasons. It is not suitable for large-scale survey of archaeological landscapes in our study region. GPR has proved highly effective at Kalavasos, and also in other recent work at the similar site of Hala Sultan Tekke (Fischer n.d.). Its non-performance at Maroni-*Tsaroukkas* is, we believe, due to specific issues in instrument setup and use and we believe can be rectified for future work. Magnetometry has proved highly effective at Maroni where soils are suitable, but is of much less utility in the very different soil conditions found in the Kalavasos site area. The next two field seasons will be aimed at extensive coverage of both sites using GPR and magnetometry. We anticipate some limited excavation after this work in an effort to confirm the nature of walls, doorways and other architectural features.

The results of this “test phase” of our project indicate that archaeological geophysics has great potential to provide insight into the configuration of past urban landscapes, without the need for extensive excavation. Combined with digital recording of the extant architecture, this should allow us to assemble relatively complete plans of two important Late Cypriot cities. This information will, in due course, serve as a basis for further archaeological work aimed at investigating particular architectural contexts. Furthermore, these methods will form the basis of a powerful resource management tool for areas under development pressure. While these data, in conjunction with existing survey data, should not be the only evidence used to establish the cultural significance of particular plots of land, they will enable us to determine the existence of buried architecture and other built features. The work of the KAMBE project should also allow us to make significant headway in investigating the vital role that urban landscapes played in shaping Cypriot society during the Late Bronze Age.

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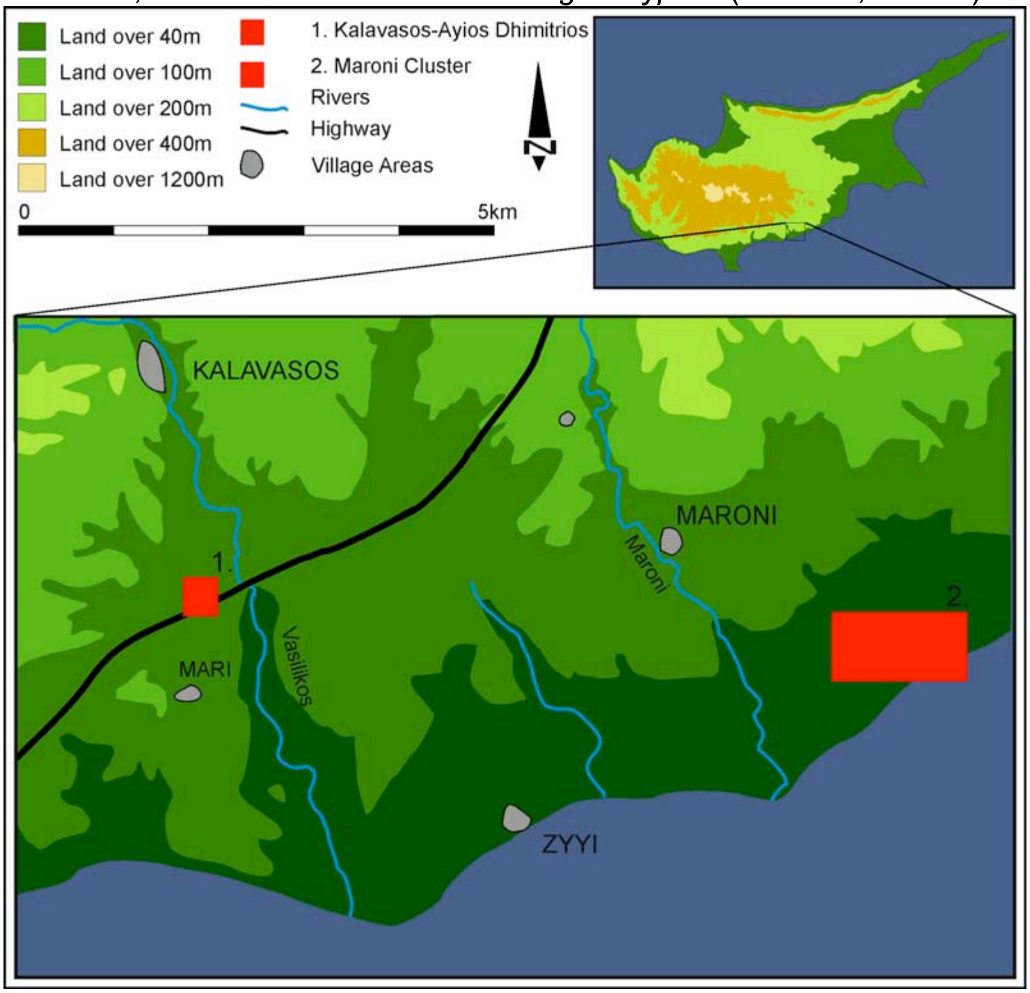

Figure 1: Map of Cyprus with detail of KAMBE Project survey region. Refer to Figures 2 and 3 for maps of areas shown in red.

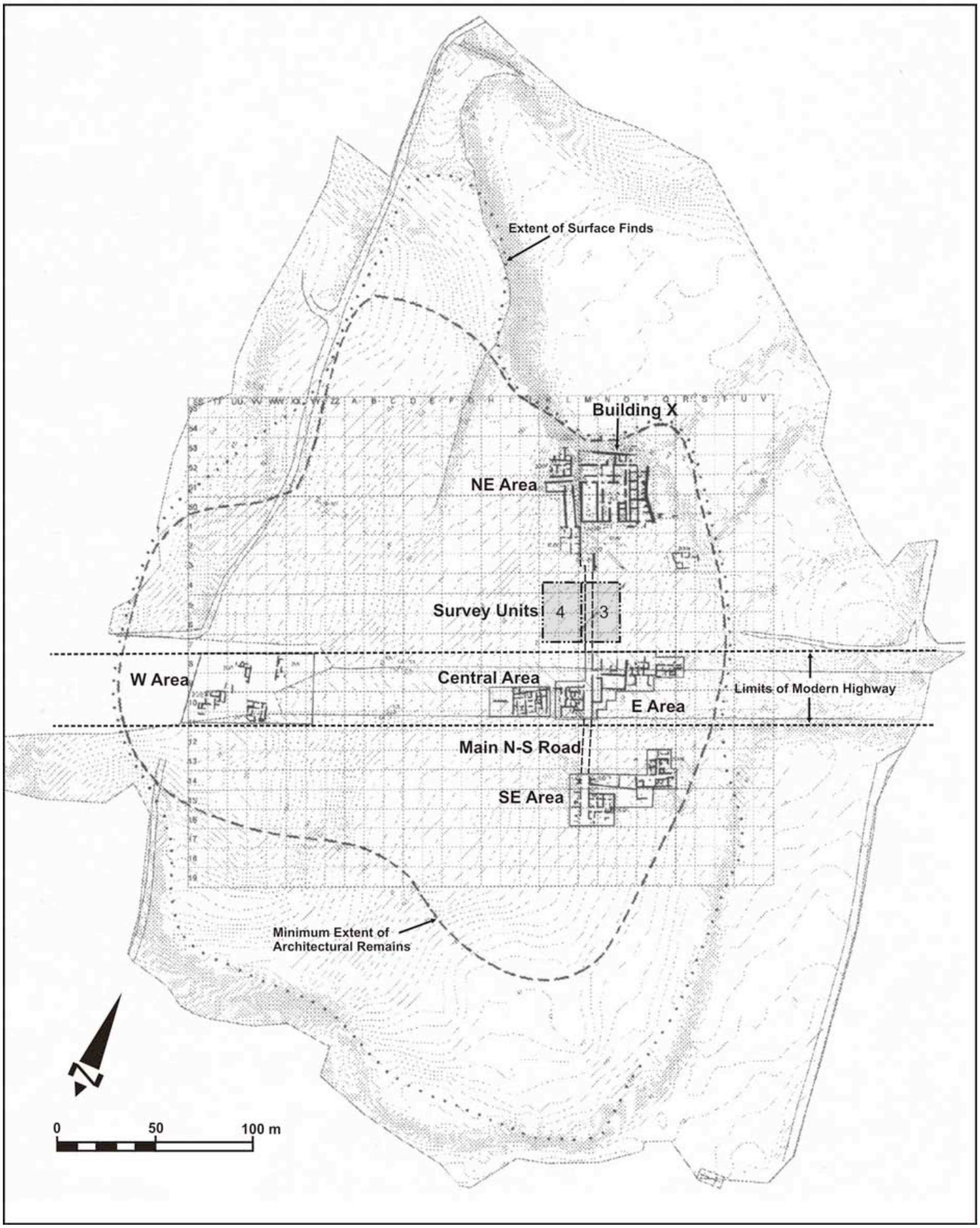

Figure 2: Site plan of Kalavasos-*Ayios Dhimitrios* showing location of excavated areas and archaeogeophysical survey units.

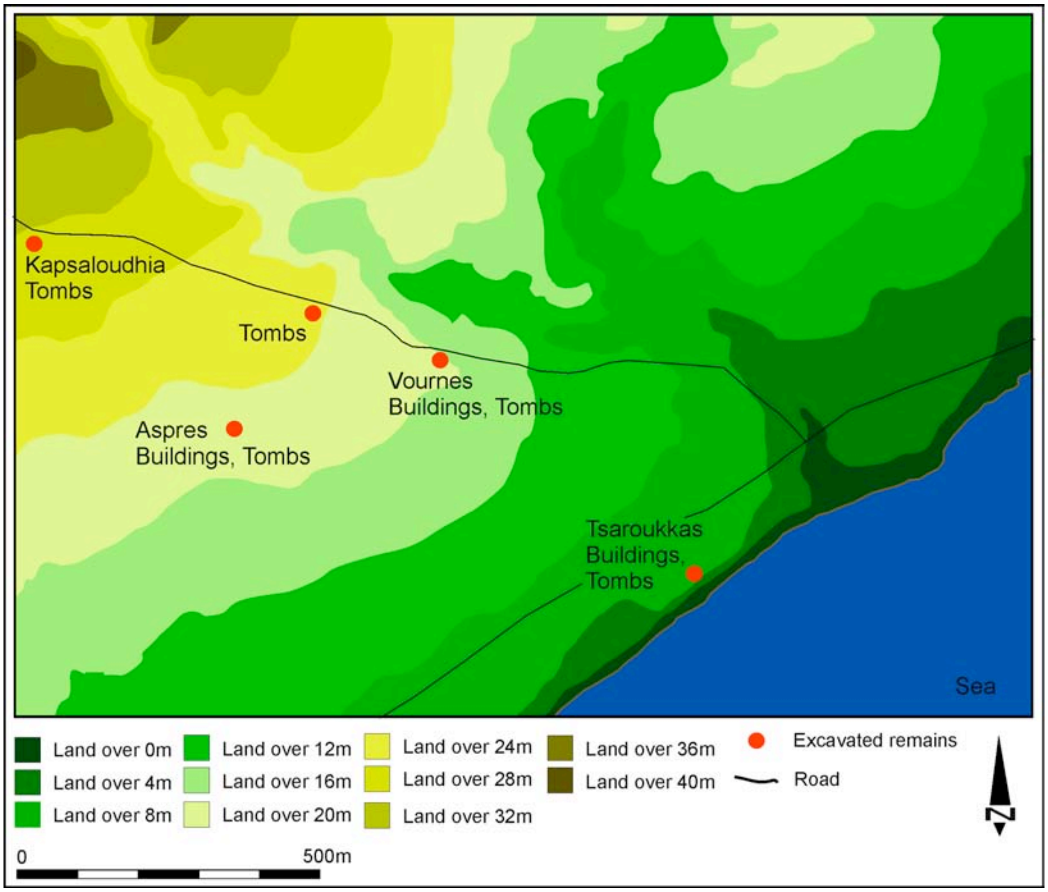

Figure 3: Maroni region showing locations of archaeological sites mentioned in text.

Figure 4: Photo of Kalavasos-*Ayios Dhimitrios* showing Units 3 and 4 from east.

Figure 5: Photo of Maroni-*Tsaroukkas* showing Units 1-4 from south-west.

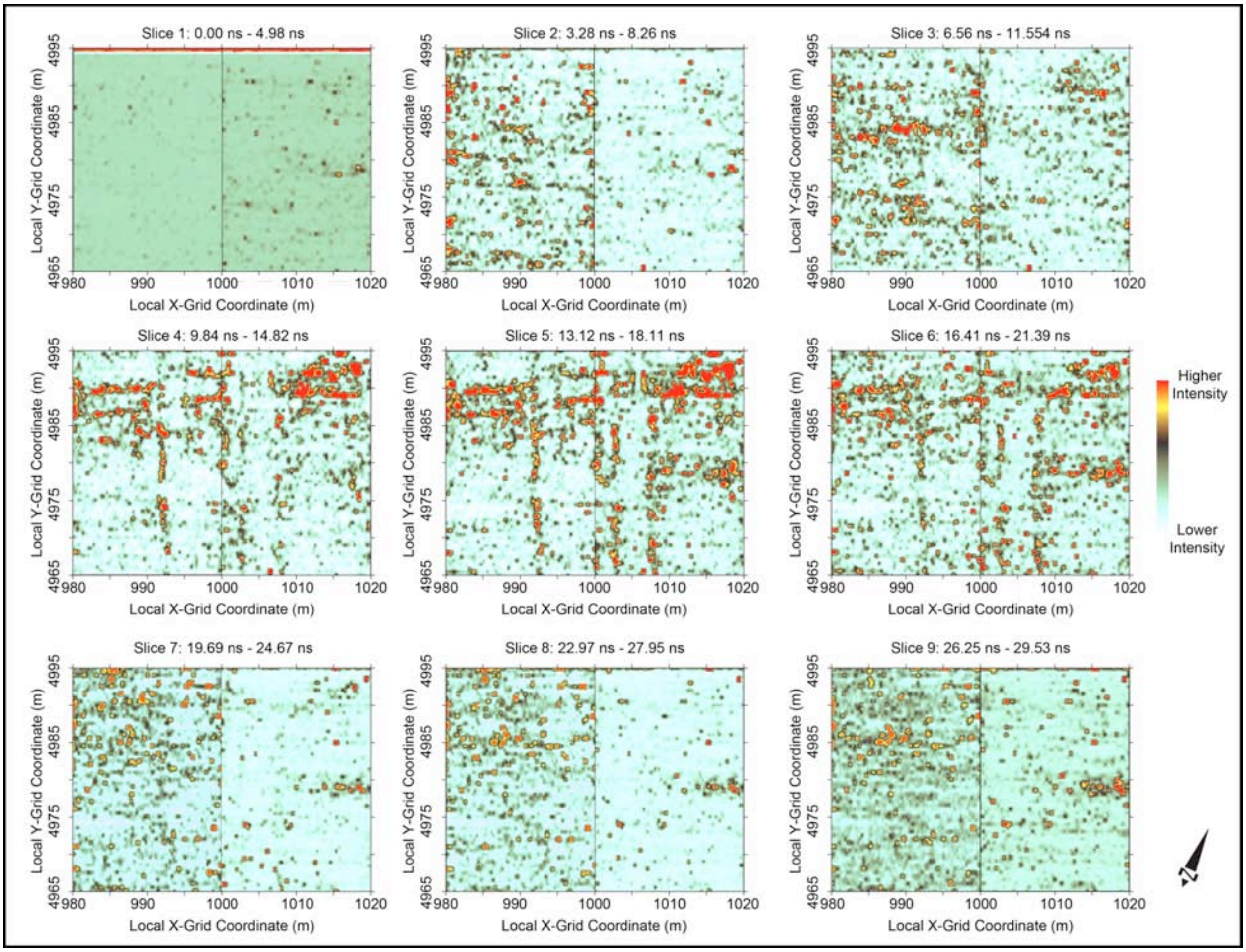

Figure 6: Kalavasos-*Ayios Dhimitrios*, Units 3 and 4 showing time slices from GPR survey (taken at 30 nS).

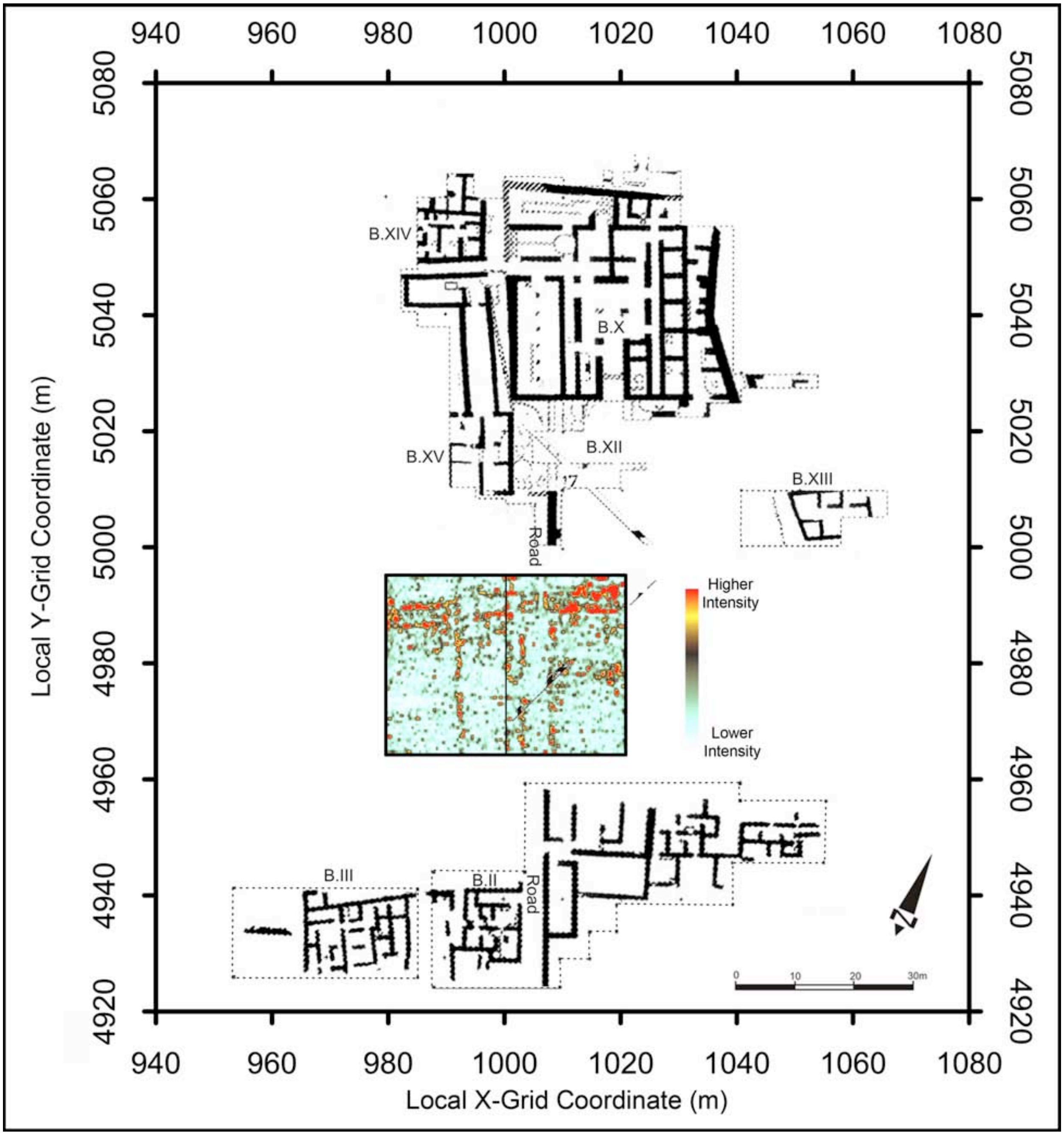

Figure 7: Kalavasos-*Ayios Dhimitrios* showing survey Units 3 and 4 in context with plot of GPR data from Time Slice 5.

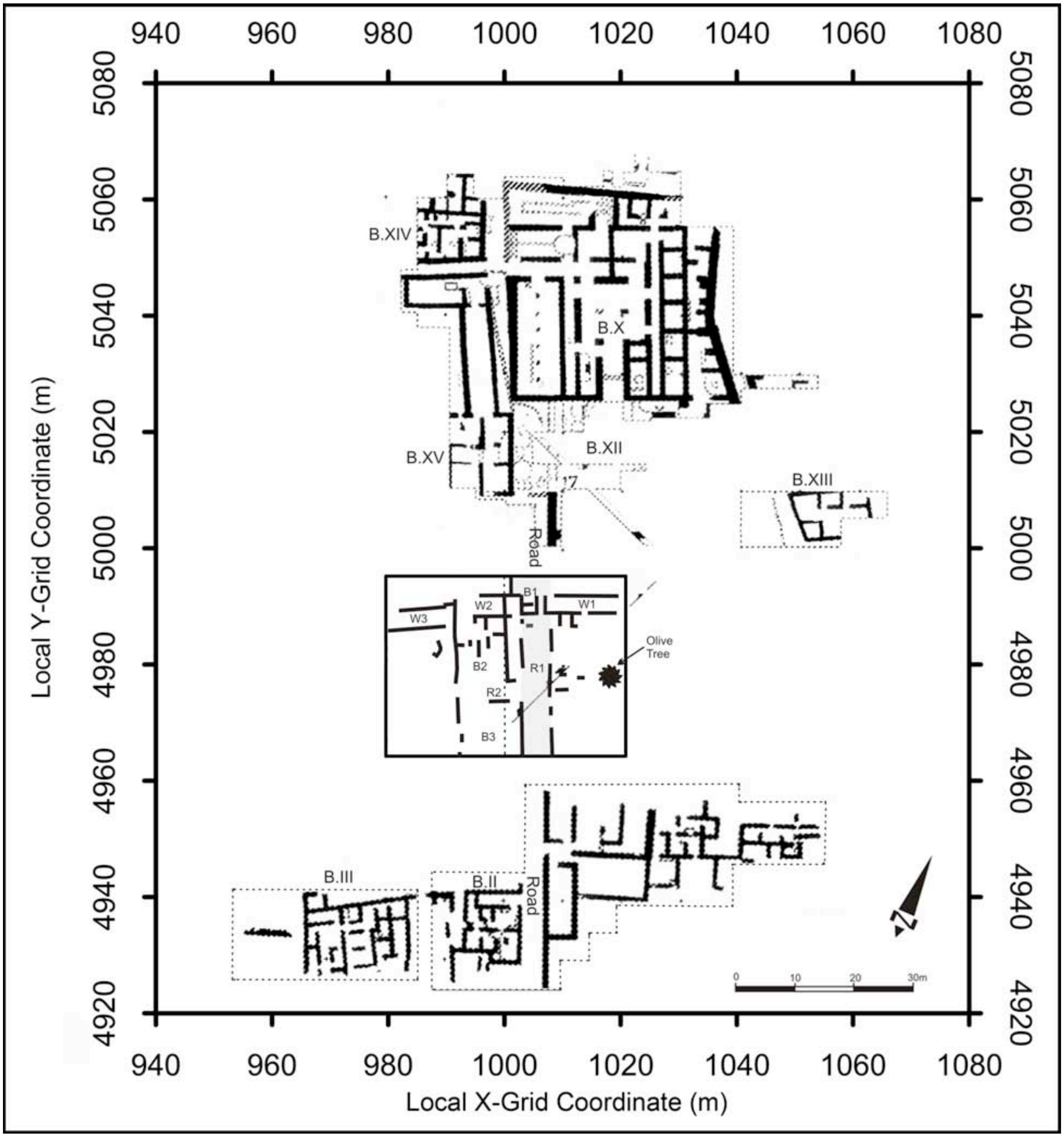

Figure 8: Kalavasos-*Ayios Dhimitrios* showing survey Units 3 and 4 in context with interpretation of GPR data from Time Slice 5.

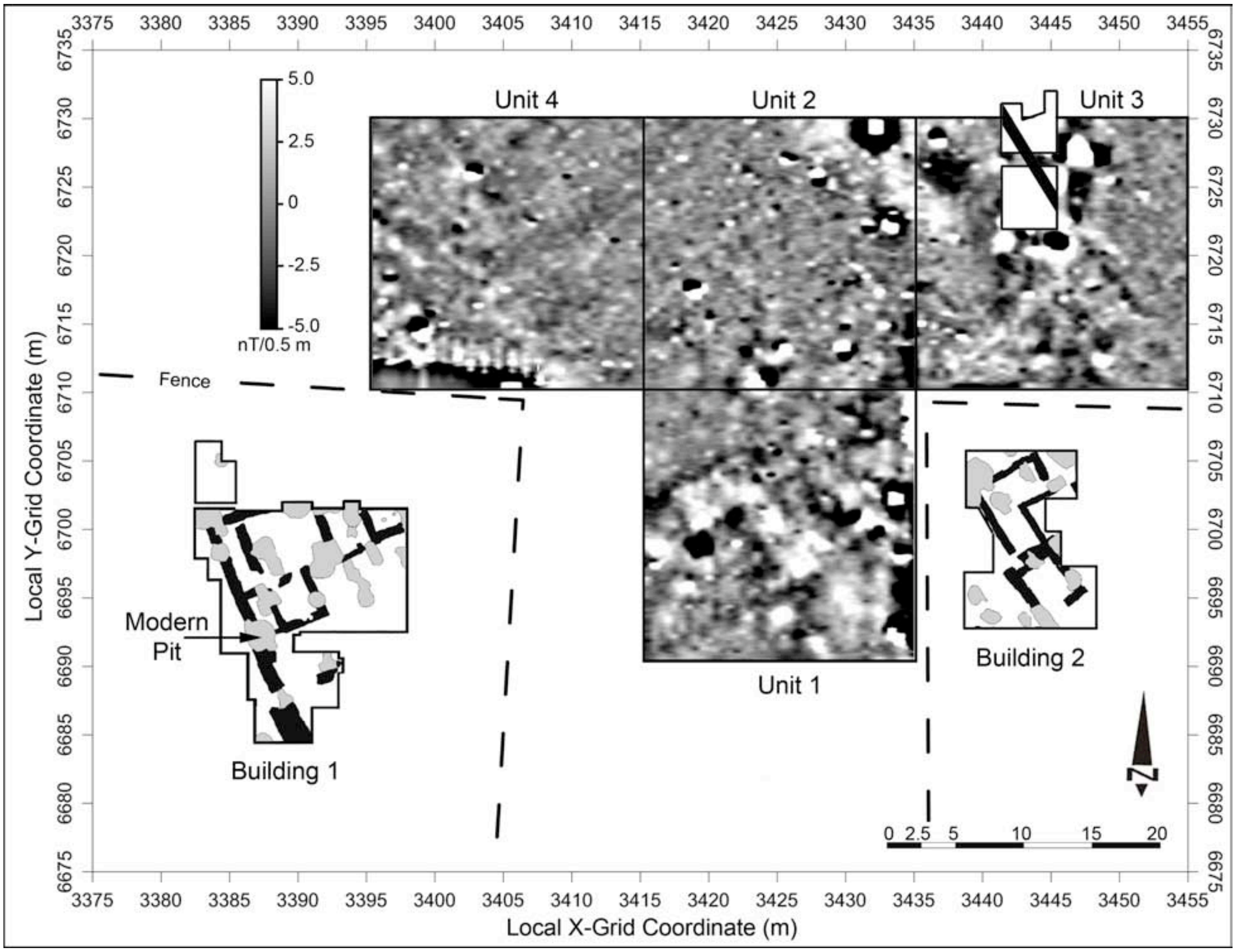

Figure 9: Maroni-*Tsaroukkas*, Units 1-4 showing plot of fluxgate magnetometry data.

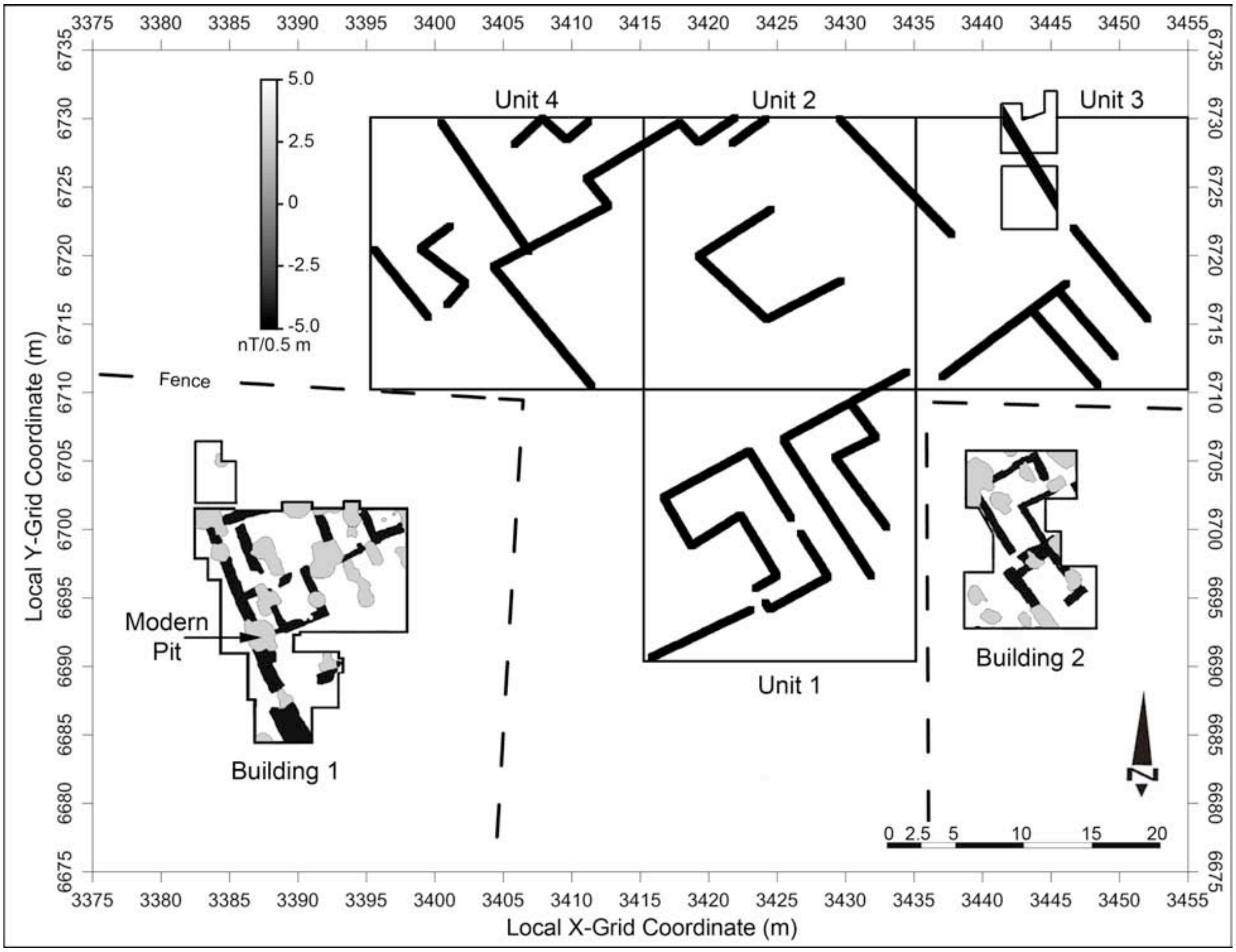

Figure 10: Maroni-*Tsaroukkas*, Units 1-4 showing interpretation of fluxgate magnetometry data.

Table 1: GPR and Fluxgate Gradiometer Processing Steps

GPR Processing Steps (in order)	Parameters/Comments
1. Import data into GPR Slice 7.0	
2. Convert data to GPR Slice format	Batch gain and wobble; 16 gain points to maximize amplitude in window
3. Set artificial navigation markers	
4. Slice/Resample data	9 slices at 5 nS thickness; Search 0 nS using autodetect feature (to remove air-to-air radar signal)
5. Background removal filter	Length= 500, Check to ensure Sample Start and Sample End are correct
6. Set artificial navigation markers for filtered file	
7. Slice/Resample data	9 slices at 5 nS thickness; Search 0 nS using autodetect feature
8. Grid Data	Grid cell size= 0.1; Krigging interpolation using auto variogram
Fluxgate Gradiometer Processing Steps (in order)	**Parameters/Comments**
1. Create composite site grid in Geoplot 3.0	
2. Clip data	To 3 sd (-51, 51)
3. Destagger each grid individually	
4. Despike mosaic	3 x 3 with threshold = 2.0
5. Zero Mean Grid	Threshold = 0.25
6. Zero Mean Traverse	
7. Edge match grids	
8. High Pass Filter	X radius=10; Y radius=10; Weighting=Gaussian
9. Interpolate in Y direction	Mode=Expand; Expand method=Sin X/X
10. Interpolate in X direction	Mode=Expand; Expand method=Sin X/X