

Toward a Definition of Minoan Agro-Pastoral Landscapes: Results of the Survey at Palaikastro (Crete)

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Agricultural production and the palatial redistribution of staples have played a key role in the debate concerning the emergence of social complexity in Minoan Crete. However, much of the focus has fallen on major settlements where such products were consumed, rather than on the landscape where agricultural surplus was produced. While there is no shortage of landscape surveys on Crete, their emphasis has typically been on the distribution of rural settlements instead of on identifying landscape structures and arrangements—such as terraces, enclosures, and field systems—that might provide data about a territory's economic focus. A key aim of the new survey at Palaikastro has been to address this bias. By combining extensive archaeological survey with differential GPS (DGPS) measurements, high-resolution aerial photography, and microrelief generation and analysis, the project has identified hundreds of structures, forming an almost continuous fossilized landscape and providing important clues on landscape management practices. The results highlight the importance of pastoral practices, to which a large part of the landscape was dedicated. Agricultural arrangements were also documented in the form of terraced areas adapted for dryland agriculture and reflecting concerns for soil retention. We argue that a highly structured landscape, indicative of pressures in land use, was established during the Middle and Late Minoan periods across Palaikastro's territory.¹

INTRODUCTION

When archaeologists first started to take into account the local socio-economic conditions on Bronze Age Crete for explaining the emergence of complexity, they could hardly ignore the substantial storage facilities at each of the main palatial sites of Knossos, Phaistos, and Malia. These facilities seemed ideally suited to the accumulation and control of large quantities of

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staple goods, such as cereals, grapes, and olives, the so-called Mediterranean triad.² With the work of Finley and Polanyi, and the decipherment of the Linear B texts, it was quite natural to see the palaces as redistribution centers.³ Although some revisions were made to this initial hypothesis, with the notion that palaces were perhaps more involved in mobilization than in pro bono redistribution, the idea that palaces relied on the (direct or indirect) control of agricultural production for their political power remained current through much of the 1980s.⁴ However, the 1990s and 2000s saw a shift in emphasis away from production, with the palaces increasingly viewed as locales primarily for feasting and consumption.⁵ Questions about economic organization remained quite current in scholarship on the Mycenaean mainland, fueled by the documentary evidence of Linear B,⁶ while on Crete, for the First and Second Palace periods at least, economic questions seemed to take a back seat. An exception to this comes in the work of Christakis' contributions on storage and political economy in the Cretan First and Second Palaces;⁷ in addition, a recent article by Privitera offers evidence for large-scale centralized storage at Ayia Triada during the Late Minoan (LM) I period.⁸ While these studies show that it is perfectly possible to investigate the Minoan economy in terms of production and not just consumption, their necessary focus on storage has limitations. Ideally, they would be counterbalanced by studies directed at other sites in the broader landscape more obviously related to the production of agricultural surplus.⁹ While the turn away from the excavation of major centers toward the survey of more peripheral areas now has a long history on Crete,¹⁰ it has not resulted in an economic understanding of how smaller sites in the landscape operated.¹¹ As a result, it

is still the case today, 45 years after the publication of *The Emergence of Civilisation*,¹² that most attempts to argue for or against the emergence of the Minoan palace (and state) as a redistributive center of agricultural surplus are based on evidence gathered from the urban centers themselves,¹³ rather than from the landscape where production activities concentrated.¹⁴

The three main palatial sites, Knossos, Phaistos, and Malia, have all seen intensive surveys in their immediate hinterlands. The western Mesara survey identified numerous sites in the region close to Phaistos, finding significant shifts in settlement distribution and land use from the Prepalatial through the Postpalatial periods.¹⁵ At Knossos, extensive surveys in the 1970s and 1980s have been followed by an intensive survey, the publication of which is currently in preparation by Whitelaw.¹⁶ Malia was surveyed in the 1990s, with final publication outstanding.¹⁷ The next largest town in terms of hectares and predicted population is Palaikastro, though it is not palatial; it is unclear whether a palace remains to be found at Palaikastro or whether this site had a nonpalatial social organization. While a good deal of excavation has been done in the town site itself, there has been only limited exploration of the wider area. The first excavators, Bosanquet and Dawkins, did identify various rural remains, such as the rock shelters of Ayios Nikolaos inland from Palaikastro.¹⁸ Subsequent work in the 1960s focused on excavation in several locales both inside and outside the town.¹⁹ The first survey, conducted in the 1980s, was quite tightly focused—in area and in purpose—the aim being to lay the ground for a major campaign of further excavation within the town.²⁰

Within this context, Palaikastro Phase 4: 2012–2016, a project under the auspices of the British School at

² Renfrew 1972.

³ Finley 1957; Polanyi 1957; see also Privitera 2014, 430–31.

⁴ E.g., Halstead 1981, 1988; Branigan 1987; Moody 1987.

⁵ Hamilakis 1996, 2002; Schoep et al. 2012.

⁶ E.g., Galaty 1999; Voutsaki and Killen 2001; Bendall 2007; Nakassis 2010.

⁷ E.g., Christakis 2004, 2008, 2011.

⁸ Privitera 2014.

⁹ Bevan 2002, 217.

¹⁰ See Gkiasta (2008) for an overview.

¹¹ But see Moody (2012) for an important attempt to take into account all the different production zones and their likely economic products. Moody shows how little we know about the economic activities of the higher altitude zones, which were

nonetheless clearly occupied.

¹² Renfrew 1972.

¹³ See, e.g., Christakis 2011; Halstead 2011; Margaritis 2013.

¹⁴ Jusseret et al. (2013) maintain that most of our ideas about Minoan agro-pastoral activities come from indirect evidence, either bioarchaeological remains on-site or Linear B documents.

¹⁵ Watrous et al. 2004, 277–304.

¹⁶ For preliminary results see Whitelaw et al. 2007; see also www.ucl.ac.uk/archaeology/research/directory/knossos_whitelaw.

¹⁷ Müller Celka 2010.

¹⁸ Bosanquet et al. 1902–1903; Dawkins 1905–1906.

¹⁹ Sackett et al. 1965; Sackett and Popham 1970.

²⁰ MacGillivray et al. 1984.

Athens and the Universities of Toronto, Nottingham, and Bristol, is aimed at providing an integrated view of the Minoan town within its landscape. The project seeks to gather data that allow comparison among the results of the bioarchaeological analysis of the excavated occupation layers at site level, the multiproxy paleoenvironmental analysis of anaerobic sedimentary sequences (which include pollen, nonpollen palynomorphs, microcharcoal, microfauna, and sedimentological indicators), and survey data at the landscape level. In the project's design, landscape data, which include survey results and the detailed archaeomorphological analysis that is the subject of this report, are vital for contextualizing the results from excavations within their wider ecological and cultural settings. We have assumed, first, that on-site bioarchaeological remains and paleoenvironmental data cannot be fully understood and interpreted without complementary landscape research that will allow insights into which environmental resources were in use and why some were selected over others, and, second, that this research in turn further enables the investigation of cultural choices and patterns. Despite the rich history of archaeological surveys on Crete, an approach designed to provide data that can be successfully compared to the bioarchaeological remains recovered on-site and paleoenvironmental data provided by sedimentary registers has rarely been implemented.²¹ We purposefully designed an approach to landscape analysis with this objective in mind: an extensive survey aimed at locating well-preserved landscape structures. These structures, which include not only rural dwellings but also terraces, checkdams, enclosures, cisterns, and wells, could then be mapped at a very high resolution, sufficient to assess and interpret their morphology following archaeomorphological procedures²² and supported by ethnoarchaeological comparisons.²³ By identifying the morphology and functionality of landscape structures, we can then propose specific land-use and production strategies.

The extensive survey covered approximately 32 km² around the Minoan town of Palaikastro, including both the coastal plain just north of the site, which is divided by the Kastri promontory into the bays of Kouremenos and Chiona, and the mountainous areas surrounding the plain of Palaikastro, which are arguably the most neglected zones in our archaeological knowledge of the study area. The survey of the coastal plain provided little material that could be securely ascribed to the Bronze Age, presumably because of the accumulation of sedimentary deposits in this area as indicated by the cores we have extracted at the Kouremenos wetland (750 m north of the site) as part of the paleoenvironmental analysis of the project.²⁴ Consequently, the survey efforts were concentrated in the mountains surrounding the plain. An intensive prospection strategy was not an option given the limited time provided by the survey permit (one month in total), the number of the survey teams (two teams of three members each), the difficulties of the terrain with slopes well over 15°, and the dense shrub vegetation that hindered movement while significantly decreasing ground visibility. In addition, the permit did not allow for the collection of material from the field. As a result, ceramic analyses were limited to the visual interpretation of on-site sherds, and the accuracy of our chronological interpretations was restricted. Nevertheless, the results of the extensive survey and the later mapping campaign of the better-preserved sites that we located provide new insights on landscape management during the Bronze Age while extending our knowledge of Minoan economic practices.

In the following section, we provide an account of the methodology employed for the location and mapping of sites. A description of the sites located then establishes a basis for the analysis of their functionality, followed by a discussion on the documented Bronze Age land-use practices in the area in relation to the subsistence and economic practices of the Minoan community at Palaikastro.

SOURCES AND METHODS OF THE SURVEY

The survey used an extensive prospection approach that attempted to balance the time and resources available with the type of landscape under investigation. The planning stage involved the acquisition of a high-resolution (0.5 m/pixel in the panchromatic band)

²¹ For surveys in east Crete, see Tzedakis et al. 1989 (Minoan Roads Project); Branigan et al. 1998 (Ziros); Whitley et al. 1999 (Praisos); Hayden 2004 (Vrokastro); Haggis 2005 (Kavousi); Costa et al. 2008 (Itanos); Schnapp-Gourbeillon et al. 2009 (Itanos); Vokotopoulos 2011 (Karoumes); Watrous et al. 2012 (Gournia).

²² See, e.g., Ballesteros Arias 2010; Palet and Orengo 2011.

²³ Exemplified by the theoretico-methodological approach described by Chang 1992.

²⁴ Cañellas-Boltà et al. 2018.

WorldView-2 multispectral satellite image of the study area. After following a geometric and radiometric correction process, for which we employed ground control points (GCPs) acquired by subcentimetric differential GPS (DGPS),²⁵ we developed pan-sharpened false and natural color red, green, and blue (RGB) composites (fig. 1 [A1]).²⁶ The RGB composites of satellite imagery were combined with a purpose-built, 10 m/pixel medium-resolution Digital Surface Model (DSM)²⁷ to plan the survey in accordance with slope, current vegetation, and accessibility. Satellite imagery has previously been employed for the location of Minoan structures in adjacent areas;²⁸ however, we used the satellite imagery not for locating or mapping structures but for planning the survey, as we considered that these sources did not provide enough spatial resolution to accurately map smaller but relevant structures such as terraces or enclosures.

Two survey teams of three members each were organized. Each team carried a Garmin eTrex handheld GPS to continuously record its position and route. The handheld GPSs were also used to record ceramic scatters, relative density of the scatters, and other features of archaeological interest. All this information was linked to a GIS-managed geodatabase where all the survey information, including the movement of the survey teams, photographs taken in the field, field notes, ceramic dispersion and concentration areas,

points of interest (e.g., structures), and findspots could be visualized and queried.

The initial extensive survey phase was followed by visits to the located sites by a group of ceramic analysts to provide basic chronological descriptions for the sites. The quality of the surface ceramics did not usually provide a detailed chronology for the sites, but a general framework was typically obtained. The last part of the fieldwork consisted of the detailed mapping and the development of plans of the located sites. The mapping of features followed a two-stage methodological approach. First, DGPS was employed to accurately map linear features such as terraces or walls (these are visible as red dots in fig. 1 [A2]) and also to take reliable GCPs. Second, a multiscale photogrammetric reconstruction was developed in three steps as follows:

1. The development of a second DSM of much higher resolution than that used to plan the survey. This high-resolution DSM of the whole study area was created through the digital photogrammetric analysis of aerial photographs provided by the Hellenic Military Geographical Service (HMGS).²⁹ We used 53 vertical aerial photographs taken in 1966 at a scale of 1:8000. Camera calibration parameters were provided by the HMGS. The GCPs of the study area included all first-order geodesic vertices (fixed surveying stations used in surveying projects) available for the region and 200 GCPs acquired through the DGPS survey. The result of the digital photogrammetry surface generation provided a 0.48 m/pixel DSM of the whole study area (see a sample portion in fig. 1 [A2]), which allowed a detailed topographic reconstruction of selected sites and the development of topography-based GIS analyses.

²⁵Two Leica Viva GS10, kindly provided by the Nottingham Geospatial Institute, were used.

²⁶WorldView-2, like many other passive satellites, acquires both panchromatic (with a high spatial resolution but no color information) and multispectral (less spatial resolution but higher spectral information) imagery. Multispectral imagery includes multiple wavelengths of reflected light. These are grouped in the image bands, which can be combined into single RGB composites. These display three of these bands as RGB. Natural color composites are RGB images made of the green, blue, and red (in this order) wavelengths of the electromagnetic spectrum. False color composites can also be produced by substituting one or more of these bands for bands grouping non-visible wavelengths such as near infrared. The pan-sharpening procedure allowed merging the higher resolution of the WorldView-2 panchromatic band with the multispectral information available in all other bands to create a high-resolution color image in which landscape details could be appreciated with colors resembling those natural to the human eye.

²⁷Developed through digital photogrammetric techniques from the British Royal Air Force aerial images of the area taken in 1945 at a scale of 1:42,000.

²⁸Pavlidis et al. 2002.

²⁹The creation of two DSMs, the first 10 m/pixel and the second 0.48 m/pixel using two sets of aerial photographs at different scales, responded to the different purposes for which they were used. The first model was used to obtain a general impression of the topography of the study area. Large-scale photographs were used to reduce computation time while producing a large DSM with enough resolution to plan the survey. The second DSM was employed to produce topographic analyses of the detected sites and therefore required a much higher resolution. Although the second model also covered the whole study area, intensive computational photogrammetric procedures were employed only in the areas in which structures were located.

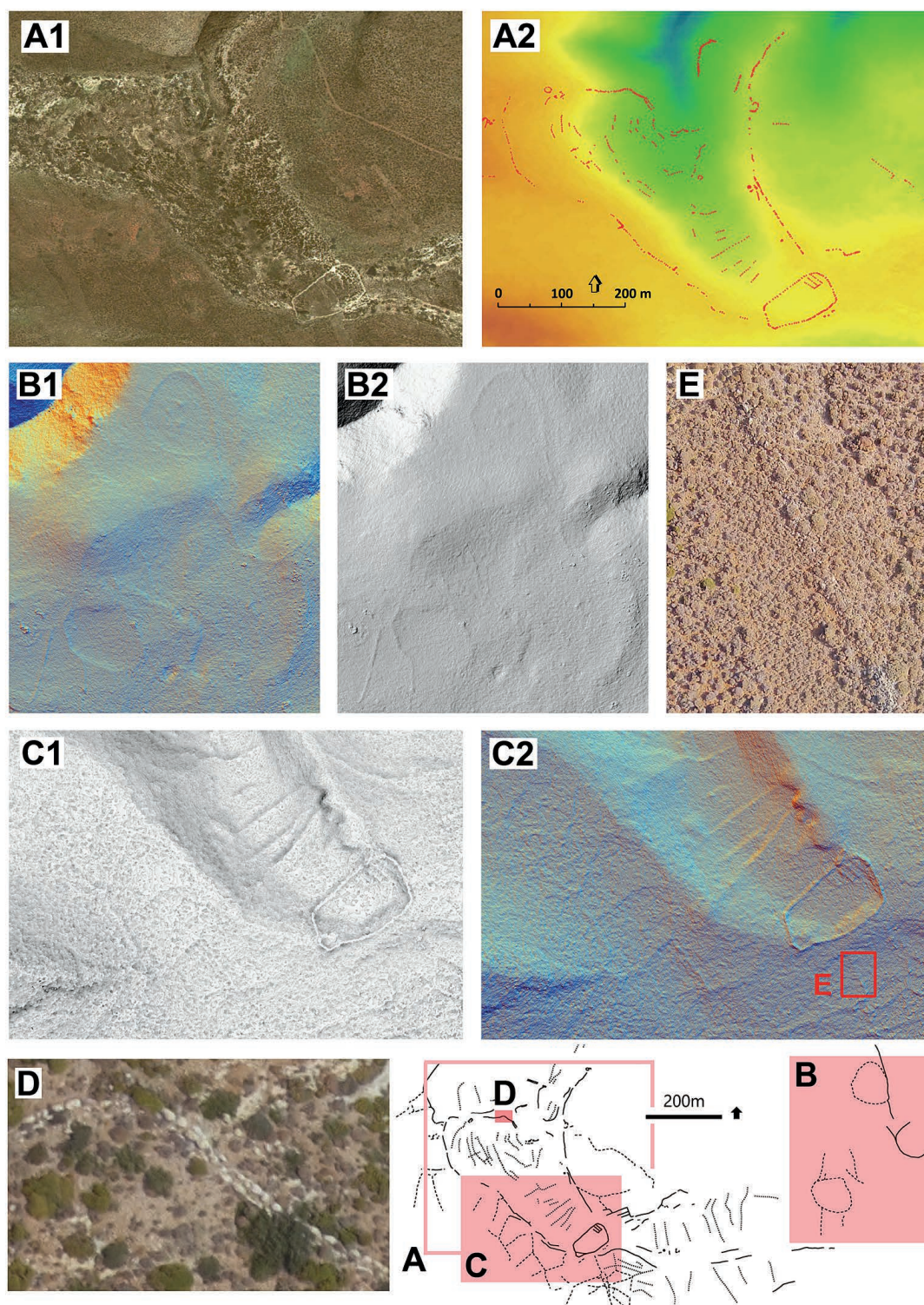


FIG. 1. Digital methodologies employed in the research using the Pano Plako site as an example (see the plan at lower right): A1, the pan-sharpened natural color RGB composite derived from the WorldView-2 multispectral satellite image; A2, the DSM derived from 1966 aerial photographs with DGPS topographic survey points (in red) on top; B1, B2, C1, C2, the combination of micror relief visualization techniques; D, E, high-resolution aerial photogrammetry used for the detection and mapping of landscape structures.

2. A drone-assisted very high resolution photogrammetric reconstruction of each individual site as defined by ceramic scatters and structures. A pre-programmed Phantom Vision 2+ drone was employed for this. The resulting DSM (see fig. 1 [B1, B2, C1, and C2]) shows different visualization methods,³⁰ and ortho-photomosaics (see fig. 1 [D, E]) had a ground resolution of approximately 15 cm that allowed the generation of microtopographies of the sites, which in turn were essential for the location of structures that were not visible on the 1966 aerial photographs or during fieldwalking. The microtopographies were treated with relief visualization tools developed for LiDAR data to improve the visibility of features. These included Sky-View factor, a DSM visualization technique that defines each pixel value as the portion of the sky visible from it (see fig. 1 [C1]),³¹ and analytical hill shading, which simulates shadows created by the relief using sources of light from multiple directions.³² The shaded relief models (see fig. 1 [B2]) were then employed as inputs for a Principal Component Analysis. RGB composites were developed from the three principal components, those accumulating most of the information available in the shaded reliefs (see fig. 1 [B1, C2]). The combination of these visualization techniques with the high-resolution ortho-photomosaics provided an excellent tool for the detection of microreliefs.
3. Terrestrial photogrammetry to map in detail the remains of structures such as buildings and monumental walls. The photogrammetric reconstruction of architectural features followed the methodology described by Orengo.³³ GCPs were drawn on the ground at regular intervals following the geometry of the structure to be reconstructed using a permanent marker pen. Photographs of the structures, in which the GCPs were clearly visible, were taken using a wifi-controlled camera on top of a pole 5 m high. The photogrammetric reconstruction was conducted using Agisoft's PhotoScan Professional.

ARCHAEOLOGICAL ANALYSIS

This methodology employed the drone-based, very high resolution orthoimages and the relief visualization outputs from the microtopographies of the sites and allowed the mapping of a very large number of structures, many of them not visible during initial fieldwalking. These were later checked with the help of a mobile GIS system with GPS, which allowed their identification on-site.

The maps developed following this methodology cannot be considered a complete rendering of the Bronze Age remains in the study area, as this methodology was not systematically applied throughout but only in selected sites where the topography, sedimentation, vegetation cover, and lack of extensive reoccupation allowed its use. It is also important to note that these remains have not been excavated—hence, there is no absolute certainty that all of them should be considered Minoan. However, a series of indicators were followed to map them as coherent complexes of Bronze Age landscape organization. The first indicator was the significant presence of Minoan pottery sherds in these areas. The distribution of Minoan pottery conformed well to the presence of agro-pastoral structures, displaying higher concentrations around habitation structures and terraced areas, although its presence can also be recognized, if at much lower frequencies, in and around pastoral enclosures. The second indicator was the lack of reoccupation as indicated by later ceramic assemblages or later structures sharing the same space, suggesting that the buildings and the pottery are coeval. The sites of Ayios Spiridon and Pano Plako, where later structures have been documented, were easy to differentiate, given the clear differences in construction techniques, the state of preservation, and the evident dissimilarities in character and morphology. Pano Plako was seasonally occupied until the 1980s, and Manolis Mavroukoulakis, who is 84 years of age and a former resident, was able to describe to us the use of the area in the past, up to the first half of the 20th century.³⁴ His descriptions confirmed the identification of the modern structures and modern land-use strategy recognized through archaeomorphological analysis. A third important indicator for the chronomorphological definition

³⁰ These can be defined as high-resolution rectified and geo-referenced images joining all drone-acquired photographs.

³¹ Zakšek et al. 2011.

³² Devereux et al. 2008.

³³ Orengo 2013.

³⁴ M. Mavroukoulakis, pers. comm. 25 July 2016 (interview conducted at Palaikastro by Halstead with the assistance of Orengo).

of these complexes is the cohesion of a group of structures. Although, in many cases, the shape of terraces or walls had to be reconstructed following a join-the-dots approach, these form coherent complex assemblages of structures that are related in space and define specific land uses that can be tested using archaeological and ethnographic evidence. This comprehensive landscape organization would have been difficult to reconstruct if these structures had not been designed together and with a specific land use in mind. Lastly, the excavation of Choiromandres,³⁵ a site just 12 km south of the study area that presents the same type of setting, structures, and spatial organization, and other similar landscape arrangements in East Crete in which agricultural terracing and enclosure systems play a prominent role, shows the knowledge and application of such techniques and strategies for landscape arrangement in comparable landscape settings during the Bronze Age.

Although the excavation of these structures would certainly provide much finer dates for their occupation and clearer morphological descriptions, we are confident that our results can be successfully employed to define the occupation and economic orientation of the people inhabiting Palaikastro's landscape.

RESULTS

The Palaikastro landscape survey documented 24 ceramic dispersion areas (fig. 2) of which five sites were sufficiently well preserved to be described as agro-pastoral production areas. These share certain characteristics with other well-known sites such as Choiromandres³⁶ and those located by the Minoan Roads Project in the Karoumes area.³⁷ The term "site" has been adopted here for the sake of convenience. By this term we mean an area of agro-pastoral exploitation; these do not correspond to traditional sites in the sense of ceramic concentration areas or single or grouped buildings. The five sites discussed here are formed by groups of interrelated agro-pastoral structures that extend over large areas and form an almost continuous occupation of the available space. Such agro-pastoral sites are well understood in landscape studies.³⁸ A description of these five agro-pastoral sites follows.

Sikia

The site of Sikia (fig. 3) is located at the northwestern sector of the study area. The distribution of ceramic material covers a relatively small area of four small hills overlooking a ravine discharging at Kalogero stream, the main collector for the plain of Palaikastro. The area shows signs of very intense recent water erosion, and a gas pipeline runs through the site. The located remains consist of two large rectangular buildings (A and B) constructed using megalithic masonry (fig. 4)—large polygonal stones joined without any mortar and located on the top of two of these hills. Two terraces close to the northeastern corner of Building A seem to have expanded the relatively flat area on top of the hill for the construction of the building. Each building shows some evidence of walls that divided the interior into three areas, although this is difficult to confirm without a thorough vegetation clearance. A small quadrangular building (C) that could correspond to a guardhouse, given its small size and topographic prominence, which exposes it to the strong summer winds, is located on the ridge of the slope to the east of Buildings A and B. Between Buildings A and B, several mostly buried or eroded terrace walls follow the contours of the hills. These might have formed checkdams across the ravines separating the hills. Checkdams are small dams across ravines or waterways designed to retain soil and redirect water and are often linked to agricultural terraces. Checkdam walls crossing the ravines have suffered most from the strong effects of water erosion in Sikia, and only one checkdam has been identified with certainty (see fig. 3, marked as "checkdam"). The ceramic assemblages found at this site (fig. 5 provides an example) point to a date in Middle Minoan (MM) II–III. Although the area of ceramic dispersion covers the whole site, ceramic densities increase considerably inside and immediately around the buildings, surpassing five sherds per square meter. The densities rapidly diminish in the terraced areas, although they are still significant wherever soil is preserved.

66): "Archaeological terms such as *site*, *catchment area*, and *settlement pattern* are inadequate for accurately describing the pastoral loci used by Grevena herders. These terms have specific connotations in the minds of archaeologists and obscure our ability to observe, describe, and analyze the spatial patterns of human activities found in the archaeological record" (emphasis original). This, we believe, is also entirely applicable to our agro-pastoral landscape arrangements.

³⁵ Devereux et al. 2008; Vokotopoulos et al. 2014.

³⁶ Vokotopoulos et al. 2014.

³⁷ Vokotopoulos 2011.

³⁸ Ballesteros Arias 2010, 27. As Chang points out (1992,

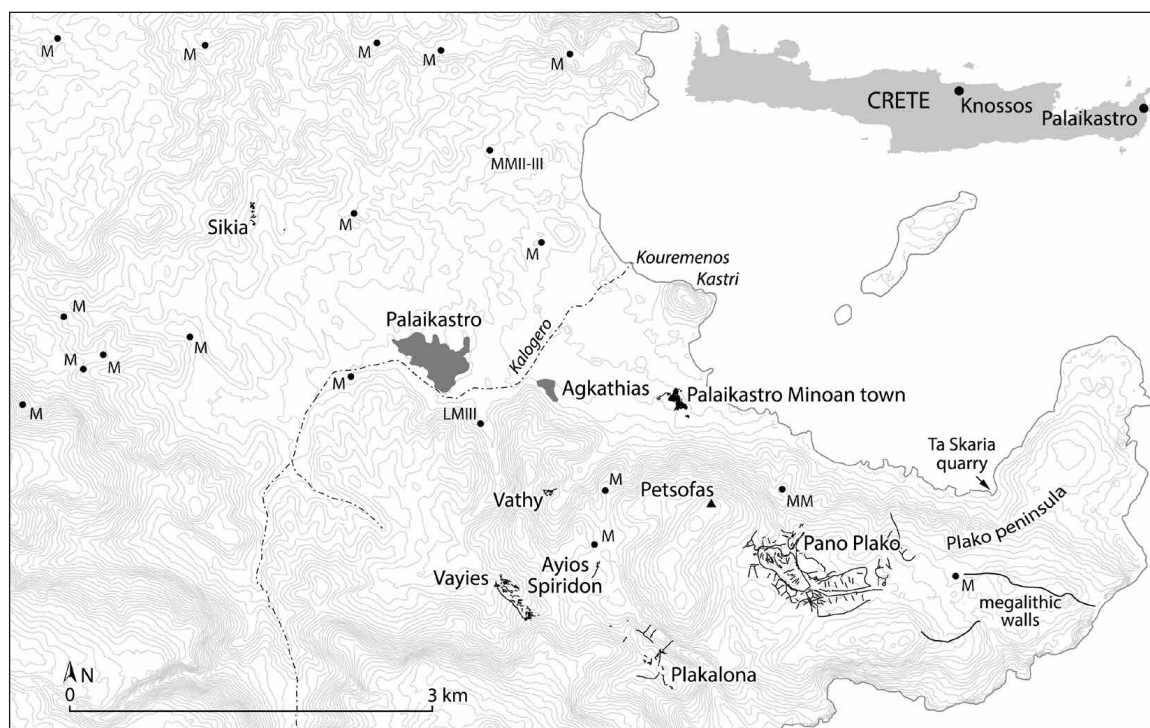


FIG. 2. General plan of the area under investigation, showing the distribution of Minoan ceramic dispersion spots and landscape structures (M = Minoan; MM = Middle Minoan).

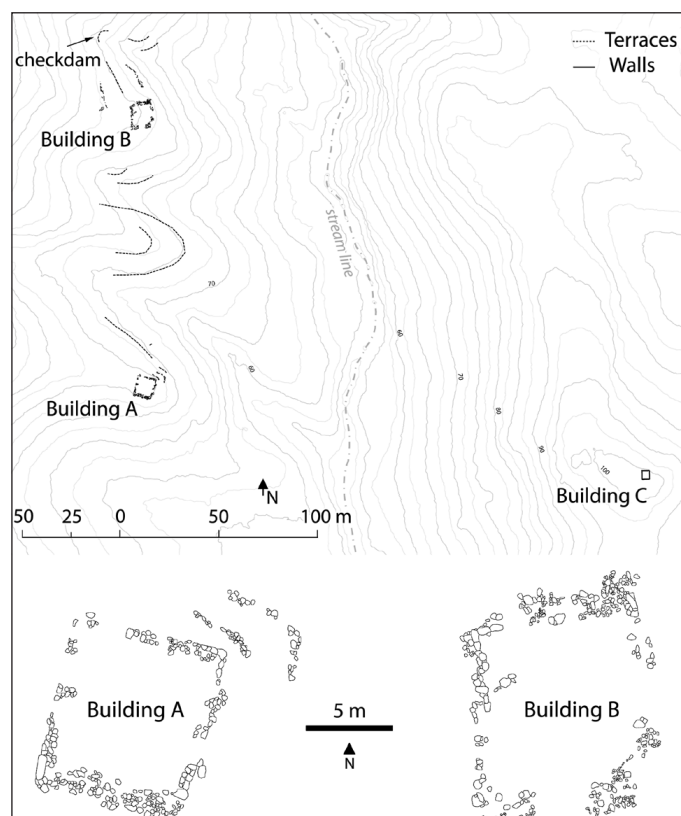


FIG. 3. Plan of the Sikia site. Buildings A and B are shown at a larger scale at the bottom of the figure.



FIG. 4. Northwest corner of Building B at the Sikia site (looking east).

Vayies

The Vayies site (fig. 6), 2 km southwest of the Minoan town,³⁹ includes three large rectangular buildings with megalithic masonry. Building A is located close to the valley bottom (fig. 7[A]). Its lower northern wall is aligned with an agricultural terrace wall and sits on top of it to make use of the leveled terrain. The eastern side of the building is not as well preserved as the western, but traces of the walls can still be found. Buildings B and C are located on the southern ridge of the valley. Building B, of considerable size, shows the presence of inner division walls more delicately constructed than the exterior walls. Its better preserved northwestern

³⁹ MacGillivray and Driessen (1990, 403, fig. 6) document the remains of a “watchtower” below a dwelling in the modern hamlet of Vayies. Although the map provided in the publication does not allow the accurate location of these remains, we assume these correspond to the hamlet 240 m northwest of Building B at the Vayies site. We adopted the name of the area for our own site without necessarily implying any type of relation with the modern hamlet. However, given the proximity of our site to the structure documented by MacGillivray and Driessen and the almost continuous spatial dispersion of structures that characterizes the rural landscape of the study area, this possible “watchtower” could have easily been part of the activities developed at our Vayies site.

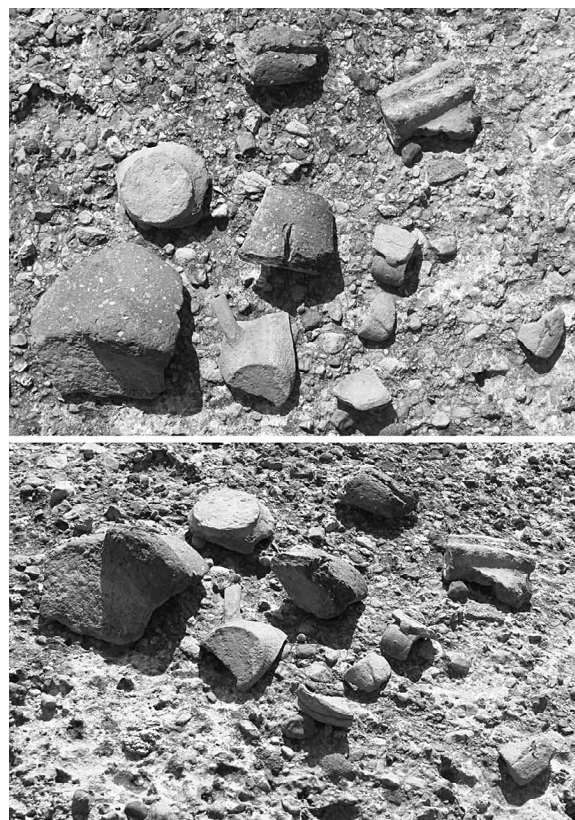


FIG. 5. A selection of MM II–III pottery found inside Building A at the Sikia site.

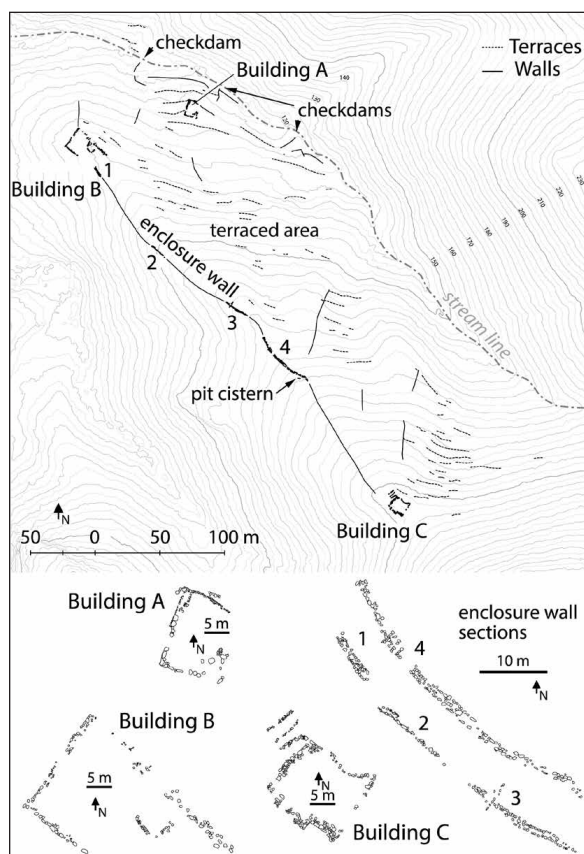


FIG. 6. Plan of the Vayies site. Buildings A, B, and C and sections of the enclosure wall between Buildings B and C are shown at a larger scale at the bottom of the figure.

and western sides have retained the soil inside Building B, keeping the inner part of the structure higher than the surrounding terrain. Three short walls, downhill from and parallel to the northwestern wall of Building C, form steps that might have facilitated access to the building. The stones from the northeastern wall have fallen and are scattered close-by, but a line of smaller stones that could have served to level the terrain for the setting of these bigger stones can still be discerned.

A double-faced wall (ca. 90–170 cm wide) runs along the ridge of the valley joining Buildings B and C, serving as an upper limit to the terraced area (see fig. 6 [marked as “enclosure wall”], fig. 7[B]). The terraced area seems to be divided by several double-faced walls of lighter construction that are roughly perpendicular to the contours and thus also to the terrace walls. Building B’s northern corner marks the beginning of a double-faced wall that extends downslope toward the north, delimiting the northwestern extreme of the terraced area of the site. The terraces extend over most of the east-oriented slope of the valley although

a few terraces have been found in the lower part of the west-oriented slope (above the northern checkdam in fig. 6). The terrace walls show a variable distance between them of 5–14 m and are well adapted to the topography of the slope, which typically varies between 7 and 16°. Although some well-preserved examples of terrace walls have been documented in the lower part of the valley, in many cases these are represented only by a single line of stones that served to level the terrain for the setting of the terrace wall (fig. 8[A]) and by topographic differences visible in the high-resolution DSM. The lower terrace walls run parallel to the stream separating the fields above from the ravine below. These present megalithic masonry just as the buildings do, although only the lower row of stones has been preserved and smaller stones seem to have been added on top of these at a later stage (see fig. 8[B]). Some of these walls would have crossed the stream to form checkdams, although they have not been preserved in the center of the stream, probably because of the continuing passage of water after their abandonment in combination with the pronounced slope of the streambed. Both the checkdams and the megalithic terrace walls near the valley bottom were probably aimed at distributing rainwater and avoiding water erosion. The pottery found on this site suggests a Middle Minoan date. On the western side of the ridge wall, a rectangular pit cistern excavated in the bedrock has been located; many more may be hidden by the low shrub vegetation covering the area.

Ayios Spiridon/Plakalona

The eponymous chapel of Ayios Spiridon is still in use, although the associated hamlet is now abandoned. Both sit in the middle of the site on the border of a small, flat, low area adequate for agricultural exploitation. The hydrological analysis shows that this area would have accumulated water from the surrounding hills before its discharge into the stream running through the eastern sector of the site. A few Minoan pottery sherds have been found in this area in conjunction with abundant modern ones. The presence of modern terraces linked to the agricultural exploitation of the area by the inhabitants of Ayios Spiridon has resulted in the reuse or destruction of most evidence of the Bronze Age agricultural arrangements, which have only been found in the periphery of the area. The site has a complex topography (fig. 9) with several small hills and significant differences in relative height. A large rectangular structure, Building A, of Middle Minoan date according to the surface pottery, sits on top

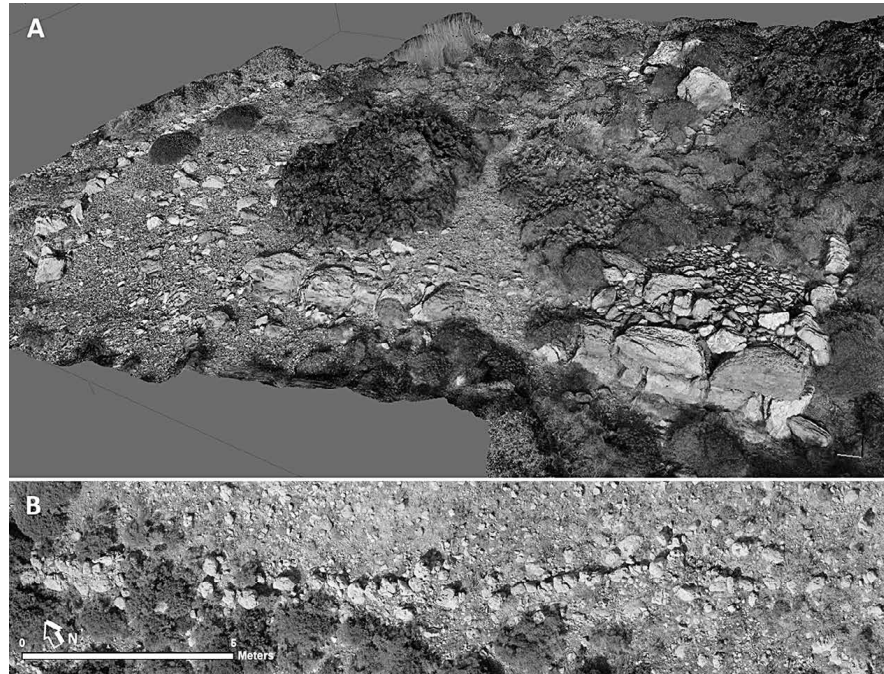


FIG. 7. *A*, photogrammetric three-dimensional reconstruction of Building A at Vayies, showing the western wall in the foreground; *B*, orthoimage of a section of the wall running along the ridge between Buildings B and C and serving as an upper limit of the site's terraced area.

of one of these. The building is associated with a series of walls that could have served to separate the lower part of the valley, where soils are deeper and adequate for agriculture, from higher areas dedicated to pastoral use. Walls demarcating distinct agro-pastoral areas are found in most other sites in the study area and are analyzed in the discussion section below. Building A is poorly preserved, and no remains of a possible southwestern wall have been found, perhaps because of the reuse of stones for the construction of the village or the church and the strong erosion suffered by the hill, which does not preserve any soil. However, the abundance of ceramic material suggests Building A could have served as a habitation. At the southern part of the flat agricultural area and 510 m southeast of the hill occupied by Building A, a rock outcrop of considerable relative elevation (ca. 40 m above its immediate surroundings) supports another small structure: Building B. The area around Building B presents surface material dating as late as LM IIIC. Its three preserved walls form a T-shaped plan delimiting a space open to the edge of the cliff. The material we found in the area is rich and includes remains of burnt bones sticking out of the soil together with Minoan pottery sherds. All ceramic material documented around the structure was Minoan, and we assume that these bones



FIG. 8. *A*, remains of the lowest course of stones of a terrace at the Vayies site, facing southeast (the GPS pole equals 1.8 m); *B*, lower terrace wall delimiting the stream at the valley bottom at Vayies, facing southwest (note that the upper stones use a different technique indicative of repairs at a later stage).

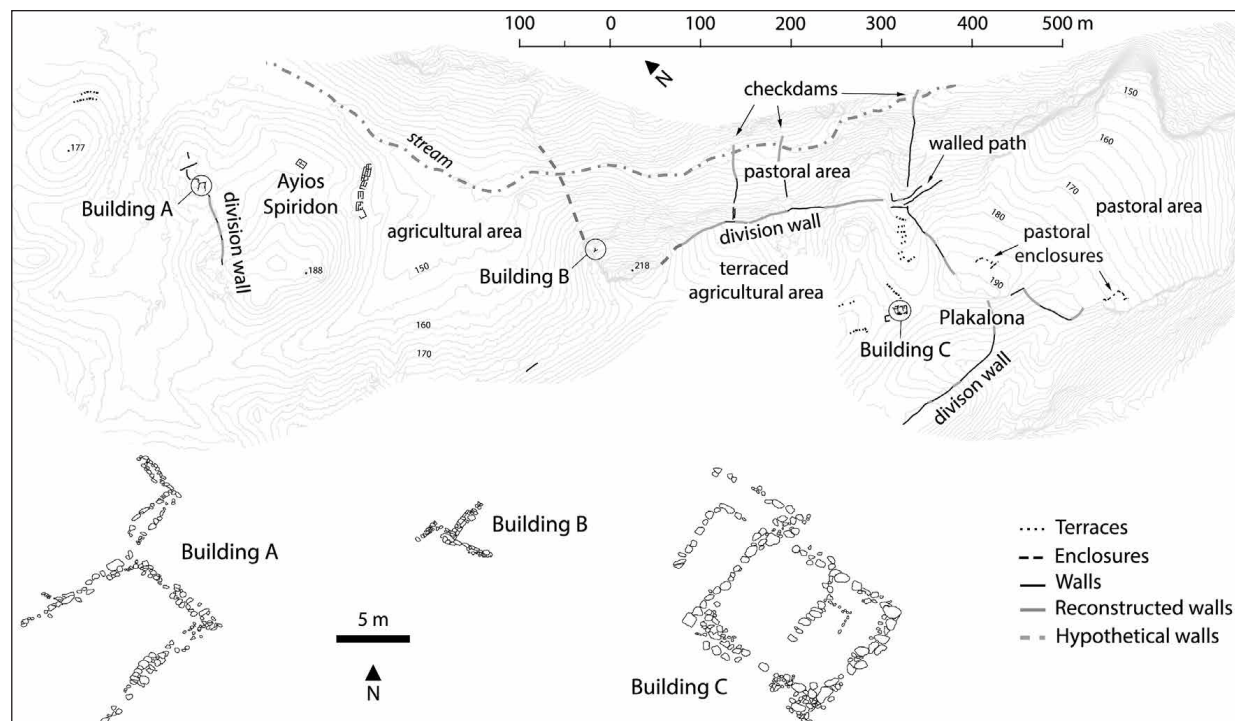


FIG. 9. Plan of the Ayios Spiridon/Plakalona site. Buildings A, B, and C are shown at a larger scale at the bottom of the figure.

may also have been of Minoan date. Unfortunately, due to permit limitations, these could not be collected for further study. Although there are not enough data to assign any clear function to this building, its small size and position, surrounded by cliffs and rock outcrops and exposed to the strong summer winds, do not seem to be ideal for habitation. The prominence of the rock outcrop makes it visible from most of the site; however, the point at which the building is located does not offer a particularly good view of the site. Building A would have been only partially visible, and Building C is not visible at all as the rock outcrop would have prevented effective visual control of the whole eastern sector of the site from Building B.

Further south, in the Plakalona area, a large structure of megalithic masonry, Building C, has been located (fig. 10). Building C is divided into three inner spaces, in a way similar to Buildings A and B at Sikia and the building at Vathy (see below), and has some associated structures outside it. This building was first documented by the Minoan Roads Project.⁴⁰ Interest-

ingly, surrounding the building (at a distance of ca. 100 m) is a double-faced separation wall (marked as "division wall" in fig. 9) of a similar construction to the "enclosure wall" at Vayies (see fig. 6). This wall separates the internal area where Building C is located from an external area presumably dedicated to pastoral use. This external area also presents a large, relatively flat, rock surface surrounded by cliffs; parts of these are visible at the top left of figure 10. The plan of this area can also be found at the right of figure 9, marked as "pastoral area"—note the step topography as indicated by the contours. At the southwest margin of this area are the remains of two enclosures, the more southern one delimiting a relatively large area against the cliff (fig. 11). This area could have acted as a natural pastoral enclosure, with the smaller enclosures inside serving to isolate young weaned offspring, pregnant females, or nursing females. The location of division walls seems to separate agricultural (see fig. 9, marked as "terraced agricultural area") and habitation areas from the valley bottom, where remains of walls perpendicular to the stream have been found. These walls could have formed checkdams although none has been preserved to the point where it would have crossed the stream. The hypothetical reconstruction of these walls, shown

⁴⁰ Tzedakis et al. 1989; Tzedakis et al. 1990; see also Nowicki 2014, 91.



FIG. 10. Northeastern wall of Building C at the Ayios Spiridon/Plakalona site (facing south).



FIG. 11. Remains of the southernmost pastoral enclosure of the pastoral area at Plakalona (facing south).

in gray lines in figure 9, indicates their plausible extension across the stream. These are located at a lower elevation than that of terraced areas, which makes it impossible to distribute water from these checkdams for agricultural purposes. The remains of a small walled path connecting the pastoral area, where the enclosures are found, with the valley bottom possibly indicates that the dams were meant to retain water for

pastoral use. Although modern terraces (not drawn in fig. 9) have concealed the possible existence of Bronze Age ones in the terraced agricultural area—except for a few visible northeast and northwest of Building C—the presence of Minoan ceramics over this slope suggests it could have been in use during this period. Apart from those terrace walls located around Building C, several others that could be related to Bronze Age

arrangements have been documented on the slopes of a hill in the northern zone of the site (150 m north of Building A). Minoan ceramics were also found on this terraced hill. The ceramics are denser on the upper part of the hill, which suggests the presence of a habitation site of which no trace remains.

Pano Plako

This site (fig. 12) shows arrangements and features such as separation walls, enclosures, and terraces similar to those present at previously described sites. However, Pano Plako is exceptional for its size and the complexity of the arrangements it presents. Although the site was reoccupied during the Late Medieval–modern period, the different types of stone employed, construction techniques, and the preservation of the structures considerably facilitates the identification of the much larger Bronze Age agro-pastoral arrangements. Surface sherds indicate an occupation from the Middle Minoan period to LM III. The remains of several quadrangular structures of megalithic masonry, which could correspond to habitation structures, have been documented.

Building A was, perhaps, first identified by the Minoan Roads Project,⁴¹ but this is uncertain as the maps provided by this project do not locate it accurately. This structure saw modern reuse as an animal pen, but the megalithic masonry and rectangular shape of the lowest rows of stones on the northwestern side of the pen differ strongly from the curved line of its southeastern side, which is constructed using irregular and smaller stones. Further, inside the pen the foundations of a double-faced, completely straight wall can still be clearly seen (fig. 13). Structure B has preserved only part of its plan, but the walls that are still visible are straight and built using megalithic masonry (fig. 14[A], marked as “structure wall,” and 14[B]). Their preservation coincides with that of the wall inside Building A, being flattened at ground level. In conjunction with the presence of LM II ceramics, a Minoan burial, discovered at the beginning of the 20th century 30 m away from Structure B in a small cavity in the rock outcrop (see fig. 14[C]),⁴² confirms the possible habitation character of the structure. Structure B and the burial cavity are separated by a megalithic wall (see fig. 14[D]).

Building A and Structure B are linked to separation/division walls similar to those documented in Vayies and Plakalona, but, in this case, they completely enclose the terraced areas forming *perivoloi* (enclosure

walls). The wall enclosing the terraces in the western sector of the site (to which Building A is linked) can still be followed through most of its extent (see fig. 1[D] for a high-resolution drone-acquired image). As the best-preserved perimeter wall, this one allows a deeper analysis of the workings of this structure. Walls roughly parallel to this *perivolos* and just outside its circumference have been found in several stretches of its route forming a walled path. At the eastern side of this *perivolos* the walled path widens considerably and opens into a quadrangular structure (see fig. 12, marked as “entrance”) that could be interpreted as a gate or entrance. This gate gives access to a wide space between terraced areas and links the central enclosure (see fig. 12, marked as “central enclosure”) with the gorge running north, where two large dams have been documented during the survey and mapping seasons. Like most other walls on this site, the width of the western *perivolos* wall is approximately 1 m, except in areas where it runs close to steep slopes, where the width increases significantly. The terraced area is completely enclosed by the *perivolos* wall. Terrace walls at this site are better preserved than those at Sikia, Vayies, and Plakalona. In this case it has been possible, without excavation, to detect almost complete ceramic vessels and other Minoan material enclosed in the construction phase of the terraces (fig. 15) and to analyze the construction technique. The terrace walls were constructed with a first layer of smaller stones at the bottom, which aimed to level the surface, and, immediately on top of and between these stones, much bigger stones, in some cases roughly worked to form a polygonal masonry style with stones well fitted together (fig. 16, bottom). Corresponding to the modern occupation phase of the site recognized in the reuse of Building A, there is a second system of terrace walls in the area that show a different construction method; these walls use irregular smaller stones roughly fitted leaving open spaces between them (see fig. 16, top). These probably correspond to a modern phase. Manolis Mavroukoulakis explained to us that his great-grandfather sowed these terraces, which he found readymade (the use of these terraces ended with Mavroukoulakis’ father).⁴³ Such reuse and upkeep might explain why Minoan terrace walls are so well preserved in Pano Plako.

Outside the walled terraces, there are pits cut in the limestone bedrock, probably created by expanding

⁴¹ Tzedakis et al. 1989; Tzedakis et al. 1990.

⁴² Dawkins 1905–1906, 1.

⁴³ M. Mavroukoulakis, pers. comm. 25 July 2016.

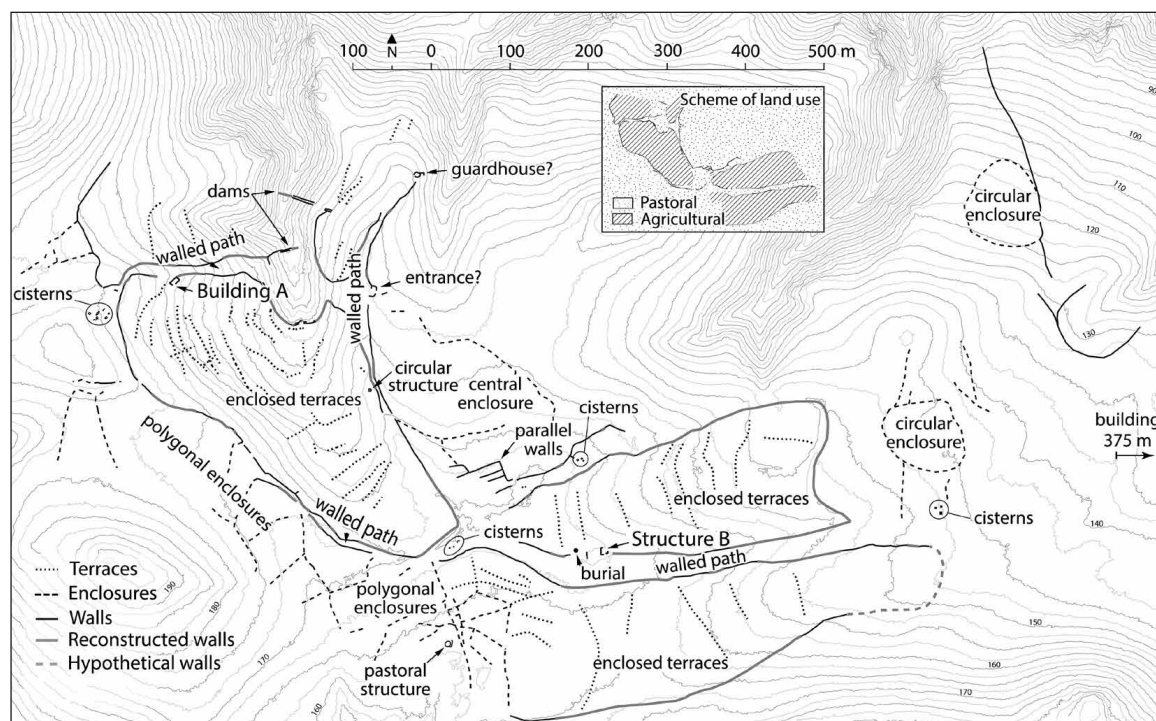


FIG. 12. Plan of the site at Pano Plako.

natural holes in the limestone (fig. 17). These are only visible in several areas where bedrock was exposed. Some of these areas present cut marks in straight angles similar to those found at the Ta Skaria quarry (see fig. 17[A]).⁴⁴ Also outside the enclosed terraced areas, we have documented a series of polygonal enclosures through microtopographical analysis. These enclosures were later confirmed by focused field survey (see lower left areas of fig. 1[C1, C2] for a topographic visualization and fig. 1[E] for a high-resolution orthoimage of one of these enclosure walls). These are most visible in the westernmost sector of the site but are also present in the central area between enclosed agricultural terraces. They divide the western sector of the site into roughly equal areas. A small oval structure (see fig. 12, marked as “pastoral structure”) found within one of these rectilinear enclosures, with a maximum diameter of approximately 9 m, and with a vestibule and main room, presents a strikingly similar plan to that of the Middle Minoan building excavated at Magarikari that has been associated with pastoral activities based on its resemblance to modern pastoral structures.⁴⁵ However,

the structure’s state of preservation and the presence of modern ceramics inside and around it strongly point to a modern date or perhaps a modern reuse of an older structure. Some other enclosures (see fig. 12, marked as “circular enclosure”), not connected to the terraced areas, have been found in the eastern sector of the site



FIG. 13. Detail of the foundations of the southeast wall of Building A at Pano Plako. Note the remains of a modern enclosure around it (facing north).

⁴⁴ MacGillivray et al. 1984.⁴⁵ Blackman 2002, 108.

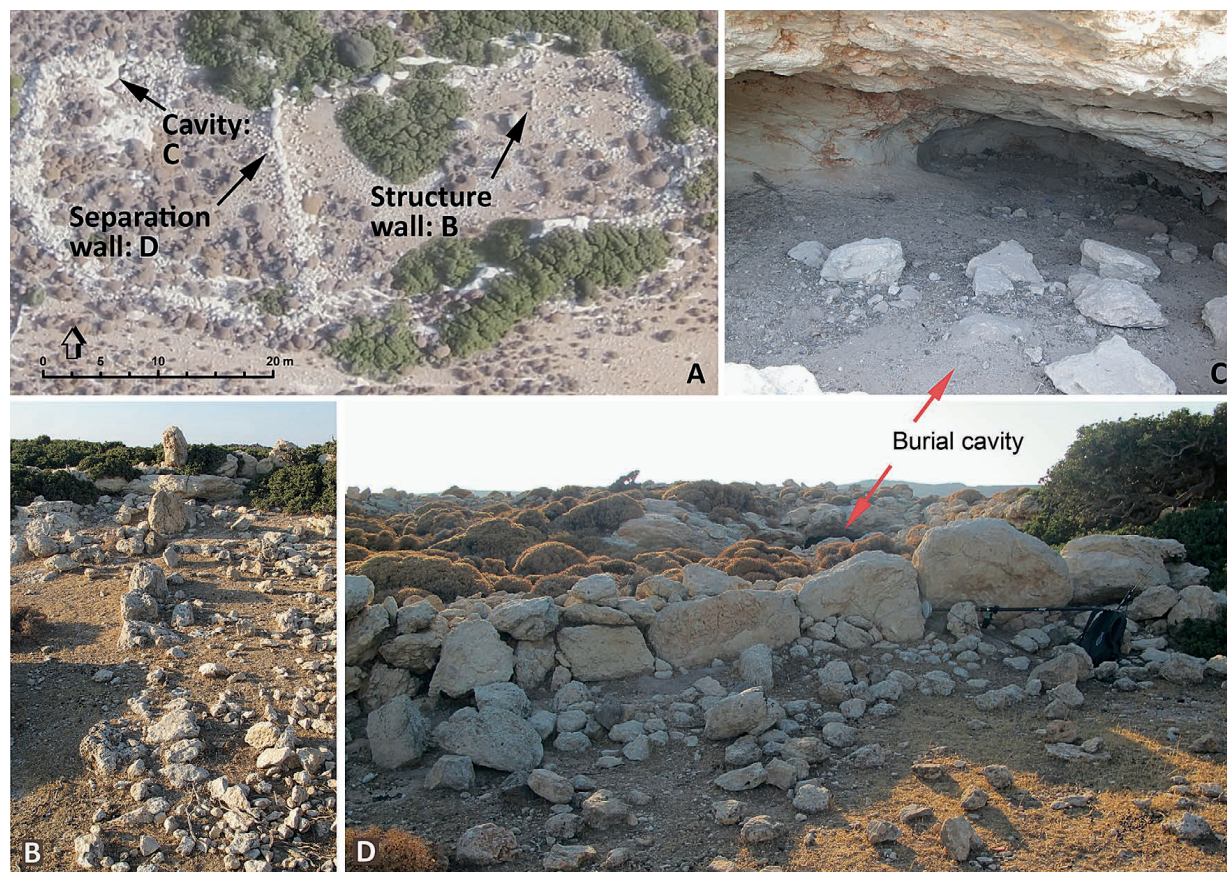


FIG. 14. The group of structures associated with Structure B at Pano Plako: A, high-resolution orthoimage of the group; B, photograph of the western wall of Structure B (facing north); C, cavity where a burial was discovered at the beginning of the 20th century (facing northwest); D, megalithic wall separating the burial cavity and the habitation area (facing northwest).



FIG. 15. Middle Minoan ceramics, including a clearly visible cup in a terrace foundation south of Building A at Pano Plako (facing southwest).



FIG. 16. Comparison between a modern terrace wall (*top*, facing west) and a possible Minoan terrace wall (*bottom*, facing west) south of Building A at Pano Plako.

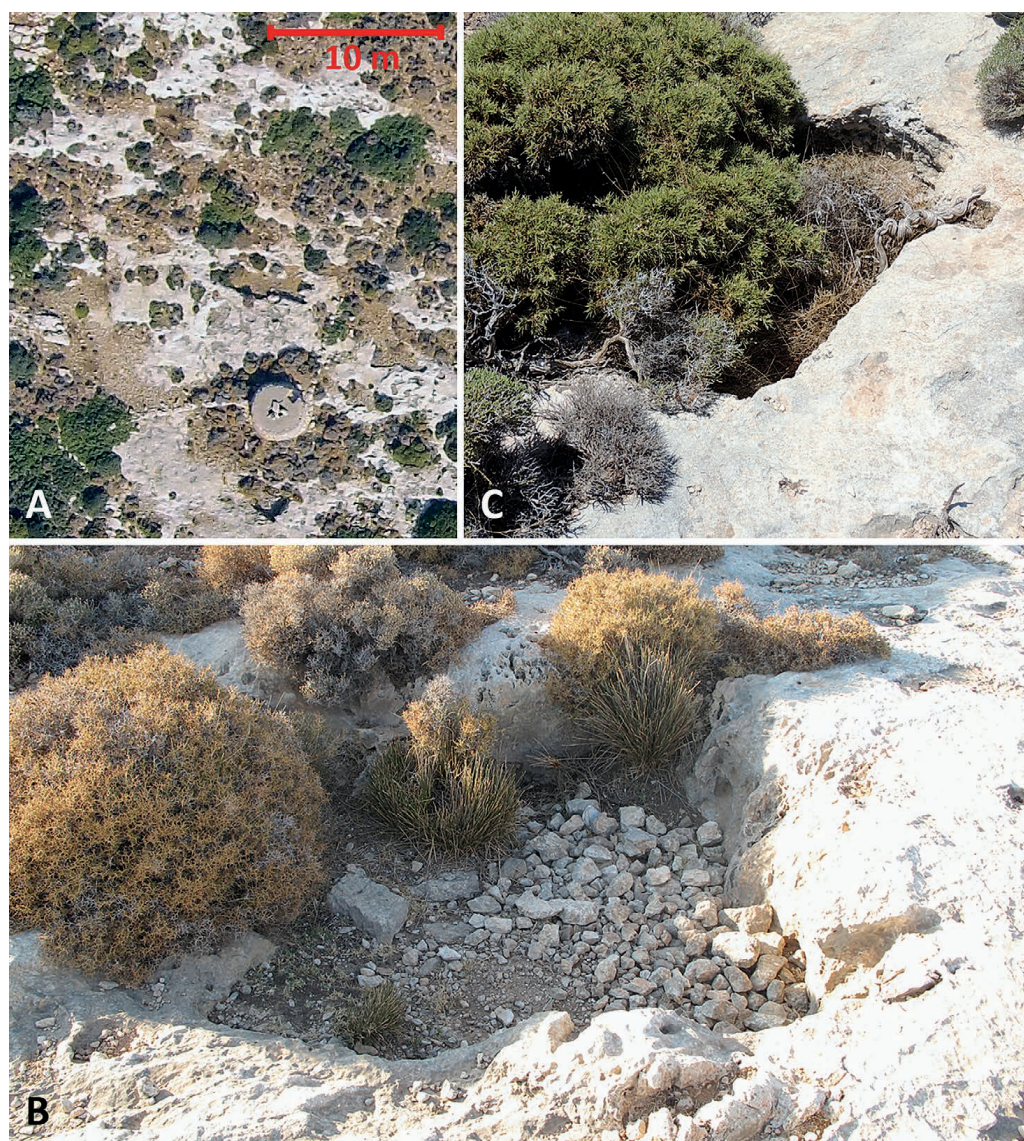


FIG. 17. A, High-resolution orthoimage of a group of pit cisterns west of Building A where the rectangular plan of some of them can be noted, and rectilinear cuts in the stone can also be discerned (modern cistern forming a circle in the lower part of the image reuses one of these); B, pit cistern located below a modern circular cistern; C, pit cistern in a group located at the central area where the three *perivoloi* (enclosing terraced areas) meet.

through microtopographic analysis. These present a circular shape and slight depression in topography, discernible in figure 1[B1, B2].

Another series of structures found at this site also deserves to be mentioned. A completely leveled circular structure (see fig. 12, marked as “circular structure”), in which only a single line of stones has been preserved, sits inside the western terraced area, without any direct connection to the *perivolos* other than its proximity. Its topographic location at the top of a ridge just inside the terraced area, coupled with an external diameter of 4 m and lack of height or rubble masonry, might suggest this

was a threshing floor, although the lack of known parallels for this period precludes a definite assignment. A second circular structure with an associated quadrangular space is located at the northern extremity of the site, where the perimeter wall surrounding the westernmost terraced area and running across the ridge ends (see fig. 12, marked as “guardhouse?”). This structure is poorly preserved and is difficult to identify on-site. Only excavation will be able to reveal its purpose, but its position, with visual dominance over the site and its approach, coupled with its shape and small size of about 7 m in external diameter, is consistent with a guardhouse.

Lastly, a series of parallel walls associated with the central enclosure (see fig. 12, marked as "parallel walls") are located in the central sector of the site. Like most other structures at the site, these walls present a high degree of erosion and are difficult to identify on-site. Their form and size could be related to sheep corrals in which troughs and feeders are distributed in parallel lines and tend to be very long and thin so many sheep can eat at the same time.

Vathy

This site, of a much smaller scale than those previously described, is nonetheless of a similar character (fig. 18). It too is located in the upper area of a small watershed. A quadrangular structure measuring 7.75 x 8 m and built of megalithic masonry is located on the upper part of a small ridge. On the west side of this structure, there is a wall forming a right angle that could have been part of the building. This kind of annex is also found in Building C at Plakalona. If this is the case, the building would have presented a size of 15.4 x 8 m. Several terrace walls associated with this building form checkdams crossing the small ravine (fig. 19). To the west, a wall made of large stones runs northwest to southeast above the building and terraces. This wall might have served a function similar to that of the separation walls documented in Vayies, Plakalona, and Pano Plako that delimit the area where terraced agricultural production took place. Surface pottery provided a date of Late Minoan III.

Other Sites

Several other sites have been identified through surface pottery assemblages in the study area. Some show the presence of terrace walls and checkdams, but no associated buildings have been identified. Figure 2 provides a distribution map of these sites. Although we recorded the extent of the areas with relatively dense concentrations of ceramics, the scale of the map in figure 2 is too small to permit these areas to be delineated. Instead, dots have been used to mark the estimated centers of the sherd scatters. In several cases, close ceramic distributions have been joined in a single dot. It is also possible that closely located ceramic concentrations were part of a single site, but discontinuities in land use, property, and erosion make this impossible to assess. If the strategy of landscape use that we documented at the previously described sites can be generalized across the study area, it would indeed be difficult to identify sites that are spatially

well defined. Rather, it seems that the Minoan landscape was characterized by a continuum of occupation and the presence of structures that might or might not be related to ceramic dispersions and habitation. It is important to stress that the delineation of well-defined sites is not a good approach to the archaeology of Palaikastro's landscape. It has been adopted in figure 2 for the sake of convenience. Where possible, we have provided preliminary chronologies for the sites; however, because of the degraded nature of sherd assemblages, many sites could only be classified as Bronze Age. We hope that ongoing ceramic analysis will help to better define the chronological frameworks for these sites.

Vayies, Pano Plako, and Ayios Spiridon/Plakalona are in the upper areas of catchments and have been little affected by erosive processes that could have hidden their structures. The lack of soil in large areas of these sites has precluded their agricultural exploitation in recent times and the growth of low vegetation. These factors contribute to the visibility of archaeological features. Conversely, most of the pottery assemblages were located in areas with sedimentation such as slopes, alluvial cones, and modern terraces (see fig. 2). It is therefore possible that some of the ceramic assemblages washed down from upper zones. In most cases, however, the presence of associated structures and the small heights of the hills in which these assemblages are found indicate that they have not moved much. The location of these assemblages in lower areas probably denotes the presence of sites that have not yet been detected because of erosion or sedimentation processes. In general, the sites with visible structures tend to be located on gentle slopes and in areas with little water catchment. It is interesting to note that, although the sedimentary plain just north of the Minoan town was surveyed, no ceramic assemblages of Minoan date were found beyond the extent of the Minoan town. This might be related to the same sedimentary dynamics: colluvium from the slopes and alluvium transported by the small Kalogero River are probably responsible for both the low visibility of sites and the absence of Minoan ceramics in the lower slopes of the area. The ongoing study of the sedimentary sequences obtained in this plain will be able to provide further insights into the possible uses of the Palaikastro plain.

Photointerpretation of the ortho-photomosaic developed from the 1966 aerial photographs allowed the documentation of several other areas with characteristics similar to those of the sites described above,

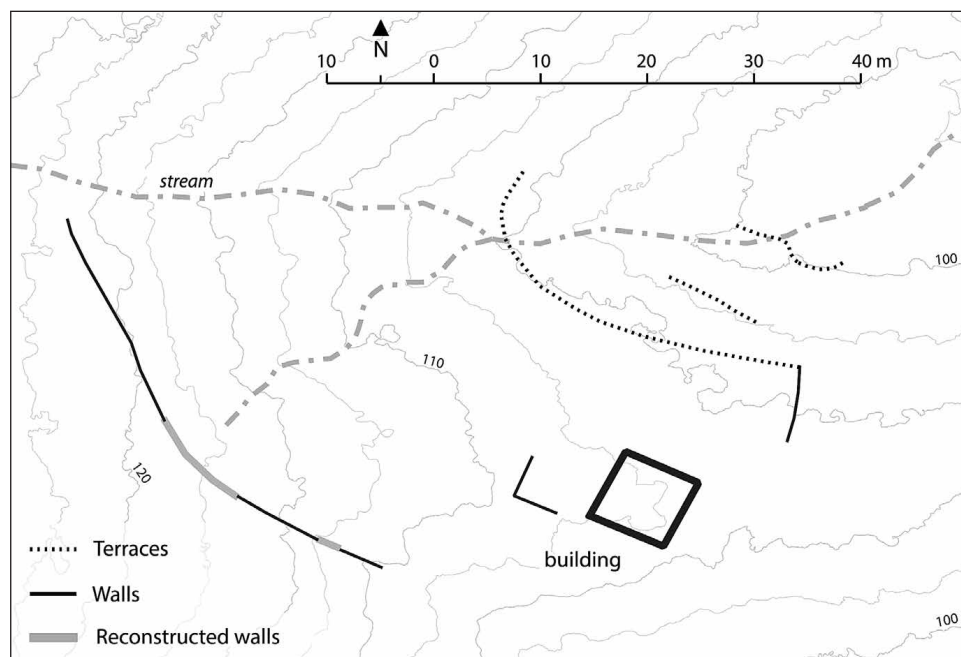


FIG. 18. Plan of the Vathy site

FIG. 19. Upper checkdam at Vathy: *left*, looking northwest; *right*, looking south.

particularly on the Plako peninsula. In this area, many unpublished sites were first identified by Cunningham in the early 2000s in the context of research for his doctoral thesis.⁴⁶ Aerial photo interpretation identified several terraced areas and large megalithic walls. These seem to divide sectors of the peninsula in ways similar to those described at Ayios Spiridon/Plakalona and Pano Plako. A recent study by members of the Lasithi Ephorate of Antiquities⁴⁷ has documented two of those large walls during fieldwork (drawn in fig. 2). In addition, a large quadrangular building of megalithic masonry east of the Pano Plako site is visible in the high-resolution drone images (indicated in fig. 12 and marked as the easternmost point in fig. 2). This structure seems to belong to another agro-pastoral site east of the Pano Plako site, at least judging by the large megalithic walls documented by the Lasithi Ephorate of Antiquities east of Pano Plako, which seem to delimit the area where the megalithic building stands. The sites and structures east of the Pano Plako site have not been further explored as they lie outside the area covered by the survey permit. Nevertheless, all this information suggests that landscape arrangements with functional spaces divided by walls as at Vayies, Ayios Spiridon/Plakalona, and Pano Plako are also present in the Plako peninsula. If this is indeed the case, it is possible that human land use formed an occupational continuum over the landscape, at least in the higher elevations of the southern sector of the study area.

TYPES OF STRUCTURES AND THEIR FUNCTIONALITY

Most of the sites discussed above have several characteristics in common: they include buildings of similar shape, structure, and construction techniques. The interior walls of buildings, when visible, are clearly of lighter construction than the exterior walls. Most sites include more than one rectangular building; the number per site seems to be associated with the size of the area exploited. Although only the Vathy site presents a single building within its area, such smaller, single-building sites were probably more common than the results of the survey seem to indicate because, given

their size and the simplicity of their landscape arrangements, these are much more difficult to trace. Habitation structures are usually located at the higher elevations of the sites, whether for topographic prominence or visual control over the enclosed area and beyond, and at the intersection of different activity areas. Consequently, habitation structures are linked to the perimeter walls separating different areas. Ceramic material is abundant and coincides with the presence of the terraces and buildings. The ceramics show that, in most cases, there has not been later reuse of the space (at least, not in a way that produced ceramic assemblages). The perimeter walls, which can surpass 1.5 m in width, usually follow the ridges surrounding the terraced areas. These walls are double faced and, in some cases, their state of preservation is good enough for them to preserve some height. A less common characteristic of the sites is the presence of smaller buildings of square or round plan; their location in prominent positions suggests that visibility of the surrounding area was of prime concern, although they are not necessarily defensive or military in character. These usually stand isolated from the rest of the structures forming the site, as in the case of Building C at Sikia (see fig. 3), when such distance is necessary to achieve a better visual control of the site.

The recent publication of Minoan terrace systems such as those at Kythera, Pseira, Choiromandres, and the sites around Karoumes, where most buildings were related to agricultural terraces, has produced important new information on Minoan agricultural systems.⁴⁸ All the sites described here show the presence of terrace walls on their slopes. Most of these walls were visible on the surface, albeit in very different states of preservation, according to site-specific sedimentation or erosion processes and the particular land-use history of each site. At Vayies, the terrace walls were mostly eroded; they were detected as microtopographic marks in the high-resolution DSM and, when visible, only the preparation for the terrace wall with a line of irregular stones was preserved (see fig. 8[A]). Terrace walls at Plakalona were almost completely buried and were visible only as parallel rows of stones (each defining an individual terrace wall) on the surface. Some of the best-preserved terraces were found in Pano Plako,

⁴⁶ Cunningham 2012. The subject of his doctoral research subsequently changed. Some of these sites are shown in Sofianou and Thanos 2015, fig. 2.

⁴⁷ Sofianou and Thanos 2015.

⁴⁸ Frederick and Krahtopoulou 2000; Vokotopoulos 2011, 139; Betancourt 2012; Vokotopoulos et al. 2014.

where terrace walls with several courses of stones could be found.

We used several indicators to identify which terrace walls are of Minoan date. First, Bronze Age pottery sherds were consistently associated with the terraced areas. The reoccupation of sites such as Pano Plako and the area around Ayios Spiridon during the modern period has produced modern ceramics, but these do not obscure the usually predominant Minoan sherd distributions. A second indicator is the type of construction used in the terrace walls: the Minoan terrace walls tend to have larger, better-fitted stones than their modern counterparts, which use smaller stones poorly fitted and with large spaces between them (a comparison can be seen in fig. 16, the lower image corresponding to a Minoan example). In the best-preserved examples, the stones seem to have been slightly worked in polygonal shapes to achieve a better fit. The presence of well-preserved Bronze Age ceramics inside the lower levels of a terrace wall is also indicative (see fig. 15). Another good marker is the relation between terraces and megalithic buildings, which are always located at the edge of terraced areas. In some cases, the buildings make use of terraces to level the terrain in which they were set (Building A at Vayies and Building A at Sikia; perhaps Building A at Pano Plako, Building B at Sikia, and Building C at Plakalona). Finally, the overall coherence of the group of structures as they define the agro-pastoral site, at least when no other occupation of the site has been documented, can offer an important clue on the dating of the group of terraces: except for Sikia, all Minoan terraced areas documented during the course of this project have been enclosed within a perimeter wall; at Vayies, Building B's northern corner connects with a wall delimiting the terraces located immediately below the building, just as seems to be the case with Building C (see fig. 6).

The distance between terrace walls is dependent on the slope. Gentler slopes, 7–15°, are preferred. A first line of stones served to prepare and level the surface of the terrain before bigger terrace stones were fitted on top and between them (see fig. 8[A]). In some cases, a bottom line can also incorporate large stones, which sit directly on the bedrock without the presence of a line of smaller stones (see fig. 16, bottom). In the few cases where terrace walls were sufficiently preserved, it has been possible to document the presence of almost complete vessels as part of the construction of the terraces (see fig. 15; note the crisp break on the conical cup, which suggests the pot was recently bro-

ken). Complete vessels used in the construction of terrace walls have previously been regarded as foundation deposits,⁴⁹ but in our case, there is no evidence to propose such ritual behavior since much of the ceramic material was clearly broken before deposition. It is possible that ceramics, which are less porous than soil, were used as fill to facilitate drainage.

The terraces are related to other structures within the site, such as buildings and walls enclosing the terraced areas. In some cases, it is still possible to see how these elements were constructed in conjunction with one another. For example, the wall forming the western *perivolos* at Pano Plako enclosing a terraced area also forms a walled path to which both Building A and the pastoral polygonal enclosures to the southwest and south are attached (see fig. 12). In other cases, the buildings were constructed on top of a terrace wall. Building A at Vayies (see fig. 6) is a good example of this: both the northern and southern walls of the building are on top of terrace walls that continue beyond the walls of the building to form terraces. In a handful of cases, the terrace walls have preserved some height. However, the terrace walls are usually identifiable only through the presence of the bottom line of aligned stones and through topographic differences in the slopes that have been detected by the drone-based microtopographic analysis. Terrace walls significantly increase their width to become checkdams when they cross streambeds (for the example at Vathy, see figs. 18, 19). The dams function to distribute moisture over the surface of the terraces and, most importantly perhaps, counteract erosion by reducing water flow. At Vayies, the streambed has been delimited by a wall made of megalithic stones, which also serves as the lower terrace wall of the site (see figs. 6, 8[B]). There seems to be a direct relation between the width of the checkdam wall and that of its catchment area or the inclination of the slope—the bigger the catchment area or more pronounced the slope, the wider the dam wall; the width of the wall must be related to the strength of the water flow it has to contain during rain episodes.

We also documented a second type of dam, built using larger stones and sometimes more than 2 m wide; these are located at the periphery of sites, often coincident with the perimeter walls. Such dams do not seem to have served any agricultural purpose as they are not directly related to terraces and could not have

⁴⁹ MacGillivray et al. 1999; Herva 2005.

distributed water onto them. An example of this type of wall can be found in the upper checkdam at Choiromandres.⁵⁰ These dams would have accumulated water in large pools in the streambeds carved in the limestone. The narrow streambeds, protected from the wind and sun, would have slowed the evaporation of the water. In our study area, this is best exemplified by the checkdams at Pano Plako (see fig. 12, between the possible entrance and Building A) and at Plakalona (see fig. 9, the hypothetically extended walls crossing the stream).

In contrast with the agricultural production attested by the terraces inside *perivoloi*, two types of structures have been found outside the terraced areas:

1. Pit cisterns cut into the bedrock were found just a few meters outside the enclosure walls at Vayies and Pano Plako (see figs. 6, 12). Some of these show a very regular, quadrangular outline, while others seem to be natural holes in the limestone that have been artificially enlarged (see fig. 17). These pits tend to be grouped; many small pits were apparently preferred to a larger single pit. The smallest pit is 1.35 m long x 0.85 m wide, and the largest measures 5 x 1.86 m. At Pano Plako, in an area of about 25 x 25 m, eight pits were found (see fig. 12, the “cisterns” at the western extremity of the site), one of them having been reused as a cistern during the modern period (see fig. 17[A], the circular structure at the bottom of the image). Unfortunately, there is no direct information on the depth of the pits because excavation was not allowed by the survey permit. However, the size of some of the smaller pits suggests that they were not deep as it would have been extremely difficult to cut the rock to a significant depth from the outside and impractical to do it from within, where more space would have been necessary to operate tools. Although these pits have been identified only at Vayies and Pano Plako, there may be more pits than we observed since they tend to fill up with sediment, and bushes tend to grow in these spots, thanks to their capacity for retaining soil and moisture. In fact, these pits were found only in areas where bedrock was exposed.
2. Two types of enclosures without terraces in their interior have been documented. The first type includes the enclosures with straight walls and

polygonal shapes linked to the western *perivolos* wall at Pano Plako (see fig. 12) and perhaps the enclosures documented at the eastern pastoral area of Plakalona (see fig. 9). These walls are extremely eroded, and some of them have been located only as microreliefs in the high-resolution drone-derived DSM (see fig. 1, lower section of images C1 and C2; fig. 1[E] for an orthoimage of one of the enclosure’s straight walls). The second type consists of isolated circular enclosures that are difficult to identify during fieldwalking. As with the previous type of enclosure, they were identified only as microtopographies. The sole documented examples of these subtle structures can be found in the eastern sector of the Pano Plako site (see figs. 1[B1, B2], 12, marked as “circular enclosure”). We recognized these isolated enclosures as Minoan because of their proximity to the enclosed terraced areas, the similarity of their double-faced walls with the walls enclosing terraced areas, the recovery of Minoan pottery, albeit scarce, at the surface, the apparent absence of any later use of the landscape (which indicates that the Minoan pottery found on the surface should correspond to the use of these structures), and their shape and sunken topography, which is clearly reminiscent of enclosures.

DISCUSSION: THE SITES WITHIN THEIR SETTING

All the sites described here are located in the upper areas of drainage basins or in small catchments. The sites were, therefore, not connected with any type of agricultural production requiring significant amounts of water distributed by irrigation. In lower parts of the watershed, more water than was available in the upper part of the catchments could have been accumulated and redirected to terraces using checkdams, as suggested by Vokotopoulos et al. for Choiromandres.⁵¹ However, the existence of the higher terrace systems indicates that they must have achieved the reduced levels of soil and moisture retention necessary for dryland agricultural production. All the agricultural areas are located on the gentlest slopes available (e.g., the slopes surrounding the terraced areas at Sikia; see fig. 3) or in areas of sediment accumulation (the best example being the central agricultural sector of Ayios Spiridon;

⁵⁰Vokotopoulos et al. 2014.

⁵¹Vokotopoulos et al. 2014.

see fig. 9). The need to exploit all available areas with a capacity for soil retention through the use of extensive terracing suggests a need to increase the existing agricultural space during the Middle Minoan period. This may be surprising, given the extensive areas for agriculture seemingly afforded by Palaikastro's sedimentary plain, which would appear to offer enough agricultural potential to sustain the town's population and some surplus in addition, judging from its current intensive use. However, sedimentological analyses of several cores extracted from the littoral floodplain of Kouremenos are beginning to provide important data that indicate a smaller sedimentary plain during the Bronze Age and thus perhaps significantly less agricultural potential than previously supposed.⁵²

Minoan enclosure walls surrounding terraced field systems have been considered defensive,⁵³ but, as pointed out by Beckmann,⁵⁴ their width would hardly have allowed a height beyond 1.7 m, rendering them unsuited for defensive purposes. Alternatively, as suggested by other authors recently dealing with these enclosure walls, they might have been useful in avoiding erosion by protecting the enclosed area from surface water runoff⁵⁵ and, perhaps more importantly, from wind erosion, given the constant strong winds characteristic of east Cretan summers, especially in the upper areas.⁵⁶ In this regard, it was described to us that ploughing at Pano Plako was done when the ground was moist to keep the soil from blowing away, reflecting a strong concern for wind erosion in the area.⁵⁷ It has been calculated that walls reduce wind speed by half within a distance of eight times their height and increase significantly the preservation of dew.⁵⁸ These measures are obviously highly increased by the location of these sites in valleys or natural depressions (see, e.g., figs. 6, 12, the terraced areas at Vayies or Pano Plako), where the slopes and ridges can provide a similar protection.

The most important function of the enclosure walls, or *perivoli*, surrounding terraced fields would have been to prevent sheep and goats from entering the ag-

ricultural fields. Enclosed terraces and walls separating agricultural fields from pastoral spaces have been documented in other coastal mountain areas with a strong pastoral economic orientation.⁵⁹ The presence of cistern pits cut in the bedrock just outside the enclosure walls further attests to the strong pastoral orientation of these areas. Such pits are common in other Mediterranean mountain areas where ethnographic evidence explains them as rainwater basins for the use of livestock, mainly sheep and goats, which are able to digest stagnant water.⁶⁰ Mediterranean karstic mountains are characterized by the lack of water, and pit cisterns have been part of the water management strategies for animal husbandry since prehistory as attested by the association of these structures with Bronze and Iron Age settlements in the island of Menorca.⁶¹ The presence of this type of cistern has been documented beyond the Mediterranean, associated with pastoral groups in the semiarid mountain environments of southeastern Turkey.⁶² Certainly the presence of multiple elongated pits points to their use by a large number of animals; a single larger and deeper cistern, such as those designed for human consumption, could, in pastoral settings, cause sheep, pressured by the flock, to fall inside and drown.

The presence of a series of large dams at Plakalona and Pano Plako just below the terraced areas excludes their use for agricultural purposes (see figs. 9, 12, marked as "checkdams" and "dams" respectively; note that gray lines show hypothetical reconstructions of these walls, which are usually badly damaged at the crossing of the stream). However, these could have served a function similar to that of the cistern pits: given their large catchment area, they should have been able to accumulate large quantities of water during sporadic rain episodes. Their topographical setting in deep and very narrow gorges carved out of the bedrock is ideally suited for this task as it offered protection from both sun and wind, reducing water evaporation and subsurface infiltration. The distribution of walled paths, particularly visible at Pano Plako but also at Plakalona, seems to prove that these were intended for the movement of animals since they link the pastoral areas of the sites with these pools while

⁵² Cañellas-Boltà et al. 2018.

⁵³ Evans and Myres 1895; Taramelli 1899; Alexiou 1979, 1980; Chrysoulaki 1999.

⁵⁴ Beckmann 2014, 23.

⁵⁵ Vokotopoulos et al. 2014.

⁵⁶ Beckmann 2014.

⁵⁷ M. Mavrokokoulakis, pers. comm. 25 July 2016.

⁵⁸ Krusche et al. 1982, 52–3; Beckmann 2014, 24.

⁵⁹ Ejarque and Orengo 2009, but see also Ballesteros Arias et al. 2006, 204.

⁶⁰ Orengo et al. 2008; Ejarque and Orengo 2009.

⁶¹ Ferrer Rotger 2010.

⁶² Hammer 2014, 276–77.

protecting the agricultural zones from the passage of animals. Water dams and basins would have served to attract and concentrate the animals grazing beyond the immediate environs of the site, functioning as a means to control them on a daily basis as they would have had to return periodically to these reservoirs to drink. Although only a single example has been found, structures for the distribution of food, such as that documented at Pano Plako (see fig. 12, marked as “parallel walls”), might have been more common in the study area. They might also have served to control the flock by providing particularly succulent food, probably derived from the agricultural production developed in the nearby terraced areas.

Several enclosures, located close to the terraced areas at Plakalona and Pano Plako (see fig. 9, marked as “pastoral enclosures”; fig. 12, marked as “polygonal enclosures” and “circular enclosure”), can also be related to the pastoral use of the landscape. Although it seems large areas of the landscape were dedicated to animal grazing, judging by the almost constant presence of perimeter walls around terraced agricultural areas, the enclosures could have served multiple functions in ovicaprine management where young weaned offspring, pregnant females, or nursing females should be kept separate. At Pano Plako and perhaps at Plakalona, the polygonal enclosures suggest strategies of grazing management. Separate enclosed areas, perhaps not meant to be grazed at the same time, could have avoided the overexploitation of particular spots. They could also be useful by concentrating the manure produced by the flock in smaller areas, allowing its collection for use as an agricultural fertilizer. Sheep manure is particularly efficient as it presents higher concentrations of nitrogen, magnesium, calcium, and potassium than cattle manure, with a similar phosphorus content.⁶³ Manure boosts soil aggregation, which, in turn, increases soil moisture retention while reducing soil loss to wind and water erosion,⁶⁴ an important aspect given the particular topographical and climatological characteristics of our study area.

In some cases, we located these enclosures through microtopographic analysis and very high-resolution aerial photography. For Pano Plako and Plakalona, microtopographic analysis provided excellent results, given their gentler topography and relative absence of

vegetation in comparison to the other sites. At sites where pastoral enclosures might have been covered or eroded by sedimentary processes or hidden by current vegetation, there is a strong possibility that these enclosures were more numerous than current results suggest. Beckmann,⁶⁵ working in the upper areas of Kritsa and Kroustas in the Ayios Nikolaos region, has documented enclosed fields, some with terraces inside, and habitation structures, separated by walled paths, of a type very similar to the ones described here, covering large areas of the landscape. In any case, the presence of perimeter walls around terraced areas in sites such as Vayies, where there is no evidence of pastoral enclosures, as well as the relatively small size of the enclosed terraces at Vayies, Plakalona, and Pano Plako and the quantity of open cisterns and nonagricultural dams, suggests we are dealing with a strongly pastoral landscape where the agricultural areas had to be enclosed and the rest of the space was dedicated to grazing. Pastoral husbandry, of course, requires much larger areas than agriculture. Even so, in view of the restricted topographical settings suitable for terracing, which are not so common in this area, pastoralism appears to have played a more important role here than is usually recognized for Minoan communities, which are typically assumed (rather than demonstrated) to have been predominantly agrarian.⁶⁶

As may be evident from the site plans, these locales can hardly be described as sites in the common sense of the word. The structures documented extend over large areas, almost forming a continuous use of the available space. There is little doubt that, given more survey time and fewer spatial restrictions, many more such structures would have been located. The sites show intensive agro-pastoral exploitation of the available space. Several factors suggest very careful management of the landscape in order to avoid erosion and the overexploitation of grazing areas. These factors include the existence of enclosed agricultural areas and pastoral enclosures of different types, the terracing with checkdams, and the use of areas high in the watersheds with topographical settings that assure protection from the strong summer winds. The compartmentalization of space with highly regulated movement between areas dedicated to different activities is consistent with this idea. The built features are

⁶³ Smith 1952; Winterhalder et al. 1974.

⁶⁴ Klausner et al. 1971; Miner 1971.

⁶⁵ Beckmann 2012, 2014.

⁶⁶ Renfrew 1972; Moody 1987; Knappett and Schoep 2000.

indicative of an already overexploited landscape where issues of soil erosion and the availability of agricultural and grazing resources were of concern to Palaikastro's inhabitants. Some authors link pastoral exploitation, in particular that of sheep and goats, to deforestation and pronounced erosion in Mediterranean mountain areas.⁶⁷ Again, the results from our multiproxy paleoenvironmental analysis of the sedimentary cores recovered from the Kouremenos wetlands just north of the site⁶⁸ will provide important clues about the management of the landscape, the availability of plant resources for pastoral use, and the presence of agricultural activities, allowing us to contextualize the evidence gathered by this survey. The comparison with bioarchaeological data obtained at the town of Palaikastro⁶⁹ will be essential for understanding how land-use systems and production were shaped by and in turn influenced the sociopolitical organization of the Minoan town.

CONCLUSIONS

Given the limitations in the permit, chronological developments from the Middle Minoan to the Late Minoan could not be dependably observed beyond the fact that the structures described here were in use during these periods. Further chronological insights would require the collection and analysis of artifacts and the excavation of selected structures in each of the located sites.

Until the results of the paleoenvironmental, geoarchaeological, and on-site bioarchaeological studies are available, only preliminary conclusions can be drawn from the data gathered from the survey and mapping campaigns in the area around Palaikastro. The results point to the possible existence of an already degraded landscape in the Middle Minoan period that resulted in the extensively managed and articulated Middle

Minoan and Late Minoan landscape documented here, where agriculture and pastoralism are complementary and well integrated. The almost continuous division and compartmentalization of the available space at Pano Plako, Ayios Spiridon, Plakalona, and Vayies suggest a landscape under intense pressure where land use has to be carefully monitored so as to both counteract erosion and ensure productivity. Such pronounced fragmentation of space has been strongly linked to intensive land use in both agricultural and pastoral mountain areas.⁷⁰ Agro-pastoral uses are distributed in space according to topographical parameters. Gentle slopes and sedimentary areas located in the upper sectors of watersheds and protected from the wind are preferred for the development of dryland agricultural activities. Yet, pastoralism seems to have had a distribution that was both much more extensive, judging by the enclosures for the protection of the terraced areas, and also intensive, given the presence of different systems of enclosures and the measures adopted to assure adequate water supply. This situation is mirrored in other, similar areas of eastern Crete such as that around the Minoan town of Zakros, where the lack of adequate areas for the development of agriculture is very evident.⁷¹ It seems, therefore, that, if any surplus was accumulated at Zakros or Palaikastro, it is unlikely to have been derived entirely from local agricultural sources. In this regard, it is interesting that, unlike other palaces, the Zakros palace does not have extensive magazines. As for Palaikastro, no central building has yet been located. This conclusion cannot be extrapolated to the central and western parts of Crete, where wetter and less windy conditions exist and where little evidence has been presented as yet of Minoan terracing and enclosures.

Nowadays, the upper areas around Palaikastro retain very little soil. The exposed calcareous bedrock and red soils derived from its slow dissolution extend over a large part of the upper areas, rendering the landscape unusable except for a few small flocks in which goats, better adapted to grazing in degraded landscapes, form half of the stock. Perhaps the most important reason that such a large number of Bronze Age features are still visible and can be mapped is precisely the failure of Middle and Late Minoan land-use strategies to avoid erosion and assure the sustainability of their agro-pastoral practices. Ironically, it might have been this

⁶⁷Thornes 1987; Riera and Palet 1993; Shiel 1999; Ayala and French 2005.

⁶⁸Cañellas-Boltà et al. 2018.

⁶⁹On-site bioarchaeological analyses under the direction of A. Livarda (archaeobotanist, University of Nottingham), aided by V. Tzevelekidi (zooarchaeology, Ephorate of Antiquities of West Attica, Piraeus and Islands, Hellenic Ministry of Culture and Sports), L. Picornell (charcoal analysis, Universidad de les Illes Balears), R. Veropoulidou (malacology, Museum of Byzantine Culture, Hellenic Ministry of Culture and Sports), R. Marlasca-Martín (ichthyofauna, Posidonia s.l.), and J.M. López-García (microfauna, Catalan Institute of Human Paleocology and Social Evolution), are ongoing and will be finalized by summer 2018.

⁷⁰E.g., Ballesteros Arias et al. 2006; Orengo et al. 2014.

⁷¹Reid 2007.

early impact on the landscape that rendered it partly unusable for later generations and, in this way, assured the preservation of this fossilized Bronze Age landscape.

Although indications of similar agro-pastoral systems have been identified at Choiromandres, and investigations at Pseira have revealed terraced fields there, particularly in LM I, elsewhere on Crete there has been little recognition of such systems. While mindful of the difficulties in dating such structures, Rackham and Moody have done much to identify terracing in the Cretan landscape;⁷² in describing a series of field systems in different parts of the island, they doubt that any date to the Bronze Age, citing only the systems at Pseira as secure examples.⁷³ The Kavousi survey has also tentatively identified Bronze Age terracing, for example at site 5 in the Ayios Antonios area.⁷⁴ Here a “complex field system” is located downslope of Neopalatial houses.⁷⁵ This is one of the few cases where we can imagine an agro-pastoral system of the kind reconstructed here for the Palaikastro region. Another site from the Kavousi survey that might be comparable is site 34, Chomatas,⁷⁶ which has since been excavated as the Chrysokamino site.⁷⁷ In the survey, the surface pottery was identified as MM III–LM IA, but excavation showed it to span the Final Neolithic to LM III periods.⁷⁸ Jusseret et al. also mention reports of Bronze Age terrace walls from the Mesara and indicate that the paucity of data probably reflects a lack of study and interest.⁷⁹ Indeed, there must be many other examples of Bronze Age terracing yet to be described as such, not least at similar locations in east Crete, such as the Vrokastro region⁸⁰ or the area of Itanos.⁸¹ As we have shown here, an important tool in their identification is a systemic approach that can show their integration within wider landscape management systems.

Whereas much emphasis has been placed on the excavation of Minoan sites and the development of archaeological surveys, the study of Minoan landscape management and land-use strategies still lags behind.

Although the landscape structures described in this paper are not the most impressive of Minoan remains available for study, they have the potential to make a significant contribution to our understanding of Minoan land use, land ownership, human impact and sustainability, population, and the Minoan economy in general.

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⁷² Rackham and Moody 1996, 140–45.

⁷³ Rackham et al. 2010.

⁷⁴ Haggis 2005, 18.

⁷⁵ Haggis 2005, 95, fig. 27, pls. 7, 11, 12.

⁷⁶ Haggis 2005, 115.

⁷⁷ Betancourt 2006.

⁷⁸ Betancourt 2006.

⁷⁹ Pope 2004, 50–1, 56; Jusseret et al. 2013.

⁸⁰ Hayden 2004.

⁸¹ Schnapp-Gourbeillon et al. 2009.

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