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Tartaron, Thomas F.
Pullen, Daniel J.
Noller, Jay S.

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Thomas F. Tartaron[1], Daniel J. Pullen[2] & Jay S. Noller[3]

With ever more inhibited programmes of excavation, new methods of site survey are always welcome. Here a soil geomorphologist joins forces with archaeologists to read the history of limestone blocks exposed on the surface at sites in southern Greece. Rillenkarren *for example are vertical grooves caused by rainfall on stones that remained for long periods in the same place. These and other observations showed that what looked like clearance cairns had in fact been piled up in the Early Bronze Age and led in turn to the definition of a new type of settlement.*

Keywords: Greece, Early Bronze Age, fortifications, stone cairns, karst geomorphology

Introduction

The investigation of two newly discovered fortified sites, Vayia and Vassa in southern Greece, contributes to a number of important issues in archaeology in general and Aegean prehistory in particular. Surveys in regions dominated by karstic limestone lithology often encounter substantial stone-built structures with limited artefactual evidence for their date. The investigation of Vayia, employing a methodology that closely integrates archaeology and geomorphology, points to ways that surface remains in karstic landscapes may be more readily dated, even with limited associated artefactual material.

Vayia and Vassa belong to the Early Bronze II (EB II) phase of the Early Bronze Age (EBA) of Greece and the Aegean (Figures 1 and 2), a time of increasing social complexity, seen in the emergence of chiefdoms, intense interregional interaction characterised by a burgeoning 'international spirit' (Renfrew 1972: 451-5) and increased competition as demonstrated in the appearance of fortifications at many sites. Exotic items with presumably high social value, including bronze daggers and tools, metal jewellery, fine drinking and pouring vessels of metal and ceramic and marble vessels and figurines, circulated among the coasts and islands of the Aegean Sea. The relatively undifferentiated pattern of small farmsteads and hamlets in the preceding EB I period was transformed by a striking expansion of settlement and the appearance of large settlements, particularly at coastal locations well situated for maritime activity (Figure 1; Broodbank 2000: 279-87; Konsola 1986; Pullen 2003). At many of these

[1] *Department of Anthropology, Yale University, New Haven, CT 06520, USA (Email: thomas.tartaron@yale.edu)*
[2] *Department of Classics, The Florida State University, Tallahassee, FL 32306, USA (Email: dpullen@mailer.fsu.edu)*
[3] *Department of Crop and Soil Science, Oregon State University, Corvallis, OR 97331, USA (Email: jay.noller@oregonstate.edu)*

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Figure 1. Satellite image of the Aegean area showing important sites mentioned in the text.

larger centres, truly monumental constructions appeared in the final two to three centuries of EB II. Monumental 'corridor houses' with long passages flanking the internal rooms are found on the Greek mainland and on the island of Aegina (Figure 3). These houses have been variously interpreted as palaces, administrative centres, residences of prominent families or lineages or even hotels or meeting halls for traders (Felten 1986; Pullen 1986; Shaw 1987; Wiencke 1989; Weingarten 1997; Nilsson 2004). In later EB II, enclosures and fortification walls surrounded some major settlements as well as smaller farmsteads or hamlets (Figure 3). There is considerable variability in their construction: some were little more than thin lines of field stones, while others incorporated elaborate semicircular or horseshoe-shaped bastions, double rings of fortification walls and other defensive features (Figure 4). The new threat that prompted increasing investment in defence has not been adequately explained, nor whether the decrease in number of mainland settlements of the subsequent EB III period is to be attributed to this threat, but evidence for warfare at some level can be inferred from the large number of copper and bronze daggers and spearpoints, sling-stones around the fortification walls at a few sites, and the arrival of the menacing

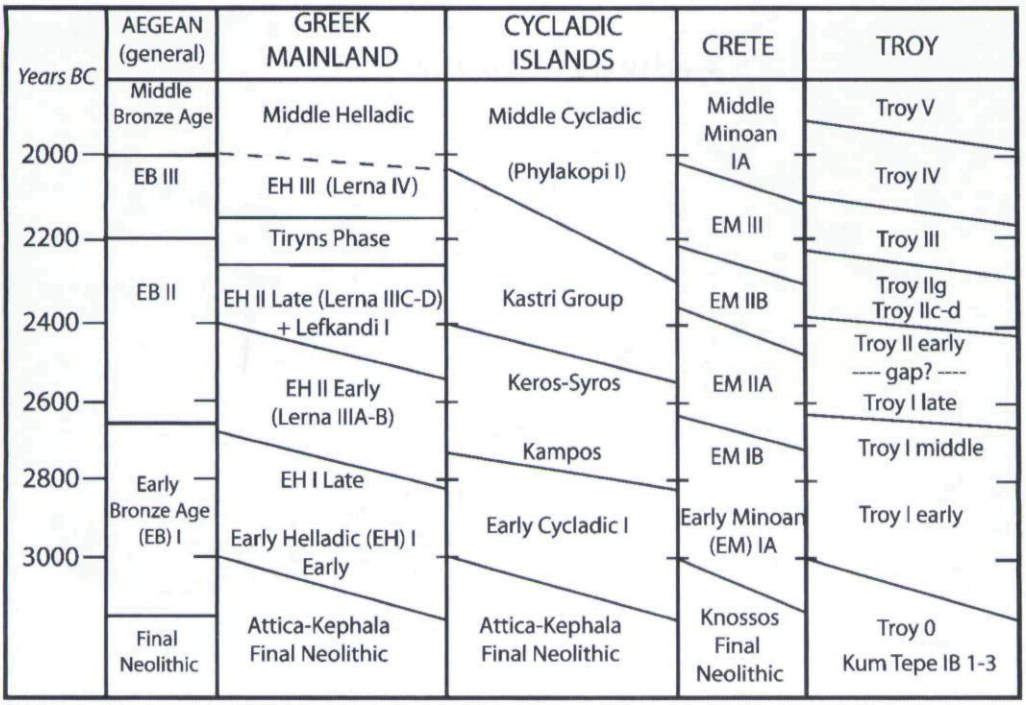

Figure 2. Chronology of the Early Bronze Age Aegean. After Foundation of the Hellenic World, http://www.fhw.gr/chronos/02/mainland/en/eh.

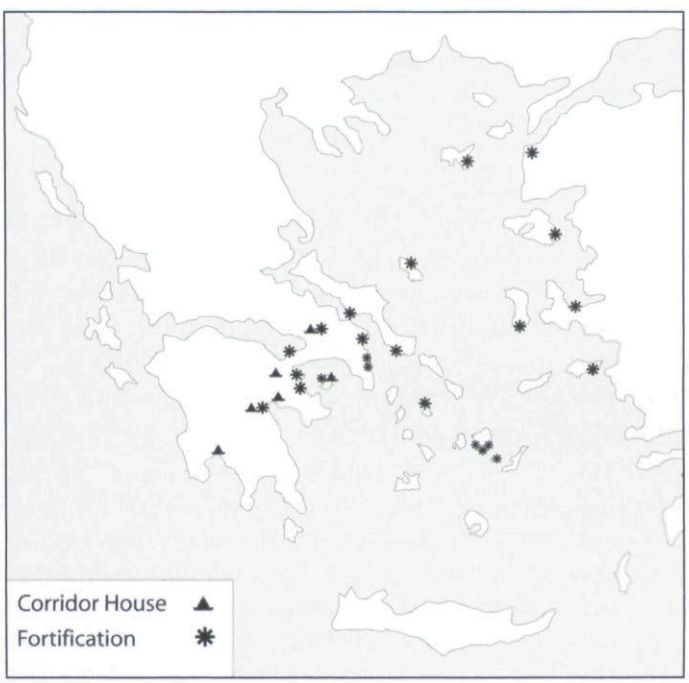

Figure 3. Locations of sites with corridor houses and fortifications.

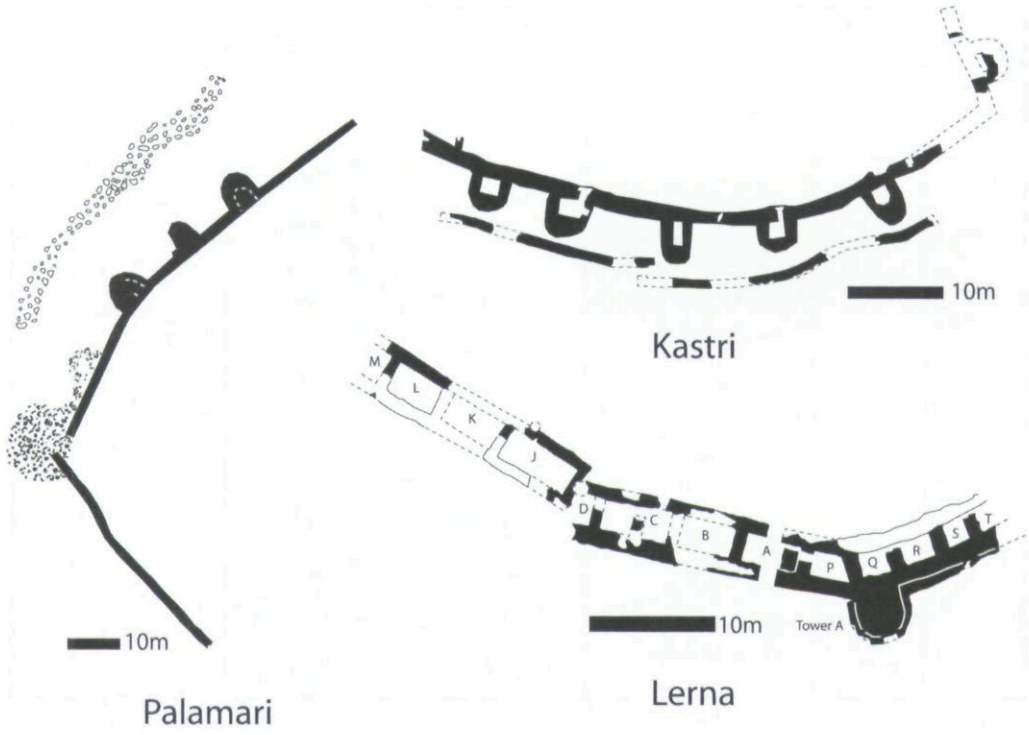

Figure 4. Simplified plans of segments of EB II fortification walls at selected sites in the Aegean.

longboat in the Cycladic Islands (Branigan 1999; Doumas 1990). It is to this vigorous and apparently turbulent world that Vayia and Vassa belong.

Vayia

The site of Vayia was discovered in the late 1990s by means of a GIS-based probability model that has been described elsewhere (Rothaus *et al.* 2003; Tartaron *et al.* 2003), and investigated in 2002 by the Eastern Korinthia Archaeological Survey (Tartaron *et al.* in press) through intensive surface survey, mapping and documentation of the architectural remains. Artefacts and features are spread over approximately 3ha on the top of a long ridge that extends north into the Saronic Gulf, overlooking natural harbours to the east and west (Figures 5 and 6). The western harbour, Lychnari, was sheltered and well suited to Bronze Age maritime activity. Vayia's rugged terrain may be characterised as a karstic limestone landscape, with associated erosional features and thin, stony soil preserved amidst widespread exposures of bedrock. The settlement area lies between 80 and 86m asl, and the sides of the ridge drop precipitously towards the Gulf, furnishing Vayia with a first line of natural defence from attack by sea. The artefacts – pottery, ground and flaked stone – indicate that the promontory was most extensively settled in the Early Bronze Age, with smaller occupations in the Late Bronze (Mycenaean), Classical/Hellenistic and early modern periods.

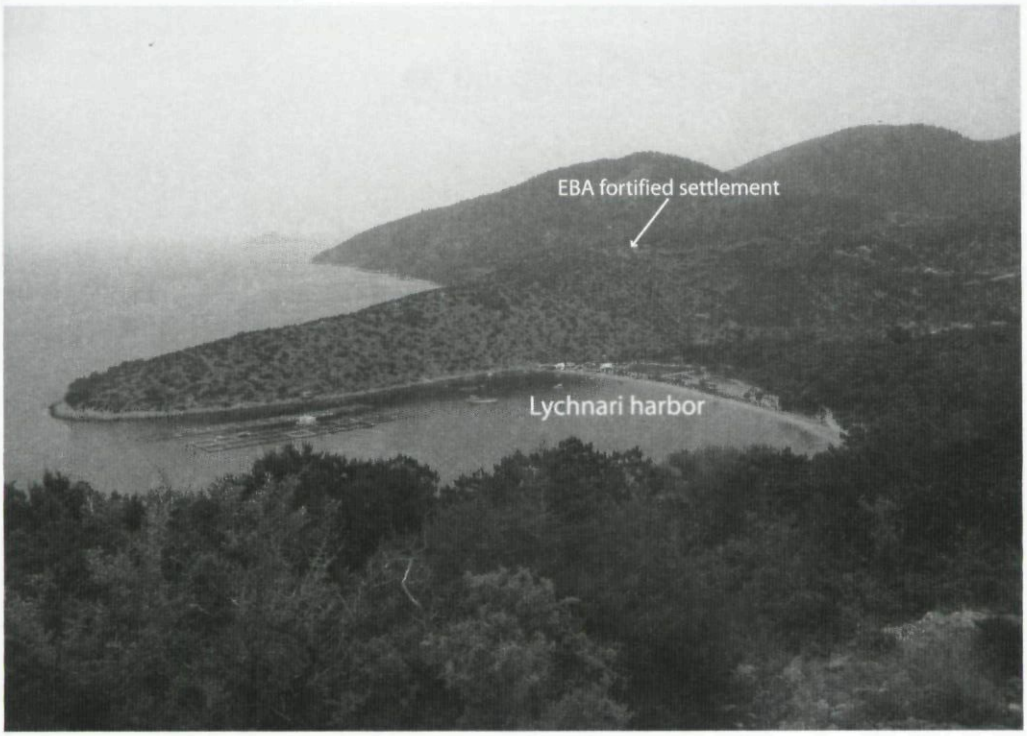

Figure 5. The setting of Vayia from the west, showing the western harbour (Lychnari) and the location of the fortified settlement on the long promontory.

Figure 6. Overview of the archaeological site at Vayia from the south, showing scattered architectural remains.

The modern surface at Vayia is littered with stone architectural remains and terrace walls, many moved from their original locations or otherwise disturbed, amidst a patchy growth of abandoned olive groves and denser thickets of *maquis* vegetation. As a result, the architectural

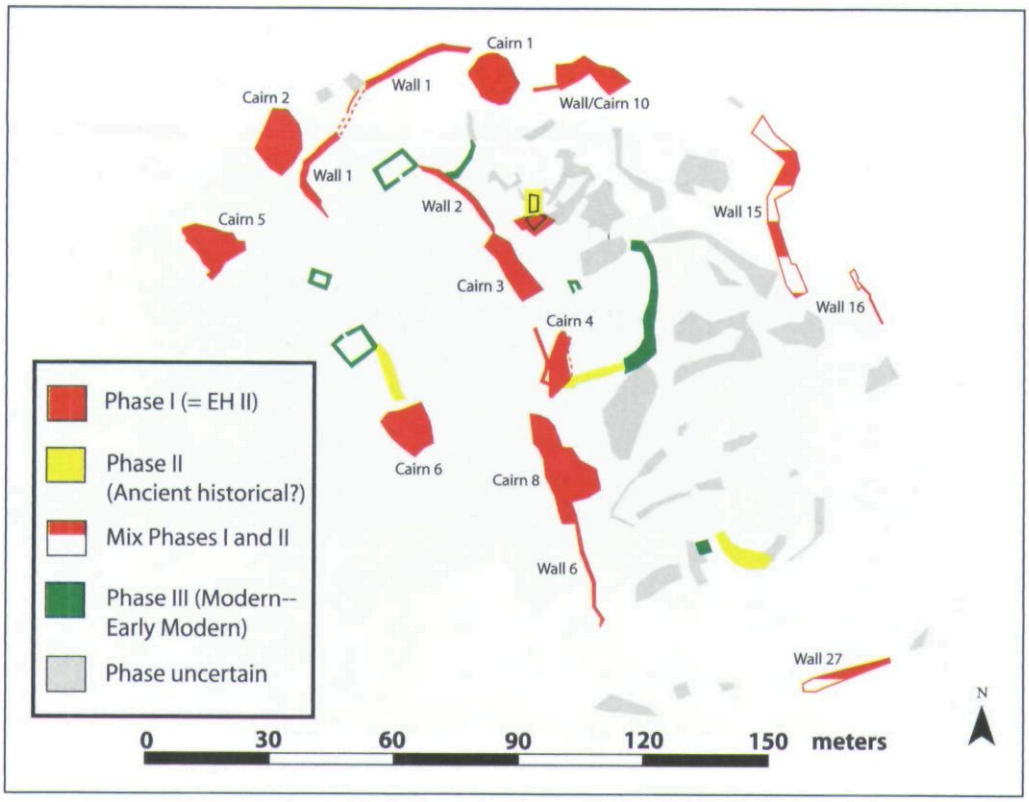

Figure 7. Plan of the mapped architectural remains, with field designations for EH II features.

Figure 8. Panoramic view of the western line of the EH II fortification from the south-west. See Figure 7 for locations.

plans and phases were not readily apparent until we undertook a topographical survey, from which it emerged that four types of architectural remains are present: relatively well-built square structures that we determined to be of early modern date; large heaps or piles of stone rubble, some recognisable as 'cairns'; linear piles of stones; and the foundations of small architectural structures (probably rooms and houses) within the area defined by the cairns. We soon recognised that the linear piles of stone and many of the cairns together formed an enclosure around the approximately 1ha core of the settlement (Figure 7), the linear stone features serving as walls connecting the cairns, which may be interpreted provisionally as bastions or towers (Figure 8). Several cairns are free-standing and located outside the

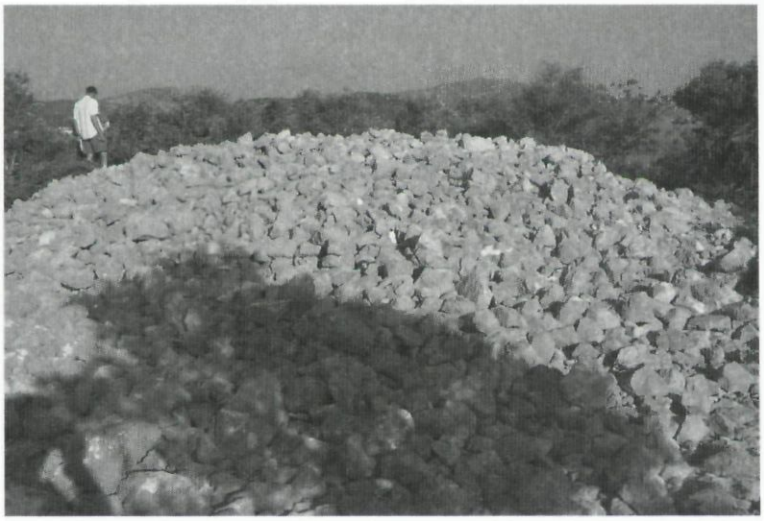

Figure 9. View of Cairn 1, showing materials and current state of preservation.

fortification wall, however, and it is not possible to reconstruct them as elements in a defensive system.

The cairns were created by stacking unworked cobbles and boulders of the limestone that mantles the site and its environs (Figure 9). Some cairns are well over 5m in diameter and 3-4m high, and few have identifiable characteristics, apart from a small central depression. Their original shape may have been rounded, square or rectangular, but today they have a more amorphous appearance as a result of collapse. Close examination revealed that the cores of the cairns contain some amount of earth and broken artefacts, along with post-depositional accumulation of aeolian (wind-transported) sediments in the interstices between stones. Nearly all stones show traces of calcium carbonate ($CaCO_3$) accretion, a significant feature for geomorphological characterisation (see below). Those cairns incorporated into the fortification wall may be understood as the substantial remnants of the lower portions of dry stone masonry towers. The function of those outside the fortification (cairns 2, 5 and 6, and other 'rock smears') is uncertain, but at least one (cairn 5) preserves a linear wall face, suggesting an originally polygonal, rather than amorphous, plan.

The linear wall features are sufficiently preserved to estimate width varying from 0.70 to 2.0m, while the extant height is generally 0.50m or less. It may be that a mudbrick superstructure surmounted the stone foundation, as at other EB II sites, including Lerna and Kolonna, but no such superstructure is preserved. It is possible that two rings of fortification walls surrounded the settlement, an inner enclosure running along the 84m asl contour, represented by cairns 3, 4 and 8, and walls 2 and 6; and an outer wall on the 82m asl contour including cairn 1 and wall 1 (Figure 7), but subsequent disturbances have removed surface evidence for the articulation of the walls' various elements. Double-walled fortifications of EB II are known at Kastri on Syros (Broodbank 2000: 313-6), Palamari on Skyros (Theochari & Parlama 1997) and at Lerna (Wiencke 2000), the latter of the casemate type (Figure 4).

Figure 10. $CaCO_3$-encrusted sherds of EH II date.

Within the walls of the settlement, numerous small architectural units can be discerned, but the confused and highly disturbed remains suggest multiple phases of destruction and rebuilding over time. Although the remains possibly indicate the lack of a planned layout, only through excavation will it be possible to sort out the chronology and changing form of the habitation area.

Artefactual phasing and dating

A basic chronology for the settlement, the fortification wall and the other stone features is provided by artefacts associated with them, and by their geomorphological characteristics. Ceramics of Early Bronze II (known as Early Helladic [EH] II on the Greek mainland) are the most abundant artefacts associated with the cairns and walls, present on their surfaces and in their interiors. Sherds from large, utilitarian *pithoi* and smaller storage jars are the most common forms, some retaining traces of a black 'urfirnis' coating. Less common are other characteristic EH II forms, including fineware sauceboats. Several pieces of andesite grinding stones, almost surely imported from Aegina, were recovered. The artefacts from the interiors of the cairns are exclusively of EBA date, and along with earth materials must have been incorporated during the initial construction. The EH II sherds are also intimately associated with the cairns because, like the stone itself, they are encrusted with a calcium carbonate ($CaCO_3$) accretionary crust (Figure 10). The accretion is found on the surfaces and breaks of the pottery, and matches similar accretions on the cairn stones. $CaCO_3$ accretions are not found on pottery of later periods. Small fragments of worn EH II pottery, concentrated on the south-eastern slope of the site and not directly associated with architecture, include a much higher percentage of finer vessel forms, and probably represent material eroded from inside the settlement and transported downhill.

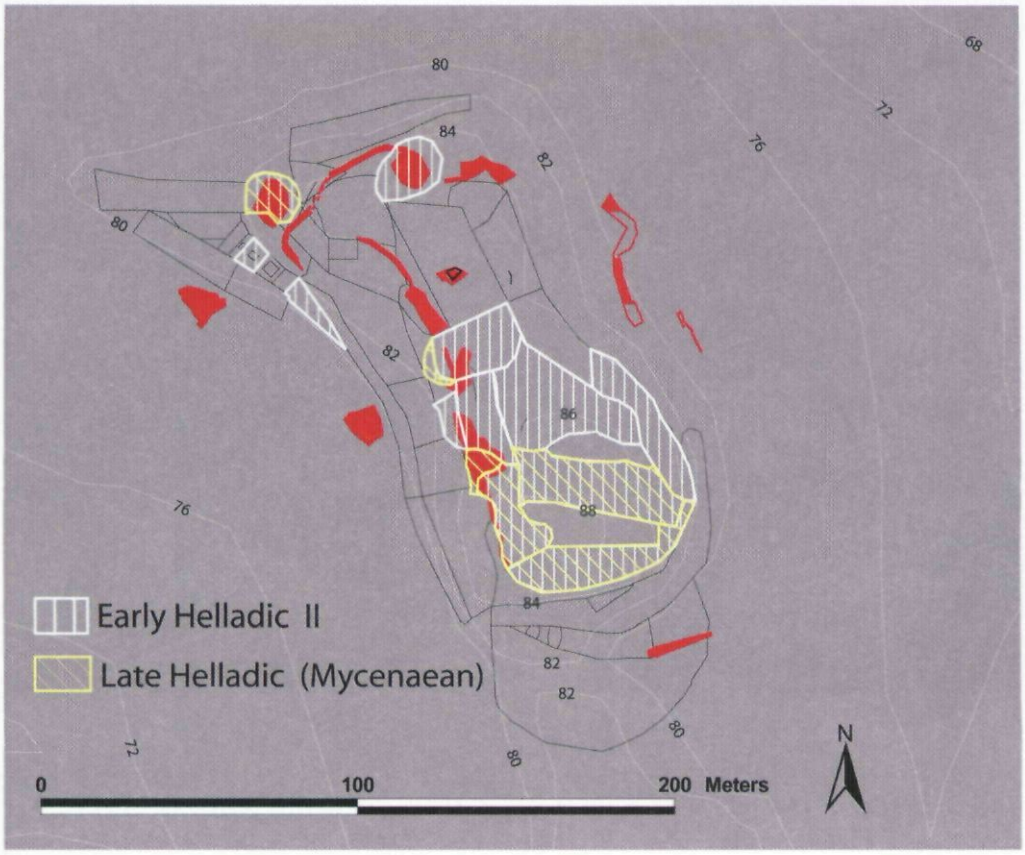

Figure 11. Plan showing the distribution of surface artefact concentrations in the main phases of Bronze Age occupation. The shapes in outline are archaeological survey units.

The archaeological survey data provide an initial impression of the spatial and diachronic patterns of settlement (Figure 11). A sparse background scatter of Final Neolithic–EH I material hints at continuity from a pre-existing community and thus the possibility of indigenous agency in the erection of the fortifications and cairns in EH II. By contrast, several phases following EH II, i.e. EH III and the entire Middle Helladic period, are unknown at the site, a pattern that fits with widespread (though emphatically not universal) abandonment of sites at the end of EH II in the southern Greek mainland (Forsén 1992; Rutter 1993). Approximately a millennium later, a Late Bronze Age (Mycenaean) reoccupation is apparent in the southern part of the site, focused perhaps on the highest point on the ridge, from which Lychnari harbour is best monitored. Classical–Hellenistic activity of the middle to late first millennium BC was fairly extensive in this region, as indicated by stone towers and other structures on the lower slopes overlooking Lychnari, as well as a fortified farmstead on a high ridge overlooking Vayia to the south. At Vayia, Classical–Hellenistic material was also focused on the southern end of the ridge. This later activity involved some reuse and modification of the architectural features; nevertheless, only for EH II is there a strong association between the artefacts and the cairns and linear features, and EH II material

Figure 12. In situ *wall face on cairn 5, showing Phase 1 rillenkarren.*

is more abundant and widely distributed within the fortified area than that of any other period.

Phasing by geomorphology

Geomorphological study of the ridge provides key evidence to support the chronological framework suggested by the artefacts. Limestone exposed on the surface suffers water erosion and other modifications in predictable and physically recognisable ways. Water may fall onto the stone, flow over it, puddle on its top surface and flow down its exposed sides. After flowing over exposed parts of stones, the carbonate-enriched water accumulates on down-turned surfaces, depositing layered accretions and pendants. These conditions create dissolution features, described collectively as *karren* (Ford & Williams 1989: 374-96, Table 9.1), which have implications for human use and reuse of limestone on the site. The stone architecture at Vayia was examined for these and other features, which to our knowledge have not been exploited in Aegean archaeology:

1. *Rillenkarren*, narrow solution channels (rills) formed by the flow of rainfall over the vertical and sloping surfaces of the rock (Figure 12). The development of the rills (length, width and depth) provides a relative measure of the span of time that the rock has been exposed on the surface. The orientation of the rills on a given stone should be vertical if the stone is *in situ*. Any stone with non-vertical rill orientation is known to have been removed from the orientation it possessed during the time of rill formation.

Well-developed rillenkarren indicate surface exposure on the order of thousands of years (Mottershead & Lucas 2001).

2. *Pits and micropits formed on flattish areas of the tops of stones where water has pooled over time.* This feature also shows the orientation of the stone during the period of pit formation.
3. *Preserved soil within a stone feature.* Soil formation or sediment accumulation within a stone feature furnishes a broad measure of the antiquity of the feature as an entity trapping sediment over time. The cairns have collected aeolian sediments since their construction, and the formation of $CaCO_3$ concentrations within these sediments indicates that they have accumulated for thousands of years.
4. *Calcium carbonate ($CaCO_3$) accretions on stones and artefacts.* Over great expanses of time, rainwater dissolves $CaCO_3$ from the carbonate-rich limestone and transports it in solution into the depths of the features, to be precipitated on the stones and artefacts lying within. Such accretions require, at minimum, thousands of years to form (Harden *et al.* 1991: 5). The association of $CaCO_3$-coated EH II sherds with the similarly coated cairn stones was noted above.
5. *Weathering colour of the stone.* The stone (bedrock and anthropogenically modified) exposed longest on the surface has taken on a dark grey surface colour, whereas more recent structures, such as the early modern houses, have a white to light grey colour with reddish stains on quarry faces. Some reuse of stones from much older structures was noted. The darkening is due to the development of an algal coating, minute black and solitary lichens, accumulation of varnish (a biological precipitate of Fe and Mn oxides and organic matter) and alteration of minerals in the limestone (Smith *et al.* 2000).
6. *Lichen formation.* Stones exposed for more than 20-50 years in Greece are colonised by crustose lichens (Noller, unpublished data) that develop a rock-hugging, disk morphology at a rate that is species dependent and typically of the order of 0.01-1.0mm growth in diameter per year (Noller & Locke 2000). The percentage of the surface area covered by lichens and the composition of species (more than five are common in the area) also change with time. Lichens can be subjected to numerical dating, but for our present purposes indicate relative age.

On the basis of these features, which we take to be indicators of age and orientation of surface exposures, we recognised two classes of geomorphic feature that define distinct phases of formation of architectural features in antiquity. Stone exposed more recently, for example in early modern to modern times, essentially lacks these features and postdates these two phases.

The first phase (Phase 1) comprises stone with long, well-developed rillenkarren, pitting, dark grey weathering colour, commonly substantial lichen cover and diameter and thick $CaCO_3$ accretion. Throughout the site, exposed bedrock exhibits these features, though bedrock exposed more recently than the first phase may not. The attributes noted on first-phase bedrock are matched on the large cairns for which we have compelling archaeological evidence for construction in EH II. In fact, every feature from which we extracted $CaCO_3$-coated EH II pottery exhibits Phase 1 surfaces. Because the bedrock and EH II features have developed similar morphological features, they must have been exposed for a comparable

Figure 13. Central cairn, Vassa. Compare with Figure 9.

length of time. In geomorphological terms, this suggests a scenario in which the Early Bronze Age inhabitants quarried or cleared the limestone from the site and its environs, exposing bedrock to these formational processes at roughly the same time that they built the large stone structures. Dramatic confirmation comes from cairn 5 (Figure 12). This cairn has a well-preserved wall face that exhibits clear Phase 1 rillenkarren that demonstrate that the face is *in situ*. The deep rills run in perfect orientation from one stone to the stone beneath it, indicating that the wall face has remained in place over the entire time of formation of the rillenkarren. Cairn 5 yielded EH II pottery sherds with substantial $CaCO_3$ accretions from both the surface and the interior. An important implication is that wherever we encounter *in situ* Phase 1 stone that forms part of an anthropogenic feature, that stone came to rest in a broad Early Bronze Age time frame, and has not moved since. Because this observation applies to wall collapse as well as preserved wall faces, we have suggestive evidence that the cairns and bastions experienced collapse or destruction in the Early Bronze Age or not much later.

The second phase (Phase 2) stone shows fewer Phase 1 attributes, and these are less developed. Notable on limestone of Phase 2 are more shallow rillenkarren, some pitting and some lichen development. The rills tend to be fewer in number and more widely spaced than on Phase 1 surfaces. The second phase appears to typify the known Classical period (broadly defined) architecture in the region surrounding Vayia, furnishing a rough approximation of the time scale for the development of Phase 2 geomorphological features. Some linear stone features on the site contain a mixture of Phase 1 and Phase 2 stone, perhaps indicating later repairs to the EH II walls.

Vassa

In the summer of 2003, while visiting a known Mycenaean site at Vassa, a few kilometres inland from the small Saronic harbour at Nea Epidavros, we stumbled upon the extensive remains of an EBA site possessing the same characteristics as the fortified settlement at Vayia. The EBA site at Vassa is situated on a prominent ridge (approximately 175-185m asl) overlooking the Dimaina pass, one of the main overland routes from the Saronic coast through the rugged interior of the Argolid to the major Bronze Age centres in and around the Argive Plain, including Tiryns and Lerna. As at Vayia, the basic architectural layout is formed by numerous stone cairns arranged in a rough oval and connected by linear stone piles, but here there is also a larger, central cairn within the stone enclosure (Figure 13). The central clearing, presumably the habitation area, is similar in scale to that of Vayia at around 1ha. There appears to be more than one concentric ring of cairns and walls, as we

suspect at Vayia, and the overall scale of the remains, with 15-20 cairns that we could discern in heavy maquis vegetation over 2-3ha, may be greater. Anthropogenic disturbance of the stone features seems less severe than at Vayia, with the result that the clearance of stone away from the relatively boulder-free interior is more obvious to the eye. On the whole, Vassa looks to be better preserved of the two sites and should reward careful study.

A brief examination of the cairns revealed Early, Middle and Late Bronze Age pottery on their surfaces. The EH II pottery is abundant and similar to that of Vayia in the range of forms and in the presence of $CaCO_3$ accretions; of particular interest is an EH II roof tile fragment from the central cairn. A small number of sherds from EH I imply that, as at Vayia, the fortified settlement may have succeeded an earlier hamlet. Some connection with Aegina is suggested by numerous fragments of andesitic grinding stones. A preliminary viewshed analysis indicates that Vassa, located 3km inland with limited glimpses of the sea, was situated primarily to control east–west movement through the Dimaina pass, and perhaps also to monitor movement to and from the uplands of the Corinthia to the north.

Preliminary interpretation

Vayia and Vassa seem to represent a previously unrecognised class of EBA fortified settlement, which for reasons of poor archaeological visibility and chronological uncertainty has been neglected and may be widespread. The respective locations of Vayia and Vassa show that they were part of at least a regional, and not simply a local, phenomenon. Although the cairns and walls give a good impression of their general size and shape, we are almost entirely ignorant of the layout and use of domestic space within the walls. The architectural traces at Vayia suggest the type of agglomerative, tightly packed residential zone that one finds at Kolonna (Phase III) and the Cycladic fortified sites, but this question will only be resolved through excavation. If the cairns incorporated into walls served as bastions or towers, the function of the free-standing cairns is far less certain. Perhaps they were simply the practical result of land clearance, but other interpretations such as burial cairns are plausible, though currently unverifiable. The geological evidence was pivotal in identifying the morphological characteristics of the cairns, and demonstrating their prehistoric age.

The EH II settlement at Vayia shows clear affinities with contemporary fortified and unfortified sites on the Aegean coast and islands. The setting, a flattish coastal promontory with a relatively steep seawards approach adjacent to a superb harbour, betrays a common concern for defensibility and a broad viewshed, but also easy access to the sea. Like Vayia, many coastal sites were founded on rugged terrain at some remove from extensive tracts of arable agricultural land – an indication of the community's maritime orientation. The oval shape and modest size, approximately 1ha, of the fortified habitation, place Vayia in a widespread group of EB II Aegean settlements at a scale beneath the large to truly enormous settlements that are known from the Greek mainland and Euboia, including unfortified sites at Lithares (3.5ha), Eutresis (8ha) and Tiryns (5.9ha), and fortified sites at Lerna (2.5ha), Thebes (20ha) and Manika (45ha). All the known Aegean fortified sites are coastal except Thebes, and those of a size similar to Vayia are found in Attica, including Askitario and Rafina, in Euboia, such as Karystos and in the islands, including Kastri

on Syros, Panormos and Spedos on Naxos, Palamari on Skyros, and Kolonna on Aegina. Free-standing fortification walls with projecting bastions or towers are characteristic of defensive architecture in the Aegean islands, as at Kastri, Panormos and Palamari. Vayia's double fortification wall, if indeed we have reconstructed it correctly, finds good parallels at Kastri and Palamari. The rather slender walls joining the bastions at Vayia would not appear to have offered an effective defence against concerted attack, but here too they fit well with the Cycladic fortification walls, most of which are less than 1.5m wide. This probably reflects the sporadic nature of EBA raiding in the southern Aegean (Branigan 1999; Doumas 1990).

Nevertheless, there are no exact parallels in the Aegean for the cairns and other constructions at Vayia and Vassa. The closest comparanda in south-eastern Europe are the stone cairns and cairnfields of coastal and near-coastal Dalmatia (Chapman *et al.* 1987, 1996; Maran 1998). These monuments take the form of isolated cairns, linear stone features, and cairnfields of up to several hundred concentrated cairns and linear features. The earliest of the Dalmatian cairns belong to the Earlier Bronze Age (2400-1800 BC), thus possibly overlapping chronologically with the latter years of EH II, but most date to the Later Bronze Age or Iron Age. The emergence of the Bronze Age cairns is associated there with an agricultural expansion involving a new strategy of cultivating marginal land on 'stony' ridges; specifically, the clearance of stone for agriculture and the desire to lay claim to the newly cultivated land through highly visible landscape markers (Chapman *et al.* 1996: 270-1). Such 'clearance cairns', piles of stones removed from the surface or plough zone, were created initially to facilitate cultivation, but some were used in the Bronze Age as burial cairns (Chapman *et al.* 1987: 125). In time, the cairns may have become focal points for ritual surrounding the fertility of the earth, and symbolic representations of social power over domestic, agricultural and mortuary (or ancestral) space (Chapman *et al.* 1996: 284-5). Linear stone features were transformed into settlement enclosures and ultimately to hillforts (Chapman *et al.* 1987: 129). In spite of certain morphological similarities, the enduring tradition of Dalmatian cairn architecture is reflected neither in scale nor in longevity in the southern Aegean, and there is little evidence for cultural contact in the EBA by which such ideas would have been transmitted.

Conclusions

An obvious strategy to resolve the questions posed by the architectural features at Vayia would be to excavate in and around them, but this is not an easy matter. Severe restrictions on the number of foreign archaeological permits in Greece mean that no return to the site may be contemplated before 2008. Nevertheless, we were able to move a long way forward by combining careful survey methods with geoarchaeological observation of the formational characteristics of the limestone. Over millennia, limestone architecture in karstic regions tends to form confusing palimpsests reflecting numerous episodes of human construction and destruction, as well as pervasive natural erosion. The case of Vayia shows, however, that it may be possible to establish both relative and absolute chronological frameworks for sites occupied over long expanses of time. The variable development of karren features provides data for relative chronological sequences of architectural remains. Broad chronometric

frameworks are possible by dating lichen and $CaCO_3$ concentrations associated with architectural features. If artefacts of known date can be convincingly associated with architectural features, greatly refined absolute dates or *termini post quem* are within reach. At Vayia, we were able to assign an EBA date to Phase 1 architecture with, but also without, associated artefacts. These efforts were integrated with intensive surface survey and site mapping to provide a very good initial sense, without excavation, of the scale, function and occupational history of the settlement.

The success of this approach holds significant implications for archaeology in karstic landscapes of the Mediterranean region and beyond. First, archaeologists should be attentive to seemingly amorphous stone concentrations that have often been left unexamined or interpreted as modern terraces or field clearance. We recognised the plan of the fortified settlement at Vayia only during the process of creating a site plan, but this experience permitted us to recognise Vassa immediately as a similar phenomenon. Second, the geochronological approach described here holds great promise where substantial stone-built structures yield limited artefactual or stratigraphic evidence for their date. In cases where recourse to excavation may be problematic or impractical in the short term, these simple geomorphological observations may furnish a general chronological framework that can be tested in future studies. Systematic characterisation of formational features on limestone architecture at a regional scale, correlated with chronological information from excavation or artefact association (as at Vayia), would produce an excellent comparative dataset. These strategies would be especially useful in the context of regional survey archaeology.

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References

BRANIGAN, K. 1999. The nature of warfare in the southern Aegean during the third millennium B.C., in R. Laffineur (ed.) *Polemos: le contexte guerrier en Égée à l'âge du bronze, Aegaeum* 19: 87-94. Liège: Université de Liège.

BROODBANK, C. 2000. *An island archaeology of the early Cyclades*. Cambridge: Cambridge University Press.

CHAPMAN, J., R. SHIEL & Š. BATOVIĆ. 1987. Settlement patterns and land use in Neothermal Dalmatia. *Journal of Field Archaeology* 14: 123-46.

–1996. *The changing face of Dalmatia: archaeological and ecological studies in a Mediterranean landscape*. London: Leicester University Press.

Doumas, C. 1990. Weapons and fortifications, in L. Marangou (ed.) *Cycladic culture: Naxos in the 3rd millennium BC*: 90-2. Athens: Nicholas P. Goulandris Foundation.

Felten, F. 1986. Early urban history and architecture of ancient Aigina, in R. Hägg & D. Konsola (ed.) *Early Helladic architecture and urbanization, proceedings of a seminar held at the Swedish Institute in Athens, June 8, 1985*: 21-8. Göteborg: Paul Åström.

Ford, D. & P. Williams. 1989. *Karst geomorphology and hydrology*. London: Unwin Hyman.

Forsén, J. 1992. *The twilight of the Early Helladics: a study of the disturbances in east-central and southern Greece towards the end of the Early Bronze Age*. Jonsered: Paul Åström.

Harden, J., E. Taylor, M. Reheis & L. McFadden. 1991. Calcic, gypsic, and siliceous soil chronosequences in arid and semiarid environments, in W. Nettleton (ed.) *Occurrence, characteristics, and genesis of carbonate, gypsum, and silica accumulations in soils*: 1-16. Madison: Soil Science of America Special Publication No. 26.

Konsola, D. 1986. Stages in urban transformation in the Early Helladic Period, in R. Hägg & D. Konsola (ed.) *Early Helladic architecture and urbanization, proceedings of a seminar held at the Swedish Institute in Athens, June 8, 1985*: 9-19. Göteborg: Paul Åström.

Maran, J. 1998. *Kulturwandel auf dem griechischen Festland und den Kykladen im späten 3. Jahrtausend v. Chr. : studien zu den kulturellen Verhältnissen in Südosteuropa und dem zentralen sowie östlichen Mittelmeerraum in der späten Kupfer- und frühen Bronzezeit*. Bonn: R. Habelt.

Mottershead, D. & G. Lucas. 2001. Field testing of Glew and Ford's model of solution flute development. *Earth Surface Processes and Landforms* 26: 839-46.

Nilsson, M. 2004. *A civilization in the making: a contextual study of Early Bronze Age Corridor Houses in the Aegean*. Unpublished PhD dissertation, Göteborgs Universitet.

Noller, J. & W. Locke. 2000. Lichenometry, in J. Noller, J. Sowers & W. Lettis (ed.) *Quaternary geochronology: applications*: 261-72. Washington, D.C.: American Geophysical Union Reference Shelf 4.

Pullen, D. 1986. A 'House of Tiles' at Zygouries? The function of monumental Early Helladic architecture, in R. Hägg & D. Konsola (ed.) *Early Helladic architecture and urbanization, proceedings of a seminar held at the Swedish Institute in Athens, June 8, 1985*: 79-84. Göteborg: Paul Åström.

–2003. By land or by sea: Chalcolithic and Early Bronze Age settlements in southern Greece and the Aegean Sea, in D. Gheorghiu (ed.) *Chalcolithic and Early Bronze Age hydrostrategies, Actes du XIVème Congrès UISPP, Université de Liège, 2–8 septembre 2001*: 25-9. Oxford: Tempus Reparatum (BAR-IS 1123).

Renfrew, A.C. 1972. *The emergence of civilisation: the Cyclades and the Aegean in the third millennium BC*. London: Methuen.

Rothaus, R., E. Reinhardt, T. Tartaron & J. Noller. 2003. A geoarchaeological approach for understanding prehistoric usage of the coastline of the eastern Korinthia, in K. Foster & R. Laffineur (ed.) *Metron: measuring the Aegean Bronze Age, proceedings of the 9th International Aegean Conference*: 37-47. Liège: Université de Liège.

Rutter, J.B. 1993. Review of Aegean prehistory II: the prepalatial Bronze Age of the southern and central Greek mainland. *American Journal of Archaeology* 97: 745-97.

Shaw, J. 1987. The Early Helladic II Corridor House: development and form. *American Journal of Archaeology* 91: 59-79.

Smith, B., P. Warke & C. Moses. 2000. Limestone weathering in contemporary arid environments: a case study from southern Tunisia. *Earth Surface Processes and Landforms* 25: 1343-54.

Tartaron, T., T. Gregory, D. Pullen, J. Noller, R. Rothaus, J. Rife, L. Diacopoulos, R. Schon, W. Caraher, D. Pettegrew & D. Nakassis. In press. The eastern Korinthia archaeological survey: integrated methods for a dynamic landscape. *Hesperia*.

Tartaron, T., R. Rothaus & D. Pullen. 2003. Searching for prehistoric Aegean harbors with GIS, geomorphology, and archaeology. *Athena Review* 3 (4): 27-36.

Theochari, M. & L. Parlama. 1997. Παλαμάρι Σκύρου: η οχυρωμένη πόλη της πρώιμης Χαλκοκρατίας, in C. Doumas & V. La Rosa (ed.) Η Πολιόχνη και η πρώιμη εποχή του Χαλκού στο βόρειο Αιγαίο Poliochni e l'antica età del bronzo nell'Egeo settentrionale: 344-56. Athens: Scuola Archeologica Italiana di Atene.

Weingarten, J. 1997. Another look at Lerna: an EH IIB trading post? *Oxford Journal of Archaeology* 16 (2): 147-66.

Wiencke, M.H. 1989. Change in Early Helladic II. *American Journal of Archaeology* 93: 495-509.

–2000. *Lerna IV: the architecture, stratification, and pottery of Lerna III*. Princeton: American School of Classical Studies at Athens.