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An agro-pastoral palimpsest: new insights into the historical rural economy of the Milesian peninsula from aerial and remote-sensing imagery

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Abstract

Examination of a number of satellite and aerial images of the Milesian peninsula has allowed the mapping of a large number of apparently ancient linear features across the landscape. These are here interpreted, for the most part, as relicts of agro-economic field systems of unknown date, but most plausibly established during the Archaic, Hellenistic or late antique periods and perhaps used for centuries after, before the economic decline of the region in the second millennium AD. While earlier survey work has noted the existence of terracing and rural divisions at certain points in the landscape, the new remote-sensing data have provided an unprecedented large-scale insight into the extent and variety of forms of division, as well as documenting the stripping of macquis overgrowth by modern farming practices, which has, on the one hand, exposed these ancient landscapes but also, on the other, poses a threat to their preservation. The extent of the linear features suggests a high degree of land use on the peninsula at certain points in the past. Further investigation of these important features has the potential to provide critical insights into the economic history of rural and urban Miletos over the last 2,000 to 5,000 years.

Özet

Milet yarımadasına ait bir dizi uydu görüntüsünün ve hava fotoğrafının incelenmesi ile arazi boyunca uzanan çok sayıdaki antik lineer özellik haritalanabilmiştir. Bunlar, çoğu zaman, tarihi belli olmayan tarımsal-ekonomik alan sistemlerinin kalıntıları olarak yorumlanmıştır, ancak en makul açıklama çoğunun Arkaik, Hellenistik veya geç antik dönemlerde kurulmuş olduğu ve belki de M.S. ikinci binyıldaki ekonomik çöküşe kadar yüzyıllar boyunca kullanılmış olduklarıdır. Daha önceki yüzey araştırmaları, arazinin belirli noktalarda teraslama ve kırsal bölünmelerin varlığına dikkat çekmiş olsa da, uzaktan algılama sistemlerinin kullanımı ile ortaya çıkan yeni veriler, bizlere bir yandan bölünme biçimlerinin kapsamı ve çeşitliliği hakkında geniş çapta bilgiler sunmuş, diğer taraftan da, her ne kadar ortaya çıkmış olan kalıntıların korunması açısından büyük tehdit teşkil etse de, modern tarımsal faaliyetler sonucu ortaya çıkmış alanların belgelenmesi imkanını sağlamıştır. Lineer özelliklerin kapsadıkları alan, geçmişte yarımadanın belirli noktalarında büyük ölçüde arazi kullanımı olduğunu göstermektedir. Bu önemli özelliklerin daha fazla araştırılması, son 2.000 ila 5.000 yıl boyunca, kırsal ve kentsel Milet'in ekonomik tarihine ilişkin çok önemli görüşler sağlama potansiyeline sahiptir.

Traditionally, archaeologists have spent a large proportion of their research efforts recording and discussing the architectural monuments of ancient cities over their rural counterparts, both because they are usually better preserved on the ground, or at least visually more impressive, and also because of the lingering effects of the primacy of powerful historical genres whose epistemological driver is the narrative agency of kings and their palaces. Bottom-up historical narratives, many of them Marxian in inspiration, that focus on rural and peasant roles in the levers of history inevitably must deal with this same skew in the archaeological record toward urban and usually elite-associated monuments. Of course, in most ancient contexts it would be wrong to draw too strong a distinction between urban and rural dynamics. Urban populations were necessarily entirely dependent on rural hinterlands, albeit that the effective hinterland of different cities may have varied immensely. At the extreme end, Imperial Rome at its peak was dependent to a huge degree on imported grain from Egypt – so when talking about the Roman 'countryside', it would be a mistake to consider Latium only. Different transport and food preservation technologies (for example salting) may have allowed some Greek and Roman cities to create long food-exchange chains, but for most cities the effective agro-economic hinterland was naturally much smaller. Despite the rise of regional-scale archaeological landscape studies over the last 30–40 years across the Mediterranean, which one might hope would have brought these rural hinterlands into better relief, the results of these studies remain poorly integrated into wider historical narratives, especially for the classical periods (with some exceptions, for example Alcock 1993). Cross-disciplinary studies of historical (and archaeological) geographies represent a laudible corrective, such as Peter Thonemann's *The Meander Valley* (2011), even if the analysis falls short of integrating available palaeoenvironmental data (cf. Knipping et al. 2008). Of course, sometimes archaeological technologies can suddenly open previously inconceivable or unexpected windows onto the past. The new data presented here, from a region where one might expect little to be left unknown, form precisely one such case.

The Milesian peninsula has been a focus of historical enquiry for over 200 years, ever since early antiquarian visitors reported their searches for remains of the ancient city of Miletos and the oracle sanctuary at Didyma. At the turn of the 20th century, a detailed topographic and architectural survey was launched for the entire peninsula, as part of the first systematic research programme on the peninsula led by Theodor Wiegand, a German scholar resident in what were then Smyrna and Constantinople (modern Izmir and Istanbul respectively). The survey, undertaken and published by Paul Wilski (1906), documented topography, identified standing ancient and recent remains, architectural spolia, water sources and the course of an apparently ancient street which cut the low Stefania (ancient Akron) ridge that splits the peninsula into northern and southern parts. This street has subsequently been associated with the 'Sacred Way' described in Hellenistic and Roman textual sources (see Slawisch, Wilkinson 2018). Impressively precise and comprehensive for its time, the survey's findings stand as evidence for a higher degree of landscape use in the past than was observed at the beginning of the 20th century. The work was so comprehensive, however, that no sustained attempt to update its findings was made until the 1990s, when a team led by Hans Lohmann undertook an extensive archaeological survey in the Milesian chora. This project aimed to synthesise and confirm various localised studies undertaken on the peninsula in the intervening years, provide a more detailed distribution map that would take account of the improved understanding of the dating of surface archaeological finds (including ceramics and prehistoric finds such as obsidian) and (in the latter years of the survey) take advantage of the newly demilitarised technology of GPS to locate sites more accurately and precisely. Though a final report of this survey remains in preparation, the interim reports (Lohmann 1995; 1997b; 1999) provide useful insights into the overall intensity of human occupation over the *longue durée*, with the sites recorded dating from the Late Chalcolithic to the Ottoman period and a particularly high number of sites identified as Roman or late Roman/early Byzantine (for a summary interim site catalogue, see Lohmann 1999).

Lohmann's preliminary reports also note a number of sites (including, S57, 70, 106, 107, 108, 109, 111, 112, 113, 117, 123, 132, 163, 178, 188, 193, 195, 220, 238, 239, 245, 399, 406, 411, 447) with terrace walls, field boundaries (*Mauerspuren*, *Flurgrenzen*) and/or what he calls *mandra* (from the ancient Greek for an enclosure or pen for animals). Some of these were associated with antique and/or late antique materials, although Lohmann is necessarily cautious about the dating (fig. 1). According to the survey results, oil presses, wells and cisterns are also commonly distributed across the landscape. Miletos, described as the 'Ornament of Ionia' by Herodotus (5.28), was one of Asia Minor's major economic and cultural powerhouses, especially during the Archaic period (ca 700–500 BC), when its residents were responsible for the foundation of colonies across the Mediterranean and Black Sea regions (Ehrhardt 1983; Herda 2008). This colonisation process and the city's long-term success as a textile town must have depended on a thriving local supply chain to support the mother city and its visitors. Making sense of these otherwise unprepossessing rural structures is therefore critical to make sense of the base Milesian economy through time (Röhling 1933; Pečírka 1971); most importantly: what was their purpose?

Lohmann addressed this question directly in 2008 in an article titled 'Altflur oder Pingenfelder', in which he weighs up his interpretation of these structures as agronomic field plots or pens (*Altflur*) against an alternative industrial suggestion put forward by Gregor and Barbara Borg (2003). The geological surveys undertaken by the Borgs across the central and southwestern areas of the peninsula identified (or re-identified) stone quarries in the form of 'pit fields' (*Pingenfelder*), as well as lines of piled up, irregularly shaped stones, which they identify as the discarded chippings from limestone quarrying. They suggest that the apparent linear or rectangular nature of these lines, visible in oblique aerial photography (see fig. 2), was simply a by-product of the method of extracting

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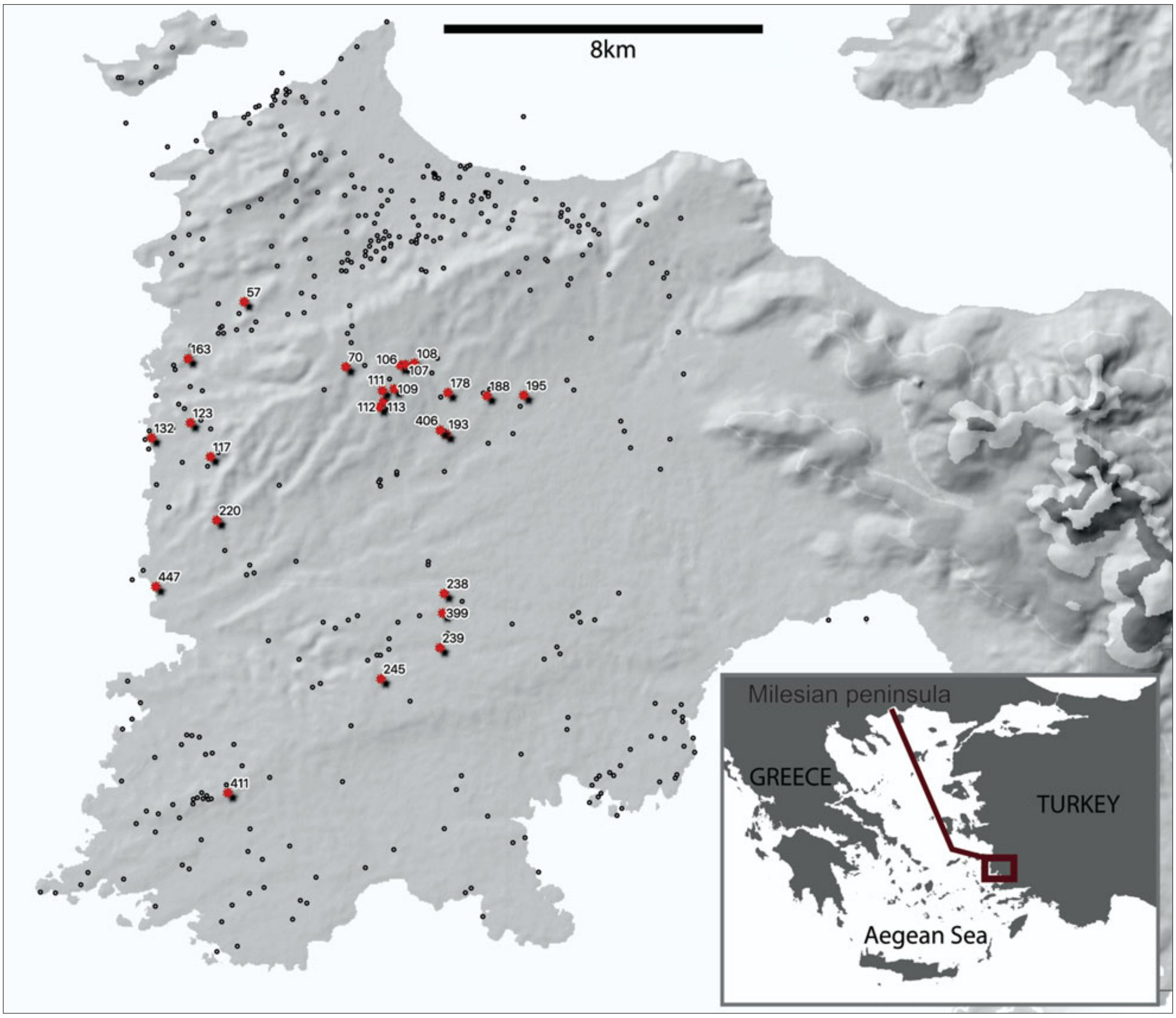

Fig. 1. Topographic map of the Milesian peninsula, with ancient coastline at approximately 200 BC; black dots represent pre-modern sites identified by the Milesian Chora Survey (Lohmann 1999); red stars represent places described as mandra *or with terrace walls in the survey catalogue (Lohmann 1999) and include site numbers. Elevation data derived from ASTER GDEM2. Inset: location of the Milesian peninsula.*

stone from pits and depositing waste at their edges, and interpret the density of these linear features as an indication of the large-scale industrial exploitation of low-quality limestone for building material for the Didyma complex, an activity with, in their opinion, serious environmental consequences. In contrast, Lohmann argues that, while quarrying was certainly undertaken on the peninsula in antiquity, the scale of the linear features and their association with archaeological remains link them more plausibly with agronomic features, with sites such as S108 at the western end of the Stefania plateau (see also fig. 1) perhaps comparable with the pastoral installations (for example, shepherding stations) previously documented by Wolfgang Radt in the 1970s on the nearby Bodrum peninsula (Radt 1970; Lohmann 1997a) and others employed in the cultivation of crops of different kinds. The environmental degradation of the peninsula, leading to the relatively unproductive wasteland encountered by Wiegand at the beginning of the 20th century, is, according to Lohmann, a result of forest clearance and agricultural over-exploitation rather than the effects of over-quarrying.

Since Lohmann completed his extensive survey of the Milesian chora, evidence for more linear structures has come to light as a result of serendipitous, albeit destructive, trends in modern agricultural exploitation of the peninsula over the last few years. Whilst there is no replacement for on-the-ground examination of structures, or indeed their excavation and scientific analysis, especially in terms of dating, recent advances in remote-sensing data availability and analysis have bought these features sharply into focus: linear features

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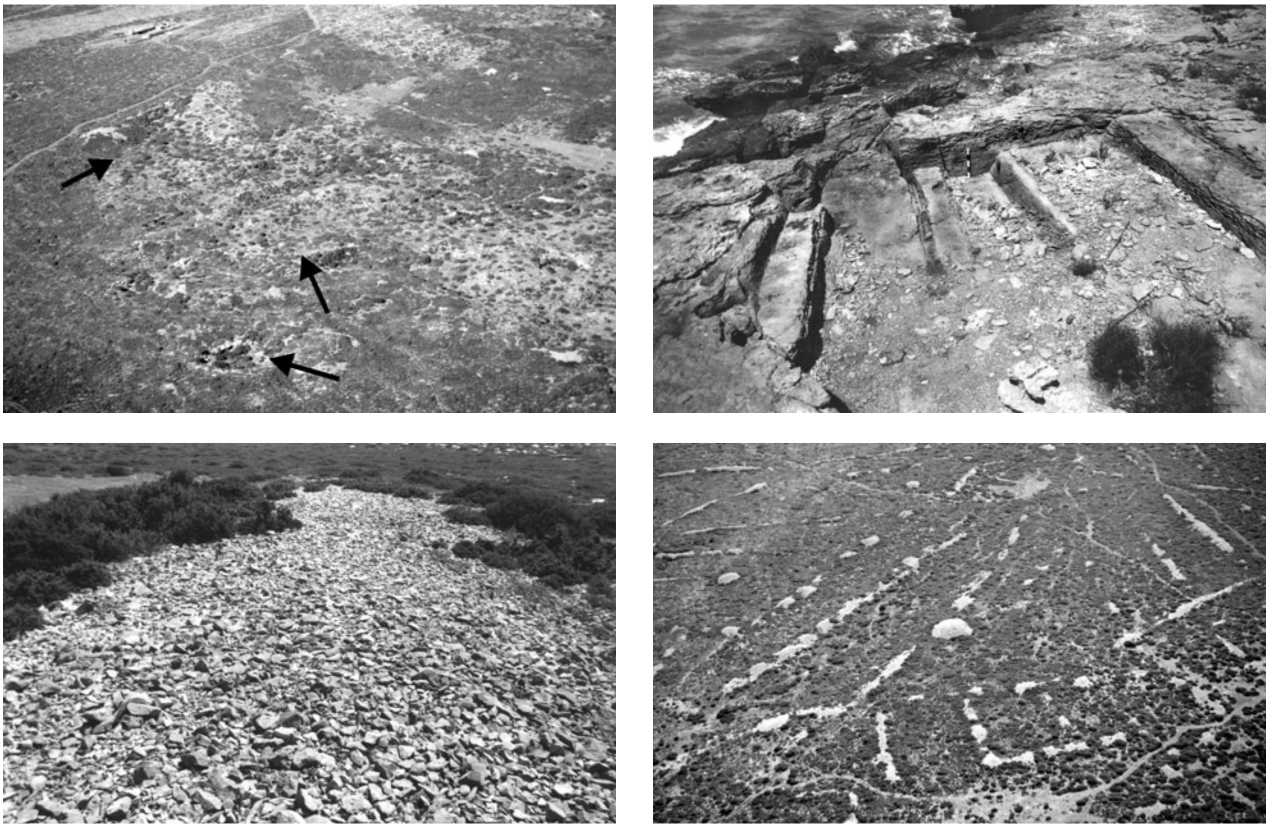

Fig. 2. Stone cairns, pits and embankments in different regions of the peninsula. Top: cuts and pits interpreted as ancient 'micro-quarries' (Borg, Borg 2003: 433, figs 3, 5); bottom: linear embankments of limestone flakes interpreted by the Borgs as waste piles from systematic quarrying of stone (Borg, Borg 2003: 433, figs 9, 10), but as field enclosures by Lohmann (2008) and here. See also figure 8 for approximate locations of 'extensive pit-fields' of limestone, according to the Borgs (Borg, Borg 2003).

with a total length of at least 300km can now be drawn across the Milesian landscape. This article describes the method used to map these features, outlines their general shapes and dimensions, and provides an interim assessment of their function, formation and significance.

Mapping the ancient linear landscape features

The origins of the current study lie in rescue excavations begun in 2012 on a recently identified Archaic Greek necropolis near the ancient harbour of Panormos, modern Mavişehir (Didim, Turkey). As part of this work, funded by the Istanbul Department of the German Archaeological Institute (DAI) between 2012 and 2015, and undertaken in collaboration with the local archaeological museum at Balat (Milet Müzesi), a section of multispectral WorldView-2 satellite imagery was acquired from Digital-Globe in order to facilitate contextual understanding of the necropolis in its landscape. Taken on 4 September 2011, and with a horizontal resolution of 0.5m per pixel, the image was later also purchased by Google from Digital-Globe and included in its mosaic of images on the digital-globe platforms, Google Maps and Google Earth (and can still be viewed by enabling the 'Historical Imagery' feature). Examining the image, we noticed a number of linear features within the dense macquis-vegetated area in the eastern portion of the image (fig. 3). On the ground, these features were obscured by high macquis and were apparently inaccessible.

Growing out of the rescue excavations, a pilot survey was conducted in 2015 under the aegis of Project Panormos; a further season of survey was undertaken in 2017. Satellite imagery, such as Google's, was used to help plan the survey. Given the level of recent building works in the area, especially since the 1980s as a result of the region's development as a major seaside resort, it was realised that historical imagery might provide a useful adjunct for identifying unknown archaeological features that may have been masked by subsequent changes. Suitable declassified CORONA imagery was not available (such imagery is available for other areas of the wider region and has provided insights into fossilised prehistoric landscapes, like that of the Early Bronze Age urban network of roads in northern Syria: Ur 2003); thus other remotely sensed data were sought. In 2016, a small sample

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of aerial photographs taken by the Turkish airforce in the late 1960s and early 1970s was purchased from the archive of the Haritacılık Genel Komutanlığı (the Turkish military mapping office). Comparison between these photographs and modern satellite imagery offers dramatic documentation of the growth of the town of Didim and its suburbs. Further linear features were identified in the aerial photographs of the southwestern corner of the peninsula (fig. 4); these had not initially been spotted because they are less clearly defined in the more recent WorldView-2 satellite imagery due to the dense vegetation. Digitisation commenced of a number of these features (undertaken by project assistant Michael Loy), though, in the absence of full-scale orthographic photogrammetry of the aerial images at the time, the level of accuracy was limited.

In 2018, we re-examined the data that had been collected in relation to these linear features with a view to completing the project, and noted that the latest Bing Maps Aerial View imagery (as of June 2018) offered higher resolution and greater clarity, perhaps in part due to the time of year the imagery was collected (although the collection date and source is not clearly specified, the Bing Maps imagery is probably derived from DigitalGlobe's multispectral satellite imagery archive and, based on comparison made using DigitalGlobe's own browsing tool at https://discover.digitalglobe.com/, it may be identical to the WorldView-2 image captured on 15 April 2015, image ID 1030010041D62500). This provided a much more accurate location of the identified linear features than the ungeoreferenced historical aerial photography. More strik-

Fig. 3. Aerial view of linear features: DigitalGlobe WorldView-2 image, 4 September 2011 (reproduced with permission).

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Fig. 4. Aerial view of linear features: photograph from the archive of Turkey's Haritacılık Genel Komutanlığı, taken in 1972 (HGK, rulo 2569 no. 7152) (reproduced with permission).

ingly, clearance of large plots of macquis vegetation in the winter of 2015, especially on the plateau ridge of the Stefania hills, laid bare linear features that had been more or less entirely obscured by overgrowth until at least the end of 2014 (based on comparison with a thumbnail image of the WorldView-3 image captured on 3 November 2014, image ID 1040010004476A00). In order to enable digitisation, data from the European Space Agency's freely available Copernicus Sentinel-1 C-band SAR (synthetic aperture radar) satellite, captured between 2014 and 2018, was processed and summarised using Google Earth Engine to provide median and maximum values of bipolar and single polarity radar reflectance for export (as spatial rasters). This previously untried source of remote-sensing data, with a resolution of 10m per pixel, provided a digitisation base-line to compare with the high-resolution WorldView imagery. In some cases, features were more clearly visible in the radar imagery than the visual-spectrum multispectral imagery, and vice versa. Multiple sources of remote-sensing data (the historical aerial photographs, the Sentinel-1 radar and visual spectrum multispectral imagery from DigitalEarth satellites, including the purchased WorldView image, and the mosaic tiles available in the Bing Maps and Google Earth/Maps platforms) were thus combined to create an extensive database of all types of visible linear features across the entire Milesian peninsula (fig. 5; see table 1 for a list of remote-sensing sources employed in this study).

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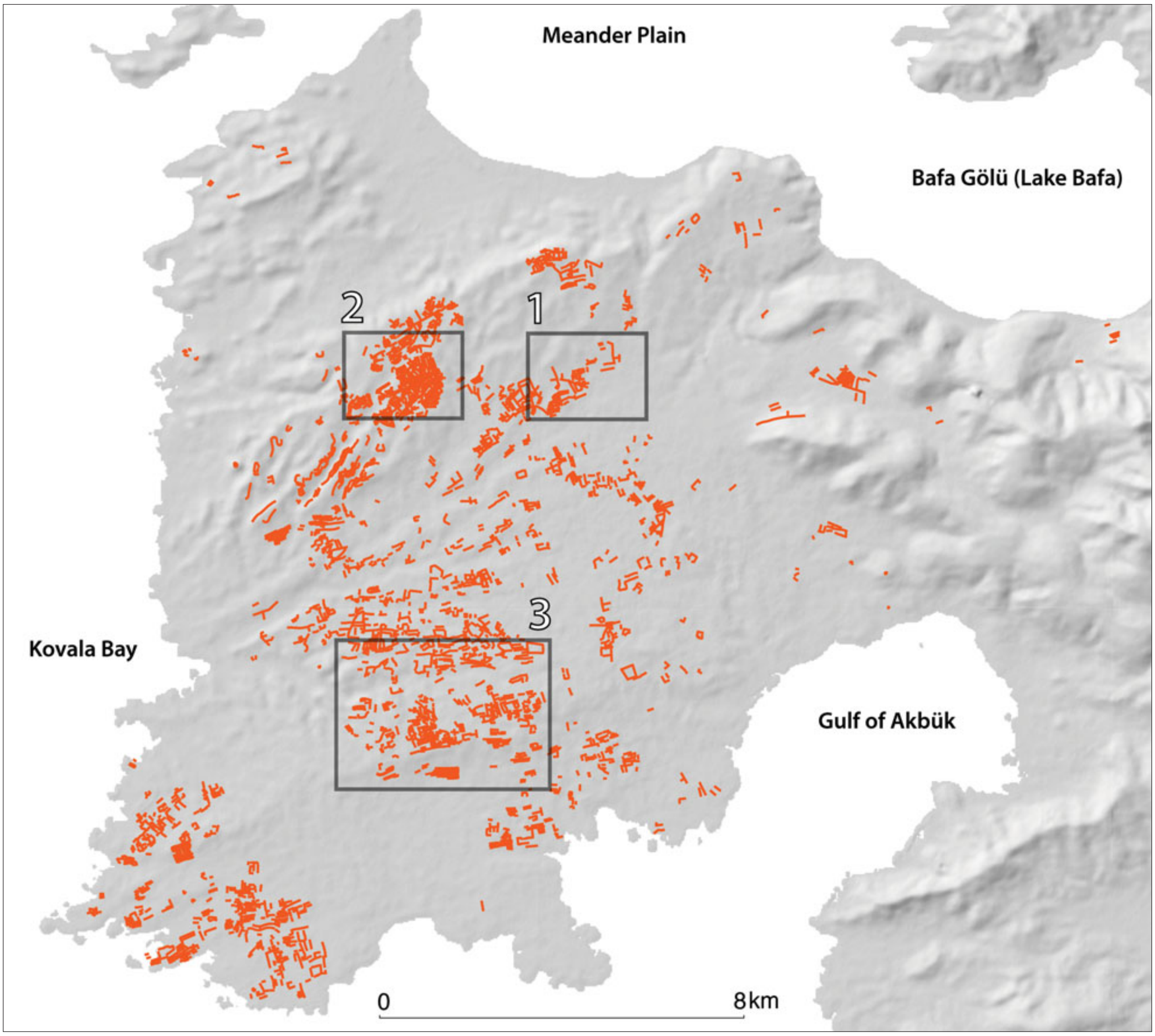

Fig. 5. Map of pre-modern linear features apparently representing field enclosures and terraces, with regions discussed in text marked: (1) eastern Stefania plateau (see fig. 7); (2) western Stefania plateau (see fig. 8); (3) Hörgüç Tepe (see fig. 10).

Engine/browser	*Base imagery type*	*Processing*	*Horizontal resolution*	*Data capture date(s) or bounds*
Google Earth Engine	ESA Copernicus Sentinel-1 C-band SAR (synthetic aperture radar)	VV/VH composite median	10m per pixel	2014–2018
	Landsat 5, 7, 8 NDVI composite	NDVI trend	30–90m per pixel	Within 1984–2018
DigitalGlobe Discover	WorldView-2 and World-View-3 (multispectral) browser images	Visual inspection	0.5–2m per pixel	15 April 2015, 3 November 2014, 4 September 2011
Google Maps/Earth	DigitalGlobe WorldView-2 visible spectrum	Visual inspection	0.5–2m per pixel	Various
Bing Maps	DigitalGlobe WorldView-2 visible spectrum	Visual inspection	0.5–2m per pixel	15 April 2015?

Table 1. Satellite and aerial data sources consulted to map or confirm linear features.

The effects of modern land-use on archaeological remains across the Milesian peninsula

While the clearance of large areas of macquis by modern farmers was clearly an unexpected boon to the identification of little understood or previously unknown archaeological features, it seems likely that, now and in the longer-term, this process of large-scale clearance and soil exposure will have negative effects on both the archaeological and natural landscapes. The clearance, apparently undertaken by machinery (i.e. bulldozers) in order to remove macquis and enable the planting of olive trees, has been undertaken on an industrial scale over the last few years. An analysis of multi-temporal NDVI (Normalised Differential Vegetation Index) trends over a 25-year period, based on eight-day averages from the Landsat 5, 7 and 8 programmes (covering the period from 1984 to 2018) and using the Google Earth platform, gives some indication of the spatial extent and speed of the transformation (fig. 6), with an acceleration in the four to five years running up to 2017. For example, vegetation indices for an area of around 110–15ha at the eastern end of the Stefania/Akron plateau (marked A on fig. 6) had already been dramatically reduced (represented by the blue channel on the RGB plot) from 1984 to 2018, as a result of macquis clearance for agricultural purposes (as is now visible in the DigitalGlobe imagery from Google Earth and Bing Maps). Another area (marked B), on the hills to the northwest of the village of Akköy, has also been cleared, although few linear features could be identified. Elsewhere on the peninsula such downward NDVI trends (blue channel) record the expansion of urban development around Didim and its satellite resorts of Altınkum, Akbük and Mavişehir, along with the development of associated road and waste infrastructure (marked C). Sentinel-2 L1C imagery from 2 July 2018 shows that further areas of macquis have been cleared at the western end of the Stefania hills in the last two years. Although the resolution of the Sentinel multispectral imagery, at 10m per pixel, is too low to provide information about the smallest linear features, the imagery does emphasise the speed and scale of clearance being undertaken and sounds warning bells about our ability to protect vulnerable ephemeral heritage traces such as rural archaeological sites.

With the soil scraped by machinery, surface archaeological remains may well have been totally obliterated, which leaves us pessimistic, although not necessarily hopeless, about the prospect of gaining further data about the structures from intensive surface survey. Depending on the level of recent destruction on the ground (which we have not yet had the chance to inspect at first hand), non-intensive re-survey of these regions or even small-scale excavations might nonetheless provide information and, given the much more comprehensive horizontal plan now available, could be targeted in a more systematic way than was possible before the clearances. We may expect further insights in the future if modern land clearance continues. But perhaps more desirably, if clearance stops, a much less destructive record of the peninsula could be created with a comprehensive LiDAR or airborne radar survey of the surface. With microtopographic and higher resolution vegetation data from these kinds of datasets, it may well be possible to fill in a number of gaps in the record in the future. Of course, these activities will require appropriate archaeological permits from the Turkish authorities, and, before such a project can be mounted, it is essential to document as much of this palimpsest landscape as possible using the available remote-sensing data, in an effort to emphasise the importance of these features and to help protect them from further destruction.

Linear features as agricultural enclosures: location, shape and purpose

Armed with our new map of linear features, it is already possible to make some initial comments on their nature and speculate about their significance. While they are widely distributed, there is a strong concentration of linear features in the swathe of land to the southeast of the ridge of the Stefania hills (ancient Akron), an area defined predominantly by very well-drained karstic limestone whose exploitation by modern farmers has been limited until recently. As Lohmann points out, such activity has often been assumed to have been similarly limited in the past (Lohmann 2008: 409–11); much of the area is still covered by macquis today. This situation contrasts with the strip of marl soils around Didim (to the southwest of this area) and that to the north of Stefania and south of the Meander plain, around Akköy, Balat and Akyeniköy, both of which are more fertile in agricultural terms and either continue to be cultivated today or else are occupied by suburban sprawl. In these more fertile regions, linear features are few or cannot be differentiated easily from modern boundaries. Those linear features that are clearly in use today have not been recorded in the database at this stage, although it may be worth examining them in the future. It should be remembered that the undifferentiated lines presented in our spatial database probably represent different physical manifestations: it is relatively clear from the satellite imagery and higher-resolution aerial photographs that some lines are formed from stone ‘embankments’, like those interpreted by the Borgs as quarrying waste (Borg, Borg 2003: 431–35) (but which could also represent collapsed dry-stone walling or boundaries of fields cleared of surface stones to aid ploughing); other lines are actually derived from soil-marks, caused by differential collection of moisture which might also be the result of walling or filled-in ditches. A small number may

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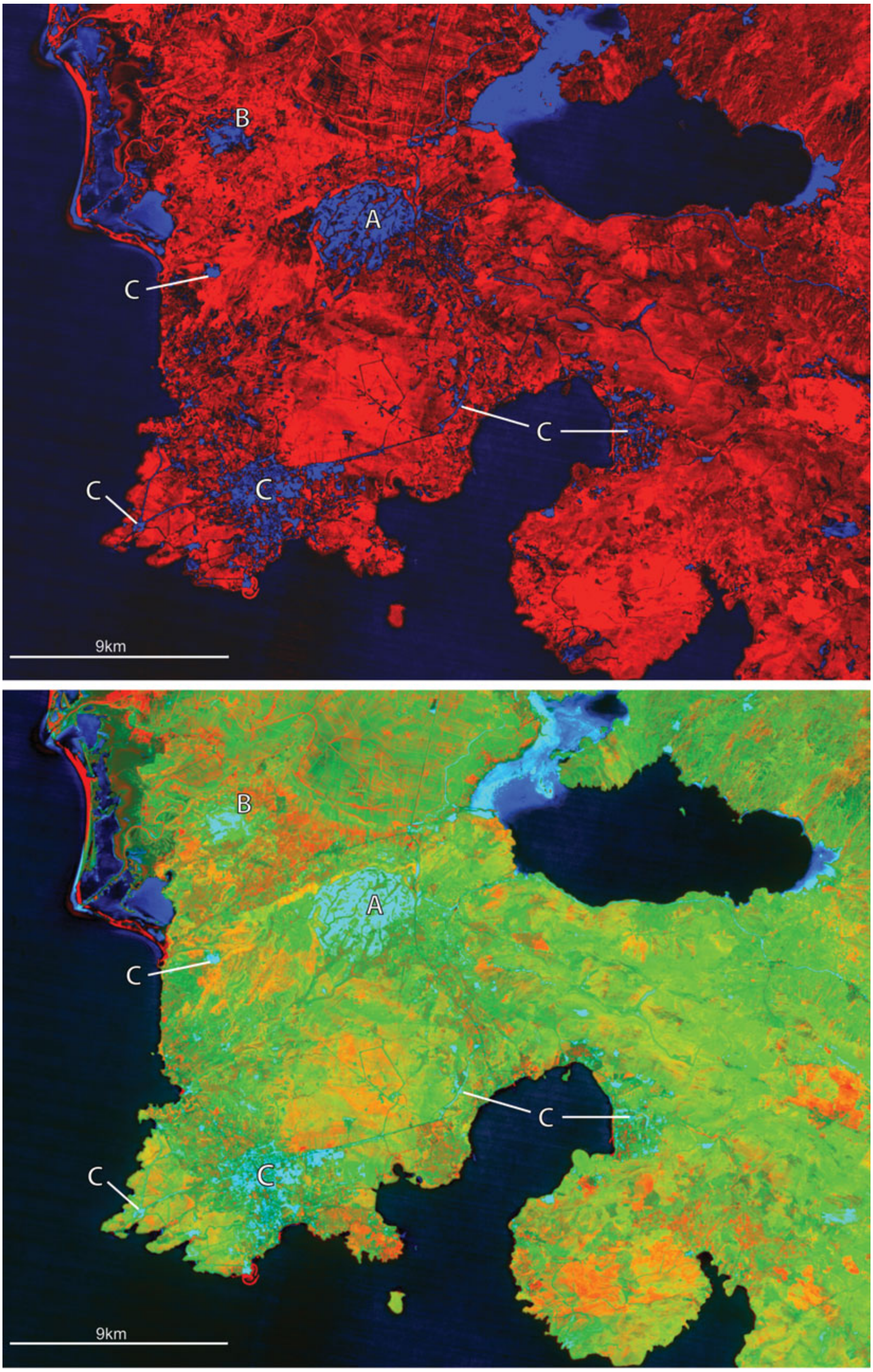

Fig. 6. Alternative representations of NDVI trends between 1984 and 2018 across the Milesian peninsula. Top: bilinear trend – blue indicates a downward trend (i.e. decreasing vegetation) and red an upward trend (i.e. increasing vegetation); bottom: mixed channel trend and intensity – here downward and upward trends are represented with blue and red respectively, and the overall intensity of vegetation is represented with green. Data derived from linear trend analysis of 2,440 images of eight-day NDVI averages derived from Landsat 5, 7 and 8 satellites, using Google Earth Engine.

represent natural geological structures in the limestone; such natural features were only digitised if they appeared to fit into a cultural system. Only a large-scale project of ground-truthing can provide a definite categorisation along these lines, but quite a lot can be said in advance of such an enterprise.

Based on comparisons with other terraced landscapes across the Aegean, and given the limited occupation of most of the Milesian peninsula over the last 100 to 150 years, we find it difficult to argue against Lohmann's general interpretation that the majority of the lines are likely to have had a pre-modern agricultural function and are quite ancient in origin. If some of the enclosures lie close to the 'micro-quarries' identified by the Borgs (Borg, Borg 2003: 431–32), we suspect any association (which would mostly be at the southwestern corner of the peninsula) is mostly coincidental based on accessibility of bedrock in these areas, although reuse for alternative functions should not be ruled out entirely; indeed, it is conceivable that close examination might provide relative dating evidence in the future. Some of the linear arrangements compare well with the ancient 'terracing' reported in southern Crete by the Sphakia Survey, which is associated, on the basis of proximity, to late Roman remains at Agios Astratigos (Price, Nixon 2005: 680–82, figs 12, 13). The longer and thinner 'plots' seen elsewhere on the peninsula can be compared to terracing identified on the western slopes of Hymettos in Attica by one of the pioneers of the archaeological use of aerial photography, John S.P. Bradford (Bradford 1956: especially pl. 9), and to the 'strip fields' visible on satellite imagery of the Omalos plain, western Crete (Rackham et al. 2010: 274, figs 26.5, 26.6).

The question, of course, is whether we can provide any precise information about the chronology of their creation and the longevity of their use or reuse, or indeed whether structures of different periods are superimposed as a palimpsest, and how they functioned within the overall rural Milesian economy. Despite the obvious parallels to other apparently ancient field systems, cited above, it is currently difficult to use the shapes of the fields as definitive criteria for their chronological origins, at least in the absence of a robust typology of field shapes for the Aegean or programmes of direct dating by OSL (optically stimulated luminescence) of accumulated sediment behind terracing (cf. Kinnaird et al. 2017). Even if shape and dimensions cannot currently provide direct dating information, they may provide useful proxy information about specific functions and hence wider significance. To demonstrate this, we will now focus on three regions with linear features and what the structures can tell us from an aerial perspective, before turning to wider spatial and environmental patterns.

Close-up: the eastern Stefania plateau

A clear case of the superimposition of later field boundaries over earlier linear features, and hence determination of their relative chronology, can be seen at the eastern end of the Stefania plateau, where modern regular fields currently in use are oriented very differently from a set of partly hidden earlier linear features in the same area (fig. 7). This alone does not, of course, provide absolute dates for each system, although visual comparison of Landsat imagery from 1984 to 2010 using Google Earth Engine shows most of this area was uncultivated until 2004–2005, suggesting that the delineation of the fields in current use is indeed a relatively recent phenomenon. Furthermore, the difference in orientation suggests rather strongly that the older system of linear features in this area represents pens, field divisions or boundaries, rather than terraces. The terrain slopes toward the southwest, but not very steeply (around 3% maximum), and, although modern farmers may be less concerned about nutrient loss when they can artificially add nitrogen, this is still an area of relatively thin soil that seems to suffer from a high risk of erosion. Thus, if these linear features were terraces, we would expect a greater degree of reuse and continuity into the modern period. The exception to this might be the areas of apparently slightly deeper soil, which represent colluvial fill from shallow run-off valleys heading southwest to the bay of Kovala and which the NDVI highlights as more heavily vegetated (and hence better watered) braided valleys (cf. fig. 6 bottom). A small group of visible linear features, apparently soil marks (marked B on fig. 7), lies just to the west of the ancient hilltop settlement of Assessos (marked A), overlain by many modern fields. Lohmann's survey recorded a number of walls and sherd clusters in this area (S229, 227, 223, 224) which are provisionally dated as Classical, Hellenistic or early Byzantine. Just to the southwest of this cluster is another site, S228, which Lohmann identifies as an Archaic farmstead on the basis of Archaic amphora rims (albeit alongside a small number of prehistoric finds); he compares this to another nearby site, S226, and argues that both could represent shepherds' stations (Lohmann n.d.).

Close-up: the western Stefania plateau

The western end of the Stefania plateau demonstrates some of the diversity of shapes represented by these linear features. Just to the east of the region labelled 'Kokkinolakka' (Greek for 'red soil') on Wilski's 1906 map (labelled 1 on fig. 5) lies a small *yayla* (pasture) or plateau, which has recently been totally cleared of macquis overgrowth. In this area, it is possible to identify large, broad rectangular or L-shaped blocks (~60–80m by 150–300m; labelled A on fig. 8) alongside much thinner and less pronounced divisions (~20m by 100m; labelled B) and

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Fig. 7. A range of aerially visible linear features on the eastern Stefania plateau, overlain on Bing Maps Aerial View tiles (derived from a DigitalGlobe WorldView-2 image, 15 April 2015). Top: raw aerial imagery; bottom: linear features highlighted. Modern field bounadries are oriented differently to these older boundaries.

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Fig. 8. A range of aerially visible linear features on the western Stefania plateau, overlain on Bing Maps Aerial View tiles (derived from a DigitalGlobe WorldView-2 image, 15 April 2015). Top: raw aerial imagery; bottom: linear features highlighted. Labelled features: (A) wider rectangular enclosures; (B) thinner, longer enclosures; (C) circular enclosures.

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some smaller circular structures (~20m in diameter; labelled C). Some of the smaller B-type shapes appear to be nested within larger structures. The fact that the lines do not seem to be superimposed here suggests that they were used contemporaneously, although we cannot be sure they were all built in the same period.

The varied shapes and dimensions suggest possible functional differentiation: A-types are of a sufficient size to be suitable for cereal cultivation, orchards or grazing; B-types, as smaller areas, might be suitable for smaller garden plots or vineyards; and C-types, as small circular structures, are plausibly threshing floors (if cereals were being cultivated in this area), sheep pens or perhaps field houses of some kind. The circular structures (C) each appear to measure around 20m in diameter, and are thus similar in size to circular structures on the Bodrum peninsula that have previously been identified as domestic structures (Lohmann 1997a: figs 4–8) and dated from the Archaic to Roman period, depending on morphology (Radt 1992: 6–7). Alternatively, the nesting of differently sized and shaped rectilinear enclosures might reflect a chronological consequence of inheritance, changing modes of ownership and/or reuse incorporating pre-existing structures into new land-use systems. Just to the east of this now exposed surface, Lohmann identified a site, S108, as a shepherding station of unspecified date (fig. 9). Unfortunately, the macquis overgrowth makes it difficult to understand the horizontal connection between S108 and the visible features nearby; nonetheless, it may be that S108 is only one part of a larger system of land-use. In the opposite direction, a few hundred metres to the southwest, lies the so-called ‘Archaic Cult Complex’ (identified by Karen Gödecken and Peter Schneider in the early 1980s and excavated by Klaus Tuchelt in 1985–1986: Tuchelt et al. 1996). It would be tempting to connect the exposed field systems to this structure, as ancient cultic institutions presumably held agricultural lands nearby as a means of economic support (as did Byzantine monastic and Ottoman *vakıf* institutions), but, from the aerial imagery alone, no structural connection can be identified and few linear structures are identifiable directly around the cult complex itself.

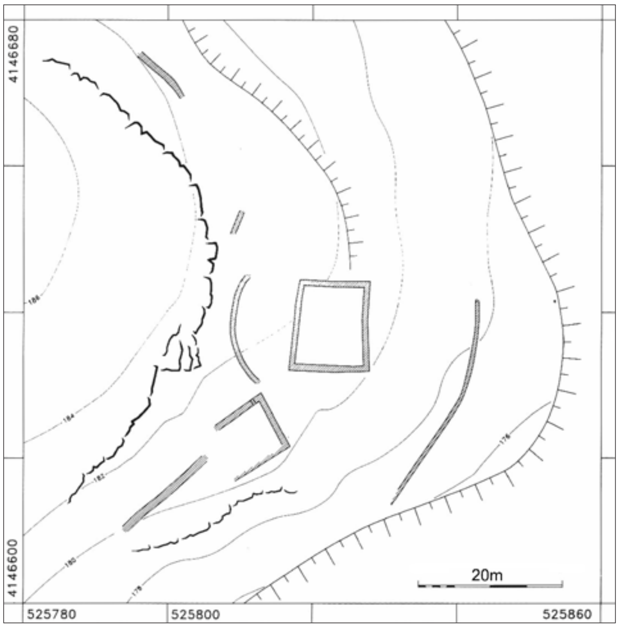

Fig. 9. Plan of the Mauergeviert *(four-walled structure) of site S108 identified during the Milesian Chora Survey (after Lohmann 1997a: fig. 11).*

Close-up: Hörgüç Tepe/Ta Manolakia

A third area, Hörgüç Tepe, provides another example of enclosure-shape diversity. It sits in a region still covered in relatively thick macquis and is one of the regions argued by the Borgs to provide evidence of ‘pit-field’ quarrying (Borg, Borg 2003: especially fig. 2). A large concentration of linear features can be identified around 2–3km to the east-northeast of central Didim, on the northern side of the modern main road going east to Akbük, Kazıklı and the Bafa Gölü (labelled 2 on fig. 5). Near the main road to Akbük, where there is a steeper gradient toward Hörgüç Tepe, many long and narrow terraces (each ~40m in width) are visible (labelled A on fig. 10). It seems likely that the terraces were continuous here, and that the gaps in the visible features are merely the result of high-density vegetation. The spacing of these terrace divisions compares well with the spacing of terraces recorded by Bradford for the plain of Attica, i.e. ‘100 to 130 ft’ = 30–40m (Bradford 1956: 175). Higher up, where the slope is less steep, a more varied division of the land is visible, with divisions of ~70m by 80m toward the west (labelled B) plus some larger blocks of ~100m by 120m toward the east (labelled C). In terms of functional differentiation, the narrower divisions (A) strongly resemble terraces used to prevent erosion and could have been used for plantations of olive trees, vines or other cultivars. Circumstantial clues point to the dating of the structures near the top of Hörgüç Tepe (on the western side of this area). Lohmann recorded a number of remains on this hill: S247 incorporates an oil press, cistern and scatters of late Classical/Hellenistic as well as early Byzantine pottery; he thus characterises this area as a late Classical/Hellenistic farmstead that was reused in the early Byzantine period (Lohmann n.d.). Slightly to the northeast, a group of stones and pottery (S408) is described by Lohmann as a disturbed Hellenistic or Roman grave monument (Lohmann n.d.). It is not unusual for graves to be associated with the edges of villages in the Greek world (Alcock 2012: 133) and, cross-culturally, grave monuments are often used to assert land rights, although there is no corroborating evidence to confirm this is the case here.

Fig. 10. A range of aerially visible linear features in the Horgüç Tepe area, overlain on Bing Maps Aerial View tiles (derived from a DigitalGlobe WorldView-2 image, 15 April 2015). Top: raw aerial imagery, contrast boosted; bottom: linear features highlighted. Divisions that appear to be modern or continue to be used have not been highlighted.

Given these associations, it is not implausible to suggest that the linear features on Hörgüç Tepe represent terraces or enclosures associated with the Hellenistic or later Byzantine establishment of a village or farmstead. Whatever the date of the linear features, the presence of an agricultural settlement of some form in both the Hellenistic and Byzantine periods makes it even harder to accept the interpretation that most of these features were the direct result of pit-field quarrying for limestone (Borg, Borg 2003: figs 3, 5; here reproduced in fig. 2 and compare fig. 11). A disused quarry noted by Wilski and re-recorded by Lohmann (marked 'ancient quarry?' on fig. 10) does confirm that some parts of the peninsula were indeed used to source stone. It is not impossible, as the Borgs suggest (Borg, Borg 2003), that this quarrying was related to the construction of the temple and other buildings at Didyma. Nonetheless, we argue that the industry does not seem to have had the large-scale environmental impact on the landscape that the Borgs envisage.

Establishment and abandonment of enclosures

If the majority of the linear features on the peninsula do indeed represent the boundaries of agricultural enclosures of various types, how did such enclosures develop through time and how did their establishment and abandonment relate to wider economic trends?

Enclosure dimensions and rural land-division systems

While our synthetic knowledge of enclosure shapes across the Aegean is not developed sufficiently to indicate dating or development, their raw dimensions can be examined in order to search for patterns that may link to particular periods. If a standardised system was being used to divide land for sale or taxation, we might expect some degree of regularity in the dimensions or area of each enclosure, or in the interrelation between plots of different sizes (for example larger plots being regular multiples of smaller plots). Whether or not we can trace the imprint of such a system via modern spatial mapping depends on whether land was indeed measured with (a) top-down aerial-perspective 'areal' or 'lineal' geometry, as opposed to either (b) less abstract ordinal measures (for example number of olive trees) or (c) proxy measures of land quality, such as volumetric measures of yields or seed volume required to generate a certain yield. In many ways (b) and (c) make more sense from the perspective of the farmer or pastoralist; (a) is really only useful from the perspective of distanced bureaucracies that administer land or manage markets in land rather than concern themselves directly with agricultural production. The domination of a certain type of land metrology over another should be strongly related to the way in which local authorities (whether local lords or larger state entities) manage rights to land and its product, and how agrarian labour is extracted through taxes or tithe. To take a Bronze Age example, the E-series Linear B records from Pylos mention land measured in a quantity of GRA, an ideographic term that appears also to be a volumetric measure of seeds needed to sow a field (Brown 1956; Bennet 1999; Uchitel 2005).

Even if land area may have been roughly calculated in Bronze Age Babylonia, many modern histories of mathematics associate the 'discovery' of certain key axioms of mathematical geometry that would allow the type-(a) calculation of land areas to early scholars such as Thales of Miletos or Pythagoras of Samos, both of Ionian origin, who were active during the sixth and fifth centuries respectively (see, for example, Hodgkin 2005: especially 40–56 with references). Leaving aside the modern obsession with the authorship of ideas (admittedly shared with ancient Greek scholars), whether either of these figures played a significant role in their discovery or these ideas were imported from Egypt is less important than the fact that their work enabled the abstract comparability of land, both urban and rural, through the technologies of geometry and survey. It is little surprise, therefore, that the earliest Greek settlements with regular gridded plans depending on the areal perspective of the abstract horizontal plane were apparently those of Miletos and the *Streifensträdte* of Magna Graecia (Hoepfner, Schwandtner 1994; Ault 2017), both dating to before the fifth century BC. Geophysical evidence and the orientation of Archaic monuments in the city of Miletos itself suggest that the city grid pattern was established in the late Archaic period (Weber 2007; Müllenhoff et al. 2009). Centralised and geometric division of the rural landscape was presumably more common in new foundations and colonies, just as it would have been much easier to design regular orthogonal grids for new or resettled cities.

Despite the mounting evidence for an Archaic 'revolution' in abstract metrology (including weight, volume and value as well as space) between the seventh and fifth centuries BC, little direct information is available about the specifics of Archaic or Classical spatial measurements (Dan et al. 2016); in part this is because urban grids, whose identification facilitates the conversion of textually referenced quanta to modern metric systems, only become more common from around the third century BC. In contrast, we know that Hellenistic city plans and rural field divisions were often recorded and laid out around particular locally defined standard measures and their multiples; areal dimensions such as for land were measured in *schoinoi* (100ft by 120ft) or *plethra* (120ft by 120ft), but the actual length of a Greek foot (*pous/podes*) potentially varied regionally between 0.295m and 0.334m (Boyd, Jameson 1981: 332). Indeed, a third-century

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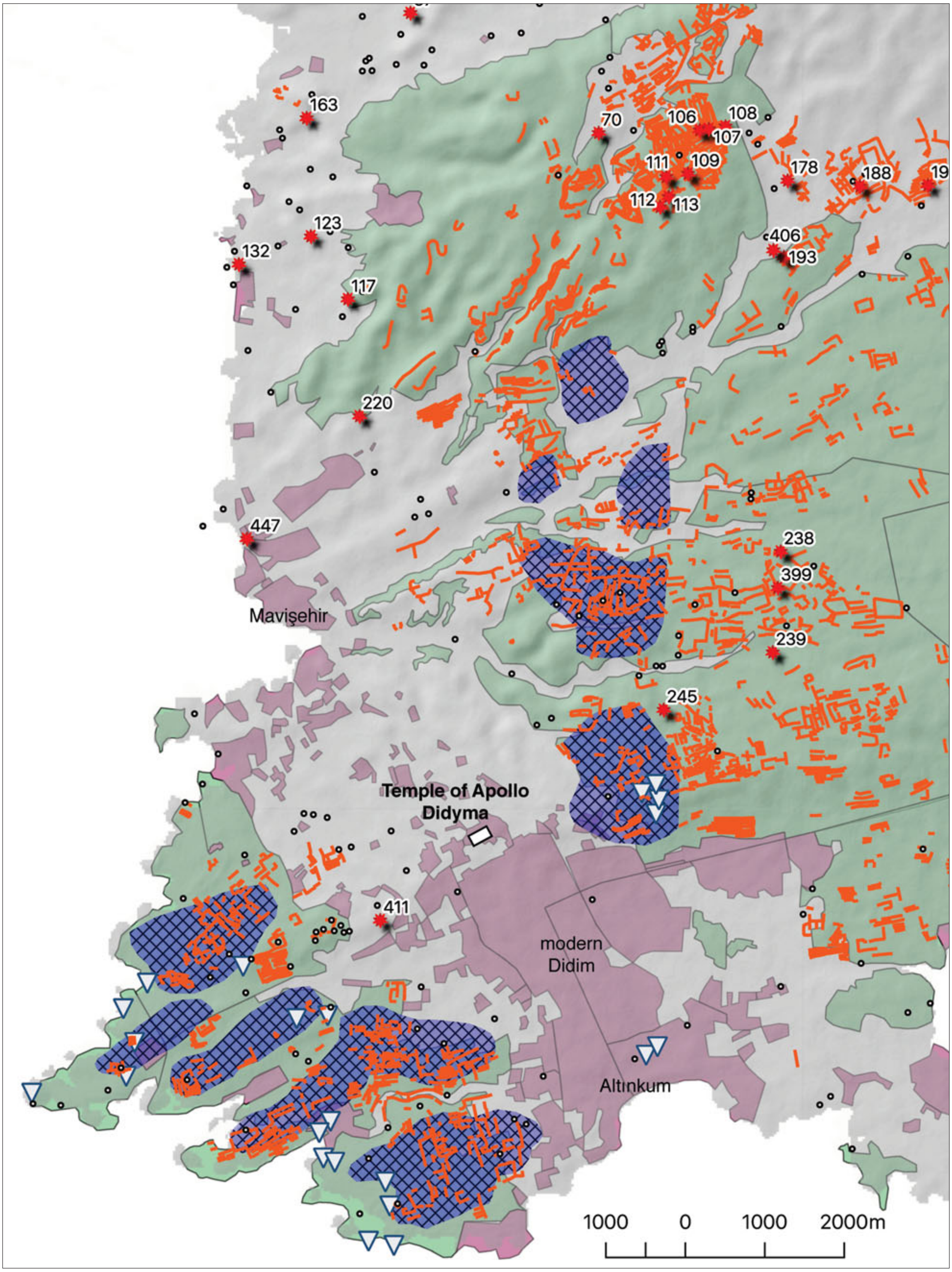

Fig. 11. Detailed map of the southwestern portion of the Milesian peninsula, showing summary locations of 'extensive pit-fields' (hashed blue regions) and 'micro-quarries' (white triangles) (redrawn from Borg, Borg 2003: 429, fig. 2), sites recorded during the Milesian Chora Survey (as per fig. 1), modern land-cover – urban (purple) and maquis (green) – and linear features identified by aerial imagery (orange lines).

inscription describing land sales from the city of Magnesia-on-the-Meander (not far upstream from Miletos) shows a preference for rounded multiples, in this case 50 *schoinoi*, as a kind of default plot size; Thonemann argues this was a result of a Hellenistic policy of relatively egalitarian land division (Thonemann 2011: 243–44). Naturally, one might read this 'egalitarianism' more cynically, as a bureaucratically convenient block that could only have been set when land was rapidly reorganised or redistributed. Roman centuriation, not evident in Ionia but well studied in areas such as lowland Italy (Bradford 1974) and Iberia (Palet, Orengo 2011), represents one of the most obvious traces of this form of large-scale rural land management, ostensibly designed to provide measurable military pensions.

Just because abstract areal measurements existed, however, does not mean rural populations abandoned non-abstract measures. During the Byzantine period, the single named unit, *stremma*, apparently related to two precise land areas, based on the quality of the land: '[approximately] 939.18 m^2 for arable land and good vineyards and 1,279.78 m^2 for inferior meadow and marginal' (Davies 2004: 113). The names of abstract quanta from many periods continue to recall practical considerations: the Roman *iugerum*/*jugerum* is derived from *iugum* (yoke), implying the path width needed for two oxen yoked together (Pliny *Natural History* 18.3). This recalls a more practical relationship to agricultural labour, just as an English acre was defined as the amount of land tillable by one farmer behind one ox in one day.

If abstract measures *were* used in the Milesian chora, then they should be detectable through modern spatial methods (i.e. using geometry to calculate areas). Naturally there are some difficulties in determining enclosure areas based on the linear features we have identified by aerial imagery. First, it is rare that all sides of a plot can be drawn unequivocally, to ensure we are measuring a meaningful bounded space of some kind. In total, 200 'complete' plots could be drawn with reasonable confidence; most of these were of the broader shape (since the end of most longer terraces could not be clearly demarcated), albeit of very varying dimensions. These complete enclosures are sparsely distributed across the entire peninsula (fig. 12 top left) and there is no region where a cluster of plots is recorded. Second, since we do not know the creation dates of the enclosures – indeed, we cannot exclude the possibility that divisions were made at different periods – it is difficult to identify particular known quanta that might provide meaningful comparison. In all cases, we need to expect a degree of error, both in terms of hypothetical ancient surveying and modern digitisation.

The areal dimensions of the complete plots follow a skewed normal distribution (fig. 12 top right), the most significant modal average peaks at 0.79ha (just under 2 acres). Only a handful (four to five) of the plots can be said to reach the approximate equivalent of 50 *schoinoi* (the Hellenistic measurement recorded in inscriptions), whatever metric value one takes to represent a Greek foot (fig. 12). Indeed, looking at the frequency distribution, it is clear that the majority of plots fall below 20 *schoinoi* (i.e. equivalent to less than 8 acres, 24 *plethron* etc.). Superficially, the overall pattern does not suggest the kind of clumping or 'multiples' of a single base-unit area that one might expect if a single dominant areal measurement was being used to define enclosure sizes. Comparison between the binned frequency distribution (fig. 12) of these areas with different Hellenistic, Roman, Byzantine and Ottoman areal metric quanta provides no obvious 'best' candidate, especially because the distribution curve is relatively shallow, meaning that, even if one candidate were more likely, the precision with which that measure was reached would be very low (for derivation and discussion of quanta values, see, on Hellenistic systems: Boyd, Jameson 1981; Heimberg 1984; imperial Roman: Thonemann 2011: 254–55; Byzantine: Davies 2004; Ottoman: Inalcık 1983). If the identified enclosures were not defined by one single systematic geometric system, and certainly not a large-scale planned division of land, we are left with two possibilities.

The first and most obvious interpretation is that enclosure shapes on the peninsula were not defined by geometric concerns at all, but instead developed more organically, perhaps according to terrain. Given the geological situation of the majority of the enclosures analysed – i.e. on well-drained karstic rock with relatively thin soils – it would not be entirely surprising if the raw areal dimension was less important than, for example, the number of olive trees that could be planted or the size of a herd of sheep that could be managed and transfered between different fragile pastures.

The alternative is the palimpsest possibility, namely that we have bunched multiple different systems (with the modal average clustering towards agriculturally practical sizes) or that some fields were defined by abstract units and others not. This is naturally much harder to test, especially given the sparse distribution of complete plots. In the end, we may be restricted by sample size.

Nonetheless, an exploratory application of a more sophisticated statistical technique to identify unknown quanta in a collection of measurements, namely Kendell's cosine quantogram analysis (cf. Pakkanen 2002; 2004; Kasiński 2019), is suggestive. Applied to the complete enclosure areas drawn, the highest-scoring possible quanta is 0.84 (fig. 13). Of the comparable listed known ancient quanta (table 2), the most readily comparable modulation of this value is the Roman *iugerum* and land values derived

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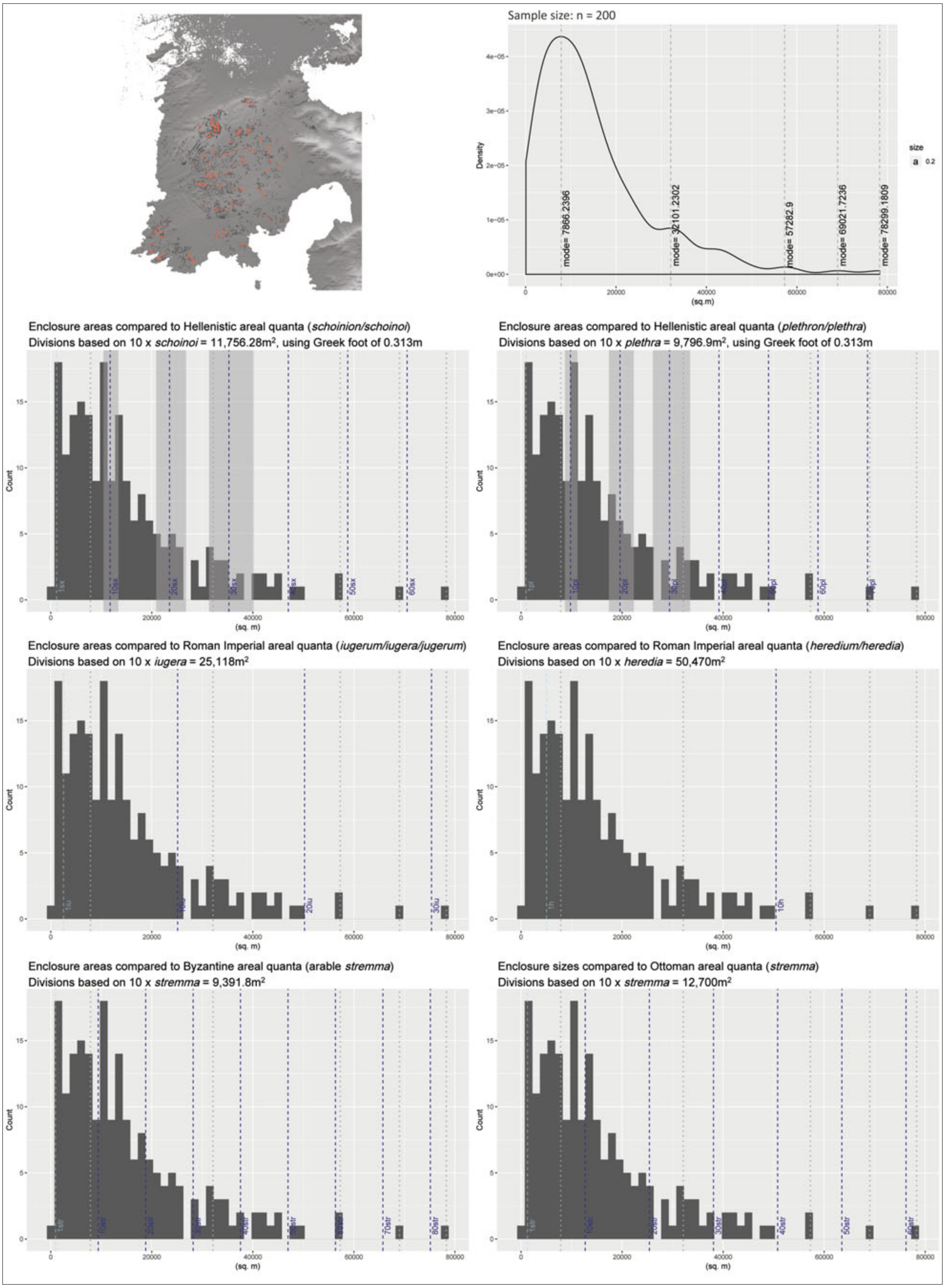

Fig. 12. Estimated surface areas (in m²) for the 200 complete plots as defined by the visible linear features (top left: map showing locations; top right: density summary with modal peaks) and comparisons of area sizes as binned frequency distributions to approximate values of pre-modern areal quanta.

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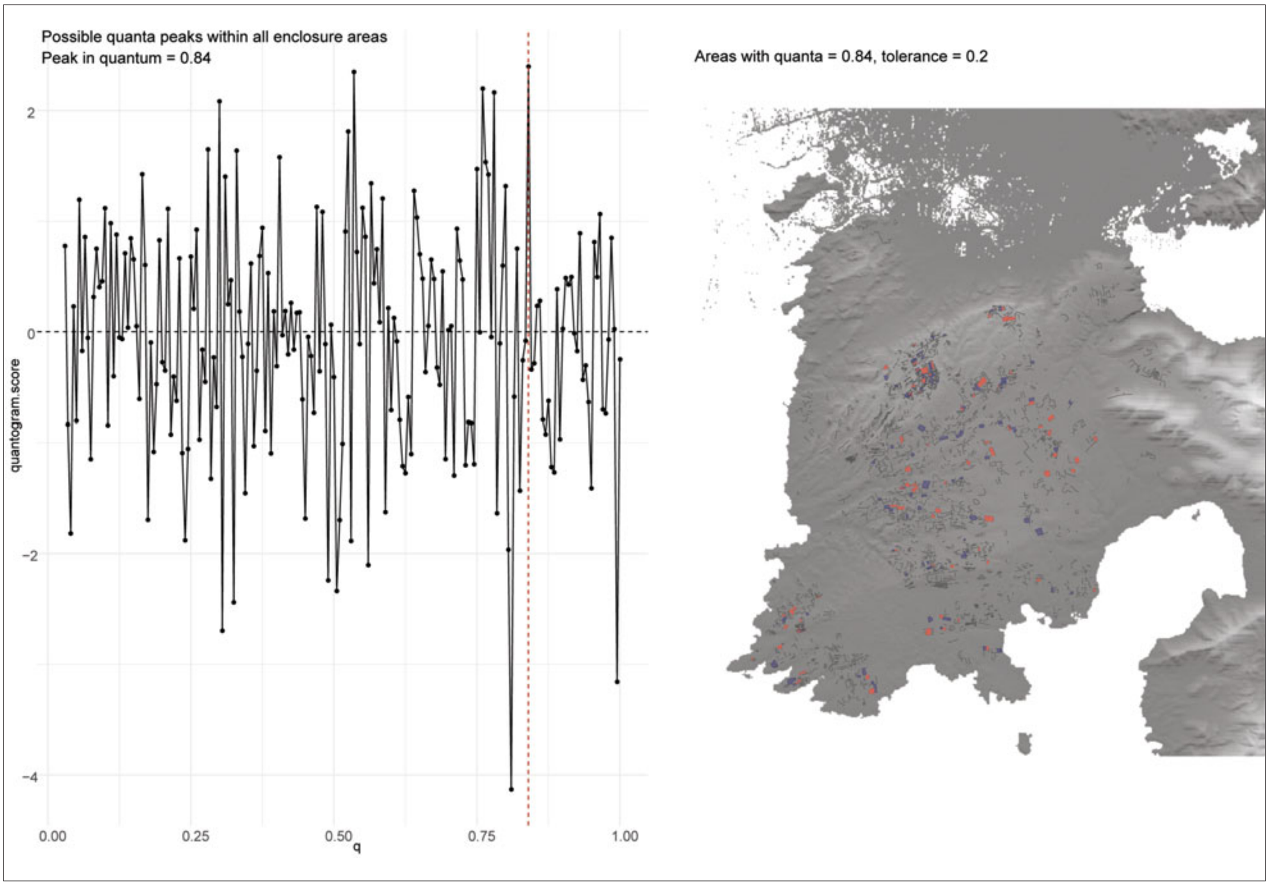

Fig. 13. Objective identification of quanta, using estimated surface areas (in m²), among the 200 complete plots. Left: cosine quantogram (generated using the pre-release version of the quantatools package by M. Kasiński), with highest scoring peak at 0.84; right: locations of enclosures with areal dimensions matching multiples of approximate Roman iugera *(tolerance to whole numbers ±0.2).*

Land measurement name	*Approximate metric equivalent (m²)*	*Quanta/0.84*	*Quanta/0.84/1,000 (rounded to 2 decimal pts)*
Hellenistic 1 *schoinoi*	1175.628	1399.557143	1.4
Hellenistic 2 *plethra*	979.69	1166.297619	1.17
Roman 1 *iuga*	109265	130077.381	130.08
Roman 2 *iugera*	2511.8	2990.238095	**2.99**
Roman 3 *jugera*	2523	3003.571429	**3**
Roman 4 *heredia*	5047	6008.333333	**6.01**
Roman 5 *actus quadratus*	1255.9	1495.119048	**1.5**
Byzantine 1 *stremma*	939.18	1118.071429	1.12
Byzantine 2 *stremma* (marginal land)	1279.78	1523.547619	**1.52**
Ottoman 1 *stremma*	1270	1511.904762	**1.51**
Ottoman 2 *(eski) dönüm*	919.3	1094.404762	1.09

Table 2. Known ancient areal quanta, with approximate modern metric equivalents and modularity compared to peak identified quanta identified with cosine quantogram (see fig. 13). Numbers in bold most closely match a multiple of the 0.84 quanta identified.

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from it (the Roman *actus quadratus*, the Byzantine and Ottoman version of a *stremma* used for low-yield areas). Assuming a small level of tolerance in measurement, this suggests that a certain number (a maximum of 80 out of 200) of the measurable enclosures could conceivably have been laid out according to Roman or Byzantine pre-assigned measurement (their locations are shown as red enclosures in fig. 13). The current result is unlikely to be statistically significant; adjusting the level of tolerance downwards has a dramatic effect and, clearly, most enclosures still do not fit the pattern. Nonetheless, the result does suggest that further statistical investigations could be fruitful; with further categorical differentiation or spatial links between each enclosure, it might be possible to assert a stronger relationship between certain fields and certain measurement systems in the future.

Settlement history, cultural breaks and land organisation

The obvious case of the superimposition of a very recent field system onto ancient enclosures in the eastern part of the Stefania plateau reminds us that abandonment is the most easily identifiable part of the life cycle of such structures. As a general principle, dramatic discontinuity in field-system organisation or the creation of a new field system should be taken as an index of profound cultural and demographic change, in which land rights or agronomic strategies are restructured or newly invented. The imposition of 'An organised field system implies a break in land tenure and land-use ... or resettlement after a period of abandonment, or a deliberate decision to redistribute land' (Rackham et al. 2010: 283). In the case of Stefania, we are faced with a clear example of the imposition of a new system following a disruption of agricultural life on the Milesian peninsula. But how long was the period of disruption in this case?

The *latest* likely abandonment of the linear structures in the eastern part of the Stefania plateau and much of the rest of the peninsula was in the 1920s. As for much of the western coast of modern Turkey, the 1923 exchange of populations between Turkey and Greece enacted by the Treaty of Lausanne is the most recent major disruption. Until 1923, the southern part of the peninsula had a sizeable local Greek Orthodox community, based around the village of Yoran. Yoran, renamed Hisar (fortress) during the early Turkish Republican period, was the village built around the remains of the Temple of Apollo at Didyma and the predecessor to the modern town of Didim, whose centre was moved to a new site, Yenihisar, 2km to the southeast of the temple, after a serious earthquake in July 1955 (Ergin et al. 1967; Yergün et al. 2014). Wiegand notes regular 'Greek' migrants coming from the island of Samos to the Meander region during harvest time or other labour-intensive periods (Wiegand's unpublished notebooks, cited in Thonemann 2001). Wilski's map, produced well before 1923, records a large number of Greek toponyms across the entire peninsula (transliterated to German), which appear to index Greek ecclesiastical or personal ownership of land or else coloured landmarks (Kokkinolakkha, Tu Konstandi tu Kolia, Tu Aristi, etc), alongside many of Turkish or hybrid Turkish-Greek origin (Bagtscheh, Arab-Alan, Tsi Hadschy Argyri, etc.). Population continuity is to be expected in the northern part of the peninsula. Around Balat (the village formerly sited on top of the ruins of Milet) and at Akköy, the larger settled Turkish Muslim population on the peninsula is more likely to have maintained its landholding structure during the tumultuous early 20th century. We suspect that some of these divisions could have been used up until the late Ottoman period; an investigation of any pre-1923 Ottoman cadastral records might help to confirm or refute this.

This *terminus ante quem* for the abandonment of the older system does not proclude an even earlier abandonment, of course, nor does it help us to determine the diachronic establishment of such linear structures in the first place, whether as part of a rapid period of imposition or the consequence of slower growth. For this we need to turn to wider knowledge of the peninsula's cultural and environmental history.

Assessing the degrees of occupation over time of the Milesian peninsula, and hence periods in which we might expect expansion into the less productive hinterland, remains difficult at this stage. Lohmann's survey of the Milesian chora is the most spatially and temporally extensive study, providing us with a useful outline of what is there. But that survey's point-based 'site-of-interest' strategy and the sometimes opaque dating methodology makes it difficult to use the results to quantify changes of settlement density or population across time. Simply counting sites defined as having remains of a settlement, a farmstead or a building by period, and adjusting for the length of that period (Lohmann 1999: 466–73), suggests the highest density of construction *in the chora* (i.e. not including the major centres at Miletos and Didyma) occurred in the early Byzantine period, followed by the (presumably late) Classical/Hellenistic and then the Archaic (fig. 14 top). This pattern contrasts with the evidence of datable diagnostic pottery densities recovered during our recent intensive survey around Panormos (fig. 14 bottom); the two peak frequencies, once weighted against individual sherd-dating precision, lie during the early Byzantine and Archaic periods. As an indicator of pottery production (and hence discard), these relative-frequency values may be a more reliable proxy for diachronic economic intensity, and perhaps population, than the extensive data; but the current limited spatial extent of this sample (i.e. fieldwalking has not yet been undertaken in the central area of the peninsula

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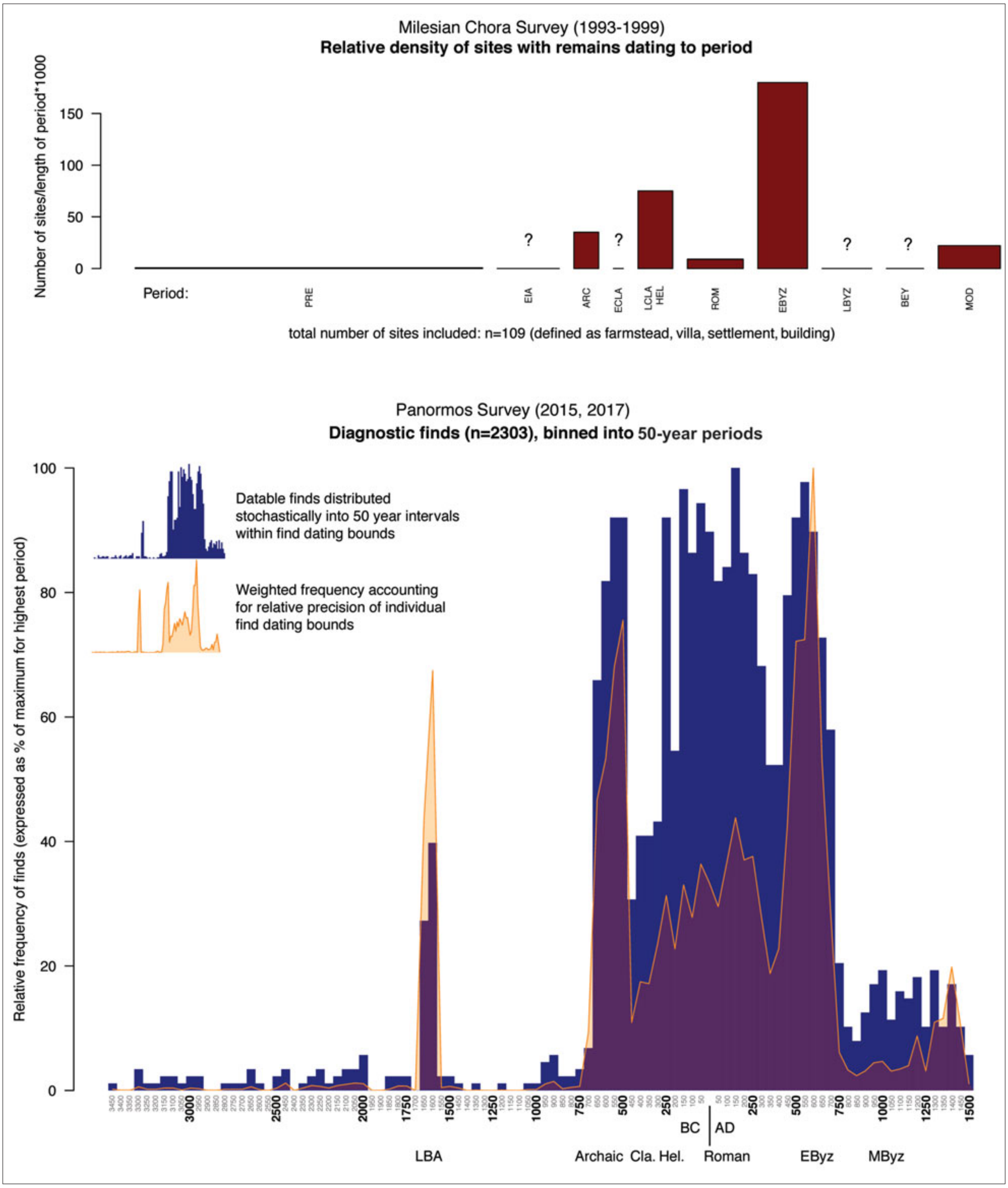

Fig. 14. Quantified archaeological proxies for relative intensity of occupation on the Milesian peninsula. Top: relative frequency of sites defined as farmsteads, settlements or buildings by the Milesian Chora Survey, per period and weighted by period length (based on Lohmann 1999); bottom: relative density of datable pottery finds from the Project Panormos survey coverage for 2015 and 2017; the blue bars represent the frequency of finds with dates defined by stochastic distribution between earliest/latest bounds; the orange line represents the same distribution weighted against the precision of each dated find, which provides a more realistic probabilistic proxy for total occupation.

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where most of the enclosures are located) means that we cannot differentiate overall occupation density from levels of settlement nucleation.

Three major Bronze Age settlements on the peninsula are known (Miletos, Tavşan Adası and Kömür Adası: Kalaitzoglou 2009). The evidence for terracing in other parts of the Aegean (for example near the Minoan settlement of Palaikastro on Crete: Orengo, Knappett 2018) suggests that prehistoric origins for such field structures are not impossible. However, so far, aside from some remains around Assesos, on the far northeastern edge of the Stefania hills (Kalaitzoglou 2009), evidence for prehistoric settlement on the Milesian peninsula has mostly been restricted to what was, before the progression of the Meander delta, a narrow coastal strip (cf. Brückner et al. 2006; 2014). The linear structures in the interior of the peninsula lie, therefore, at some distance from Bronze Age settlement.

At the other end of the temporal spectrum, historical data suggest that the entire Milesian peninsula and nearby Meander valley suffered a serious economic decline following ca AD 1500; the cause of this remains unclear (a climatic shift has been cited as explanation – see, for example, Niewöhner et al. 2016: 280; cf. Thonemann 2011: 297–302 – but the resolution of the cited data is limited). On material and historical evidence, the most plausible time span for initial establishment and/or growth of these field systems is between the Archaic and late Byzantine/early Beylik period (700 BC to AD 1500), but, as suggested in the close-up analysis of the datable remains associated spatially with the enclosures and the pottery densities from Panormos, the Archaic, Hellenistic or early Byzantine seem the most plausible periods for any kind of agricultural expansion.

Environmental proxies and agricultural expansion

Palaeoenvironmental proxies can provide further clues to understanding the fluctuating exploitation of the region, with some caveats. Evidence for increased land clearance and a rise in mixed farming from the Hellenistic period comes from palynological data from cores taken from the Bafa Gölü (a marooned former outlet of the sea) in the 1990s. M. Knipping and colleagues (2008: 373–76) record indicators for animal pasturing (in the form of the presence of *Plantago lanceolata*, *Rumex* and *Sarcopoterium*) throughout the first millennium BC and into the post-antique period in the Baf S1 core. Fluctuating signatures of pine and oak throughout this time frame suggest differing degrees of land clearance across this period; a higher frequency of pine and oak is an indicator of a less open landscape (for example, core section Baf S1-4). Olive pollen (*Olea*) remains remarkably low into the mid-first millennium BC (core section Baf S6-1), despite the fact that olive cultivation was well known in the Greek world by the Archaic and Classical periods (Foxhall 2007). In the Hellenistic and Roman periods (core sections Baf S6-2 and 3), however, the levels of olive pollen grow substantially, implying increasing exploitation of this crop, alongside other airborne pollinating fruit crops (*Juglans*, *Castanea* and *Vitis*, i.e. walnut, chestnut and grapevine) and indicators of pasturing and cultivation (*Cerealia*). Following this, sometime in the Roman period, olive and other anthropogenic indicators appear to decline (Baf S6-4).

Based on a reanalysis of the data from the upper levels of the Baf S6 core, Adam Izdebski recently argued that, following a period of pastoral indicators in the fourth and fifth centuries, there is a revival of olive pollen from the *later* early Byzantine period, around the sixth century AD, onward, which he sees as fitting the Milesian chora data (Niewöhner et al. 2016: 277–79). He also argues that the basic system of cultivation seems to continue relatively unaltered, albeit with minor fluctuations of indices of pastoralism and/or cultivation, up until the 15th century AD. Izdebski's analysis, and this final claim in particular, have not been received uncritically: Alex Herda, Helmut Brückner, Marc Müllenhoff and Maria Knipping refute the reanalysis as overstretching the chronological resolution, especially given the analytical unreliability of the material originally used to provide radiocarbon dates and the small number of dates, which makes the creation of age-depth models highly problematic (Herda et al. 2019: 57–60). The other problem with the palynological data as a whole is the spatial catchment of the pollen deposits: the prevailing winds in the region are from the southwest, which would bring pollens from across the central peninsula into Bafa (Niewöhner et al. 2016: 274–75); but the deposit regime is not well known and it is possible that the effective catchment varied over time according to different regimes of water circulation (whether from sedimentary flow from the slopes around Bafa or from the river Meander).

Taken at face value, the palynological evidence nonetheless hints at two main periods of major agricultural expansion on or near the Milesian peninsula, which we could potentially associate with the development of the enclosures: the initial large-scale expansion of olive and fruit cultivation on the peninsula (perhaps during the late first millennium BC, roughly the Hellenistic era) and, following a decline, a second expansion focused around olive production (perhaps at some point in the late first millennium AD, i.e. the Byzantine period). Examination of erosion and sedimentation rates across the peninsula offers potential corroboration, or otherwise, of the palynological data (core samples from near Yeniköy on the northern side of the peninsula were studied, for example, but the basis of the conclusions is unclear: Bay 1999: 84). Cores have not been taken from within the watersheds south of the Stefania ridge, where most of the enclosures lie.

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Concluding remarks: enclosures and the rural economy of Miletos

The map of these linear features, the majority of which we interpret as agricultural enclosures, is a critical piece of the puzzle, but it needs to be integrated more fully with palaeoenvironmental, historical and detailed archaeological evidence of land-use on the peninsula. Their location (primarily in regions of the peninsula that today are, or at least were in the 1990s, outside the main areas of settlement) prompts many questions, which remain difficult to answer definitively. As we have seen, certain periods of Milesian history can be linked more plausibly to an expansion of agriculture than others (the Archaic, Hellenistic and early Byzantine periods, in particular) based on archaeological and palaeoenvironmental indicators. Nonetheless, given the wide variation in enclosure morphology and dimensions, it seems likely that the enclosures are not the product of a single moment in time but that the system grew organically over a long period, with fields added agglutinatively according to functional need (cf. the apparently agglutinative pre-Classical enclosures in the Homs region of Syria: Philip, Bradbury 2010) or, in the case of the few abstract-sized fields, according to abstract measures.

The size of many enclosures would not preclude their use for cereal cultivation, but the lack of standardisation and the poor quality of soils in the regions where the linear features have been identified favours a functional specialisation of most enclosures towards either olive and vine cultivation or else managed pasturing in a fragile ecozone (i.e. rotating animals between different areas); both functions fit with the palaeoenvironmental data. Is it possible to say if one of oleaculture, viniculture or pastoralism was more important than the others? At present, probably not. Miletos was famous in Greek and Roman times for its woollen products (for ancient references, see, for example, Aristophanes *Lysistrata* 726; Strabo *Geography* 11.578; Pliny *Natural History* 8.73; Virgil *Georgics* 3.306; Theocritus *Idylls* 1.28), and the environmental evidence also suggests that pastoralism, perhaps organised around wool production, was a constant if fluctuating component of the Milesian economy from at least the first millennium BC, if not before. Lohmann argues (Lohmann 1997a) for the presence of a shepherding station around Stefania, and this might suggest that at least some enclosures could have been pastures or pens rather than cultivable fields, especially given that many of the enclosures in the centre of the peninsula are in areas that would be very difficult to plough and are too well drained to maintain productive soils for cereals. On the other hand, the wool for the Milesian textile industry could have come from sheep grazing over a much wider region than the ‘core’ peninsula itself, into the Carian hinterland, albeit that the political fragmentation that restricted control outside polis territories might have favoured keeping herds closer at hand before the Roman era. Of course, if the enclosures were primarily pastoral in function, they could be very ancient, even prehistoric.

On the other hand, if we assume that the enclosures identified in the aerial imagery are better associated with olive and/or grapevine production, then the palaeoenvironmental evidence currently points to two periods of major olive/grape expansion: the Hellenistic and the early Byzantine periods. Of the two, we suspect that it is the Hellenistic (and perhaps late Classical) period that offered the opportunity for large-scale land restructuring as the region recovered from the political and economic collapse of the long fifth century. This may provide the most likely chronological origin for the bulk of the visible field systems. Perhaps later, during the late Roman or early Byzantine period, a further set of enclosures (identifiable by their more regular abstract sizing) was added – a conclusion that fits with the association of many of Lohmann’s rural sites with early Byzantine material culture. We accept, however, that other readings of the data are possible. In particular, there are unanswered questions concerning the extent to which the Bafa cores provide an accurate representation of the entire Milesian peninsula. While totally unquantifiable at present, it should be noted that Archaic Miletos’ most well-known resident, Thales, was famous for having made a considerable amount of money by investing in olive production, his motivations for doing so and his method of success notwithstanding (Aristotle *Politics* 1259a.1). A more tractable but as yet unexplored source of information to compare against the environmental data may be the distribution and quantities of Milesian amphoras, whose contents, distributed around the Mediterranean and Black Sea regions, would have been liquid (i.e. wine or olive oil) and for which we have considerable evidence during the Archaic period (Monakhov, Kuznetsova 2017).

This initial documentation of linear features on the Milesian peninsula and our attempts to make sense of them with the available published data from the area have highlighted the continuing incomplete state of our knowledge of field systems in the Aegean region. They also re-emphasise the need for multidisciplinary investigations in multiple regions before such features can be linked more precisely into our narratives of economic history. Future work will need joined-up investigation of the whole area – combining remote-sensing data (ideally using LiDAR and/or airborne radar to penetrate the macquis) and on-the-ground re-survey and excavation might help to clarify competing interpretations. Stronger conclusions could have been made here with more ground truthing, but, given the speed of change on the peninsula as a result of current agricultural practices and urban growth, it was far more urgent to publish our results quickly so that the remains can be more easily protected. Further aerial and ground investigations are essential to determine the long-term history of the Milesian peninsula and contribute to a better understanding of the relationship between land-use patterns and economics across Asia Minor over the last 5,000 years.

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