An agro-pastoral palimpsest

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 landscape. These are here interpreted, for the most part, as relict 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 had noted the existence of terracing and rural divisions at certain points in the landscape, the new remote sensing data has 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 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 2000 to 5000 years.

1. Introduction

Archaeologists have, traditionally, spent a large proportion of research effort 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 role 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 their 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 only consider Latium. Different transport and food preservation (e.g. salting) technologies may have allowed Greek and Roman cities to create long food exchange chains, but at most other 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 bring 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, e.g. Alcock 1993). Cross-disciplinary studies of historical (and archaeological) geographies such as Peter

Thonemann's *The Meander Valley* (2011) represents a laudible corrective, 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 for which one might expect little to be left unknown, is precisely one of those cases.

The Milesian Peninsula has been a focus of historical enquiry for over 200 years, 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 nineteenth century, as part of the first systematic excavations on the peninsula led by Theodor Wiegand, a German scholar resident in what was then Smyrna and Constantinople between 1899-1911 (modern İzmir and İstanbul respectively), a detailed topographic and architectural survey was launched for the entire peninsula. The survey, undertaken and published by Paul Wilski (1906), documented topography, identified standing ancient and recent remains, architectural spoilia, water sources and the course of an apparently ancient street which cut the low Stefania (ancient Akron) ridge which splits the peninsula into a northern and southern part. 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 findings stood as evidence for a higher degree of landscape use in the past than was observed by visitors such as Wiegand at the beginning of the twentieth century AD. The work was so comprehensive, however, that no sustained attempt to update its findings were made until the 1990s when a team led by Hans Lohmann undertook an extensive archaeological survey in the Milesian Chora with the aim of synthesizing and confirming various localised studies undertaken on the peninsula in the intervening years, providing a more detailed distribution map that would take account of better understanding of the date of surface archaeological finds (including ceramics and prehistoric finds such as obsidian), as well as (in the latter years of the survey) taking advantage of the newly demilitarized technology of GPS to more accurately and precisely locate sites. Though a final report of this survey remains in preparation, the interim reports (Lohmann 1995; Lohmann 1997b; Lohmann 1999) provide useful insights about the overall intensity of human occupation over the longue durée, with sites recorded dating from the Late Chalcolithic to the Ottoman period, and a particular high number of sites identified as Roman or Late Roman/ Early Byzantine (for summary interim site catalogue, see Lohmann 1999).

Lohmann's preliminary reports also refer to 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) as having terrace walls, field boundaries (*Mauerspuren*, *Flurgrenze*) and/or what he calls "mandra" (from ancient Greek, meaning enclosure or pen for animals), some of which were associated with Antique and/or Late Antique materials although Lohmann is necessarily cautious about the dating (FIGURE 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 era (ca. 700–500 BC) when its residents were responsible for the foundation of colonies across the Mediterranean and Black Seas (Ehrhardt 1983; Herda 2008). Overseas colonialism and the city's longer 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 making sense of the base Milesian economy through time (Pečírka 1971; Röhling 1933). What was their purpose?

In an article entitled *Altflur oder Pingenfelder,* Lohmann (2008) addressed this question directly, weighing 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 Borg and Borg and students across the centre and south-west areas of the peninsula, identified (or, re-identified) stone quarries in the form of "pit fields" (*Pingenfelder*), as well as lines of piled irregularly shaped stones which they argued were the discarded chippings from limestone quarrying. They suggested that the apparent linear or rectangular nature of these lines, as visible from oblique aerial photography (see FIGURE 2), was simply a byproduct of the method of extracting stone from pits and depositing waste at the edge of quarrying pits, 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 serious envir-

onmental consequences, they argue. Lohmann, by constrast, argued that while quarrying was certainly undertaken on the peninsula in antiquity, the scale of the linear features and their association with archaeological remains, is more plausibly characterised as agronomic features, with sites like S108 on the western end of the Stefania plateau (see also FIGURE 1) perhaps comparable to the pastoral installations (e.g sheparding station) previously documented by Wolfgang Radt in the 1970s on the nearby Bodrum peninsula (Radt 1970; Lohmann 1997a), and others for cultivation of crops of different kinds. Environmental degradation on the peninsula, leading to the relative 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-mining.

Naturally there is no replacement for on the ground examination of structures, or indeed their excavation and scientific analysis, especially with regards to providing more concrete dating clues. 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. Recent advances in remote sensing data availability and analysis brings these features starkly back into the light: linear features with a total length of at least 300 km 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.

2. Mapping of ancient linear landscape features using multiple high-resolution, multi-temporal remote sensing sources

The origin of the current study was 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 German Archaeological Institute's Istanbul Department (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 DigitalGlobe in order to facilitate contextual understanding of the necropolis in its landscape. Taken on 4th September 2011, and with a horizontal resolution of 0.5 m per pixel, the image was later also purchased by Google from DigitalGlobe and included in their mosaic of images for their digital globe platforms, "Google Maps" and "Google Earth" (which can still be viewed by enabling the "Historical Imagery" feature). Examining the image, the current authors noticed a number of linear features within the dense macquis-vegetated area on the eastern side of the image region (FIGURE 3a). From the ground, these features were obscured by high macquis and were apparently inaccessible.

Growing out of these rescue excavations, a Project Panormos pilot survey season was undertaken in 2015 (funded by the DAI), which contined again in 2017 (funded by the McDonald Institute for Archaeological Research, the BIAA and the Wainwright Fund). 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 sea-side tourist resort, it was realised that historical imagery might provide a useful adjunct for identifying unknown archaeological features, which may have been masked by subsequent changes. Suitable declassified CORONA imagery was not available (unlike for other parts of the Middle East where they have provided insights into fossilized prehistoric landscapes like that of the Early Bronze Age urban network of roads in northern Syria, see Ur 2003), so other remotely-sensed data was sought. In 2016, a small sample of aerial photographs taken by the Turkish airforce from the late 1960s and early 1970s were therefore purchased from the archive of the Haritacılık Genel Komutanlığı/HGK (the Turkish military mapping division). The comparison between these photographs and modern satellite imagery provides a dramatic document of the growth of the town of Didim and its suburbs. Further linear features were identified in the aerial photographs on the south-west corner of the peninsula (FIGURE 3b), which had not initially been spotted because they were less clearly defined in the more recent World-

View-2 satellite imagery due to the dense vegetation. A number of these features began to be digitised (this work done by project assistant Michael Loy), though in the absence of full-scale orthographic photogrammetry of the aerial images at that time, the level of accuracy was limited.

In 2018, the current authors re-examined the data collected on these linear features with a view to completing the project. 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 image was collected. (Note: although the collection date and source is not clearly specified, the imagery in Bing Maps is also probably derived from DigitalGlobe's multispectral satellite imagery archive, and based on comparison with DigitalGlobe's own browsing tool at https://discover.digitalglobe.com/, 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 strikingly, 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 (by comparison with thumbnail image of the WorldView-3 image captured 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, taken over a period from 2014 to 2018, was processed and summarised using Google Earth Engine to provide median and maximum values of bipolar and single polarity radar reflectance for expot. This previously untried source of remote sensing data, with a resolution of 10 m per pixel, provided a digitisation base-line with which 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 remote sensing data were thus combined (the historical aerial photographs, Sentinel 1 radar and visual spectrum multispectral imagery from DigitalEarth satellites including the purchased WorldView image and compared with mosaicked tiles available in Bing Maps and Google Earth/Maps platform) to create an extensive database of currently visible linear features of all types across the entire Milesian Peninsula (FIGURE 4; see TABLE 1 for list of remote sensing sources leveraged in this study).

3. Positive and negative 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 longer-term, this process of large-scale clearance and soil exposure will have negative effects on both the archaeological and natural landscape. 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 (Normalized Differential Vegetation Index) trends over a 25 year period based on 8-day averages from the Landsat 5, 6, 7 and 8 programmes (covering the period from 1985 to 2017) using the Google Earth Engine platform, gives some indication of the spatial extent and speed of the transformations (FIGURE 5), with an acceleration in the 4-5 years running up to 2017. For example, vegetation indices in an area of around 110-115 ha on the eastern end of the Stefania/Akron plateau (marked A) had already been dramatically reduced (represented as blue channel on the RGB plot) from 1982 to 2017, 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), has also been cleared on the hills to the north-west of the village of Akköy, although few linear features could be identified. Elsewhere on the peninsula, such downward NDVI trends (blue channel) index the expansion of urban development around Didim and its satellite resorts of Altınkum, Akbük and Mavişehir along with associated road and waste infrastructure (marked C). Sentinel-2 L1C imagery from 2 July 2018 shows further areas of macquis have been cleared on the western end of the Stefania hills in the last 2 years. Although the resolution of Sentinel multispectral imagery at 10 m per pixel is too low to provide information about the smallest linear features, it 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 a pessimistic although not necessarily hopeless prospect for gaining further data about the structures from intensive surface survey, for example. Depending on the level of recent destruction on the ground (for which the authors 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 targetted 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 microtopography and higher resolution vegetation data from these kind of datasets, it may well be possible to fill in a number of gaps in the data in the future. All of these things will require appropriate archaeological permits from the Turkish authorities. 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 effort to emphasize the importance of these features and to help protect them from further destruction.

4. 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 widely distributed, there is a strong concentration of linear features in the swathe of land to the south-east 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, has often been assumed to be similarly limited in the past (Lohmann 2008: 409-411); much of the area is still covered by macquis today. This situation contrasts with the strip of marl soils around Didim (to the south-west 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 sub-urban sprawl. In these more fertile regions, linear features are few, or cannot be easily differentiated from modern boundaries. Those linear features which are clearly in use today were not recorded in the database at this stage, although it may be worth re-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 visual satellite imagery and higher-resolution aerial photography that some lines are formed from stone "embankments", like those interpreted by Borg and Borg as quarrying waste (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 represent natural geological structures in the limestone; such natural features were only digitised where they appear to fit into a cultural system. Only a large-scale project of ground-truthing would 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 Borg and Borg, we suspect any association (which would mostly be on the south-west corner of the peninsula) is mostly coincidental based on accessibility of bedrock in these areas, although re-use for alternative functions should not be ruled out entirely; indeed conceivably 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 as part of the Sphakia Survey (Price, Nixon 2005: 680-2 and esp. figs. 12 and 13), which were associated on the basis of proximity to Late Roman remains at Ag. Astratigos; while the longer and thinn-

er shaped-"plots" seen elsewhere on the peninsula could be more easily compared to terracing identified on the west slopes of Hymettos in Attica by one of the pioneers of archaeological use of aerial photography, John S. P. Bradford (Bradford 1956: esp. pl. 9); or indeed the "strip fields" visible on satellite imagery on the Omalos plain, western Crete (Rackham et al. 2010: 274, fig. 26.5 and 26.6).

The question, of course, is whether we can provide any precise information about the chronology of their creation; the longevity of their use or re-use, or indeed whether structures of different periods are superimposed as palimpsest; and how they functioned as part of the overall rural Milesian economy. Despite the obvious parallels cited above to other apparently ancient field systems, it is currently difficult to use the shape of the fields as a definitive criteria for chronological origin, at least in the absence of a robust typology of field shapes for the Aegean or programmes of direct dating by OSL of accumulated sediment behind terracing (cf. Kinnaird et al. 2017). If shape and dimensions cannot currently provide direct dating information, it may nonetheless provide useful proxy information about specific function and hence wider significance. To demonstrate this, we start by focussing 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.

A. Close-up: the eastern Stefania plateau

A clear case of superimposition of later field boundaries on earlier ones and hence relative chronology can be seen on the eastern end of the Stefania plateau, where modern regular fields currently in use are oriented very differently from a set of partly hidden early linear features in the same area (FIGURE 6). This fact does not in itself provide absolute date of 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 shapes of the fields in modern use are indeed a relatively recent phenomenon. However, the difference of orientation does suggest rather strongly that the purpose of the older system of linear features in this area was as pens, field divisions or boundaries, rather than as terraces. The terrain slopes toward the south-west, but not very steeply (maximally around 3%), and although modern farmers may be less concerned about nutrient loss when they can artificially add nitrogen, these are still area of relatively thin soils which seem at high risk from sheet erosion. If these linear features were terraces, therefore, we might expect a greater deal of re-use and continuity into the modern period. The exception to this may be the areas of apparently slightly deeper soil which represent colluvial fill from shallow runoff valleys heading south-west to the bay of Kovala, and which NDVI highlight as more vegetated (and hence better watered) braided valleys (cf. FIGURE 5b). A small group of visible linear features, apparently soil marks (marked B on FIGURE 6) lie just to the west of the ancient hilltop settlement of Assessos (marked A), overlain by many modern fields. Lohmann's survey already recorded a number of walls and sherd clusters in this area (S229, 227, 223, 224) and provisionally dated as Classical, Hellenistic or Early Byzantine. Just to the south-west of the cluster is another site, S228, which Lohmann identified as an Archaic farmstead on the basis of archaic amphora rims (albeit alongside a small number of prehistoric finds), which he compared to another nearby site, S226, both of which he argues could represent a shephard station (Lohmann n.d.).

B. Close-up: western Stefania plateau

The western end of the Stefania plateau demonstrates some of the diversity of land shapes represented by these linear features. Just to the east of the region labelled *Kokkinolakka* (Greek "red soil") on the Wilski map (labelled "1" on FIGURE 4), lies a small *yayla* (Turkish 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 (~60–80 m x 150–300 m, labelled A on FIGURE 7); alongside much thinner and less pronounced divisions (~20 m x 100 m, labelled B); and some smaller circular structures (~20 m 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 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 do suggest possible functional differentiation: A, are of a sufficient size to be suitable for cereal cultivation, orchards or grazing; B as smaller plots might be suitable for smaller garden plots or vineyards; and C as small circular structures are plausible as either

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 20 m in diameter, similar in size to circular structures on the Bodrum peninsula previously argued to be domestic structures (Lohmann 1997a: figs. 4–8), that have been suggested to date from the Archaic to Roman eras, depending on morphology (Radt 1992: 6-7). Alternatively, the nesting of differently sized and shaped rectilinear enclosures might reflect a chronological consequence of inheritance or changing modes of ownership, and/or re-use incorporation of pre-existing structures into new land-use systems. Just to the east of this now exposed surface, Lohmann identified a site, 'S108' (FIGURE 8), and interpreted it as a shepherding station, of unspecified date. Unfortunately, the macquis overgrowth makes it difficult to understand the horizontal connection between S108 and the visible features nearby, but 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 south-west, lies the so-called "Archaic Cult Complex" (identified by Karen Gödecken in the early 1980s and excavated by Klaus Tuchelt and team 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 had associated agricultural lands nearby by which they could be supported economically (just as in Byzantine monastic or Ottoman *vakıf* institutions); but from the aerial imagery alone no structuring connection can be currently identified, and few linear structures are identifiable around the cult complex itself.

C. Close-up: Hörgüç Tepe / "Ta Manolakia"

A third area, Hörgüç Tepe, provides another example of enclosure shape diversity, in a region still covered in relatively thick macquis cover, and is one of the regions argued by Borg and Borg to have provide evidence of "pit field" quarrying. A large concentration of linear features can be identified around 2-3 km to the east-north-east of modern central Didim, on the northern side of the modern main road going east to Akbük, Kazıklı and the Bafa Gölü (labelled "2" on FIGURE 4). Near the main road to Akbük, where there is a steeper gradient toward Hörgüç Tepe, many long and narrow terraces (each ~40 m in width) are visible (labelled A on FIGURE 9). It seems likely that the terraces were continuous here, and the gaps in visible features are merely the result of the higher intensity of vegetation. The spacing of these terrace divisions compares well with the spacing of terraces in the plain recorded by Bradford for Attica, i.e. "100 to 130 [imperial] ft.", 30-40 m (Bradford 1956: 175). Higher up, where the slope is less steep, a more varied division of the land is visible, with divisions of ~70 m x 80 m toward the west (labelled B) plus some larger blocks ~100 m x 120 m 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 olive tree plantations, vines or other cultivars. Circumstantial clues point to possible dating of the structures near the top of Hörgüç Tepe (on the western side of this area). Lohmann identified 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, together interpreted as a late Classical/Hellenistic farmstead that was reused in the Early Byzantine period. Slightly to the north-east, S408, a group of stones and pottery is described by Lohmann as a disturbed Hellenistic or Roman grave monument (Lohmann n.d.). It is not unusual for ordinary 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 which would confirm that this is what is happening here. 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 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 and 8, here reproduced in FIGURE 2; cf. map on FIGURE 10). A disused quarry record by Wilski and re-recorded by Lohmann (marked "ancient quarry" on FIGURE 9) does confirm that some parts of the peninsula were indeed used to source stone. It is not impossible, as Borg and Borg suggest that this quarrying was related to the construction of temple and other buildings at Didyma. But we would also argue that the industry does not seem to have had the large-scale environmental impact on the landscape that Borg and Borg envisaged.

5. Establishment and abandonment of enclosures

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

A. Enclosure areal dimensions and rural land division systems

While our synthetic knowledge of enclosure shapes in the Aegean is not at a stage to indicate dating or development, the raw dimensions can be examined to search for patterns which 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, e.g. larger plots being regular multiples of smaller plots and vice versa. Whether or not we can trace the imprint of such a system from 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 (e.g. 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 type-(b) and type-(c) make more sense from the perspective of the farmer or pastoralist; type-(a) is really only useful from the perspective of distanced bureaucracies that want to 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 which appears also to be a volumetric measure of seeds needed to sow a field (Brown 1956; Bennet 1999; Uchitel 2005). Western histories of mathematics commonly locate the "discovery" of general axioms of mathematical geometry, which would allow type-(a) calculation of land areas, to scholars Thales of Miletos or Pythagoras of Samos, both of Ionian origin, who were active during the 6th and 5th centuries respectively. Leaving aside modern obsession with authorship of ideas (admittedly shared with ancient Greek scholars), the question as to whether or not either of these named figures played a significant role in discovery or indeed whether these ideas were imported from Egyptian predecessors is less important than the fact that their work enabled the possibility of 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 abstract horizontal plane were apparently those of Miletos and the *Streifensträdte* of Magna Grecia (Hoepfner, Schwandtner 1994; Ault 2017), dating before the 5th century BC. Geophysical evidence and the orientation of Archaic monuments in the city of Miletos itself suggests 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 7th and 5th 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 convertion of textually referenced quanta to modern metric systems, only become more common from around the 3rd century BC. By 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 land were measured in *schoinoi* (100 ft x 120 ft) or *plethra* (120 ft x 120 ft), but with the actual length of a Greek foot (*pous/podes*) potentially varying between 0.295 to 0.334 m regionally (Boyd, Jameson 1981: 332). Indeed an inscription describing land sales from the 3rd century BC city of Magnesia-on-the-Meander (not far upstream from Miletos), show a preference for rounded multiples, in this case 50 *schoinoi*, as a kind of default plot-size, which Thonemann has argued was a result of a Hellenistic policy of relatively egalitarian division of land (Thonemann 2011: 243-244). Naturally one might read this "egalitarianism" more cynically, as instead a bureaucratically convenient block which could only have been set when land was rapidly reorganised or redis-

tributed. Roman centuriation, not in evidence for much of 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 had two variant meanings, based on the quality of the land: "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 a path width needed for two oxen yoked together (Pliny HN 18.3) recalling 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 deriving 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 unequivocally drawn, 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 (FIGURE 11a); and there was no region where an entire cluster of plots can be comprehensively recorded. Second, since we do not know the date of creation of the enclosures—indeed, we cannot exclude the possibility that divisions were made at different periods—it is difficult to identify particular known quanta which 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 (FIGURE 11b), the most significant modal average peak at 0.79 ha (just under 2 acres). Only a handful (4-5) of the plots could be said to reach the approximate equivalent of 50 *schoinoi* (FIGURE 11c), the important Hellenistic quanta recorded in inscriptions, whatever metric value one takes to represent a Greek foot. 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 (FIGURE 11c, d, e and f) of these areas to 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: Hellenistic systems, Boyd, Jameson 1981; Heimberg 1984; imperial Roman, Thonemann 2011: 254-255; 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. 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 transfer between different fragile pastures.

The alternative is the palimpsest possibility, namely that the same result could arise because 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 and objective statistical technique to identify unknown quanta in a collection of measurements, namely Kendell's cosine quantogram analysis (cf. Pakkanen 2002; Pakkanen 2004; Kasiński 2019), is nonetheless suggestive. Applied to complete enclosure areas drawn, the highest scoring possible quanta

is 0.84 (FIGURE 12a). Of the comparable listed known ancient quanta (TABLE 2), the most readily comparable modulation of this value is the Roman *iugera*, and land values which were derived 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 provides the suggestion that a certain number (maximum 80 out of 200) of measurable enclosures could conceivably have been laid out according to Roman or Byzantine pre-assigned measurement (their location shown as red enclosures in FIGURE 12b). 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, but the result does suggest further statistically investigations could be fruitful: with further categorical differentiation or spatial link between each enclosure, it might be possible to assert a stronger relationship between certain fields and certain measurement systems in the future.

B. Settlement history, cultural breaks and land organisation

The obvious case of superposition of very recent field onto the ancient enclosures on 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 "[a]n 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 imposition of a new system following a disruption of agricultural life on the Milesian peninsula. But how long was that period of disruption in this case?

The *latest* likely abandonment of the linear structures on the eastern Stefania plateau and much of the rest of the peninsula was in the 1920s. As with much of the west coast of modern Turkey, the 1923 exchange of populations between Turkey and Greece enacted by the Treaty of Lausanne provide 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 Apollo Temple of Didyma and the predecessor to modern town of Didim whose centre was moved to a new site, Yenihisar, two kilometres to the south-east of the temple after a serious earthquake in July 1955 (Ergin et al. 1967; Yergün et al. 2014). Wiegand also noted regular "Greek" migrants from the island of Samos during harvest or other labour intensive periods to the Meander region (as we have been reminded by Thonemann 2011: 301). The Wilski map, produced well before 1923, records a large number of Greek toponyms across the entire peninsula (transliterated to German spelling), which appear to index Greek ecclesiastical or personal ownership of land or else coloured landmarks (*Kokkinolakkha, Tu Konstandi tu Kolia, Tu Aristi*, ...) alongside many of Turkish or hybrid Turkish-Greek origin (*Bagtscheh, Arab-Alan*, *Tsi Hadschy Argyri,* etc.). Population continuity is to be expected on 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 are more likely to have maintained their 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 into 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 much to establish the diachronic establishment of such linear structures in the first place, whether as part of a rapid period of imposition, or a slower growth. For this we need to turn to wider knowledge of the peninsula's cultural and environmental history.

Assessing the degree of occupation on the Milesian peninsula and hence periods in which we might expect expansion into the less productive hinterland remain 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 currently difficult to use the results to quantify changes of settlement density or population across time. Simply counting sites defined as having remains of

settlement, farmstead or building by period, and adjusting for the length of that period (Lohmann 1999: 466-473) suggests the highest density of construction *in the chora*, i.e. not including the major centres at Miletos and Didyma, to be the Early Byzantine period, closely followed by (presumably Late-)Classical/Hellenistic, and then Archaic (FIGURE 13a). This pattern contrasts with the data from datable diagnostic pottery densities recovered in our recent intensive survey around Panormos (FIGURE 13b), where the two peak frequencies once weighted against individual sherd dating precision, lie during the Archaic and Early Byzantine periods. As an indicator for pottery production (and hence discard), these relative frequency values may be a more reliable proxy for diachronic economic intensity, or 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 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, see Kalaitzoglou 2009). The evidence for terracing in other parts of the Aegean (eg., near the Minoan settlement of Palaikastro on Crete, see 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 north-east 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; Brückner et al. 2014). The linear structures in the interior of the peninsula lie therefore, at some distance to the Bronze Age settlement. At the other end, historical data suggests that the entire Milesian peninsula and nearby Meander valley suffered a serious economic decline following ca. AD1500, the cause of which remains unclear (a climatic shift has been cited as explanation, e.g. 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 currently most plausible time span for initial establishment or growth of these field systems is between the Archaic and Late Byzantine/Early Beylik period (700BC to AD1500), but as suggested in the close-up analysis of 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.

C. Environmental proxies and agricultural expansion

Palaeoenvironmental proxies can provide further clues to the fluctuating exploitation of the region, with some caveats. Evidence for increasing 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. Knipping et al. (2008: 373-376) register indicators for animal pasturing (in the form of presence of *Plantago lanceolata*, *Rumex* and *Sarcopoterium*) throughout the 1st millennium BC and into the post antique period from the "Baf S1" core. Fluctuating signatures of pine and oak through this time suggest differing degrees of land clearance through this period; a higher frequency of pine and oak is an indicator for a less open landscape (e.g. core section Baf S1-4). Olive pollen (*Olea*) remains remarkably low into the mid-1st millennia BC (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 (section Baf S6-2 and 3), however, the levels of olive pollen grow substantially, implying a rising exploitation of this crop, alongside other airborne pollinating fruit crops (*Juglans*, *Castanea* and *Vitis*, i.e. walnut, chestnut and grapevine), and indicators for pasturing and agriculture (*Cerealia*). Following this in (Baf S6-4), sometime in the Roman period, olive, and other anthropogenic indicators, appear to decline. Based on a reanalysis of the same data from upper levels of the "Baf S6" core, Adam Izdebski recently argued that following a period of pastoral indicators in the 4th and 5th centuries, there was a revival of olive pollen from the *later* early Byzantine period, around the 6th century AD onward, which he sees as fitting the Milesian Chora data (Niewöhner et al. 2016: 277-279). He also argues that the basic system of cultivation seems to continue relatively unaltered, albeit with minor fluctuations of indices of pastoralism or cultivation well up until the 15th century AD. Izdebski's analysis and this final claim in particular has not been received uncritically: Alex Herda, Helmut Brückner, Marc Müllenhoff and Maria Knipping refute the reanalysis as over-stretching the chronological resolution, especially given the analytical unreliability of originally used to provide radiocarbon dates and small

number of dates makes creating 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 south-west, which would bring pollens from across the central peninsula into Bafa (Niewöhner et al. 2016: 274-275), but the deposit regime is not well known and it is possible that the effective catchment varied in time according 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 with which we could potentially associate the development of enclosures: the initial large-scale expansion of olive and fruit cultivation on the peninsula (perhaps the late 1st millennium BC, roughly the Hellenistic era), and following a decline, a second expansion focussed around olive production (perhaps some point the late first millennium AD, ie. the Byzantine period). Examination of erosion and sedimentation rates across the peninsula offer a potential source of corroboration or discord with palynological data (core samples from near Yeniköy on the northern side of the peninsula were studied, for example, but the basis of the conclusions unclear Bay 1999: 84). Cores within the watersheds south of the Stefania ridge, where most of the enclosures lie, have never been taken.

6. 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 which 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 which today are, or at least were in the 1990s, outside the main areas of settlement) prompts many questions which remain difficult to answer definitely. As we have seen, certain periods of Milesian history can be more plausibly linked to an expansion of agriculture than others (the Archaic, Hellenistic and Early Byzantine periods in particular) based on archaeological and palaeoenvironmental indicators, but given the large variation in enclosure morphology and dimensions, it seems likely that the enclosures are not the product of a single moment in time and that the system grew organically over a long period of time, 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 standardization 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 of which fit better with the palaeoenvironmental data. Is it possible to say whether 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; Plinius, Naturalis Historia 8.73; Vergil, Georgics 3.306; Theocritus, Idylls 1.28). 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 1st millennium BC, if not before. Lohmann previously argued for the presence of a shepherd 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 which 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 restricting 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 asso-

ciated 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 period. 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 5th century. This may provide the most likely chronological origin for the bulk of visible field systems. Perhaps later, during the later Late Roman or Early Byzantine period, a further set of enclosures (identifiable by their more regular abstract sizing) were added on, a conclusion which 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 open questions about 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 famous resident, Thales, was famous for having made 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 amphora, whose contents once distributed around the Mediterranean and Black Seas would have been liquid–i.e. wine or olives, 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 peninsula has highlighted the continuing incomplete state of our knowledge of field systems in the Aegean region. It also re-emphasizes the need for multi-disciplinary investigations in multiple regions before such features can be more precisely linked 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), 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 is 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 tell 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 5000 years.

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