ARCHAEOLOGICAL RECONNAISSANCE OF UNINVESTIGATED REMAINS OF AGRICULTURE (AROURA): ANNUAL REPORT 2010

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Introduction and Summary

Members of the 9th Ephorate of Prehistoric and Classical Antiquities (IX EPCA, Thebes), UMBC, and University of Michigan, in official collaboration (V.L. Aravantinos and M.F. Lane, Co-Directors), carried out geophysical and surface surveys of the plain immediately around the Late Helladic IIIB fortification of Gla (Γλας) in the northeastern Kopaïs, mainland Greece, between 4 October and 14 November 2010. They also undertook subsurface sampling of soils under the terms of permit number 483 from the Institute for Geological and Mineralogical Exploration (ΙΓΜΕ). Fieldwork was funded by a New Research Grant from the Institute for Aegean Prehistory.

The acronym of the joint geophysical and surface survey is AROURA, an allusion to Homeric ἄρουρα and Mycenaean *a-ro-u-ra* (Pylos tablet PY Eq 213.1). The principal aim of this fieldwork was to apply Dr. Lane's model of a landscape under a system of extensive cultivation in the Late Helladic period—such as is indicated in Linear B texts from several archives, including those of Thebes—to an area where conditions of preservation of constituent features should be optimal for archaeological discovery. The plain within the Mycenaean polder around Gla was chosen for several reasons. Firstly, the establishment of the stronghold of Gla appears to be contemporary with the construction of the polder, the fortification then protecting massive stores of agricultural products and defending the surrounding territory from which these products surely came (see Ιακωβίδης 1989, 1998). Secondly, all previous historical and geomorphological accounts of the Kopaic Basin indicate that it has been an environment of net sediment deposition since the abandonment of Gla and the surrounding drainage works, around the end of the 13th century BCE, until the completion of the modern drainage works in the early 20th century CE (see Knauss, Heinrich, and Kalcyk 1984). Such an environment increases the chance that traces of extensive Late Helladic agricultural plots are preserved, in contrast to the net erosional environments around most known Mycenaean citadels. Finally, aerial photographs and satellite images exhibit a variety of distinct "field marks" (crop and soil marks) in and around the polder containing Gla, the great majority of which strongly suggest features of cultural origin preserved beneath the ground surface (Figure 1).

The AROURA field season of 2010 was overall a success in several respects. It sampled over 36 hectares of land on every side of Gla and around the Mycenaean polder dike to the west, it met its research objectives for the first year, and it began to produce evidence that may answer research questions pursued over the long term.

Research Objectives and Questions

Objectives specific to the 2010 campaign of AROURA were five: (1) to seek confirmation of the AROURA model of extensive agriculture by applying survey and sampling strategies that should render visible features of the size, dimensions, and orientation expected; (2) to strike a balance between sampling from areas containing field marks and previously identified Mycenaean drainage features and areas on every side of Gla, particularly between its four gates and the surrounding landscape; (3) to demonstrate the utility of geophysical techniques for investigating ancient agricultural practices and strategies, thereby laying the groundwork for further specific methodologies; (4) to set up the fieldwork conditions and lay the interpretative foundation for confirmation of the nature geophysical results by independent means ("ground-truthing") in this and future campaigns; and (5) to apply survey data to begin to answer questions left by previous investigators of the Project Area, some of whom were unable to carry out systematic archaeological fieldwork (Knauss, Heinrich, and Kalcyk 1984). These questions include: (a) what is the nature of the field marks in and around the polder around Gla? (b) what relation exists between land use in the polder and the known stores of crops inside Gla's walls? (c) what is the diachronic relationship between the construction of the polder and features discovered within it? (d) how was irrigation or drainage (or both) controlled within the polder? (e) how and when did the Mycenaean mechanisms for claiming land from the Kopaic wetlands come to an end?

In addition to the objectives and questions above, AROURA has advanced long-term goals for research under subsequent archaeological and geological permits. These include (1) clarifying the relation of Gla to the anthropogenic landscape of the Late Helladic III period, including land use in the polder and various settlements in the surrounding uplands, (2) exploring whether Mycenaean land management system and claiming of land throughout the Kopaïs (not just around Gla, but also around other sites) was ecologically sustainable, (3) trying to determine whether the Mycenaean drainage system and polders represent a cause of or response to a subsistence crisis (or both), and (4) examining the evidence of Gla's connection with the two major Late Helladic settlements in the wider region, Thebes and Orkhomenos.

Methods and Techniques

Spatial Control and Sampling

Spatial control for scientific sampling of the landscape surrounding Gla in 2010 and coming years was achieved by definition of a Project Area centered on the fortification, consisting of a grid of squares 30 m on a side comprising 1,000.35 hectares (10,003.5 stremmata; Figure 2). The grid extends from Mt. Fteliá in the south to the traces of the Mycenaean canalization of the Melas River (Mavropótamos), just to the north of the present river channel, and from National Road 1 (Athens–Thessaloniki) in the west to the gentle slopes of Souvlí in the east. Thus it is not only constrained closely by physical boundaries, but it also includes contrasting landforms that may have been exploited differently from each other during the Late Helladic. The grid was oriented to align with the modern land tracts in order to obviate the trouble of personnel with instruments frequently crossing modern field boundaries, irrigation channels, and other obstacles. Intersection points on the grid were located in advance of geophysical and surface sampling to within five centimeters of their mapped position with differential global position system (DGPS) receivers (specifically, the exceptionally rapid and accurate Javad Triumph-1 GNSS device; Figure 3).

Within this grid, areas for sampling were delineated according to the project's objectives (see above). Each of these was given a Latin letter designation, from A through J, and each was in turn divided into two or three "transects" set off from one another so as to avoid the possibility of the edges of a transect aligning by chance with a linear subsurface archaeological feature or geophysical anomaly. Within each area, transects were assigned Arabic numerals 1 through 3 (see Figure 2), and within each transect, grid squares were identified with a letter–number coordinate pair. Sampling areas were later grouped into "sectors" for purposes of interpretation (see "Results" below).

Geophysical Methods and Techniques

The sole geophysical technology applied in 2010 was magnetometry. Magnetometry was selected for several reasons. Firstly, magnetometers can detect features of all the types expected, including built, excavated, or planted field partitions; drainage or irrigation ditches; scars in the subsoil from repeated plowing in one direction; pits for planting vines and crop trees; and built or excavated traces of structures for storage, refuge, and crop processing. Corresponding anomalies are caused by local differences in weakly magnetic iron oxides occurring naturally in soil. Secondly, they can also distinguish between features of different type by the character of the magnetometric anomaly. Finally, the type of magnetometer employed, a dual fluxgate gradiometer (the Bartington 601-2), can travel over low vegetation, collects data especially rapidly in pedestrian traverse, and is capable of detecting both shallow and deep (1.5 m+) anomalies (Figure 4).

Within transects 90 m wide, blocs of grid squares of dimensions 60 m by 90 m were delineated and divided with high-tensile 1-by-9-mm plastic binding strap («πλαστικό τσέρκι»), between corner stakes located with DPGS, in such a way that traverses one meter wide could be walked with the magnetometer (Figure 5). Traverses were walked back and forth within 30-by-30-meter squares and likewise "zigzag" between each of the six grid squares constituting a bloc. Magnetometric readings (samples) were taken every 0.125 (1/8) meter along traverses one meter wide. Continuously laying out and taking apart the demarcating strapping permitted between 1.62 and 2.70 hectares (16.2–27.0 stremmata) to be sampled per day, the lower end of this range due mainly to high wind or heavy rain in any day. Paper forms for sketching a map of a sampled grid square, and for recording vegetation, soils, land form, and modern and ancient structures in each, were also completed.

Independent Verification of Results (*"Ground-truthing"*)

That magnetometry does not detect archaeological features cannot be over-emphasized, even to seasoned archaeologists. Magnetometric data, no matter how likely cultural in origin, objectively remain anomalies in the earth's magnetic field until their archaeological significance is decided by appropriate means. AROURA therefore undertook preliminary tests to determine the nature and character of anomalies detected by two means: (1) using a hand-driven soil auger to remove stratified soil cores from areas containing interesting magnetometric anomalies, as well as from nearby comparative magnetometrically neutral ("background") areas (Figure 6); and (2) pedestrian collection of objects from the ground surface (mostly pottery sherds) in selected areas, to see whether the type, quality, or quantity of these correlated in any way with the presence of certain anomalies. The former method had the further aim of recovering cultural material that could be precisely dated by typology, or discovering organic material that could be subjected to accelerator mass spectrometry (AMS) radiocarbon dating.

Anomalies for soil augering were relocated with the magnetometer, and their position recorded with a handheld GPS receiver (Garmin eTrex HCx) to within 3 m (± 1σ). As a rule, soil coring employed an auger with an open-sided Dutch "mud" bit, which presented the best compromise between easy removal of soils of the kinds observed in the Project Area (mainly silts and silt loams) and conservation of the soils' consistence and structures. In a few places, particularly the first two cores from Transect H2, an open-sided barrel auger was employed. The pedestrian surface collection proceeded along traverses 2 m wide within grid squares 30 m on a side. Finds were collected and recorded by traverse and grid square. Specific forms were filled in that recorded the environmental and archaeological conditions of grid squares in which soil augering or surface collection was undertaken.

Results

Polder Dike Sector

The Polder Dike Sector comprises the sampling areas to the west and east of the Late Helladic IIIB polder dike (as identified by Knauss, Heinrich, and Kalcyk 1984) possessing the highest concentration of rectilinear field marks of any area (see Figure 1). It is bounded to the west by National Road 1 (western edge of Project Area) and to the east roughly by two broad, not quite parallel field marks identifiable in aerial photographs and satellite images (see Figures 1 and 27).

Area G. All of transect G1 was sampled with the magnetometer, except for a patch some 20 m at widest near the transect's west corner, where a pile of fertilizer presented an obstacle, and at its far southeastern end, where planted maize could not be traversed with the instrument. The magnetometric data revealed a grid of very subtle negative anomalies (i.e. less magnetic than the average background) forming near-perfect squares, approximately 30 m on a side, oriented almost to the cardinal directions (white lines in Figure 7). This network of squares corresponds exactly to the pattern of dark crop marks observed in aerial photographs and satellite images (see Figure 1). (The fine, closely spaced striations perpendicular to the main axis of the transect in Figure 7, as in presentations of other transects, correspond to modern plowing or to furrowed field boundaries and firebreaks.) Thus magnetometry not only provided more information about the nature of the crop marks, but it also added details to their pattern, exhibiting what appears to be subdivision of some squares into equal quarters (Figure 7). Hypotheses concerning the magnetic subtlety of these and other anomalies are considered further under "Interpretations" below. Suffice it to compare here the bright white haloes and borders in a few spots in the visual representation of the data (see Figure 7) that correspond to modern irrigation standpipes, a pump-house adjacent to the transect, and a farm lane paved with crushed iron-rich laterite.

Transect G2 was likewise sampled almost entirely, except for the northwestern edge, where a raised concrete irrigation channel and parallel farm lane (also paved with magnetically susceptible laterite) impeded prospection. G2 exhibits the subtle magnetometrically negative network pattern too (Figure 8), albeit more faintly and with greater interference from overlying modern magnetically susceptible refuse. Nevertheless, the magnetometric data demonstrate that anomalies corresponding in form to the known field marks extend to areas farther to the east. Significantly, the southeastern half of G2 crosses over one of the broad quasi-parallel linear crop marks used to define the eastern edge of the Polder Dike Sector. This linear feature corresponds in the magnetometric data to a very subtle negative anomaly running parallel to which, about 20 meters to its east, is a very subtle negative anomaly, perhaps with a slight positive component too (see Figure 8).

Two soil cores were taken from Transect G1, one over a magnetometrically neutral area, within a square formed by linear negative anomalies, and another at the intersection of two of the latter (2010G1-01 and 2010G1-02, both in grid square G1f3). The former involved augering to a depth of 112 cm below grade into grayish lake mud apparently devoid of cultural or biological content. Specifically, the soil profile consisted of a dark grayish brown (Munsell hue 10YR4/2) recent, upper plow zone (A_p) of silt loam, which was succeeded gradually, after about 32 cm depth, by a light brownish gray (10YR6/2) silt loam (lower plow zone, designated A2). The latter contained weakly platy structures, with about 10% dark gray (10YR4/1) mottles and up to 1% fragments of shell 2–3 mm diameter. Shell fragments were also in the A_p horizon, between about 18 and 32 cm deep, in about the same proportion, albeit smaller in size (1–2 mm), suggesting upward movement and attrition through plowing. The A2 horizon was clearly followed at about 86 cm by a grayish brown (10YR5/2) loamier, though poorly mixed and sorted, horizon (A3) with weak, incipient prismatic structures and distinct light gray (10YR7/2, c. 10%) and light olive brown (2.5Y5/6, c. 1%) mottles. These mottles had the texture of medium to coarse sand, the light gray having the consistency of slaked lime. Fragments of shell persisted, albeit smaller (1–2 mm), making up perhaps 1% of the matrix. At about 100 cm, the A3 horizon shared a clear boundary with a light brownish gray (10YR6/2) silt loam containing weakly prismatic structures and distinct dark grayish brown (10YR4/2, c. 5%) and light yellowish brown (10YR6/4) mottles, some of the latter of which were visibly and tangibly wet. The shell fragments and sandy fraction found in A3 disappeared below the boundary with this so called “A4” horizon.

Core 2010G1-02, although having a recently formed plow zone some 40 cm deep, virtually identical to that of 2010G1-01, possessed different lower A horizons. Beginning clearly at 40 cm and continuing to 62 cm below grade, its A2 was a dark grayish brown (10YR4/2) silt loam with weakly platy structures, no mottling, and about 1% shell fragments between 1 and 5 mm wide. Horizon A2 was clearly separated from succeeding A3, which was a grayish brown (10YR5/2) silt loam with weakly platy structures and distinct mottles of dark grayish brown (10YR4/2) making up about 20% of the matrix. It contained somewhat more fragments of shell (1–4-mm diam.) than A2 did, but still less than 5%. At about 115 cm, horizon A3 gave way to a loamy but poorly mixed soil, designated A4. Its base color was light gray (2.5Y7/2) containing about 30% distinct, grayish brown (10YR5/2) mottles. Its structures were moderately prismatic, often coinciding with vertical mottling, and it was somewhat harder than the overlying horizons. It contained no discernible fragments of shell. It was pursued to a depth of 143 cm, after which it was judged sterile lake sediment, and augering was abandoned.

Since both profiles came down to light gray, poorly mixed loamy soil between about 100 and 115 cm, possessing mottling and with prismatic structures, it is reasonable to conclude that the overlying horizons in each case represent the soil comprising the magnetometric anomaly. Excluding the plow zone, the A3 horizon in each was most distinctive in color, texture, and inclusions. A2 in each makes a transition gradually from the plow zone and shares characteristics with both it and underlying A3. In the "neutral" area between linear anomalies, A3 is distinctly loamy with coarse inclusions, including what appears to be limestone particles or calcium carbonate concretions. In the area of the linear anomaly, horizon A3 seems to be the end point of a gradual transition from the plow zone, in terms of colors, textures, and inclusions. The soil core from the area between linear anomalies was therefore distinct from that from the one of the linear anomalies, and the latte may involve a layer of lake sediment.

Area H. Area H exhibited most of the strongest magnetometric anomalies found anywhere. These consisted of the same network pattern of quadrilaterals (if not true squares) some 30 to 40 m on at least one side, visible as dark crop marks in Figure 1. However, here the anomalies are much stronger and have a positive magnetic character (with respect to the average background). Such a pattern of magnetometrically positive anomalies has elsewhere in the world proved to correspond to a system of ditches or canals. Especially clear in Area H is how no other pattern of magnetometric anomalies that cannot readily be attributed to ferrous refuse on or near the surface is found inside the quadrilaterals delimited by the linear network. This absence suggests no associated permanent habitation or residence: no architectural elements, no pits, no hearths, etc. The pattern is thus consistent with—though not proved to be—cultivated fields separated by ditches.

The only parts of Transect H1 not sampled with magnetometry were one grid square and short lengths of adjacent traverses in the west and the easternmost portions of two grid squares to the southeast, which fall beyond the Mycenaean polder dike (Figure 9). The parts avoided in the west were not sampled because they were full of weeds over two meters high. The strong white haloes displayed in this transect are due either to ferrous refuse in the field or, along the northeastern edge, to the presence of a dilapidated shed with corrugated steel roof. The polder dike identified by previous investigators (see Knauss, Heinrich, and Kalcyk 1984) runs along the eastern side of the sampled part of H1. However, any corresponding magnetic anomaly is almost entirely disguised by modern ferrous refuse (grainy patterns in Figure 9).

Only the northeastern half of Transect H2 was sampled because the corner stakes in the southwestern half were repeatedly destroyed by plowing. Here too was a high concentration of modern ferrous material, particularly on the north side, and for this reason, portions of a few traverses were not sampled to avoid the obscuring effect of its magnetic signal. Nonetheless, the network pattern observed in Transect H1 clearly continues, displaying an exceptionally strong positive linear anomaly in the southern corner.

As already suggested, one difference between the network pattern of anomalies observed in Area G and that observed in Area H is how it does not always define squares in the latter. Rather, roughly the eastern half of the revealed pattern appears to be on a different alignment from the corresponding part to the west. The lines of the former run from north-northeast to south-southwest, parallel to the polder dike, whereas those in the latter run more exactly from north to south. However, the east–west lines remain nearly parallel in both halves of the sampling area, resulting in the formation of rhomboid and trapezoid quadrilaterals. Further work with the project's geographic information system (GIS) will help determine whether either or both of the network patterns in Area H are aligned with (run parallel or perpendicular to) those in Area G and elsewhere, or whether they seem to be an independent system with topographical origin elsewhere. The pattern could, of course, represent successive lay-outs of similar features.

Three soil cores were taken from Area H, two from one of the linear anomalies and another about 16 m away in one of the neutral areas between (all in grid square H2b3; 2010H2-01, 2010H2-02, and 2010H2-03 respectively; see Figure 9). The profiles of 2010H2-01 and 2010H2-02 exhibited a plow zone some 50 to 65 cm deep that consisted of a soft, weakly granular (2–3 mm), grayish brown (10YR5/2) silt loam. This was followed, to a depth of between 110 and 120 cm, by a horizon, designated A2, consisting of a grayish brown (10YR5/2) silt loam, mottled about 10% yellowish brown (10YR5/4 and 10YR5/6). In core 2010H2-02 in particular, this horizon contained about 1% yellowish red (5YR5/4) silty or fine sandy concentrations that looked like degraded ceramic.

From about 80 cm deep to the bottom of the A2 horizon in both cores were shell fragments between about 2 and 5 mm diameter, increasing from about 1 to 3 percent of the matrix with depth. Toward the bottom of horizon A2 in both profiles, between about 100 and 105 cm, an integral sherd of pottery was observed, in each case of about 6 mm maximum width. In core 2010H2-01, the sherd appeared to be a fragmentary loop handle, while in 2010H2-02, the sherd belonged to a vessel body. Both fragments were yellowish red (5YR5/6 or 5/8). Below A2 was another grayish brown silt loam horizon, designated A3, with weakly platy structures and diffuse light brownish gray (10YR6/2) mottles amounting to about 30% of the matrix. It appeared to be devoid of shell fragments or cultural material. It was augered to a depth of 135 cm in 2010H2-02.

The third soil core taken from Area H, 2010H2-03, was placed so as to compare a magnetometrically neutral area with the two cores above positive anomalies. Its upper, very recent plow zone (A_p) appeared to be only 17 cm thick, consisting of a loose, weakly granular (1–2 mm) grayish brown (10YR5/2) silt loam, like that observed in the other two cores, albeit shallower. After about 17 cm, it fairly clearly gave way to a lower plow zone (A2), a brownish gray (10YR6/2) silt loam with strong platy structures (2–4 mm), a hard consistence, and about 40% gray (10YR7/2) and 20% brownish yellow (10YR6/6) mottles. The mottles appeared to correspond respectively to poorly mixed silt and sand fractions in the matrix. Horizon A2 gradually, at about 85 cm, turned into a grayish brown (10YR6/2) silt loam, designated A3, with strong prismatic structures (3–4 mm) and mottling much like that seen in A2. It was wet enough below 85 cm that the sediments quickly became intractable to the hand auger. Horizon A3 furthermore appeared to be sterile.

Hence the soil profiles corresponding to the linear positive anomalies are not only virtually identical to each other, but they are also distinctly different from the profile corresponding to the area between these anomalies. The increasing concentration of shell fragments toward the bottom of horizon A2 in the former, as well as the presence of pottery sherds, is consistent with gradual in-filling of a ditch through erosion. In contrast, the latter profile is consistent with conformant strata of lake sediment, whether cultivated or uncultivated. Judging from 2010H2-02, there may be an intact ground surface between 65 and 80 cm below grade.

Pedestrian surface collection in plowed grid squares in Transect H2 hinted that the positive linear anomalies in Area H2 and likewise the pottery found in soil cores 2010H2-01 and 2010H2-02 could be of Mycenaean date. The plow zone, shown to be between some 50 to 65 cm deep (confirmed by the landowner Mr. Dheláris of Traghána, Fthiotidha), yielded sherds of pottery from various periods, probably refuse from segments of the polder dike that stood above floodwaters through most of its history. These finds include material compatible with LH III wares (roughly contemporary with Gla), such as black- / dark-brown- / red-striped body sherds, fine pinkish and / or buff fabrics or slips, and coarse wares with milky (probably quartz) fabric inclusions. Some of these, however, given their degree of erosion and abrasion, could be of Protogeometric or later antique date (Fig. 10; I. Fappas, IX EPCA, pers. comm.; S. Vitale, pers. comm.), while others are clearly much later, such as the concave base sherd with brown glaze and interior white-painted decoration. Nonetheless, the presence of such material in the plow soil suggests that the sherd found in intact horizons in 2010H2-01 and 2010H2-02 are of the same age or older.

Area I. All but the far southeastern 90 m of Transect I1 was sampled with magnetometry. Likewise, the adjoining 60-by-90-m northwestern bloc of Transect I2 remained unsampled (see Figure 2). The avoidance of prospection both these areas was due to the presence of garden vegetable crops and an array of aluminum irrigation pipes with steel fittings. Both transects provided corroboration and further evidence of the network-like pattern observed in aerial photographs and satellite images.

Transect I1 contained a series of subtle, linear negative magnetic anomalies that appear similar in character and orientation to those observed in Transect G1 some 120 m to the south. However, here, where the anomalies are strongest, they take the appearance of a herring-bone pattern (Figure 11). If the pattern in I1 has a cultural origin, as it seems in Area G and Area H, then the smaller interval between the linear anomalies may represent a deliberate shifting or laying out anew of a grid. However, the fact that the perpendicular interval between them appears to be nearly 15 m, compared with nearly 30 m in Areas G, suggests that, for some archaeological or geomorphological reason, quarter or half subdivisions of the pattern observed in G and H are detected here only in alternating rows.

Transect I2 did not yield any clear evidence of the same network pattern. However, its western corner does contain a segment of one of the wide linear anomalies running from north-northwest to south-southeast, the other of which appears in the southeastern half of Transect G2 (see Figure 8). It is differently oriented from that in G2, lying closer to a north–south line (Figure 12). Here two distinct negative anomalies are separated by about 15 m of magnetometrically neutral ground. The east-northeastern line may be paralleled on its outside edge by a faint positive anomaly in addition. As previously noted, this broad linear anomaly and its corresponding field mark, as well as one not quite parallel passing through Areas G and J, seem to mark the eastern limit of the network pattern. Certainly, no pattern of magnetometric anomalies in I2 undermines this observation.

West Sector

This sector comprises Area J and the part of Area F that could be sampled in 2010, which share certain characteristics, especially in their topsoils. For the most part, they also lie in a zone defined by the edge of the network pattern of field marks and magnetometric anomalies to the west (the two broad quasi-parallel linear features previously noted) and an arbitrary line running roughly southward from the western rump of Gla to the western end of Mt. Fteliá to the east (see Figure 2). This eastern line divides them from the South Sector, which comprises the previously identified Mycenaean "road–dam" (Straßendamm).

Area F. Only Transects F2 and F3 could be sampled in 2010 (Figures 13 and 14). All of the precisely placed corner stakes on the southwestern edge of Transect F1 had been removed by local landowners by the time the survey team was prepared to sample it, making replacement uneconomical with the tools at hand. The far southeastern 30 m of F2 and F3 similarly remained unsampled because plowing or mowing had destroyed corner points. The far northwestern 11 m of F2 and 10 m of F3 were not sampled because of the presence of a highly magnetic raised concrete irrigation channel at this end of each transect (cf. G2), and because a discrepancy between features appearing on the 1:5,000-scale topographic plan and those actually on the ground meant that the west and north corners of both transects fell on a farm road paved with crushed rock.

Neither Transect F2 nor Transect F3 presented magnetometric anomalies of particular archaeological interest, even though the northwestern end of F2 comprises an area into which the eastern edge of the network pattern of field marks is seen to encroach. If there are corresponding anomalies, they may not be discernible in the data because of the quantity of ferrous material, particularly the northwest end of F2. White haloes in Figure 13 on the northwestern and southwestern edges are the result of concrete irrigation ditches. Emerging from the southwestern edge, about halfway along the transect, is a large dark (positive) patch followed by an equally large white (negative) patch; together these represent the burnt chassis of a mechanical tractor. Smaller white patches, generally with a black center or edge or both, represent ferrous refuse (such as fencing wire) embedded in the topsoil. (The grainy strips running perpendicular to the long axis of the transect represent recent deep furrowing to create firebreaks.) There is the merest suggestion of two intersecting negative linear anomalies at the northwestern end of F2, oriented roughly with those observed in Areas G and I. However, given their alignment with strong anomalies resulting from modern ferrous refuse, they may be an artifact of the data.

What is interesting—and the main cause for including Area F with Area J in the West Sector—is how all of the sampled portion of Transect F2 and the far southeastern 60 m of F3 comprise grayish silty topsoils (> 90% silt) similar to those in J1, albeit somewhat darker in color (10YR4/1–4/2 versus 10YR5/1–5/2). Moreover, the final 60 m of F2 especially, and to a lesser extent the same portion of F3 (in any case < 1% of the surface), contain large fragments of shells, some nearly whole, of what has tentatively been identified as a freshwater snail of the genus *Lymnaea,* characteristic of the topsoils observed in Transects J1 and J2 too.

Area J. Area J consists of two of the longest transects of the 2010 field campaign, J1 and J2, each 360 m long (Figures 15 and 16). The only portions of these transects that could not be sampled with magnetometry this year were the bloc of 60 m by 90 m at the northwestern end of J1, where plowing earlier on the day of investigation had destroyed the corner stakes, and a 30-by-90-m strip 30 m from the southeastern end of the same transect, where recent plowing, resulting in loose topsoil and furrows some 30 cm deep, prevented effective traverse.

Transect J1 crosses over the northernmost of the two aforementioned near-parallel linear field marks that seem to mark the eastern limit of the network pattern observed in the Polder Dike Sector (see Figures 1 and 27). It also captures a segment of another, fainter, curving field mark, also visible in aerial photographs and satellite images, that intercepts the linear feature some 60 to 70 m south of J1 (indicated in Figure 15). Magnetometry indicates that the anomaly corresponding to the linear feature is different in size and perhaps character from what has been taken as its quasi-parallel counterpart farther to the south. It consists of a subtle negative anomaly, two to three meters wide at most, adjoined to the east by an equally subtle, but nonetheless distinct, parallel positive anomaly.

Transect J2 comprises the greatest magnetometric enigma of the 2010 survey. The northwestern two thirds of J2, at least, comprise a distinct, though irregular, pattern of positive anomalies, made up mainly of shorter or longer line segments (Figure 16). The pattern may indeed continue into the remainder of the transect, but the signals of a modern pump-house and related overhead electrical cables and support pole (white haloes in Figure 16), as well as recent plowing (fine diagonal lines) and ferrous refuse in the ditch by the road encircling Gla (dark and light patches at southeastern end), may obscure it. Furthermore, “tendrils” of some of the positive anomalies appear to enter into Transect J1 within 100 m of its southwestern end (see Figure 15).

The pattern of anomalies is consistent with carefully maintained ditches surrounding cultivated fields. Clearly, however, the pattern contrasts sharply with the system of fields and ditches hypothesized with respect to the field marks and corresponding magnetometric pattern in Area H. Moreover, no corresponding field marks are seen here. Examination of the soil profiles in the modern ditch on the northeast edge of J2 revealed nothing that would suggest a non-cultural origin, and the intersecting lines, no matter how irregular, are inconsistent with the generally parallel faulting and folding of the underlying Cretaceous limestone (of which the outcropping of Gla itself consists).

Two soil cores were taken from Transect J1, 2010J1-01 and 2010J1-02 (both in grid square J1d3; see Figure 15). The first was located above the linear negative anomaly, the second, for comparison, 6.5 m to the northwest, in a magnetometrically neutral area. The profile of 2010J1-01 began with an upper plow zone (A_p) about 36 cm deep, consisting of a loose grayish brown (10YR5/2) silt that dried rapidly in sunlight, changing color to a light brownish gray (10YR6/2). After a clear boundary at about 36 cm and continuing to about 70 cm, was a somewhat harder, dark grayish brown (10YR4/2) silt loam containing up to 1% shell fragments between 1 and 5 mm wide, which was designated A2. Below horizon A2 was A3, a relatively thin horizon spanning the depth of about 70 to 74 cm. It was a grayish brown, poorly mixed silt loam with weakly prismatic structures, mottled with pale brown (c. 30% 10YR6/3) and brownish yellow (c. 5% 10YR6/6). Immediately below horizon A3, at a depth between about 74 and 140 cm, was another poorly mixed silt loam, designated A4, whose structures were moderately prismatic, and which was about 40% mottled with brown (10YR5/3) and 5% mottled with brownish yellow (10YR6/8). Below c. 85 cm, its three soil colors tended toward 33% of the matrix each, while the brownish yellow became less bright (Munsell chroma reduced from 10YR6/8 to 10YR6/6). No shell fragments were observed in A3, while only one (c. 5 mm diam.) was observed in A4 and could be a product of augering. At about 140 cm below grade, the A4 horizon gave way to a slightly hard light gray (10YR7/2) silt loam with strongly prismatic structures and a few distinct yellow (10YR7/6) mottles (c. 30%) that followed these vertical structures. The soil was augered to a depth of about 150 cm, after which it was decided this A5 horizon represented sterile lake sediment.

Soil core 2010J1-02 presented a similar profile, though one that may be critically different in a minor detail. It too had an upper plow zone about 36 cm deep, consisting of a loose grayish brown (10YR5/2) silt. Below about 36 cm, it gradually turned into a gray (10YR5/1) silt (A2), slightly harder, containing up to 1% shell fragments between 1 and 3 mm wide. This A2 horizon ended clearly at a depth of about 50 cm, after which was a new horizon (A3), pale brown in color (10YR6/3), with gray (10YR5/1) and brownish yellow (10YR6/6) mottles, about 20% each. The horizon's structures were weakly prismatic at the top, tending toward moderately to strongly prismatic below 90 cm, while the brownish yellow mottles became more distinct (10YR6/8) below the same depth. This evidently sterile horizon was pursued to a depth of about 110 cm below grade.

Thus two soil features seem clearly to distinguish the profile of 2010J1-01 from that of 2010J1-02 and may therefore account for the magnetometric anomaly corresponding to the former: (1) presence of a thin, mottled A3 horizon in 2010J1-01, absent in 2010J1-02, and (2) more intense brownish yellow (10YR6/8) mottling toward the top of the A4 horizon of the former, in contrast with the opposite tendency in A3 horizon of 2010J1-02, which is otherwise of similar color, texture, and structure. It may therefore be hypothesized that 2010J1-01 horizon A4 represents a positive (built or laid) archaeological feature, which often has a magnetometrically negative character. In its texture and mottles, it is consistent with redeposited lake sediments, such as previous investigators noticed made up the fill of the larger, stone-lined dams around Gla.

Two soil cores were also taken from Transect J2: 2010J2-01 and 2010J2-02 (Figure 16). The former was located over one of the strong positive linear anomalies, while the latter was located within a neutral area between them. The plow zone of 2010J2-01 was a loose grayish brown (10YR5/2) silt that quickly dried in sunlight to a light brownish gray (10YR6/2). This A_p shared a clear boundary with a lighter (10YR6/2), somewhat more compact silt with distinct grayish brown (10YR5/2) mottles (c. 40%), designated A2. It contained something under 1% fragments of shells, as well as whole conical snail shells (again tentatively identified as *Lymnaea* sp.) below the depth of 25 cm. At 35 cm, a third horizon, designated A3, was clearly defined. It was rather darker than the A2 (10YR4/2), a moderately well mixed silt loam of soft but not loose consistence, with distinct grayish brown (10YR5/2) mottles (c. 20%). There was a slight increase, up to perhaps 1% of the matrix, of very small fragments of shell (≤ 1 mm).

Just over 50 cm below grade, the auger unexpectedly sank with little or no resistance to a depth of about 75 cm, and below this depth, the soil changed again. The new horizon, A4, was the first of a series distinct in several important respects from those lying over it. Although grayish brown (10YR5/2) silt loam, its top 10 cm, at least, had a loose consistence, becoming somewhat harder with depth. Below 100 cm deep, it began to manifest prismatic structures. It contained about 40% faint light brownish gray (10YR6/2) mottles, as well as a few (< 1%) fine to medium sand-size coarse inclusions resembling concentrations of calcium carbonate. Also noteworthy in the matrix were the poorly mixed shell fragments (c. 1–5 mm diam.), perhaps amounting to 1%, particularly in the loose uppermost sediment. The A4 horizon, as defined in the field, seemed to grade into the underlying A5 horizon, and the two may in fact reflect the same formation processes. On the approximate boundary between them, 110 cm below grade, the soil became loamier and harder, but its structures remained weakly prismatic. It contained about 30% distinct light brownish gray (10YR6/2) and about 5% white (10YR8/1) mottles, of which the latter seemed to be connected with a few fine to medium sand-size white concentrations resembling calcium carbonate (> 1% of matrix). A mixture of shell fragments persisted (c. 1–3 mm diam., c. 1% of matrix).

At about 122 cm deep, horizon A5 gave way clearly to what was designated A6: a light gray (10YR7/2), poorly mixed, poorly sorted loam, with strong prismatic structures (c. 2–5 cm). Horizon A6 was also mottled, about 10% light brownish gray (10YR6/2), with a greater amount of white (10YR8/1) than the immediately overlying horizon. However, the number of white concentrations, as well as the amount of shell fragments (c. 1–2 mm diam.), diminished in the first few centimeters of the horizon. The matrix also contained a very few (< 1%) sand-size flecks of yellowish red (10YR4/6) that could be degraded ceramic. Horizon A6 graded into the final identified horizon at a depth of about 133 cm. This horizon was one of four judged in the field to deserve the appellation “B horizon,” in this case B_{ht}, because of clear evidence of illuviation in the form of its strong prismatic structures and prominent olive yellow (2.5Y6/8) mottles that were coated with a dark gray (10YR4/1) clay film below about 140 cm. It was basically pale yellow (2/5Y8/2) poorly mixed loam that became intractable below about 150 cm depth. However, at about 145 cm below grade, a piece of charcoal, possibly burnt root, was recovered from within the matrix (radiocarbon sample 2010J2-01).

Again, the core from the nearby background area, 2010J2-02, contrasted. Not only was it shallower by approximately half a meter, but it also lacked the several gradual transitions between horizons seen in 2010J2-02. Its upper plow zone horizon was about 28 cm thick, consisting of a loose grayish brown (10YR5/2) silt containing less that 1% shell fragments of 1 to 3 mm diameter, which changed clearly into a soft dark grayish brown (10YR4/2) silt loam—the lower, more compact component of the plow soil— containing about the same proportion of generally larger shell fragments (c. 1–5 cm), apparently mainly around the boundary between the A_p and this A2 horizon. Around 55 cm below grade, the A2 horizon turned gradually into what was designated A3, a slightly hard, light brownish gray (10YR6/2), poorly mixed loam, possessing faint grayish brown (10YR5/2) mottles (c. 30%) and moderately prismatic structures (3–4 cm). About 1% of the matrix consisted of shell fragments (c. 1–3 mm diam.), and coarse inclusions were fine to medium sand-size white (10YR8/1) concentrations, some of which could be decomposed shell. Finally, at about 70 cm deep, the A3 horizon gradually became what was called in the field the A4 horizon, a light gray (2.5Y7/2) silt loam with strongly prismatic structures, a slightly hard consistence, and clear grayish brown (2.5Y5/2, c. 10%) and light olive brown (2.5Y5/6, c. 1%) mottles. After about 100 cm in depth, both the mottles and the shell fragments previously observed diminished toward zero.

The contrast between the two soil profiles in Transect J2, one above a strong positive anomaly and the other in a neutral area, resembles the contrast between similarly located soil profiles in Transect H2. The profile of 2010J2-01—with its gradual succession of horizons and shell content—like that of 2010H2-01 and 2010H2-02, is consistent with a gradually in-filled ditch or canal, whereas that of 2010J2-03, like that of 2010H2-03, is consistent with conformant lake sediments. Horizon A3 of 2010J2-02 could represent the ground surface into which the hypothetical ditch was cut.

North Sector

The North Sector comprises Area A, which spans fields to the north of the Gla's summit, and Area B, which spans tracts less than 200 m from Gla's northern gate. Both these areas share certain magnetometric characteristics too. Only the far southeastern bloc of 60 m by 90 m in Transect A1 could be sampled because staked-out points in it had been destroyed by plowing or burning stubble. It contained no anomalies of archaeological interest. The southeastern half of Transect B1 plus the far northwestern bloc of 60 m by 90 m in Transect B2 could not be sampled because of the presence of a crop of cotton.

Area A. Transect A2 was sampled with the magnetometer in its entirety. In addition to the usual magnetometric "noise" from a scattering of ferrous refuse throughout the fields and the furrowed field boundaries / firebreaks (stripes perpendicular to the long axis of the transect in Figure 17), there were also two strong ferrous signals nearly halfway along the transect's main axis. Given their orientation and spacing, they undoubtedly represent buried parts of irrigation standpipes, such as are visible in Transect G2.

Of geomorphological and archaeological interest are the slightly meandering negative anomalies with a positive outline for most of their length that run roughly from west to east through the southeastern half of Transect A2. Corresponding field marks for these are found in some satellite images. Their characteristics are typical of ancient water courses, including naturally in-filled channels, presumably the net positive component, and deposited coarse material, presumably the net negative component. For there to be indication of water flowing so close to Gla at some point in its past is unexpected, unless in certain periods one of the branches of the twined Kephissos and Melas Rivers ran past here, rather than farther to the north, as has usually been observed. It should be emphasized that not only has this interpretation of the magnetometry not been confirmed, but there is at present no way of knowing how ancient any feature corresponding to these anomalies may be.

Of archaeological interest too are several anomalies at the southeastern end of Transect A2. About 30 m from the transect's east corner is a cluster of round positive anomalies, lacking the clear polarity of ferrous material. They are about 10 m in revealed diameter. Such anomalies are often discovered to correspond to deliberately or naturally in-filled pits. Similar clusters are found in the northwestern end of Transect B1 (see further below). Finally, along the southeastern edge of Transect A2 are two relatively strong positive anomalies with indistinct borders, some 20 to 30 m wide. These may correspond to a concrete drainage conduit buried beneath the adjacent farm lane, a culvert of which is visible in the land tract immediately to the north of Area A. It is also worth noting that both Mr. A. Andhrítsos, mayor of Akraífnio, and Mr. P. Yperífanos, President of the City Council of Orchomenós, have attested to the presence of a German air force runway during the Second World War in this adjoining land tract, which could account for some unusual magnetic anomalies in the vicinity.

Area B. The northwestern, sampled half of Transect B1 lay in an abandoned field. Besides the usual smattering of recent ferrous refuse and perpendicular traces of modern furrowing, B1 contains, in the first 30 m to the northwest, two clusters of "pit-like" anomalies like that in the eastern corner of Transect A2. The clusters are about 15 to 20 m wide, and the constituent magnetometrically positive anomalies are about 1 to 3 m diameter (Figure 18).

The three 60-by-90-m blocs of Transect B2 sampled contain no anomaly that cannot readily be ascribed to a modern feature (Figure 19). For example, the circular haloes in the northwestern half of the transect correspond to modern irrigation fixtures. Two principally positive linear anomalies meet with a dominantly negative one (with a positive northern border) at a right angle at almost exactly the middle of the southwestern edge of the transect. The straightness and consistent width of the latter, together with its perfect west–east orientation (conforming to the Greek Army's Hatt-Bessel grid), strongly suggest that it is related to the buried modern drainage canal of the same orientation and size identified in Area C. Furthermore, the convergence of both sets of linear anomalies on the irrigation fixture indicates that all the lines represent modern features.

The nature of one of the clusters of so called pit-like anomalies in Transect B1 was tested by augering out a soil core from above it and an adjacent neutral area. The first of these, 2010B1-01, did not disappoint. Its plow zone (A_p) consisted of a soft dark grayish brown silt loam including discernible shell fragments (< 2mm diam.) and pearly flecks (probably shell < 1 mm diam.), together making up nearly 1% of the matrix. Between 30 and 50 cm deep, a new horizon (A2) was defined, also historically plowed, which was a considerably harder, grayer (10YR4/1) silt loam with about 5% clear, light brownish gray (10YR6/2) mottling. Pearly flecks and discernible shell fragments continued, but the matrix also began to manifest something under 1% yellowish red (5YR5/6) silty or sandy flecks, also under 1 mm diameter, which resembled degraded ceramic. Gradually, between 50 and 55 cm depth, a third horizon (A3) emerged, which was of the same basic color and texture as the immediately overlying one, but with incipient prismatic structures and further clear mottling (c. 10% 10YR7/2 light gray, c. 10% 10YR6/2 light brownish gray, and c. 5% 2.5Y5/6 light olive brown). At about 55 cm below grade, the auger began to pull up soft pieces 1 to 5 cm in diameter of what, in the pedological circumstances, could only be degraded ceramic, yellowish red (5YR5/8) in color. From this point to about 67 cm below the surface, a further horizon was defined (A4), which contained about 10% of the identified degraded ceramic in a mixed fill of dark gray (10YR4/1) silt loam (c. 70%), yellowish brown (10YR5/6) fine sand (c. 10%), and (particularly below 60 cm), white (10YR8/1) concentrations 3 to 5 cm in diameter (sub-rounded; Figure 20). The structures of this lens or fill were strongly prismatic, suggesting downward movement of water over a long period. Below the

A4 horizon was a light gray (10YR7/2) poorly mixed and sorted loamy sediment with prominent white mottles (c. 40% 10YR8/1), designated horizon A5. It also contained the same white coarse component observed in A4, and it appeared devoid of pieces of shell observed in overlying horizons. Hand augering stopped at 69 cm below the surface where this sediment became intractable.

The profile if 2010B1-01 is therefore consistent with a deposit of pottery, perhaps with other material, in a hollow or pit, either as refuse or as deliberate fill. A portion of the degraded ceramic and evident fill was taken for possible radiocarbon dating, since residues of burning, such as charcoal, often accompany pottery (sample 2010B1-01).

The profile of the second core from Transect B1, 2010B1-02, while similar to that of its counterpart, was sufficiently different to support this hypothesis. Its recent plow zone was virtually identical to that of 2010B1-01. However, it ended fairly abruptly at about 26 cm, giving way to a soft grayish brown (10YR5/2) loam with faint dark grayish brown mottling (c. 10% 10YR4/2) and a greater proportion (c. 1%) shell fragments (c. 1–3 mm). This A2 horizon continued to a depth of about 38 cm, after which an A3 horizon appeared, similar again to that in 2010B1-01. It was a hard dark grayish brown (10YR4/2) silt loam, mottled with about 30% dark gray(10YR4/1) and 5% light olive brown (2.5Y5/4). Rather than having incipient prismatic structures, it had moderately platy structures (c. 2–3 cm). Although it contained no shell fragments greater in size than 1 mm, it did contain the previously mentioned pearly flecks and white (10YR8/1) film resembling calcium carbonate on the surface of some structures (both < 1% of total). Near the boundary with A4, 50 cm below grade, it also comprised fragments of soft concentrations, up to 1 cm in diameter, of yellowish red (5YR5/8) material, again probably degraded ceramic. The A4 horizon continued to a depth of about 60 cm. It was a dark grayish brown (10YR4/2) silt loam, heavily mottled with dark gray (c. 30% 10YR4/1), white (c. 30% 10YR8/1), and light olive brown (c. 5% 2.5Y5/4). Its structures were moderately prismatic with a very dark gray (10YR3/1) clay film on some prisms. Indeed, for this reason, A4 was better defined as B_{htk}, because of its structures, mottling, and films. This horizon graded into a white (10YR8/1) poorly mixed loam, faintly mottled with about 20% light gray (10YR7/2), containing no discernible shell fragments or other biological material. This sediment, named A5 in the field, appeared to be sterile, and it began to be intractable to augering by hand at about 67 cm. It is essentially the Quaternary alluvial lake sediment and so plausibly called the C (parent material) horizon.

Hence, although both 2010B1-01 and 2010B1-02 yielded what is undoubtedly degraded ceramic at about 50 cm below grade, the ceramic continued into the succeeding mixed horizon in the former, whereas it lay on or around the boundary with the succeeding horizon in the latter. In the former, at least, tiny bits of ceramic seem to be mixed into the overlying horizon, perhaps where the deepest plowing has reached. It is therefore plausible to hypothesize that the A3 horizons of both cores together represent an old ground surface, now between about 38 and 55 cm below grade.

East Sector

Area C. Area C is currently the only component of the East Sector. All of Transect C1 was sampled with magnetometry, except for two swaths, one about 20 m long, on each edge of the northwestern half where water up to 40 cm deep was standing (Figure 21). The northwestern 180 m of Transect C2 were sampled before corner stakes were removed by mowing the clover (Figure 22). (Note that grid square C1h3 = grid square C2a1.) The quantity of stone on the surface of C1 was exceptionally pronounced, amounting to nearly 50% in a band about 20 to 30 m wide running roughly from east to west through the transect and consisting in large measure of cobbles, channers, and coarse gravel. The source of these stones is most likely the intermittent stream running west from Souvlí into the plain, which is indicated on the Greek Army's 1:5,000-scale topographical plans, and which has now been diverted into peripheral ditches. For much of this stream's history, it must have collided with the Mycenaean canal and accompanying dike, previously identified by Knauss, Heinrich, and Kalcyk (1984), or their remains, and this encounter may account for the widespread accumulation of stone particularly in Transect C1.

Magnetometric sampling revealed a strong positive anomaly corresponding to the LH IIIB canal–dike system running approximately from northeast to southwest through nearly the middle of the transect, bordered by a weaker negative anomaly to the northwest (perhaps remains of the dike; see Figure 21). It also comprises about five strongly positive anomalies, seen about midway on the length of the linear anomaly, of the kind usually corresponding to in-filled pits (perhaps repairs to the canal, or features much later than it). Another strong positive anomaly, surely a buried channel, can be seen running across the Mycenaean canal and continuing into Transect C2. It is oriented exactly east to west on the Hatt–Bessel grid. It provides information about the nature of crop marks visible in current satellite images, as well as about unexplained linear features first indicated on the earliest Greek Army Geographical Service's (ΓΥΣ) 1:50,000-scale map of the region (1954). No such features appear in the British Lake Copais Company's plan of irrigation and drainage works (now in the possession of the Οργανισμός Κωπαΐδας), and so the anomaly certainly represents a phase of irrigation or drainage immediately following the Greek state's appropriation of the property in 1953. (The white halo seen in Figure 20 about 90 m along the southwest edge of C1 corresponds to a modern pump-house.)

The only interesting anomalies in Transect C2 are the continuation of that corresponding to the modern irrigation–drainage feature and roughly parallel, weaker positive anomalies to the south of it, which, though their nature is still enigmatic, are most likely connected with it (Figure 22).

Two soil cores were taken from Transect C1 in order to determine the nature of the "pit-like" anomalies in the Mycenaean canal, to see if datable cultural or organic material could be recovered from one, and to produce more data on the relatively high degree of stoniness in C1. Core 2010C1-01 was located over one of said positive anomalies, while core 2010C2-02 was located a few meters to the west in a magnetometrically neutral area (see Figure 22). The plow zone (A_p) in the former appeared fairly deep, descending to about 51 cm, and it consisted of hard grayish brown (2.5Y5/2) silt, including about 1% small to medium round and sub-round gravel. At a depth of about 32 cm, a single fleck (c. 1 mm diam.) of what may be yellowish red (5YR5/8) ceramic was observed, perhaps washed into the area by the aforementioned stream. Between 51 and 67 cm below grade, an A2 horizon was defined, whose upper boundary with the plow zone was gradual, but whose lower boundary was abrupt. It was light olive brown (2.5Y5/3) silt (c. 90%) with faint brighter mottles (2.5Y5/6, c. 5%) and poorly sorted inclusions of coarse sand and small gravel (< 1%). Below 67 cm (horizon A3), essentially the same light olive brown matrix continued, but it was suddenly more heavily and distinctly mottled (c. 20% 2.5Y5/6). At about 70 cm below grade, it appeared to contain up to 30% round or sub-round small gravel, making further augering by hand impossible.

The profile of 2010C1-02 was simpler and different. The plow soil here was seen to be about 39 cm deep, consisting of hard grayish brown (2.5Y5/2) silt and containing something under 1% small to medium round or sub-round gravel. It shared a clear boundary with the A2 horizon, which was a poorly mixed light olive brown (2.5Y5/3) silt loam, mottled with white (2.5Y8/1, c. 10%) and lighter olive brown (2.5Y5/6, c. 5%) and possessing weakly prismatic structures. Inclusions consisted of coarse sand (< 1%) and shell fragments (< 1%, increasing to c. 1% after at 50 cm below grade). At about 78 cm below grade, this sediment became intractable to hand augering.

In 2010C1-01, the high concentration of gravel below 67 cm may represent the bottom of the LH IIIB canal, whereas in 2010C1-02, the prismatic soil structures and shell fragments below 39 cm may indicate that the area to the west of the canal–dike was under standing water more recently than the area directly above it. Conversely, there may have been water coursing through the LH IIIB canal longer than water simply lying above it after it had filled in.

South Sector

This sector consists of Areas D and E, both of which cross over the previously identified Mycenaean “road–dam” (Straßendamm) that runs from the eastern tip of Gla south-southwest to Mt. Fteliá. They were placed so as to investigate the area above and to both sides of this feature. All the transects in these areas—D1, D2, E1, and E2—were sampled in their entirety. Together they constituted the most magnetometrically “quiet” area of any sampled in 2010.

Area D. The Mycenaean road–dam shows up as a subtle positive anomaly, about 7 or 8 m wide, running through the southeastern third of Transect D1 (Figure 23) and the western corner of D2 (Figure 24), outlined on its east-southeastern edge and in places on the opposite edge by a narrower, stronger negative anomaly. The latter almost certainly corresponds to limestone boulder retaining walls (around an earth fill), such as previous investigators reconstructed. A steel probe detected stone at about 65 cm below grade above each of these negative anomalies on their length.

Two soil cores were augered from either side of the road–dam in Transect D1 (grid squares Dh2 and D1j2; see Figure 23) so as to compare their profiles and contents. Each profile was different from the other, but the differences shed no light on the absence of detectable magnetometric anomalies in both places. The upper plow zone of 2010D1-01, to the west-northwest of the dam, was a soft dark grayish brown (10YR4/2) silt loam with weakly platy structures, containing less than 1% shell fragments of 1 to 2 mm diameter and a similar proportion of smaller flakes. It graded into a harder, dark gray (10YR4/1) silt loam with weakly prismatic structures and similar inclusions, designated horizon A2, at about 25 cm below the surface. At about 36 cm below grade was a clear boundary with a new horizon (A3), a dark grayish brown silt loam with a complex structure of alternating moderately developed prisms and plates appearing to correspond to specific mottles (c. 20% 10YR4/1 dark gray, c. 10% faint 10YR6/4 light yellowish brown). Furthermore, there was an increase in shell fragments between about 1 and 3 cm diameter to circa 1%, and calcareous (10YR8/1 white) inclusions the size of coarse sand or very small gravel were present, also about 1% of the matrix. White films also coated some of the structures in the sediment.

At about 65 cm deep, horizon A3 graded into A4, a very hard, poorly mixed loamy, dark gray (10YR4/1) sediment with heavy mottling (c. 20% 10YR3/1 very dark gray, c. 20% 10YR 4/2 dark grayish brown, c. 10% 2.5Y6/4 light yellowish brown, c. 10%7.5YR5/6 strong brown). Near the boundary with the underlying B_{htk} horizon, at about 80 cm depth, the strong brown mottles seemed to contain a very few (<< 1%) root molds of less than 1 mm diameter. The final sampled horizon was a poorly mixed and sorted yellowish brown (10YR5/4) sandy loam with weakly prismatic structures coated in places with a very dark gray (10YR3/1) clay film, especially below 89 cm. This horizon was also heavily mottled with yellowish brown (10YR5/8, c. 10%) and grayish brown (10YR5/2, c. 5%) sediments, as well as containing white (10YR8/1, c. 10%) films and concretions. It appeared to be sterile, containing no visible shell fragments. It was labeled "B_{htk}" because of its structures, mottling, and sediment films. (Indeed, given the grayness of the overlying horizon, A4 may better be defined as the eluviated E horizon.) It became impossible to auger this horizon by hand below about 92 cm.

The profile of 2010D1-02, to the east-southeast of the dam, was simpler and in some respects similar. Its A_p horizon was essentially the same as that in 2010D1-01. It came to a clear boundary at about 30 cm below grade with a soft, grayish brown (10YR5/2), weakly platy silt loam (lower plow zone, A2), which was distinctly mottled (c. 10% 10YR4/2 dark grayish brown, c. 10% 10YR8/1 white, and c. 1% 10YR6/6 brownish yellow). The white mottles included the aforementioned coarse calcareous fraction. Curiously, no shell could be discerned in this horizon. At about 50 cm below the surface, this A2 horizon gradually became yellower (2.5Y6/3), more prismatic, and harder (A3 horizon). It too contained distinct grayish brown (10YR5/2, c. 10%) and white (2.5Y8/1, c. 10%) mottles, as well as olive yellow (2.5Y6/6, c. 5%). Only one 2-mm piece of shell was observed, and this could have been a product of augering. The A3 horizon in turn gradually became more poorly mixed at about 80 cm, with a high proportion (c. 30%) of prominent brownish yellow (10YR6/8) mottles, the calcareous fraction continuing or increasingly somewhat. At about this boundary (c. 80 cm), what appeared to be carbonized root matter was recovered for radiocarbon dating (sample 2010D1-01). Because of this horizon's structures, mottling, and apparent sterility below 80 cm, it was designated B_{hk}. It became intractable to augering by hand at about 100 cm deep.

The relationship between the profile of 2010D1-01 and that of 2010D1-02 is obscure. However, the shallower incidence of prismatic structures and the higher incidence of shell fragments in the former offer the slightest suggestion that the area to the west-northwest of the road–dam has been under water more recently or for longer. More cores are needed to put this conjecture to the test.

During geophysical sampling, it was casually observed that there appeared to be very few if any collectible surface remains to the west-northwest of the road–dam, whereas there was a considerable number on the dam's opposite side. In an effort toward more systematic observation, surface collection was made of six grid squares (D2c1–3, D2d1–3) in the stubble field to the east-southeast of the dam (estimated 51–60% surface visibility). Want of time prevented a collection from the opposite side for comparison (but see "Area E" below). At the time of writing, thorough expert quantitative and typological analysis has yet to be carried out. However, it is worth noting here that pottery sherds consistent with LH IIIB wares were discovered, including a kylix stem, abraded by plowing, with a pinkish (10YR7/6) fabric and traces of a buff (7.5YR7/4) slip.

Area E. Transect E1 was the quietest of all areas sampled with magnetometry. It contained no anomalies of archaeological interest (Figure 25). Transect E2 exhibited the continuation of the LH IIIB road–dam in its southeastern third, as well as a subtle and enigmatic, almost parallel positive linear anomaly in its northwestern third (Figure 26). The latter, which does not appear to continue on a line into Area D, will be subject to further geophysical and subsurface investigation in a future campaign.

Pedestrian surface collection was conducted over 12 grid squares (E2e1–3, f1–3, g1–3, h1–3) in a plowed field (91–100% visibility) spanning the Mycenaean road–dam. At the time of writing, thorough quantitative and typological analysis by experts had yet to be done with the material gathered. However, although as in other parts of the Project Area, the ceramic was much eroded and abraded, several pieces consistent with regional LH types were recovered. These included in particular sherds of flat-bottom coarse ware vessels with yellowish red (c. 5YR5/6–5/8) fabric containing small (< 1 mm diam.) milky (probably quartz) inclusions, thought to be of regional manufacture (B. Liš, pers. comm. Mitrou 2010). The casually observed higher density of surface remains to the east-southeast of the dam than to the west-northwest seemed to be sustained on closer examination. Statistical study involving the project's GIS will clarify this.

Interpretations

Landscape History and Organization of Space (see Figure 27)

An important accomplishment early in the 2010 campaign was demonstration that the network pattern of field marks to the west of Gla, around the LH IIIB polder dike, finds corresponding geophysical anomalies of distinctly magnetic nature. More interesting, the magnetic character of the anomalies on one side of the dike is different from that of the anomalies on the other. Subsurface testing suggested that the relatively intense positive anomalies on the western side correspond to ditch fill, while the relatively subtle negative anomalies on the eastern side correspond to a different kind of feature, perhaps an eroded area, built bank or bank accompanied by a small ditch. Proper soils with distinct horizons can hardly have developed either in the natural wetlands nor during the polder's brief history, much as they have hardly developed since the completion of the modern drainage of the Kopais in the middle of the 20th century (see, for example, Greek government bulletin Εφ. Κυβ. 14/9/2001 Αρ. Φυλ. 1195: 16409–10). Thus the obvious explanation of the contrast to the west is that ditches (or canals) filled up with sediment from distant sources, such as alluvium carried into the Kopaic Basin by the periodically flooding Kephissos and Melas rivers; the concentration of the alluvium, especially while the ditches were still open, would account for much of the contrast.

Possible explanations of the low contrast to the east is more complicated. If the subtle negative anomalies represent a fill (a supposition not corroborated by subsurface testing), then it could be that most of the sediment accumulating in ditches there came from local erosion, where formation processes had only created little contrast, unclear even when horizons became inverted. If, on the other hand, these anomalies represent embankments or, very simply, level areas, then the weak contrast may be due either to the slight removal of weakly magnetic material, such as topsoil from pathways or, conversely, the slight magnetic "improvement" of topsoil in the areas between.

In general, the subtlety of magnetometric anomalies of any character in the Project Area could be owed to the greater part of them having been plowed away, rather than simply to natural formation processes. However, the respectable thickness, some 55 to 60 cm, of what appears to be fill in Transect H2, at least, suggests this is not the case. In any case, we should consider the possibility that features corresponding to each of the contrasting anomalies were put to different purposes. For example, a system of "wet" fields may have existed on the "lakeward" side of the dike, delimited by ditches several meters wide and half a meter or more deep, whereas a system of "dry" fields may have existed on the polder side of the dike, served by minor drainage / irrigation ditches, the matter from which was used to create raised field partitions or pathways.

The pattern of relatively intense positive magnetometric anomalies in Area J, especially Transect J2 by Gla's western gate, is distinctly different from the patterns observed in Area G and Area H, around the polder dike. To start, there are no visible corresponding field marks in aerial photographs and satellite images of this area, though a few hundred meters away, near the southwestern curve of Gla, there is a pattern of crop marks that in many respects resembles that of the anomalies in Area J. This observation should serve, at least, as a reminder that variation in local environmental conditions can disguise surface evidence of subsurface geophysical anomalies or archaeological features. In particular, different post-depositional processes may be at work in different places. Furthermore, not only is the layout, if it may be called that, of the corresponding features (presumably ditches) very different from the rectilinear pattern around the dike, but also the magnetometric character of the anomalies here, in contrast with those in Area G, suggests that this part of the territory once encompassed by the polder was not drained in the way that the part including Area G was at the time their respective features came into being. Hence it could be that the features in Area J either antedate the construction of the polder or postdate its disintegration. We may even be confronted with evidence of two different systems of cultivated fields separated in time—even three, if that in Area G is separate from that in Area H. All these conjectures await thorough ground-truthing.

The production of negative evidence may also be considered a major achievement of AROURA in 2010, specifically the absence of any evidence of cultural activity in the zone immediately around Gla, with the exception of known major hydraulic engineering features and a few likely pits scattered around to the north. In fact, this "empty quarter" around Gla may be bounded to the west by the same anomalies–crop marks that delimit the network pattern of hypothetical cultivated fields in the area around the dike. There are several direct implications of this observation. One simply is that there is no “lower town” (or “Unterstadt”) around Gla worthy of the name; it is very improbable that significant remains of such are to be found in the areas between the transects sampled in 2010 on all sides of Gla to within 30 or 60 meters of the outcropping. This may be a surprise to some, but not to those who have cautiously observed that Gla’s design and location suggest that it is not just another Mycenaean “citadel” or “acropolis” but rather a stronghold built for a particular purpose (e.g. Ιακωβίδης 1998). Another implication is that the zone around Gla, extending westward to the hypothesized field system was deliberately kept free of human activity that would leave a lasting mark. Conversely, if the field marks and magnetometric anomalies are taken as evidence, the hypothetical field system was restricted to the area of the polder dike by features centered around Gla. Whatever the date of the former, they indicate advance planning in the regularity of their dimensions and design.

The discovery of evidence pointing to standing or flowing water, particularly in the “empty quarter,” was also new. Area A manifest geophysical anomalies consistent with ancient stream courses (or “paleochannels”), while Area C manifest surface and subsurface evidence of gravel, cobble, and channer accumulation most likely from a recorded intermittent stream. The former could date to any time since the end of the last ice age and perhaps earlier, though it is difficult not to entertain the thought of water flowing past Gla’s low and apparently vulnerable northern gate in the Late Helladic IIIB. The latter provides an example of exactly the kind of seasonal flow that German investigators argued the dam-and-canal system to the east of Gla was meant to protect against.

As for evidence of standing water, there is the aforementioned possibility of different sources and rates of reflooding of the polder after Mycenaean times, which resulted in the formation of anomalies of different character on each side of the polder dike. There is the suggestion too, in the form of very silty topsoils with a high count of freshwater snail shells, that a band of land to the west of Gla, passing through Area F and Area J, as well as possibly through part of Area D to the south, has been inundated more frequently or for longer than other areas within the polder, as it is currently understood. Whether parts of the polder were deliberately flooded in the Late Helladic IIIB, perhaps as an outer defensive perimeter for Gla, is an intriguing thought for which no evidence exists. Whatever the case, fieldwork in 2010 makes possible a number of new questions about the nature and character of the landscape around Gla, as indicated in Figure 27.

Stratigraphy and Chronology

In the profiles of every set of soil cores placed so as to compare a distinct magnetometric anomaly with an adjoining neutral area, there was a marked contrast. Moreover, in virtually all the profiles (except possibly 2010C1-01 and 2010C1-02) a clear non-subsoil (and often organic) horizon, undisturbed by modern activity, could be identified with the anomaly or its neutral counterpart—in other words, with a shared stratum. Nowhere does the plow zone appear to be deeper than 70 cm, and horizons associated with anomalies and presumed constituent features are found between 50 and 130 or more cm below grade. The potential for discovery of intact, in situ, pre-modern archaeological features in the plain is very high.

Finds from the surface of the plow zone, including recently plowed soil, in Area D and Area H are compatible with Late Helladic ceramic wares. This fact strongly implies that similar material found in underlying horizons in the latter area (and, by extension, below the plow zone in Area B) is of the same age or older. It can confidently be asserted, at least, that the *terminus ante quem* for the deeply buried finds is considerably earlier than early modern or medieval times, though an Ottoman Period field system has not been ruled out completely. Radiocarbon dates from subsurface samples, which may support or refute this reasoning, are expected in the spring of 2011.

Finally, whether the contrast of the anomalies to the west of the polder dike with those to the east is thought to be due to different formation processes or different construction of pertinent features, their differing character alone suggests that they first came to be while the polder still functioned as a polder—that is, as dry land versus the Kopaic lake. If the features in question were made after the reflooding of the polder, when presumably only the top of the Mycenaean dike was standing above the wetlands, then one would expect the character of the linear anomalies on both sides to be similar to each other, for example, bearing the magnetometric "signature" of in-filled ditches (cf. also those in Area J) or, oppositely, raised areas.

Conclusions and Further Work

By the time of writing, mid-November 2010, we already know immeasurably more about the ancient landscape around Gla than we did when fieldwork began in October 2010, though fieldwork has posed as many questions as it has answered. Any simplistic expectation that a Cyclopean fortification should fit the stereotype of a citadel with its "Unterstadt" is not met here; evidence from immediately around Gla and farther afield in its polder so far indicates a different and more complex landscape. Nevertheless, given the landscape's extent, it may provide evidence of what to expect, if conditions are right, of the further periphery of landscapes around other Mycenaean strongholds and settlements.

Future fieldwork will focus on (1) further examining the nature of the geophysical anomalies around Gla, especially where they appear subtle, (2) clarifying where and how the network pattern to the west is divided from the "empty" quarter to the east, around the fortification, (3) investigating further evidence of flowing water and inundation within the polder, and (4) examining peripheral areas, especially to the east, with an eye to collecting datable evidence from the surface. Techniques to be employed will be magnetometry, supplementary electromagnetic / conductivity survey, surface collection, and, if permitted, further verification of results through soil coring.

—MFL