# ARCHAEOLOGICAL RECONNAISSANCE OF UNEXPLORED REMAINS OF AGRICULTURE (AROURA): PRELIMINARY FIELDWORK REPORT OF 2011

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## Introduction and Summary

### *Authority, Scope, and Aim of Project*

AROURA is an official collaboration (συνεργασία) between the IX EPCA of the Hellenic Ministry of Culture and Tourism, UMBC, and the University of Michigan (as sub-awardee of grants), co-directed by Vassileios L. Aravantinos, Superintendent of IX EPCA, and Michael F. Lane of UMBC. It consists of geophysical sampling and surface survey of the plain immediately around the Late Helladic IIIB fortification of Glas in the northeastern Kopaic Basin, Viotía Prefecture, mainland Greece (Figure 1), carried out under the terms of permit 4ΑΘΒΓ-ΩΥ from the Hellenic Ministry of Culture and Tourism and permit 221 (of year 2011) from the Institute of Geology and Mineral Exploration (ΙΓΜΕ). Fieldwork was funded by a Renewed Research Grant from the Institute for Aegean Prehistory (INSTAP). Timothy J. Horsley is the Principal Geophysical Investigator, assisted by Allison E. Cuneo. Ms. Athina Papadaki is the official fieldwork Collaborator (Συνεργάτιδα) on the part of the IX ECPA. Weston S. Bittner is the Geographical Information Systems (GIS) Specialist. Participants in fieldwork in 2011 also included Sandra C. Gammon (post-graduate, Monmouth Univ.), Evantheia V. Iliopoulou (graduate of Aristotle Univ. of Thessaloniki), and Jonathan M. Kerr (graduate of UMBC).

The principal aim of AROURA is to detect evidence of land use for agriculture and attendant practices in the Late Helladic III (c. 1300–1190 BCE) polder—i.e. area of land claimed from water, behind a dike—surrounding the contemporary fortress of Glas (Γλας). It takes an experimentalist approach to testing certain hypotheses that have been advanced concerning the nature of the agricultural regime overseen by Mycenaean palaces throughout the southern Aegean, which sustained their system of taxation and finance. Palace-supervised agriculture is generally thought to have been extensive, that is, deliberately based on low human labor input but high animal and technological inputs, and reliant on a few modestly yielding, easily planted, low-maintenance crops. However, this understanding of palace-sector agriculture is derived almost exclusively from records in the Linear B script discovered in several palace archives, whereas the archaeological evidence from several non-palace sites of the same period indicate that intensive agricultural strategies were also undertaken in some places. Enormous storehouses inside Glas' walls, in which evidence of at least two to three metric tons of a single species of wheat (einkorn, *Triticum monococcum*) was found, are consistent with a palace-sponsored regime of extensive agriculture. In addition, felicitously, the Kopaic Basin, which tends naturally to be a shallow lake with wetland margins in a post-Pleistocene climate, is an ideal environment for preservation of traces of extensively cultivated land tracts (e.g. plow scars, irrigation and drainage ditches, field divisions, outbuildings). Therefore, Dr. Lane, co-director, has devised a topographical model of Mycenaean Era (c. 1390–1190 BCE) land plots cultivated and maintained in the expected manner, and this model informs the scale of sampling and the methods and techniques employed in the field. Crop and soil marks (hereafter "field marks") apparent in aerial photographs and satellite images strongly indicate preservation of intact remains of archaeological interest below the ground surface (Figure 2).

*Objectives in 2011*

The concrete objectives of AROURA during its field campaign in the autumn of 2011 were built on and complemented those that were realized in 2010. They are as follows:

1) to examine further the regular, network-like (hereafter "reticulate") pattern of magnetic anomalies around the polder dike to the west of Glas, detected with fluxgate gradiometer in 2010, especially where the pattern is particularly subtle or gradually becomes indistinct;
2) to clarify how this pattern is separated from the almost geophysically "empty zone" around the fortress to the east, in the middle of the polder;
3) to explore how, apparently by way of much the same kind of feature (long linear magnetic anomalies and corresponding field marks and deposits), the reticulate pattern is linked directly to the outcropping of Glas;
4) to investigate further the evidence of water having flowed at some point through the area comprised by the polder (i.e. magnetic anomalies typical of paleochannels);
5) to sample with geophysical techniques and systematic collection of objects from the ground surface (hereafter "surface collection") of areas to the north and east of Glas, with the particular goals of collecting datable material and of linking the fortress to contemporary sites on the polder's periphery; and
6) to test ("ground-truth") geophysical results through stratigraphic soil coring and profiling of the sections of modern irrigation ditches.

*Achievements in 2011*

AROURA attained all of its objectives and made progress beyond these in 2011.

1. In the first two weeks of fieldwork, it conducted magnetometry on over 14 hectares of land within the LH III polder, on every side of Glas.
2. It determined through soil coring and ditch section profiling that the reticulate pattern of magnetically negative anomalies (see above) corresponds to a layer or lens of sediment with clear characteristics, appearing to be deliberately deposited soil, and that such anomalies in turn find correlates of distinctive signature in spectral data from earth satellites.
3. It began to test specific landforms, such as deposition in the entrance to the Vrýstika Sinkhole, that may detail the geomorphological history of the polder, especially episodes of flooding and desiccation.
4. It floated and screened soil strata sampled in 2010, from one of which a radiocarbon date corresponding to the Middle Neolithic Period has already been obtained, rendering plant and invertebrate remains for quantitative analysis and environmental interpretation.
5. Finally, AROURA completed an intensive surface collection of a significant portion of the multiphase settlement site of Aghía Marína Pýrghos (AMP), showing, inter alia, that it is contemporary with the Late Helladic occupation of Glas and the immediately succeeding period, following the destruction of Glas.

*Future Fieldwork and Medium-term Objectives*

In 2012, AROURA will pursue its objectives for 2011 further, employing new technologies, such as soil electromagnetic / conductivity testing. In particular, it will concentrate geophysical prospection on areas northwest and southeast of Glas, where evidence of water-control mechanisms connected with Mycenaean canals and channeled rivers are expected, and to the northeast, in the plain between Glas and AMP. Surface collection at AMP will be expanded on the summit of its knoll and extended to areas beside and outside of its Cyclopean perimeter wall. Funding will also be sought for a wide range of scientific studies in the field and laboratory—including palynology, archaeomalacology (mollusk analysis), soil micromophology, radiocarbon dating, thermoluminescence dating of sediment, and further archaeobotany—to be continued into 2013, the AROURA "study year." This study year will involve, in addition, further analysis, typology, and subsequent cataloguing of artifacts collected from the ground surface in several parts of the study area from 2010 onward. Preparations are being made for targeted excavation of features associated with geophysical anomalies, as well as of selected parts of AMP. A field school for undergraduate and graduate students is included in these plans.

## Methods and Techniques

### *Spatial Control and Sampling Strategy*

Before fieldwork began in 2010, AROURA defined a Project Area comprising 1,000.35 hectares. In 2011, this area was extended to include AMP and now comprises 1,018.44 hectares. It consists of a sampling grid of squares 30 meters on a side, which is centered on a crossroad on the north side of the outcropping of Glas (loc. GGRS-87 metric coordinates E 0428686 / N 4259744), and it is derived from a square 3 kilometers on a side (see Figure 1). It is oriented parallel and perpendicular to the modern agricultural field boundaries. It is bounded approximately by the canalized Melas (Mavropótamos) River to the north, Mt. Fteliá (including the Vrýstika Sinkhole) to the south, National Road E1 (Athens–Lamía) to the West, and the alluvial fan of Souvlí to the east. Hence it encompasses various hydraulic features and landforms that may have been exploited differently from each other in Mycenaean times. The 30-meter grid squares represent a common standard unit of geophysical prospection.

Areas of investigation are delimited within the Project Area / sampling grid. Each targets an area in a different part of the polder or adjacent areas, on all sides of Glas, where the potential for archaeological discovery may be variable. They in turn are divided into "transects" for sampling of contiguous grid squares, which are generally 90 meters wide and several hundred meters long. The orientation of the grid facilitates continuous sampling and obviates crossing of built and excavated field boundaries with cumbersome equipment. In some cases, adjacent transects have been offset from each other by 30 or 60 meters, so as to avoid the chance of linear subsurface anomalies of interest running parallel to the vertices of transects being thereby elided or obscured. Transects are designated by a Latin letter (A–N) according to their area (except "AMP" for the eponymous site) and a subordinate Arabic numeral grid squares within transects are known by a coordinate pair of lower-case Latin letter (NW–SE axis) and Arabic number (SW–NE axis). The NW end of the former axis is called "grid north," the southwest end of the latter "grid west," and so forth. After completion of fieldwork in 2010, areas of investigation were grouped into "sectors" of similar characteristics, for ease of interpretation (see "Results").

The corner points of blocs of six contiguous grid squares, 60 meters by 90 meters, were located and staked out to within 5 centimeters of their mapped position with Altus APS-3 GNSS (differential GPS) base station and roving receiver (Figure 3). Blocs of such dimensions are conveniently sampled continuously with geophysical instruments, and intermediate intervals can be accurately measured by other means (see below). The corner stakes of transects in agricultural land on the plain consisted of 1.5-meter bamboo poles topped by flagging tape of alternating color, along one axis of the transect. At AMP, where animal traffic is frequent, these were eventually replaced by more permanent 20-centimeter wooden stakes with the corner point (e.g. 1N, 2E, 3S, 4W) written in permanent marker on each side and topped in flagging tape, each driven to a depth of 18 to 19 centimeters into the ground. At AMP in 2011, the east (grid SE) corner of AMP2, the most precisely located point of this bloc on fairly level ground, was chosen as the beginning point for laying out grid squares. Lay-out was accomplished with 100-meter fiberglass tapes on perpendicular and hypotenuse lines, with the assistance of an orienteering (Brunton) compass, adjusted to the magnetic declination at Glas in October 2011 (Figure 4). The observed horizontal error from corner AMP2E on the summit of AMP (where the slope is less than 8%) was equal to or less than 30 centimeters over 30 meters (1%), and on the surrounding slopes (where the gradient is up to 40%), it was equal to or less than 1 meter over 30 meters (3.3%). All horizontal GIS lay-outs distribute this error accordingly.

The position of points outside of transects, such as for ditch section profiles, was determined on the basis of maps, vertical aerial photographs, and satellite images corrected to the Greek Geographical Reference System (GGRS-87) projection–coordinate system. Once located in the field, these positions were measured again with stand-alone GPS receiver (Garmin eTrex HCx) set to GGRS-87 / Universal Transverse Mercator (UTM) metric parameters, so as to make relocation on the basis of field records alone possible.

### *Geophysical Prospection*

As in 2010, AROURA employed the Bartington Grad 601-2 dual fluxgate gradiometer for magnetometry, because of its ease of use in pedestrian traverse, rapidity in collecting data, and capability of detecting anomalies due to shallow and deep (1.5+ m) features. Magnetometry is the most frequently applied geophysical technique worldwide, used under various conditions where contrast in iron oxides in topsoil and subsoil exist, and it is capable of detecting the full range of features expected, including cuts and fills, and stone and mud-brick structures.

Data were collected every 0.125 meter on traverses spaced 1.0 meter apart. To realize this pedestrian procedure, 60-by-90-meter blocs of six grid squares were demarcated with high-tensile plastic binding strap, every 1 meter on the short axis and every 4 meters in 30-meter squares on the long axis. Traverses were thus walked back and forth within grid squares. Continuously laying out and taking apart the demarcating plastic strapping permitted between 2.16 and 2.70 hectares to be sampled per day, varying mainly with terrain and ground cover (Figure 5). Description of the topsoil, vegetation, relief, and modern and ancient structures, as well as a sketch map, was recorded on standard forms for each bloc of grid squares.

Data were downloaded from the Grad 601-2 with proprietary software (v. 3.16) and processed with ArcheoSurveyor (v. 2.5.12). In the illustrations provided for the results described in the appropriate section below, all data have been subjected to the clipping to ± 5 nano-Teslas (nT), zero-mean traverse, and (where anomalies are intense) edge-matching algorithms, and interpolation on the y-axis (resolution 0.5 × 0.125 m). Each image is plotted at a range of ± 0.5 nT to aid comparison between survey areas. It may be noticed that almost all of the magnetic anomalies of archaeological interest are very subtle, less than 3 nT and mostly within ± 0.5 nT (cf.7.0 nT between limestone and soil at Plataia, southern Viotía; M. Boyd, pers. comm. 2010). These attenuated responses do not, however, signal vestigial subsurface features, as ground-truthing in 2010 and 2011 showed. Rather, their character is due to the mainly minerogenic soils on a carbonate substrate, whose magnetic susceptibility is low, and, as is expected in theory and indeed appears, the lack of time in both the Mycenaean and modern eras for topsoils to have formed naturally.

### *Soil Coring*

Starting in 2010, the nature and character of features corresponding to magnetic anomalies were tested by removal of stratified soil cores with a hand-driven auger (Figure 6). Cores were removed both from directly above anomalies and from adjoining magnetic background (relatively neutral) areas for comparison. This method has the further aim of recovering organic matter that can be subjected to accelerator mass spectrometry (AMS) radiocarbon dating. As a rule, soil augering employed an open-cylindrical Dutch "mud" bit (with 2-inch / 5-cm flanges), 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, especially at the entrance of the Vrýstika Sinkhole, a two-inch screw bit was used to penetrate gravelly layers, usually followed by the mud bit. Below 150 centimeters at the Vrýstika Sinkhole, a one-inch (c. 2.5-cm) cylindrical peat sampler was used, because of intractable soil stickiness. Segments of soil core were stored in stratigraphic order in 1-meter sections of cylindrical polyvinyl chloride (PVC) pipe, cut in half lengthwise. These bear a relevant label and are wrapped in polythene cling film for refrigeration in the Wiener Laboratory of the American School of

Classical Studies at Athens until flotation and wet-sieving are possible (see below). A complete description of each soil profile, conforming with the standards of the U.S. Department of Agriculture, was recorded on a standard form. Soils were augered to a depth of 2 meters or two 1-meter lengths of PVC storage tray, whichever was reached first, depending mainly on soil expansion and compression during coring.

### *Flotation and Wet-sieving*

Partial and whole samples of soil horizons from cores taken in 2010 were floated and sieved in 2011. The flotation tank was a modified form of the SMAP type, consisting of a 55-gallon (208 l.) steel drum fitted with a tap for introducing water to an interior showerhead (for agitation of samples), water release spigot at the base, wire screen for supporting the mesh for coarse fraction, and rim-spout (sluice) for buoyant fine fraction. The coarse fraction was collected on plastic mesh of 2-mm aperture, inside the tank, while the fine fraction was collected in a 250-micron screen mounted below the sluice, outside the tank. Soils were dissolved simply in available well water in most instances, though where the clay fraction was deemed high (ca. 30% or more), a 10 percent solution of sodium hexametaphosphate deflocculant (Calgon) was added for every circa one liter of soil. Both recovered coarse and fine fractions were air-dried, the latter in paper towel, and they were packaged in 1-mm self-sealing plastic bags for delivery to the analyst, Dr. Evi Margariti, Leventis Fellow at the British School of Archaeology at Athens, who will study them in 2011–12. Standard forms were filled in for each sample floated, including information about the relevant horizon and its archaeological context.

### *Ditch Section Cleaning and Profiling*

An additional method of testing magnetometric results, initiated in 2011, was the cleaning of vertical sections of modern irrigation ditches where anomalies or field marks of interest, or both (as determined by magnetometry results or perusal of GIS data), intersect these ditches horizontally, and then drawing and describing the revealed stratigraphic profile. Foliage of grass and weeds was removed with sickle and pruning knife, and superficial eroded sediment was removed with trowel and hand-brush. Exposed sections were at least three meters wide, one standard deviation of the accuracy of the single GPS receiver used to record its position (see above), in order to guarantee capture of the interesting features and to facilitate relocation. Depth measurements were made from an arbitrarily placed, level horizontal baseline at the top of the section (Figure 7). Sketches and stratigraphic description of the profiles were made in field notebooks.

### *Surface Collection at Aghía Marína Pýrghos* (*AMP*)

The collection of moveable finds at AMP aimed to be total, and the sampling units were 2-by-2-meter squares. Any object of archaeological interest, artifact or not—including some that probably postdate the completion of the modern drainage works in the middle of the 20th century—which could be removed from the ground surface between thumb and index finger, or by pressure exerted by two fingers on an edge (but no more), and could be fitted in a 15-by-30-cm water-resistant paper field-walking bag (Figure 8) was collected for cleaning, sorting, analysis, and catalogue. The 2-meter sampling unit represents a reasonable compromise between topographical precision and unmanageable detail. It is also precise enough to correlate with extant architectural features, and it makes results directly comparable to those of field walking for surface collection on 2-meter traverses around Glas in 2010. Finally, it allows investigators enough room to maneuver around each other. Collection units were measured from the base and datum lines established for the grid square, using fiberglass tape or length of plastic strapping marked every meter. A pin-flag was placed at each corners of every unit. Sampling units are known by a coordinate pair pertaining to the 30-meter grid square, starting with a numeral between 01 and 15 for the easting and ending with a numeral between 01 and 15 for the northing (grid directions; e.g. AMP2c2-0102, AMP2c2-0201).

Sampling proceeded by row from grid south to grid north, west to east in each row. Each unit was cleared of the leafy part of plants, including dead vegetation, to the degree that sickle, pruning knife, and small gardening rake permitted (Figure 9). It was then searched thoroughly, from one side to the other, by sight and with fingertips (Figure 10). The grid square was mapped row by row as collection proceeded, indicating architectural and topographic features that might prove interesting, the degree resolution being about 20 cm. The numeral designation and brief provisional description of the contents of every bag were recorded on standard forms. Each bag bore an estimate of ground surface visibility after cleaning (Figure 11), which was subsequently recorded on forms in the project house laboratory.

Once in the laboratory, finds were cleaned gently with warm tap water and toothbrushes, and allowed to dry in the open air. They were then divided among 16 material classes (the great majority belonging to “Ceramic, pottery”) and assigned a new bag label on which was recorded their find spot (collection unit), material category, and a more exact description that that given in the field.

*Use of Satellite Data*

AROURA purchased data from the Worldview-2 sun-synchronous satellite in 2011. The package consists of 10-bit (2048 value / band) panchromatic (0.4-m resolution) and eight-band multispectral (2.0-m resolution) data. So far they have been used to create geo-referenced high-resolution red–green–blue composite images to complement maps and aerial photographs of the Project Area (see Figure 2), as well as to explore the spectral characteristics of field marks associated with known magnetic anomalies, the near infrared bands being especially useful. In 2011–12, Mr. Bittner, GIS Specialist, will carry out systematic and statistical examination of the satellite data, a process known as “supervised reclassification,” to discover exact correlations of spectral values with magnetic anomalies and corresponding ground-truthed features.

## Results

*Polder Dike Sector*

*Area F*. Only Transect F1 was investigated in 2011, a transect that was unavailable for sampling in 2010 due to the destruction of corner stakes. It consisted of three 60-by-90-meter blocs of grid squares, of which only the southern half could be sampled in 2011 because of the presence of a potato crop. Transect F1 was located so as to frame the southern extent of the reticulate pattern of magnetically negative anomalies detected in Area G and suggested also by field marks appearing in historic aerial photographs. It was thought also that one of the previously identified wide, linear “bounding” anomalies, as they were provisionally called in 2010, might also pass through this transect.

As one can see in Figure 12, there is considerable magnetic interference from a raised concrete irrigation channel on the northeast (grid east) edge of the transect (white band) and a modern barn in the west (grid northwest) corner of the sampled section (black shadow). There are also the characteristic discrete-magnetic bipole signals of ferrous refuse on and in the topsoil, especially around the barn. There are, nonetheless, the faintest traces of magnetically negative anomalies aligned as one would expect of the pattern so clearly displayed in Transect G1. These are found mainly in the in the east corner and measure between 0.0 and –0.2 nT. However, it seems that the interval between them here may be approximately 15 meters. They may be bounded to their east by a long, linear feature, corresponding to a field mark and, in Transect G2, to an anomaly running from the northwest toward the southeast, Area M, and western end of Mt. Fteliá. It is noteworthy in this context that Area F, including Transects F2 and F3 too, straddles the border between the Polder Dike Sector and West Sector, where the reticulate pattern may fade out in a band of especially silty soils (see “West Sector” below).

*Area G*. The southern end of 320-meter long Transect G2 was explored with the aim of extending the area sampled in 2010 and of studying more closely the boundary area between the reticulate pattern of anomalies to the west and the virtually magnetically empty zone around Glas to the east. One of the wide, linear bounding anomalies runs roughly from north-northwest to south-southeast through the middle of G2, between Area N to the north and Area M at the tip of Mt. Fteliá.

As in all the cultivated field around Glas, there is a considerable amount of ferrous debris—e.g. machine parts, lengths of wire, shotgun shells—which are represented in Figure 13 by small and intense black-and-white bipolar respons. There are, as well, large steel installations, such as well standpipes, that generally appear as white (magnetically negative) blossoms around a black (magnetically positive) core, or sometimes vice versa. Despite such modern magnetic interference, some underlying magnetic anomalies may be detected. None of these exhibits any of the regularity observed in Areas G, H, and I, in the direction of the polder dike. Rather, stretches of magnetically negative anomalies meander slightly throughout the sampled area, and they are accompanied in places by magnetically positive bands, a pattern typical of graded paleochannels, seen previously in Transect A2. Where anomalies are continuous, mainly along one dimension, and magnetically positive, they seem to intersect each other at various angles. Thus they resemble a less intense version of the irregular pattern observed in Transect J2 in 2010 and J3 in 2011, which shows every sign of representing a web of infilled desiccation cracks.

Segments of two soil cores obtained in 2010 underwent flotation and sieving: one, 2010G1-01 represents a magnetic background area between the linear negative anomalies making up the reticulate pattern in Transect G1; the other, 2010G2-02, represents the soil horizon correlated with one of the linear anomalies itself, and, given evidence from 2011 in turn, the grayish lens in seen in ditch profiles 2011I2-P01 and 2011I2-P02, among others (see below).

*Area H.* Area H was not subject to any direct sampling in the field in 2011. However, segments hypothesized to be ancient ditch fill from two soil cores removed from Transect H2 in 2010, 2010H2-02 and 2010H2-03, were floated and wet-sieved. Both of these are known to contain gravel, mollusk shell, and small, degraded sherds of pottery. The fine and coarse fractions were delivered to Dr. E. Margariti for analysis in late 2011 or early 2012.

*Area I*. One section of Area I was targeted for geophysical examination, a section that could not be sampled in 2010 because of the presence of a delicate vegetable crop. This bloc at the northern end of I2 presented something of a magnetometric enigma. Whereas aerial photographs and satellite images display the clearest field marks anywhere around Glas (see Figure 2), the magnetometric results were exceptionally subtle here (Figure 14). Indeed, the results from I1 to the northwest, closer to the polder dike, and from the remainder of I2 in 2010 were clearer, although the former exhibited a "herring bone" (rather than reticulate) pattern of circa 15 or 30 meter intervals (another cause for curiosity). Nonetheless, there is a pattern, and it corresponds largely to the field marks. More specifically, the pattern conforms in orientation, dimensions, and magnetic character to the clear network of anomalies observed in Transect G1 to the south. The largest of the constituent linear anomalies are magnetically negative, and they enclose at least one almost square trapezoid, about 30 meters on a side. In one place, at least, the magnetically negative linear anomaly is paralleled by a narrower magnetically positive one, coupling that is typical of a levee and accompanying ditch, as was suggested in G1 in 2010. The overall pattern is somewhat further obscured by what appear to be overlying magnetically positive anomalies, one of which is aligned with the modern field boundaries, and both of which have characteristics of magnetically enhanced topsoil fill. They therefore may represent reburied modern excavation.

Area I, including points in Transect I2, was subjected to ground-truthing through ditch section cleaning and profiling and stratigraphic soil coring. Two profiles—2011I2-P01 and 2011I2-P02—were prepared, located on the opposing banks of a ditch running along the grid west (southwest) side of the tract containing Area I, at points where one of the magnetically negative anomalies (that possibly paralleled by a positive) and its corresponding field mark intersect the ditch. In both instances (Figures 15 and 16), a lens of predominantly white (10YR8/1) or light gray (10YR7/1) silt loam ②, very nearly 220 centimeters wide and about 18 to 22 centimeters thick, was discovered below the modern plow zone. Given the angle at which the linear negative anomaly intersects the ditch, nearly 45 degrees, the exposed diagonal width corresponds to a perpendicular width of about 150 to 160 centimeters. There appears to be a layer ③ of predominantly grayish brown at the grid south end of this feature, and though the boundary between it and the underlying stratum is indistinct (at least in the exposed stretch), it is attractive to think that it represents topsoil washed into a ditch paralleling the elevated feature, accounting for the observed thin magnetically positive anomaly. It was not detected in 2011I2-P02, but it is conceivable that it is lost in the lower reaches of stratum ① in this profile, which is a dark grayish brown (10YR4/2) silt loam, the upper part of which, at least, is plow soil.

Noteworthy is a limestone cobble floating in the upper part of 2011I2-P02 ① above lens ②. It raises another interesting question about the system of features and anomalies in this and surrounding areas. Observation in the field, as well as local informants (esp. N. Polýmeros, Kástro), suggests that at least in Area G and Area I (not to mention west of the Project Area, in the polder around Tourloghiánnis), concentrations of limestone cobbles and small stones are encountered in the fields (Figure 17) that have no geomorphic explanation. It is therefore plausible to think that stones, such as that appearing in 2011I2-P02, were an element of the system of features, perhaps an upper pavement or lateral revetment, now largely plowed out or otherwise deliberately removed.

Soil cores 2011I2-01 and 2011I2-02 are complementary (Figure 18). The former was placed on the alignment of a magnetically negative anomaly in I2 with the gray/white lens seen in profile 2011I2-P02, the latter in a presumably neutral background area, between anomalies and field marks, some 5 meters to the southeast of the first. The stratigraphic profiles are not only distinct from one another, but they also exhibit correlates with buried features causing magnetic anomalies. In 2011I2-01, below the fill for a modern farm lane, itself likely excavated from the adjacent trench, and the underlying A2 horizon, itself equivalent to adjoining plow zone, was a horizon at a depth of between about 105 and 145 cm, with field designation A3, consisting of light gray (10YR7/2) silt loam. This is only about 10 centimeters deeper than the gray/white lens observed in 2011I2-P01-P02, and the grade at the point of augering is, in fact, somewhat higher than that recorded in the ditch profile. Thus this A3 horizon resembles the lens in the nearby ditch profiles in color, texture, and depth, though it appears to be somewhat thicker. A sample of sediment was taken from this horizon for AMS radiocarbon dating. The core was pursued to a depth of about 200 centimeters through two mottled, predominantly grayish (10YR7/2, with 10YR6/1) subsoil horizons ($B_w1$ and $B_w2$), the latter of which had up to 1 percent shell fragments (all probably molluscan).

In contrast, the upper part of 2011I2-02 consists of a modern fill (to c. 66 cm), a thin underlying A2 horizon (c. 66–87 cm), and a horizon labeled AB—a predominantly dark grayish brown (10YR4/1) clay loam, containing up to 5 percent very dark gray clay films on its platy structures, and about 1 percent very fine shell fragments. The latter spans a depth of about 87 to 120 centimeters. Below it is a clearly eluviated (E) horizon (10YR7/2 light gray, mottled c. 30% 10YR6/1 gray) of silt loam, descending to about 150 centimeters, and two subsequent illuviated subsoil horizons ($B_h1$ and $B_h2$), cored to a final depth of about 195 centimeters. Given the similarity of the A2 horizons and the clearly subsoil nature of the horizons below AB/A3 in each core, it is not just evident that 2011I2-01's A3 represents the hypothesized raised feature corresponding to the magnetically negative anomaly (levee?), but it is also plausible that 2011I2-02's AB represents the ancient ground surface onto which such features were laid, and into which adjoining excavations may have been made.

Three more soil cores were removed from within Transect I2 proper (Figures 19 and 20): 2011I2-03 from a magnetic background area; 2012I2-04 from the intersection of two linear magnetically negative anomalies (where, in fact, a superposed positive anomaly is seen as well); and 2001I2-05 above another linear magnetically negative anomaly, part of the reticulate pattern. The profile of 2011I2-03 consisted of a relatively thin modern plow zone ($A_p$, c. 0–30 cm), followed by a relatively thick, predominantly light gray (10YR7/2) but mottled (c. 20% 10YR6/6 brownish yellow, 5% 10YR5/1 gray) silt loam subsoil ($B_w$, c. 30–85+ cm). The profile of 2011I2-04 contrasted with this, albeit not as 2011I2-01 to 2011I2-02. The silt loam plow zone ($A_p$) again appears to be about 30 centimeters thick. Below it is a horizon, designated A2, that is a distinctly dark gray (10YR4/1) silt loam mottled brown (2.5Y2.5/1) and light yellowish brown (10YR6/4), containing up to 5 percent shell fragments, and continues to a depth of about 70 centimeters. This horizon is succeeded by one designated A3, which is a light brownish gray (10YR6/2) silt loam (mottled with about 20% 10YR5/2 grayish brown) containing about 3 percent fine to medium subround gravel. Beneath this, and to a depth of about 200 centimeters is a silt loam $B_{wt}$ horizon, whose predominant color is very pale brown (10YR7/3).

It should be noted that there are patches tens of meters on a side, particularly in the middle of the northernmost bloc of Transect I2 (whence 2011I2-03), in which modern tillage has turned up some of the mottled light grayish or brownish subsoil. So it seems the ancient ground surface may have undulated by 50 centimeters or more. This estimate of undulation seems to be confirmed in 2011I2-05, where the $B_w$ horizon (mainly 2.5Y7/2 light gray) is not identified until below 100 centimeters. Above it are an Ap horizon (c. 0–30 cm), A2 horizon (c. 30–64 cm), and A3 horizon (c. 64–115 cm), the last of which—being a light gray (10YR7/2) silt loam, mottled with gray (c. 15% 10YR6/1) and brownish yellow (c. 15%10YR6/8)—is similar in color, texture, and elevation to the gray/white feature and negative anomaly observed in ditch profiles 2011I2-P01-P02, as well as in core 2011I2-01.

The profile of 2011I2-04, which was also meant to test a linear negative anomaly, differs sharply, its A3 resembling that in 2011I2-05, while its A2, which is comparatively very dark and gray, is likely to represent the magnetically positive anomaly that seems to be superposed on the reticulate pattern of linear negatives. Hence, once again, the negative anomalies and correlating field marks are represented by sometimes slightly mottled gray or white (10YR6/1–6/2, 7/1–7/2) horizons or lenses.

*Area N.* Area N, consisting of Transects N1 and N2, was staked out for the first time in 2011. Its aim is twofold: (1) to investigate whether and how the reticulate pattern of negative anomalies (and some parallel positives) extends northward toward Area J and the northern end of the Late Helladic polder dike; and (2) to capture a western branch of what appears to be a convergence of long (if not also wide) linear magnetically negative bounding anomalies and field marks, appearing also in Transect J1 to the north of Area N.

Transect N1 (Figure 21)—farthest to grid north and closest to the terminus of the polder dike by the hill of Topólia (Kástro)—was deeply furrowed in its central section at the time the magnetometer was available, and so only a corridor of 30 by 120 meters (through two blocs of grid squares) was sampled here, if for no other reason than to preserve the instrument operator from injury. As almost everywhere else in the polder around Glas, the anomalies here are very subtle. The grid north end, which is close to the intersection of two major farm roads, is contaminated with bits of ferrous refuse (evident as bipolar responses). Nevertheless, three groups of anomalies are detected. The first, in the narrow corridor in the middle of N1, appears as a pair of linear magnetically negative anomalies running diagonally (roughly true west to east) and, between 25 and 30 meters away, a parallel linear magnetically negative anomaly, perhaps adjoined by a positive. All these anomalies intersect the edges of the transect at about 45 degrees, which, together with their spacing, is consistent with the reticulate pattern seen especially clearly in Transect G1. (The reticulate pattern runs parallel and perpendicular to the polder dike.) Of possibly considerable significance is how the seemingly wider central east–west anomaly corresponds to a field mark seen in satellite data to run from the northwest edge of Glas westward through Transects J2 and J3 (see "Area J" below). The second group consists of fainter traces of what may be the same reticulate pattern in the northwest end of Transect N1, while the third consists of at least one segment of a magnetically negative anomaly in the transect's southeast end that lines up with those observed in its center.

Transect N2 (Figure 22), like Transect J2 to its north, contains a broken web of fairly strong magnetically positive anomalies that are completely consistent with, and most likely represent, desiccation cracks. (A trailer laden with irrigation pipes accounts for the large magnetic bipole in the grid south end.) Also clear is a long, though not wide, linear, magnetically net-negative anomaly paralleled on its east edge, at least, by a narrower magnetically positive one. This anomaly can be seen to continue in Transect J1, sampled by magnetometry in 2010, where its profile was exposed in 2011 in a modern irrigation ditch (see "West sector" below). This pairing of negative and positive, which is similar to that of some of the bounding anomalies, intersects the edge of the transect at about 45 degrees, again consistent with the reticulate pattern to the west. There are faint perpendicular, mainly magnetically negative anomalies appearing to branch away from it to the west, but nothing particularly convincing.

One soil core was removed from Transect N1: 2011N1-01 (Figure 23), from above one of the magnetically negative linear anomalies that may make up a pattern. Because of hostile weather, the core was not sunk deeper than 75 centimeters. However, in that span, the auger passed through the plow zone ($A_p$, c. 0–40 cm) and a thin A2 (c. 40–53 cm), which may be the loamier base of the silty plow soil, and into a distinctively light gray (10YR7/2) horizon designated A3. Although coring did not penetrate lower than this horizon, its color and depth are, at least, consistent with that of horizons and lenses of sediment that elsewhere correlate with the magnetically negative reticulate pattern.

*West Sector*

*Area J.* Transect J3 (Figure 24) was located on the opposite side of the asphalt Kástro–Kókkino road from Transect N2 in order to capture the convergence of several north–south and east–west field marks, some of the latter of which run toward Glas. It was eventually realized as a bloc and a half of grid squares, overlapping partially with Transect J2 (of 2010). As expected, segments and intersections of magnetically positive anomalies, such as are typical of infilled desiccation cracks, were detected. There are traces too of magnetically net-negative anomalies appearing to coincide topographically with the intersection of two field marks: one running from north to south, approximately parallel to that observed in J1 and N2, and so c. 45 degrees to the transect edge, and another running from east to west, not quite perpendicular to it. The east–west one may correspond to the wide, linear anomaly detected in the center of Transect N1, as well as to the linear field mark seen in satellite images to run westward from the northwest edge of Glas (see further below). However, presence of these anomalies in J3 is ambiguous.

Four profiles were made of sections of the modern irrigation ditch on the northeast (grid east) side of the tract containing Area J: 2011J1-P01; 2011J2-P01, 2022J2-P02, and 2011J2-P03. The first of these is on the grid east (northeast) side of the ditch at a point where a narrow linear, possibly bounding anomaly intersects it. This is the anomaly above which core 2010J1-01 (Figure 25) was removed in 2010. In this profile—as indeed in the section opposite, though this was less methodically studied—a distinctly bounded lens of predominantly light brownish gray (10YR6/2, mottled c. 40% 10YR6/1 gray) silt loam was discovered. It is a little more than a meter below the grade of the modern farm lane fill, and so about 40 centimeters below the top of adjacent plow land. The angle of intersection at this point in the ditch is about 45 degrees. The lens, which in section is about 160 centimeters wide and 30 centimeters thick, should represent a feature with perpendicular width of about 100 to 115 centimeters. It is bounded on each side (abutted in appearance) by a layer of predominantly grayish brown (10YR5/2) silt loam including up to 1 percent fine fragments of shell. It is attractive to think, though not yet provable, that either or both of these deposits are the fill of a ditch parallel to the elevated feature; certainly, the magnetometric data suggest a magnetically enhanced fill, perhaps topsoil, to the east side of the feature. The lenticular feature is similar in form, vertical dimension, color and texture to those discovered in 2011I2-P01 and 2011I2-P02, and it presumably corresponds also to the A3 horizon of soil core 2010J1-01, encountered between about 70 and 75 centimeters deep, which consisted of a grayish brown (10YR5/2) silt loam, heavily mottled with pale brown (c. 30% 10YR6/3). Both this A3 horizon and the thicker underlying A4 horizon (field designation) of 2010J1-01 were subject to flotation and wet-sieving. It is thereby hoped that organic matter for dating of the feature and the surface onto which it was laid, as well as for reconstruction of its biotic environment, will be obtained.

Ditch profile 2011J2-P01 and 2011J2-P03 (Figures 26 and 27) were positioned so as to intercept the long linear field mark, seen in satellite data and possibly corresponding to anomalies in Transect J3 and Transect N1 (see above). In each, at the base of the modern plow zone (in turn, beneath a modern fill or concentric-plowing ridge), is what appears to be a truncated segment of a lens of material that may correlate with the field mark and, by extension, with the magnetically net-negative anomaly. In 2011J2-P01, it is found at the grid south edge of the profile, and it consists of a predominantly white (10YR8/1) firm, mainly silty sediment, comprising almost an equal part of light brownish gray (10YR6/2) that contains a very few fine, sub-round limestone and possibly chert pebbles. In 2011J2-P03, the lens is less prominent, consisting of a light brownish gray (10YR6/2) silt mottled 5 to 10 percent with very pale brown (10YR7/3). However, in both profiles, the silt loam plow soil above is browner (10YR5/2) and the stratum below generally grayer or darker (10YR5/1, 10YR4/2) and of different texture and consistence.

Ditch profile 2011J2-P02 (Figure 28) had a rather different purpose from the others. It was meant to intercept one of the hypothetical desiccation cracks obvious in Transects J2, J3, and N2 (and possibly evident elsewhere), to determine if the corresponding anomaly was caused by a feature in the soil or a feature of the rock substrate. However, the trial was inconclusive, there being no non-conformity, possibly because the point of intersection of the unpredictably non-linear anomaly with the ditch was missed in section. A further attempt to test the nature and character of the irregular anomalies in Transect J2 was made through soil core 2011J2-01 (Figure 29), which was removed from the bottom of the ditch on the grid east side of J2 at a point where a rill in the section suggested a truncated crack. Nothing about its profile suggested any extraordinary pattern of drainage, such as one should expect from bedrock fracturing.

Further support for the hypothesis that the irregular pattern of magnetically positive anomalies so prominent in J2 results from rapid drying of soil takes the form of desiccation cracks observed in Area B in 2011 (Figure 30). These are one meter or more apart and 20 centimeters or more deep in places, after only a few weeks of almost continuous sunshine. Moreover, in 2010, the auger passed abruptly through a layer of sediment just below the plow zone in 2010J2-01 that could well have been a loose fill of such a crack. The prevailing hypothesis is that the irregular pattern of anomalies represents a web of desiccation cracks resulting from the exceedingly rapid drainage of the Kopaic Lake with the opening of the British Lake Copais Company's canal system in 1892. The hypothesis is consistent with locals' accounts of how, after this drainage, the soil on the edges of the lakebed became "like ash" (σαν στάχτι) and subsequently required re-irrigation (N. Polýmeros, Kástro ; L. Yperífanos, Orchomenós).

Finally, with respect to Area J, segments of four soil cores removed in 2010 were floated and sieved: the A3 and A4 horizons of 2010J1-01, which correlate with a narrow linear negative anomaly, and the A4 and A5 horizons of 2010J2-01, which may correspond to the fill of a hypothetical desiccation crack.

*Area K.* Only Transect K1 (Figure 31) could be sampled in 2011, because Transect K2 was, at the time the gradiometer was available, a fallow field of tall grass and weeds impassable to the operator with the instrument. (Later in the season it was entirely plowed.) K1 targeted the meeting of the polder dike with the ancient canalized Melas, as it flows around Topólia. However, precisely because it is in a tract of land beside the viaduct to Kástro (Topólia) over National Road E1 and an entrance ramp to it, it is generously sprinkled with ferrous rubbish (magnetic bipolar responses). Furthermore, there is a wooden and corrugated steel shed on the grid east edge of K1, which causes a huge magnetically positive shadow in the data presentation. Aerial photographs and satellite images suggested that anomalies of archaeological interest might be detected in both Transect K1 and Transect K2. However, only segments of linear net-negative anomalies, some possibly intersecting at a right angle but none obviously aligned with another, may be present. The segment of a wider, rather more plausible linear negative anomaly, running from north-northeast to south-southwest through the north end, represents a modern tractor path.

*Area M.* M1 was the first transect sampled in Area M and the only one in 2011 (Figure 32). It contains several curious anomalies, none of which, unfortunately, can be tied definitively to observed patterns or to the larger, previously identified Late Helladic drainage works. All but the northernmost three grid squares of the transect were sampled, there being a cotton crop in the way. The grid south end was characterized by gray silt topsoil with a relatively high incidence of limestone channers and cobbles, as well as some desiccation cracking. The magnetically negative burst of white at this end is due to the presence of a concrete pumphouse with steel machinery and plumbing, while the prominent magnetically negative linear anomaly flanked by narrower positive anomalies coincides with two deep furrows and a ridge between them marking a present field boundary (indicated also on the base map of Figure 35).

The biggest curiosity is the linear positive anomaly, preserved in segments at least, running from north-northwest to south-southeast before possibly turning southeastward and running parallel to the transect's edge. Despite the fact that it appears to lie under the magnetically negative modern ridge, the orientation of what may be its southern end, its general straightness, and its appearing not to be created by excavation of consecutive pits, as the peripheral canal detected in Transect C1 appears, suggest that it too is modern. There may be two intersecting mainly negative anomalies to the west of the ridge and underlying it, but the fact that one of these is roughly parallel to the positive anomaly of the ridge is cause to suspect modern origin.

*North Sector*

*Area A.* Geophysical sampling of Area A in 2010 could not include Transect A1 because the corner stakes had been destroyed by fire before magnetometry could take place. So the transect was revisited in 2011 (Figure 33). A1 was placed to capture any archaeologically relevant anomalies due north of Glas, though given the previous year's results from A2, the hope in 2011 was to detect further evidence consistent with paleochannels indicating water flowing past the north side of Glas at some point in its history.

What is immediately clear is that there are segments of varying length of somewhat meandering magnetically positive anomalies, which are faint variations of the irregular pattern associated with desiccation cracking in Transects J2, J3, and N2. (The large magnetic bipole and empty traverse intervals just left of center in Figure 33 represent a wooden pole supporting electrical lines.) What is fairly clear too is the linear magnetically negative anomaly, some three or four meters wide, running from north-northeast to south-southwest, only a few degrees off the cardinal, through the eastern corner of the transect. This response measures between 0.0 nT and –0.3 nT in strength. Adjoining its eastern edge may be a narrower positive anomaly. A perpendicular negative anomaly intersects it near the point at which it leaves the grid south edge of A1. Continuation of the larger anomaly to the north would, of course, intersect the Melas in its ancient channel, whereas continuation to the south would lead directly to the north scarp of Glas at its highest point, immediately below the north wing of the residential complex. Continuation of the narrower perpendicular would intersect the similarly narrow, roughly north–south linear bounding anomaly detected in Transect J1.

*Area B.* Transect B3 (Figure 34) was located as close as reasonably possible to Glas' north gate in the hope of intercepting any attendant features, including approaches from the Melas or AMP. It was also thought that more pit-like anomalies might be discovered, such as that from which the sole radiocarbon data of 2010 was obtained (see below). Instead, the outstanding feature of B3 is variegation of strong, closed-curve, magnetically positive anomalies surrounded by similarly shaped negative anomalies, especially in the southern end of the transect. (The two prominent bipolar responses in the south end probably signal buried standpipes.) Such a pattern of alternating positive and negative anomalies of this scale is consistent with undulations or unevenness of bedrock close to the surface. This geomorphic phenomenon may account also for magnetically positive anomalies of the same order of magnitude detected in 2010 in the southern end of Transect A2, within 90 meters of the grid north end of B3. Finally, there are a few relatively strong discrete positive responses, 0.8–2.5 nT in strength, that are consistent in nature and character with infilled pits or areas of intense burning. In any case, the surface of these spots was invisible under clover 20 to 40 centimeters high at the time of magnetometry.

A sample of the A4 horizon of soil core 2010B1-01, whence the radiocarbon date of calibrated BC 5480–5370 (± 2σ), was floated and wet-sieved to recover organic matter and further fragments of the highly decomposed ceramic it contained. Core 2010B1-01 was sunk into one of the pit-like anomalies in Transect B1, and the horizon in question appears to be a mixed fill.

*Area L.* This was a new area of investigation in 2011. Transect L1 (Figure 35) was intended to capture evidence of any feature midway between Glas and AMP, as well as anything of archaeological interest beneath the surface near the point at which the Late Helladic peripheral canal, identified by previous investigators and detected by AROURA in 2010, meets the Aghía Marína ridge. Unfortunately for this aim, only the grid northernmost bloc could be sampled with magnetometry in 2011 because of the presence of cotton plants in the remainder of the tract.

The only anomaly of certain interest in the sampled bloc is a subtle positive one running nearly due east–west across its middle, and between 0.0 and 0.25 nT in strength. There may be two short perpendicular positive anomalies running southward from this, near the center of the bloc, but their apparent alignment may be an artifact of data collection. The alignment of the sure east–west anomaly is reminiscent of the orientation of the post-1954 Greek irrigation canal rediscovered in Transects C1 and C2 in 2010, though it is not as strong. However, it falls nearly exactly where such a modern irrigation ditch is indicated on the Hellenic Military Geographical Service's 1:50,000-scale map of 1955 (Figure 36). Thus it may be a shallow trench that received one of the concrete irrigation channels with parabolic cross-section, whose ruins litter the plain, especially in the direction of AMP.

*East Sector*

*Area C.* Transect C3 was intended for the investigation of the base of the slope of Souvlí on the opposite side of the Late Helladic peripheral canal from most of the remainder of Area C. Significantly, the grid south end of Transect C2 had in 2010 exhibited clusters of pit-like anomalies, like those seen in Transect B1 and now possibly in B3. However, C3 could not be sampled in 2011—evidently a major year for cotton production.

The A2 horizon of soil core 2010C1-01, which represents a magnetic background area and possibly an old ground surface, and the A2 horizon of 2010C1-02, which may represent inwash to the nearby Mycenaean peripheral canal after its abandonment, were floated and sieved in 2011 for recovery and analysis principally of organic remains for environmental interpretation from 2011 to 2012.

*Possible quarries.* About 400 meters east of Transect C3, at the bottom of the Cretaceous limestone scarp above Souvlí that is the edge of the Kopaic graben, are several locales that German investigators tentatively identified in the 1980s as quarries that provided stone for Glas' walls. AROURA relocated three such hollowed-out places in 2011. Each one currently contains a private animal shed or small orchard, or both (e.g. Figure 37), so they could not be examined closely. They all appear to be quite plausible quarries, none being conformant in plan or elevation with the limestone's bedding. Macroscopically, the stone is identical to that used to build Glas' outer circuit wall. However, chemistry and microscopy may be needed to prove this observation.

*South Sector*

*Area D.* Samples from soil cores 2010D1-01 and 2010D1-02 were subjected to flotation and wet-sieving. They are thought to represent the subsoil (possibly an ancient surface) into which were inserted the retaining walls of the revetted canal running from Glas' eastern tip to the peripheral canal at Mt. Fteliá. It is hoped that the results of analysis of the recovered fraction can provide means of determining land use on each side of the canal in the Mycenaean Era.

*Area E.* Augering of two soil cores that was attempted but not completed in 2010 was finally accomplished in 2011: core 2011E2-01 and core 2011E2-02 (Figure 38). The first was removed from a magnetic background area in Transect E2, while the second was located above a narrow, linear, positive anomaly cutting through the transect, suggesting a ditch paralleling the revetted canal, which is to its south. The background area yielded a profile fairly typical of soils in the South Sector known from 2010's results: a dark grayish brown (10YR4/2) silt loam $A_p$ (c. 0–40 cm); a white (10YR8/1) silt loam E (c. 40–76 cm); and a mottled light brownish gray (10YR6/2) silt loam $B_{hk}$ (76+ cm). In contrast, the profile from above the anomaly possessed a dark grayish brown (10YR4/2) clay loam A2 horizon (c. 40–68 cm), mottled 30 percent with light brownish gray (10YR6/2) and containing at least 1 percent shell fragments. Below this were several heavily mottled light gray or yellowish B horizons (predominantly 2.5Y6/2, 6/3, 7/2). While the A2 horizon is shallow in comparison with the depth of stone wall courses in adjacent Area D (c. 50–65 cm), it could still be the fill of a narrow trench, perhaps a modern one parallel by very strange coincidence to the southbound revetted canal. Alternatively, though not especially plausibly, one of the upper mottled B horizons could be the cause of the positive anomaly.

*Vrýstika Katavóthra* (*Sinkhole*)

*Soil coring.* In 2011, for the first time, a core was taken of sediment at the entrance of the Vrýstika Katavóthra, one of the improved sinkholes through which the Kopaic Lake was drained in antiquity. The fieldwork of previous investigators has determined that, in different periods, the Mycenaean peripheral canal that runs east and south of Glas around Fteliá, and the Krates Canal, commissioned by Alexander the Great, emptied into this sinkhole. It was therefore targeted for augering, because it was thought to contain deeply stratified sediments bearing evidence of episodes of drainage and flooding.

The auger was sunk on fairly level ground outside the cavern entrance, where the ground begins naturally to sink (Figure 39). It is worth noting that there is evidence of heavy machinery having been used to move earth, stone, and remains of an abandoned concrete irrigation canal into the cave's entrance, and this activity may have removed some recently formed topsoil. The earth-moving was probably done to claim some adjacent land occupied by the irrigation channel for arboriculture.

Five horizons were identified, designated A1 through A5 in the field, all clay loam but the last, which was silt loam (Figure 40). Augering proceeded to a depth of 120 centimeters before a layer of impenetrable stone was encountered. The core was then shifted about 50 centimeters to the east, where, at the same depth, a difficult but penetrable layer of fine gravel was found. The final depth of augering was 267 centimeters, at which point two meter-long PVC trays had been filled and, besides, the soil's stickiness was making it intractable. Only the last of the defined horizons, A5, a mottled grayish brown (2.5Y5/2) sediment, shows any sign of subsoil formation processes.

Of special interest are several concentrations of gravel or horizon boundary features, or both, which may indicate hydrological changes in the vicinity of the Vrýstika Katavóthra over time. Found below 15 centimeters deep within the A1 horizon, as defined (0–70 cm), was fine, angular limestone gravel. As the stone does not appear to be water-washed, one might productively wonder if it is to be associated with the excavation of one of the major modern irrigation canals, after 1954, the nearest being about 60 meters to the southwest. At the top of A2 (c. 70–120 cm), within a few centimeters of the boundary with A1, is a concentration of strong brown (7.5YR5/8) material (about 10% of the matrix), with a texture like coarse sand. In the absence of chemical analysis, one might still plausibly suppose that this represents sesquioxide accumulation from leaching after the desiccation and subsequent rapid re-irrigation of the Basin's margin during execution the modern drainage program. Horizon A2 includes about 1 percent very fine sub-round limestone gravel and no more than 1 percent very find shell fragments, whereas underlying A3 (c. 120–195 cm) includes about 1 percent fine sub-round gravel and similar amount of very fine or fine shell fragments. While variations in sediment bedding or grading cannot be discerned given present equipment and procedures, horizons A2 and A3 together manifest an arrangement of inclusions that one would expect of a landscape flooded, if only intermittently. In the top 5 centimeters or so of horizon A4 (c. 195–230 cm), is a yellowish (2.5Y6/8, 7/3) concentration, perhaps 15 percent of the matrix, with the texture of fine sand. This may represent an episode of gradual or methodical drainage, though, needless to say, the date is uncertain. A4 contains an especially high incidence, about 2 percent, of fine to medium shell fragments, as well as some whitish concentrations that are probably decomposed shell. A sample of the underlying A5 horizon (230+ cm) was taken in the hope of obtaining a radiocarbon date from it that would provide a terminus post quem for it and the overlying horizons.

*Mycenaean guard post.* While removing the core from the entrance to the Vrýstika Katavóthra, the AROURA team visited the remains of what has been identified as a Mycenaean guard post some two hundred meters away (Figure 41), which is thought to protect the improved sinkhole, as well the route toward it and possibly onward to Glas, from the direction of Akraífnion (ancient Akraifia). The masonry is crude cyclopean. Its south wall and most of its east and west walls have been demolished since it was recorded in the 1880s, most likely to make way for modern agricultural outbuildings (Figure 42).

*Aghía Marína Pýrghos* (*AMP*)

*Intensive surface collection.* The whole of 30-meter grid square AMP2c2 was sampled intensively as described in "Methods and techniques" above. Approximately 825 separate objects were collected from the ground surface of this square alone after clearance of foliage. Estimated visibility within each 2-meter collection unit ranged from 10 to 90 percent, but the median value was 60 percent. Although a proper statistical study remains to be done, it appears already that the greatest visibility occurs around bedrock outcropping, animal burrows, and evergreen oak stands that have penetrated ruined wall foundations. The latter two categories also comprised the greatest quantity of Mycenaean pottery.

Finds' dates span the Mycenaean Era, if not also earlier, to the twentieth century CE. The overwhelming majority consisted of ceramic, either pottery sherds of various typological period or fragments of roof tile of various style. However, there are also a few flakes of dark brown chert and chunks of laterite that appear out of place, and what are likely shells of freshwater snails transported to the hill top. Medieval pottery wares associated with the ruins of the eponymous watchtower (πύργος) on the summit of AMP are probably represented by yellow-glazed earthenware. There are a few small sherds that may represent Early Geometric wares, such as have been previously attested at AMP (see Fossey 1988: 283–6). Most important for connecting AMP with Glas and the landscape around it are several sherds of Late Helladic IIIB2–C wares (S. Vitale, pers. Comm. 2011; Figures 43 and 44). These date the settlement there to the time of the building and inhabitation of Glas and the century immediately following its demise. The Mycenaean decorated sherds appear mainly to have been brought to the surface by animal burrowing and root action (see above), which implies that the settlement of the same date on the summit is largely preserved beneath the considerable medieval ruins (see below).

*Mapping and phasing.* As explained in the methodological section above, grid square AMP2c2 was mapped in detail (to about 20 cm), as sampling of rows of collection units was completed. The map (Figure 45) provides significant new information about the extant buildings on the summit of AMP. Several previously unmapped walls were discovered. All of these are clearly part of a system that runs parallel and perpendicular to the walls of the square-plan watchtower, and they have fragments of roof tile buried in their collapsed courses, reminiscent of those in the watchtower's walls. So it appears that the medieval fortification is rather greater than the tower and includes a perimeter wall enclosing at least half a hectare. One ramification of this realization is that the cists on the summit, long touted as Mycenaean, may well be medieval. Not only are they aligned with the walls (and oriented east–west), but one of the smallest cists, perhaps a child's grave, lies directly beneath the alignment of one of the walls, suggesting it was consciously so buried. Furthermore, up-cast Mycenaean pottery appears to come from levels underlying them.

Nevertheless, some Mycenaean architecture is evident on the summit, and it seems largely to be preserved beneath the remains of the medieval walls. Indeed, it appears that the medieval architects or engineers deliberately reused the cyclopean masonry as building foundation in long stretches. This observation too bodes well for good preservation of Late Helladic remains in situ.

*Character of fortifications.* There appear to be several cyclopean terrace walls below and around those mapped since Noack's visit in the late nineteenth century. There is a gateway about two meters wide between massive pseudo-ashlar jambs, in the innermost circuit wall (Figure 46). Spanning the interior of this wall are remains of several internal walls, in many places making use of the natural outcroppings of truncated limestone beds. From these may extend traces of tertiary walls. Cists some two meters wide, lined with large flat stones, abut the inner circuit wall.

The medieval fort surely incorporates some of the existing Mycenaean stone in its masonry. The collapsed tower's walls, as well as apparently sections of the walls attached to the fort, the latter extant only in their foundations, are of fairly typical later medieval, pre-Ottoman construction: roughly trimmed blocks and rubble, including some reused stone, with fragments of ceramic roof tile used to fill gaps and reinforce the cement (see Andrews 2006: 219–36). In terms of construction alone, the fortification is just possibly late Byzantine, but chances are that it dates to the time of one of the Duchies of Athens, i.e. from about 1205 to 1460 CE. Archival sources and epigraphy give us the names of the Burgundian (1205–1311) and Catalonian (1311–1388) lords of Kardhítsa (ancient Akraifia, modern Akraífnio), the nearest town at this time: Flamenc and Puigpardines, respectively (see Buchon 1845: 409; Rubió y Lluch 1907: 229, 231).

The fortification is apparently organized with the watchtower in the northwest corner, on a terrace with a retaining wall, although the west wall has yet to be discovered with certainty. A large concentration of broken roof tile, glazed pottery and other ceramic that may be medieval, and building stone, indicate that an interior structure, perhaps barracks, was built up against the south outer wall. The easiest approach is from the direction of the cyclopean gate, and so would have forced visitors past the south wall and around to the east, where a wide gateway is found (Figure 47), probably opening onto a yard and a path to the watchtower's door.

*Evidence of antiquities looting.* AROURA detected evidence of recent opportunistic attempts to dig into the ancient remains, including removed boulders, beneath which grass and weeds had hardly time to wilt (Figure 48). Local informants have told team members that Martíno is a major center of illegal antiquities looters, and Lárymna is its entrepôt, both less than 20 kilometers away. All the larger (c. 2-m long) cists on the hilltop (most of these in AMP2c2) appear to have been emptied in the distant past. All the above information was reported, along with photographic evidence, to the local antiquities wardens (αρχαιοφύλακες) and AROURA Collaborator Ms. A. Papadaki of the IX EPCA.

## Synthesis and Interpretations

In 2011, AROURA expanded on its results from 2010. More territory was subjected to magnetometry and further ground-truthing was carried out through soil augering. Given that no more than three persons were available at any time during the field campaign and that the gradiometer was effectively available for only eight of the twelve days of the rental period, because of a software–firmware incompatibility beyond the AROURA team's control, the project's productivity in these phases increased by about 50 percent in 2011 over 2010.

Especially with the additional technique of ditch section cleaning and profiling, the nature and character of the magnetic anomalies were more fully determined. It was discovered that the reticulate pattern of anomalies continued into Area N to the north, that it indeed seems to be bounded to the east by wider or narrower linear anomalies, and that several similar anomalies link the reticulate pattern to the west around the polder dike to Glas in the middle of the polder. The ditch profiles revealed that the magnetic negative anomalies that are the main constituent of both the reticulate and bounding features, as well as possibly lesser positive anomalies that sometimes parallel them, have distinctive correlates: the former correlates with a gray/white lens of generally firm silt loam, appearing to be re-deposited subsoil (lake mud), between about 2.0 and 2.5 meters in section, while the latter may correlate with a dark brownish sediment, possibly the fill of a parallel ditch. The soil cores are consistent and conformant with the stratigraphy of the ditch profiles. We can therefore confidently state that these cut–fill and built/laid features are causes of specific magnetic responses, and that the uncommon weakness of the anomalies is not due to the paucity of remains below the plow soil but rather to the rock substrate and to soil formation processes.

Soil augering was applied to good effect at the Vrýstika Katavóthra too. Sediments there are deeper than two and a half meters, and, judging from previous stratigraphies of the Kopaic Basin, probably continue downward another two or more meters. The core removed in 2011 exhibits a number of features that, without having been microscopically examined, are plausibly correlated with flooding and desiccation events, which, when dated, may be linked chronologically to Glas and the features in the Mycenaean polder.

At AMP, the state of preservation of remains dating to both medieval and Mycenaean eras, as well as probably to other periods, is very good. Indeed, with intensive surface collection of just one grid square at AMP, AROURA has determined that the medieval fort is greater in extent than previously realized, that it preserves remains contemporary with Glas in situ, and that the cists, presumably graves, recognized by archaeologists since the 1890s, are probably medieval rather than Mycenaean. Furthermore, Late Helladic pottery sherds indicate that the settlement persevered into the century following the final destruction of Glas, thus raising the question of how long the polder was maintained and persisted thereafter.

## Conclusions and Future Plans

The generally good state of preservation both on the plain inside the polder and on the summit of AMP means that the potential is great for important archaeological discovery providing answers to AROURA research questions and connecting Glas properly with its agricultural and settlement landscapes. Hence fieldwork employing the same methods and additional complementary methods is fully justified in 2012 and beyond.

Although AROURA has not positively dated any anomaly–feature in the polder to the Late Helladic, the circumstantial evidence for such a date is overwhelming. All previous research of the construction of the polder and cyclopean canalization of the rivers that flood the Kopais, including unpublished work of the Greek state's superintendencies, indicate that the mechanisms of drainage are contemporary with Glas (LH IIIB) if not somewhat earlier too. Efforts at drainage in Classical Antiquity appear to be largely restricted to the western side of the Kopaïs, around Khaironeia and Lebadeia, with the exception of the central Krates Canal, and they were short-lived. Reuse of Mycenaean dikes in the Roman Imperial Period, and possibly in the Archaic too, as argued by Jost Knauss and colleagues, seem to be restricted to the Bay of Akraifia, on the opposite side of Mt. Ptoön from Glas. Ottoman state-sponsored rice cultivation, possibly reusing Hadrianic mechanisms, appears also confined to the area around Lebadeia/Livadheiá; there is no rice harvest recorded for Topólia during this period (M. Kiel, pers. comm. 2011), and furthermore, the pattern of anomalies–features around the polder dike is inconsistent with the design of Ottoman rice paddies (Batakliev 1923: 150–4). Finally, there is absolutely nothing in the records of the modern French, British, and Greek drainage agencies that indicates or intimates that the features discovered are a result off their undertakings. AROURA continues to concentrate much of its energy on establishing an absolute chronology for these features.

—MFL

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