REPORT ON FOUR GRADIOMETER SURVEYS IN THE CHORA OF METAPONTO,

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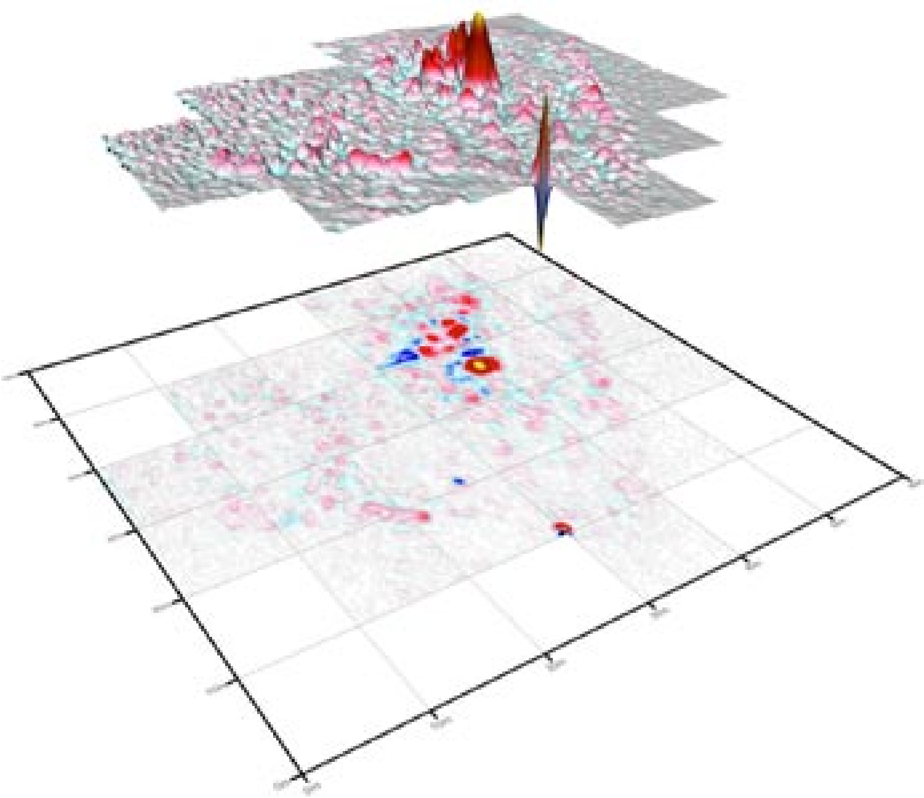

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*In August 2003, the Institute of Classical Archaeology (ICA) conducted four gradiometer surveys in the chora of Metaponto. The four areas included a large field below the ancient indigenous/colonial site of Incoronata which dates from the 8th to 6th centuries BC, one small area of Incoronata "*greca*" itself, a small but dense pottery/tile scatter northwest of Metaponto between the Basento and Bradano valleys (Site 327), and a large pottery/tile scatter to the southwest of Metaponto adjacent to a tributary of the Cavone River (Site 829).*

*Each survey revealed useful archaeological information. The field below Incoronata was found to contain at least two anomalies indicative of large oval pits, possibly burials. At Incoronata "*greca*," an intensive survey revealed the existence of small and large pits and perhaps the foundation of at least one circular structure. Site 327, a probable Greek farmhouse, contained a dense scatter of pottery dating from the 4th to 3rd centuries BC. The survey, however, revealed no subsurface linear features whatsoever, which leads us to conclude that repeated plowing has destroyed and scattered the foundations. An intensive survey of Site 829, a pottery/tile scatter of Classical and Hellenistic date, revealed a large rectilinear structure with internal rooms, likely a farmhouse, measuring approximately 40 meters by 25 meters. A large magnetic signature appears near the center of the surveyed area in what seems to have been a courtyard. Its size and dimensions strongly suggest the existence of a kiln, a view bolstered by the presence on the surface of abundant vitrified clay (ceramic slag), tile fragments, and a dense cluster of ceramic sherds. If it is a rural Greek farmhouse, as the evidence implies, it may be among the largest found to date in southern Italy.*

The report concludes that the soils of the Metapontino contain sufficient magnetic susceptibility, and known sites carry sufficient thermoremanent pottery and brick fragments to make magnetic survey techniques highly effective at elucidating subsurface structures. While the fluxgate gradiometer will not replace intensive field survey as the primary means of discovering isolated rural sites, it has proven itself very effective at producing useful information on known or highly suspected areas. It will prove a useful tool for future surveys in the Metapontino.

1. INTRODUCTION[1]

The chora of Metaponto (or Metapontino), comprising some 400 km^2, has been the scene of intensive and innovative archaeological field surveys over the past two decades (1981-present). These surveys have revealed a rich archaeological territory: nearly a thousand sites of archaeological interest have been identified and recorded, a significant portion of which have been excavated and published.[2] These include indigenous settlements, colonial farmhouses, necropoleis, roads, rural sanctuaries, springs, Roman villas, and kiln sites. Indeed the ancient city and its territory have a legacy of archaeological experimentation. Field survey techniques were pioneered here, revealing a wealth of information about a colonial polis' rural hinterland heretofore unknown and understudied. The use of aerial photography to expose ancient territorial "division lines" and other archaeological features had some of its beginnings in the Metapontino.[3] And the field of geophysical prospection was initiated here as well. In the 1970s, the Lerici Foundation in Rome pioneered a new type of remote sensing using a magnetometer, revealing the Hippodamian street plan of the ancient city without turning a spade. Their success here and at Sybaris laid the groundwork for future geophysical work on archaeological sites around the world.[4] Today, magnetic methods are the mainstay of archaeological prospection.

The wealth of sites in the Metapontino presents an attractive prospect for employing modern geophysical survey techniques. During thirteen working days between August 4 and 20, 2003, the Institute of Classical Archaeology (ICA) conducted archaeological prospection surveys of four areas utilizing a fluxgate gradiometer (Fig 1). The aim of these surveys was twofold: (1) to test the soils of the chora to determine their magnetic susceptibility and hence suitability for magnetic survey, and (2) to apply magnetic survey techniques to known and suspected sites, particularly those known only by their telltale signature, the surface artifact scatter. The four areas included

1. **Incoronata Viggiano**: A large field below the ancient indigenous/colonial site of Incoronata which dates from the 8th to 6th centuries BC;
2. **Incoronata "*greca*"**: The northeast spur;
3. **Site 327**: A small but dense pottery/tile scatter dating to the 4th and 3rd centuries BC located northwest of Metaponto between the Basento and Bradano valleys; and
4. **Site 829**: A large pottery/tile scatter of Classical and Hellenistic date located southwest of Metaponto and adjacent to a tributary of the Cavone River.

[1] The authors would like to thank Dr. Rosetta Torraco, Administrator of ICA's Centro di Agroarcheologia at Metaponto, who made our stay at Pantanello most pleasant; Drs. Cesare Raho and Eloisa Vittoria for the pleasant company and wonderful dinners; Dr. Antonio De Siena, director of the National Archaeological Museum at Metaponto; and the helpful staff at Azienda Pantanello.
[2] The standard publication format for ICA's annual field survey is its Annual Report (1974 to present). The surveys have resulted in other publications too numerous to list here. For a sample, however, see Carter 1990a, 1990b, 1993, and 1995.
[3] Adamesteanu 1973.
[4] Linington 1972-1973.

Before detailing the methodology and results of the survey, let us take a brief look at the various techniques of archaeological prospection and geophysics.

2. GEOPHYSICS AND ARCHAEOLOGICAL PROSPECTION

There are a variety of remote-sensing methods available to archaeology today to aid in detecting buried features. Magnetometers and their offshoot, gradiometers, measure local disturbances in the earth's magnetic field caused by the presence of ferromagnetic materials. Ground-penetrating radars (GPR) fire waves of electromagnetic energy into the ground and measure reflections of differential densities. Soil resistivity methods detect changes in soil porosity.[5] The advantage of all three lies in their ability to provide multidimensional images of buried features without the need for arduous exploratory digging. The resolution of these images is determined by a number of factors, such as sampling rate and accuracy, soil density and composition, and the degree of operator error. These instruments are becoming increasingly affordable, and their software more powerful and accessible, to those at the operator level. Their utility lies in the speed with which a small team can collect enormous amounts of data in a short period of time. Data processing often takes place on site, thereby allowing the team to direct their survey energies toward the most promising areas with little wasted time.

Of these three instruments, the gradiometer is the most widely used instrument for archaeological remote sensing. Gradiometers were first introduced in the 1950s and were improved substantially over the following two decades.[6] Among the first to use magnetic methods in Italy, as mentioned above, was R.E. Linington of the Archaeological Prospecting Section of the Lerici Foundation (*Sezione Prospezioni Archeologiche della Fondazione M.M. Lerice del Politecnico di Milano*). Building on successful prospecting work of Lerici's team at Sybaris,[7] Linington conducted a large-area proton magnetometer survey of Metaponto (1968 to 1971) and revealed the Hippodamian street plan, temples, kilns, and agora of the city.[8] The quality of survey work at both Sybaris and Metaponto, and the sheer amount of interpretive data, set the standard for all future magnetic surveys. The Lerici Foundation has left a great legacy of archaeological prospection that continues today in the very region where it all started.

In general, the gradiometer consists of two vertically-aligned sensors and a small onboard computer for collecting readings. As the surveyor walks a pre-established grid, the sensors constantly measure the Earth's magnetic field in units known as nanoTeslas (nT).[9] Subsequent postprocessing of the data reveals fluctuations in the field caused by subsurface features. These fluctuations have three main causes, the first and foremost of which is the presence of objects manufactured from iron. On Iron Age sites, for example,

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[5] The most comprehensive treatment on archaeological prospection is Clarke 1996; see his bibliography there for additional information on various techniques. On GPR, see Conyers and Goodwin 1997. A more summary but up-to-date treatment is Garrison 2003.
[6] See English Heritage 1995; Clarke 1996, 16-26.
[7] Rainey and Lerici 1967; Rainey 1969.
[8] See above, n. 4.
[9] The nanoTesla, referred to in the field as a "gamma," is equivalent to 0.002 percent of the Earth's total field strength of 50,000 nT.

these objects include, among other things, iron weaponry, armor, and jewelry. Burials containing such objects stand out quite prominently on gradiometer maps.

The second source of fluctuation is the presence of thermally-altered materials such as ceramics, bricks, and hearths. A reducing environment causes iron oxides (magnetite, maghemite, and hematite) to form from very small ferrous inclusions in the original clays;[10] the conversion takes place upon cooling, a process known as thermoremanence. Surface pottery scatters, for example, often appear as elevated background "noise" on a gradiometer map (see especially Fig. 7); the fields of individual sherds and fragments, randomly scattered as they are, produce little net effect.[11] Kiln bricks, because of their numerous, intense firings and concentrated iron oxides, retain enormous amounts of thermoremanence and are usually the "loudest" of all materials detected in gradiometer surveys (see Fig. 10).

The third source of fluctuation derives from ferri- and ferromagnetic minerals present in soils.[12] In the presence of a magnetic field (such as the Earth's), these minerals induce their own individual fields, which, like thermoremanent materials, appear as a low background, or ambient, "noise" on gradiometer surveys. A soil's susceptibility to magnetization varies from region to region, depending on the amount of magnetic material it contains. Human alterations of these soils appear as interruptions in the ambient field—the primary phenomenon by which the detection of subsurface features takes place. These alterations include soils compacted by human use (i.e. roads, well-traveled foot paths) and pits/ditches dug out and subsequently backfilled. The latter applies to earth removed for structural foundations, drainage canals, and pits (burials, rubbish dumps, sewage pits, etc.). Building stones, particularly limestone, are generally magnetically neutral, and therefore appear as useful intrusions—or discontinuities—in gradiometer data. Add to these causes such variables as operator error, local geological intrusions (such as igneous rock), and the occasional solar flare, and it becomes obvious that the interpretation of gradiometer data must be an informed process.

3. SURVEY DESIGN AND METHODOLOGY

The 2003 gradiometer survey team had two goals in mind at the outset. The first was to test the soils of the Metapontino to determine their magnetic susceptibility, and hence their suitability for gradiometric surveys.[13] Once that determination was made, the second goal was to conduct gradiometer surveys on three types of sites to determine effectiveness:

[10] van Klinken 2001, 50-51. When these inclusions magnetize, they orient themselves to the local magnetic field and, upon cessation of their use, remain so oriented. Studies, such as Reinders et al. 1999, have determined that it is possible to match these orientations (in terms of inclination and declination) against a chronological curve of the palaeofield, thus providing a date of their final use.

[11] Clarke 1996, 65.

[12] Garrison 2003, 69-70.

[13] Linington's magnetometer survey (1972-1973) demonstrated that the soils of the lower alluvial plain were appropriate for such work. Our survey areas ranged from valley floors to upland marine terraces, in other words, areas more prone to natural geological intrusions. Hence the need for testing.

- Areas near ancient sites with suspected subsurface features (sampling survey)
- Ancient sites with known subsurface features (intensive gradiometer survey)
- Pottery scatters which presuppose subsurface features (intensive gradiometer survey)

Incoronata Viggiano fulfilled the first type-site listed above. This large, uncultivated field in the lower Basento Valley included a light scatter of ceramics associated with Incoronata "*greca*," which is located a short distance to the south.

Incoronata "*greca*" fulfilled the second type-site. This combined indigenous and colonial settlement dates from the 8th to 6th centuries BC. and is located on a coastal terrace directly overlooking the Basento valley. The site was only partially excavated in the 1970s and 1980s, thus leaving large tracts unexplored. We surveyed the entire northeastern spur with the intent to detect subsurface features that may have been missed by the excavators.

Sites 327 and 829 fulfilled the third category. Site 327, a small and dense ceramic and tile scatter dating to the 4th-3rd centuries BC, is located between the Bradano and Basento River valleys. Site 829, a large and dense ceramic and tile scatter of Classical and Hellenistic date, is located on a minor tributary stream of the Cavone River, some 12 km southwest of Metaponto. Both scatters initially presupposed subsurface features.

The surveys were conducted using an FM36 fluxgate gradiometer manufactured by Geoscan Research. Grid lines were established using standard meter tapes, a theodolyte, and stadia rod. Cardinal north was sighted with a standard field/orienteering compass. The grids for Incoronata Viggiano measured 20 x 20 m, with a sampling rate of 0.5 m (2 samples/meter). Traverse lines were spaced 1.0 m apart. This larger grid spacing and sampling rate were tailored for large-scale gradiometer prospecting. The remaining sites called for a more intensive survey sampling to achieve greater image resolution. These grids measured 10 x 5 m, with a sampling rate of 0.25 m. Traverse lines were spaced 0.5 m apart, which gave 8 samples/meter. All grids for the 2003 survey were measured on the 0.1 nT sensitivity setting. Diurnal variations were not recorded.[14] Further survey specifications can be found in the Appendix.

Data processing took place twice per day, once during the lunch break and again in early evening. GeoPlot software (version 3.00), supplied by Geoscan Research, receives the downloaded data from the gradiometer and displays it in several ways: shaded relief plot, trace plot, dot-density plot, and statistics. There are several mathematic functions that aid in filtering, or smoothing, erroneous data in the site's composite map. These include despike, low-pass filter, destagger, zero mean traverse, and interpolation, all of which were used. Once the site's composite map is smoothed for display in GeoPlot, it may be exported as a Surfer Binary file. Upon importation into Golden Software's Surfer (version 8.0), a powerful mapping program with excellent visual display modes, the images can be further processed and refined for interpretation. All gradiometer maps in this report were published in Surfer.

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[14] We did not record diurnal fluctuations in the local magnetic field for three reasons: we did not have a diurnal sensor or magnetometer to do so; using the gradiometer (or dual sensor) method, as opposed to the total field method (with one sensor), did not call for it; and we logged zero drift at the beginning and end of each grid at a predetermined area relatively free of magnetic noise. This latter step ensured a zero basis for each grid and thus the same baseline for detecting all features.

The final step in data processing was to geo-reference the gradiometer display maps produced in Surfer. During the survey, the coordinates of the corners of each grid were recorded with a Trimble GeoExplorer XT GPS receiver, using the UTM coordinate system on the WGS84 datum. These coordinates were then differentially postprocessed using data recorded by a dedicated GPS base-station in Matera (45 km to the NW) participating in the EUREF GPS array (station code "mate"), downloaded from the Internet archive of the Scripps Orbit and Permanent Array Center (SOPAC) at the University of California at San Diego (http://sopac.ucsd.edu/), giving the coordinates an ultimate average horizontal accuracy of 40-60 cm. (The average uncorrected horizontal GPS error at the time of the survey was ca. 10 m.) The gradiometer display maps were georeferenced by assigning the corrected coordinates of the corner points to the map-corners in RSI's ENVI remote sensing software package (version 3.6). The georeferenced images were then displayed over aerial photographs of the area in ESRI's ArcGIS software package (version 8.3) for presentation.

4. RESULTS AND INTERPRETATION

4.1 Incoronata Viggiano

Incoronata Viggiano was the first of the four surveys conducted. This large field, 200 x 100 m in dimension, lies on the southwestern edge of the lower Basento valley. It is fenced in on the east by a grove of orange trees, on the west by a row of utility poles carrying electrical lines (a source of interference for the gradiometer), on the north by an irrigation canal and cement bridge, and on the south by two abandoned machinery buildings. Just south of these buildings lies the modern road, and just beyond that the hill-top site of Incoronata "*greca*." The proximity of the uncultivated field to the ancient site, as well as a light scatter of associated pottery on the field's surface, suggested to us that there may be associated buried remains (Fig. 2). The large size of the survey area mandated a large grid dimension and a widely spaced sample interval.[15] Thus, surveying south to north using west-to-east traverses on 20 m x 20 m grids, we widened our swath from 40 m to 100 m, at which point we switched to sampling every other series of east-west grids. In this manner we surveyed three additional 100 x 20 m swaths proceeding northward and covered two hectares in four days.

A number of anomalies were detected, none of which were visible on the surface (Fig. 3). The numerous small but intense spikes (±5 to ±40 nT) may be assumed to be of modern origin, likely tools or machinery parts associated with the nearby machinery storage buildings; their signal shapes and intensities indicate that they lie close to the surface. (A small screwdriver, for instance, can register as a 5 nT "hit" from only a few centimeters beneath the soil.) The reader will notice that the intensity of these sharp spikes diminishes with distance proceeding northward away from the buildings. One enormous monopole anomaly in the center of the survey area measured well over 207 nT; its reading was truncated because the instrument surpassed its ability to measure above

[15] On large-scale fluxgate gradiometry and its associated problems, see Gaffney et al. 2000.

that reading on the most sensitive setting. It, too, is most likely of recent origin and buried just below the surface.

Only two pit-like anomalies warrant further comment. The first, an oblong anomaly of +12 nT, is in the lower right hand corner. The second anomaly, located in the upper right quadrant of the survey area, is a larger version of the first, but is somewhat weaker at only +7 nT. The actual physical dimensions of these anomalies may be deduced from the "full-width half-max" rule, whereby "the width of the response peak at half the maximum signal is equal to the width of the buried feature, or its depth if this is greater."[16] The results are 2.0 x 3.5 m for the first anomaly, and 2.5 x 6.0 m for the second. These anomalies represent the classic magnetic signature of ovoid/rectangular pits. Could they be cist graves or open inhumations? While it is tempting to speculate, their relative isolation is not easily explained, especially since Incoronata's necropolis was located on a plateau more than a kilometer to the west. However, a small plot of indigenous burials postdating the 8th century BC were excavated just to the northeast of Incoronata "*greca*," between the slopes of the plateau and the modern road.[17] If excavation reveals that they are indeed graves, then a more intensive magnetometer survey would be warranted for this field and adjacent areas.

4.2 Incoronata "*greca*"

Incoronata "*greca*" was a combined indigenous and colonial Greek settlement dating from the 8th to 6th centuries BC. Italian excavations began under D. Adamesteanu in 1971 and continued for over two decades under Orlandini of Milan University.[18] Both concentrated on the northwestern spur and the necropolis to the west. In 1977-1978, a team from the University of Texas excavated several trenches on the southeast spur.[19] Both teams uncovered numerous pits containing indigenous, colonial, or mixed deposits of 8th- and 7th-century date, the largest of which (B and D) were found on the southeast spur (Figures 4 and 5). They were less than 0.60 m deep and measured some 5.0 m in diameter on the long axis.[20] A rectangular socle/mud-brick structure (5.0 x 2.5 m) was also uncovered, as well as the remains of a small sanctuary dating to the first half of the 6th century BC.[21] Nearby, however, on the flat-topped northeastern spur overlooking the Basento valley itself, only one excavated trench is recorded, though there are several test trenches and spoil mounds present today. Since the area was a likely candidate for ancient subsurface features, we spent three days surveying here. We established a series of E/W and N/S grids encompassing 2,650 m^2 that conformed to the edges of the spur.

Due to the intensive sampling rate (8 samples/meter), modern surface features appear in sharp focus: deep wheel tracks on the surface, apparently from a large tractor, appear on the gradiometer map and demonstrate the instrument's sensitivity (Figures 6

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16 Clarke 1996, 91.
17 Carter (forthcoming).
18 Adamesteanu 1971, 18-20. The site's excavation reports are published in a multi-volume series (1991-2003, 6 volumes to date) under the name *Ricerche Archeologiche all'Incoronata di Metaponto*.
19 Carter 1978; 1993.
20 Carter (forthcoming).
21 Carter 1978, 401, Pl. 36, 1.

and 7). The shallow trench and spoil mound from earlier exploration appears as well. These were the only surface features visible on the site.

The instrument's ability to detect subsurface features, on the other hand, was hindered by a high signal-to-noise ratio caused by the high density of ceramics on the surface. In this case, the pottery noise was on the order of ±2-3 nT. Thus, weaker features were lost in this 4-6 nT shadow, leaving only features greater than ±2-3 nT to stand out.

The highest spike, a bipolar anomaly of (+33/-45 nT), occurred in the southwest corner at (A) and may be associated with a weaker, though spatially larger, anomaly of +9 nT at (B), which is roughly 2.0 x 1.5 m in dimension. Just to the west we detected a +5 nT anomaly at (C) and an +11 nT anomaly at (D), both of similar shape. It is difficult to determine whether these are associated with (A) and (B). However, the signatures of B-D suggest pits that were subsequently backfilled. Similar signatures appear in the northernmost grid at (E)(+6 nT) and just to the south at (F)(+11 nT). These pits are likely similar to those excavated by both the Milan and Texas teams. They have been variously interpreted as rubbish/ceramic deposits, basements of elevated huts, and hut foundations.

The cluster of anomalies at (G) in the top center represent an exploratory trench and its spoil mound, still well-defined after at least a decade. Just to the east of the trench at (H) is a cluster of anomalies, the largest of which is +23 nT. Its intensity, and the fact that it is surrounded by lesser, negative values, hint at the presence of a ferrous object or objects. This is also the case with regard to the anomalies just to the east, though of lesser intensity (ca. +8 nT). Pit B on the SE spur, for example, contained a host of ceramics and several iron objects such as a small sickle, a projectile point, and a spear head. While the magnetic signature of any one of these, *per se*, would be quite small, when combined and placed in a pit, all these elements combined would give off a comparably strong signal, and perhaps that is what we see here around (H) and its anomalous neighbor to the east.

The intense signature of (I) on the wheel tracks, a +25 nT anomaly, may represent an actual artifact. However, its tight signal, isolated as it is, is more likely indicative of a modern ferrous object, a hammer or tape-reel perhaps, unknowingly buried (or run over) during the original field work.

In addition to these isolated and semi-isolated anomalies, there are also several quite weak linear anomalies – weak enough to warrant extreme caution in interpretation. The first is an apparent elliptical structure at (J). It measures between 6.0 m and 8.0 m in diameter and is coherent over 60% of its circumference. Signal values of the ellipse's interior were not sufficient to overcome the ceramic noise of the site. It is worthy of further investigation. Another apparently linear feature, though quite less articulated, is found at (K), again elliptical in shape and measuring approximately 8 or 9 meters in diameter. Unfortunately, these anomalies, in addition to the faintest hints of rectilinear structures in the center of the site, are too weak to describe with any confidence. Until trial excavations are performed, they must remain enigmatic.

4.3 Site 327

Site 327 is a small pottery/tile scatter located in the fertile uplands between the Basento and Bradano River valleys, some 6 km WNW of Metaponto. The ceramics date from the 4th to 3rd centuries BC, roughly contemporary to the 4th-century BC farmhouse site at

Ponte Fabrizio some 500 m to the north.[22] Site 327 was first detected and recorded during field survey in 1982 and then re-surveyed in 2001. (The field was in an uncultivated state during the gradiometer survey.) The actual number of ceramics visible on the surface declined by nearly 44% (from 94 to 53) in the intervening 19 years. Adjacent fields had recently been plowed, which goes a long way toward explaining the marked decrease in visible evidence. Our expectations of finding buried structures were not optimistic. This was to prove realistic in post-processing.

Figure 8 shows the intense signal of a steel irrigation pipe that cuts WNW to ESE across the northern end of the site, as well as the dirt road it parallels to the south. Ceramic noise throughout the survey area was quite light, on the order of ±1 to 1.5 nT. Above these values only three tight clusters stand out, ranging from +1 to +11 nT. Two of these clusters (*a* and *b*) lie under the dirt road. The third cluster (*c*) is centered on the primary concentration of surface ceramics. The only linear features detected correspond exactly to the axes of ploughed furrows (10-15 cm deep). Two reasons may be posited to explain the data. First, the ceramics were part of a dump associated with a nearby settlement (five other contemporary pottery scatters are located within 350 m of the site). Second, whatever structures existed here, whether of wood or stone, have been mixed up and scattered by plowing. The survey was discontinued after one day of work.

4.4 Site 829 (near Castello S. Basilio)

Site 829, located during the 2001 field survey, is a surface scatter site lying about 12 kilometers southwest of Metaponto along a tributary of the Cavone River. In addition to the surface ceramics of Classical and Hellenistic date, the site is littered with small and large river cobbles, large tile fragments, and large lumps of vitrified clay (ceramic slag) (Fig. 9). The field (once again sown in summer wheat this year, harvested before the survey) is defined on the east and north by steep slopes ascending to Pleistocene marine terraces; on the east side there is also a small stream fed by an irrigation pumping station on the terrace above. The field widens slightly to the north/northwest of the site and continues in that direction down the valley for several kilometers. The nearby terraces are composed primarily of clay deposits. The slope is estimated to be approximately between 30:1 and 35:1.

As with Incoronata “*greca*” and Site 327, we used a very high sampling rate (8 samples/meter) to achieve resolution sufficient for detecting buried structural traces. Unlike Site 327, however, we were not disappointed. The first five grids surveyed revealed two linear anomalies oriented at right angles to each other (298° and 028°). Over the next two days (the last scheduled days of the season), we widened our survey area to 60 m x 60 m to reveal a large rectangular structure (Figures 10 and 11). Its long axis (oriented at 028°) is approximately 40 m, its short axis 27 m. Area A (27 x 18 m) is defined on the northwest and southeast by thick foundations of at least 0.50 meters. The southwest foundation is not wholly articulated, and may never have been contiguous. The immense size of this enclosure (486 m^2), with interior walls apparent only near the southeast foundation, makes interpretation difficult, as does the site’s ceramic noise,

[22] On this farmhouse, see Carter 1990a, fig. 5.

which averages ±2 to 3 nT. If it was a roofed structure, the space would certainly have been subdivided further in order to support the roof, which was apparently tiled judging from surface finds; perhaps the interior wall foundations have since disappeared. If it was an enclosure, say for animals or horticulture, then Area B may be assumed to be the actual domestic structure.

Area B is defined by the extension of Area A's southeast foundation and what appears to be another foundation (a weak linear anomaly) separating it from the "courtyard." This corridor space is 7 x 23 m (161 m^2) and may have been subdivided; traces of foundations perpendicular to the outer, SE wall are difficult to distinguish from the background noise.

Area C, the "courtyard," so named because it appears to be bordered on three sides by well-defined spaces, measures 15 x 22 m (330 m^2). It contains a host of intense anomalies and ceramic noise. The largest is +81/-32 nT, with lesser bipolar anomalies stretching northeastward along the main axis of the structure; these range from +46 to 24 nT. By virtue of the number of surface ceramics concentrated in this area, as well as tile fragments and highly-magnetic lumps of vitrified clay, we may tentatively identify the largest hit as a kiln. Its neighboring anomalies may be smaller kilns or concentrations of ceramic debris such as kiln wasters.

Kilns, as mentioned above, register intense magnetic signals due to the thermoremanence of their bricks/ceramics. Here we may speculate briefly on the estimated depth below the surface and the size of this hypothetical kiln. As a rule, the strength of an anomaly falls off inversely to the cube of its depth below the sensor.[23] (For *linear* features, signal strength falls off inversely to the *square* of its depth below the sensor.) As kilns in Britain, for example, average about 130 nT at 1 m below the sensor, we may tentatively state that our kiln is between 0.5 and 1.5 m below the surface, certainly no deeper. In other words, if our +81 nT kiln were exactly 1 m below the sensor (that is, about 0.70 m below the surface assuming, reasonably, an average sensor height of 0.30 m), then at 2 m (or 1.70 m) down it would measure only 3 nT. Thus a mid-range number is a safe, though of course highly speculative, estimate and based solely on average kiln signal intensities.

The physical dimensions of an anomaly may be deduced from the "full-width half-max" rule, used above (p. 9). The width of the kiln spike is approximately 4.4 meters, which makes the actual width of the kiln approximately 2.2 meters; its depth is certainly not greater, as we saw above.

Area D on the northwest side of the "courtyard" appears to have some communication with Area A. The relationship is not at all clear, however. Likewise with Area E, whose western border fades into the field of pottery noise.

The intense ±112 nT anomaly south of the southern "wall" may be explained as a buried modern ferrous object. However, the –23 nT hit in the bottom center of Area A may be contemporaneous with the site, perhaps a buried pithos, ceramic deposit, or iron object.

[23] Clarke 1996, 78: Desvignes et al. 1999.

Historical Context of Site 829

The resolution of Site 829's gradiometer image is sufficient to make some preliminary observations and to fit it into the historical context of other farmhouses, both within the chora and at other Greek sites of the Classical and Hellenistic periods. It must be stated at the outset, however, that excavation is needed to ground-truth the tentative plan in Figure 11: gradiometers cannot distinguish stratigraphical layers or diachronic construction, nor can they detect mud-brick walls.

The first aspect to point out is the immense size of the site:

Area A:	486 m^2
Area B:	161 m^2
Area C:	330 m^2
Total:	**977 m^2**

Within the chora of Metaponto, this is certainly the largest rural site documented. Throughout the Mediterranean of the Classical and Hellenistic periods, it numbers among the largest. Heretofore, the largest farmhouse of 4th-century BC date in the chora was excavated at Fattoria Stefan (Fig. 12).[24] This farmhouse occupies some 192 m^2 and could easily fit within Area A on our plan. It shares nearly the same axis as Site 829. If we range farther afield in time for comparanda, we find a late Hellenistic farmhouse at Sant' Angelo Nuovo, a *pastas* (or corridor) house measuring 11.9 x 22.5 m (268 m^2), and a 4th-century AD Roman rural dwelling at San Biagio, which measures 17.7 x 17.7 (313 m^2).[25] The only rural structure in the area that approaches the size of Site 829 is the Roman villa at Termitito.[26] It dates from the Late Republican period to the 4th century AD and measures 30 x 40 m, an estimated 1,200 m^2.

Only in Sicily and on the Greek mainland do we find contemporary houses of comparable size. Two colonial Greek houses at Camarina, "Jurato" and "Capodicasa," both dating to the 5th century BC, enclose 600 m^2 and 437 m^2 respectively.[27] Like Site 829, their large courtyards are located on the northern side. Two large Classical farmhouses with towers were surveyed at Palaia Kopraisia in southern Attica by Lohmann. The first (LE 16) measured ca. 40 x 30 m, the area of its enclosure totaling some 1,200 m^2.[28] The courtyard (ca. 12 x 15 m, or 180 m^2), appears to have been open to the west. No kiln was reported. The second farmhouse (LE 17), situated on a knoll about 160 m to the southeast of LE 16, measured some 35 x 20 m (700 m^2), including its westward-facing courtyard. It, too, revealed no evidence of a kiln.

Within the chora of Metaponto, there are a number of farmhouse sites with associated kilns. The farmhouse at Termitito had one nearby, as did the 6th-century BC farmhouse at Cugno del Pero and the indigenous settlement at Tolve.[29] A kiln was

[24] Adamesteanu 1973, 59, fig. 3; Carter 1998, fig. 1.14.
[25] On Sant-Angelo Nuovo, see Carter 1983 and 1994, 180, figs. 12-13; on San Biagio, see Carter 1980, 22, fig. 22.
[26] De Siena and Giardino 1994, fig. 7.
[27] Pelagatti 1980-1981, 723-29, figs. 163, 168.
[28] Lohmann 1992, fig. 15.
[29] Termitito: De Siena 1996, 172, 720; Cugno del Pero: Adamesteanu 1974, 83; Tolve: Russo 1996.

discovered near the farmhouse at Sant'Angelo Vecchio,[30] and a tile kiln appears to have served several farmhouses in the neighborhood of the *pastas* house at Sant'Angelo Nuovo.[31] The large 4th-century BC farmhouse at Cappa d'Amore (unpublished) had a well-preserved kiln located some 30 m away (Fig. 13).[32] It is of the cylindrical updraft type, a regular shape for ancient Greek kilns.[33] It is approximately 4 m in outside diameter, its stoking tunnel some 2 m in length.

To our knowledge, however, none of these cited examples of farmhouses included a kiln placed *within* the enclosure. This seems to make sense: kiln fires burn above 900 degrees centigrade—dangers from heat and embers come immediately to mind. However, ethnographic research in Moknine, Tunisia, for example, has shown that kilns are often placed within houses.[34] Nevertheless, we should not discount the hypothesis that Site 829 was a ceramic production center, a rural industrial site, especially when we consider the convenience and close proximity of water and clay beds. Also, in terms of surface artifact count and scatter area it numbers in the top 30 of over 800 surveyed sites within the chora. While this idea does not agree with the surface finds that suggest domestic habitation—loom weights and cooking wares, among other things—this does not mean that the site did not change hands or function over the course of its lifetime. So, to summarize, whether Site 829's kiln was designed for domestic use or commercial production, or both, remains unknown – and unknowable – at present.[35] These preliminary observations demonstrate that Site 829 is exceptional in terms of size and archaeological potential. It certainly warrants further investigation.

Observations on Pottery Scatters

Site 829, discovered at the very end of the 2001 field survey season, was density-mapped and sampled for diagnostic artifacts as part of the regular survey methodology employed that season. The site was walked at 10 x 10 m intervals for the mapping exercise, with maximum counts reaching 300 artifacts in a given 10 m segment; diagnostic artifact sampling was performed at 3 m intervals, producing a total of 67 artifacts. (Following the gradiometer survey, in late August 2003 the site was revisited and intensively sampled at 1 m intervals, producing 196 diagnostic artifacts.) The artifact density map showed two peaks, spaced approximately 25 m apart. Display of the gradiometer image over the georeferenced artifact density map demonstrates that the two peaks of artifact density correspond nicely to the "Courtyard"/"kiln" area and the area west of the structure where much pottery noise appears (Fig. 14). We may conclude that, at this site in any event, there was very little horizontal movement of pottery between the initial discovery and this year's gradiometer survey, despite the (presumably two) intervening seasons of plowing and cereal cultivation.

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30 Edlund 1981.
31 See above, n. 25.
32 Adamesteanu 1974, 86.
33 Sparkes 1991, 23, fig. II.8; see Cuomo di Caprio 1992 for an excellent, up-to-date study on Hellenistic kilns at Morgantina in central Italy.
34 Dr. Eleni Hasaki (pers. comm.).
35 According to Dr. Hasaki (pers. comm..), Site 829's kiln, if indeed it is ca. 2.2 m in diameter, would be somewhat large for exclusively domestic use.

The close physical correspondence between artifact densities and architectural remains suggests that the degradation of Site 829 has only recently begun, an impression reinforced by the sheer mass of artifacts visible on the surface and the presence among them of numerous large stones typically used in the foundations of Greek farmhouses. The preservation of the site was presumably guaranteed by the relatively shallow (ca. 40 cm maximum) cereal cultivation that appears to have been practiced in this particular plot for many seasons. Site 829 is obviously in imminent danger of complete architectural destruction, however, and the cause of this must be sought in either at least one previous, more invasive plowing event (wheat may be a recent introduction to this field) or extensive erosion of the field-surface due to accumulated plowing events, which have lowered the surface to the tops of the foundation-walls. (Sites in the Metapontino are typically buried beneath 50-100 cm of accumulated soil; accumulated soil depth in a stream valley, as is the case with Site 829, is generally even greater.)

Site 327 offers a striking contrast to Site 829, and perhaps a prediction of the latter's eventual fate. When first documented during the 1982 field survey season, Site 327 was characterized by an "extremely heavy" surface artifact scatter over an area of ca. 40 x 30 m and the abundant presence of foundation stones – signs of a relative "fresh kill," as Site 829. When it was revisited in 2001, Site 327 was characterized by only a "heavy" surface artifact scatter covering an area of ca. 70 x 50 m – more than twice the original area – and no foundation stones were visible in the immediate vicinity (indicating that they had been collected and removed by the owner). Thus the site has been spread and diluted by 20 years of plowing (and perhaps other mechanical activities), and the 2003 gradiometer survey shows that the site has been completely erased at an architectural level. Such may be the fate of Site 829 unless the decision is made to excavate and document it to preserve a record of its potentially extraordinary features.

5. CONCLUSIONS AND RECOMMENDATIONS

The four gradiometer surveys conducted in August 2003 lay the groundwork for future magnetic surveys in the Metapontino. They demonstrate that the local soils and geology are, in general, magnetically susceptible and thus enable us to detect and interpret cultural anomalies with relative ease. This translates into less energy directed toward exploratory excavation to achieve similar, if not identical, results. These surveys also inform us of the types of sites on which gradiometer surveys are best conducted: sites with highly suspected buried features and the ubiquitous pottery scatters. Sites like Incoronata "*greca*" and Site 829 would have taken weeks to explore by trial excavation; it took our small survey team no more than 3 days at each site. Gradiometer surveys of sites with only suspected buried features (such as Incoronata Viggiano), if kept to a reasonably defined area, say less than three hectares, may also produce useful archaeological information without turning a spade. On the other hand, large-area gradiometer surveys, on the order of entire walled cities, have been conducted with spectacular results, particularly in the U.K. but also at Metaponto itself. And time spent processing the field data was minimal, measured in hours, not days.

In order to supplement the important field survey work conducted in the Metapontino over the last two decades, we recommend that a small gradiometer survey crew (four people maximum) conduct seasonal work on sites worthy of elucidation. Such sites may include pottery scatters of 6th-century BC date and earlier, the areas surrounding previously excavated necropoleis, and even the environs of Metaponto itself. Table 1, for example, shows 45 sites within the chora (surveyed from 1981 to 2001) with the largest counts of surface artifacts. Of these, 23 sites include material from the 6th century BC or earlier. Quick and efficient gradiometer surveys of any of these sites would help ICA and local archaeologists determine which are the most promising sites to excavate or conserve. Especially illuminating would be a gradiometer survey of the area outside the city walls and in areas of presumed harbor installations. These small gradiometer survey teams may be composed of one or two permanent members and supplemented by student volunteers who rotate in and out of the field survey team. This wide range of survey experience gained by such participants would be quite valuable, both for them and for ICA.

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Incoronata Viggiano

Instrument:	GeoScan Research Fluxgate Gradiometer, FM36
Sample Trigger:	ST1
Grid Size:	20m x 20m
Sample Interval:	0.5m
Traverse Interval:	1.0m
Reading Average:	Off
Log Zero Drift:	Yes (before and after each grid surveyed)
Traverse Direction:	West to East
Traverse Pattern:	Parallel
Orientation:	North up
Surface Noise:	±3-4 nT
Time(s) of Day:	8:30am to 1:00pm, 4:00pm to 6:30pm.
Balance/Adjustment:	8:30am, 4:00pm

Corrected Outermost Corner
Positions (UTM, WGS84):
NW
NE
SE
SW

Incoronata "*greca*"

Instrument:	GeoScan Research Fluxgate Gradiometer, FM36
Sample Trigger:	ST1
Grid Size:	10m x 5m
Sample Interval:	0.25m
Traverse Interval:	0.5m
Reading Average:	Off
Log Zero Drift:	Yes (before and after each grid surveyed)
Traverse Direction:	West to East
Traverse Pattern:	Zigzag
Orientation:	North up
Surface Noise:	±2 - 2.5 nT
Time(s) of Day:	8:30am to 1:00pm, 4:00pm to 6:30pm.
Balance/Adjustment:	8:30am, 4:00pm

Corrected Outermost Corner
Positions (UTM, WGS84):
NW
NE
SE
SW

Incoronata Viggiano

Instrument:	GeoScan Research Fluxgate Gradiometer, FM36
Sample Trigger:	ST1
Grid Size:	20m x 20m
Sample Interval:	0.5m
Traverse Interval:	1.0m
Reading Average:	Off
Log Zero Drift:	Yes (before and after each grid surveyed)
Traverse Direction:	West to East
Traverse Pattern:	Parallel
Orientation:	North up
Surface Noise:	±3-4 nT
Time(s) of Day:	8:30am to 1:00pm, 4:00pm to 6:30pm.
Balance/Adjustment:	8:30am, 4:00pm

Corrected Outermost Corner
Positions (UTM, WGS84):
NW
NE
SE
SW

Incoronata "*greca*"

Instrument:	GeoScan Research Fluxgate Gradiometer, FM36
Sample Trigger:	ST1
Grid Size:	10m x 5m
Sample Interval:	0.25m
Traverse Interval:	0.5m
Reading Average:	Off
Log Zero Drift:	Yes (before and after each grid surveyed)
Traverse Direction:	West to East
Traverse Pattern:	Zigzag
Orientation:	North up
Surface Noise:	±2 - 2.5 nT
Time(s) of Day:	8:30am to 1:00pm, 4:00pm to 6:30pm.
Balance/Adjustment:	8:30am, 4:00pm

Corrected Outermost Corner
Positions (UTM, WGS84):
NW
NE
SE
SW

Figure 1. Map of the chora of Metaponto, showing the locations of sites mentioned in the text.

Figure 2. (Top) View of Incoronata Viggiano from atop Incoronata "*greca*", looking northward. The survey area lies just beyond the two machinery storage buildings. (Left) Bjørn Lovén walks a traverse with the gradiometer at Incoronata Viggiano.

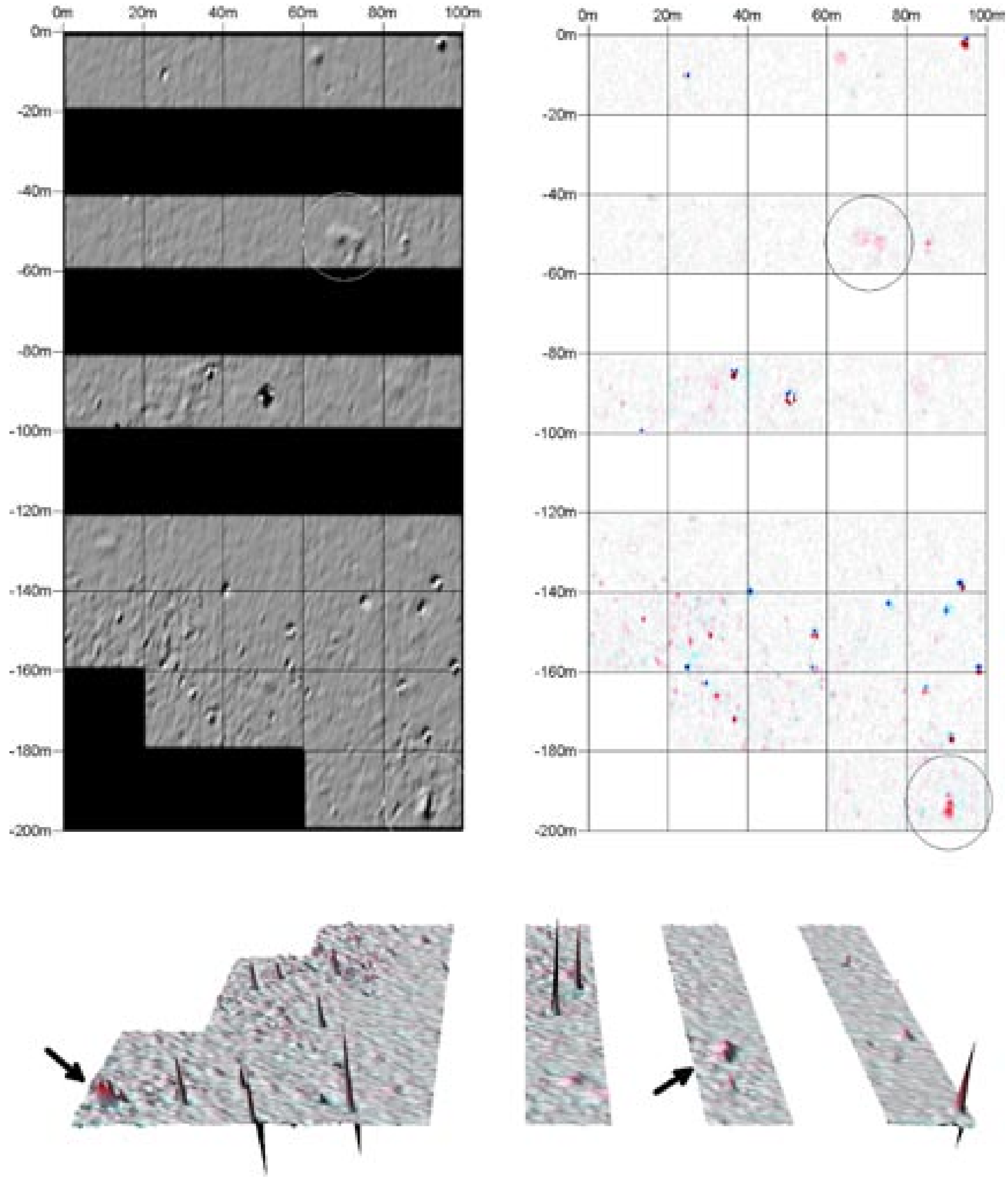


Figure 3. Three gradiometer maps of Incoronata Viggiano: (Top left) A 2D shaded relief plot; (Top right) A magnetic contour map; (Bottom) A 3D shaded relief map (looking westward) showing magnetic "mounds" which likely represent pits, and magnetic spikes which likely indicate modern ferrous debris. Of particular interest are the two large hits delineated by circles (above) and arrows (below). Though only excavation would reveal the source, their size and intensity are often associated with funerary deposits. They were not visible on the surface.

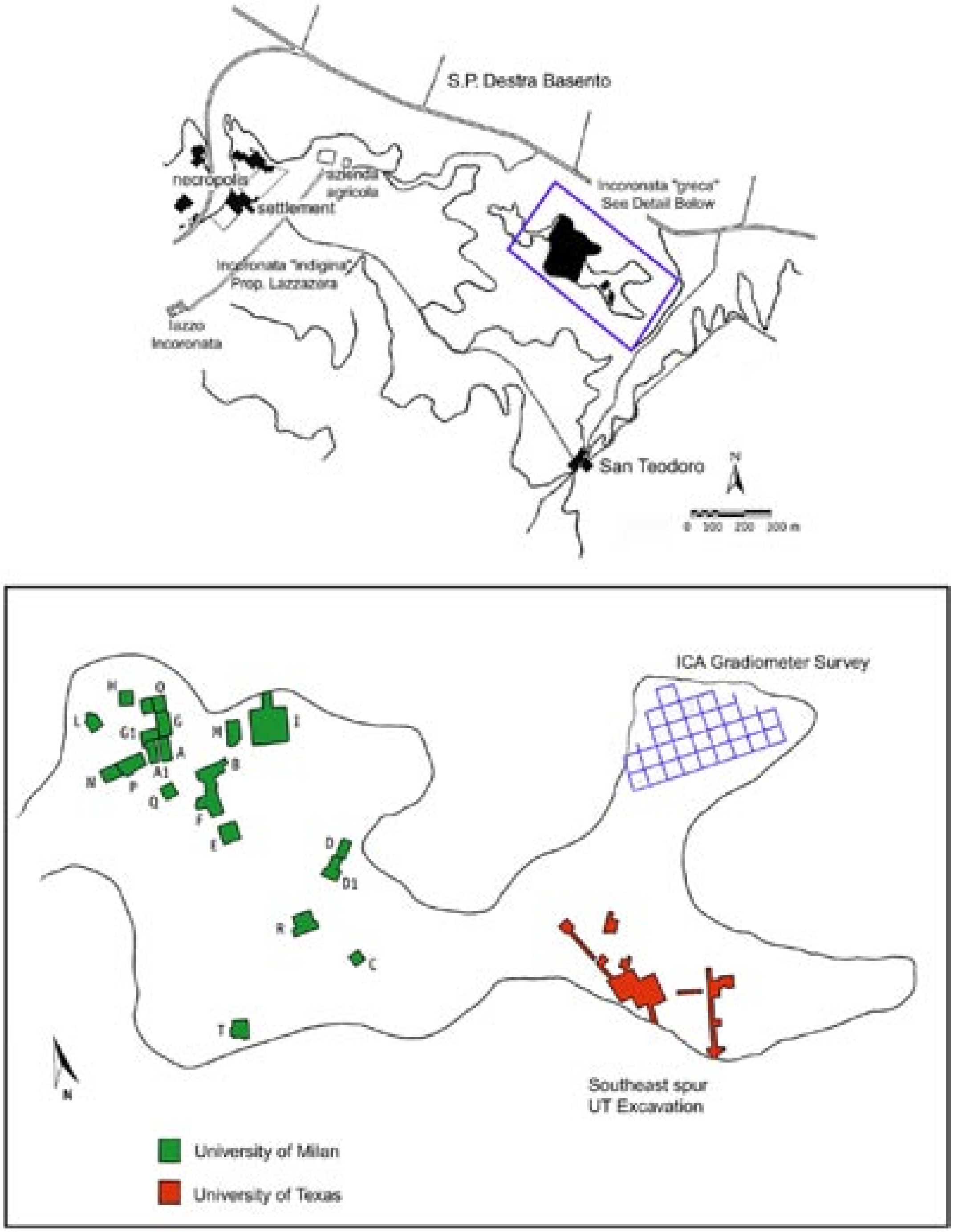


Figure 4. Incoronata. The top map shows the entire settlement area, both indigenous (west) and "*greca*" (east). The 2003 gradiometer survey concentrated on the northeast spur, to the north of the UT excavations.

Figure 5. Aerial photo of Incoronata "*greca*," looking northward. The UT excavations are visible in the center foreground. The northeast spur is just above the road that bisects the plateau.

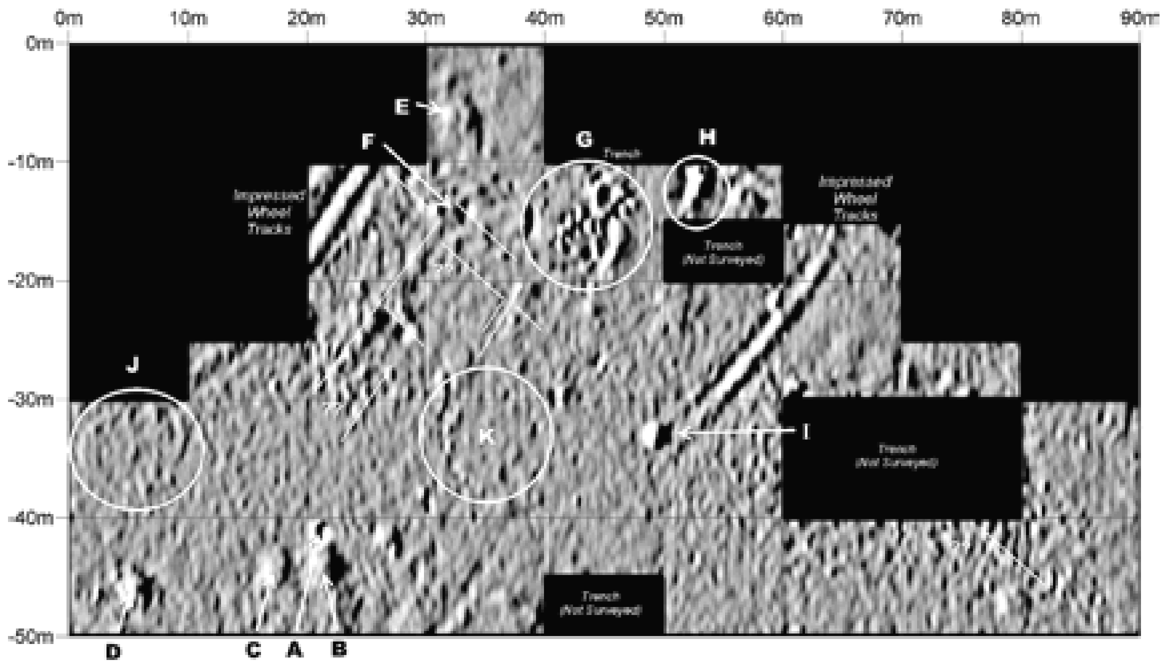


Figure 6. Magnetic shaded relief plot of Incoronata "*greca*" (northeast spur). Elliptical shapes at J and K are barely discernible, as are the linear features just to the north of K.

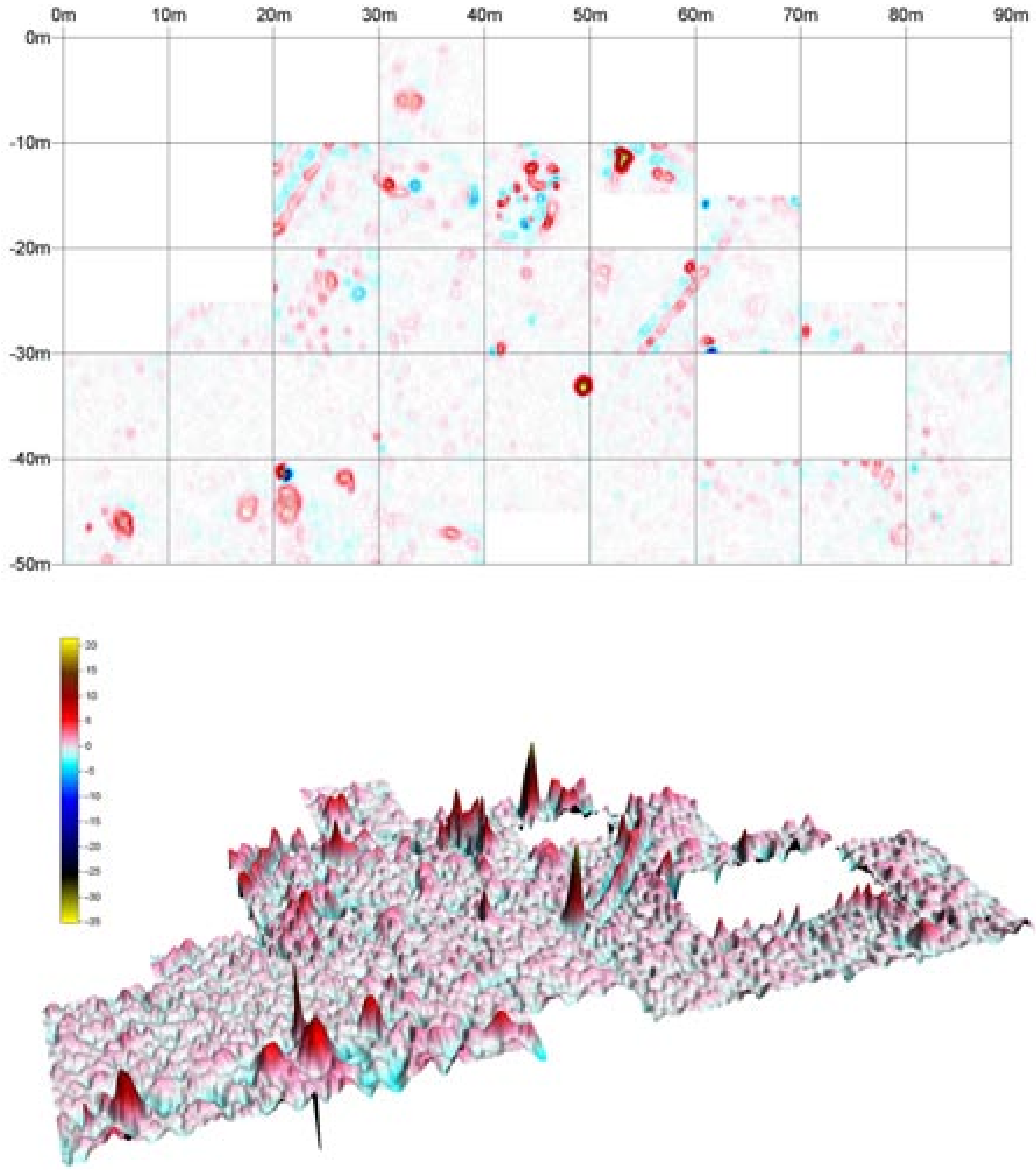


Figure 7. (Top) Magnetic contour map of Incoronata "*greca*." (Above) A 3D magnetic relief map of the same area. Note the strong ceramic noise throughout the site.

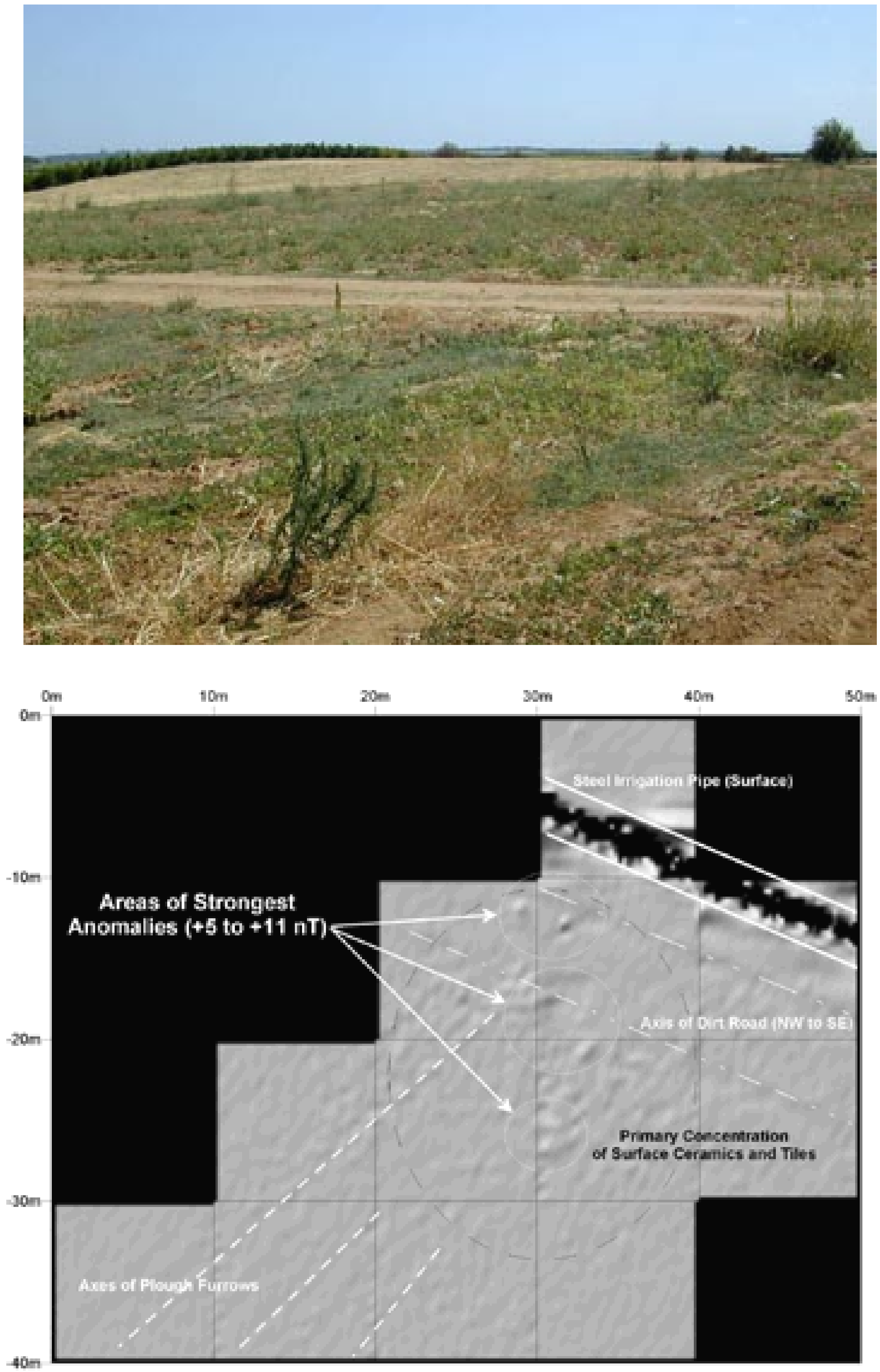


Figure 8. (Top) Site 327, view looking southwest. The irrigation pipe was later installed along this side of the dirt road. (Above) Site 327 shaded relief plot.

Figure 9. (Top) Site 829 was located by field survey in 2001. (Above) Large and small lumps of vitrified clay (ceramic slag), as well as surface ceramic sherds.

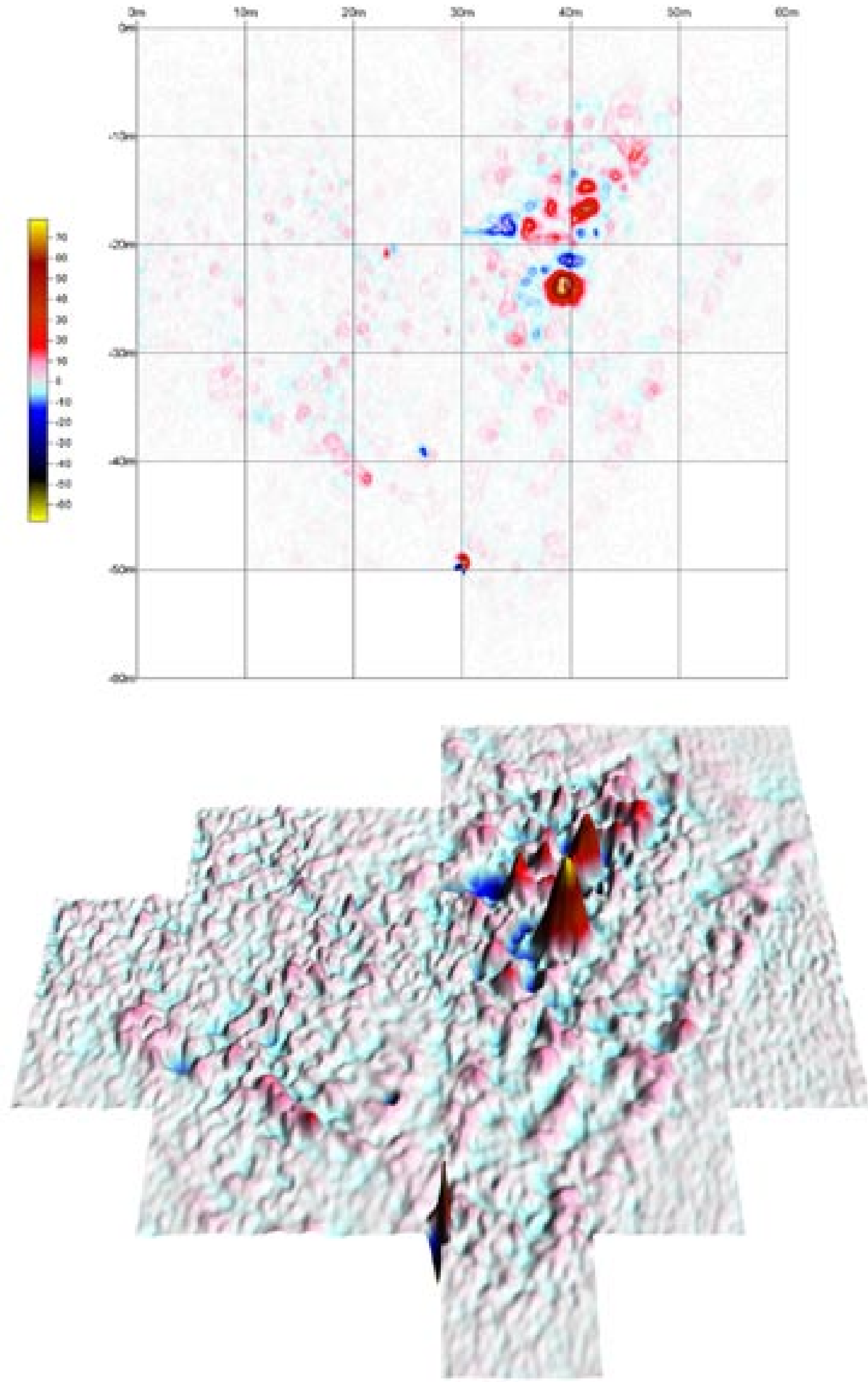


Figure 10. Site 829. (Top) A magnetic contour map of the site. (Above) A 3D shaded relief map. Note the ceramic noise prevalent throughout the entire site. North is up on both maps.

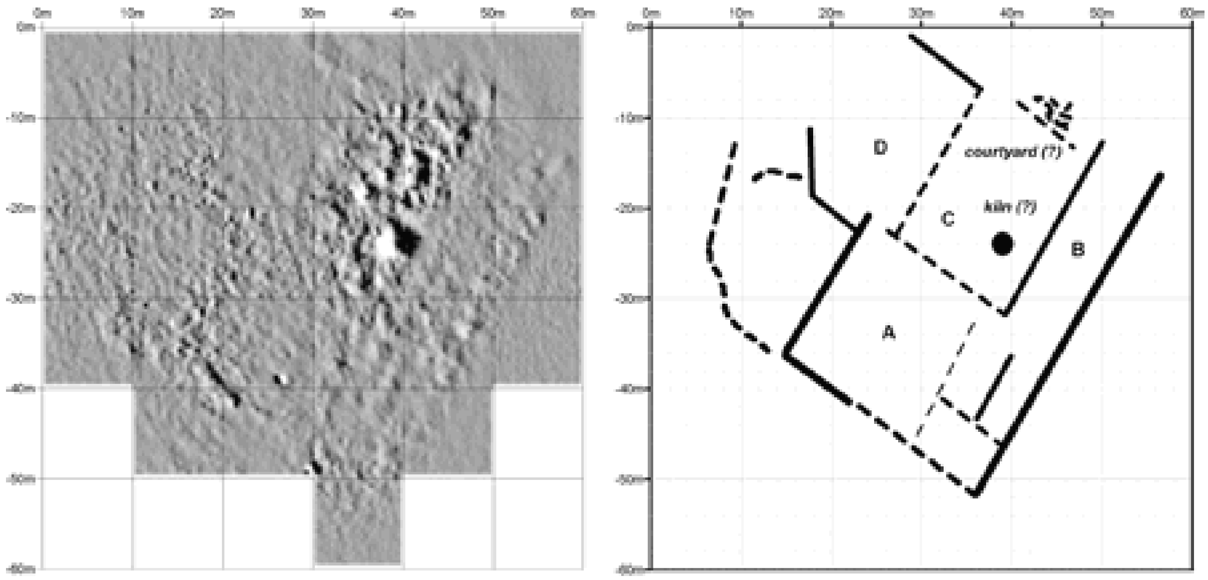
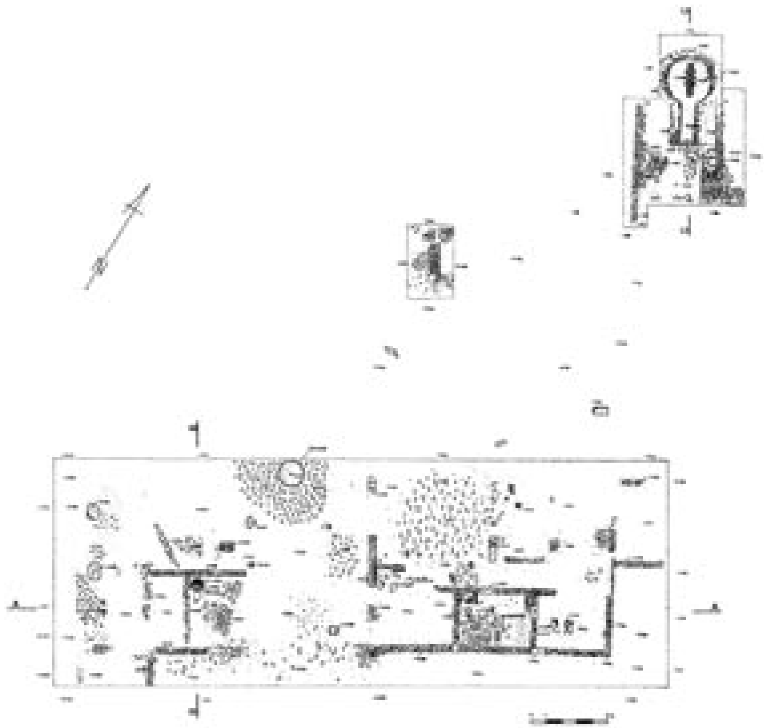


Figure 11. (Left) Shaded relief plot of Site 829. (Right) Tentative reconstruction. Interior divisions of Area A are barely discernible. (North up)

Figure 22. Fattoria Stefan, a large Greek farmhouse of the late 4th century BC. At 192 m^2, it is the largest Classical- and Hellenistic-period farmhouse so far recorded in the chora of Metaponto. It could easily fit within Area A at Site 829. Compare its axis and arrangement of rooms with those of Figure 11. Note particularly how Room 3 and Area 10 on this plan open up to the west, similarly to that of Area D at Site 829. Also note the axis of this central courtyard (6) to that of the "courtyard" on Site 829.



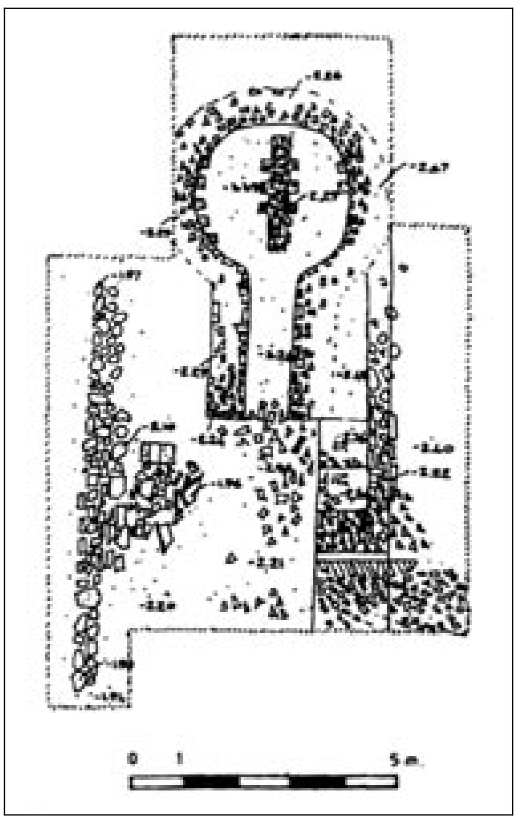


Figure 13. Classical farmhouse at Cappa d'Amore in the chora of Metaponto. Note the shape and size of the kiln at left. The kiln at site 829 is likely similar to this one. (Adapted from Adamesteanu 1974, 86)

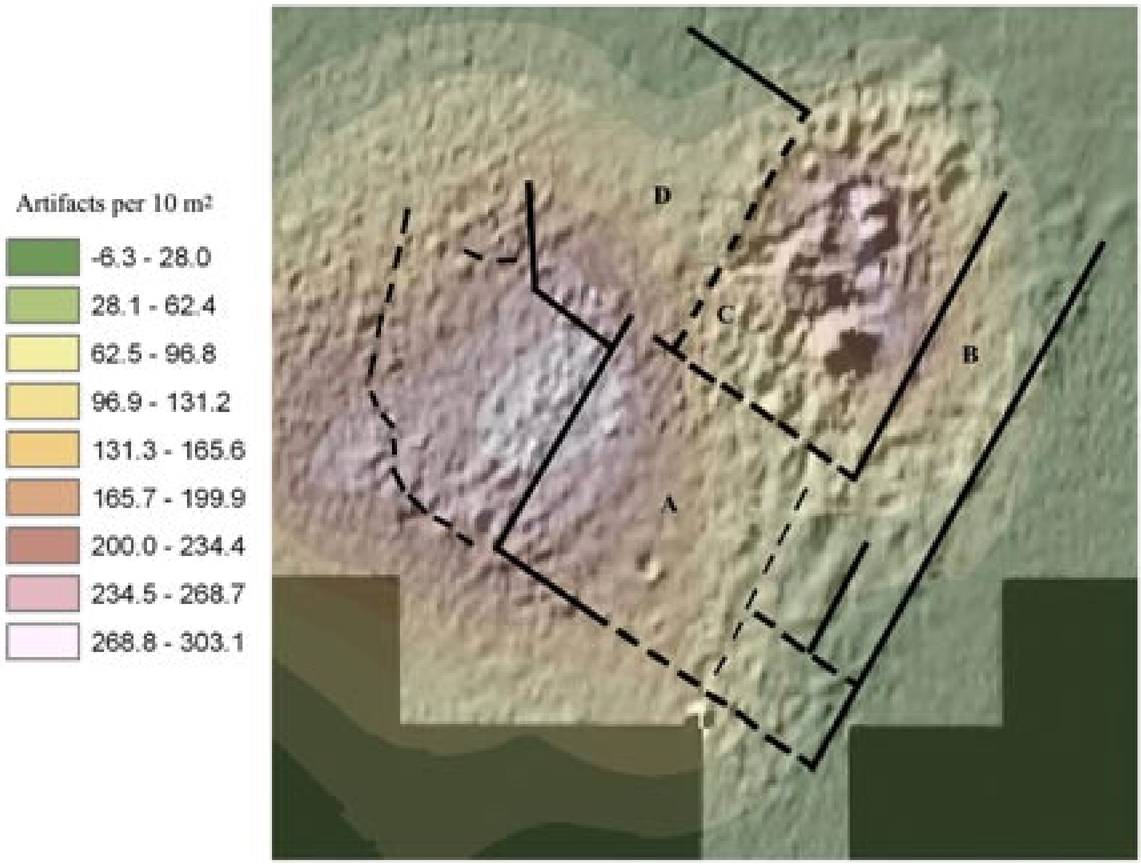


Figure 14. Site 829. Artifact density map from the field survey laid over the 2003 gradiometer survey map. The two peaks of highest densities correspond to the "courtyard/kiln" area (Area C) and the area NW of Area A. Note that there is still a close physical correspondence between artifact densities and apparent architectural remains.