KECK GEOLOGY CONSORTIUM

PROCEEDINGS OF THE TWENTY-SECOND ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2009
Franklin & Marshall College, Lancaster PA.

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ISSN # 1528-7491

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National Science Foundation
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ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY
ISSN# 1528-7491

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Funding Provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)
GEOARCHAEOLOGY OF THE PODERE FUNGHI, MUGELLO VALLEY ARCHAEOLOGICAL PROJECT, ITALY

Project Director: ROB STERNBERG: Franklin & Marshall College
Project Faculty: SARA BON-HARPER: Monticello Department of Archaeology

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STACEY SOSENKO: Franklin and Marshall College
Research Advisor: Rob Sternberg

Funding provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)
INTRODUCTION

Geophysical techniques provide an avenue in archaeological research for efficient and relatively non-destructive data collection. These techniques, through characterization of vertical and horizontal patterns in geophysical properties, can be used to identify subsurface features and provide an understanding of soil context (Clark, 1996; Johnson, 2006).

Recent advances in down-hole magnetic susceptibility instrumentation, techniques and software for data processing (Dalan, 2008) have provided an opportunity for investigations at the Podere Funghi. Magnetic susceptibility testing provides fine-scale vertical information pertinent to the interpretation of archaeological patterns. Geophysical methods were employed at the Podere Funghi to understand these spatial relationships of subsurface properties and Etruscan occupation of the site.

Down-hole magnetic susceptibility testing was conducted at the Podere Funghi using a coarsely sampled grid to broadly characterize the site. Susceptibility data along a single transect (N1080) of this grid can be compared with data collected by others on the project (soil phosphate, magnetometry, shovel test pit (STP), artifact spatial sampling, and coring). Integrating these various methods of data collection will provide insight as to which techniques are complementary. Magnetic susceptibility techniques were also applied to characterize specific features and areas of the site. A closely spaced set of down-hole tests was employed to understand the vertical and horizontal limits of an anomaly identified during a 2007 magnetometer survey in the field north of the Podere Funghi.

Within an excavation trench (NW3) near Poggio Colla, a handheld magnetic susceptibility sensor was used to record a closely spaced set of measurements. Previous work in the vicinity of NW3 found 7th century artifacts following rainstorms that had eroded parts of the hillsides, but had not been able to ascertain the nature of the site or the origin of the finds.

METHODS

Magnetic susceptibility quantifies the ability of a material to become magnetized. While magnetometers map magnetic anomalies due to local changes in magnetization, they make no distinction between anomalies resulting from changes in magnetic susceptibility and magnetic remanence. Magnetic susceptibility measurements can be used to distinguish features with a susceptibility contrast from those with a magnetic remanence.

Magnetic susceptibility investigations are crucial to the understanding of subsurface magnetic properties; the down-hole sensor provides fine-scale vertical information that is not available with a magnetometer. A combination of field and laboratory testing allows for archaeologists to gain a better understanding of the distribution of archaeological features and also site formation processes (Dalan, 2006b).

Field Testing

Magnetic susceptibility surveys were conducted at the Podere Funghi, the field north of the Podere Funghi, and the NW3 trench located northwest of Poggio Colla. The Bartington MS2 meter and...
MS2H down-hole magnetic susceptibility probe were used for the collection of data from the Podere Funghi site and the field to the north. The Bartington MS2 meter and MS2F field surface probe were used to conduct measurements along the NW3 trench wall.

The Podere Funghi down-hole magnetic susceptibility tests were conducted at 10 m intervals across the site. In total, 70 locations were tested (Fig. 1). At each location, measurements were taken at 2 cm depth intervals starting at 10 cm below the surface. Depths tested ranged from 15 to 128 cm, dependent on the depth achieved with the corer used to make the hole for testing. An AMS 33 inch soil probe with a 36 inch threaded extension and compact slide hammer was used for sampling purposes. Tests generally ended at decomposing bedrock, except in the south to southwest region of the site where they ended in dense clays. Using MultiSus FieldPro software, both a manual and timed test were run at each location to ensure repeatability of results. The timed test served as an initial rapid reconnaissance test. During this test, the MS2 sensor was lowered down the core hole at a constant rate as readings were automatically recorded. For the second and slower manual test, measurements were logged by pushing a button as the sensor was positioned in increments down the core hole.

Large thermal drift values resulting from significant temperature changes between air and soil were encountered. Thermal drift was reduced by placing the Bartington MS2H sensor in the core hole to equilibrate for a few minutes before beginning testing. Following equilibration, the probe was quickly removed from the core hole, zeroed in mid-air and measurements of magnetic susceptibility were then taken. This procedure was employed in both the manual and timed tests.

It is possible to compare data collected along the E1000.5 and N1080 transects of the Podere Funghi grid with other Keck Podere Funghi research projects. Samples were collected from these two

![Figure 1. Podere Funghi site, Italy. Image produced using ArcheoSurveyor3D illustrating the 70 magnetic susceptibility down-hole tests. Test locations forced to flat ground due to extreme elevation differences. Multiply plotted values by $10^{-5}$ for SI susceptibility.](image-url)
transects for laboratory magnetic testing. The test locations at the Podere Funghi were offset from the centers of the shovel test pits (STPs) by 50 cm. STP data identified plowzone depths and other stratigraphic changes as well as artifact content.

In the field north of the Podere Funghi, a 2 m interval surrounding the identified magnetic anomaly from the 2007 magnetometry study was investigated. Ten different locations were tested. Data collection at this site followed the same procedures as discussed for the Podere Funghi.

Within the NW3 trench, a Bartington MS2 meter and MS2F field surface probe were used to collect magnetic susceptibility data along vertical profiles spaced at 0.5 m intervals across the trench wall. At each of these locations, measurements were taken at 2 cm depth increments from the surface to the bottom of the trench. A total of 11 vertical transects were measured at the NW3 trench.

**Laboratory Testing**

Samples were collected when coring in preparation for use of the down-hole sensor along the E1000.5 and N1080 transects. These cores were divided and bagged by 5 cm increments. In preparation for measurement, samples were dried, ground, homogenized, and then packed into Althor P15 nonmagnetic boxes (5.28 cc).

Laboratory testing of samples collected from the E1000.5 and N1080 transects were completed using the Bartington MS2B dual-frequency susceptibility sensor and a counter and computer interface designed by James Marvin of the Institute for Rock Magnetism at the University of Minnesota. The MS2B was used to measure mass magnetic susceptibility (in contrast to field measurements of volume susceptibility, these are normalized by the density of the sample) and the frequency dependence of susceptibility.

Magnetic susceptibility depends on the concentration of magnetic minerals in the sample, types of magnetic minerals present, and the size of the magnetic grains. Frequency dependence of susceptibility is the percent difference in susceptibility measured using two frequencies. This property is used to look at the contribution of ultra fine magnetic grains. The greater the percentage difference between the low frequency values and high frequency susceptibility values, the greater the concentration of small magnetic grains present in the sample (Dalan, 2006b).

**RESULTS**

**Podere Funghi**

As seen in Figure 1, general patterns in susceptibility across the Podere Funghi include low values in the
southeast region of the field and high values along the west edge and in the northern region. Within each of those regions, there are also localized areas of high and low susceptibility. For example, the southeast corner of the Podere Funghi is an area of higher magnetic susceptibility than surrounding values. The southern portion of the E1000.5 transect also includes a region of high susceptibility relative to surrounding susceptibilities.

Down-hole tests at the Podere Funghi documented a plowzone that is consistently higher in magnetic susceptibility than subsurface soils. With increasing depth, magnetic susceptibility decreases; in general, topsoil values are 1-2 times greater than subsoil values. Figure 2 illustrates this along the N1080 transect.

Although susceptibility values and profile trends were relatively uniform across the site, there were specific areas with anomalously high and low magnetic susceptibilities (Fig. 1 and Fig. 2). While some test locations have indicated anomalous regions it is important to recognize that not all anomalous areas within the Podere Funghi site have been identified due to the large spacing between test locations. Also, sampling was not sufficient to determine the horizontal limits of these anomalous regions.

Figure 3. Laboratory magnetic susceptibility results for samples collected along the N1080 transect. Data collected from mass susceptibility and frequency dependence of susceptibility testing.
Timed and manual tests produced comparable results demonstrating the repeatability of the susceptibility measurements. The measurements collected from the manual tests were used for data interpretation because measurements logged with the manual tests were more accurate to the exact depth of the down-hole probe in the core hole during testing.

The magnetic susceptibility tests in the laboratory were used for comparison to the field results. The laboratory results captured similar magnetic susceptibility trends as recorded by field tests along the E1000.5 and N1080 transects (Fig. 2. and Fig. 3). Laboratory measurements of the frequency dependence of susceptibility revealed a higher concentration of ultra fine magnetic grains in the topsoil as compared to the subsoil.

Field north of the Podere Funghi

A magnetic anomaly in the field north of the Podere Funghi was identified during a 2007 magnetometer survey. Magnetic susceptibility was employed to explore the vertical and horizontal limits of that anomaly. Background magnetic susceptibility values range from 2.00x10^-4 to 4.00x10^-4; this was typical of decomposing bedrock at that site. Data collected from three of the down-hole test locations show magnetic enhancement (Fig. 4). Magnetic susceptibility values from the center of this anomaly where coring encountered baked material indicate the highest values (1.72x10^-2).

NW3 Trench

Using the MS2F field surface probe, magnetic susceptibility testing of NW3 trench indicated localized regions of anomalously high magnetic susceptibility towards the center of the trench. The data collected at NW3 will be compared against profile data for archaeological interpretation.

DISCUSSION

The magnetic properties of a soil are dependent on the factors contributing to soil formation, including human occupation, environmental influences, and duration of magnetic enhancement (Dalan, 2006a). Surface soils typically become enhanced magnetically resulting in greater magnetic susceptibility values than the underlying subsoil. Soil enhancement processes often include those of human activity and other inorganic/organic processes (Dalan, 2006b). Trends appear to illustrate a general region of low susceptibility in the southern area of the Podere Funghi and high in the northern area. Magnetic enhancement is indicated at the Podere Funghi site as illustrated in Figure 2 along the N1080 transect. The magnetic susceptibility values of the site soils decrease with depth, with lower layers, near decomposing bedrock, being less magnetic than surface soils. Magnetically enhanced near-surface layers demonstrate increased frequency dependence of susceptibility, indicating not only more magnetic minerals but more small magnetic grains. Fine magnetic grains are typical of developed enhanced surface soils.

Laboratory results indicated similar magnetic susceptibility peaks along the N1080 transect to those measured during the field susceptibility survey thus verifying the accuracy of the field susceptibility tests. Comparison of laboratory
and field susceptibility trends illustrates that the field data provides a more detailed picture of how susceptibility varies with depth (Fig. 2 and Fig. 3). This is due to the fact that collected samples were homogenized over 5 cm intervals while field measurements were logged at 2 cm intervals. High magnetic susceptibility values recorded during field tests might also be influenced by magnetic deposits, artifacts, or thin anthropogenic layers near the down-hole probe.

Down-hole testing of magnetic susceptibility requires a considerable amount of preparation prior to recording measurements. Coring the holes and collecting samples for laboratory analysis takes time. However, this method for geophysical analysis provides insight into vertical and horizontal relationships that is not found with other geophysical methods. Preparation of samples for laboratory measurement also takes significant effort, but can provide valuable information regarding magnetic properties of grains within soils.

CONCLUSION

Magnetic susceptibility studies at the Podere Funghi, the north field, and NW3 trench produced information on the magnetic properties of site soils as well as on anomalous areas of magnetic susceptibility that may relate to cultural features of the site. As with the magnetometer, the magnetic susceptibility down-hole probe is not affected by magnetic influences far from the sensor (Challands, 1992). Because the MS2H can be lowered down a core hole, it provides vertical information on the soil profile, locating a known depth of a feature. In conjunction with vertical and horizontal information the decreased sensitivity from strongly magnetic features allows for an accurate portrayal of relationships across the site.

The coring of the holes in preparation for the down-hole magnetic susceptibility testing and collection of samples for laboratory testing takes a considerable amount of effort. However, the field and laboratory measurements themselves proceed quickly. Data collected from the field and laboratory tests provide valuable information regarding soil magnetic enhancement, feature identification, and accurate depth location.

The purpose of the magnetic susceptibility study was to identify the usefulness to both large and small scale archaeological investigations. The magnetic susceptibility survey conducted at the Podere Funghi focused on a broad characterization of soil magnetic properties. Because of the 10 m interval spacing, potentially only a small sample of the archaeological features were located and the limits of these features were not determined. In the field north of the Podere Funghi, in which the spacing between down-hole tests was much smaller, the specific vertical and horizontal limits of the magnetic anomaly were determined. This approach could also provide a much more representative sample of features within an area.

ACKNOWLEDGEMENTS

Many thanks to the Podere Funghi Keck project directors, Dr. Rob Sternberg and Dr. Sara Bon-Harper, for providing support and thoughtful management of all the Podere Funghi Keck projects. I would also like to thank Stacey Sosenko, Rowan Hill, Maija Sipola, Anna Pendley and Jane Didaleusky for their assistance in field coring and data collection. I am most grateful to Dr. Rinita Dalan for proposing this opportunity and for providing outstanding support throughout the completion of this project. I am also greatly thankful to Minnesota State University Moorhead for providing additional financial support for this project.

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