KECK GEOLOGY CONSORTIUM
PROCEEDINGS OF THE TWENTY-SECOND
ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY
ISSN# 1528-7491

April 2009

2008-2009 PROJECTS

THE BLACK LAKE SHEAR ZONE: A POSSIBLE TERRANE BOUNDARY IN THE ADIRONDACK LOWLANDS
(GRENVILLE PROVINCE, NEW YORK)

Faculty: WILLIAM H. PECK, BRUCE W. SELLECK and MARTIN S. WONG: Colgate University
Students: JOE CATALANO: Union College; ISIS FUKAI: Oberlin College; STEVEN HOCHMAN: Pomona College; JOSHUA T. MAURER: Mt Union College; ROBERT NOWAK: The College of Wooster; SEAN REGAN: St. Lawrence University; ASHLEY RUSSELL: University of North Dakota; ANDREW G. STOCKER: Claremont McKenna College; CELINA N. WILL: Mount Holyoke College

PALEOECOLOGY & PALEOENVIRONMENT OF EARLY TERTIARY ALASKAN FORESTS, MATANUSKA VALLEY, AL.

Faculty: DAVID SUNDERLIN: Lafayette College, CHRISTOPHER J. WILLIAMS: Franklin & Marshall College
Students: GARRISON LOOPE: Oberlin College; DOUGLAS MERKERT: Union College; JOHN LINDEN NEFF: Amherst College; NANCY PARKER: Lafayette College; KYLE TROSTLE: Franklin & Marshall College; BEVERLY WALKER: Colgate University

SEAFLOOR VOLCANIC AND HYDROTHERMAL PROCESSES PRESERVED IN THE ABITIBI GREENSTONE BELT OF ONTARIO AND QUEBEC, CANADA

Faculty: LISA A. GILBERT, Williams College and Williams-Mystic and NEIL R. BANERJEE, U. of Western Ontario
Students: LAUREN D. ANDERSON: Lehigh University; STEFANIE GUGOLZ: Beloit College; HENRY E. KERNAN: Williams College; ADRIENNE LOVE: Trinity University; KAREN TEKVERK: Haverford College

INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, CO

Faculty: DAVID P. DETHIER: Williams College and MATTHIAS LEOPOLD: Technical University of Munich
Students: EVYE GANNAYAW: The U. of the South; KENNETH NELSON: Macalester College; MIGUEL RODRIGUEZ: Colgate University

GEOARCHAEOLOGY OF THE PODERE FUNGHI, MUGELLO VALLEY ARCHAEOLOGICAL PROJECT, ITALY

Faculty: ROB STERNBERG: Franklin & Marshall College and SARA BON-HARPER: Monticello Department of Archaeology
Students: AVERY R. COTA: Minnesota State University Moorhead; JANE DIDALEUSKY: Smith College; ROWAN HILL: Colorado College; ANNA PENDLEY: Washington and Lee University; MAJIA SIPOLA: Carleton College; STACEY SOSENKO: Franklin and Marshall College

GEOLOGY OF THE HöH SERH RANGE, MONGOLIAN ALTAI

Faculty: NICHOLAS E. BADER and ROBERT J. CARSON: Whitman College; A. BAYASGALAN: Mongolian University of Science and Technology; KURT L. FRANKEL: Georgia Institute of Technology; KARL W. WEGMANN: North Carolina State University
Students: ELIZABETH BROWN: Occidental College; GIA MATZINGER, ANDREA SEYMOUR, RYAN J. LEARY, KELLY DUNDON and CHELSEA C. DURFEE: Whitman College; BRITTANY GAUDETTE: Mount Holyoke College; KATHRYN LADIG: Gustavus Adolphus College; GREG MORTKA: Lehigh U.; JODI SPRYJACAR: The College of Wooster; KRISTIN E. SWEENEY: Carleton College

BLOCK ISLAND, RI: A MICROCOSM FOR THE STUDY OF ANTHROPOGENIC & NATURAL ENVIRONMENTAL CHANGE

Faculty: JOHAN C. VAREKAMP: Wesleyan University and ELLEN THOMAS: Yale University & Wesleyan University
Students: ALANA BARTOLAI: Macalester College; EMMA KRAVET and CONOR VEE NEMAN: Wesleyan University; RACHEL NEURATH: Smith College; JESSICA SCHEICK: Bryn Mawr College; DAVID JAKIM: SUNY

Funding Provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)
Keck Geology Consortium: Projects 2008-2009
Short Contributions – ITALY

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

MAGNETIC SUSCEPTIBILITY INVESTIGATIONS OF THE PODERE FUNGHI, ITALY
AVERY R. COTA: Minnesota State University Moorhead
Research Advisor: Dr. Rinita Dalan

GEOCHEMICAL AND MINERALOGICAL COMPARISON BETWEEN CLAYS AND CERAMICS FROM THE ETRUSCAN ARCHAEOLOGICAL SITES OF POGGIO COLLA AND PODERE FUNGHI, TUSCANY, ITALY
JANE DIDALEUSKY: Smith College
Research Advisors: Bosiljka Glumac and Robert Newton

PHOSPHORUS ANALYSIS OF THE PODERE FUNGHI
ROWAN HILL: Colorado College
Research Advisor: Paul Myrow

ARTIFACT DISTRIBUTION AND GEOARCHAEOLOGICAL INVESTIGATION OF THE PODERE FUNGHI
ANNA PENDLEY: Washington and Lee University
Research Advisors: Dr. Sara Bon-Harper, Dr. David Harbor, and Dr. Robert Sternberg

GEOMORPHIC AND ANTHROPOGENIC IMPACTS ON ARTIFACT DISTRIBUTION WITHIN THE PLOWZONE IN THE PODERE FUNGHI, TUSCANY, ITALY
MAIJA SIPOLA: Carleton College
Research Advisor: Mary Savina, Carleton College

MAGNETOMETRY IN THE PODERE FUNGHI AT THE ETRUSCAN ARCHAEOLOGICAL SITE OF POGGIO COLLA
STACEY SOSENKO: Franklin and Marshall College
Research Advisor: Rob Sternberg

Funding provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)
PHOSPHOROUS ANALYSIS OF THE PODERE FUNGHI

ROWAN HILL: Colorado College
Research Advisor: Paul Myrow

INTRODUCTION

Among many geoarcheological techniques, phosphorous (P) measurements have become a popular method of soil chemistry analysis (Oonk et al, 2009; Holliday and Gartner, 2007). P is stable in the soil over a long period of time and accumulates in areas of intense human activity, making it a reliable indicator of such activity in ancient soils. P takes many forms within soils. It can be in solution, or in solid but easily soluble form, both of which are considered available P. It can also be tightly bound to other soil particles as stable P. Organic orthophosphates (PO$_4$) are of interest to archaeological studies because they are more likely to result from human activity, and because they can remain in the soil, adsorped onto clay particles, for an extended period of time. Inorganic phosphates can be even more stable when they become occluded, i.e., incorporated into particle structures (Holliday and Gartner, 2007). More stable forms of P in soil are harder to extract for analysis.

Sources of P that are of interest at archeological sites such as the Podere Funghi include ash, waste from latrines or animal pens, and waste produced by cooking and other practices that produce a concentrated amount of organic matter. In the millennia since Etruscan occupation, the Podere Funghi was farmed and could have been fertilized repeatedly, adding P that is not archeologically significant. In the case of the Podere Funghi, the soil P of interest is about 2200 years old, so none of the easily available P is expected to be of Etruscan provenance.

METHODS

Field methods

We dug shovel test pits (STPs) on a 5-meter grid covering the Podere Funghi. Each pit was dug as a cylindrical hole with a 50 cm diameter. The hole was dug to the bottom of the plow zone, which is marked by a change in stratigraphy from a well mixed sediment to any of several different layers, including decomposing bedrock, potential habitation layers (tile and charcoal inclusions), mottled blue and orange sandy clay, gray-blue clay, or any combination of the above. The bedrock is yellow-brown sandstone at a depth of 30-100 cm below the surface. I took samples from the bottom of all the STPs that were deemed to have archeological potential, as well as several control samples from the plow zone. STPs were not sampled below the blow zone if the plow zone went down to bedrock or decomposing bedrock. The samples were taken directly below the plow zone, or in the case of plow zone samples they were taken between 15-20 cm below the surface. The samples were placed in plastic bags, that are resistant to phosphate leaching, for lab analysis at the Colorado College. The samples were dried and ground for XRF and wet chemical analysis.

XRF Methods

X-ray fluorescence spectroscopy (XRF) is a non-destructive method for analyzing the chemical composition of soil samples. It can only determine total P, making it impossible to tease out what proportion of the total P is archeologically significant in the study. The XRF can produce accurate readings even at low P concentrations, and is relatively quick and easy. Although XRF analysis has not been widely used in archeology, Marwick (2005) shows a prime example of its successful application.

Soil samples were analyzed using the polarizing energy dispersive x-ray fluorescence spectrometer at Colorado College. No additional sample preparation was performed on the dried and ground samples.
All the samples from below the plow zone were measured for a total of 81 data points. Twenty-one samples from the plow zone were analyzed using the XRF spectrometer as well. This provides a control of the natural variability of P over the field. The data were recorded in Microsoft Excel and plotted using Surfer 8.

**Extraction Methods**

An HCl extraction and measurement using visible light spectrophotometry was used for total orthophosphate (PO$_4$) analysis of 28 samples. The method chosen is one of several commonly used variations of the phosphomolybdate blue reaction. The samples were soaked in 1 M HCl and analyzed by colorimetry using a spectrophotometer. For each sample, 1 gram of soil was added to 40 ml of 1 M HCl and shook on an oscillating shaker for 4 hours at medium speed. Samples were then put in a centrifuge for 15 minutes at 2500 rpm. The samples were then prepared for colorimetric analysis. Five milliliters from each sample extract were pipetted into a 50 ml volumetric flask. The flask was brought up to 35 ml with deionized water, and 10 ml of Murphy-Riley solution (the color-producing reagent) were added to each flask. Murphy-Riley solution is made up of 1.056 g of ascorbic acid dissolved into water and mixed with 175 ml of Murphy-Riley reagent in a 250 ml volumetric flask. Murphy-Riley reagent consists of 111 ml of concentrated sulfuric acid diluted to 1000 ml with deionized water in a 2000 ml volumetric flask. Ammonium molybdate (9.6 g) was dissolved in water and added to this mixture and the flask was brought up to volume. The flasks were brought up to volume with deionized water and after 45 minutes to an hour the samples were measured on the spectrophotometer at 880 nm. A set of five standards, ranging from 20 to 100 ppm phosphate, and a blank were also run with this process. This method was taken from Kolb and Homburg (1991).

**RESULTS**

A total of 81 samples from below the plow zone range between 146 ppm and 3530 ppm P based on the XRF data. The mean value is 1048 ppm P, with a standard deviation of 597 ppm. The highest value came from sample L-19-1, taken in the northeast corner of the field. This value is 770 ppm higher than the second greatest value of 2760 ppm, from sample D-28-1. All the highest values were from samples taken along the northern edge and southeast corner of the field. A sample (STP I-07) taken in the southeast corner of the field (located at E 1030 N 1025) yielded a peak P value of 2580 ppm P; nearby STP J-06 (E 1035 N 1020) has an elevated P value of 1761 ppm. Figure 1 shows a contour of P values taken from below the plow zone and analyzed by XRF. The data gained from the acid extraction/spectrophotometry procedure are quite similar to the XRF data (Fig. 2), but they provide less coverage of the field, with only 28 samples analyzed. All the highest values come from the same STPs that produced the highest values during XRF analysis. The concentration of P is much lower for the chemical extraction procedure than for the XRF analysis (Fig. 2). The mean STP measured 1067 ppm P when analyzed by XRF, while the mean was 91 ppm P for the chemical extraction data. Samples analyzed from the plow zone range between 530 ppm and 1653 ppm P. The mean for samples taken from within the plow zone is 937 ppm, with a standard deviation of 336 ppm. The plow zone sample with the highest value is K-25-2, which was collected on the east side of the field on the northern end (Fig. 3). A sample taken close by, J-26-2, has a comparable value of 1543 ppm P.

**DISCUSSION**

The data analyzed by XRF from samples taken below the plow zone (Fig. 1) indicate three main areas of interest. Each of these areas are supported both by high P values from the chemical extraction data (Fig. 2) and by high artifact counts (Fig. 4 and 5) or total artifact weight (Fig. 6). Since the XRF data correlate well to the chemical extraction data and provide a more comprehensive analysis of the Podere Funghi, they will be used for the discussion. There is a large difference in the P values obtained by XRF and those obtained by chemical extraction, as seen in the results or by comparing the scales.
Due to the age of the P in the samples, there is a good chance that the acid was unable to bring all the P into solution. Another factor is that the coloring reagent (the Murphy-Riley solution) only reacts with orthophosphates, so if significant portions of the archeological P have mineralized, they would not affect the coloring reaction. Chemical extraction of P has been used for archeological purposes for years and is a widely accepted procedure (Holliday and Gartner, 2007; Oonk et al, 2009). XRF analysis for P is not yet a widely used method in archaeology (Marwick, 2005). The chemistry data must therefore be taken as a guideline showing relative concentrations, rather than absolute concentrations. However, the close correlation between the XRF and the chemical extraction data (Fig. 1 and 2) shows that for the purposes of this project, XRF analysis is a highly effective method for quickly measuring total P.

Figure 1. Samples taken from below the plow zone and analyzed by XRF. Circles represent sampling locations. Note high P values in the southeast, northeast and northwest corners.

Figure 2. Samples taken from below the plow zone and analyzed using acid extraction and colorimetry. Circles represent sampling locations. Despite the smaller sample size, there are strong correlations between figures 1 and 2.

Figure 3. Samples taken in the plow zone and analyzed with the XRF. Circles represent sampling locations. Although the data set is small, note that the values of the plow zone samples fall in a relatively narrow range around 1000ppm P. The peaks in this graph are much lower than those of the samples taken from below the plow zone. This shows that the plow zone is relatively homogeneous and that the peaks in Figure 1 are noteworthy.
strong correlation between high P values measured by XRF and areas where high artifact count and weight were recorded provides further support for the use of XRF. For this reason, the XRF data will be used as the primary dataset.

The southeastern corner of the field, I-07 (E 1030 N 1025) has a high P value of 2580 ppm P. This sample peak corresponds to nearby peaks in the artifact count. STP J-06 (E 1035 N 1020) has a very high total artifact weight (Fig. 6). Sample I-07 was also taken along the western boundary of a semicircle of high fine ware counts (Fig. 4). This area has high archaeological potential and would merit further investigation in the form of excavation, or at least some coring. In the northeastern corner of the field, high fine ware counts were recorded for several STPs, including L-19 (E 1045, N 1155). The highest P value was recorded from the sample taken from STP L-19, measuring 3530 ppm P. The coarse ware count is also elevated at L-19 (Fig. 5), so this area also has high archeological potential. The second highest P value comes from STP D-28 (E 1005, N 1150) in the northwestern corner of the field. The local artifact peak is just one STP north at D-29 (E 1005, N 1155). This could provide support for erosion carrying artifacts down slope. It is possible that the soil P is less prone to erosion than the artifacts, since the artifacts were taken from the plow zone and the P samples from below the plow zone. There were high artifact counts on several of the northern STPs, which are on a steep slope below the excavated area. Although there is a single high P value at I-27 (E 1030, N 1145) to support the high artifact concentration, there is a lack of P data in the area where there are high artifact concentrations in the northern section of the H row (E 1025) on Figure 6. Interpretations (by project co-director Bon-Harper) of the stratum just below plow zone provided the decisions of which STPs to sample for P. STPs that went down to solid or decomposing bedrock were not sampled. This means that
although the distribution of P sample locations does not evenly blanket the Podere Funghi, the areas that were not sampled are highly unlikely to have been occupation areas, at least in a way that would show up using P analysis. There are two exceptions. The first is in the northern center of the field where the building and kilns were excavated and no P samples were taken since these areas were not open for sampling during the 2008 season. The second exception is the southwestern corner of the field. No P samples were taken in this corner because 93 STPs were dug there in 2007, before any P samples were taken, and were refilled at the end of the 2007 field season, making the lower plow zone interface inaccessible to sampling.

The samples taken from within the plow zone provide a control for the data set taken from below plow zone. While the median value is almost identical for both data sets (851 ppm P below the plow zone and 828 ppm in the plow zone), the range of the plow zone samples is much smaller than from the samples taken below the plow zone. This indicates that the peak values seen below the plow zone are likely to be of archeological significance; since the plow zone is relatively homogeneous it provides a control and further supports the reliability of the XRF dataset taken from below plow zone.

CONCLUSIONS

Phosphorous analysis using XRF is an excellent method to add to the arsenal of techniques used in archeology. The data show three main areas of interest in the Podere Funghi for future exploration, one in the southeast corner, one in the northeast corner, and one in the northwest corner. These three locations each show exceptionally high P values that correspond to nearby high artifact concentrations. The steep slope north of the excavation also has a high P value, corresponding to high artifact counts in the general area and providing support for the possibility of erosion and down slope transport.

REFERENCES


Marwick, Ben, 2005, Element concentrations and magnetic susceptibility of anthrosols: indicators.
of prehistoric human occupation in the inland Pilbara, Western Australia: Journal of Archeological Science v.32, no. 9, p. 1357-1368.

Oonk, S., C.P. Slomp, D.J. Huisman, 2009, Geochemistry as an Aid in Archaeological Prospection and Site Interpretation: Current Issues and Research Directions: Archeological Prospection v. 16, p. 35-51.