MAGNETIC SUSCEPTIBILITY AND RESISTIVITY OF COLLUVIAL UNITS AT THREE SITES IN GREVENA, GREECE

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Introduction

Colluvial units containing cultural debris are found at the sites known as Potamia, Aghia Paraskevi, and Paleogla in the county of Grevena, Macedonia, Greece. The materials relating to human habitation that are most common in these colluvial units are potsherds from different time periods. Fragments of charcoal, burned mudbrick, and roof tiles are also found in the colluvium The purpose of this study was to determine whether the soil horizons containing evidence of human habitation differed in their geophysical properties from those horizons that are devoid of cultural materials. Such a relationship would allow sites in Grevena that are not *in situ* to be located using geophysical prospecting methods. The Grevena Project, for whom this study was undertaken, has been documenting sites throughout the county of Grevena since 1987.

Previous Work

Tite and Mullins (1971) and Thompson and Oldfield (1986) documented a correlation between elevated magnetic susceptibility of soils and human occupation levels at archaeological sites. Magnetic susceptibility is dependent on grain size and parent material of the soil. Mullins (1977) stated that magnetic enhancement of topsoil is a widespread phenemenon due to conversion of particles of iron oxide from a weakly magnetic form to a strongly magnetic form. Tite and Mullins (1971) found that fires and increased concentrations of organic materials at human habitation sites aid and enhance the natural processes of iron oxide conversion. Clark (1990) explored the relationship between cultural remains and resistivity anomalies. He stated that resistance of the earth is controlled by the amount and distributionof moisture in a unit. Cultural materials, as well as the porosity of the soil, will affect resistivity and create resistivity highs if the cultural remains are consolidated (e.g a wall) or resistivity lows if mositure is prevalent throughout the unit (e.g. in a ditch).

Field Work

We attempted to measure magnetic susceptibility of the colluvial units in the field using a Bartington susceptibility meter, but due to equipment problems, this was impossible. The samples were collected at measured intervals within given horizons in each soil profile. Stainless steel dental instruments were used to free the samples from the profile face. Soil was scraped from the profiles into plastic boxes about 8 cm^3 in volume. These samples were taken back to the United States for analysis. In November 1993, measurement of the magnetic susceptibilities was completed using a Bartington Susceptibility Meter with an MS 2B probe. The probe has a 36-mm inner diameter sample cavity. Measurements may be taken at two different frequencies, 0.46 kHz and 4.6 kHz; one measurement at each frequency was taken in order to observe the effect grain size might have on susceptibility of the sample. The masses of each sample were recorded, and the readings given by the MS 2B were converted into mass specific susceptibility measurements.

Resistivity was measured using different techniques at each site. The Wenner electrode configuration was used to test resistivity of the colluvial units in outcrop. This technique was experimental, but it was employed at Potamia and Paleogla with some success. A profile over approximately 60 m of colluvial unit MS5 at Potamia was also completed, as well as a mini-profile into the outcrop face of MS6. At Aghia Paraskevi, a sounding was completed along 50 m above soil profile OB53. A profile was also run on the outcrop face of this unit. At Paleogla, resistivity testing consisted entirely of soundings into the outcrop face of several different colluvial units. Results of the soundings were plotted on a bilogarithmic scale and matched with theoretical resistivity curves to obtain apparent resistivity values for the units measured (Orellana and Mooney 1972).

Results

Magnetic Susceptibility

Table 1 lists the susceptibilities of each of the units containing cultural debris from each of the sites studied. The susceptibilities of the soils from both profile MS5 and MS6 are similar. The anomalous unit in this group of soil horizons is horizon AB, with a susceptibility that is remarkably higher than all of the

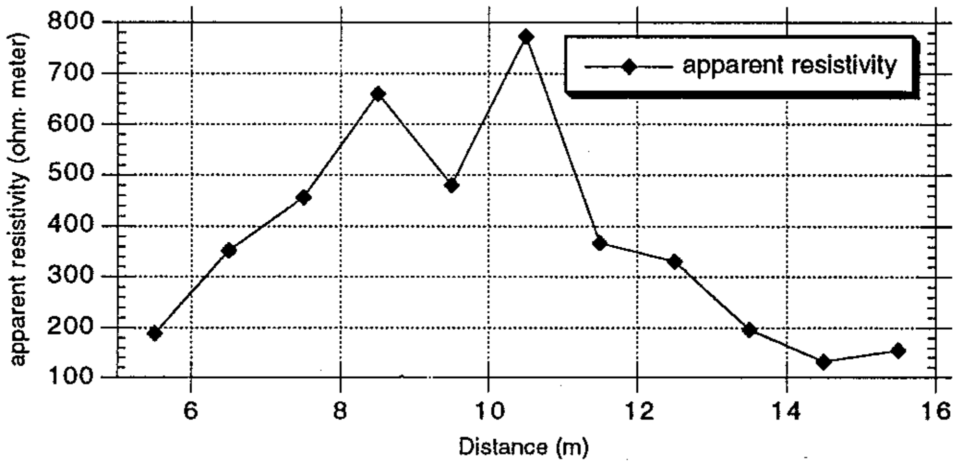

Figure 3. Resistivity profile over a known wall at the Paleogla site. The wall is located at 9-11m.

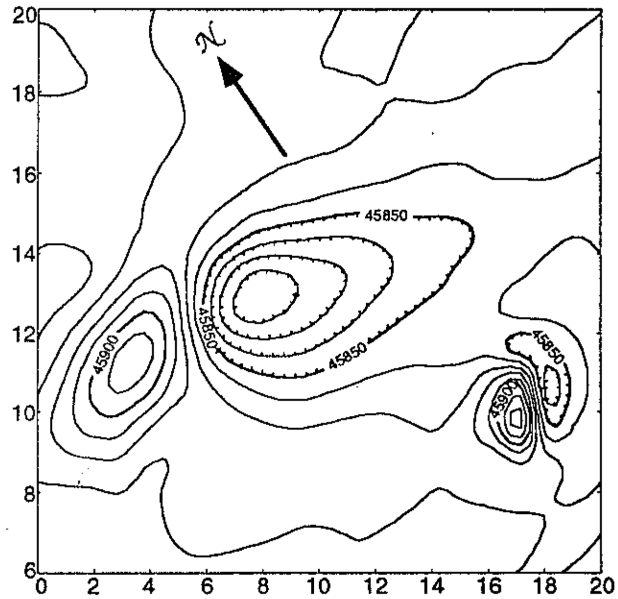

Figure 4. Contour map of data from the Asprokambos site, showing two distinct dipole anomalies.

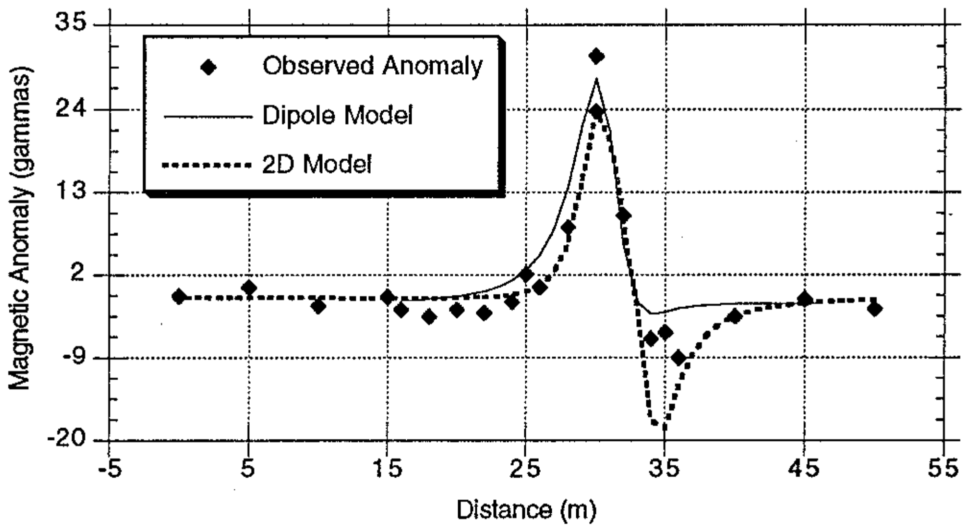

Figure 5. Model of magnetic anomaly at Emilianos. The observed data are plotted over the two models: 2D rectangle (3.3m x 1.8m, depth=1.7m, susceptibility $=3x10^{-4}$) and sphere-dipole (radius=1.2m, depth=1.5m, susceptibility $=3x10^{-4}$).

other low frequency measurements. The profile that it comes from consists of a colluvium that was noticeably different from the colluvium in profile MS5; MS6 was a more compact unit and was redder in colour. This might indicate the presence of more hematite in MS6 as a whole, and thus explain the overall trend towards higher susceptibility that the readings from this profile seem to indicate. At Potomia, the magnetic susceptibility of the bedrock, which was a buff sandy mudstone, is lower than the susceptibility readings of all horizons in profiles MS5 and MS6.

At Aghia Paraskevi, that the lowest horizons in profiles OB53 and MS4 have the lowest susceptibilities. Savina and Doyle(1988) note that in horizon IIIACa, a piece of unusual "pie-crimped-edge" pottery was found, so there do exist cultural artifacts at that lowest level. The susceptibilites of the colluvial fills at this site resemble the high-susceptibility layer found at Potamia, namely horizon AB from profile MS6. When compared to the Plio-Pleistocene sands that underlie this site, which have a susceptibility like IIACa, it can be said that the occupation layers have an overall higher magnetic susceptibility.

Paleogla is a site at which the susceptibilities are highly variable. Profile OB29 (Savina and Doyle, 1990) contains a dark black layer probably composed of a concentration of organics. This profile also contains the remains of a wall. The horizon with the highest susceptibility in this profile is IIA12, and sandstone blocks of the wall as well as charcoal can be found in this level. The susceptibilities of the two other horizons in the profile, IIA11 and IIAB, are remarkably lower in both low frequency SI and high frequency SI readings. In general, it may be said that those units at Paleogla with the highest susceptibilities: PG4 C, PG4 IIB2, and PG4 B4 - all contain either charcoal or mud brick. The presence of fire at this site does not always seem to elevate susceptibility, however; profile PG5, which is a very thin profile composed of a fire pit and an occupation layer, has remarkably low susceptibility in the horizons surveyed. The bedrock at Paleogla, composed of Plio-Pleistocene gravels, cobbles, and sands, has an average susceptibility of 1.59×10^{-8} SI units low frequency and 1.59×10^{-5} SI units high frequency. In comparison with the bedrock, then, the magnetic susceptibilities of the colluvial units appear overall to be higher.

Resistivity

Figure 1 illustrates the results of the profile completed over colluvium MS5 at Potamia. A profile was also completed in the outcrop face of profile OB53 at Aghia Paraskevi. The a-spacing of the electrodes in each of the four horizons surveyed at OB53 was 10 cm; any slight error in spacing would have affected the results tremendously. However, the results indicate higher resistivity as one moves down the profile. According to Savina and Doyle (1988), artifacts are found even in the lowest horizon of this colluvium. The profile does not indicate that any one horizon in soil profile OB53 has an anomalous resistivity. Comparatively, the profile results over colluvial unit MS5 at Potamia are much more variable. They seem to suggest numerous subsurface conditions that alter the resistivity along the outcrop. Because this soil profile consists of a colluvium made up of in part by different sized pottery fragments overlying Plio-Pleistocene mudstone, it is no wonder that the results of the profile indicate many subsurface anomalies.

The results of the sounding over horizon OB53 indicate that it is much less homogenous than the profile in the outcrop face would have one believe. The theoretical curve that best matches the points given by this sounding indicates that $r_1 = 200$ ohm-meters. This curve does not fit the data points very well, however, and it can thus be inferred that the layers of the colluvium over which the sounding was completed are not very homogenous, since resistivity was so variable along a 50 m spread. The sounding completed on layers of profile OB29 indicate that each layer has a very different susceptibility. However, these data are very noisy. Horizon IIA12 has an apparent resistivity of 11 ohm-meters, while horizon IIAB has an apparent resistivity of 100 ohm-meters. Such lateral variability is unlikely within the distance of 30 cm.

Discussion

Geophysical prospecting methods can be used to locate areas of human occupation. The success of these methods is, however, site-specific. Enhanced magnetic susceptibility correlates with artifact-rich colluvium with varying degrees of success at Potamia, Aghia Paraskevi, and Paleogla. The horizons in which evidence of fire was clearly present, and yet there was no noticeable magnetic susceptibility enhancement, are somewhat baffling. They do, however, demonstrate that magnetic susceptibility testing is not an infallible indicator of human habitation in any given area. Aghia Paraskevi is the site at which experimental sounding in individual horizons gave the best result, yet the sounding over the outcrop seems to indicate that resistivity of the materials in the outcrop may not be as homogenous as the individual horizon data indicate. High resistivity of layer IIAB in profile OB29 does correlate with a high susceptibility value for that same layer, but it is unlikely that the resistivity data for this soil horizon are reliable. However, presence of wall fragments in layer IIAB may be responsible for the high resistivity readings obtained from this layer; if this is the case, resistivity prospecting at profile OB29 supports the idea that individual cultural horizons can be identified by their resistive properties.

Acknowledgements

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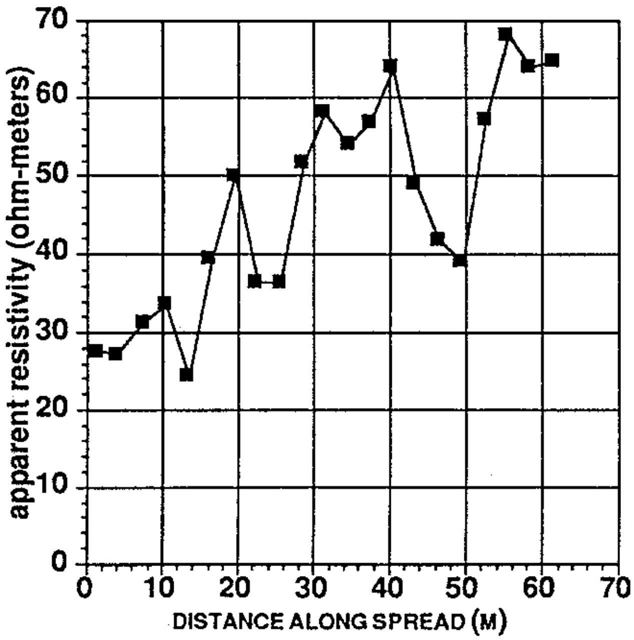

FIGURE 1
PROFILE OVER MS5, POTAMIA

TABLE 1. MAGNETIC SUSCEPTIBILITIES OF COLLUVIAL LAYERS WITH ARTIFACTS

POTAMIA

Profile MS5

horizon	cm	susc LF SI units x10^{-7}	susc HF SI units x10^{-4}
A1	0-7	6.48	6.33
Bw	7-24	5.94	5.79
IIAb	24-60	6.68	6.27
IIBw2	60-90	5.55	5.24
IIIBw3	90-200+	5.14	4.89

Profile MS6

horizon	cm	susc LF SI units x10^{-7}	susc HF SI units x10^{-4}
Aj	0-5	5.80	5.53
AB	5 to 28	1.49×10^{-6}	1.43×10^{-3}
Bt	28-70	5.59	5.28
Bkj	70-100	4.75	4.35
IIC	100-120	4.97	4.64

bedrock

susc LF SI units	susc HF Si units
6.18×10^{-8}	6.57×10^{-5}

AGHIA PARASKEVI

Profile OB53

horizon	cm	susc LF SI units x10^{-6}	susc HF SI units x10^{-3}
A12	8 to 30	1.39	1.34
A13a	30-53	1.09	1.06
IIACa	53-82	1.00	9.87×10^{-4}
IIIACa	82-145	8.51×10^{-7}	8.33×10^{-4}

Profile MS4

horizon	cm	susc LF SI units x10^{-6}	susc HF SI units x10^{-3}
A2	5 to 25	1.75	1.70
Bj	25-46	1.62	1.59
B2	46-75	1.31	1.28
BC	75-94	5.23×10^{-7}	4.97×10^{-4}

bedrock

LF SI units	HF SI units
5.37×10^{-7}	5.12×10^{-4}

PALEOGLA

Profile PG3

horizon	cm	susc LF SI units x 10^{-7}	susc HF SI units x 10^{-4}
B1	9 to 53	8.61	7.90
B2	53-100	5.84	5.25

Profile PG4

horizon	cm	susc LF SI units x 10^{-7}	susc HF SI units x 10^{-4}
C	7 to 15	3.94	3.73
IIABb	15-40	7.40	6.64
IIB2	65-109	4.30	3.82
B4	50-60	3.87	3.57

Profile PG5

horizon	cm	susc LF SI units x 10^{-7}	susc HF SI units x 10^{-4}
A	0-5	7.09	6.54
B1	5 to 49	9.20	8.53

Profile OB29

horizon	cm	susc LF SI units x 10^{-7}	susc HF SI units x 10-4
IIA11	5 to 35	8.68	7.81
IIA12	35-55	1.11×10^{-6}	1.00×10^{-3}
IIAB	55-95	8.62	7.31

Reconstruction of Topography at Archaeological Sites in Grevena, Greece

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Introduction

For the past several summers a large scale reconnaissance survey has been conducted in the province of Grevena, Greece which is located in western Macedonia. The purpose of this survey is to identify the locations of as many archaeological sites as possible and assess the possibility of future excavations. In order to determine which sites would be the best candidates for full scale excavation, several aspects concerning the landscape of the site must be taken into consideration. During the four weeks of field work in Greece, we attempted to answer some of the geologic questions at several different sites. The purpose of this project was to restore the landscapes of two sites to their appearance at the time of occupation. These two sites, Emilianos-Aghios Nikolaos and Potamia-Itea, are both located with in 30 km of the town of Grevena.

Emilianos is a Hellenistic/Roman site that is characterized by an abundance of pot sherds, burned mud brick, and roof tiles. The eastern portion of the site has undergone severe erosion, while the land to the west has a gentle slope. The eroded portion of the site is composed of heavily weathered shale and is dominated by a series of small scale ridges and gullies. The material that has been eroded is not present on site, but has been carried downstream by the river that is located at the base of the slope.

The second site, Potamia, is comprised of a colluvial fill rich in anthropogenic material, including pot sherds, mud brick, and roof tiles. The colluvium is bordered on the south by alluvium with virtually no archaeological debris and to the north by limestone-shale bedrock.

Methods

The methods used at the two sites varied due to the different processes that caused the landscapes to change in appearance. At Emilianos, where the topography was formed by erosion, extensive surveying was conducted to generate a topographic map of the present landscape. The surrounding gently sloping topography was used as a rough estimate as to what the now-eroded portion of the site looked like at the time of occupation. After the topographic map was generated, a series of trend surfaces of increasing order were fit to the present day surface to estimate the stages of erosion (Figs. 1 and 2). The surfaces created by the computer are based on mathematical functions of differing order. A first order function produces a plane, a second order function results in a simple curved surface, and higher order functions generate more complex surfaces that more closely resemble the actual topography.

In contrast, Potamia is a site characterized by depositional processes. The portion of the site which is of major interest, the area underlain by the colluvium, was investigated so that the correct amount of material could be replaced upslope. A survey done at a Roman site in Portugal indicates that the area receiving sediment is four to eight times larger than the area supplying the material (Clarke, 1992). This rough parameter was used in the reconstruction of this site as the area of deposition can be measured. Extensive surveying also was conducted at this site, and a topographic map of the area was again created. Electrical resistivity and magnetic surveys were then conducted to help determine the thickness of the colluvium. An expanding-spread traverse was run across the fill to estimate the thickness of the deposit. Five magnetic lines with different orientations were surveyed across the colluvium in an attempt to identify the lateral extent of the fill. Although the contacts are not clear from the magnetic data, the depth of the objects causing individual anomalies can be estimated using a profile of the anomaly and the relationship between the width of the curve at half-maximum value and the depth of the object (Telford et al., 1990, p.84) (Fig. 3). Several point source anomalies, caused by concentrations of artifacts in the colluvium, were present on the magnetic map of the area. By estimating the depths to these anomalies the results of the electrical resistivity survey are supported.

Once the thicknesses of the colluvium at different points is known, the volume of the material can be determined by constructing an isopach map of the colluvial deposit. Once this volume is known, this material is then subtracted from its present location and added to the slope above the deposit. The colluvium was replaced first by adding an equal amount to each point in an area roughly a quarter of the size of the depositional area on the upper slope. A linear relationship