The Nikopolis Project - Integration of Geophysical Prospection, Satellite Remote Sensing, and GIS Techniques in the Study of Epirus, Greece.

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ABSTRACT

As part of the Nikopolis Project, a multidisciplinary survey project in southern Epirus, a number of prospection techniques have been used to help address questions related to the settlement patterns of the region and the management of its cultural resources.

Geophysical techniques, including magnetometry, soil resistivity, and conductivity, were employed to investigate specific areas of archaeological interest and complement the data obtained by surface survey. These micro-regional geophysical surveys were able to identify a number of archaeological details, reconstruct the remnants of the surface archaeological features, and pin-point various subsurface patterns. Resistivity soundings and core drilling were carried out to enhance our knowledge of the stratigraphy and the vertical extension of certain features.

Satellite remote sensing techniques have also been employed to facilitate the study of the wider region. Supervised classification was utilized in the analysis of SPOT satellite images in an effort to correlate landscape features with archaeological sites. The procedure was successful and resulted in the discovery of several Paleolithic findspots.

The results of these analyses will be integrated with other project data in a GIS to be used as an analytical tool for the management of the cultural resources of Epirus.

The use of the various remote sensing techniques illustrates their importance in studying the regional level dynamics of ancient landscapes.

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INTRODUCTION

A number of prospection techniques have been applied complementary to the systematic surface surveying as part of a large scale multidisciplinary campaign in Southern Epirus (NW Greece) with aim to study the diachronic settlement patterns of the region and examine the interaction among human occupation, environmental variation, adaptation through time and land resources. The area of investigations covered a broad region of about 800 km^2 extending north from the Ambracian Gulf to Louros River near the modern city of Ioannina. The need of the archaeological iresearch in the area was imposed by the critical expansion of industrial and tourist development that threatens the archaeological relics of the region under study.

The Nikopolis Project has been conducted under the auspices of the Centre for Archaeological Studies of Boston University as a joint untertaking with the Greek Archaeological Service (12th Ephoreia of Prehistoric and Classical Antiquities, directed by Angelika Dousougli and the 8th Ephoreia of Byzantine Antiquities, directed by Frankiska Kephallonitou). The project was also sponsored by the American School of Athens.

In four survey seasons (1991-1994) more than 20 sites were investigated through the use of geophysical prospection, balloon photography and satellite remote sensing techniques. Half of the above sites, of Bronze/Neolithic Age up to the Byzantine era, exhibiting increased concentration of sherds or important surface archaeological remnants, were investigated through the application of geophysical prospection techniques. Total magnetic field measurements (difference mode and pseudo-gradiometer technique), electromagnetic and soil resistance measurements, including resistivity soundings, were carried out covering a total area of more than 2 hectares (10,756 sq. m. for the 1994 survey season). Tethered balloon photography was applied in a number of sites in order to obtain a closer picture of the surroundings of sites with important surface monuments. Multispectral satellite imagery was also employed covering the extended area of interest. Image processing techniques, including multivariate statistics and supervised classification techniques were capable in pinpointing soil category areas of remarkable archaeological interest.

GEOPHYSICAL SURVEYING

The methodology followed during the geophysical prospection module of the project was intended to study further the areas identified as sites of particular archaeological interest on the basis of surface finds and sherd distribution identified by the surface survey. The intra-site geophysical survey was carried out using different prospection techniques.

The magnetic surveys were conducted using two Geometric 856 proton magnetometers. Measurements of the total magnetic field intensity were taken with a sensor height of 30cm above the surface and 1m step interval. In a few

cases, a sensor height of 70cm was used as well. In both cases, the raw magnetic data were corrected for the diurnal changes of the earth's magnetic field. In other cases, the pseudo-gradiometer method was applied in an effort to minimize the high frequency anomalies originating by large metallic pieces or surface modern structural features.

A Wenner configuration with spacings of a=0.5, 1.0 & 1.5m was used in electric soundings with a Geohm-3 Soil Resistance meter. The geometric factor (ñ=2ða . R) was applied to transform the data in resistivity units. The same configuration was used in soil resistance mapping (a=0.5m).

A Geonics EM-31D electromagnetic conductivity meter was also employed in a few cases (Ormos Vathy/Agios Thomas & Grammeno) because of the need to investigate at a depth larger than 1-1.5m. The conductivity survey was performed with a 3.7m distance between the coils and 1m height above the surface of the ground, while the coil dipoles were operating at a vertical level. The effective depth of investigation was considered to be ~5m below the surface.

A preliminary processing of the data was carried out right after the data collection. A more systematic processing followed after the survey season. A change of coordinates was applied in order to combine the separate contiguous blocks to produce a larger mosaic. Statistical analysis was performed for the common rows of the contiguous grids and a correction factor was introduced to achieve the best matching among them. Adjacent grids were combined and processed simultaneously. Gridding procedure made use of cubic spline interpolation. Filtering was also applied in certain cases of severe masking of the magnetic data due to large metal pieces. The removal of the first order magnetic trend (using a least squares' interpolation) was helpful in cases of strong geological magnetic influence. The application of the residuals, similar to the second derivative of the magnetic potential field, enhanced the details of the most interesting short range anomalies and emphasized their outline.

CASE STUDIES OF GEOPHYSICAL PROSPECTING

A summary of the sites investigated through the application of geophysical prospection techniques is provided in the table below. Most of the sites explored have proved to be of archaeological interest.

GEOPHYSICAL SURVEYING	
STRONGYLI	
GRAMMENO	
MICHALITSI	Lion's Tomb & Slag fields
KASTRI	Lower slopes of the Akropolis
ORMOS VATHY	Agios Thomas - Ancient Nikopolis Port
ORMOS VATHY	Agios Minas
ORMOS VATHY	"Kleopatra" site

RIZOVOUNI	Kastro (church plateau)
PALAIOROFOROS	Lower City
LOUROS RIVER	Kastro Rogon (lower region)

Soil resistance and total magnetic field intensity measurements have been obtained in an agricultural field lying in the plain of **Grammeno**. Recent plowing activities had exposed vast quantities (>35,000) of sherds. Geophysical prospection has +++++++++

A magnetic survey was also conducted at the site of **Michalitsi**, just SE of the peak of Kouveli. The survey was conducted in the lower slopes of the hill, at the edge of the Classical/Hellenistic cemetery with a characteristic lion monument (Lion Tomb) discovered by S. Dakaris in 1974. Magnetic surveying at the lower slopes of the hill has located a number of high intensity anomalies, probably associated to a metal kiln or smelting facility. This evidence is strengthened by the iron slag pieces that were found during the intensive suface survey prior to the geophysical survey and the vegetation contrast of the region. The search of the road leading to the Lion's Tomb at the site of Michalitsi has not been conclusive. Magnetic measurements and electric soundings were not capable in identifying any related anomalies in the vicinity of the ancient cemetary.

The geophysical survey in **Kastri** was carried out in three different areas lying in the lower slopes of the Acropolis. The most interesting of them was the area of the cisterns [identified by Dakaris], only one of which is currently visible from the surface. A magnetic survey, with two different sensor heights (30 cm & 70 cm), has identified a number of anomalies that are probably associated to a cistern system. The magnetic anomalies were also verified with electric soundings.

In 1994 field season, three grids were laid out in the site of **Agios Thomas, in Ormos Vathy** that has been identified as the port of ancient Nikopolis. A total area of 1600 m^2 was covered with both magnetic and electromagnetic techniques.
A number of linear features, perpendicular to one another, along with other isolated anomalies are obvious in both datasets. Different processing techniques emphasize various kinds of anomalies. The high frequencies of the quadrature component of the EM-31D conductivity meter (proportional to the soil conductivity) exhibit an infrastructure of linear anomalies, two of which extent in the W-E direction and one of them in the S-N direction (parallel to the coastline). The in-phase component of the EM-31D conductivity meter (proportional to the soil magnetic susceptibility) has shown similar results. Shadowing techniques have drastically enhanced the corresponding anomalies. It has to be stressed

that the depth of investigation is larger (~5m) than the one corresponding to the magnetic prospection of the site.

A common profile was also chosen to be scanned with all methods in order to verify the existence of the subsurface features. A tranverse extending in the S-N direction was scanned with a proton magnetometer (h=30cm and 70cm), the EM-31D conductivity meter (measurements of both quadrature and in-phase components) and the soil resistance meter (Wenner array, a=0.5m and a=1.0m). Most of the geophysical anomalies registered in all datasets, providing further support for their presence.

A magnetic and pseudogradiometer (h=30 & 70cm) survey was conducted in the area of the church of **Agios Minas**, in **Ormos Vathy**. Around the church there have been signs of ruins of an ancient building, portions of which have become an integrated part of the interior of the church. A strong magnetic trend originating from the building masked the data around the church. The external magnetic noise was decreased in the map of the magnetic gradient, which shows a close similarity to the residuals of the total magnetic field intensity data. A number of interesting linear anomalies extending from the church show portions of the outline of an ancient building, possible a small temple. Another grid in the area between the church and a modern cistern was found to include a number of isolated anomalies, some of which are of dipole nature and may be related to shallow iron fragments. Other linear features, in the eastern part of the grid, may be related to structural remains.

A magnetic and soil resistance survey was carried out over an area of 2400m^2 in **Kleopatra's site** of **Ormos Vathy**. The landform was saddle shaped and a distribution of sherds and lithic tools was obvious on the surface. A curved feature that runs from the NE part of the surveyed area to the west side is obvious from the magnetic data. A Wenner array resistivity survey (a=1m) was not able to confirm the above feature, which is probably related to the flow of organic material due to soil erosion during the rainy season.

Three grids were investigated during the geophysical survey of the lower city of **Palaioroforos**. One of them was laid out over the remains of an ancient structure. An intensive surface survey was performed right before the geophysical survey in order to examine the possible correlation with the magnetic anomalies. The outline of the structure is emphasized in the map of the magnetic residuals. Some other magnetic anomalies within the structure register quite well in relation to the tile and the total sherd concentration suggesting evidence of an internal activity area.

In addition to geophysical prospection surveying, a geological coring was performed in various sites under the auspices of the Archaeometry Lab of the University of Minnesota at Duluth. Surface surveying data and coring samples have indicated that in ancient times the coastal line along the **Phanari bay** (at the mouth of the Acheron River) was extended about 3-4 km inlands. Preliminary examination of cores has also suggested that in antiquity, there were periods

during which the **Ambracian Gulf** extended north up to the mountain line surrounding the Thesprotiko valley. Although cores suggested that the Holocene marine transgressions extended up to the mountain ridges, sites of higher elevation, like the plain of Grammeno, were not flooded during this period - in contrast, as it was confirmed by the geophysical prospection results, there was intense habitation activities

REMOTE SENSING & GEOGRAPHIC INFORMATION SYSTEMS (G.I.S.)

High quality SPOT images of the wider region have been enhanced through various filtering techniques and have been used in the preliminary survey plans for overlaying surface survey information regarding the culrural remains, environment and the landscape.

Satellite images have been especially successful in locating exposed deposits of Plio-Pleistocene sediments ("red beds"). The early stages of the surface survey campaign have shown a clear correlation between exposed deposits of Pleistocene sediments and Paleolithic sites. According to T. van Andel, red beds were formed in shallow basins (as a result of local faulting) which were filled by limestone clays and have been subsequently exposed to periodic flooding and evaporization episodes. The red beds of **Kokkinopilos** have been selected as the training site for the supervised classification that followed. The characteristic spectral response (signature) of the site was calculated based on multivariate statisical analysis and it was eventually used for searching the entire image for areas of similar spectral characteristics. The adjustment of the standard deviation of the spectral signature was achieved through the interactive feedback by the survey data. About 0.06% (~100 hectares) of the entire image was identified as having a similar spectral signature.

Ground-truthing followed the image processing analysis. About 6 locations, falling in the above spectral category, were surveyed in the subsequent field seasons. Five of them have shown clear evidence of lithic scatters associated to red soil deposits. One area, lying SE of Kokkinopilos, on the opposite side of the Louros River, was characterized as a Middle Paleolithic site, based on the typology of the lithic material. Two other areas, one located SE of the modern village of **Thesprotiko** and the other near the coast, east of the village of **Kastrosikia**, were found to be related to agricultural fields with distinct reddish sediments bellow a shallow soil horizon.

Although the relation between red soil sediments and Paleolithic sites is still under investigation, it is clear that the correlation between them is high. In these terms, satellite remote sensing, through image classification techniques, has proved to be a powerful tool of site discovery. The validity of the above results is expected to provide the stimulus for expanding the search in isolating the spectral signature of other archaeological-related features, such as ancient limestone quarries.

In addition to satellite imaging, balloon photography took place at the sites of Ayios Yeoryios, Palaiorophoros, Kastri Rizovouni and Kastro Rogon. Aerial

photogaphs (grey scale, color and infrared) and multispectral imagery were obtained through the use of a tethered blimp. Multispectral images were digitized and enhanced in the same way as satellite images. The submeter resolution of the balloon images has proved extremely useful in recording small dimension features.

Digitized topographic maps and aerial and satellite imagery were used for the production of thematic maps through processing by a Geographic Information System database. Topographic maps (1:5,000) of the Hellenic Military Geographical Service were digitized through Arc/Info and were incorporated to AutoCAD mapping system. The data have been integrated into a larger geographic information system (GRASS) that synthesized overlaps of topographic maps and remotely sensed images. The computer generated images have been cross-correlated to the actual landscape through a ground-truthing procedure. Portable global positioning systems (G.P.S.) with an accuracy of less than the spatial resolution of the images (<20m) have been used for calculating the actual location in the field. Topographic survey was carried out with an electronic total station, providing digitized measurements that were eventually were used in Autocad drawing system.

CONCLUSIONS

Archaeological reconnaissance of the wider region of southern Epirus was achieved through a multidisciplinary survey project that managed to integrate a number of remote sensing techniques.

Micro-regional and multi-dimensional geophysical prospection techniques have been applied successfully in conjuction to surface surveying and core drilling, providing valuable information for the subsurface archaeological relics and their relation to the surface remnants. The application of different geophysical techniques was capable in mapping the details of the shallow archaeological features and increasing the confidence level about the suspected geophysical targets.

Satellite remote sensing managed to recognize and isolate the spectral signatures of red soil sediments and pinpoint areas that are related with the specific soil morphology characteristics. The results of the supervised clasification procedure and ground-truthing through surface survey has identified a number of Palaiolithic sites that are associated with red beds.

The integration of micro-scale geophysical prospecting and macro-scale satellite and airborne remote sensing has managed to provide a more detailed picture of the archaeological mosaic of SW Epirus. The results of the Nikopolis Archaeological Project are expected to become a valuable tool for the management of the cultural resourses of the region, stressing the importance of the integration of remote sensing techniques in the regional archaeological research.

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