A Multi-disciplinary Approach to Industrial Sites of the Vrokastro Region of Mirabello, Eastern Crete

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ABSTRACT

Since 2002, a multi-disciplinary geophysical and geo-archaeological project has been carried out in the wider area of Priniatikos Pyrgos, within the Istron coastal area, in eastern Crete. The site, consisting of surface or partially buried relics spanning the prehistoric (4000 BC) to Roman periods and later historical periods, constitutes one of the best examples of the diachronic exploitation of the coastal regions in Crete. The goal of the project is to identify the function, size, and condition of the site of Priniatikos Pyrgos in relation to other coastal settlements in the Bronze Age and historical periods.

Topographic mapping through the use of EDM and GPS was employed for the mapping of the surface monuments and sites. Ikonos satellite imagery and a time sequence of aerial photographs were used for capturing the changes in the land-use patterns of the region. Further geomorphological information was collected through digitization of geological and environmental maps, together with a recent geological mapping survey and selected coring that was carried out in specific areas of interest. A number of plots were further explored through geophysical prospection techniques using magnetic, electric resistivity and electromagnetic methods. The above information was entered to a Geographical Information System which was connected to an elaborated database regarding the archaeological sites and their surrounding landscapes.

Geophysical data suggested that part of the site comprised workshop areas during the prehistoric and historical periods, indicating functional similarities to other ports identified on the northern and southern coasts, such as Kommos, Mochlos, Poros and Gouves. The workshop area was probably related to both ceramic production (mainly in the prehistoric periods) and metalworking (mainly in historical periods). Further evidence of architectural relics has been suggested by the processing of the geophysical data. Shallow trenching and the analysis of geological cores indicated that location of the Istron River near Priniatikos Pyrgos may have shifted over time and it is probably responsible for the deep colluvial deposition noticed in the wider coastal area. Finally, GIS tools have been used to further explore the cultural landscape by examining the communication among the settlements and the habitation trends in different chronological periods.

1. ARCHAEOLOGICAL EXPLORATION OF THE VROKASTRO AREA, MIRABELLO, EASTERN CRETE

In the early 20th century, H. Boyd, R. Seager & E. Hall began the archaeological exploration of eastern Crete excavating the Bronze Age town of Gournia, near the Isthmus of Hierapetra (Hawes *et al.*, 1908). This Neopalatial town was clustered around a small palace, the only regional administrative center yet to be identified in the Mirabello area. In 1903, Boyd and Seager also looked for other sites for future excavations, and climbed to the summit of Vrokastro, a coastal peak west of Gournia.

Edith Hall returned to Vrokastro in 1910 and 1912, and excavated a Bronze Age and Early Iron Age settlement and related cemeteries for the University Museum in Philadelphia (Hall, 1914). The settlement of Vrokastro remains one of the few excavated sites belonging to this time period within Crete. Although Hall's work was pioneering, she acknowledged in her 1914 publication of the site that the area surrounding the settlement was rich in antiquities: "A circuit of five kilometers indeed would scarcely include the district where traces of geometric remains abound." (Hall, 1914: 82). During the last week of her 1912 excavation season at Vrokastro, Edith Hall began a small excavation of a Roman and Minoan port town, or "shipping station" as she called it, on a small sandy coastal headland below the peak of Vrokastro. Its importance is demonstrated through its size, quality and variety of artifacts, especially pottery, and widespread trade contacts. Hall's last excavation season at Vrokastro was not followed by archaeological fieldwork in the area. Several decades were to pass before Barbara Hayden, of the University of Pennsylvania, continued Hall's early exploration. This renewed investigation of the settlement of Vrokastro included a new plan of the site and a new publication of the Vrokastro pottery and figurines excavated by Hall (Hayden, 1983, 1991, 2003).

The Vrokastro Archaeological Survey Project (1986-95) continued investigation of this important site and the region; this project was directed by B. Hayden and J. Moody (2004, 2005). This intensive, systematic survey was initiated in order to document the archaeological, historical, and environmental framework for the settlement of Vrokastro and other

ancient to medieval sites within the region. Another goal of the survey was to determine which regional site might merit further exploration, including excavation. Specific publications of the survey included papers concerning the development and settlements of the region during the Archaic period (Hayden, 1995) and the Final Neolithic-Early Minoan periods (Hayden, 2003) (Fig. 1). The Vrokastro Survey was implemented through a four-part research program that included an archaeological, historical, scientific, and ethnographic component.

The final goal of the Vrokastro Survey was to determine which site within the survey boundaries merited further exploration, including excavation. The small coastal headland of Priniatikos Pyrgos, first excavated by Hall in 1912, became the focus of the next stage of regional exploration – the Istron Geoarchaeological Project (2002-2006). This site was selected for further investigation based on its broad chronological range, which encompasses most of the Bronze Age and a large part of historical antiquity, the quality and variety of artifacts found on the promontory, and its potential function--that of a gateway or primary harbor site the west-central Gulf of Mirabello.

2. TOPOGRAPHIC MAPPING AND GEOPHYSICAL INVESTIGATIONS

During the period of 2002-2003, EDM and GPS mapping was carried out along the coastal zone, from the base of Ioannimiti to the promontory of Vrionisi, while the geology mapping included the registration of tectonic blocks and fault scarps, analysis of sediment cores and the enhancement of the geological map. GPS measurements (Fig. 2) were focused in contributing to the EDM mapping of the ancient sites, geological/geomorphic features, and areas where remote sensing was conducted, and also in establishing ground control points for the rectification of the Ikonos satellite imagery. The GPS survey was expanded from the base of Ioannimiti to the promontory of Vrionisi.

The remote sensing survey employed ground based techniques (magnetic, soil resistance and electromagnetic techniques), auger coring for studying the distribution of the magnetic susceptibility, aerial and satellite imagery for mapping the surface architectural remnants and digitization techniques and GIS for the representation of the distribution of sites in the three-dimensional relief in order to study their relations to the natural settings of the region. In 2002, geophysical grids were laid out on the promontory of the Priniatikos Pyrgos and in the vicinity of it, while in 2003 they were expanded further to the east, south and west of the promontory (Fig. 3). Most of these areas were located in olive grove or uncultivated fields, where concentration of sherds and/or worked stones has been seen.

In the geophysical survey, a Geoscan FM36 fluxgate gradiometer was used for measuring the vertical magnetic gradient with an effective investigation depth of about 1-1.5m. Similar penetration depth was also achieved through the use of a Geoscan RM15 soil resistance meter employing the Twin probe configuration of electrodes with a 0.5m separation of the mobile probes. A Geonics EM31 conductivity meter was used for measuring the soil conductivity and soil magnetic susceptibility having an effective investigation depth of about 4-6m. A specific map coordinate system was chosen for each geophysical mosaic of grids, which was registered to the appropriate geodetic system of coordinates (namely EGSA'87), based on the GPS/EDM mapping data. Thus, after the rectification of the satellite image, it was possible to overlay the geophysical maps at their corresponding location. In terms of regional archaeological surveys, the specific project is one of the few to employ a suite of geophysical and satellite remote sensing techniques in Crete. Similar methodology and mapping techniques were applied during the survey project at Itanos (E. Crete) (Sarris *et al.*, 2002; Vafidis *et al.*, 2003).

Pre-processing of the data was needed in order to create a common base level (0-level base line) for all grids. Processing of the adjacent grids was conducted simultaneously through kriging interpolation. Selective despiking techniques and compression of the dynamic range of values were also employed to isolate anomalies close to the background level. The above processes were carried out through the use of the GPP package (Kalokerinos, *et al.*, 2004). The GPP package has been developed on a LINUX platform by using GCC compiler and then was ported using Borland C compiler in order to be executed in a command (GCC) window in WINDOW NT environment. Pre-processing options of the GPP include geometry correction of the grids, evaluation of statistical parameters, and mutation of dummy values and shifting of the X, Y coordinates. Main Processing includes the application of de-spiking techniques based to the noise level (estimated by the dynamic range of measurements and the standard deviation from the mean), grid equalization and line equalization to smooth out the data and to avoid stripping effects. Other filters such as high-pass filters (gradient) or the calculation of first horizontal derivatives have been helpful in emphasizing the high frequency components of the geophysical maps. Finally, interpretation maps were made based on the features that were identified during the different processing steps.

The results of the geophysical survey suggested a possible wall enclosure of the promontory to the north and the existence of kilns and furnaces at the central area of the promontory (Fig. 4). Metal slag fragments supported the hypothesis that some of these kilns were used as metal working facilities. More kilns, probably used for pottery production as there was no evidence of any surface slag distribution, were also suggested in the area located to the west side of the promontory (Fig. 5). The same region showed evidence of architectural relics, the alignment of which suggested that most of them belong to a specific occupation layer, although there is evidence for the existence of at least one more building phase. Measurements of the magnetic susceptibility carried out at soil samples collected along 3 different transverses suggested that the center of the activities of the settlement is located at the top of the promontory, although the settlement might

have been expanded further to the south with a less intensive occupation. Just a few traces of architectural relics have been suggested by the interpretation of the geophysical maps, to the south of the promontory, at the edge of the slopes of the hill. On the other hand, a higher density of architectural relics appears further to the south and to the east, where the village and soccer field are located. Taking in account the direction (towards the sea) of a couple of wide high resistance anomalies (probably correlated to disturbed soil, rubble deposition and other alluvium material carried away from older branches of the Istron River) located towards the SW and SE side of the promontory, it may be also suggested that the older Istron River branches were directed to the sea from both sides of the Priniatikos Pyrgos, leaving probably a small path to the mainland from the SW direction. If this hypothesis is true, then the settlement might have been expanded slightly separate from the workshop area, similarly to what it has been noticed at Gouves (Vallianou, 1997: 333), where in similar river delta settings, the center of ceramic production seems to be separated from the main settlement.
The above indicate that the coastal site of Priniatikos Pyrgos was used as a workshop – probably as a pottery workshop in the prehistoric period and as a metal working facility during the later phases of its occupation (roman period?). Located on a coastal hill in the middle of the flood plain of Istron River, the site offered ideal conditions for the operation of ceramic kilns and metal furnaces, as the NW winds could provide the necessary conditions for the firing of them. Still, the extent of site remains unknown and it is unclear if the site can be considered to belong to a harbor network where exchange of pottery and metal artifacts was taking part in the wider Mirabello bay.
In order to investigate the hierarchy of the settlements in different periods, a number of analytical tools were used in the Geographic Information Systems environment. Spatial distribution of settlements, clustering of sites, their correlation with the geomorphic attributes of the environment (altitude, slope, aspect, geology, etc), site catchment analysis, least-cost-paths and viewshed analysis were all included among the main processing procedures that were computed. The above processes were repeated for different periods in order to examine the diachronic evolution of settlement patterns in the landscape of Vrokastro region (Fig. 6).

3. GEO-ARCHAEOLOGICAL STUDIES

The location of Istron maritime area implies that the area follows the general subduction trend of East Crete. Moreover, a local river discharges diachronically its fluvial sediments within the Istron bay. Hence, the landscape evolution at the coastal zone of Istron area is governed by three simultaneously concurring and inter-affecting major agents: i) the sea-level oscillations due to the universal eustatism, ii) the local foresaid submerging tendency, and iii) the sedimentation of the fluvial/delataique deposits in the near-shore belts.
In the specific project, geological investigations involved field reconnaissance and *in situ* description of all the formations that make-up the Istron area. Further to our observations, associations to the neotectonic features were conducted. This led to the construction of a geological map of the project area, 1:5,000 in scale, corresponding to the selected piece of land, where all outcropping geological formations and the observed tectonic features were drawn.
Along, *in situ* studies were carried out on fluvial/deltaic deposits, aiming to assess the terrestrial and marine (or sub-limnic) depositional rate during the Holocene (last 10,000 years). Also, a series of coring, trenching and absolute dating techniques were involved in order to reveal geomorphic processes which might have affected on prehistoric and archaeological constructions and may occur along the coast line as well as to investigate the evolution of the Istron valley itself in the Late Holocene. Coring and trenching was carried out along a) the present course of the main river crossing the Istron valley in order to determine if the course of the river has changed and when this might have occurred, b) its estuary, where the river meets the sea and c) within the Istron valley, to determine how many meters of deposition occurred during cultural and pre-cultural periods, the extent of deposition during Bronze Age, Greek-Roman, and later periods. A total depth of approximately 50 meters of core was extracted using T101, Denison, double-divided and Auger types of coring. The cores were extracted placed in dark plastic tubes, thus enabling luminescence dating studies and other relevant processing. As far as trenching is concerned, ditches were excavated using backhoe. A total length of 25 meters (4 to 5.5 meters in depth) was dug in six trenches.
Field observations within the Istron area identifying alluviation processes on a mainly carbonate (limestones and marbles) bedrock, along with initial laboratory results support a steady and slow subsidence in the coastal zone, well suited in framework of the Late Holocene. Specifically, observations on fluvial deposits below the present riverbed, obtained by coring and trenching procedures, exhibit a transition from pebbles and cobles at bottom of the sequences to finer material to their upper parts. The pebbly section of these deposits indicates a depositional environment characterised by a lower mean sea level, when the river was extended to the exposed by the regression land. Under those circumstances, the river was able to transfer its coarser material further towards the sea. Later, the gradual transgression moved the delta of the river further inland and reduced the river's transportation ability. These new geomorphic conditions made coarser material to deposit further inland, allowing only the fine ones to be transferred at larger distances. Thus, the stratigraphic observations are in consistency with the local regime of subsidence.
Absolute chronology on the other hand, involved the application luminescence dating techniques (TL/OSL) on sand-sized quartz grains, dating the time of deposition of the sampled formations. All measurements for evaluating the natural absorbed dose (palaeodose) are carrying on, by using an automated RISØ TL/OSL reader. Moreover, measurements of

natural radioactivity at the accurate sampling points were taken systematically in order to conclude to accurate dose rate measurements. A portable NaI(Tl) scintillometer (Saphymo-stell, type spp-2) was used for this purpose. Besides, the project was also engaged in tracing geological formations within the project area which might have been used as raw materials in prehistory and antiquity. This investigation was carried out by associating objects, archaeo-technological remains and building stones to the local potential raw material sources.

4. FINAL REMARKS

Preliminary results of the Istron Geoarchaeological Project indicate that Priniatikos Pyrgos was the primary industrial center of the Vrokastro region for millennia (ceramics, iron-working), and exploration of its coastal environment has revealed its topographical setting and the probable location of a Minoan settlement that corresponds to the industrial quarter on the headland of Priniatikos Pyrgos. Continuing exploration of this site and its coastal environment will include an excavation of these industrial features (2005) and further exploration of the geomorphic and settlement history of the Istron coastal zone.

REFERENCES

HAWES, H. B., *et al.* (1908) – *Gournia, Vasiliki, and other Prehistoric Sites on the Isthmus of Hierapetra, Crete.* Philadelphia.

HALL, E. H. (1914) – *Excavations in Eastern Crete, Vrokastro.* University of Pennsylvania, The University Museum, Anthropological Publications 3: 3. Philadelphia: The University Museum.

HAYDEN, B. J. (1983) – New Plans of the Early Iron Age Settlement of Vrokastro. *Hesperia,* 52: 4, p. 367-387.

HAYDEN, B. J. (1991) – Terracotta Figures, Figurines, and Vase Attachments from Vrokastro, Crete. *Hesperia,* 60: 1, p. 103-144.

HAYDEN, B. J. (1995) – *Aegean Archaeology.*

HAYDEN, B. J. (2003) – *Reports on the Vrokastro Area, Volume 1.* Philadelphia.

HAYDEN, B. J. (2003) – Final Neolithic – Early Minoan I/IIA Settlement in Vrokastro Area, Eastern Crete. *American Journal of Archaeology*, No 107, p. 363-412.

HAYDEN, B. J., *et al.* (2004) – *Reports on the Vrokastro Area, Eastern Crete. Volume 2: The Settlement History of the Vrokastro Area and Related Studies*. University Museum Monograph 119. Philadelphia: University of Pennsylvania.

HAYDEN, B. J. (2005) – *The Vrokastro Reports, 3: Site and Pottery Catalogues.* Philadelphia.

KALOKERINOS, G., *et al.* (2005) – GPP: A Program To Automate The Geophysical Data Processing. *1st International Conference on Advances in Mineral Resources Management and Environmental Geotechnology, AMIREG 2004*, 7-9 June 2004, Chania – Crete, Greece.

SARRIS, A., *et al.* (2002) – "Ancient Itanos (Erimoupolis, Lasithi): Creating An Archaeological Site to a Remote Sensing Laboratory". *Archaeometry 98 Proceedings of the 31st International Symposium of Archaeometry (Budapest, 26 April – 3 May 1998),* Series Editors: E. JEREM & K. T. BIRO. *British Archaeological Reports (BAR) International Series 1043 (I): Archaeolingua Central European Series* 1, Archaeopress, Volume I, p. 157-164.

VAFIDIS, A., *et al.* (2003) – High Resolution Geophysical Imaging of Buried Relics in Itanos Archaeological Site. In DOERR, M. and SARRIS, A. – *Proceedings of the 30th Conference, CAA2002 International Conference: Computer Applications & Quantitative Methods in Archaeology: The Digital Heritage of Archaeology*, Herakleion, Crete, April, 2002, Archive of Monuments and Publications, Hellenic Ministry of Culture, p. 245-250.

VALLIANOU, D. (1997) – The Potters' Quartier in LM III Gouves. In LAFFINEUR, R. and BETANCOURT, P. P., *TEXNH II*, p. 333-343.

FIGURES

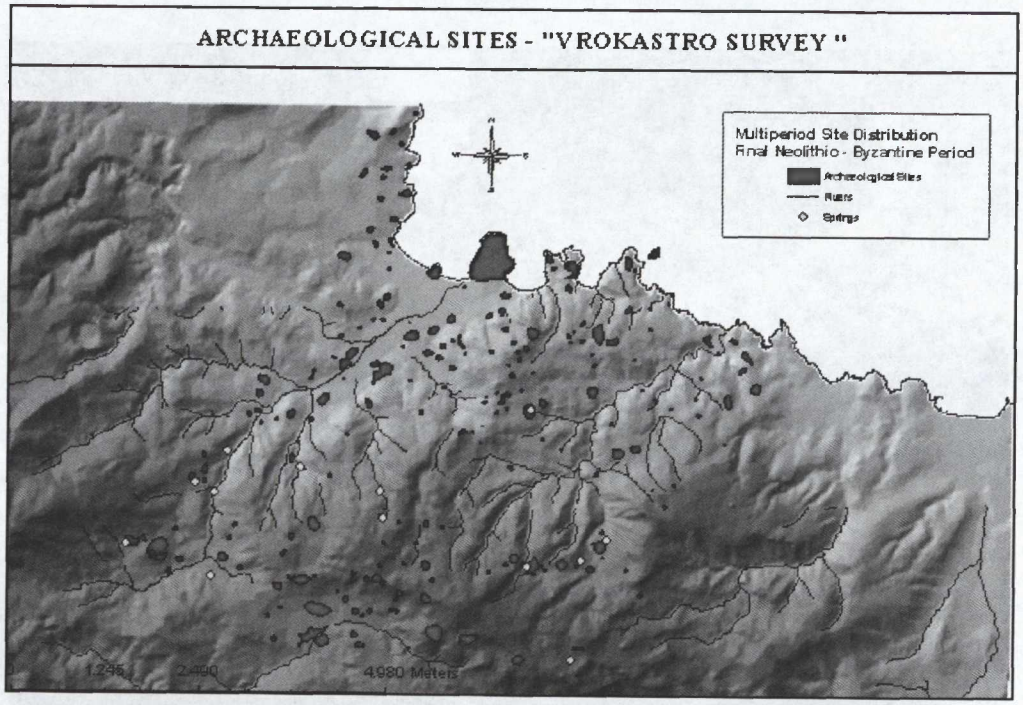

Fig. 1 – Map showing the coastal area of Istron and Priniatikos Pyrgos which constituted the focus of the Istron Geoarchaeological Project.

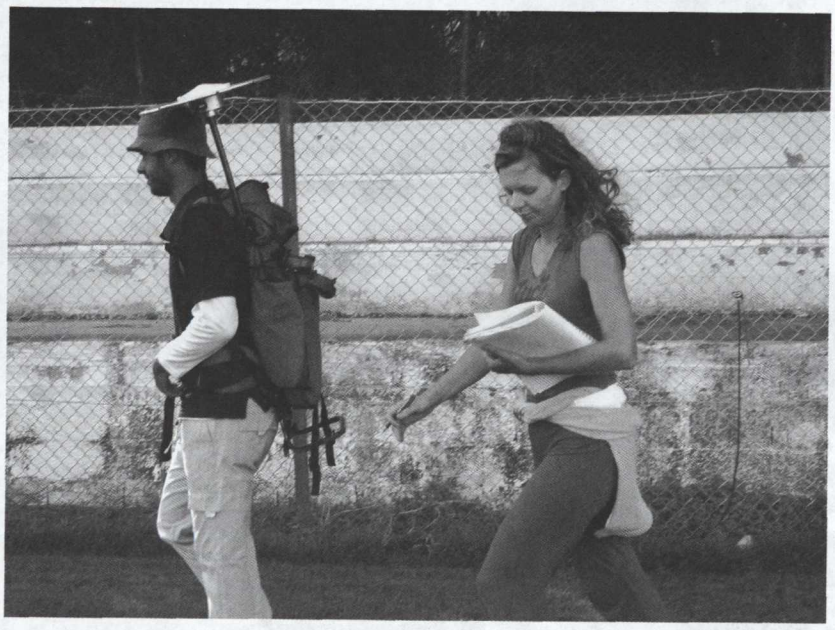

Fig. 2 – GPS survey was carried out using 2 Ashtech Z12 GPS receivers in differential mode. Static measurements were taken all over the area covered by the satellite image with emphasis on the coastal region of Istron.

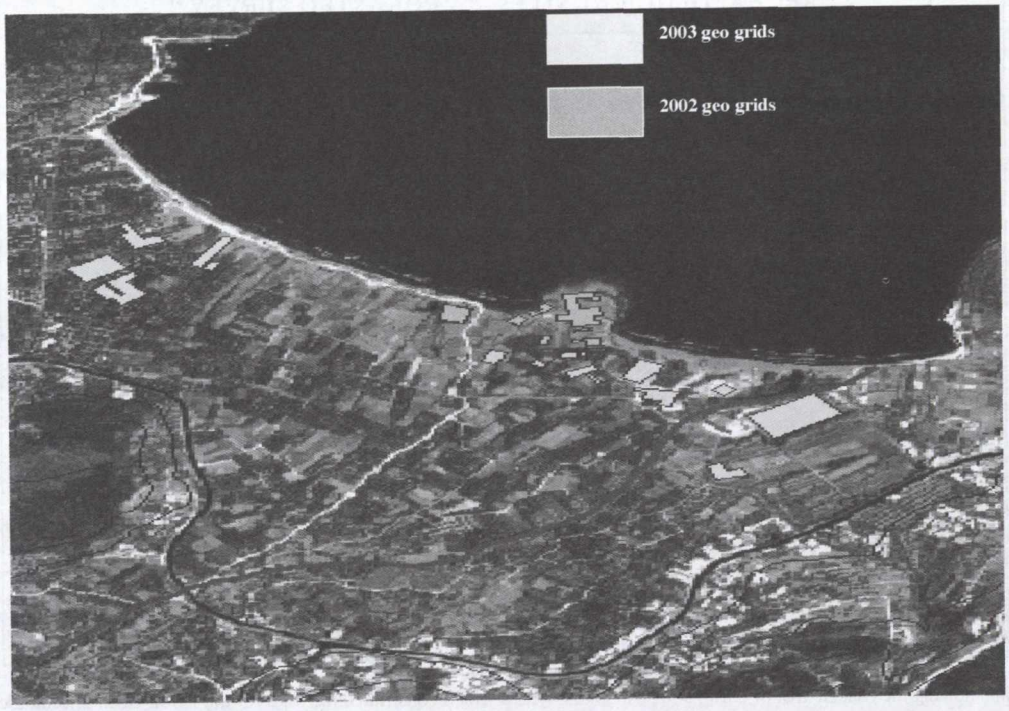

Fig. 3 – General layout of the geophysical grids scanned in both 2002 and 2003 field seasons, overlaid on the rectified Ikonos image.

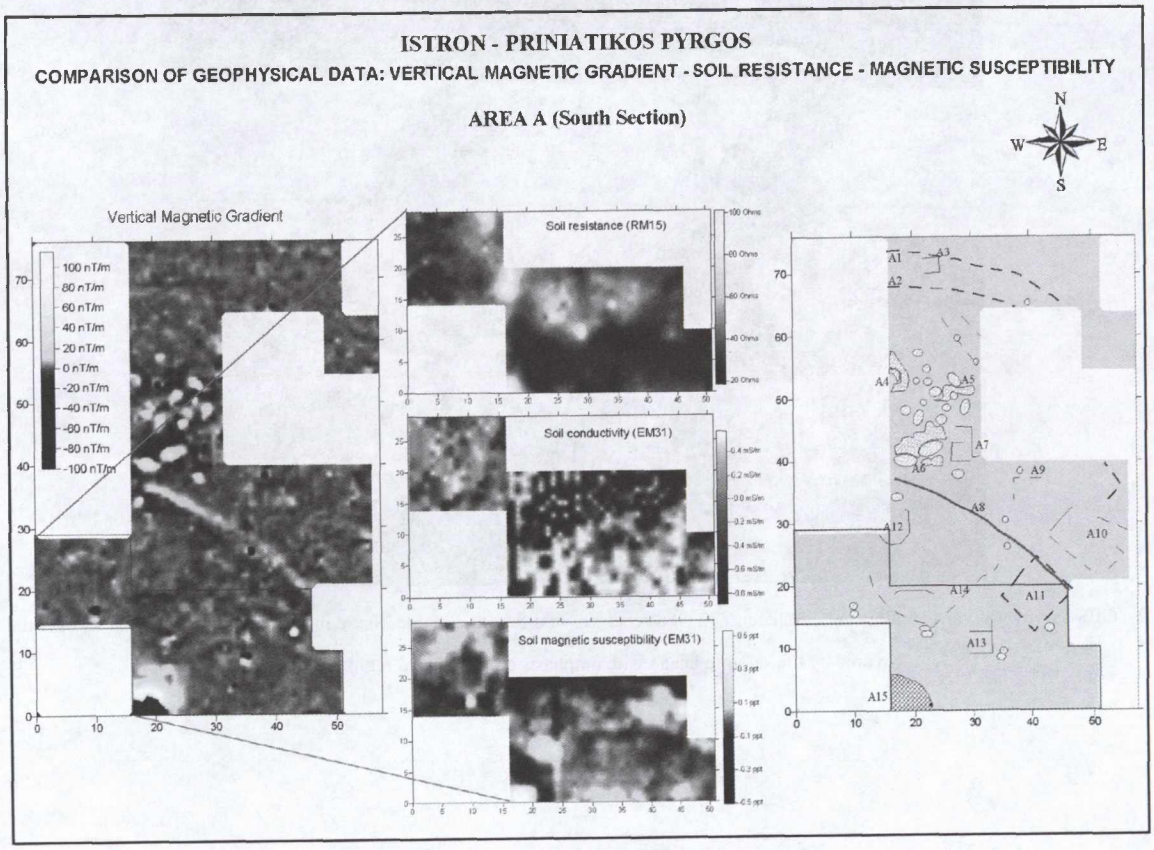

Fig. 4 – Geophysical mapping of the top of the promontory of Priniatikos Pyrgos.

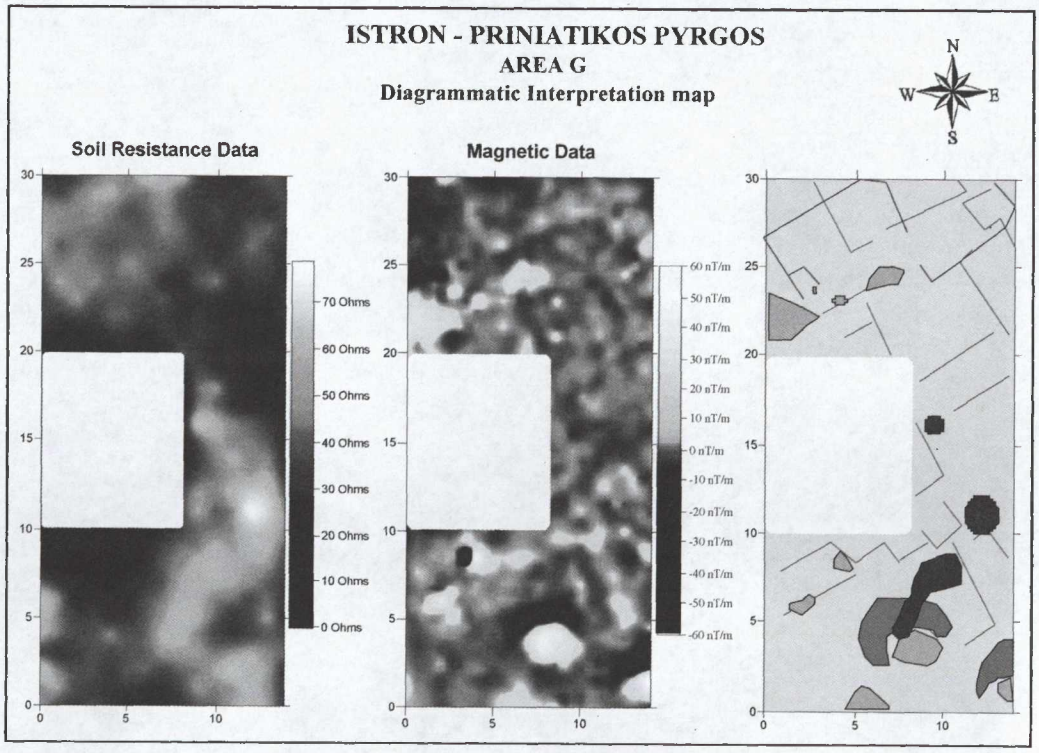

Fig. 5 – Soil resistance and magnetic measurements taken in the west side of the promontory suggested further evidence of kilns and structural remains.

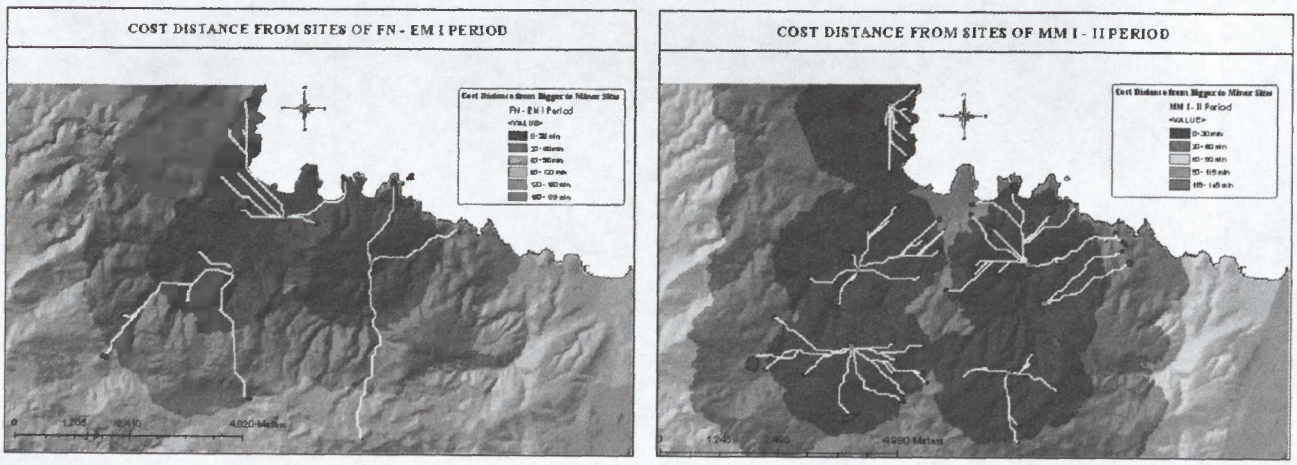

Fig. 6 – Cost distance analysis computed for two different periods (FN-EMI & MMI-II), indicating the evolution of the hierarchy of settlements in the region of Istron.