AERIAL AND REMOTE SENSING ARCHAEOLOGY IN EASTERN MACEDONIA, GREECE

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KEY WORDS: Aerial and Remote Sensing Archaeology, QuickBird-2, WordView-1, GIS, marks of Via Egnatia.

ABSTRACT:

A systematic and extended research was conducted in the area of Aerial and Remote Sensing Archaeology, in N. Greece (E. Macedonia), for locating new archaeological sites. Its main target was the locating of the marks of the buried ancient Via Egnatia that used to pass through two major ancient cities of the area, Amphipolis and Philippi. The research data consisted of historical and contemporary aerial photographs, diachronic QuickBird-2 and WordView-1 satellite images, as well as contemporary and historical maps. A new, targeted Geographical Information System was created for the documentation, management, study and analysis of the research data and the marks of the covered constructions. The system provides new management tools of spatial and descriptive information and even scientists with limited computer knowledge can use it with ease.

1. INTRODUCTION

Via Egnatia was built between 146 and 125 B.C., and it constituted the main roman military and commercial main road from Dirrachio to Constantinople. In the area of Eastern Macedonia (N. Greece), it passed through the Northwest foothill of mount Paggaio and it ensured the communication of two major ancient cities (Collart, 1937; Roman Numismatics, Art, History and Archeology, 1996-2009; Karadedos and Nikolaidou, 2006), Amphipolis and Philippi (Fig. 1).

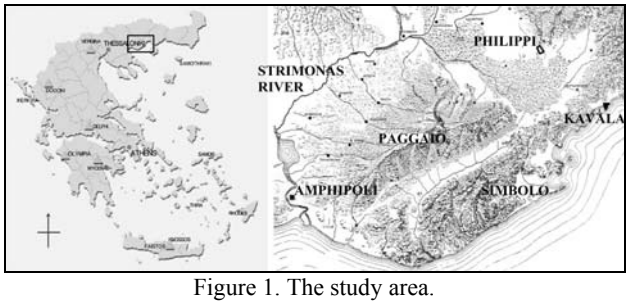

Figure 1. The study area.

In 2002, the inter-scientific group has conducted a research of Aerial Archaeology in the northwest of Philippi, where marks of the covered ancient road were located (Georgoula *et al.*, 2003). The excavation cuts that followed (2003 and 2004) in locations of the marks have proved the original assumptions (Karadedos and Nikolaidou, 2006). The positive results were the motive for the realization of a systematic research of Aerial and Remote Sensing Archaeology, for locating Via Egnatia from ancient Amphipolis to Philippi, which is a wider study area of a total size of 500 Km^2. The systematic, methodical procedure of the use of all the data (historic documents, diachronic aerial photographs, satellite images, maps, etc), that the research group suggests and follows, as well as the new GIS implemented for the correlation and management of data and marks of the buried constructions, have proven most valuable for the documentation not only of the position of the ancient Via Egnatia but also of thousands of others remains of archaeological interest, located on either side of it.

2. RESEARCH DATA AND THEIR PROCESSING

2.1 Contemporary maps

Six maps were gathered of a scale of 1:50,000, dated 1970, of the Hellenic Military Geographical Service (H.M.G.S.), six maps of the Institute of Geology and Mineral Exploration of a scale of 1:50,000 and forty nine maps of a scale of 1:5,000, dated 1982, of the M.G.S. The maps had a different projectional system and so, after their digitalization, they were georeferenced to a fixed modern reference system (Greek Geodesic Referencing System of 1987, EGSA 87). After completing their study, valuable conclusions ensued on the geomorphology and the pedological characteristics of the wider area. Apart from those, a contemporary cartographic background was derived (EGSA 87).

2.2 Historical maps

With the aid of digital technology (Balletti, 2000; Balletti and Miniutti, 2001; Guerra, 2000; Guerra *et al.*, 2001a; Guerra *et al.*, 2001b; Guerra, F. and Balletti, C., 2002; Guerra, 2002; Niederost, 2004; Kaimaris *et al*., 2004), the comparison between a historical and a contemporary map is achieved, resulting in the identification of locations, toponyms and the collection of valuable information regarding their historic development. Apart from those, constructions and settlements lost with time can be located in the historical maps and thus their locations can be identified in the background of contemporary maps.

It is for those reasons that a research for locating and collecting historical maps of the study area was conducted. In the National Centre of Maps and Cartographic Heritage, three historic maps of 1901, 1910 and 1925 were found, of a scale of 1:200,000, which contain valuable information for the locations and the names of the settlements of the time. The first map, of a scale of 1:200,000 (''KAVALA 42°41°''), is of Austrian-Hungarian publication and it constitutes the first scientific effort of cartographic depiction of the area of N. Greece. It's one of the 282 pieces of paper of the general military map ''Generalkarte'', made during the program of the third Austrian-Hungarian mapping (1869-1887) in the years of Francis Joseph I. The second map, of a scale of 1:200,000 and dated 1910, is a re-edition of the Generalkarte series. The third map, of a scale of 1:200,000 and dated 1925, is the result of the Greek re-editions of the ''Generalkarte'' series by the Cartographic Military Service, during the years 1920 to 1926 (EKECHAK, 2003). Four (4) more modern maps, of a scale of 1:50,000, that also cover all the study area and were drawn up by the American army in 1945 were discovered in the Mining Inspectorate of N. Greece. Eight historical maps dated from 1916 to 1928 of a scale of 1:20,000 to 1:100,000 were also collected.

A special category of the maps used was that of the seventy six (76) maps of the Spatial Distributions of the rural properties, of a scale of 1:5,000. They are drawn up by the Greek State for all the Greek area sectionally, in the course of fifty (50) years (~1925-1975). For the present study, they are included in the historical maps, since in the study area they concern the time period between 1928 and 1940.

The overlapping of historical maps with contemporary ones has lead to useful conclusions (Kaimaris *et al.* 2004), such as the specification of the historic development of toponyms and the location of unknown historic settlements and constructions (for example, possible locations of bridges of the ancient Via Egnatia) in the study area (Fig. 2). Finally, the historical maps of the Spatial Distributions of the rural properties were a valuable tool for the acceptance or the rejection (Georgoula *et al.*, 2003) of the initial interpretations of the traces that came up during the photo interpretation of the telescopic images (for example, the identification of a linear mark of a covered rural road of 1930).

2.3 Selective Field Study

During the Selective Field Study, a handheld GPS was used, a contemporary small scale map and a digital camera for the photographic documentation and the identification of coordinates of all high interest locations such as architectural remains. Locations identified in the historical maps were also searched on the field. Other than those, information was verified (source: competent state authorities) and collected, where that was deemed necessary, regarding the types of soil (rocky, fine, thick, mixed, etc) and vegetation (barley, tobacco, natural field, etc) cover.

In Figure 2 appear the known archaeological locations of the historic years of the wider area (source: competent public archaeological service) as well as information that came up during the processing of the historical maps and documents. For instance, the locations of the "miliaria" (marble columns on which the distances from the great cities were recorded in roman miles), and the unknown bridge of the ancient Via.

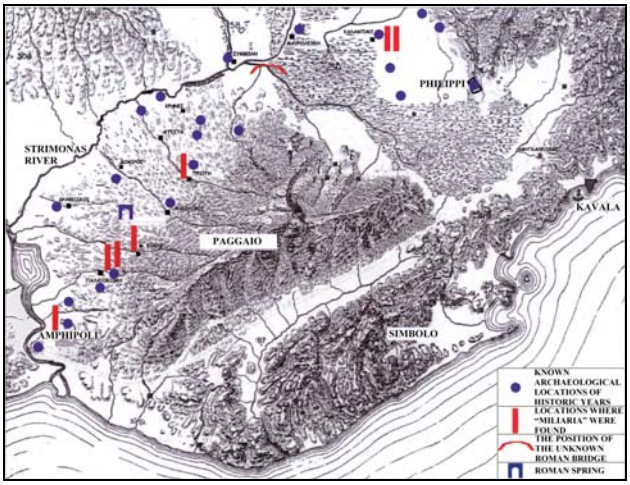

Figure 2. Historic Study and Selective Field Study.

2.4 Analogue remote sensing data

The extensive study conducted by the aerophotography section of the Hellenic Military Geographical Service (H.M.G.S.), the Hellenic Mapping and Cadastral Organisation (H.M.C.O.) and the Topographic Directorate of the Ministry of Rural Development and Food, that constitute the public authorities for the provision of photogrammetric material in Greece, has lead to the collection of 319 vertical aerial photographs of a scale of 1:6,000 to 1:42,000, dated from 1945 to 1996. Their digitalization was performed in 1200 dpi (grayscale, 8bit) and their medium quality (brightness and low contrast) made their digital processing necessary (Histogram Equalization, Brightness/contrast, Sarpen, Unsharp Mask, Convolution, Wallis Filter), a processing that improved their photometric characteristics. Regarding their geometric correction, a known Digital Terrain Model was used (D.T.M.) as well as ground control points with three-dimensional coordinates. The result was the production of orthophotomaps of different scales, 1:1,000 to 1:20,000, of analogue accuracy. Thus, a more supervisory view of the area to be studied is offered as well as the possibility to correlate the various marks, enforcing the process of their interpretation. In addition, the query of the measuring information in relation to the coordinates (longitude, latitude) of the marks of the buried constructions is allowed, information that is crucial for their interpretation. So, the materialization of the location of the marks in the real area (ground) is a trite process as their locations are already precisely known on the orthophoto mosaic.

2.5 Digital remote sensing data

Five (5) different archive satellite images of the optic system QuickBird-2 were searched and collected (spatial resolution panchromatic image 0,6m and multispectral image 2,4m) and one (1) WordView-1 satellite image (spatial resolution panchromatic image 0,5m), that together covered about 2/3 of

the study area. For the rest of the area, the satellite image was provided with a programmed take. The optimum time frame for the take came up after systematic research, which was based on the study of four (4) different satellite images in an area of limited surface. During that research, various factors were taken into account, such as the growing cycle of the crops, of the natural vegetation, the elements that the soil consisted of and detailed climatological and meteorological conditions, combined with the clarity and the number of the marks that were observed. The conclusions of this special study for finding the optimum date for the take have lead to a satellite image which allowed for the successful location of dozens of new marks.

For the improvement of the spatial analysis of the multiphasmatic data, a technique of composing the panchromatic and the multiphasmatic image was implemented, with transformation to the main components (Principal Components Analysis, PCA). On the new images, geometric corrections were made with the use of a known Digital Terrain Model (D.T.M.) and ground control points with three-dimensional coordinates, thus allowing the production of orthoimages of a spatial accuracy of about one (1) meter.

3. GEOGRAPHICAL SYSTEM OF MARK MANAGEMENT

For the optimum management, analysis, and correlation of the larger volume of data such as the terrestrial photographs and other information of the historic study and survey, the contemporary, historical, geological maps and charts of the land distributions, aerial photographs, satellite images, and traces, that are the result of the photo interpretation of the diachronic remote sensing data, a new Geographic System of Mark Management was created. With appropriated applications that ensure the optimum user interface, the easy input and management of data and their quickest possible processing (Roustanis *et al.*, 2007).

4. THE MARKS OF VIA EGNATIA

Dozens of linear marks have been traced (diachronic aerial photos and satellite images), marks that at first were considered to belong to the category of the marks of Via Egnatia. By combining them with all the research data, the final marks which materialize the course of the Via have become evident and are presented in Figure 3.

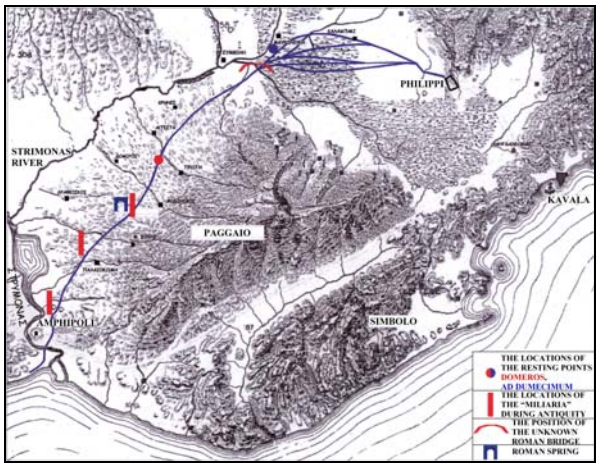

Figure 3. The course of Via Egnatia (blue line).


Figure 4. Linear mark of vegetation of the covered Via Egnatia (QuickBird-2).

In the Philippi valley, west of the city, a linear mark of the ancient road appears in the diachronic aerial photographs (less clearly) and in the satellite image (more clearly) (Fig. 5).

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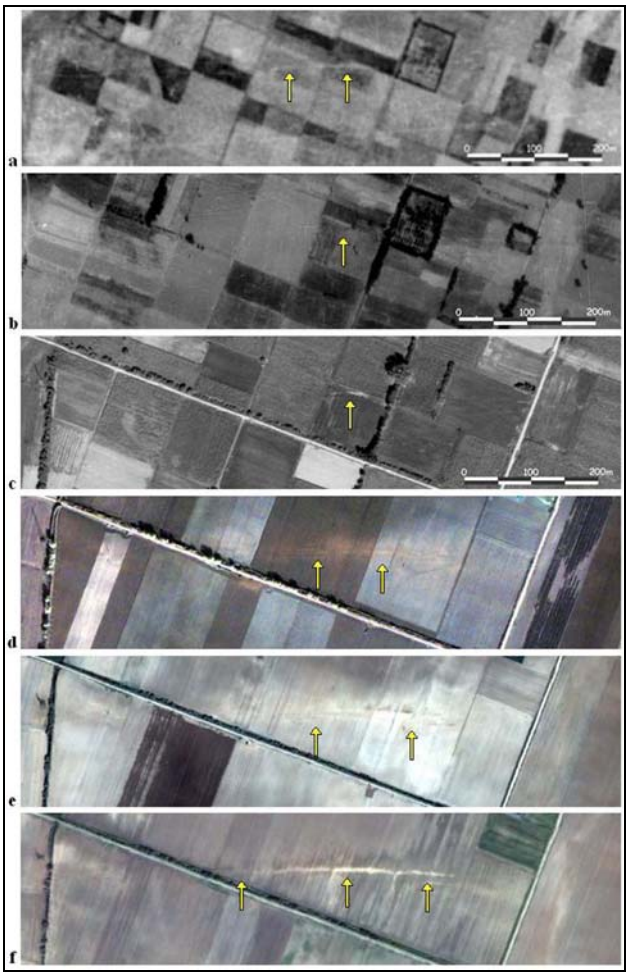

Figure 5. a. Aerial photograph of 1945, H.M.G.S., scaled 1:42,000, b. 1965, H.M.C.O., scaled 1:15,000, c. 1996, H.M.C.O., scaled 1:15,000, d. QuickBird-2 satellite image of 2004, e. QuickBird-2 of 2005, f. QuickBird-2 of 2005 (during the optimum period for the location of the marks). Linear mark of Via Egnatia of 6m width and 300m length.

Having identified the course of the ancient road, the location of the geographic position and the mapping of the two (2) resting points was allowed, based on their distances recorded on the "His walking Bordeaux" (Early Christian Pilgrimage, 1999), and of the "miliaria", based on their distances recorded on their surface (Fig. 3)

5. BURIED AND LOW-RELIEF CONSTRUCTIONS

Apart from the linear marks that belong to the category of Via Egnatia marks, more marks were located that can be sorted in two basic categories. In the first category we have constructions that are entirely buried in the soil, while in the second category we have low-relief constructions and are not covered by soil and/or vegetation.

5.1 Buried constructions

Four hundred and ninety (490) individual constructions and one hundred and six (106) groups of buried constructions were identified. The first category includes marks of:

a) Ground plans (Figure 6),

b) Urban designs, like the one in Figure 7. A system of parallel and vertical roads that determine street blocks of 45x45 meters in an area of 280 km^2 is presented. The distribution of the agricultural properties of 1928 does not allow any concurrence of the marks with the former land distributions, which were covered by the modified distributions that followed. (Kaimaris *et al.*, 2008,a),

c) Buried circular constructions with a diameter of 15 to 50 meters (Figure 8),

d) Buried fortification constructions, like the fortification (Georgoula *et al.*, 2004) in the Philippi valley.

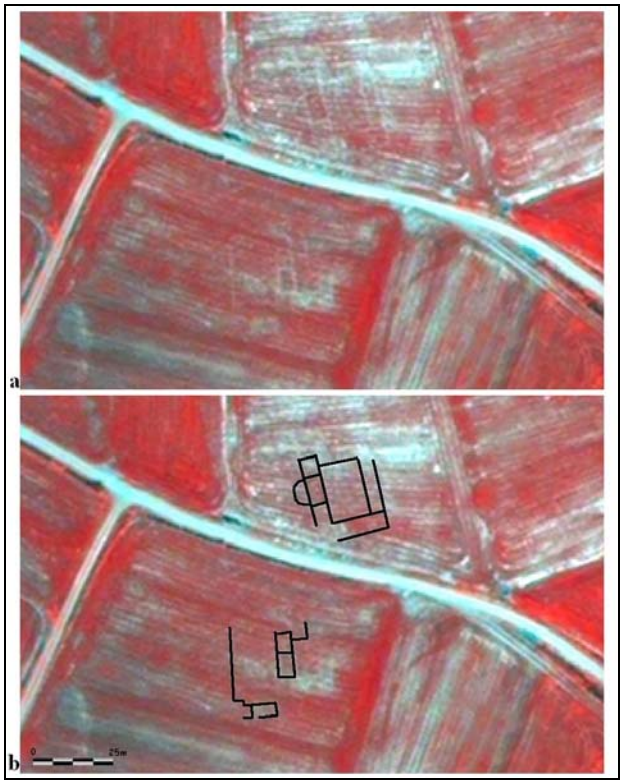

Figure 6. a. QuickBird-2 of 2005 (during the optimum period for the location of the marks), b. Attribution of the linear marks of covered building constructions.

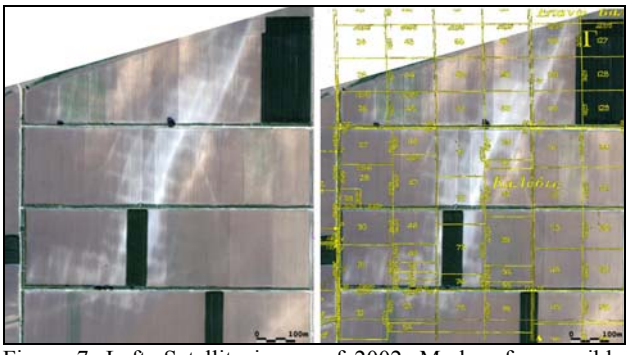

Figure 7. Left: Satellite image of 2002. Marks of a possible ancient settlement. Right: The distribution of agricultural properties of 1928 does not allow the concurrence of the marks with the limits of the parcels of land of that time.

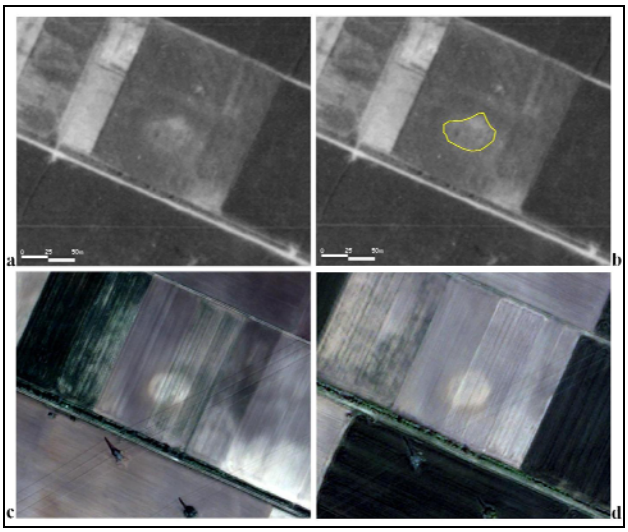

Figure 8. Covered concrete circular construction with a diameter of about 30 meters. a: Aerial photograph of 1993, H.M.C.O., scaled 1:15,000, b. Attribution of mark, c: QuickBird-2 of 2002, d. QuickBird-2 of 2004.

5.2 Low-relief constructions

Four hundred and forty (440) individual constructions and sixty four (64) groups of low-relief preserved constructions were identified. In this category we have:

a) Low-relief fortification constructions (Figure 9) (Kaimaris *et al.*, 2008,b).

b) Low-relief circular construction with a diameter of 15 to 50 meters (Figure. 10).

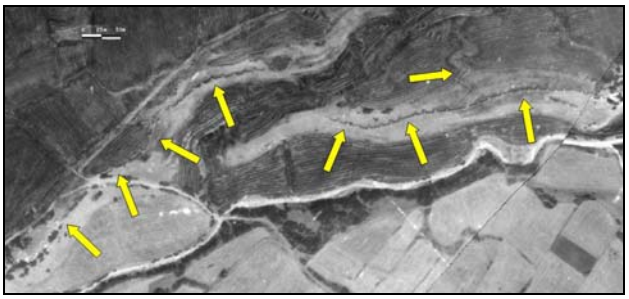

Figure 9. Aerial photograph of 1977, H.M.C.O., scaled 1:15,000. Low-relief constructions that are attributed to military trenches of the Balkan Wars or of the First World War. The constructions are also located in the aerial photographs of 1945 and in the contemporary satellite images.

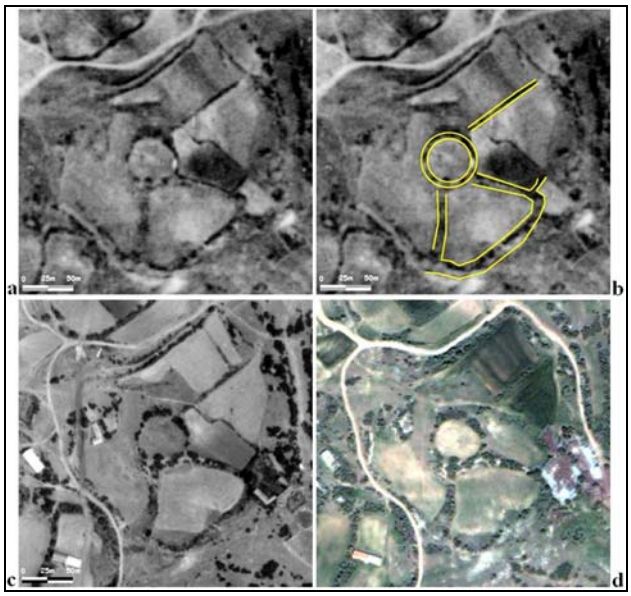

Figure 10. a. Aerial photograph of 1945, H.M.G.S., scaled 1:42,000, b. Attribution of the circular construction with a diameter of 50 meters and of linear radial elements, c. Aerial photograph of 1977, H.M.C.O., scaled 1:15.000 d. QuickBird-2 of 2002.

6. CONCLUSIONS - SUGGESTIONS

The inter-scientific research group systematizes the methodology of locating archaeological sites in extended areas. In the methodology that it suggests and follows, the research group includes and considers essential the traditional methods of the Historical survey. As the research group progresses, it processes and studies historical and contemporary maps, and it proves that the maps of the Spatial Distributions of the rural properties of a scale of 1:5,000 –for the research area they date back in 1928– are a valuable source of information, since they help in the interpretation of many marks. It is based on the use of historical and contemporary archive aerial photographs of different scales that illustrate the study area diachronically. We must mention that locating the marks in these photos is a random event, since the photos were taken for cartographic reasons and probably during a period that is not suitable for locating marks. Same goes for the satellite archive images. Therefore, the methodology suggests a systematic, targeted research that helps choosing the optimum time frame for taking new photos in order to locate new marks. The new Geographical System of Mark Management that the research group uses proves to be a valuable as well as an indispensable tool for the management, correlation, and evaluation of the research data.

The course of the ancient Via Egnatia from Amphipolis to Philippi, which was the principal aim for applying the methodology, was located and determined spatially with great accuracy. In addition, hundreds of other places of archeological interest were located (covered or preserved). In these places we suggest excavating cuts, geophysical research, and diachronic control of how the precision of the observation evolves and of the marks' geometry, by using a remote controlled helicopter that has already been constructed (Patias *et al.*, 2008).

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