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The geological structure of Kastas hill archaeological site, Amphipolis, eastern Macedonia, Greece

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Abstract

This paper presents research results on the geological structure of Kastas hill in Amphipolis, as well as the broader area. They consist of geological and geomorphological observations at Kastas hill, the called "133" hill, and the surrounding areas, on their geological structure, the stratigraphy and the palaeoenvironment. Kastas hill is the site of the largest burial mound discovered in Greece to date. The slopes of its embankment were recorded and modelled in detail using near field photogrammetry. The problem of distinguishing between in-situ geological formations and ex-situ anthropogenic deposits is also addressed. The bulk volume of Kastas hill consists of natural sediments; these sediments are exposed as successive alternating beds of grayish loose and cohesive sands with scattered pebbles and locally with cobbles. Clayey beds up to ~20-30 cm thick intercalate between the sands. At the top of the hill the anthropogenic deposits are typical of Macedonian tumuli, with soil and clay alternations for sealing and stabilizing them. Paleosoil horizons were observed both in natural sediments and within anthropogenic substrates. Two horizons were sampled for dating by different methods (OSL – optical stimulated luminescence and 14C – Accelerated Mass Spectroscopy), showing the development of successive deposits during the Iron, Archaic and Classical ages. The AMS dating of a charcoal which is closely associated to the construction of the main monument yielded an age of Cal. BP 2310 = Cal. 360 BC.

Keywords: *Strymon basin, tumulus stratigraphy, Amphipolis tomb, neotectonic faults, Lazarides excavation, soil dating*

Περίληψη

Στην εργασία αυτή παρουσιάζονται ερευνητικά αποτελέσματα για τη γεωλογική δομή του λόφου Καστά στην Αμφίπολη, καθώς επίσης και της ευρύτερης περιοχής. Πρόκειται για γεωλογικές και γεωμορφολογικές παρατηρήσεις του λόφου Καστά, του λεγόμενου λόφου «133» και της περιβάλλουσας περιοχής, σε ότι αφορά τη γεωλογική τους δομή, τη στρωματογραφία και το παλαιοπεριβάλλον. Στον λόφο Καστά έχει ανασκαφεί ο μεγαλύτερος τάφος που έχει ανακαλυφθεί έως τώρα στην Ελλάδα. Τα πρανή του τύμβου καταγράφηκαν και μοντελοποιήθηκαν με λεπτομέρεια χρησιμοποιώντας φωτογραμμετρικές μεθόδους κοντινού πεδίου. Επίσης, συζητείται το πρόβλημα του διαχωρισμού των φυσικών από τις ανθρωπογενείς αποθέσεις. Το μεγαλύτερο μέρος του όγκου του λόφου Καστά αποτελείται από φυσικά ιζήματα, τα οποία εμφανίζονται ως εναλλασσόμενα στρώματα γκρίζας συνεκτικής και χαλαρής άμμου, με χάλικες και τοπικά κροκάλες. Αργιλούχα στρώματα πάχους έως 20-30 cm παρεμβάλλονται ανάμεσα στα στρώματα άμμου. Στην κορυφή του λόφου, οι ανθρωπογενείς αποθέσεις είναι τυπικές των Μακεδονικών τύμβων, με εναλλαγές αργίλων και εδάφους για τη σφράγιση και σταθεροποίησή τους. Παρατηρήθηκαν ορίζοντες παλαιοεδαφών τόσο στα φυσικά ιζήματα, όσο και στις ανθρωπογενείς αποθέσεις. Δύο ορίζοντες χρονολογήθηκαν με διαφορετικές μεθόδους (OSL και ^{14}C AMS), δείχνοντας ανάπτυξη διαδοχικών αποθέσεων κατά τη διάρκεια της Εποχής του Σιδήρου, την Αρχαϊκή και την Κλασσική περίοδο. Η χρονολόγηση με τη μέθοδο AMS ενός θραύσματος ξυλάνθρακα που συνδέεται άμεσα με την κατασκευή του κυρίως μνημείου, έδειξε βαθμονομημένη ηλικία 2.310 BP (360 π.Χ.).

Λέξεις Κλειδιά: *Λεκάνη του Στρυμόνα, στρωματογραφία τύμβου, τάφος Αμφίπολης, νεοτεκτονικά ρήγματα, ανασκαφή Λαζαρίδη, χρονολόγηση εδαφών*

1. Introduction

Kastas is a small hill near the modern village of Amphipolis and the homonymous archaeological area (Figure 1). It was the focus of widespread public interest after the largest burial mound in Greece and an elaborate burial monument were discovered in 2014. The monument was found buried into the hill, covered by anthropogenic fill and surrounded by an almost perfect circular marble wall ~500 m long and ~3 m high with a marble cornice of probably Thasos Island provenance (K. Peristeri and M. Lefatzis, personal communication).

The first excavations on Kastas hill were performed during 1965 - 1980 by an archaeological team led by D. Lazarides. He hypothesized that a large funeral monument of Macedonian era was situated at the centre of the hill, and proceeded to excavating deep trenches at the hilltop. Most of the hill's upper surface was dug out and removed, leaving behind only three pillars of the initial sediments as reference points of the initial height and morphology of the hill. No large Macedonian grave was found, but surprisingly an older Iron Age – Archaic era graveyard was located deeply buried (Lazarides et al., 1992; Lazarides, 1993). The excavated land fill was deposited around the circumference of the hill. Since 2012, Mrs. Katerina Peristeri, chairperson of the Serres Antiquities Ephorate, performed large-scale excavations, discovering and unearthing the monument.

Discovery triggered discussions among the archaeological community, dealing mainly with the construction age of the buried monument (Classical or Roman), how many times was used, etc. Similarly, several opinions regarding the nature of Kastas hill, were expressed e.g. the hill is an artificial tumulus at its entirety, Strymon river flooded the area and silted the interior of the monument, etc.

This paper presents the first results of the geological research performed between November 2014 (when the initial stage of the excavations had been completed) and December 2015 (when the entire area of the excavation was covered with geotextile and land filled to be protected from erosion).

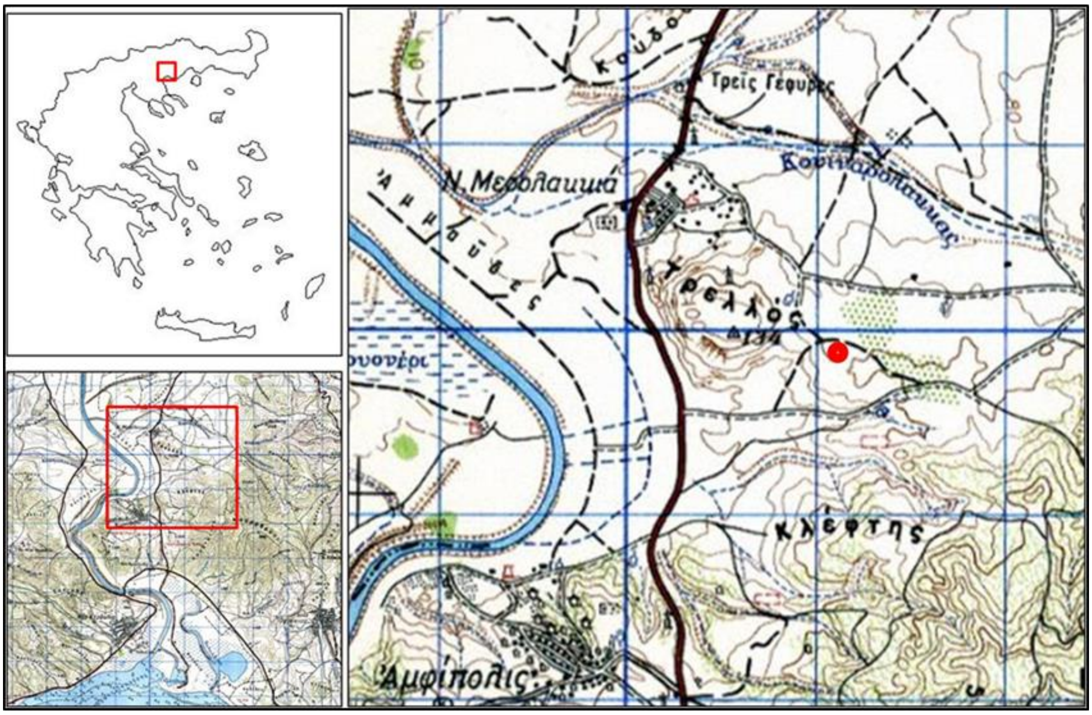

Fig.1. Topographic map of the study area; red circle depicts Kastas hill (extract from the topographic map 1:50.000 Rodholivos Sheet, Hellenic Army Geographical Service).

2.Geographical and geological setting

Kastas hill is a small circular hill (~160 m in diameter and ~111 m high) and is part of a hilly terrain at the southern part of Strymon basin, close to the Strymon River banks, 2 km NE from Amphipolis village and 1 km SE from Mesolakkia Village. Hill 133 is an adjacent hill west of the Kastas one (Figure 2a).

Strymon River and Strymonikos Gulf basins are elongated tectonic depressions situated in Eastern Macedonia (Karystineos, 1984; Tranos, 2011; Mouslopoulou et al., 2014; Syrides, 1995, 2000; Zagorchev, 1992). They have a NNW to SSE direction and were formed during Neogene. The pre-Neogene basement consists of metamorphic rocks of the Rhodope Massif along their eastern side (Pangeon and Mavrovouni Mts.) and metamorphic rocks of the Serbomacedonian Massif along their western one (Kerdyllia Mt.) (Xidas, 1978). These basins were gradually infilled by mainly clastic sediments (conglomerates, sands, gravels, silts clays, marls), with a total thickness of more than 2 km, as indicated in oil exploration borehole logs.

The currently available data indicate that after the formation of these depressions until Upper Miocene fluvio-terrestrial coarse clastic sediments (Basal Folge of Gramann and Kockel, 1969) were deposited followed by fluvial – lacustrine – marshy sediments with lignite.

Two marine transgressions were observed in these basins. The first occurred during late Miocene (Dafni beds), followed by a brackish environment with Paratethyan mollusk faunas (Choumnikon beds). The second marine invasion took place during Lower Pliocene, while a gradual regression was observed during Late Pliocene. The Pleistocene is characterized by extensive terrestrial sediments (fans and fanglomerates) along the mountain piedmonts (Figure 2b) (Syrides, 1995, 1998, 2000).

During Neogene, the currently separated Strymon River and Strymonikos Gulf basins were connected. A Pleistocene tectonic event faulted the wider area causing uplift of a hilly ridge (Amphipolis horst) between Pangeon and Kerdyllia Mountains. This tectonic event also caused intense vertical movements, uplifting the margins with the Neogene sediments at an altitude of up to 300 m and causing subsidence of the central parts. Strymon River gradually eroded the Amphipolis horst creating the epigenetic valley of Amphipolis Straits.

During Holocene, the central parts of the Strymon Basin were covered by extensive shallow lakes and marshes. In the 1930’s extensive reclamation works created the present-day environment.

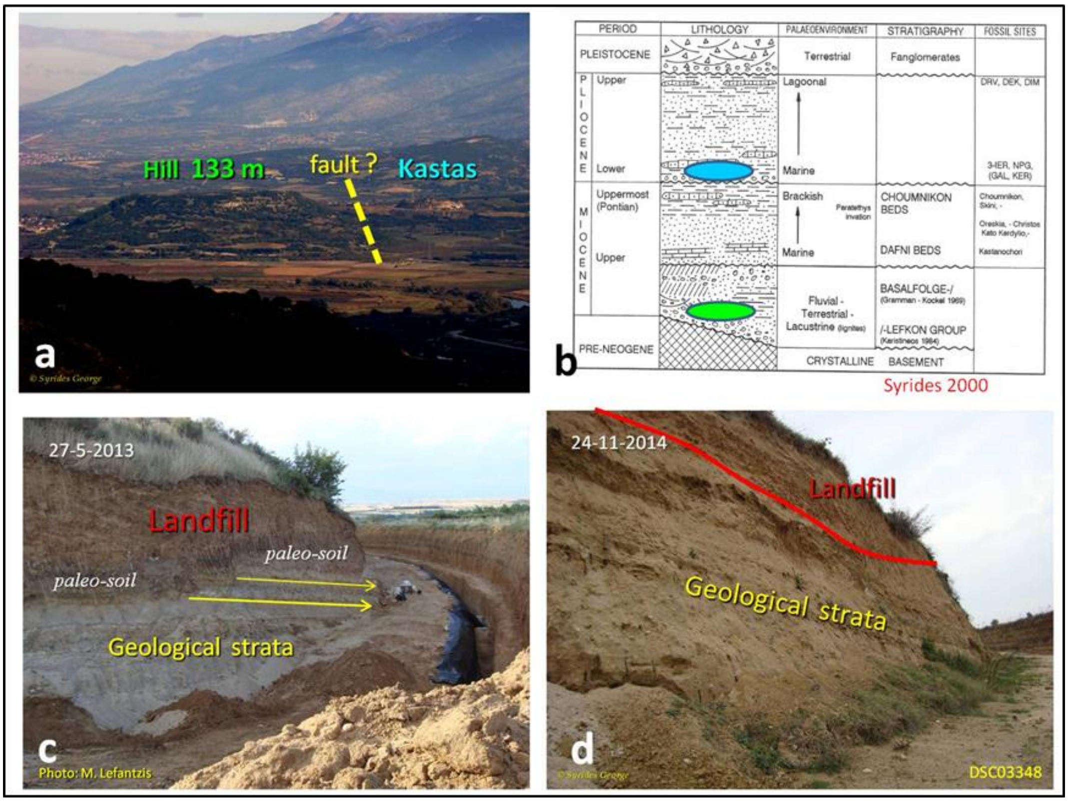

Fig.2. a) General view of the study area from SW b) Stratigraphic column of the south part of Strymon basin (Syrides, 2000) Neogene sediments are depicted with green oval for hill 133 and blue oval for Kastas hill. c) Dipping strata, ancient landfill and paleosoil exposed along the excavation trench of the marble wall (May 2013). d) The same place one and half year later (November 2014).

At the top of a hilly terrain along the foothills of Kerdyllia Mt. (altitude 270 – 240 m) two successive horizons of fossiliferous Neogene sediments are exposed. The lowermost, consisting of marly limestone, contains marine Mollusks (*Pecten sp.*, *Chlamys sp.*, *Venus sp.*, *Ostrea sp.*) and Forams (*Borelis sp.*) while the upper one consists of sands and sandstones and contains *Limnocardiids* and *Dreissenids*, indicating a Paratethyan influence (Syrides, 1998, 2000). Along the road cut of foothill 133, gray marls of the lower lignite-bearing series beds are exposed. Gray marl outcrops also at higher altitudes at hill 133, while marly massive limestone outcrops at its upper parts. This marly limestone was possibly quarried and used as the main building material of the Kastas monument. Kastas hill consists of sand and gravel beds alternating with thin beds of sandstone, silt and clay. These sediments have also a broader extent in the area north and east of Kastas hill and they contain marine fossils of Pliocene age.

3. Methods

Extensive and detailed field reconnaissance and fieldwork took place in the area of Kastas hill. The research was performed along the excavation trenches, where fresh sections of the hill substratum were revealed, exposing the subsurface stratigraphy along the circumference of the hill, as well as close to the burial monument that is located at the south margin of the hill in contact with the marble retaining wall. The main research objectives were to clarify the nature of the sediments, to recognize and separate the naturally occurring sediments from the ancient human land fill, to study the sediment characteristics (stratigraphy, lithology, depositional environment and age, etc.), as well as to study the tectonics that possibly affect them.

4. Results

The bulk volume of Kastas hill consists of natural sediments; these sediments are exposed as successive alternating beds of grayish loose and cohesive sands with scattered pebbles and locally with cobbles. Clayey beds up to ~20-30 cm thick intercalate between the sands.

The natural stratigraphy of Kastas hill is preserved along the artificial sections around the hill (Figure 2c, d), as well as in excavations close to the monument (Tholos), which are also identified in geophysical investigations (Pavlides et al., 2016; Syrides et al., 2016; Tsokas et al., 2016). The objective of separating the natural from the anthropogenic material was facilitated by using a 3D digital model of the hill's outcrops. This model was constructed using a dense point cloud extracted from 272 overlapping photos taken along the circumference of the hill. They were then input into several open source photogrammetric software modules and the result was a continuous surface model approximating the original one. The layers of the hill were initially distinguished in natural sediments, which were geologically dated, and man-made deposits. The results were used in the simulation of the geophysical model, in which they were complemented with geological, stratigraphic and neotectonic elements, to propose a more comprehensive geological model of the hill. The planned geotechnical drilling, when implemented, will contribute substantially in this direction.

The sandy beds contain scattered marine Mollusks (*Ostrea sp.*, *Pecten regiensis*, *Chlamys sp.*, Figure 3), indicating an early Pliocene age and deposition in a shallow marine environment with clastic sedimentation (sand, pebbles, cobbles) (Psilovikos and Syrides, 1983; Syrides, 1993, 1995, 2000). Those strata dip in opposite directions along the circumference of the hill. At its SE part, they dip towards N-NW, while at its NE part they dip towards SE (Figure 4a). This is an indication for a SW-NE trending fault zone that cuts through the hill affecting the strata. Local collapse of the hill scarps obscures direct observation of this zone. Nevertheless, the existence of a linear anomaly

(Figure 4b) was detected by the geophysical survey (Syrides et al., 2016; Tsokas et al., 2016). Several minor faults are also present in sites around the hill. Two groups of inactive minor faults appear in the natural sediments of Kastas Hill, the first one near the monument Tholos and the second on the northeast side of the hill (Figure 4c, 4d). The existence of another fault at the southern side of the hill and an even larger one between hills 133 and Kastas is probable, based on geological observations in the surrounding area.

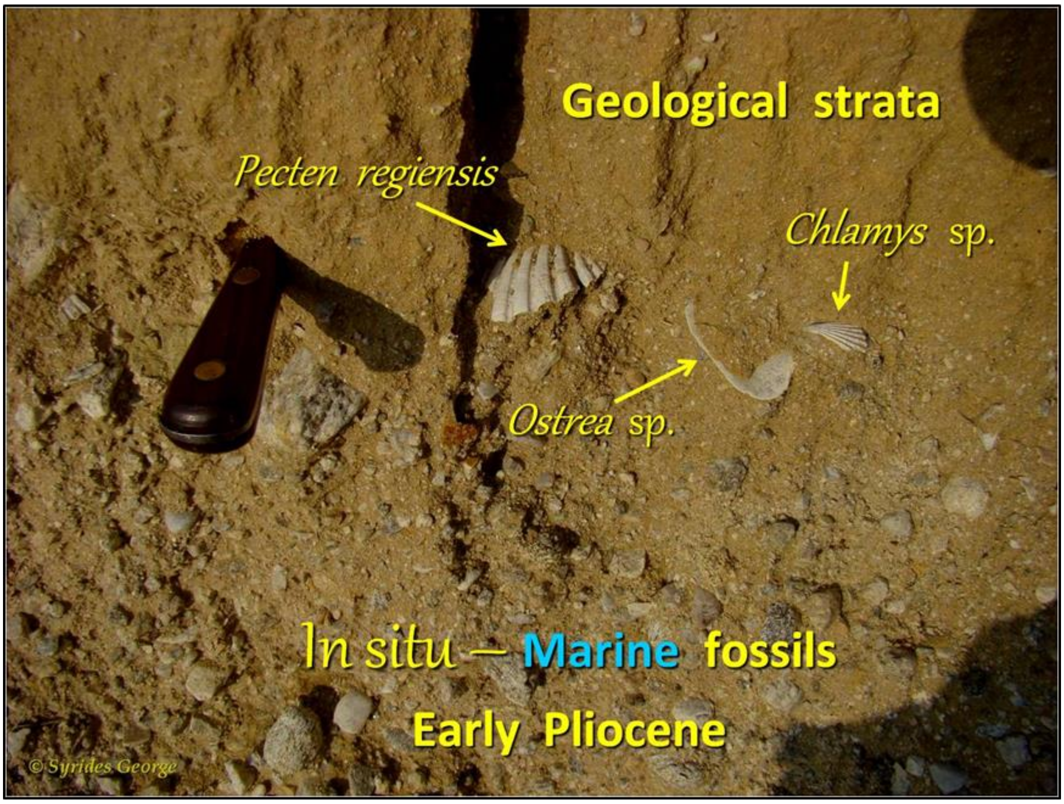

Fig.3. In situ Pliocene marine fossil mollusks from the sandy-gravely strata of Kastas hill.

The archaeoseismological indications of the broader area (Strymon Valley, Philippi, Thasos) help to pinpoint earthquakes that are reported in written sources, such as the earthquakes of 597/98 and 618/620 AD (Bakirtzis 1989; Mentzos 2005; Papazachos & Papazachou 2003). The current research interest is focused on an unknown, very strong earthquake after the middle of the 7th century AD, which probably originated from a seismogenic source (active fault) very close to Amphipolis, but it is quite difficult to associate the observed and inferred faults with historical and modern earthquakes.

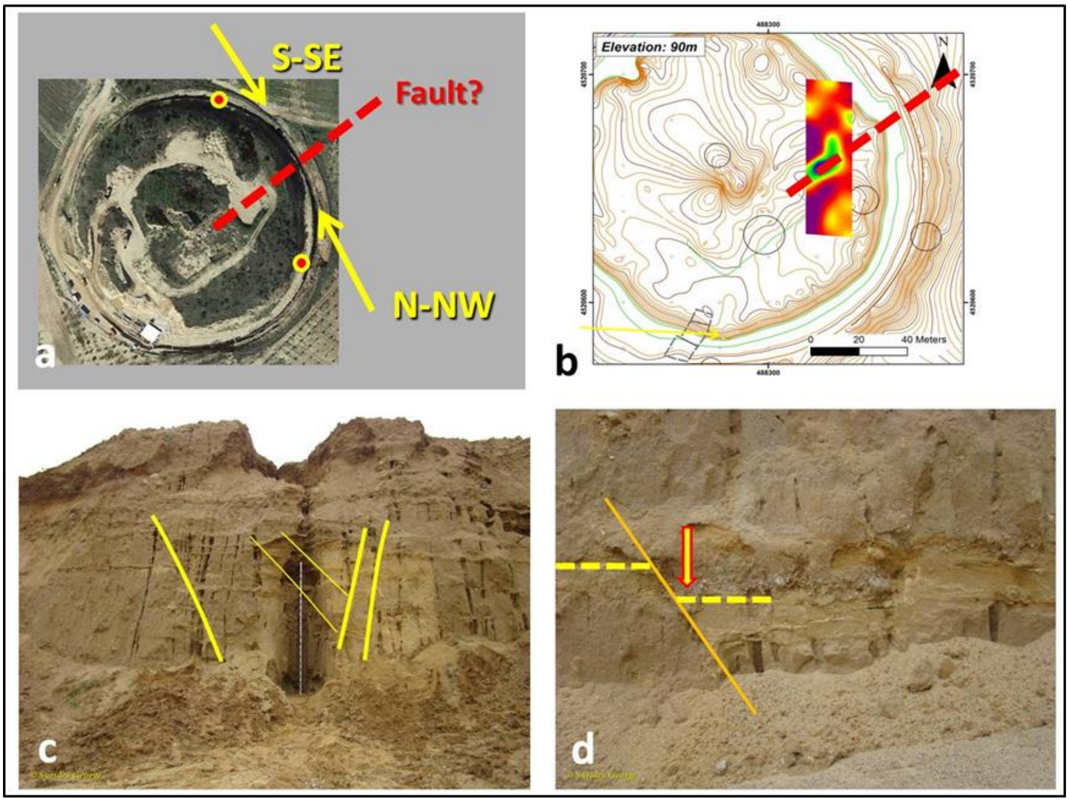

Fig.4. a) Neogene strata dipping towards opposite directions and estimated fault line. b) Geophysical investigation confirms this fault-line (Tsokas et al., 2016). c) Small faults affecting the Neogene strata at the south side of Kastas hill. d) Relative displacement of a small fault, south side of Kastas hill.

5. Human interventions on Kastas Hill

At the top of the hill the excavations led by Lazarides removed a large amount of the upper part of the hill, revealing an Iron age – Archaic graveyard. Geological prospecting of the area shows that this graveyard is situated on top of the natural sediments and is founded at the natural upper surface of the hill, following a characteristic paleosoil horizon. During subsequent times the initial hill morphology was altered after the construction of the burial monument. The architect of the excavation M. Lefantzis (personal communication) states that the hill was artificially shaped and land filled to a specific form and at the top of the hill the rectangular base (removed partly by Lazarides excavations) of a large mark ("Sima") was constructed, possibly supporting the well-known Lion of Amphipolis statue (initial site of the statue). Our observations show that the deposits covering the natural sedimentary sequence (marked by the Iron Age – Archaic Era graveyard) are anthropogenic and their thickness up to 6 m and locally even more. This anthropogenic land fill consists of alternating beds of sand, soil, clay; this favors water sealing and stability and is common in various Macedonian tombs and tumuli (Syrides, personal observations). Below and around the rectangular base of the "Sima" the stratigraphy of the ancient land fill reveals a very detailed and careful thin layering. Alternations of thin (5-20 cm) sandy layers with thin (3-5 cm) silty-clayey layers are purposely forming a “herring bone” stratification.

Per D. Egglezos, civil engineer of the excavation, this type of land fill and the dimensions of the base of the “Sima” can support heavy loads (like the Lion statue). “Sima” building blocks exhibit a well weathered surface and many of them appear fractured (Figure 5a). The geometrical and physical properties (strike, dip, heave and filling material) of those microfractures were systematically measured, where possible. The rose diagram of Figure 5b shows the distribution of the fracture strikes. They are predominantly aligned in a SW-NE direction, subparallel to the main assumed fault zone that cuts through the hill; Nevertheless, the association of these fractures to the observed faults is weak with the available data. Considering that they are mostly perpendicular to the external surface of the “Sima” wall, their most probable causative factor should tentatively be a heavy load that stood on top of it.

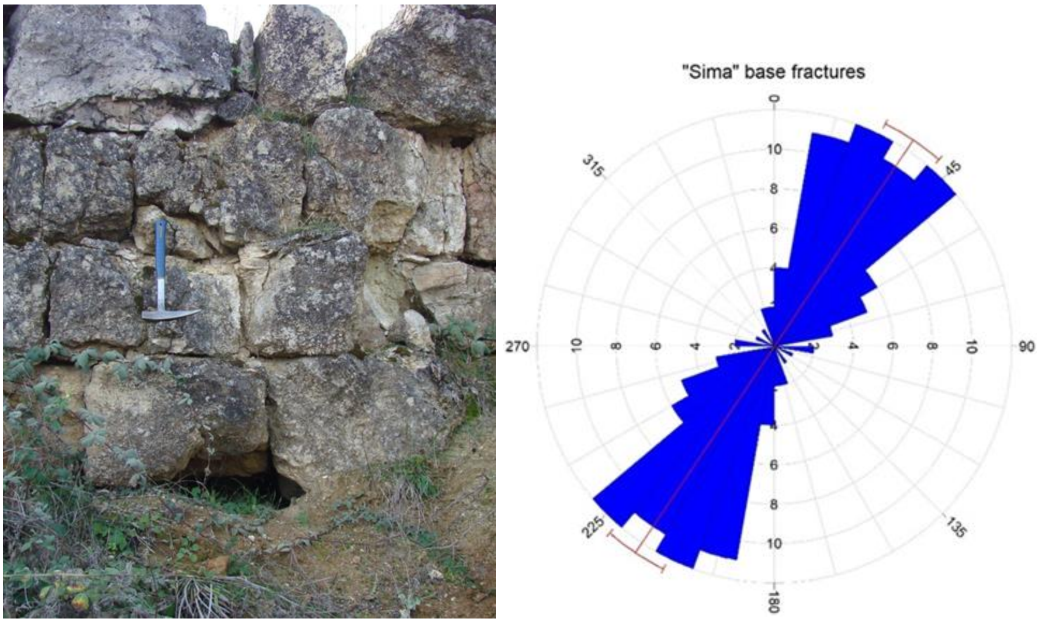

Fig.5. a) Partial detail of the “Sima” stone base and the small fractures that were measured for the estimation of deformation b) Rose diagram of the fractures’ strike.

Two types of land fill were observed on Kastas hill: an ancient one associated with the construction of the burial monument and a recent one (Lazarides excavations) that was deposited around the circumference of Kastas hill and in several cases on top of the ancient land fill. Radiocarbon and OSL dating of selected soil samples from the paleosoil covering the Iron age – Archaic graveyard and below the ancient land fill yielded ages ranging between 1000 – 600 BC (Figure 6). This represents the time span that the paleosoil covering the graveyard was “active” before the ancient land fill covering.

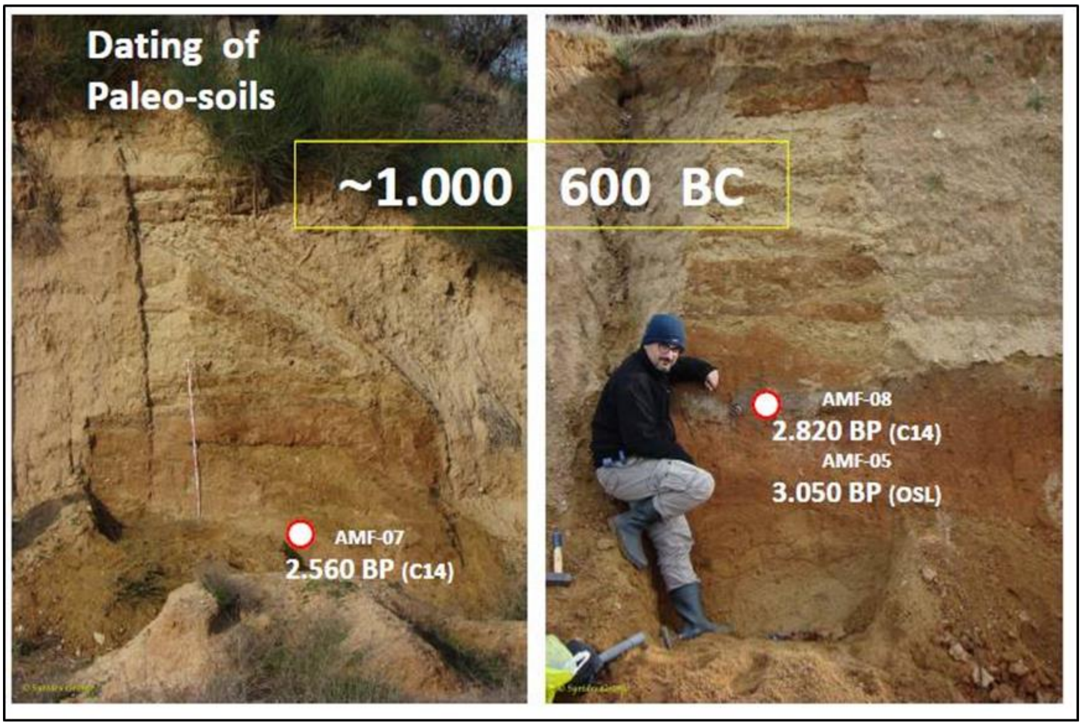

Fig.6. Sampling and dating of paleosoil horizons at the upper part of Kastas hill (OSL dating by the Nuclear Physics and Archaeometry Laboratories of the University of Ioannina).

As mentioned above, the monument was built at the south margin of the hill. The method of construction was similar to the present-day "cut and cover" one. Initially a rectangular trench was dug out in the geologic strata, into which the monument was constructed and land-filled. The arch geometry of the roof of the monument indicates a simultaneous "built and land fill" construction, i.e. a simultaneous building and land filling of the trench after each row of stones. This is essential and fundamental for the construction of an arch.

A few small charcoal fragments were found into the land filling covering the base of the arch (Figure 7). Due to the above-mentioned construction method, the age of this charcoal which is considered to be fire residue, is closely associated to the construction of the Arch. The charcoal was dated at Beta Analytic laboratories (USA) using AMS ^{14}C determination with ^{13}C isotope correction. Results show that the sample has an average age of 2250 ± 30 a BP (before 1950), which is diurnally reduced to 300 ± 30 BC, i.e. late 4th – early 3rd century BC. By projecting the dating curve to global ^{14}C data calibration curves, the age is further calibrated at 2310 a BP, i.e. 360 BC. Archaeological research will further explore the site and give the definitive answer. To have more reliable dates, more detailed systematic sampling and analysis with different methodologies is needed.

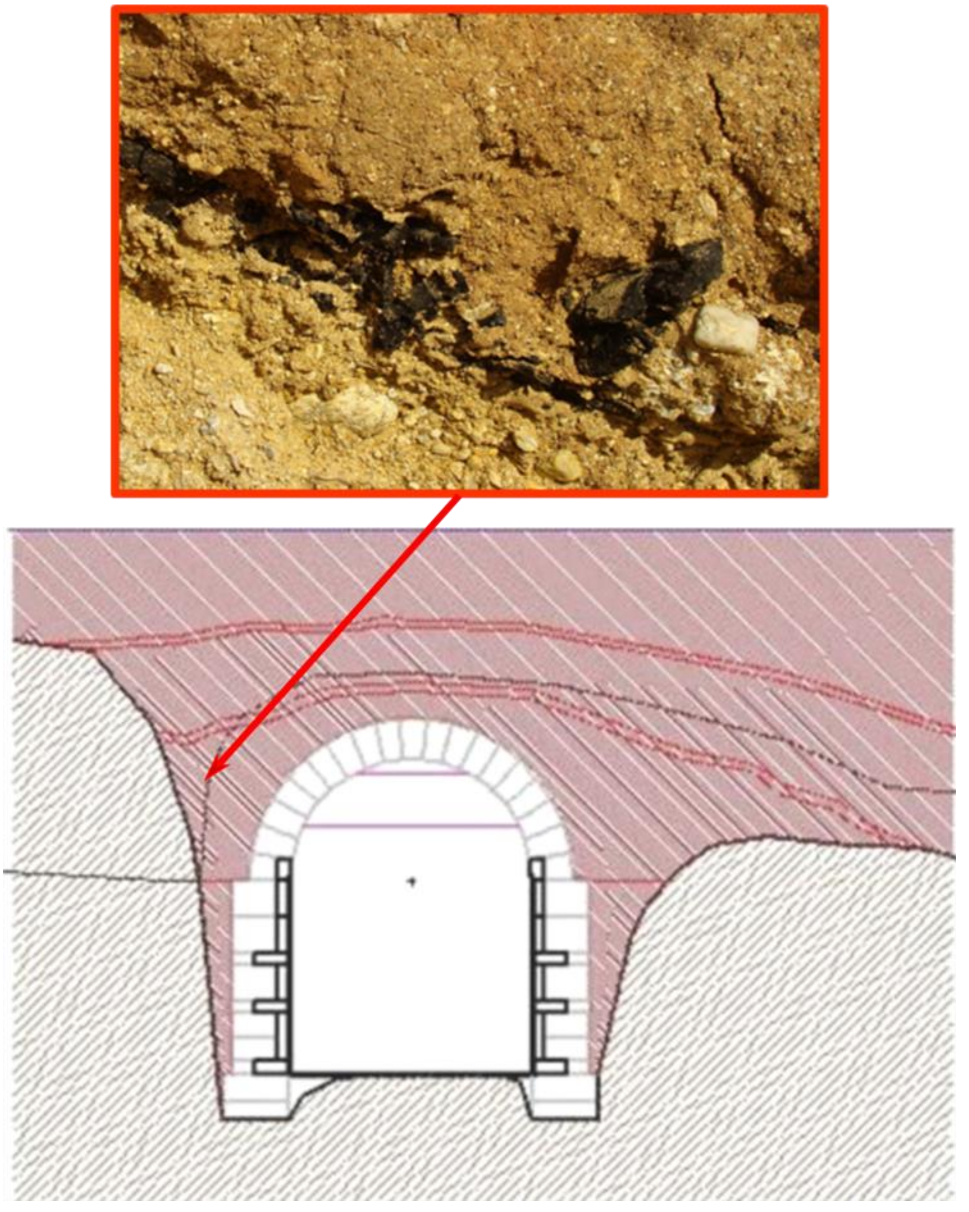

Fig.7. Correlation and relative position of the charcoal found into the ancient land fill that covers the monument (cross section of the monument after M. Lefatzis). Charcoal fragments are concurrent with the construction of the Monument.

6. Concluding remarks

Kastas hill is a natural hill consisting of Pliocene sediments. During Iron age – Archaic era a graveyard was active at its upper surface. During the Classical period, the hill was heavily affected by human interventions. It was land filled at the top and had its circumference modified to form an almost perfect circular hill. The mechanical characteristics of the landfill, as well as the pattern and characteristics of the fractures of "Sima" building blocks, show that it can support a heavy superimposed monument like the Amphipolis Lion statue. For the first time, absolute age determinations were performed in Kastas hill sediments. Paleo-soil formation (below landfill) was active from Iron age/Archaic era up to Classical period. Charcoal from the land fill of the monument allows for first time a direct dating of the construction of the monument during Late Classical period and not Roman, as was previously suggested.

Further research is needed to investigate the possible different phases of human interventions. Some critical issues are:

- Continue and extend the investigation in the land fill that surrounds the monument, to locate more datable samples that are closely associated to the construction of the monument.
- Investigate the ancient excavation around Kastas hill that isolated the hill from the surrounding hilly terrain.
- Identify the successive stages of surface modification and land fill through additional sampling and OSL and ^{14}C AMS dating.
- Locate probable quarrying sites of the marly limestone used for the monument construction.

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