Quaternary evolution of the Agia-Agiokambos area as a possible outlet of the Eastern Thessaly plain to the Aegean Sea*

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ABSTRACT: This study deals with the geomorphological investigation of the Agia-Agiokambos area as being a possible outlet of the eastern Thessaly plain (Larissa basin) towards the Aegean sea during the Pleistocene period. For this purpose, detailed geomorphological mapping in the field was performed, with the use of air-photographs at different scales, topographic maps and sheets by applying GIS and DTM technology.

The Agia – Agiokambos area geotectonically belongs to the Pelagonian zone and comprises a basement of metamorphic rocks overthrust by a complex of metamorphic ophiolitic rocks and metasediments all in the form of a syncline extending from Ossa to Mavrovouni-Pillion mountains, having an east-west trending axis which almost coincides with the Agia-Agiokambos direction. This syncline was filled by a Pliocene lake that was severed by Early Quaternary N-S fault tectonism forming also the Aegean sea.

During the Quaternary, this area was uplifted from NE to SW. Thus, the geomorphological evolution of the study area is the result of the combination of tectonism, lithology and geomorphic fluvial processes.

In the Early Pleistocene, after the draining of the Pliocene lake, the newly formed drainage system of Pouri, served as an outlet of Larissa basin. The continuous NE-SW uplift obstructed the easterly flow of Pouri drainage system and resulted in a reverse flow in the form of Amyros stream draining inland towards the west.

Key-words: *Agia-Agiokambos area, eastern Thessaly, drainage network, reverse flow, Quaternary.*

ΠΕΡΙΛΗΨΗ: Σ' αυτή την εργασία μελετάται γεωμορφολογικά η περιοχή Αγιάς-Αγιόκαμπου (Ανατολική Θεσσαλία) ως πιθανή έξοδος της ανατολικής Θεσσαλικής πεδιάδας (Λεκάνη Λάρισας) προς το "Αιγαίο" κατά την διάρκεια της Πλειστοκαινικής περιόδου.

Γι' αυτόν το σκοπό, πραγματοποιήθηκε λεπτομερής γεωμορφολογική χαρτογράφηση στο ύπαιθρο, χρησιμοποιήθηκαν αεροφωτογραφίες διαφόρων κλιμάκων, τοπογραφικοί χάρτες και διαγράμματα. Τα δεδομένα επεξεργάστηκαν με τεχνικές Γεωγραφικών Συστημάτων Πληροφοριών (ΓΣΠ).

Η περιοχή Αγιάς-Αγιόκαμπου ανήκει γεωτεκτονικά στην Πελαγονική ζώνη. Το υπόβαθρό της αποτελείται από μεταμορφωμένα πετρώματα στο οποίο ευρίσκεται επωθημένη μία σειρά μεταμορφωμένων – οφιολιθικών πετρωμάτων και μετά-ιζημάτων δίνοντας ένα σύγκλινο που εκτεινόταν από το όρος Όσσα προς βορρά προς τα όρη Μαυροβούνι και Πήλιο στο νότο, με άξονα Α-Δ που συμπίπτει με τη διεύθυνση Αγιάς-Αγιόκαμπου. Αυτό το σύγκλινο πληρώθηκε από μία Πλεοκαινική λίμνη, η οποία κατατμήθηκε από ρηγματογόνο τεκτονισμό κατά το κάτω Τεταρτογενές ο οποίος διαμόρφωσε και το Αιγαίο.

Κατά την διάρκεια του Τεταρτογενούς, η περιοχή ανυψώθηκε κατά διεύθυνση ΒΑ-ΝΔ. με συνέπεια η γεωμορφολογική εξέλιξη της, να είναι το αποτέλεσμα του συνδυασμού της τεκτονικής, της λιθολογίας και των γεωμορφολογικών ποτάμιων διεργασιών.

Στο Κάτω Πλειστόκαινο, μετά την εκφόρτιση της Πλειοκαινικής λίμνης το νεοσχηματισμένο υδρογραφικό δίκτυο του Πουρί ρέματος, χρησίμευσε σαν έξοδος της λεκάνης της Λάρισας. Η συνεχής ανύψωση της περιοχής κατά ΒΑ-ΝΔ διεύθυνση, εμπόδισε την προς ανατολάς ροή του υδρογραφικού δικτύου του Πουρί ρέματος και είχε σαν αποτέλεσμα την την αποκοπή και αναστροφή της ροής του ανάντη τμήματός του, με τη μορφή του υδρογραφικού δικτύου του Άμυρου ρέματος που ρέει προς την ενδοχώρα στα δυτικά.

Λέξεις-κλειδιά: *Περιοχή Αγιάς-Αγιόκαμπου, ανατολική Θεσσαλία, υδρογραφικό δίκτυο, αναστροφή ροής, Τεταρτογενές.*

INTRODUCTION

The Hellenic region has undergone significant morphological changes during the Tertiary-Quaternary. The plain of Thessaly can be divided into two elongated NW-SE basins which correspond to the principal fold and fault structures of the Hellenides formed during the Alpine orogeny and Quaternary fault tectonism. These basins are Karditsa in the west and Larissa in the east (Fig. 1).

In Pliocene times, the existing lakes in Larissa basin as well as the then - Aegean area, were already separated by four mountain masses that were from north to south Olympus, Ossa, Mavrovouni and Pillion. The ensuing Quaternary fault tectonism formed the Aegean Sea and caused considerable morphological changes in the area (Fig.2).

Based on the aforementioned, this study focuses on the Quaternary morphological evolution of the Agia - Agiokambos area in order to determine the geomorphological development that led to the possible outlet of the Larissa basin to the Aegean Sea.

For this purpose, detailed geomorphological mapping in the field was performed focusing on knick points, gorges, planation surfaces, alluvial fans, talus cones and slope changes. In addition, in an attempt to extract geomorphological characteristics with quantitative measurements, longitudinal profiles of several channels were constructed. This

* Εξέλιξη της περιοχής Αγιάς – Αγιόκαμπου κατά το Τεταρτογενές, δυνατότητα πιθανής εκφόρτισης προς το Αιγαίο της ανατολικής Θεσσαλικής πεδιάδας

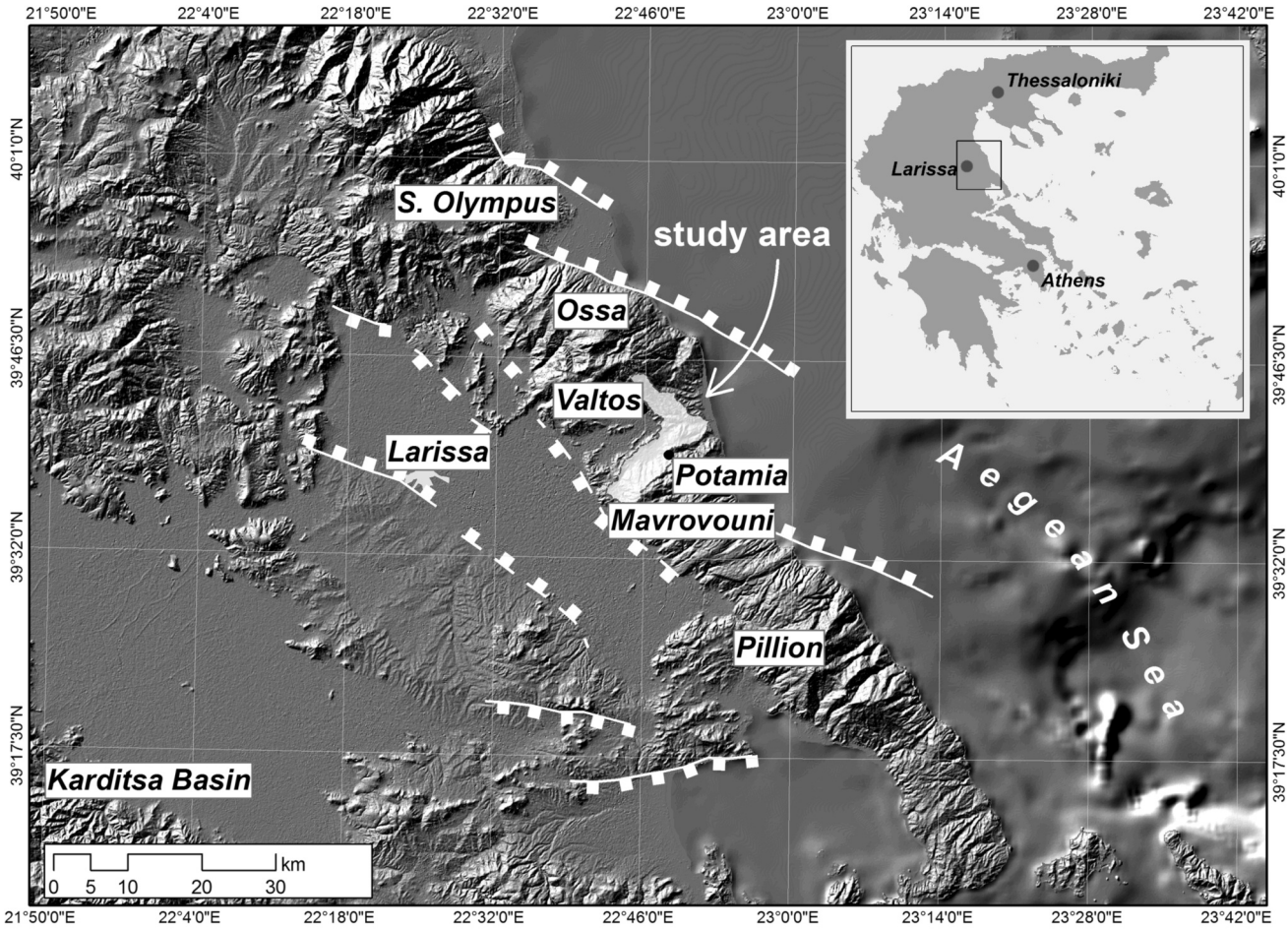

Fig. 1. DEM of the study area showing the examined drainage basin. Inset shows it in relation with Greece. The main faults are also depicted. Offshore faults have been drawn according to LACASSIN *et al.* (2007). Faults with bold lines revealed the active ones. Barbs are on the downthrown block.

work was carried out by using GIS and DTM technology through accurate analysis of aerial photographs at different scales, 1:5,000 topographic sheets and 1:50,000 topographic maps. The products of these techniques, allowed the assessment and visualization of the final constructed maps.

GEOLOGY

In the broader area of Thessaly several scientists have dealt with its geology (KOSSMAT, 1924; BRUNN, 1956; AUBOUIN, 1959; SCHNEIDER, 1968; KATSIKATSOS *et al*., 1982; 1986; DEMITRACK, 1986; KILIAS & MOUNDRAKIS, 1987; CAPUTO, 1990) but very few have engaged in the study area.

The area belongs to the Pelagonian zone. According to the geological maps of IGME (Agia - Panagia Agias, Karitsa, and Platykambos), the basement of this area is a system of metamorphic rocks of Lower-Middle Triassic age, more than 800m thick, occupying a great part of Mavrovouni – Pillion mountains (Fig. 3). This system is overlain by a tectonic nappe of Lower-Upper Cretaceous age, known as "Eohellenic tectonic nappe", which is a complex of metamorphic ophiolitic rocks and metasediments having a thickness of more than 800m, studied in detail by KATSIKATSOS *et al*. (1982). This succession of formations has created a syncline having an axis of east-west direction which almost coincides with the Agia-Agiokambos direction. In the region of Agia, occupying a great extent of the area, there are marbles of Upper Cretaceous age having a thickness of approximately 250 m overlying transgressively the tectonic nappe.

In the area from the villages of Agia and Potamia and especially to the east towards the sea, exist terrestrial and lacustrine formations of Pliocene age (Agiokambos series) filled the old syncline reaching a maximum elevation of about 300m at Panagia Malati (Fig. 3). The series are composed of distinct sedimentary units of lacustrine deposits of well stratified marls and clastic and terrigenous sediments of white and red layers. The observed thickness is 400 m. The beds are dipping considerably towards the west, due to posterior tectonic events (Photo 1).

Upper Pleistocene terrestrial deposits of consolidated cones and talus material are present in the study area, while the Holocene deposits are composed of talus, scree, colluvial, fluvio-torrential and coastal sediments. South of Agia exists a marshy area (between Amyros and Leptokarya streams), whose bluish argillaceous deposits reach a depth of about 80 m (personal communication of local drillers).

Olympus-Ossa-Mavrovouni-Pillion mountains, a 20Km long topographic range corresponds to a succession of uplifted metamorphic rocks (VERGELY & MERCIER, 1990) and especially Olympus has been recognized as a "tectonic window". The mechanism, timing, amplitude and rates of this uplift are, however, a matter of debate among researchers. VERGELY & MERCIER (1990) argue that the opening of the Olympus tectonic window took place between Oligocene and Late Miocene, prior to the post-Upper Miocene extensional period, which was regarded as a compressional effect. SCHERMER (1990), on the contrary, associated the uplift of mantle rocks in the Olympus with low-angle normal faults. Finally, on the ground of correlations of planation surfaces in a wider scale, FAUGÈRES (1975) proposed an about 2 Km uplift and opening of the tectonic window in Pleistocene times, while PSILOVIKOS (1981) assigned an uplift of 550-950 m

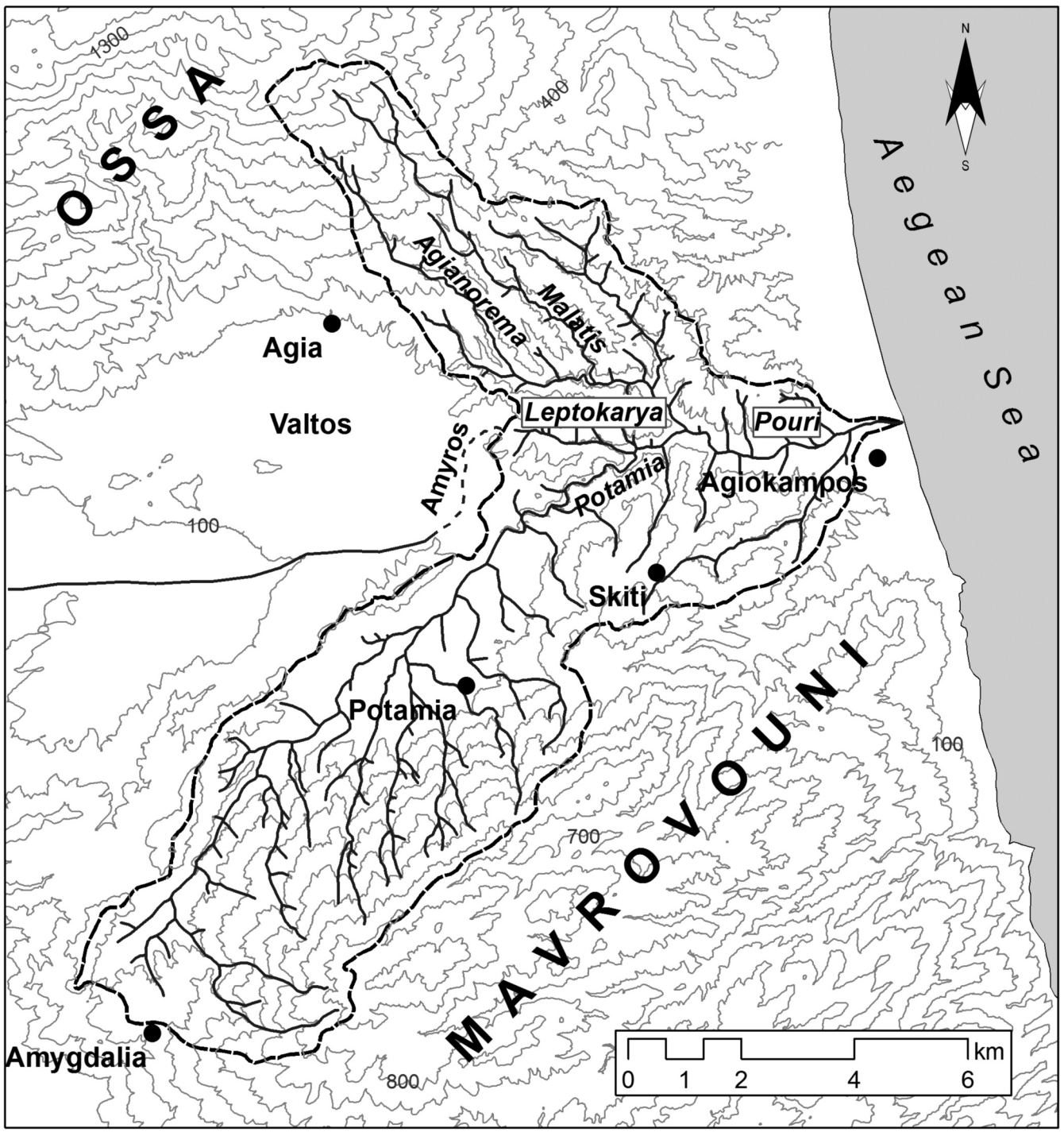

Fig. 2. Topographic map of the study area.

during the Quaternary. Recently NANCE (2010), has dealt with the eastern flank of mount Olympus for the Late Pleistocene suggesting rates of uplift of 1.3mm/yr in the last 210 Ka and 1.6 mm/yr in the last 125 Ka. Moreover, the geomorphological and biological evidence of a 60 cm seismic uplift along the Ossa-Mavrovouni-Pillion range at about 1500 BP, suggests that this uplift is still continuing during the Holocene (STIROS *et al*, 1994).

GEOMORPHOLOGICAL ANALYSIS

Today's drainage network between Agia-Agiokambos is occupied by two major tributary systems and a minor one in between. In the north extends the Agianorema stream which reaches up to ~1100 m on Mount Ossa. In the south, there is Potamia stream which extends to the south-west up to 400 m on Mount Mavrovouni. In between, there is the Leptokarya torrent which, although has a length of only 3 Km seems to be a key tributary for the morphological evolution of the study area, since its valley joins Larissa basin (Amyros stream) to Pouri torrent and eventually the Aegean sea (Fig. 4).

The age of the drainage system of Pouri is clearly Quaternary. It has evolved on Pliocene lacustrine deposits (Photo 2). However, the upstream parts of Agianorema and Potamia are much older because, in Pliocene times, they emptied in the then existing lake. Leptokarya stream, being in the area

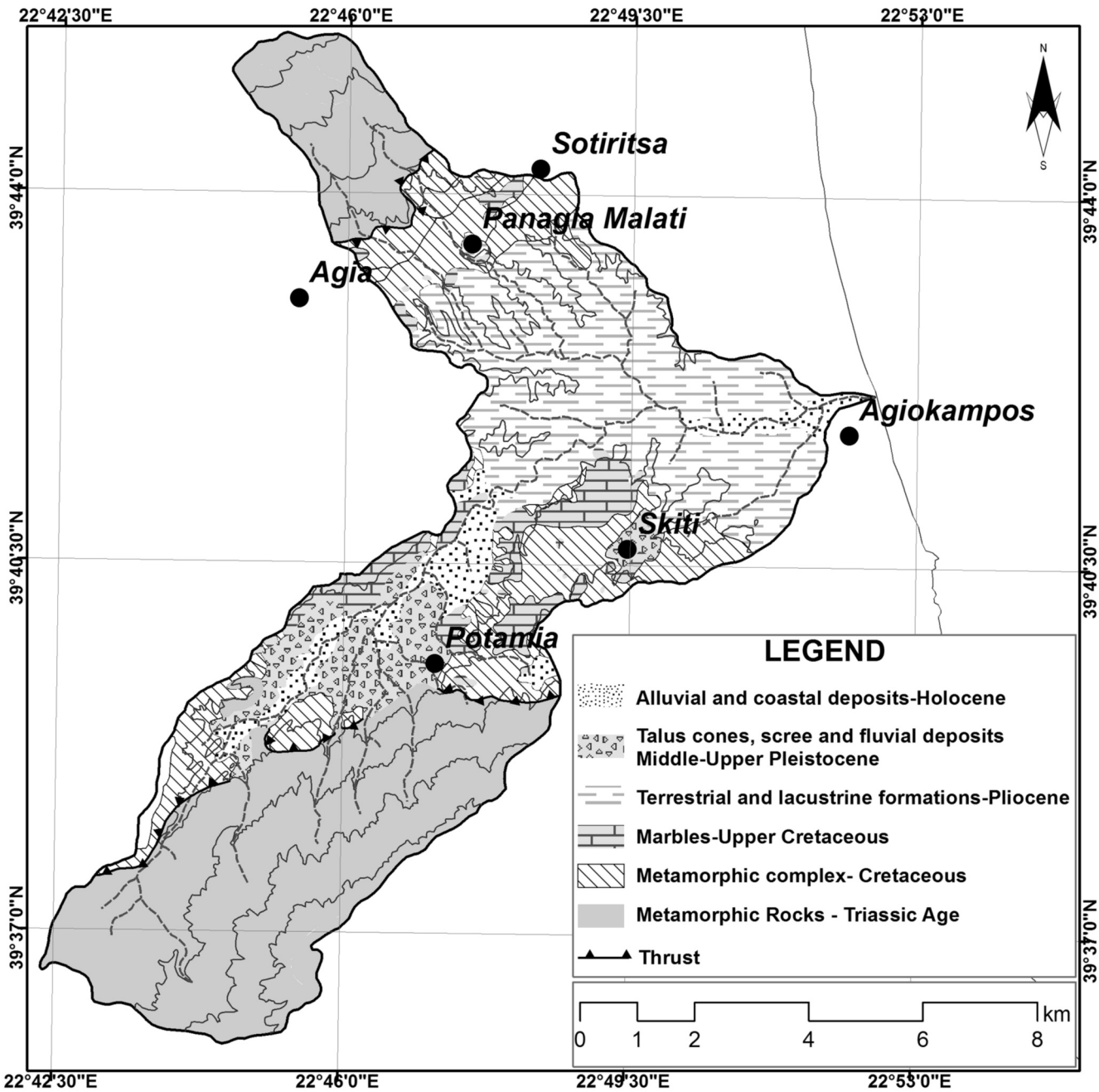

Fig. 3. Geological map of the study area.

of the lake at that time, did not exist. In early Quaternary, fault tectonism disrupted the Pliocene lake which was much larger, extending to the east in today's Aegean sea. There followed the development of Pouri drainage system.

By middle Pleistocene the lacustrine deposits began uplifting from NE to SW resulting in increased downcutting. In the northern parts of the drainage network (Agiannorema-southern Ossa) the incision is still active in the easily erodible marls and terrestrial deposits. These tributaries of mount Ossa (Agiokambos-Malati) have been affected by the NE-SW uplift as their main channel valleys are asymmetric showing steeper southwestern valley slopes and gentler northeastern ones. In the south (Potamia- northern Mavrovouni), the downcutting has reached the underlying Upper Cretaceous limestones and has been entrenched in the area of the Monastery of Agioi Anargyroi (Photo 3). The continuing uplift of the area was delayed by the hard to erode limestones and resulted in Quaternary deposition in the upstream parts of Potamia.

In the Early Pleistocene period the lacustrine deposits were much lower in elevation and the newly formed drainage system of Pouri was also the outlet of the inner eastern Thessaly basin (Larissa basin) through Amyros – Leptokarya streams. There continued uplift of the lacustrine deposits to the SW resulted in the severing of the outlet to the Aegean during the Late Pleistocene. Today, there are two remnants of this old drainage extension, Amyros stream flowing towards the west to the Larissa basin and Leptokarya rema to the east, being a much shorter stream, in the Pouri drainage basin (Fig. 2). Between the two streams (Leptokarya – Amyros) there exists today a marshy area that advocates the process of uplift which resulted in the westerly reverse flow of Amyros stream (Photo 4). This process is quite recent as exemplified by the longitudinal profile along Amyros-Valtos-Leptokarya (Fig. 5). At an elevation of approximately 60m on the Leptokarya side a knickpoint is observed in the profile, which is attributed to the outcropping of limestones underlying the lacustrine deposits. The elevation of the drainage divide is today at 154 m. In the west, Amyros stream and Valtos area are located at 110 m. The elevation of the confluence of Leptokarya stream with Potamia is at 40 m. This means that the elevation difference between Amyros – Valtos at the divide, although recent, happened sometime ago since it has uplifted at least by 45 m. The reversal of flow should have started sometime between Middle and Late Pleistocene times as a thickness of approximately 80 m of bluish argillaceous sediments have been reported in the Valtos – Amyros marshy area. As previously mentioned the NE - SW uplift of the study area has clearly affected the longitudinal profiles of Agianorema and Potamia (Fig. 6). The Agianorema stream issuing from mount Ossa has a much steeper gradient and shorter length while Potamia located in Mavrovouni area is much gentler and longer.

Regarding the terrestrial deposits of Potamia area, these were probably formed during the Middle Pleistocene following the uplift of the Pliocene lacustrine deposits from the

Photo 1. Pliocene conglomerates tilted towards the SW and displaced by local secondary faults.

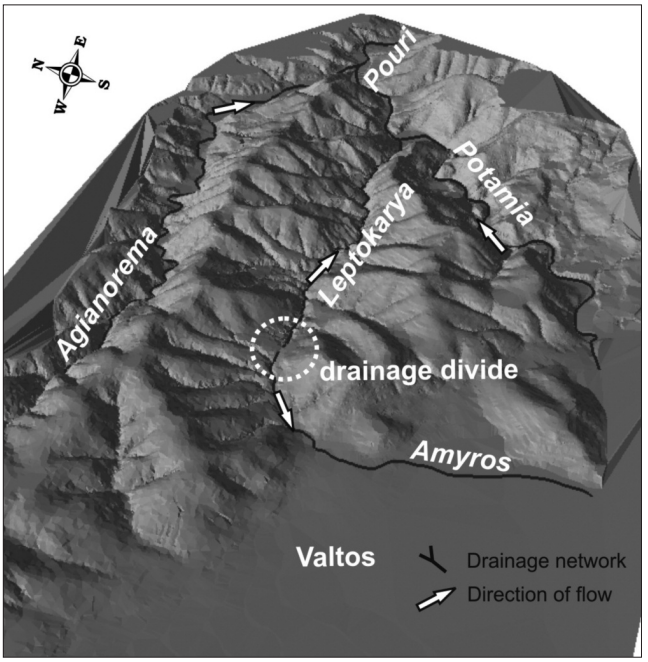

Fig. 4. DEM of the drainage systems of the study area.

Photo 2. Deeply incised, by Potamia stream, uplifted Pliocene lacustrine deposits, viewed to the north from Skiti village.

Photo 3. Deeply incised limestones by Potamia stream overlain by Pliocene lacustrine deposits at the Monastery of Agioi Anargyroi.

Photo 4. In the foreground is the Valtos marshy area. On the right-hand side middle background on the right of the conical hill is Amyros stream, pointed with an arrow.

Photo 5. View towards the south of the Agiokambos beach. In the background are Pillion and Mavrovouni mountains.

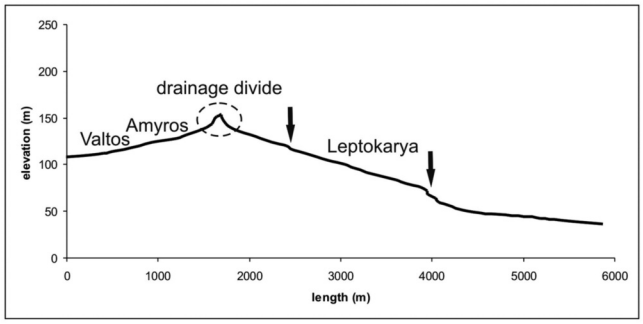

Fig. 5 Longitudinal profile along Amyros-Valtos-Leptokarya.

NE. In the beginning, the marls and the terrestrial deposits of the lake were easily eroded. When, however, Potamia stream reached the underlying limestones the incision slowed down considerably and resulted in the fluvial deposition in the upstream part of Potamia village area. In recent times, there seems that the uplift rate has diminished; deposition in the Potamia village area has stopped, followed by downcutting which resulted in the formation of the 20 m terrace, probably with the formation of a short lived lake.

The coastline of Ossa-Mavrovouni is linear with a NW - SE direction and has obviously being affected by fault tectonism (Photo 5). However the Neogene formations, although linear, are located 700-800 m further inland from the present shoreline, clearly suggesting an erosional process preceeding today's position of the coast. The present coastal morphology is quite stable, mainly the result of marine processes. The particle size distribution along the shore is coarser in the north becoming finer towards the south depending on the prevailing winds, wave regime and longshore current.

CONCLUSIONS

Based on geomorphological analysis in relation to the geotectonic regime of the area, it is concluded that the possibility of the presence of an outlet of the eastern Thessaly plain (Larissa basin) can be safely supported. Following the draining of the Pliocene lake that existed between Agia and today's Aegean sea, there followed the formation of a Quaternary drainage system (Pouri) which utilized it as an outlet of Larissa basin. The ensuing NE-SW uplift eventually blocked the upstream part of the basin which resulted in a reverse flow (Amyros) towards the west.

The geomorphological observations suggest that the uplift of the study area occurred during the whole Pleistocene period, in agreement with the proposed uplift of the whole area of Olympus-Ossa mountains. In the study area, the Pliocene formations are found at a maximum elevation of about 300 meters (Panagia Malati). Thus a minimum uplift rate of 0.3 mm/yr is obtained for the period starting from the Middle-Upper Pleistocene until today (about 1 Myr) for the

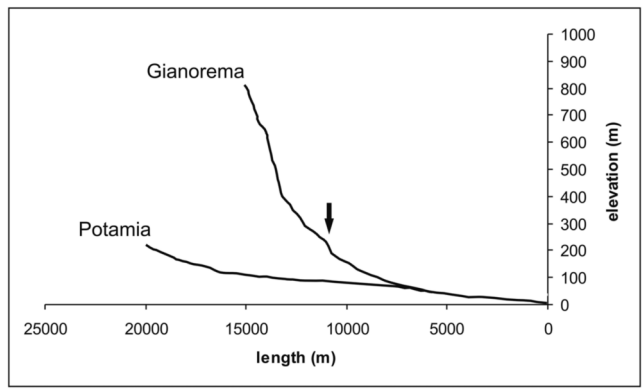

Fig. 6. Combined longitudinal profiles of Gianorema and Potamia streams.

Agia-Agiokambos area.

In conclusion, today's relief is therefore the result of the combination of tectonism, lithology and geomorphic fluvial processes.

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