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## TRACES OF PRE – TYMPHIAN GLACIATIONS ON ATHAMANION MASSIF, PINDOS MOUNTAIN CHAIN, GREECE

**ABSTRACT:** STAMATOPOULOS L. & PALMENTOLA G., *Traces of pre – Tymphian glaciation on Athamanion Massif, Pindos mountain chain, Greece.* (IT ISSN 0391-9839, 2017).

Pindos is the longest Hellenic mountain chain and as such, constitutes the backbone of the Greek peninsula. It takes part of the overall mountain system of western Balkans and it represents the continuation of the Dinaredes trending NNW to SSE in the Hellenic mainland. In this work, we present evidence of pre-Tymphian glaciation events on Athamanion Massif (Tzoumerka) in Epirus, northern Pindos.

The first evidence for such pre-Tymphian events derives from the position of four moraine-ridge systems. Interpretation of such an emplacement may involve two possibilities: either the presence of lateral valleys on a higher level, such as that of Mangano and Fuskes peaks, which were occupied by an extensive and high glacial tongue that was able to abandon lateral moraines in that place, or that the particular moraines were abandoned in a landscape much different than today's with deep or even non-existent valleys.

Since all altitude data reported from the last glaciations event are particularly low, as well as, average reported altitudes for amphitheatrical valleys (cirques) are also low, we deduce that those moraines were emplaced pre-Tymphian and subsequently were buried and protected by slope deposits.

The moraines were probably emplaced before their valleys were incised. Moraine deposits were carried to their present position and they were subsequently solidified. These moraines have been detached from their feeder amphitheatrical valleys and occur presently as isolated ridges overlaid by cryoclastic breccias subjected to diagenesis.

This observation suggests that some very important changes took place in the landscape-forming conditions: actually, the detritus of the cryoclastic breccias was derived from the escarpment of the Mangano and Fuskes peaks and it descended and was emplaced on the new slope formed by the pre-Tymphian lateral moraine. In any case, a relief inversion occurred. Probably this new configuration of relief, assisted by climatic and hydrologic conditions, did provide sufficient stability to lead towards the consolidation of the breccia formations.

**KEY WORDS:** Pre-Tymphian Glaciations; Athamanion (Tzoumerka) massif; Pindos Chain; Greece.

**ΠΕΡΙΛΗΨΗ:** ΣΤΑΜΑΤΟΠΟΥΛΟΣ Λ. & ΠΑΛΜΕΝΤΟΛΑ Γ., *Ίχνη προ – Τύμφιων παγετώνικων αποθέσεων στα Αθαμανικά όρη, της οροσειράς της Πίνδου, Ελλάδα.* (IT ISSN 0391-9839, 2017).

Η Πίνδος είναι η μακρύτερη οροσειρά της Ελλάδας και ως τέτοια, αποτελεί τη ραχοκοκαλιά της ελληνικής χερσονήσου. Είναι μέρος του ευρύτερου συστήματος ορεινών όγκων των δυτικών Βαλκανίων και αντιπροσωπεύει τη συνέχεια της οροσειράς των Διναρίδων, έχοντας Β/ΒΔ προς Ν/ΝΑ κατεύθυνση προς την ηπειρωτική χώρα.

Σε αυτή την εργασία, παρουσιάζουμε δεδομένα προ-Τύμφιων (Pre-Tymphian) παγετωδών γεγονότων που έλαβαν χώρα στην Ήπειρο και συγκεκριμένα στα Αθαμανικά Όρη της Βόρειας Πίνδου.

Τα πρώτα στοιχεία για τη προ-Τύμφια παγετώδη δραστηριότητα προέρχονται από τη θέση τεσσάρων ράχων μορένων. Η ερμηνεία μίας τέτοια δημιουργίας ράχων, πιθανά περιλαμβάνει δύο γενεσιουργίες διαδικασίες: Είτε τη παρουσία κεκλιμένων κοιλάδων σε μεγαλύτερο υψόμετρο, όπως αυτών των κορυφών του Μάγγανου και των Φουσκών οι οποίες είχαν καλυφθεί από μία εκτεταμένη και μεγάλου πάχους παγετώδη γλώσσα η οποία δημιούργησε κεκλιμένες μορένες στη περιοχή, είτε οι συγκεκριμένες μορένες δημιουργήθηκαν σε ένα περιβάλλον πολύ πιο διαφορετικό του σημερινού, με βαθιές ή ακόμα και μη υπάρχουσες κοιλάδες.

Δεδομένου ότι τα διαθέσιμα υψομετρικά δεδομένα των τελευταίων παγετωδών γεγονότων στη περιοχή, είναι ιδιαίτερος ανεπαρκή, όπως επίσης και τα διαθέσιμα μέσα υψόμετρα των αμφιθεατρικών κοιλάδων είναι επίσης χαμηλά, συμπεραίνουμε ότι οι μορένες στη περιοχή δημιουργήθηκαν προ-Τύμφιου και στη συνέχεια καλύφθηκαν και προστατεύθηκαν από πλευρικά κορήματα.

Οι μορένες πιθανότατα δημιουργήθηκαν πριν δημιουργηθούν οι κοιλάδες τους. Μορενικές αποθέσεις αποτέθηκαν στη παρούσα θέση τους και μετέπειτα διαγενέθηκαν. Αυτές οι μορένες αποσπάστηκαν από τις μητρικές αμφιθεατρικές τους λεκάνες και εμφανίζονται σήμερα ως μεμονωμένες κορυφογραμμές υποκειμένες κρυσταλλικών λατυποπαγών τα οποία βρίσκονται σε καθεστώς διαγένεσης. Η συγκεκριμένη παρατήρηση υποδηλώνει πως κάποιες πολύ σημαντικές αλλαγές που αφορούν τις συνθήκες δημιουργίας του τοπίου έλαβαν χώρα: Ουσιαστικά, τα κορήματα των κρυσταλλικών λατυποπαγών προήλθαν από τον κρυστό των κορυφών του Μάγγανου και της Φούσκας από όπου μεταφέρθηκε και αποτέθηκε στο νέο κρυστό που δημιουργήθηκε από τις προ- Τύμφιου κεκλιμένες μορένες. Σε κάθε περίπτωση υπήρξε αναστροφή του αναγλύφου. Πιθανά, αυτή η νέα διαμόρφωση του αναγλύφου, επικουρούμενη από τις κλιματικές και υδρολογικές συνθήκες, παρείχε επαρκή σταθερότητα για να οδηγηθούμε στη διαγένεση των λατυποπαγών σχηματισμών.

**ΛΕΞΕΙΣ ΚΛΕΙΔΙΑ:** Προ-Τύμφιο (Pre-Tymphian), Μορένες, Οροσειρά Πίνδου, Αθαμανικά Όρη (Τζουμέρκα).

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## INTRODUCTION AND GEOLOGICAL SETTING

Pindos is the longest Hellenic mountain chain and as such, it constitutes the backbone of the Greek peninsula. It belongs to the overall mountain system of western Balkans and it represents the continuation of the Dinarides, trending NNW to SSE into the Hellenic mainland. In this paper, we will present the observations and detailed arguments for pre-Tymphanian glaciations events on Athamanion Massif (Tzoumerka). Athamanion Massif is situated in northern-central Pindos, between 39° 22'N - 39° 39'N and 21° 04'E - 21° 15'E in Epirus, north-western Greece (fig. 1A). The massif consists of Eocene to Lower Miocene sedimentary successions of the "Ionian zone", of Triassic to Upper Eocene sedimentary sequences of the "Gavrovo zone" and of Upper Cretaceous to Eocene sedimentary successions of the "Pindos zone" (fig. 1B), (Brunn, 1956; Aubouin, 1959; Vakalas, 2003).

## PREVIOUS INVESTIGATIONS

Aubouin (1961) has mapped the general area in a 1:50000 scale (Pramanda sheet).

He recognized two categories of glacial landforms: Firstly, those above 1900 a.s.l. that were assigned to a Würmian age and secondly the moraines at altitudes between 1900-1400 a.s.l. as older than Würm, probably Riss. In our case, we are using the equivalent stratigraphical terms of glacial stages for Pindos Mountains of Vlasian and Tymphanian instead of Riss and Würm respectively (Hughes & *alii*, 2006).

We contest this interpretation which is solely based on the criterion of altitude. We argue that, the same moraine deposits mapped by Aubouin (1961) as Vlasian represent the maximum glacial expansion during Tymphanian.

Recent glacial research in the high cirques of Mt. Tymphi, in an area adjacent to the north of Athamanion Massif, has

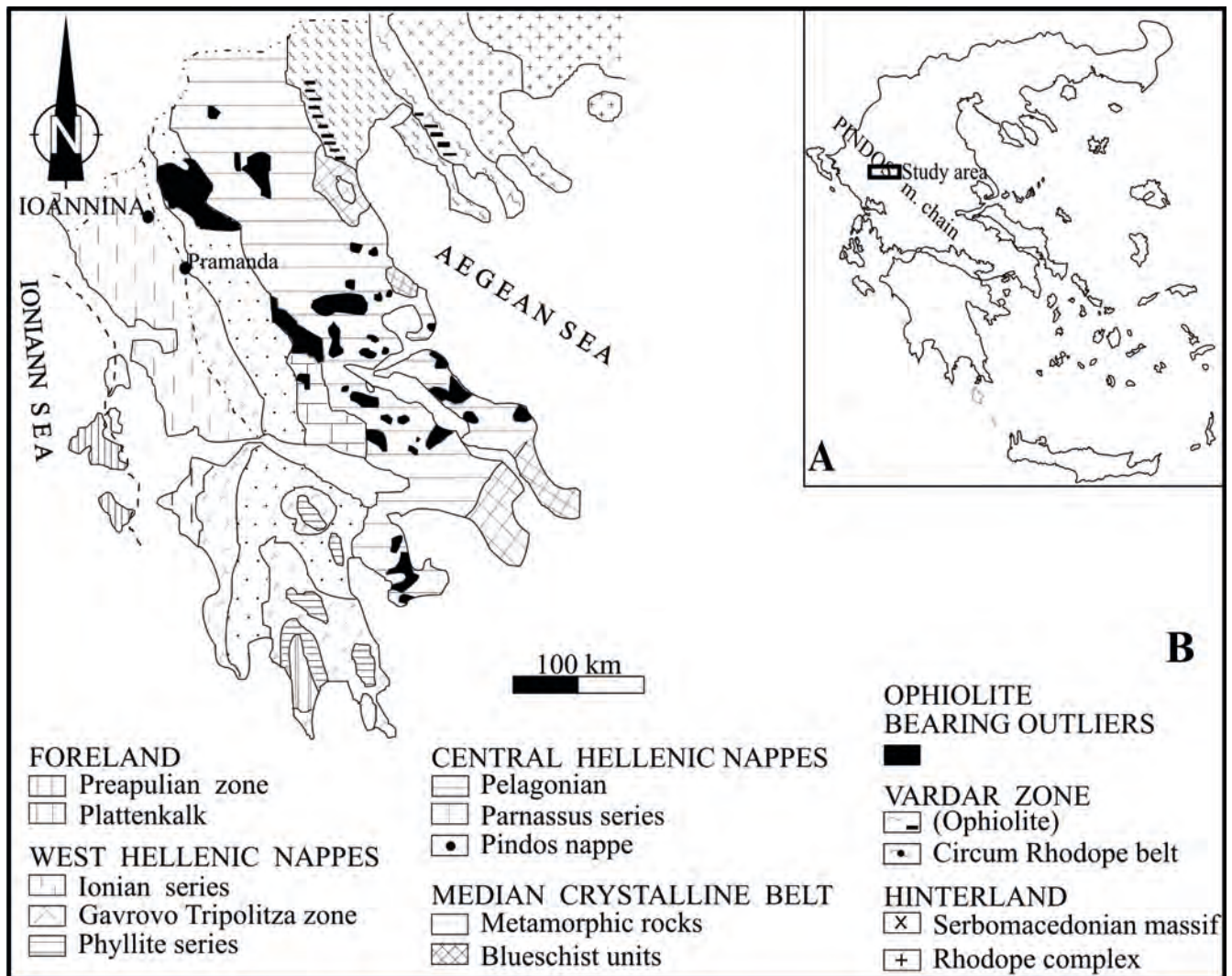


FIG. 1 - A. Map of Greece showing the Pindos mountain chain. The inset box shows the study area. B. Simplified geotectonic map of the Hellenides (modified after Doutsos et al. 2006).

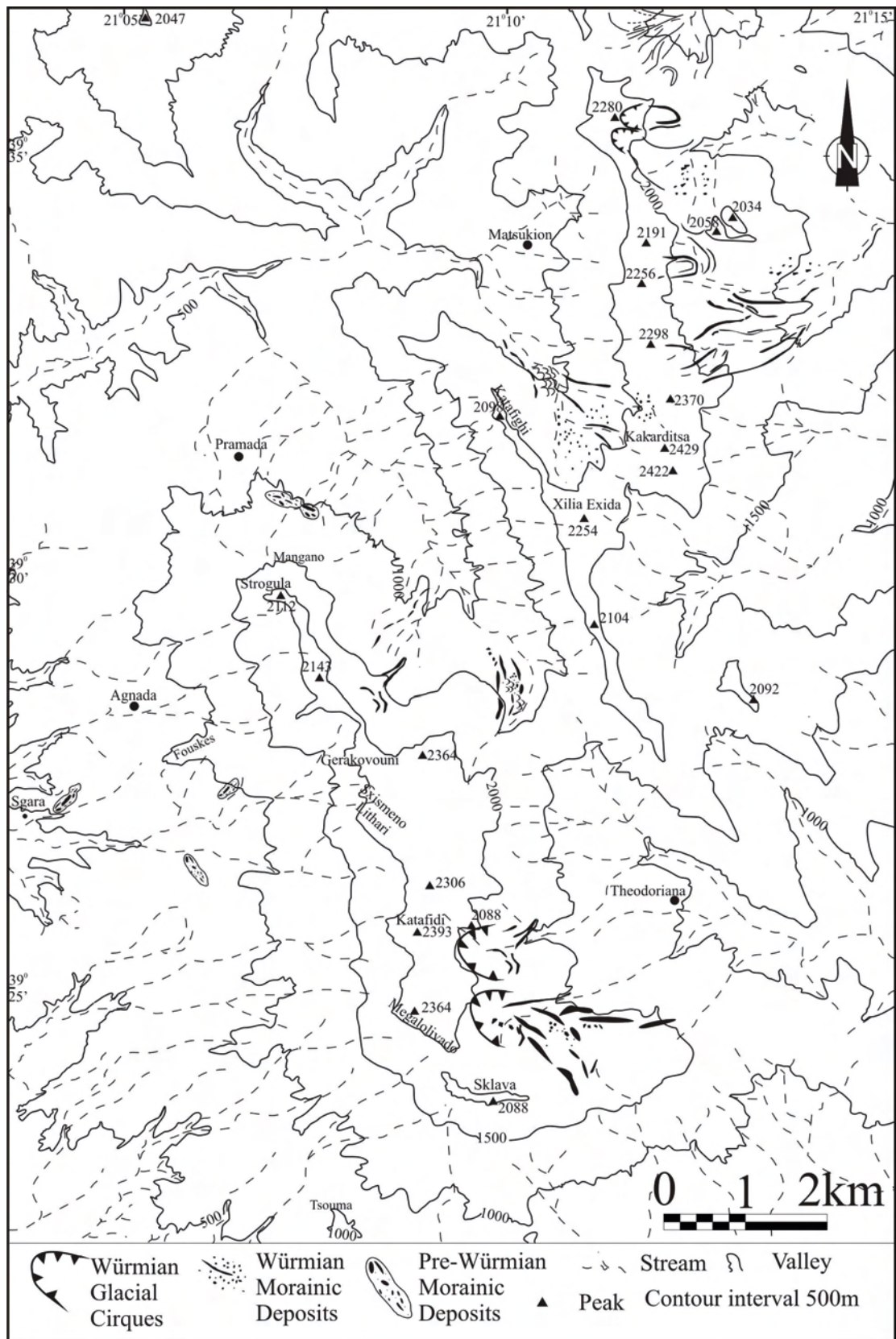


FIG. 2 - Geomorphological map of the main ridge of Mount Athamanion showing the locations of the pre-Würmian (pre-Tymphan) moraines deposits described in the text and the main Würmian (Tymphan) glacial landforms. The map was based on H.M.G.S. 1:50 000 topographic sheets.



provided age-dates for lithified glacial deposits, indicating that the earliest recorded glaciations occurred over 350.000 years ago i.e. during Middle Pleistocene, (Woodward & *alii.*, 2004; Hughes, 2004). This time framework is further supported by Smith & *alii* (1997) which suggests an Early - Middle Pleistocene age for the periglacial unit at Mt Olympus. Ribolini & *alii* (2011) mention a glaciation phase occurring during the Middle Pleistocene near Prespa and Ohrid lakes. This is attributed to the till found on the lakes shores and on the mountain ranges bordering the lakes. The till signs expanded well below the examined area of Galicia Mountains in FYROM and that indicates an extended phase of Middle Pleistocene glaciation in the area.

Pope et al. (2017) suggest Middle Pleistocene age for the large glacial activity of Chelmos mountain in North Peloponnese. They also suggest that the studied smaller valley and cirque glaciers and the boulders on the moraines of these glacial phases are of Late Pleistocene age.

Woodward & Hughes (2011) mention an inconsistent chronological framework for the glacial sediments and landform of Mount Olympus. They also suggest two major phases of glaciation regarding Mount Tymphi, pointing to a more complex Pleistocene history in the area than the one suggested by Palmentola & *alii* (1990) but without being able to quantify the age difference between lower and higher altitude moraines and the exact cold stage they formed in.

Finally, during the past decades Federici (1977, 1980) and Kotarba & *alii* (2001) carried out several investigations on glacial landforms in this sector of the Apennines and noted glacial deposits of Middle Pleistocene age. Federici (1977) suggests that glacial deposits, which extend much lower than moraines assigned to the Late Würmian, have been noted in many areas of the Italian Apennines. They are often partially cemented, are having a pink hue and are often fragmentary, incomplete and no radiometric dating has established their age.

Federici (1980) also reported the existence of glacial deposits on the North sector of Apennines whose loca-

tion, morphology, lithology and weathering rate could be explained only by previous glaciations.

Kotarba (2001) mentions that based on Uranium dating's, carried out on calcite crystals in moraine deposits, an ancient glaciation phase which affected the Campo Imperatore depression (Gran Sasso Massif) has been referred to the late-middle Pleistocene (Riss Auct.). This glaciation (Piano Racollo Glaciation) was found to be much wider than the Upper Pleistocene (Würm) one (Coppe di Santo Stefano Glaciation), whose landforms and deposits are much more evident in the area.

## PRE-TYMPHIAN LANDFORMS

The Athamanion Massif is one of the most extensively glaciated mountains of Pindos and it includes a number of high peaks such as Kakarditsa (2429 m), Chilia Exida (2254m), Katafighi (2098m), Strogoula (2112 m), Gerakovouni (2364 m), Sxismeno Lithari (2306 m), Katafidi (2393 m), Megalolivado (2199 m) and Sklava (2088 m). Pramada village is located near Strogoula peak (fig. 2). In the study area, the massif is mainly made by compact but fractured limestones of Eocene age (Aubouin 1959), these rocks are notoriously very conservative as regards to the morpho-climatic relics. This is the reason why many of the glacial cirques of Tymphian age are perfectly preserved on the Athamanion Massif (fig. 2). On the other hand, flysch sequences are very easily erodible, and in some cases, only the overlying welded moraine deposits can preserve the buried flysch deposits.

During our geomorphological study, which was based on mapping, field observations and measurements and photo interpretation, we have observed along the Pramada-Melissourghi area, SW of the village Pramada and along Agnada-Sgara area on the Fuskes dorsal, at altitude which range between 1100-800 m. a.s.l., rock deposits which consist of large well-striated clasts (fig. 3) and boulders in a

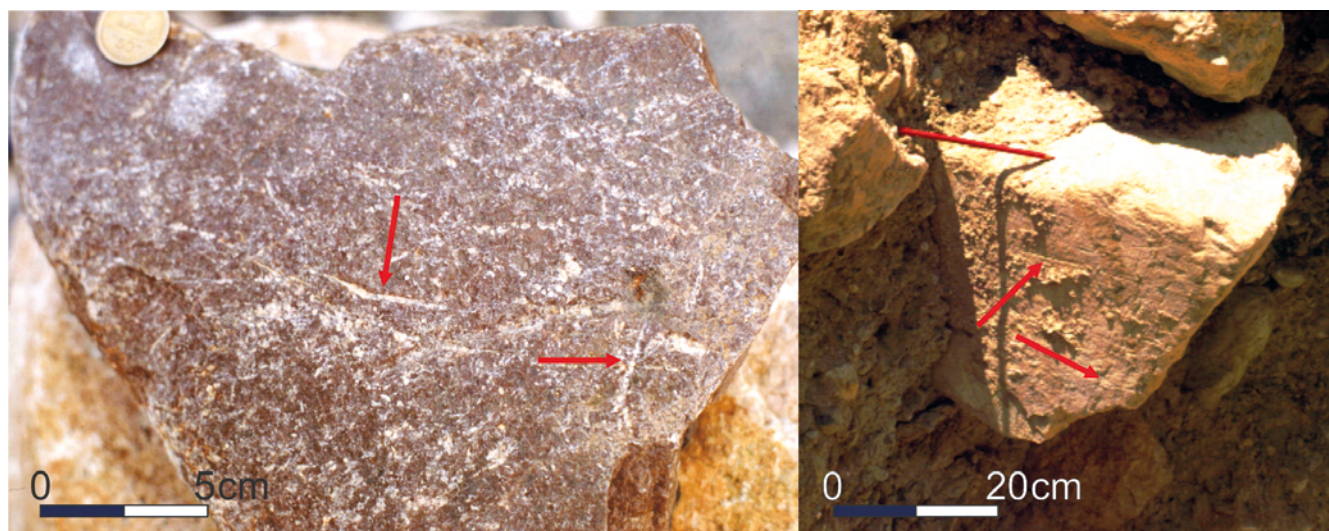


FIG. 3 - Photographs showing well-developed striations (indicated by arrows) on cobbles of pre-Tymphian moraines in the study area.

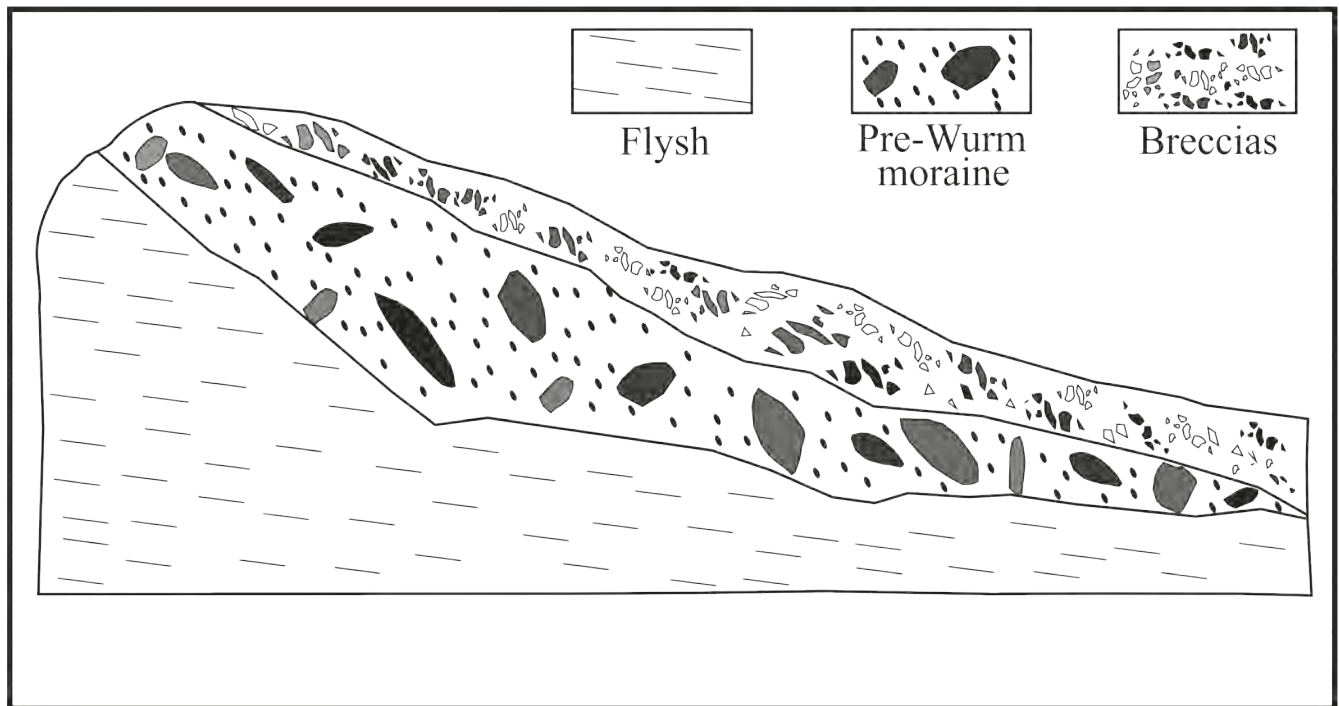


FIG. 4 - Simplified section showing the pre-Würm (pre-Tymphian) moraine covered by cryoclastic cemented and rubefatte breccias. (Not in scale)

lithified matrix of sandy poorly-sorted gravel. These characteristics allow us to attribute these deposits to a moraine.

These moraine deposits are covered by a well-cemented cryoclastic breccia (fig. 4) and have a clearly distinct lithostratigraphy and morphology compared to a different type of moraines, undoubtedly more recent, of Tymphian age. However, the pre-Tymphian moraines are located at altitudes 1100-800 m. a.s.l., clearly lower than those we consider Tymphian (2000-1400 m a. s. l.). This altitude discrepancy can be interpreted in one of the two following ways:

- a) the valley, where these pre-Tymphian moraines are located, was covered by a thick and extensive glacial tongue which when it withdrew, left these pre-Tymphian lateral moraines in situ;
- b) these pre-Tymphian moraines have been emplaced in a very different landscape than the present topography, i.e. in very shallow valleys or these valleys were incised later due to glacial withdrawal assisted by climatic and hydrological conditions.

The pre-Tymphian moraines have been detached from their feeder amphitheatrical valleys (circuses) and occur presently as isolated ridges covered by cryoclastic breccias subjected to diagenesis.

Pre-Tymphian moraines and the overlying breccias are strongly welded. The fact is probably due to an intense underground water circulation, as at those altitudes rainfall amount per year is really relevant. In this condition, as the clasts and matrix are mainly made of limestones, the circulation water is rich in calcium carbonate that welds the grains.

After all, as consequence of this process, the pre-

Tymphian moraines and breccias protect the buried flysch that has a very low resistance to erosion. Obviously, in a landscape of flysch, moraines and breccias form ridges. In other terms, a geomorphic sequence of relief inversion occurred, in the sense that a former valley, in which the pre-Tymphian moraines accumulated, became a ridge.

In the study area, the detritus of these breccias was probably derived from the escarpment of the Mangano and Fuskas peaks and was emplaced on the new slope formed by the pre-Tymphian lateral moraine. Probably this new configuration of relief provided sufficient stability to lead towards the consolidation of these breccias with climatic and hydrogeologic conditions mitigating towards this end.

## CONCLUSIONS

Despite our conclusions that the Tymphian glacial landforms occurred at topographic positions between 1600-1300 m a.s.l., we suggest that altitude of occurrence cannot constitute the unique criterion for ascribing a glacial landform to a certain time framework.

We have studied moraine deposits consisting of large striated clasts in a lithified sandy gravel matrix which occur at altitudes between 1100-800 m., a.s.l. and if morphological and stratigraphic parameters are correctly appraised, they have pre-Tymphian ages. Particularly the well-cemented cryoclastic breccia cover, probably derived from the nearby Mangano and Fuskas peaks in the study area, would be indicative of pre-Tymphian ages for these moraine deposits.

The 'moraines on ridges' configuration of such pre-

Tymphian glacial deposits may involve two possibilities of interpretation: either the presence of a lateral valley on a higher level, such as that of the Mangano and Fuskes peaks, which was occupied by an extensive and thick glacial tongue that was able to abandon lateral moraines in that place, or that the particular moraines were abandoned in a landscape much different than the present landscape with less deep or non-existent valleys. In any case, the “moraines-ridges” configuration represents a new inverse relief.

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