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LATE OROGENIC UPLIFT OF THE HELLENIDES

T. Doutsos*

ΣΥΝΟΨΗ

Μέσα στις μολασσικές λεκάνες των Ελληνίδων οροσειρών είναι γνωστό από αρκετά χρόνια ότι υπάρχουν δομές συστολής που σχηματίστηκαν κατά το Μειόκαινο. Ωστόσο τελευταία πολλοί συγγραφείς αναγνώρισαν μέσα σ' αυτά τα πετρώματα δομές διαστολής και πρότειναν ένα μοντέλο τύπου "basin and range" για την υστερο-καινοζωϊκή εξέλιξη των Ελληνίδων.

Η τελευταία ορογενετική ανύψωση των Ελληνίδων είναι το αποτέλεσμα συνεχούς σύγκλισης και διείσδυσης πολλών μικροπλακών από την Απούλια πλάκα. Η συμπιεστική ανύψωση στα τελευταία στάδια της σύγκρουσης πλακών συντελείται από οριζόντια - και πλαγιοανάστροφα ρήγματα. Τελικώς το ορογενές κατέρρευσε στα πλαίσια ενός διαγωνίου εφελκυσμού.

ABSTRACT

In the Hellenides, shortening structures within the Miocene molasse are known since long ago. Nevertheless recently, most authors recognized extensional structures within these rocks proposing a "basin and range" type model for the late Cenozoic evolution of the Hellenides.

Late orogenic uplift of the Hellenides is the result of a continuous convergence and indentation of several microplates by the Apulian plate. Syncompressional uplift in the late stages of the plate collision is accomplished by pure-and reverse strike-slip faults. Finally the whole orogen collapsed by transtension.

ΕΙΣΑΓΩΓΗ - INTRODUCTION

In the last decades, the nature of late orogenic uplift of collisional mountain belts represents one of the major controversies in tectonics today. Several kinematic models have been proposed:

a) syncompressional uplift and continuous underplating below the overriding plate (Hsu 1991).

b) syndistensional thinning by synchronous formation of "extensional metamorphic complexes" (Lister & Davis 1989).

c) Compression and extension taking place synchroneously or successively at different structural levels (Platt 1986).

d) Obliquely convergence of plates causing transpression (Vauchez & Nicolas 1991).

e) Tectonic escape and extrusion processes as a result of convergence of plates having irregular margins.

These kinematic models can be tested in late orogenic basins now superimposed on the suture of collided plate margins. In the Hellenides the

* University of Patras, Department of Geology, GR-26110 RION/PATRAS, GREECE.

western margin of the Apulian plate had collided with several microplates lying between the Apulian and European plates during the Late Cenozoic time (Smith 1977, Mountrakis 1985, Jones & Robertson 1991, Doutsos et al 1993). Suture zones in that area consist of high metamorphic gneisses, blueschists and late kinematic granites often covered by Upper Cenozoic late-orogenic sediments. We carried out structural mapping and mesoscopic analysis of faults on three parts of the Hellenides marked by suture zones: 1) The Mesohellenic Trough 2) The Central Aegean region and 3) The Circum Rhodope Belt.

Η ΜΕΣΟΕΛΛΗΝΙΚΗ ΑΥΛΑΚΑ - THE MESOHELLENIC TROUGH

Tectonic setting

The Mesohellenic Trough formed above a major tectonic contact which separates the Apulian platform in the west from the Pelagonian microcontinent in the east (Brunn 1956). The trough contains a flysch sequence at the bottom and a flyschoid to molassic sequence at the top (Fig. 1). The latter was deposited during Oligocene and Miocene times (Zygojiannis & Sidiropoulos 1981) with a maximum thickness of 3500m. Oligocene subsidence was mainly active along the western margin of the through whereas during the Miocene the depocentre moved northeastward through time (Fig. 1). As older molassic

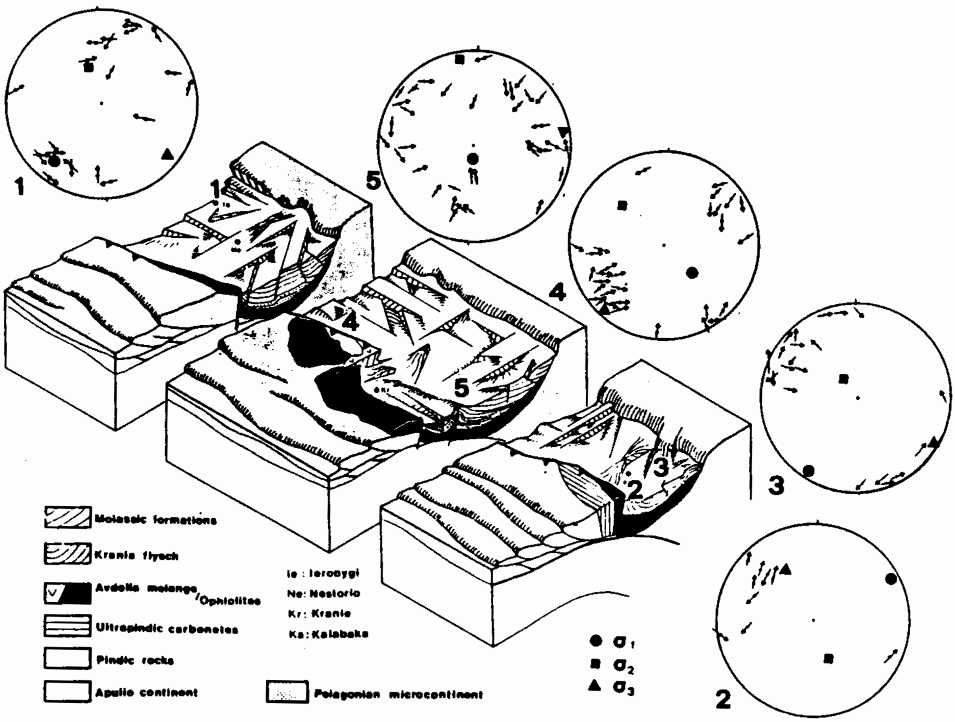

Fig. 1: Schematic block diagram of the Mesohellenic Trough showing the tectonic framework during the Apulian and Pelagonian convergence. Stereoplots show the orientations of mesofracture sets for 5 stations (modified after Doutsos et al. 1994).

Σχ. 1: Σχηματικό μπλόκ διάγραμμα της Μεσοελληνικής αύλακας που δείχνει την τεκτονική διάρθρωση κατά την σύγκλιση της Απούλιας με την Πελαγονική πλάκα. Στερεογραφικές προβολές των προσανατολισμών των μεσοσκοπικών διαρρήξεων για 5 σταθμούς (τροποποιημένο από Δούτσος κ.α. 1994).

formations crop out in the southeast (the Kalabaka area), where the though narrows considerably, an asymmetry along the trough-axis is also outlines.

Structural data and synthesis

The Mesohellenic Trough was developed as a piggy back basin along the eastern flanks of a giant pop-up structure, which consists of west verging, foreland propagating thrusts within the Pelagonian plate. Tectonic and sedimentary changes along the trough axis result from the irregularity of the Apulian margin: a) Two small Apulian-indentors at the terminations of the trough caused syncompressional wrenching extented into the middle Miocene. The latter comprise a conjugate system of NW-and NE- trending faults which can be characterised as pure-and reverse strike-slip faults (Fig. 1:1,2 and 3). Computed stress calculations of striation on the fault planes (for methods s. ETCHEOPAR et al. 1981, Onken 1988) reveal = σ_3 (minimum compressive stress) nearly vertical; σ_2 (intermediate compressive stress) in the NNW direction, parallel to the trough axis; and σ_1 (maximum compressive stress) in the ENE direction, perpendicular to the trend of the Apulian margin. b) In the central part of the trough, where the Apulian margin shows a concave geometry syncompressional wrenching terminated in the lower Oligocene and began syndistensional thinning. It is accomplished either by NW-trending grabens (Fig. 1:4) and or by NE-trending grabens (Fig 1:5).

We conclude that two small Apulian indentors at the termination of the trough caused until middle Miocene tectonic escape toward the central part of the trough. In this part or the trough collision terminates in the Early Oligocene and is followed by isostatic collapse and extension.

Η ΚΕΝΤΡΙΚΗ ΑΙΓΑΙΑΚΗ ΠΕΡΙΟΧΗ - THE CENTRAL AEGEAN REGION

Tectonic setting

The central Aegean region is a part of the Attic-Cycladic massif, which is composed of a stacked sequence of nappes mainly established during the Alpine orogeny in the Early Eocene (Marinos & Petraschek 1956, Durr et al.1978). It is the result of continuous underplating of the Apulian platform below the Eurasian plate. Two metamorphic events one in the Early Eocene (450-500°C, 14 kb, Dixon 1976) and the other in the Late Oligocene (450-480°C, 4-7kbar, Jansen & Schuiling 1976) took place during this plate convergence. In Naxos and Sifnos the younger metamorphism culminated in of formation the thermal domes (s. also Buick & Holland 1989).

Throughout Miocene, all teconic units were intruded by I- and S-type granitoids (Altherr et al. 1982). These rocks crystallized at high levels in the crust at depths of 5-10 Km deduced from metamorphic assemblages in the country rocks (Buick 1991a). Synchronous with the emplacement of the granites, molassic sediments accumulated. In many islands the Lower Miocene lies unconformably above the basement whereas in other islands tectonic contacts have been recognized (Roesler 1978, Durr & Altherr 1979).

Structural data and synthesis

Transpressional and transtensional structures have been observed within the molassic cover and the underlying granites.

a) The molassic cover in the Anafi island is separated from the pre-Neogene basement by a steeply dipping NNE-trending fault (Fig. 2A). Kinematic indicators along small faults such as sigmoidal flexures on the scale of 1 to 10m, mesoscopic folds (Fig. 2A,2 and A-A') and slickensides

Η ΠΕΡΙΡΟΔΟΠΙΚΗ ΖΩΝΗ - THE CIRCUM RHODOPE BELT

Tectonic setting

The Circum Rhodope Belt is a Mesozoic volcanosedimentary sequence which belongs to the northeasternmost part of the internal Hellenides (Fig. 3: Jacobshagen et al. 1978). It represents a dismembered piece of the Paleotethys oceanic crust, which started to be subducted under the southern margin of the Rhodopian massif in Jurassic time (Robertson et al 1991). After the paroxysm of folding in Middle Eocene time, the Circum Rhodope Belt

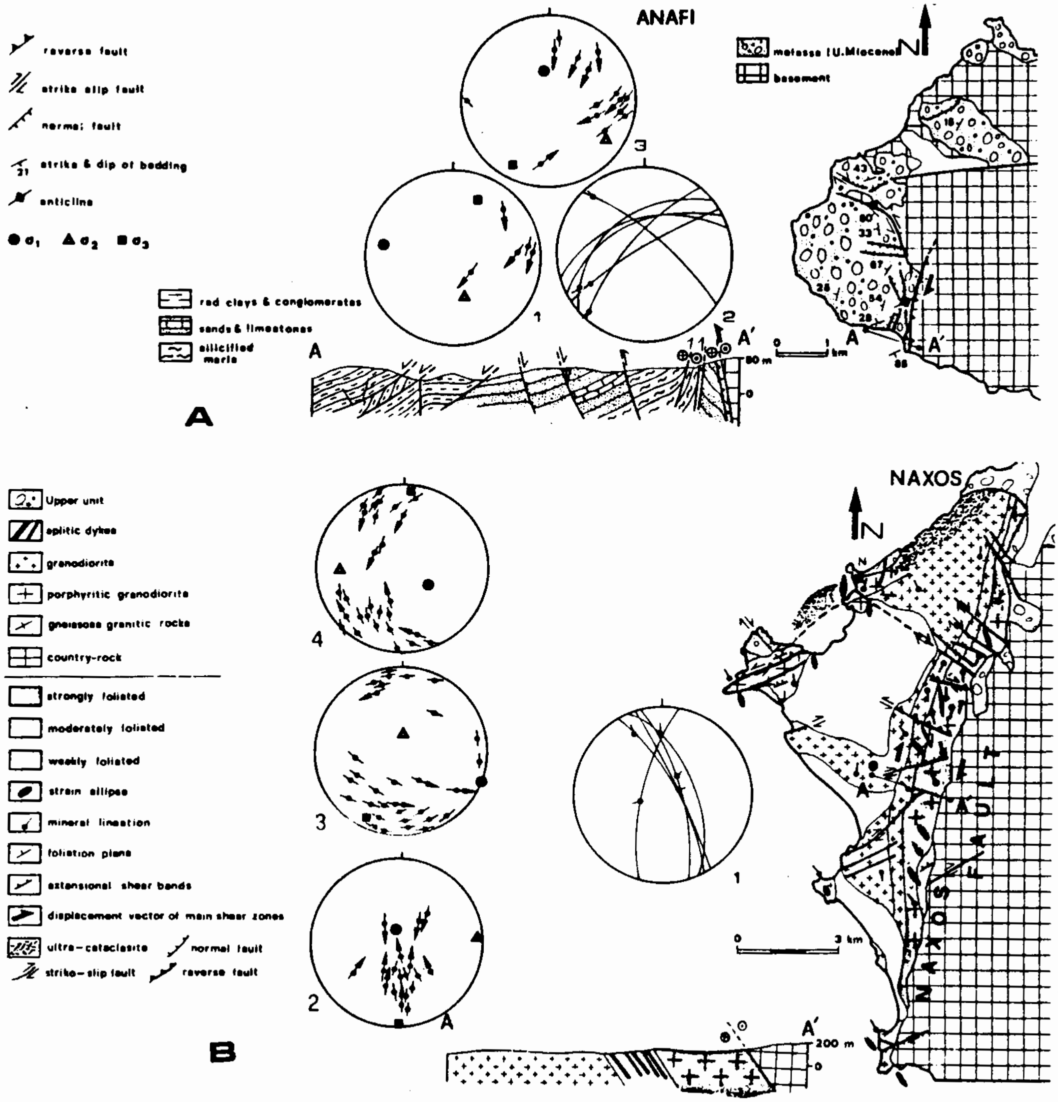

Fig. 2: Structures presented in stereoplots and maps within the molassic cover (A, Anafi island) and within the granites (B, Naxos island) (modified after Boronkay & Doutsos 1994).

Σχ. 2: Δομές που παριστάνονται με στερεογραφικά δίκτυα και χάρτες στο μολασσικό κάλυμμα (Α, νήσος Ανάφη) και στους γρανίτες (Β, νήσος Νάξος) (τροποποιημένο από Μπορονκάυ & Δούτσος 1994).

(Fig. 2A:1) suggest right-lateral, oblique-thrust movements. In the footwall of the marginal fault three other NNE-trending faults with forward and backthrust components form a 300m wide zone of transpressional structures (Fig. 2A: A-A'). Further west the tectonic pattern changes to transtensio. A 700m wide asymmetric horst is bounded by N-S to NW-trending oblique-normal faults (Fig. 2A:3).

b) The granodiorite in the western part of Naxos island is separated from the metamorphic basement to the east by a right-lateral ductile shear zone with a small thrust component (Fig. 2B: Naxos fault). Ductile shearing along the Naxos fault was synchronous with doming and horizontal shortening (F_2 and F_3 folds of Buick 1991a) in its hanging wall rocks. Mylonites in the footwall of the fault form a 1.5 Km wide zone and are grouped into two NNE-trending subzones: an eastern one with strain ratios of 6 to 12 consisting of ultramylonites and a western one with strain ratios 2 to 6 consisting of proto-mylonites (Fig. 2B). Intrafolial folds within the mylonites of the western sub-zone trend NNE (Fig. 2B:1), whereas eastward, toward the pluton border they become gradually vertical. Such strain partitioning into components parallel and normal to the faults is reported from many strike-slip terrains in the world.

In the late stages of deformation ENE-and WNW-trending oblique normal faults were formed within the granodiorite, as a transtensional mechanism. During this process the ό1 axis change gradually from a horizontal to a vertical position (Fig. 2B:3 and 4).

Although the Naxos granodiorites are syntectonic in relation to transpression and transtension there are evidence of a former extensional event. During this event a low angle NNW dipping solid state foliation and a NNW dipping stretching lination was formed (Fig. 2B:2).

Summarizing we conclude that late orogenic uplift in the central Aegean region took place simultaneous with the formation of transpressional core complexes. In the last stages of collision the overthickened crust began to collapse by transtension.

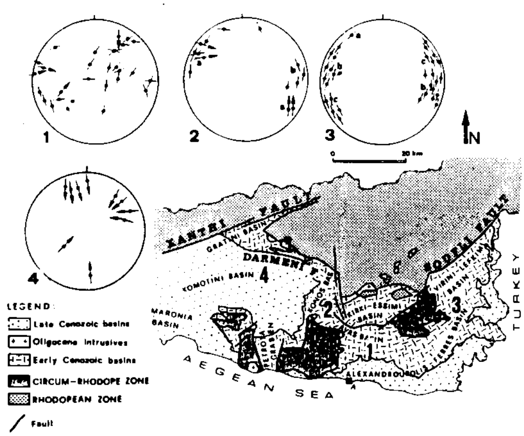

Fig. 3: Simplified geologic map of the Circum Rhodope Belt and stereoplots showing fault data for 4 stations (modified after Karfakis & Doutsos 1994).

Σχ. 3: Απλοποιημένος γεωλογικός χάρτης της Περιροδοπικής ζώνης και στερεογραφικά δίκτυα που δείχνουν στοιχεία ρηγμάτων από 4 σταθμούς (τροποποιημένο από Καρφάκη & Δούτσο 1994).

subsided and was filled with a thick volcanosedimentary sequence. Unconformably over this sequence lie Neogene and Quaternary marine and terrestial sediments.

Structural data and synthesis

The post-nappe evolution of the Circum Rhodope Belt can be subdided into the following stages a) Early orogenic extension. During this event the Avas basin and the Petrota basin were formed. The sedimentary infilling of these basins is internally deformed by WNW to NW-trending normal-and or oblique normal faults (Fig. 3:1). b) Transpression. During this event the boundary between the Rhodopian massif and the Circum Rhodopian massif acted as right-lateral strike slip fault of crustal scale. It comprises three segments: the Xanthi fault, the Darmeni fault and the Soufli fault. Mesoscopic faults collected in the hanging-wall of these faults are grouped into a set of NE dextral faults and a conjugate system of NNW-and sinistral slip- and dextral faults respectively (Fig. 3:2 and 3). c) Late orogenic extension. During this event the northern part of the Circum Rhodope Belt remained stable whereas its southern part either submerged by the Aegean Sea or was covered by thick alluvial deposits (s. Komotini basin Fig. 3). Stereoplots of fault data collected of Neogene outcrops reveal an orthogonal system of NW and NE-trending normal faults (Fig. 3:4). Summarising we conclude that orogenic collapse in the Circum Rhodope Belt was interrupted in the Oligocene time by an extensive transpressional event.

ΓΕΩΔΥΝΑΜΙΚΗ ΕΡΜΗΝΕΙΑ - GEODYNAMIC INTERPRETATION

From the structural correlation of late orogenic basins, which had developed above suture zones in the Hellenides, we conclude that convergence of the Apulian and European plates continued until the Upper Miocene. Syncompressional shortening and wrenching played the most important role in the late stages of plate collision. Kinematic analysis of fault data in the Mesohellenic Trough reveal that convergence was directed perpendicular to the Apulian margins. In contrary, the predominant occurrence of NE dextral structures in the central Aegean region and the Circum Rhodope Belt indicate oblique convergence of the colliding plates.

The last stages of the orogenic evolution are characterized by transtension, during which the overthickened crust began to collapse. In some parts of the orogen, however collapse began early in the orogenic evolution whereas in other parts strike-slip faulting and shortening continued. In that areas uplift is the result of extensive indentation. In the central Aegean region where lower structural levels are exposed, indentation of plates with irregular margins lead to the formation of granites. In the Circum Rhodope Belt which represent a weak and unstable zone of a dismembered piece of the Paleotethys, early extension is more pronounced.

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