Δελτίο Ελληνικής Γεωλογικής Εταιρείας τομ. XXV/1, 509-526, 1991
Πρακτικά 5ου Επιστημονικού Συνεδρίου, Θεσσαλονίκη, Μάϊος 1990

Bulletin of the Geological Society of Greece vol. XXV/1, 509-526, 1991
Proceedings of the 5th Congress, Thessaloniki, May 1990

PRELIMINARY GEOTECTONIC INTERPRETATION OF THE EAST MEDITERRANEAN CHAIN AND THE HELLENIC ARC.*

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Abstract

Based on advanced geophysical interpretation of a multichannel regional seismic exploration integrated with new geological observation on the emerged lands, the reconstruction of the tectonic setting of the Hellenic Arc has been performed. Outer of the trench, an accretionary zone is recognized where the dominating tectonics is given by imbrication of blocks, detached from the subducting paleo-oceanic margin of the African Plate. The inner zone is formed by overthrusted blocks coming from different paleogeographic positions. The accretionary zone (East Mediterranean Chain) is consistently wider at the two sides (Ionian and Levantine) than at the apex area (Cyrenaica). This is due to the incipient collision with the Cyrenaican margin while in the Ionian and Levantine seas the accretion is still free to expand. This fact is very propably the cause of the formation and development of a sinistral strike-slip shear zone in the eastern side of the Hellenic Trench along the Pliny trough.

Σύνοψη.

Η γεωφυσική έρευνα στη Ανατολική Μεσόγειο επέτρεψε την εκπόνηση ενός νέου τεκτονικού χάρτη της περιοχής της "Οροσειράς της Ανατολικής Μεσογείου" καί της Ελληνικής Τάφρου. Η όλη δομή της οροσειράς έχει τον χαρακτήρα επαυξητικής ζώνης στο μέτωπο τού Ελληνικού Τόξου, με αποκόλληση των ιζημάτων τού Μέσο-Καινοζωικού από το υπόβαθρό των. Το φαινόμενο αυτό συμφωνεί με τις γεωλογικές παρατηρήσεις από τις Ελληνίδες. Επίσης η Οροσειρά της Ανατολικής Μεσογείου έχει μεγαλύτερο πλάτος εμφάνισης στην πλευρά του Ιονίου όπως καί στήν πλευρά τού Λεβαντίνου, ενώ αντίθετα έχει μικρό πλάτος στην κεντρική περιοχή όπου έχει σμικρυνθεί. Τούτο οφείλεται στην έναρξη της σύγκρουσης με το Αφρικανικό περιθώριο στην κεντρική περιοχή, σε αντίθεση με τα άκρα, όπου η σύγκλιση είναι ακόμα ελεύθερη καί η επέκταση της επαυξητικής ζώνης συνεχίζεται. Η έναρξη της σύγκρουσης είναι πιθανά το αίτιο γιά την ανάπτυξη αριστερόστροφης διατμητικής ζώνης οριζόντιας ολίσθησης στην ανατολική πλευρά της Ελληνικής Τάφρου κατά μήκος της λεκάνης τού Πλινίου.

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Προκαταρκτική γεωτεκτονική ερμηνεία της Οροσειράς της Ανατολικής Μεσογείου καί τού Ελληνικού Τόξου.
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1. INTRODUCTION

During the last decades our knowledge on the structure, stratigraphy and geodynamics of the Eastern Mediterranean, in general, and of the Hellenic Arc and its surrounding area, in particular, has remarkably progressed, due to the development of geophysical investigations and especially of the multichannel seismic profiles.

Seismic sections and/or regional stratigraphic and structural reconstructions of the Hellenic Arc and surrounding area have been consistently based on seismic information, presented in several papers(Finetti & Morelli 1973, Mülder, 1973, Finetti, 1976, Biju-Dival et al., 1976, 1978, Finetti, 1982, 1984, Finetti & Del Ben, 1989). Gravity and surface magnetic surveys have been also very helpfull for outlining the regional aspect of the area (Morelli et al., 1975, Makris, 1985).

In this paper, the regional study of the Hellenic Arc and surrounding area has been based mostly on the interpretation of the multichannel seismic lines MS, granted to us by the Osservatorio Geofisico Sperimentale-Trieste. The location map of the O.G.S lines is presented on fig.1. Usefull information has been also taken from the deep-water boreholes of DSDP project (Leg 13 & 42) and from the boreholes on the continental platform of the Ionian Sea from various companies of petroleum research. These borehole data helped us to calibrate the seismic horizons and to understand the regional stratigraphy.

2. PHYSICOGEOGRAPHIC-GEODYNAMIC UNITS

The Eastern Mediterranean is characterized by an overall compressional geodynamic regime, as a result of the convergence between the European and the African plate. The main consequence of this convergence of the two plates is the formation of the active orogenic Hellenic Arc and of the East Mediterranean Chain (fig.2).

The Hellenic Arc is the result of the subduction of the East Mediterranean lithosphere, northern margin of the African plate, under the Hellenic margin of the European plate. The subduction front marked by the Hellenic Trench is not a continuous simple depression but a succession of elongate trenches reaching the depth of 5km. Behind the Hellenic Trench we can distinguish the other parts of the Hellenic Arc, such as the island arc (Peloponnese, Crete, Dodecannese), the Cretan back-arc basin and the Aegean volcanic arc.

The East Mediterranean Chain is a wide zone in the Eastern Mediterranean which develops immediately south and parallel to the Hellenic Trench. The term "Mediterranean Ridge" primarily proposed by Emery et al. (1966) was based on the bathymetry, and had ascribed to this area the nature of a middle-oceanic ridge. However, later on new results from the geophysical investigation and especially the interpretation of seismic reflection lines indicated that the nature of this area is not an extensional regime of a middle oceanic ridge but a compressional regime justifying the term "Eastern Mediterranean Chain" (Finetti, 1976) which is today widely accepted.

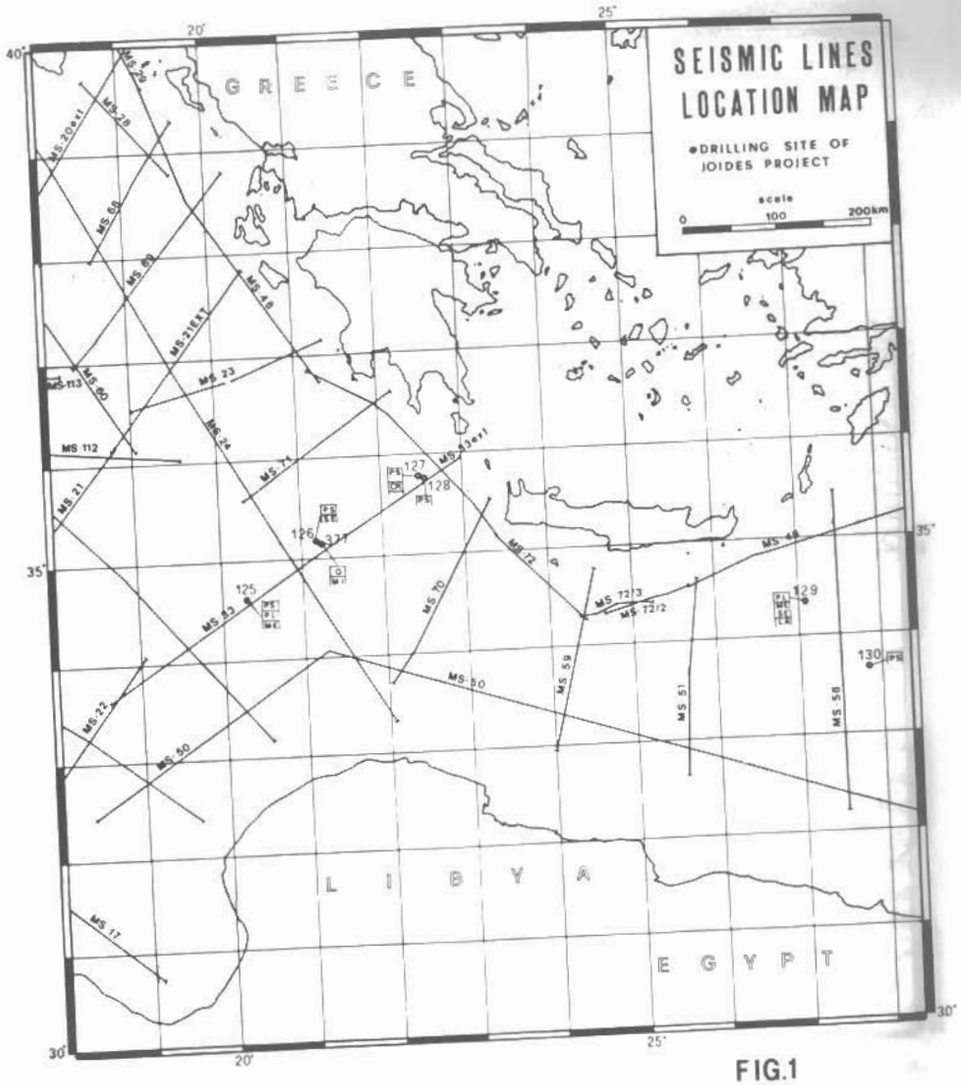

FIG.1

The East Mediterranean Chain is surrounded to the west and northwest by the Ionian Abyssal Plain, the Apulian platform and the Calabrian Arc, whereas to the south by the African margin along the Libyan and the Aegyptian coasts, from the Syrte gulf in the southwest to the Nile fan in the southeast. The Ionian Abyssal Plain is characterized by a flat sea-floor with maximum depth of 4084m, costituting with the Hellenic Trench the

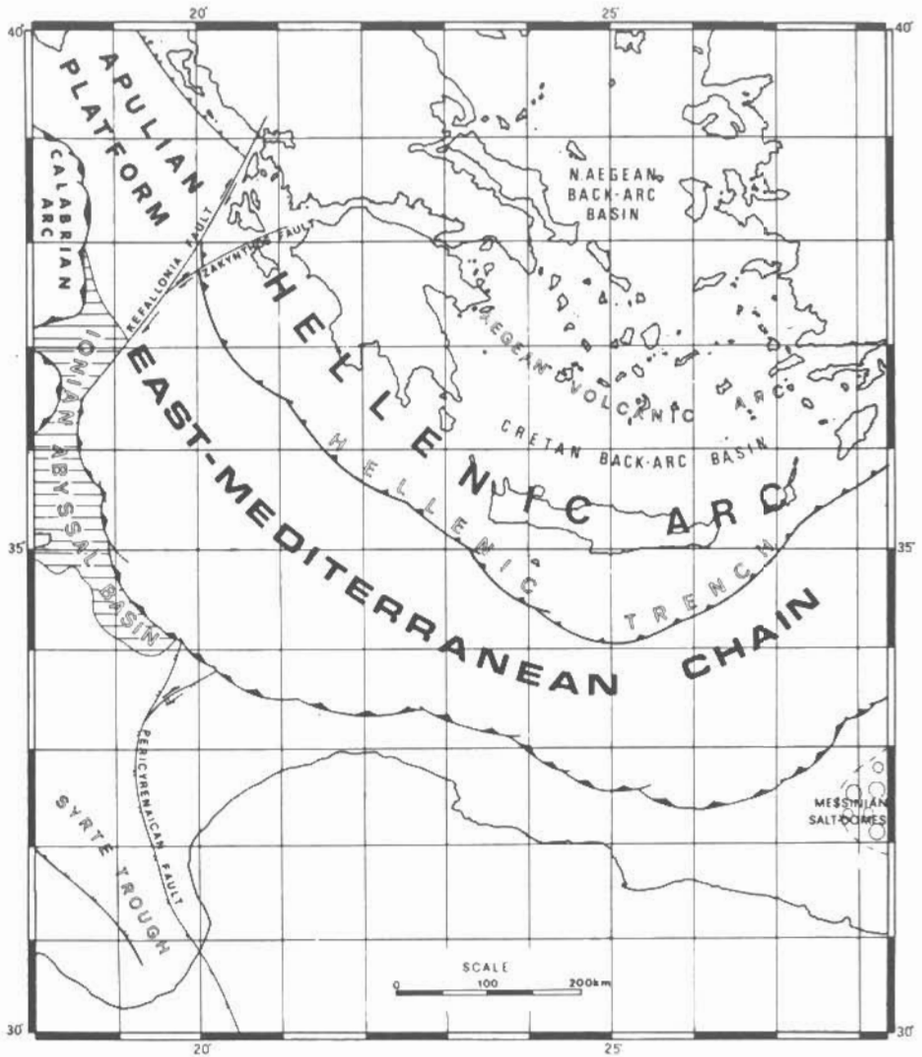

FIG.2

deepest regions in the Mediterranean. This region is regarded as a remnant of the old Tethyan ocean (Finetti, 1982). The Ionian Abyssal Plain is bordered to the north by the Apulian platform and to the south by the Syrte gulf. The Apulian platform represents the tectonic foreland of the Hellenides coming from the east as well as of the Apennines coming from the west. This opposite direction of tectonic transport is observed since the early Tertiary. The Syrte gulf represents the passive margin of the African plate with extensive tectonics since the Late Paleozoic. The Nile fan area is characterized by the great thickness of the sediments and the salt-domes overlying the African margin.

3. GEOPHYSICAL ANALYSIS OF THE STRATIGRAPHY AND TECTONICS OF THE EAST MEDITERRANEAN CHAIN AND THE HELLENIC ARC.

The interpretation of the seismic lines was facilitated by the stratigraphic data provided by the deep-water boreholes(DSDP project) and by the boreholes on the continental platform made for petroleum research. Thus, it became possible to determine some seismic horizons, with adequate reliability and to establish a regional stratigraphy for the area of the East Mediterranean Chain. The following horizons have been identified in the area explored:

- A_0=Seafloor
- A_1=Base Upper Quaternary
- A_2=Base Lower Quaternary
- A_3=Top Lower Pliocene
- A =Base Plio-Quaternary
- B =Base Messinian
- K =Top Mesozoic
- J =Base Cretaceous
- T =Base Jurassic
- Z_b=Basaltic basement, generally of oceanic type
- Z =Generally crystalline-metamorphic basement of continental type

The analysis of the stratigraphy and the structure of the Hellenic Arc and East Mediterranean Chain is more convenient if one follows the entire interpreted seismic line MS-59 from south to north (fig.3a-e). This line is representative for the whole structure, showing an undeformed area in the Cyrenaican platform and then going towards north it crosses the whole imbricated structure of the East Mediterranean Chain until the tectonic front of the Hellenic Arc south of Crete. In fact the East Mediterranean Chain corresponds to the accretionary area in front of the Hellenic Arc.

3.1. EAST MEDITERRANEAN CHAIN

The East Mediterranean Chain extends from the Ionian Sea to the Cyprus Arc. It is affected by compressive geodynamics, characterized by repeated overthrusts formed from Miocene to Present. The deformation involves a sedimentary sequence of Jurassic-Quaternary age, covering the paleo-oceanic crust.

As we can observe, on the seismic line MS-59 from sp.2024 to 1900 (fig.3a) and on the seismic line MS-50 from sp.12960 to 12660 and from 12670 to 12400 (fig.4a-b), the compressive tectonics initially affect the upper part of the sedimentary sequence in the

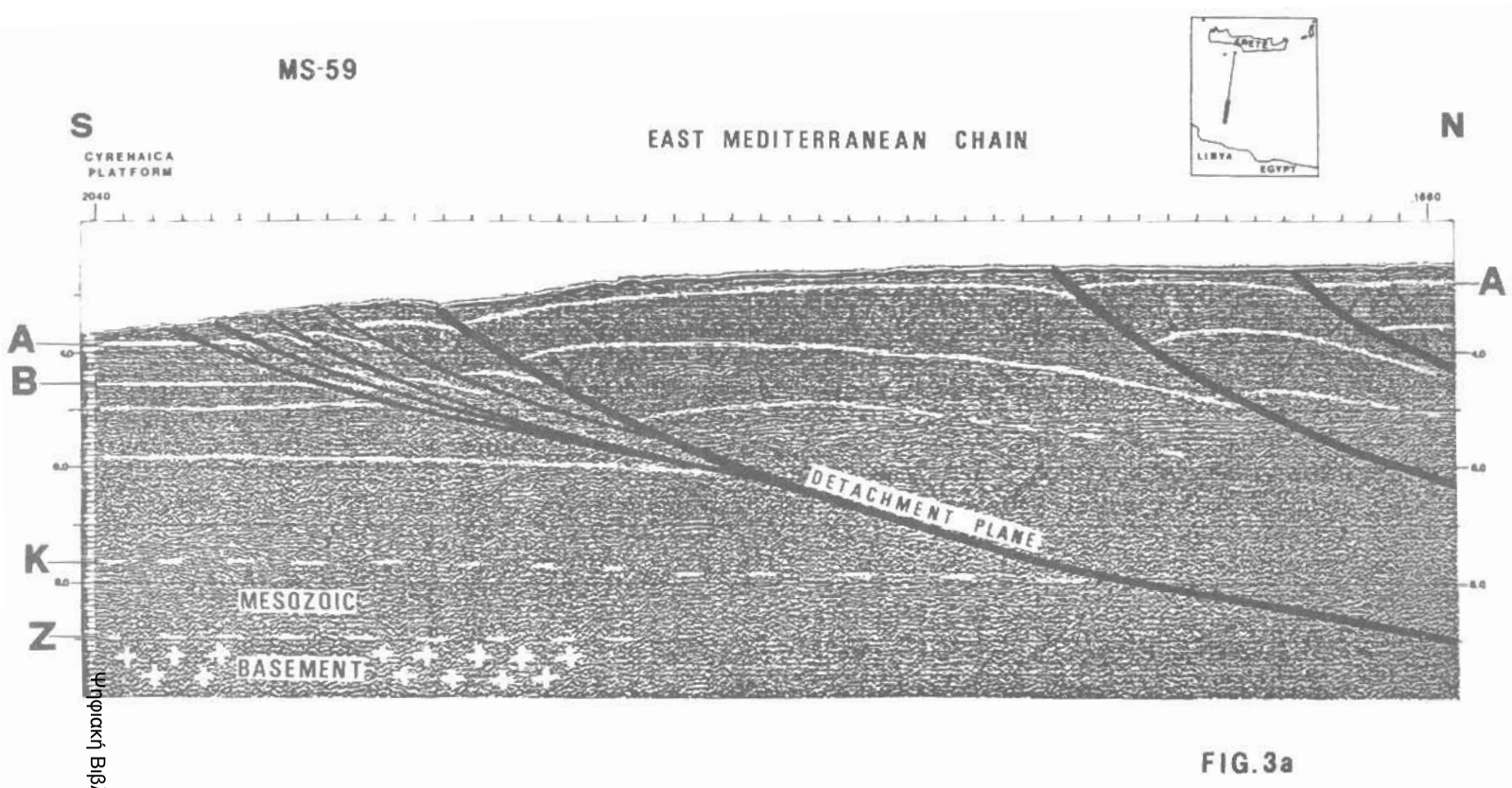

FIG.3a

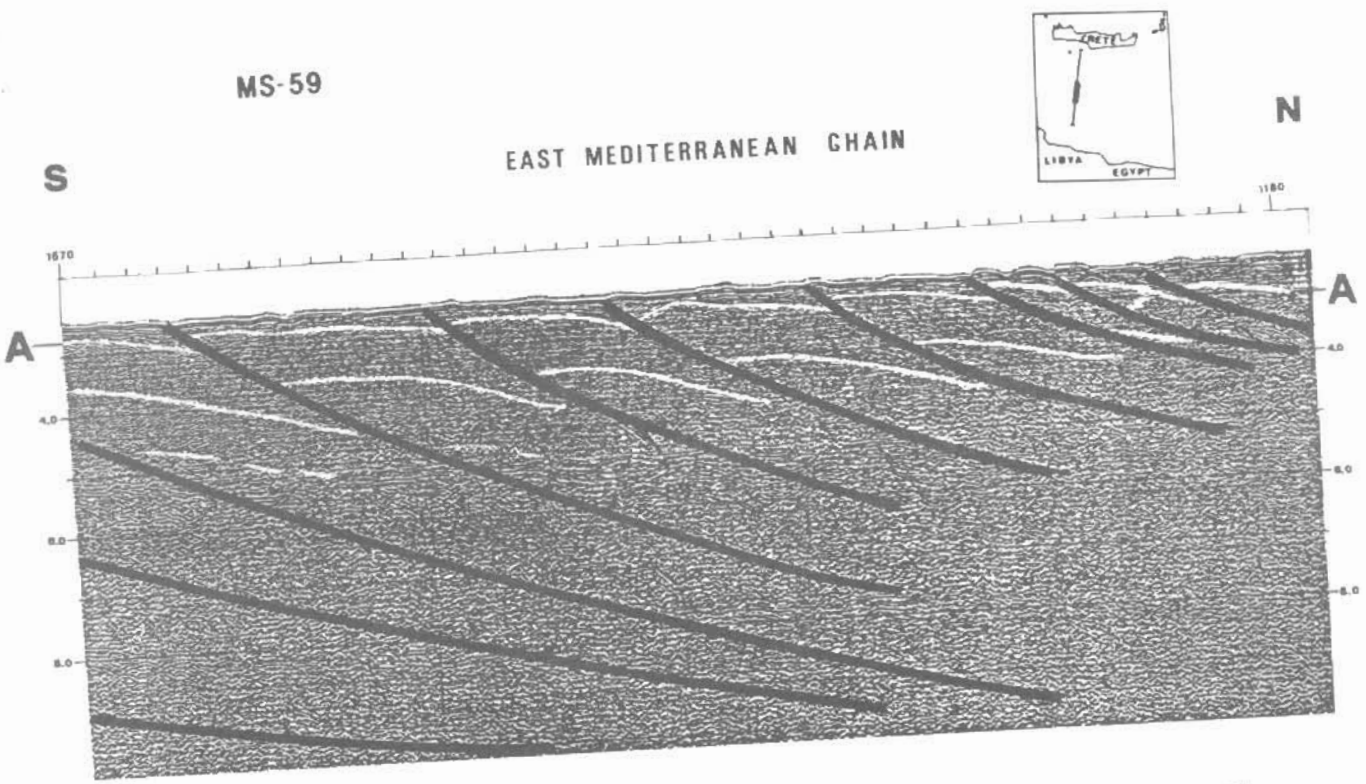

FIG.3b

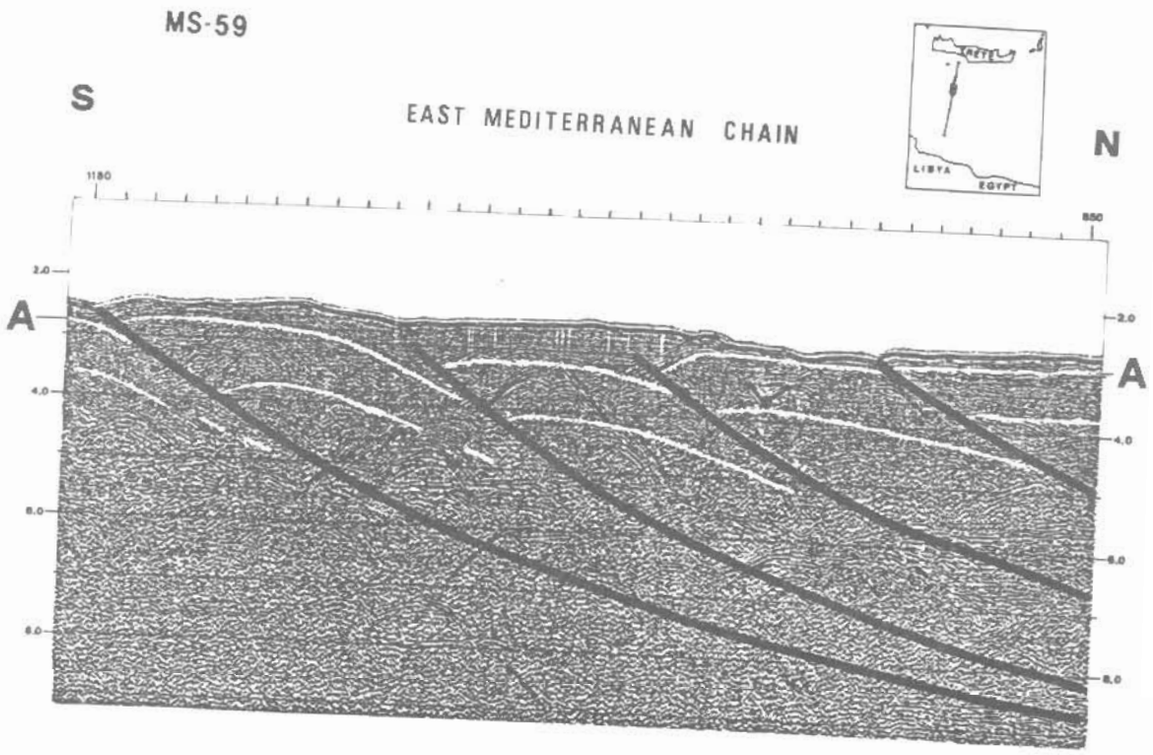

FIG. 3c

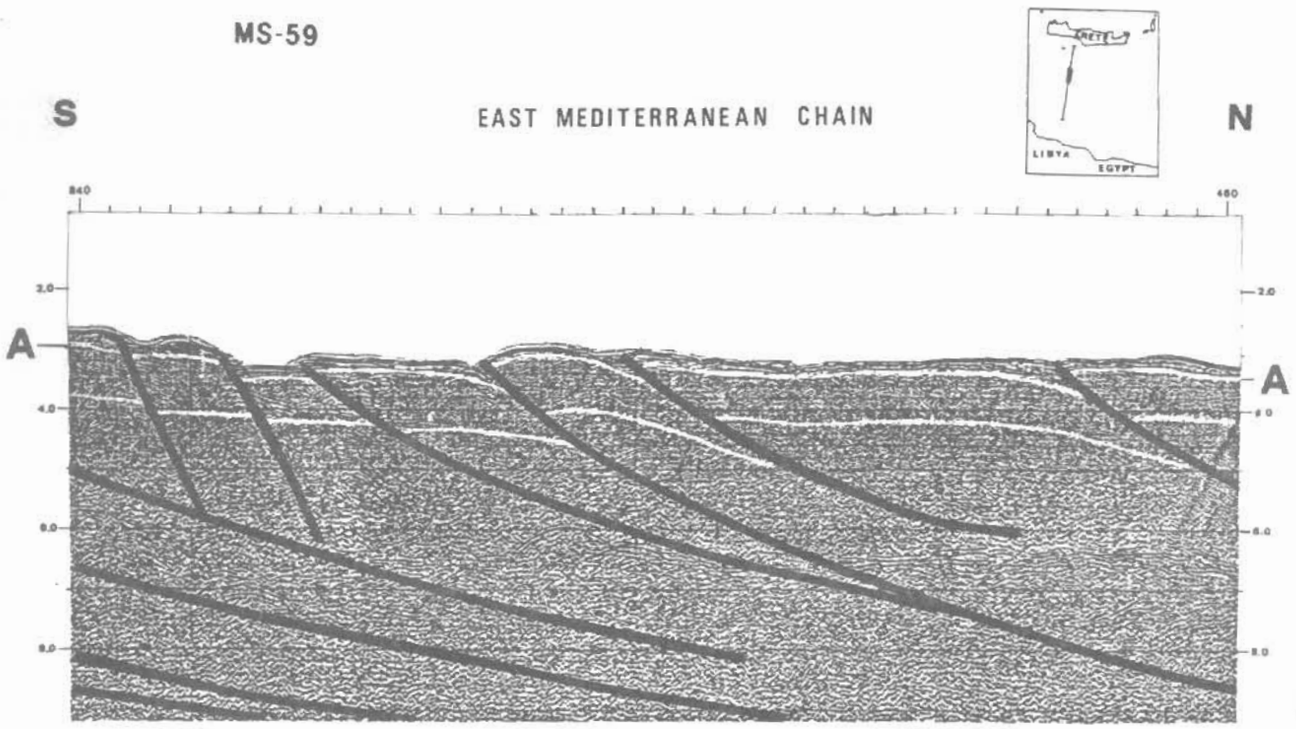

FIG. 3d

MS-59

EAST MEDITERRANEAN CHAIN

S

HELLENIC ARC

N

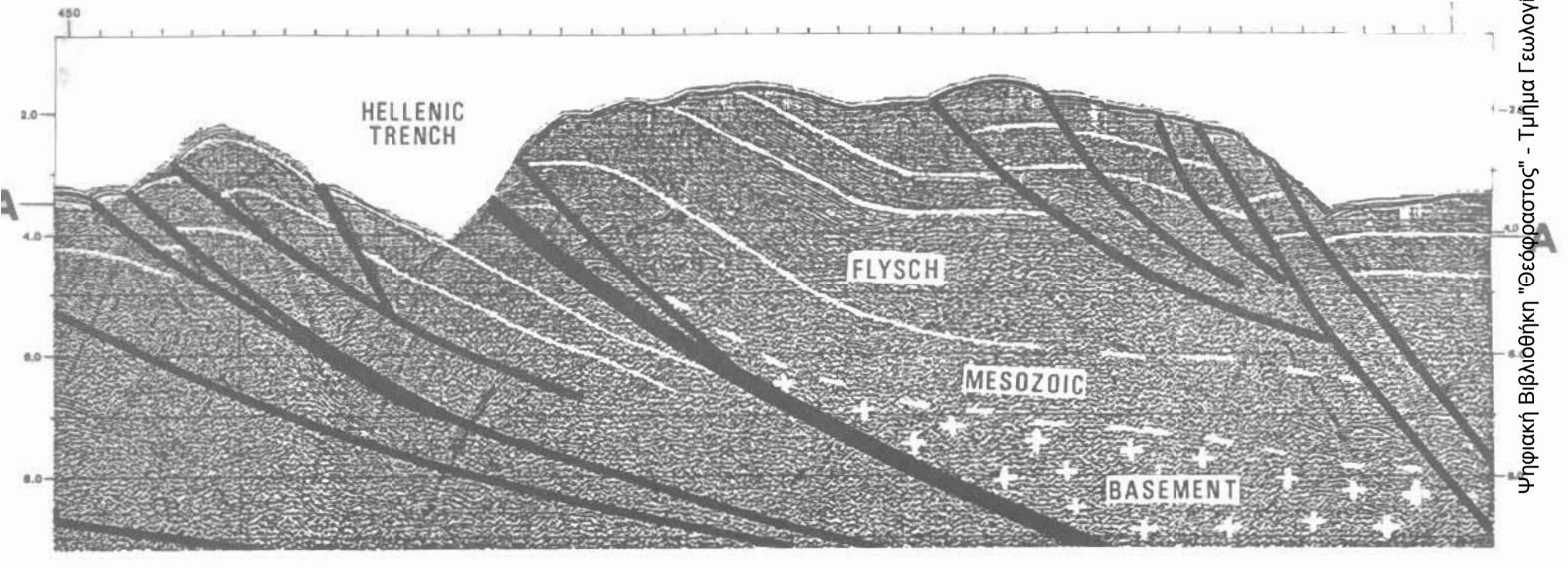

FIG.3e

outer zone. In this part the detachment plane corresponds to the base of the Messinian salts. Continuing towards the inner part of the East Mediterranean Chain the tectonic deformation, progressively deepens affecting the whole succession from the Tertiary to the Mesozoic (fig.3b-e). This deformation produced a repeated imbrication of thrust sheets. The thickness of the thrusting process gradually increases innerward. This ibrication probably becomes progressively younger towards the East Mediterranean Chain away from the Hellenic Trench indicating an expantion.

The thickness of the Plio-Quaternary sediments, seismic interval "A-Ao", is relatively small in the whole area of the East Mediterranean Chain;at an average rate it reaches about 200-400m(0.2-0.4sec). The calibration of the horizon "A" was based on data furnished by the deep-water boreholes of DSDP project (Leg 13 & 42).

Where the Messinian exists, it is possible to observe a characteristic reflection corresponding to the base of the evaporitic salt, (horizon "B"). The presence of the evaporite frequently causes intensive noise. This is due to the rough surface of the evaporite, which creates an intensive scattering.

3.2 HELLENIC ARC

The Hellenic Arc can be subdived as follows:the Hellenic Trench, the island arc, the back-arc basin and the volcanic arc.

The Hellenic Trench (fig.3e and 5a) involves the zone of subduction of the East Mediterranean oceanic crust under the continental crust of the Hellenic margin of the European plate. It brings in contact the southern part of the Aegean plate, affected by a compressive tectonism and involving also the crystalline-metamorphic basement, with the overthrusted sheets of the accretionary zone. On the west, it follows a direction parallel to the coast of Peloponnese and terminates in the area of the Kefallonia fault. Towards the east it extends until the Rhodos Trough.

The island arc extends from the South Ionian Sea to the South Aegean Sea and, as mentioned aboved, the tectonic deformation involves also the crystalline-metamorphic basement. Some transcurrent faults intersect the arc. Fig.3e shows the tectonic aspect of this region, as well as, the seismic horizons "A", "K" and "Z". The calibration of the seismic horizons was made from seismic observations in the account areas and the conclusions about the geological aspect of the seismic interval from geological observations in the continental area.

A great thickness of the Plio-Quaternary sediments is observed along the island arc region with maximum along the Peloponnesian coast(about 700m), as we can observe, on the seismic line MS-23 from sp.1 to 490 (fig.5b). Between the horizon "Ao"and the "A" very good reflections exist due to the low velocity of the trasmission of the seismic waves. These results indicate that this interval is composed of unconsolidated sediments (confirmed also by the boreholes of petroleum research). The thickness of the Plio-Quaternary sediments, permits to determine besides the "A" horizon, also the horizons "A_1", "A_2" and "A_3". The Messinian salts can be traced below the Plio-Quaternary sediments. The thickness of the Messinian is very small. The horizons "K" and "Z" can be recognized at great depth.

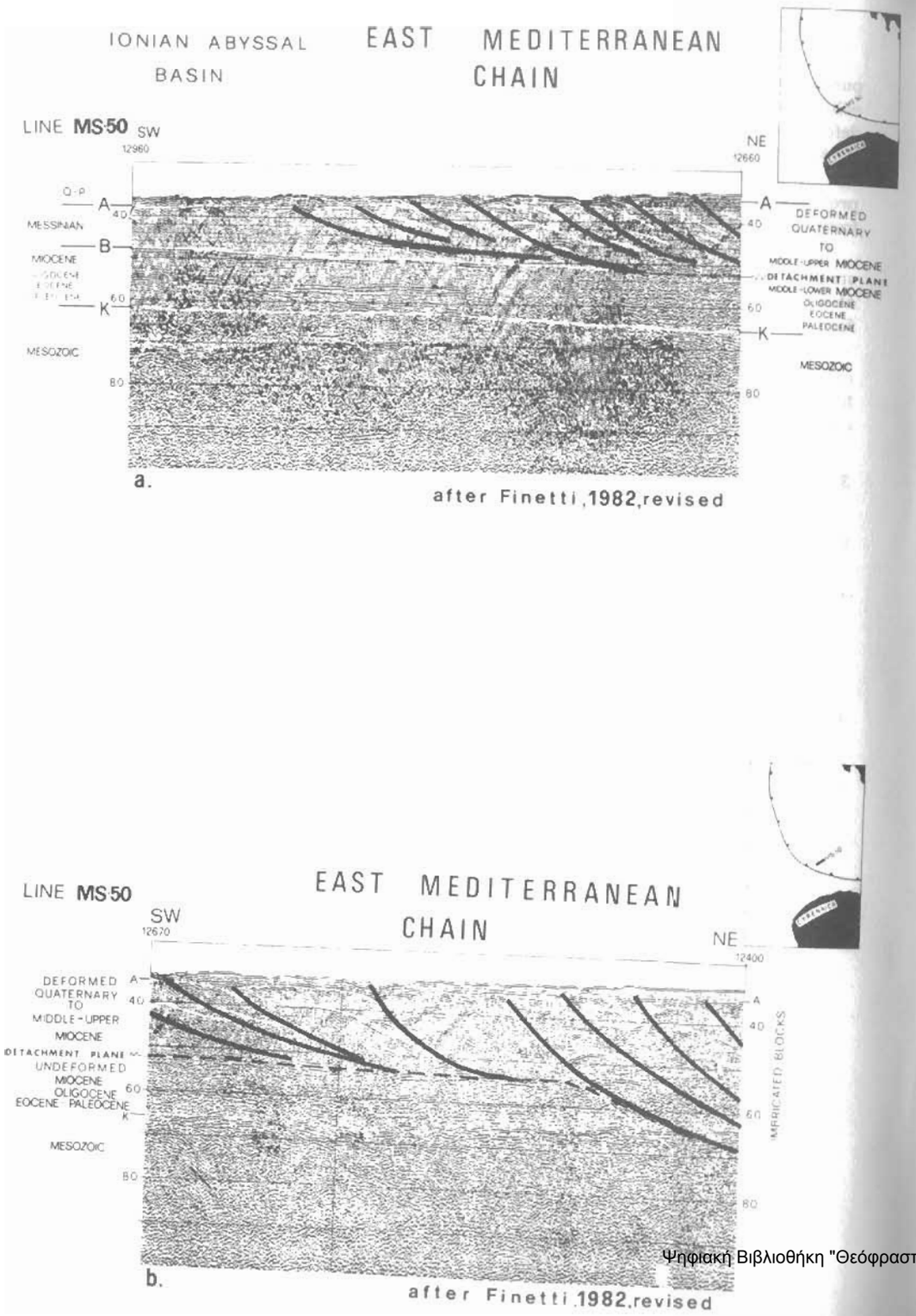

FIG.5

The back-arc area is extended along the Cretan Sea from the Argolic gulf to the Carpathian Sea, and is characterized by a distensive geodynamic regime. The maximum of the Bouguer anomaly (+180mgal) occurs in this region, due to the rise of magmatic masses. The Moho is calculated at 27km which is the minimum depth in all the Aegean area(Makris, 1985).

The Kos, Milos, Nisyros, Santorini and Methana volcanoes represent the volcanic arc, with important activity throughout Quaternary.

4. THE TECTONIC STRUCTURE AND SIGNIFICANCE OF THE EAST MEDITERRANEAN CHAIN AND HELLENIC ARC.

The correlation of the stratigraphic and tectonic features between the seismic profiles of fig.1 permitted us the compilation of a tectonic sketch map of the area between the present African and European plates (fig.6). This tectonic sketch shows the general arcuate geometry of the imbricated thrust sheets which follow, in general, the geometry of the Hellenic Arc. Thus, in the Ionian side it has a NW-SE trend whereas in the Levantine side it has a NE-SW trend. It is noteworthy that the East Mediterranean Chain is much more wide in the western and eastern sides than in the central area, where it is in contact with the Libyan margin.

A comparison of the structure along the western side of the East Mediterranean Chain and along the central area (fig.7) shows that in the west, the accretionary wedge of the detached and imbricated formations of the East Mediterranean Chain is overthrusting the last oceanic remnant of the Tethys, whereas in the central area the same accretionary wedge has already reached the African margin and has been considerably shortened. In other words, in the Libyan segment north of Gebel Al Akhadar Uplift it is likely that the subduction of the African margin below the Hellenic-European margin is in transition towards the final geodynamic stage of collision.

It is remarkable that this pre-collision stage of the accretionary zone of the East Mediterranean Chain may very well be the cause for the transform motion of the eastern side of the Hellenic Trench, mainly along the Pliny Trench(Le Pichon et al., 1979). Thus, the south-westward motion is still favoured by the existence of the Ionian Abyssal Plain whereas the Cyrenaican margin constitutes an obstacle to this motion and hence a sinistral strike-slip shear zone is produced.

The main result of this preliminary study is that the East Mediterranean Chain has to be considered as part of the Hellenic Arc. It is noteworthy that the actualistic model of the East Mediterranean Chain can be traced back by the history of the Hellenides both in general terms, since all the tectonic units of the Hellenides have been detached from their basement and in particular for each tectonic unit when considering its history, from the last pre-orogenic stages to its final position in the orogenic geometry of the evolving arc (e.g. the Ionian zone).

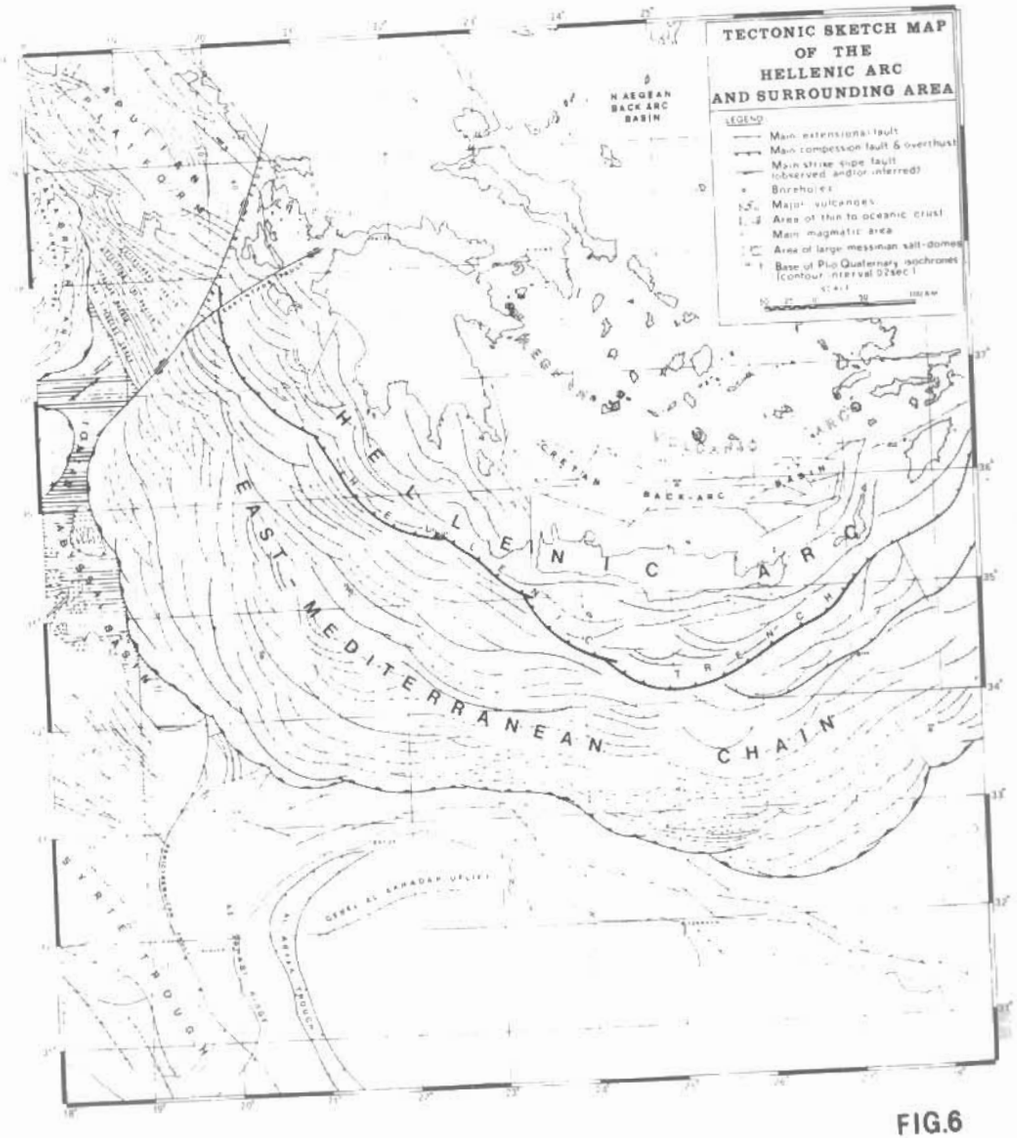

FIG.6

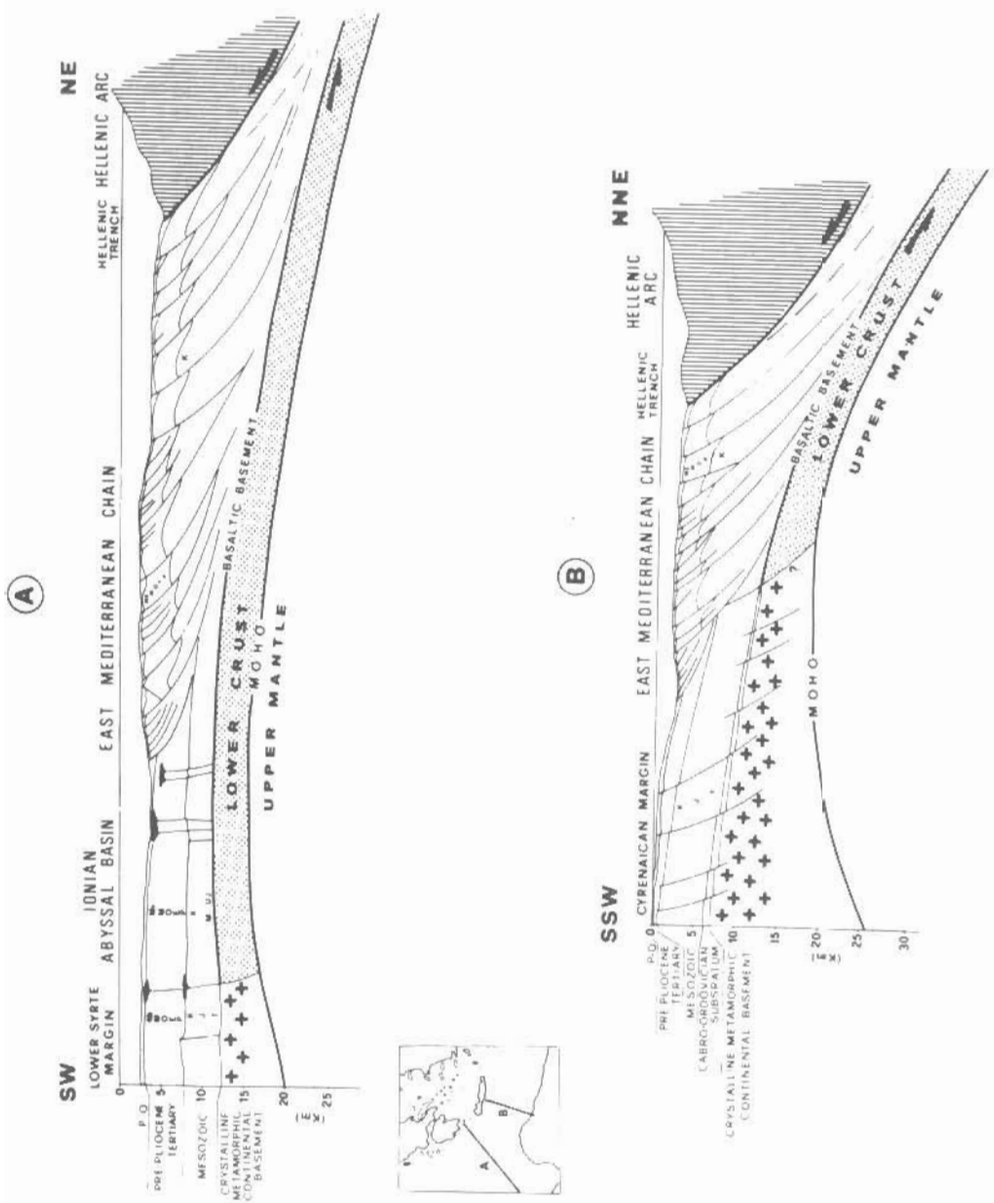

FIG.7

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