THE INTERMEDIATE DEPTH SEISMICITY RELATED TO THE HELLENIC SUBDUCTION

Hatzfeld,D.*, Makropoulos,K.**, and Hatzidimitriou,P.***

* Laboratoire de Geophysique Interne et Tectonophysique, IRIGM, BP 53X, 38041 Grenoble Cedex, France.
** Department of Geophysics, University of Athens, 15784 Ilissia, Athens, Greece.
*** Geophysical Laboratory, Aristotelian University, PO-Box 352-1, 540 06 Thessaloniki, Greece.

A B S T R A C T

Precise ISC earthquake locations, as well as microearthquake locations obtained with a dense network of portable stations, show that the Hellenic slab is not parallel to the Hellenic trench. In the western part the slab is dipping shallowly NNE for about 200 km beneath the Peloponnese and then steepens abruptly. In the eastern part, the slab is dipping more steeply beneath the Dodecanese. Very little seismic activity is located in the central part of the slab, beneath the Sea of Crete.

Intermediate depth focal mechanisms show T-axes roughly aligned with the dip of the slab, but P-axes are trending NNW-SSE in the western part and NNE-SSW in the eastern part, and therefore parallel to the trench. The slab is subjected to a complex set of forces, probably due to the response to its contortion.

ΕΝΔΙΑΜΕΣΟΥ ΒΑΘΟΥΣ ΣΕΙΣΜΙΚΟΤΗΤΑ ΤΟΥ ΕΛΛΗΝΙΚΟΥ ΤΟΞΟΥ

Hatzfeld,D., Μακρόπουλος,Κ. και Χατζηδημητρίου,Π.

Π Ε Ρ Ι Λ Η Ψ Η

Ακριβείς συντεταγμένες σεισμικών εστιών από το Διεθνές Σεισμολογικό Ινστιτούτο και από δίκτυο φορητών σεισμογράφων δείχνουν ότι η βυθιζόμενη λιθοσφαιρική πλάκα στο Ν.Αιγαίο δεν είναι παράλληλη με την τάφρο. Στο δυτικό τμήμα η πλάκα βυθίζεται με μικρή γωνία με διεύθυνση ΒΒΑ για απόσταση περίπου 200Km κάτω από την Πελοπόννησο και στη συνέχεια η κλίση αυξάνεται απότομα. Στο ανατολικό τμήμα η πλάκα βυθίζεται με μεγάλη κλίση κάτω από τα Δωδεκάνησα ενώ μικρή σεισμική δραστηριότητα εντοπίζεται στο κεντρικό τμήμα της πλάκας κάτω από την Κρήτη.

Οι μηχανισμοί γένεσης των σεισμών ενδιαμέσου βάθους δείχνουν τους άξονες Τ να έχουν διεύθυνση παράλληλη με τη κλίση της βυθιζόμενης λιθοσφαιρικής πλάκας ενώ οι άξονες Ρ έχουν διεύθυνση ΒΒΔ-ΝΝΕ στο δυτικό τμήμα και ΒΒΕ-ΝΝΔ στο ανατολικό τμήμα, δηλαδή είναι παράλληλοι με την τάφρο. Η λιθοσφαιρική πλάκα δέχεται επομένως ένα πολύπλοκο σύστημα δυνάμεων το οποίο είναι πιθανά αποτέλεσμα της αντίδρασης στην παραμόρφωση την οποία δέχεται.

INTRODUCTION

The evidence of an active subduction zone beneath the Aegean sea is based mainly on the presence of intermediate depth earthquakes (70<z<300 km) beneath the Hellenic arc. Focal depths increase towards the inside of the Hellenic arc (Papazachos and Comninakis, 1971; Makropoulos and Burton 1981), but the seismic zone, and therefore the shape of the subducted slab is not well constrained by the small number of earthquakes there. With no seismic station closer than 200 km to epicenters, it is difficult to map the subduction zone accurately. Furthermore, because the magnitudes of the intermediate depth earthquakes are generally smaller than mb=5.0, it is rarely possible to use body wave modelling techniques to determine the depths (Taymaz et al., 1990). We thus have a poor image of the intermediate depth seismicity and therefore of the geometry of the slab.

Very few intermediate depth focal mechanisms have been computed. McKenzie (1972, 1978) computed fault plane solutions using both long-period and short-period polarities. Ritsema (1974) reported some focal mechanisms, using both long period and short period data, but he did not show polarity data. Papazachos (1973, 1977), Drakopoulos and Delibasis (1982), Karakostas (1988) also computed intermediate depth focal mechanisms, using short period regional phases reported in bulletins. Because of the relatively low magnitude range of the intermediate depth earthquakes and because of the strong lateral heterogeneities in the velocity structure, it is difficult to assess the reliability of the intermediate depth locations using teleseismic arrival times. Taymaz et al. (1990) used body wave modelling to constrain both focal depths and fault plane solutions of earthquakes. But because of the magnitude required to use such technique (around mb 5.5), they were able to compute solutions only for the southern part of the arc, around Crete.

In this paper we refine the shape of the seismic zone by filtering the ISC data and by locating earthquakes of small magnitude recorded in a dense temporary seismological network. We also compute several intermediate depth focal mechanisms.

ISC DATA

The most reliable global seismological catalog is the International Seismological Center Bulletin, which reports earthquakes using all the available arrival times recorded in stations located around the world. But it is difficult to estimate the precision of these locations. The number of recording stations and their azimuthal coverage generally improves the location of an earthquake, but as Barazangi and Isacks (1979) showed in a study of the subduction zone beneath South-America, the number and azimuthal distribution of local stations as the consistency of pP readings determine the control in the depth of the earthquakes. So we will define 5 different classes of earthquakes depending on the availability of pP phases and of records in local stations as their azimuthal coverage (Hatzfeld and Martin, 1992).

Among a total number of 23277 earthquakes located by ISC

between 1964 and 1984, we extracted 677 events of magnitude greater than 3.5, recorded in more than 15 stations, located deeper than 40 km, and belonging to one class as defined earlier. Among these, 277 events are considered to be located better than 30 km in depth, because their location is controlled both by upgoing rays and downgoing rays (Fig. 1).

We observe a deepening of the earthquakes towards the inner part of the Hellenic arc, but no earthquake deeper than 150 km. No intermediate depth earthquake is located North of the Corinth Gulf, and most of them are located on both ends of the Hellenic arc, beneath the Peloponnese and the Dodecanese islands, and only very few earthquakes are located beneath the Sea of Crete. Beneath the Peloponnese the seismic zone deepens towards the NE. The slab is deeping shallowly for about 200 km, down to 100 km and then steepens abruptly down to 150Km beneath the Gulf of Corinth. Beneath Rhodos and the Dodecanese islands a dense cluster of earthquakes is located at a depth of 150 km, and therefore the slab seems to deepen more steeply toward the North-West.

The 100 km isodepth contour is therefore not parallel to the trench. In the western part it is located at about 200 km of the bathymetric Matapan trench, when it is located only at 100 km of the Pliny trench in the western part.

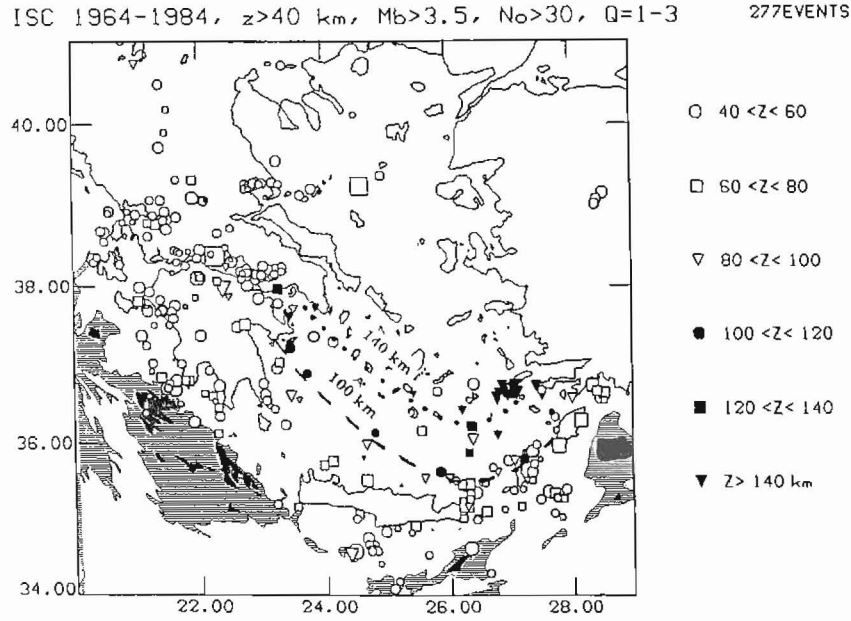

Fig.1. Seismicity map of the ISC earthquakes located deeper than 40 km and with an accuracy better than 30 km.

MICROEARTHQUAKE SEISMICITY

During 1986-1989, we conducted several microearthquake surveys within the Aegean. We deployed from 45 to 85 portable

seismological stations for a time period of 7 weeks (Hatzfeld et al., 1989, 1993). The earthquakes that we recorded are generally located with a greater accuracy than the teleseismically located events. About 100 earthquakes were located deeper than 40 km and are likely to be related to the subducted slab beneath the Hellenic arc. Among those we selected 85 events which are recorded in more than 8 stations and with statistical errors smaller than 20 km.

A map of the intermediate depth seismicity, which does not represent a complete image of activity but is the superposition of 3 pictures, each of them gathered during 7 weeks, shows that the seismic zone is deepening towards the inner part of the Hellenic arc (Fig. 2).

We plotted cross sections across the Epirus, the Peloponnese and the Dodecanese (Fig. 3). These cross sections are different. We do not observe any earthquake deeper than 50 km beneath the Epirus. It is therefore likely that no subduction zone exists North of the Ionian islands. Beneath the Peloponnese the earthquakes define a very gentle slope starting at the trench for about 200 km, and then a steeper slab further northeast, beneath Attiki. Beneath the Dodecanese, earthquakes define a steep zone starting closer to the trench and dipping more steeply. Very little intermediate depth activity is observed in the middle of

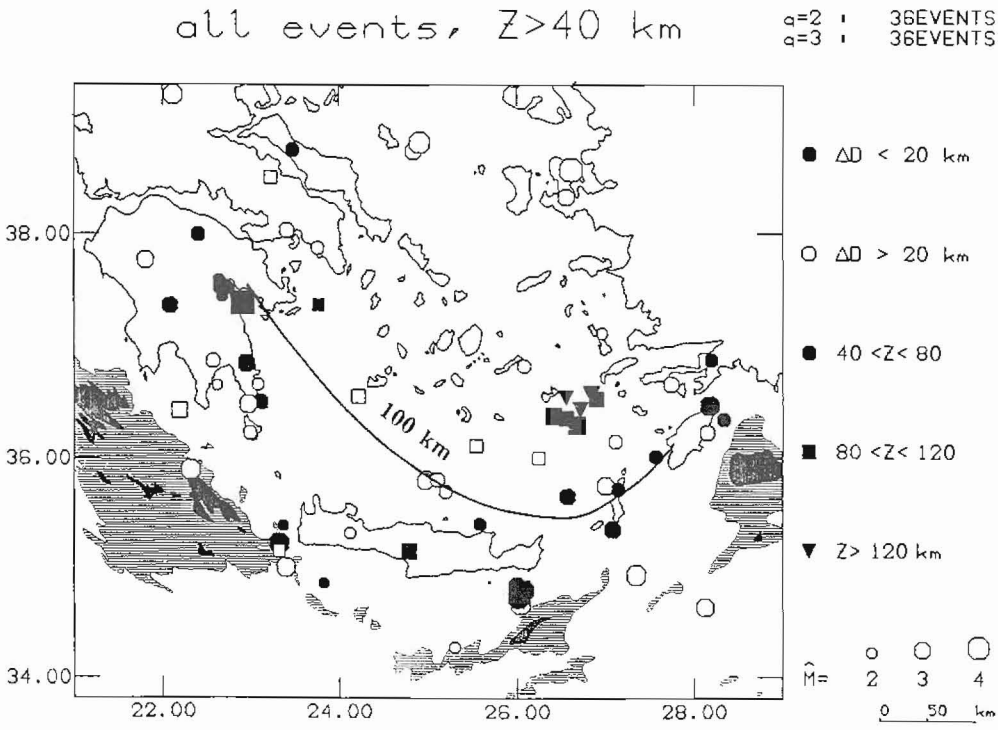

Fig.2. Seismicity map of the microearthquakes recorded during the 3 experiments and located deeper than 40 km.

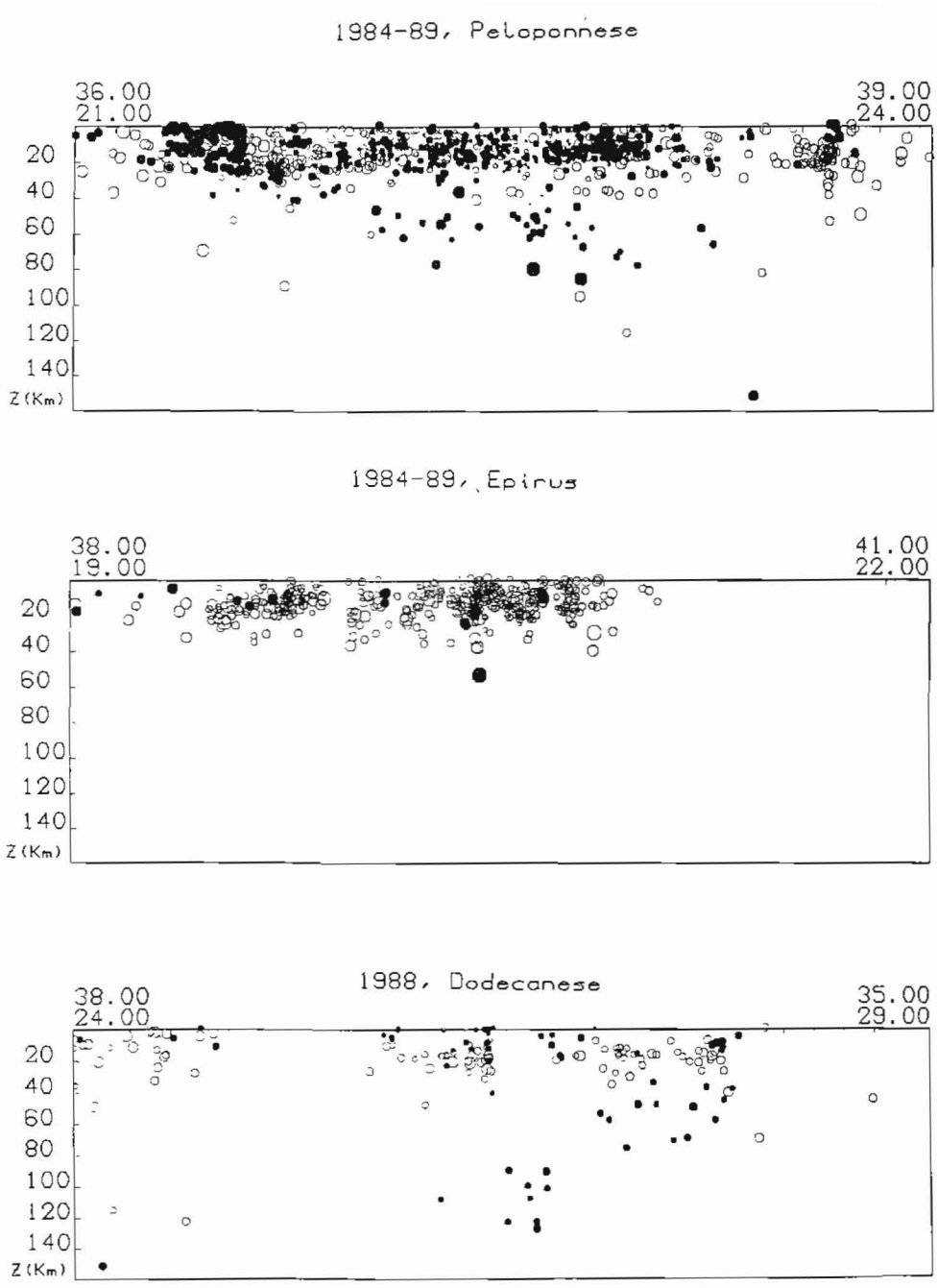

Fig.3. Cross sections of the seismicity recorded during the 3 experiments conducted in the Aegean.

the arc, beneath the Cyclades islands where active volcanoes are observed. The seismic zone is therefore not parallel to the Hellenic trench and shows an asymmetry between the gently dipping western part and the steeply dipping eastern part.

FOCAL MECHANISMS

To compute focal mechanisms using polarities of regional (refracted) phases is always a risky task. Because we had a seismological network above the seismic zone we were able to compute with less difficulties focal mechanisms of intermediate depth. We separate the 38 earthquakes into 2 families: those ranging between 40 and 70 km deep cannot be unambiguously related to the subducted slab when they are located in the inner part of the trench, those located deeper than 70 km are likely to be related to the dipping slab.

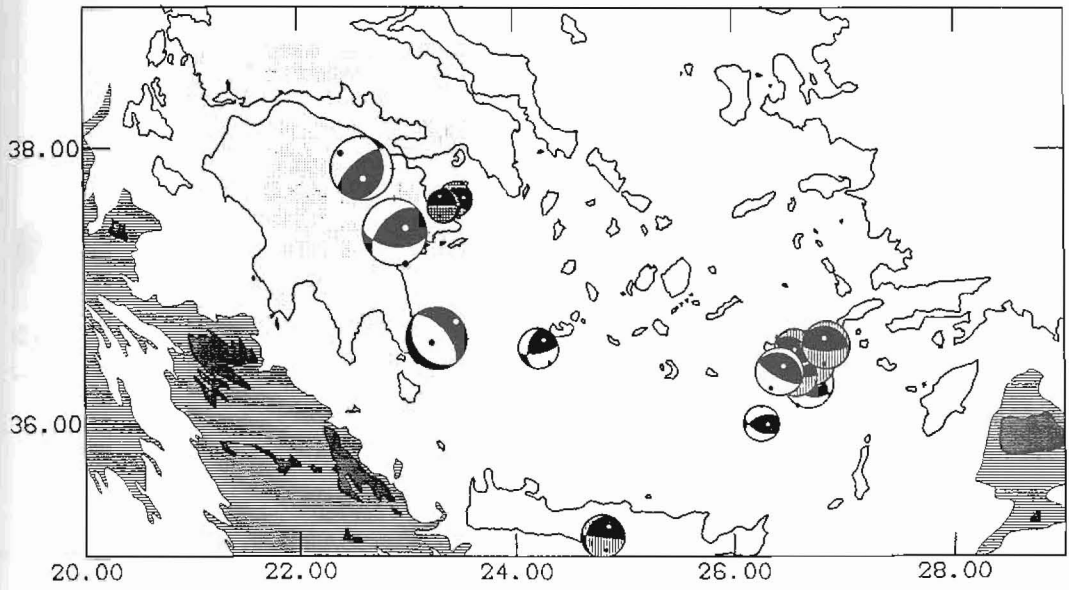

Fig.4. Focal mechanisms of earthquakes located deeper than 70km.

1) Depths greater than 70 km (Fig. 4).

The 7 solutions for the Dodecanese show a similar pattern of T-axes plunging steeply NNE and P-axes nearly horizontal and trending N-S to NNE-SSW. Among the 6 solutions located beneath the Peloponnese, 5 of them again show T-axes plunging downdip, but the P-axes are horizontal and trending NW-SE. The last solution, which seems located within the subducted slab and not at the upper part, shows normal faulting with a T-axis trending NE-SW and can be due to the bending of the slab. Finally one solution located beneath Crete, at a depth of 100 km, is more typical of those of subduction zone with a T-axis aligned downdip and a P-axis perpendicular to the slab.

Therefore the T-axes are likely dipping down the local dip of the slab, but the P-axes are almost horizontal and parallel to the local strike of the slab.

2) Depths between 40 and 70 km, (Fig. 5).

Focal mechanisms show a complex pattern. In the eastern part we observe that most events show T-axes plunging downdip as it is usual in subduction zone, but in the western part, beneath the Peloponnese, the solutions are random.

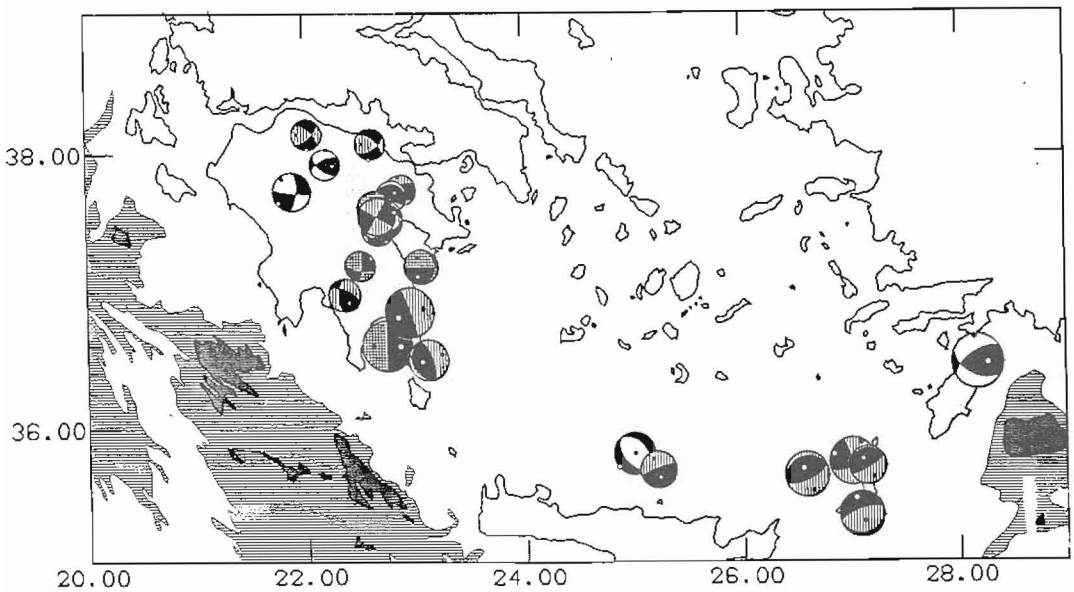

Fig.5. Focal mechanisms of earthquakes located between 40-70 km.

Therefore, it seems that the deepest events show T-axes located downdip and probably related to the pull of the slab as it is usual in subduction zone, but the P-axes are horizontal, trending parallel to the slab and could reflect a global E-W compression due to the bending of the slab. The earthquakes located between 40 and 70 km show also a simple pattern in the eastern part where the slab seems also to be simple, but a complex pattern in the western part where the slab is dipping shallowly, this pattern could be due to coupling between the two lithospheres.

CONCLUSION

A careful reexamination of ISC data, as well as the results of several microearthquake surveys, show that the intermediate depth seismicity shows some distinctive features. The seismic activity is low compared to the shallow activity observed along the Hellenic trench, and very few events are observed in the

middle of the arc beneath the Sea of Crete. It is therefore not clear if the slab is continuous or discontinuous. The seismic zone is not parallel to the trench. In the western part the slab is dipping shallowly for about 200 km before steepening and it is dipping steeper in the eastern part. Focal mechanisms in the 40-70 km depth range show a complex pattern in the western part, probably due to the interaction of the subducted and the overriding lithosphere, but a much more simpler pattern in the eastern part with the T-axes plunging downdip. Focal mechanisms located deeper than 70 km show also T-axes plunging downdip which can be related to the pulling of the slab, but also P-axes nearly horizontal and trending parallel to the trench, which implies horizontal bending or shortening of the slab. Thus, we think that the hellenic subduction is significantly asymmetric and contorted.

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