DEEP STRUCTURE AND DYNAMICS OF THE LITHOSPHERE-ASTHENOSPHERE SYSTEM IN THE MEDITERRANEAN REGION

St. MUELLER

Institute of Geophysics, ETH-Hoenggerberg, CH-8093 Zurich, Switzerland

In plate-tectonic terms the Mediterranean-Alpine region can be described as a broad transition zone between the African and Eurasian lithospheric plates which is outlined by the recent seismicity (Fig. 1). The present crust-mantle structure is the result of a dramatic evolution since the Early to Late Cretaceous with dynamic processes mainly governed by the counterclockwise rotation of Africa versus Europe which has led to an increasing lithospheric shortening from West to East (MUELLER and KAHLE, 1993). Superimposed on this large-scale dominant motion are regional tectonic deformations which are associated with compressive, strike-slip and extensional structures. The observational data available indicate that most of these features reach deeply into mantle and can only be understood as manifestations of processes involving the entire lithosphere-asthenosphere system.

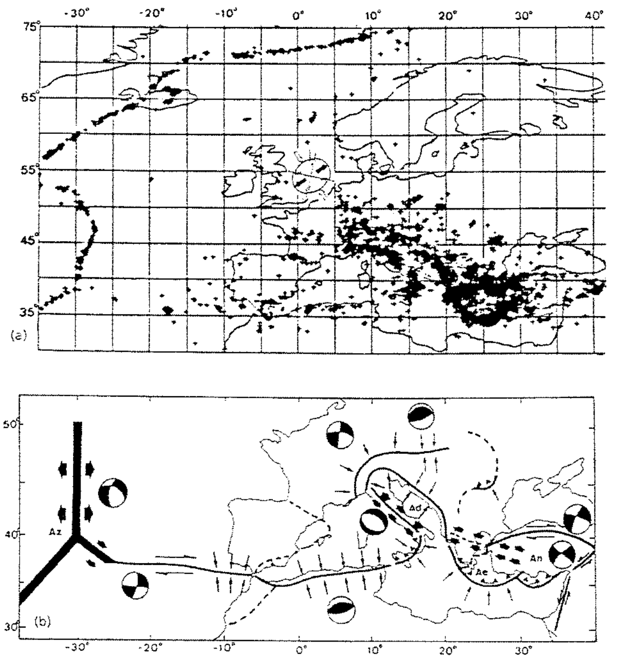

Figure 1: **(a)** The plate boundaries between N-America, Africa and Eurasia as outlined by the recent seismicity. The inset in the North Sea depicts a simplified seismotectonic stress scheme for central and NW Europe. **(b)** Generalized plate boundaries and seismotectonic stress patterns in the E-Atlantic as well as in the Mediterranean and Alpine region (after MUELLER, 1989). **Ae** = Aegean plate; **An** = Anatolian plate. **Az** = Azores triple junction; **Ad** = Adriatic promontory (or Apulian "microplate").

An attempt has been made to present a summary of the dominant structural and dynamic features which characterize the broad transition zone between the two major plates (Fig. 1). The multidisciplinary synthesis is based on the most recent geophysical and geodetic data for the Mediterranean-Alpine region. It can be demonstrated that - superimposed on the large-scale counterclockwise rotation of the African plate - complex seismotectonic processes affecting the lithospheric fragments between Africa and Europe play an important role. Their dynamics is triggered by thrusting, transcurrent motions, rifting and back-arc spreading associated with seismicity. Examples of regional cross-sections illustrating lateral heterogeneities of the upper-mantle structure are derived from the dispersion analysis of seismic surface-waves, the tomographic inversion of P- and S-wave traveltimes, long-range seismic refraction profiling and deep-reaching near-vertical reflection surveys. Beneath a highly differentiated crustal structure pronounced lateral variations of seismic wave velocities are indicative of abruptly changing features in the upper mantle. Based on space-geodetic data obtained as part of the WEGENER-MEDLAS Project within NASA's worldwide Crustal Dynamics Project (CDP) it has been possible for the first time to define in more detail the active tectonic framework by very-long baseline interferometry (VLBI), satellite laser ranging (SLR) and at the same time to aim at resolving in finer detail the kinematics of active earthquake belts by densifying the network of existing GPS measurements. In hazardous areas either continuous monitoring or repetitive measuring campaigns at shorter time intervals should now be carried out. This would allow to finally determine the space and time variations of the regional strain and stress tensors.

The results available so far have illustrated that intra-lithospheric detachment and wedging phenomena (MUELLER, 1990), differential rotations and strongly variable deformation rates have shaped the present tectonic appearance of the Mediterranean-Alpine realm. They quantitatively substantiate ongoing crustal movements (of up to 50 mm per year), such as the present northward motion of the Arabian plate, the westward motion of the Anatolian plate, the back-arc spreading in the Aegean sea and the subduction along the Hellenic arc. It could be shown that the plate contact in the Western Mediterranean region is primarily under a SE-NW compressive stress leading to a lithospheric shortening of 4 mm per year in the west to 9 mm per year in the northern Ionian sea. There is now sufficient evidence that the entire lithosphere-asthenosphere system is involved in these deep-reaching processes which significantly contribute to the potential hazard associated with impending earthquakes and volcanic eruptions.

REFERENCES

MUELLER St., 1989. Deep-reaching geodynamic processes in the Alps, *in:* Alpine Tectonics (edited by M.P. Coward, D. Dietrich and R.G. Park). Spec. Publ. Geol. Soc. London, 45: 303-328.
MUELLER St., 1990. Intracrustal detachment and wedging along a detailed cross-section in Central Europe, *in:* Exposed Cross-Sections of the Continental Crust (edited by M.H. Salisbury and D.M. Fountain, NATO-ASI Series (Kluwer Acad. Publ., Dordrecht, The Netherlands), C 317: 623-643.
MUELLER St. and KAHLE H.-G., 1993. Crust-mantle evolution, structure and dynamics of the Mediterranean-Alpine region, *in:* Contributions of Space Geodesy to Geodynamics: Crustal Dynamics (ed. D.E. Smith and D.L. Turcotte). American Geophys. Union, Washington, D.C., Geodyn. Ser., 23: 249-298.

IONIAN BASIN DEEP CRUSTAL STRUCTURES AND ITS WESTERN MARGINS

R. NICOLICH[1], F. AVEDIK[2], L. CERNOBORI[3], A. HIRN[4] & STREAMERS/PROFILES Working Groups

[1] DINMA-Univ. of Trieste, via Valerio 10 TS Italy
[2] IFREMER Brest, France
[3] CNR-Ist. Talassografico Trieste, Italy
[4] I.P.G. de Paris, Pl. Jussieu 4, Paris, France

In the Ionian basin the discussion about the crustal structure had to relay on moderate penetration seismic of the seventies, limited by the source power and by the low coverage (FINETTI, 1982). The vertical reflection seismic was supplemented with spatially averaging refraction velocity-depth measurements with OBS or ESP techniques (MAKRIS *et al.*, 1986; FERRUCCI *et al.*, 1991; DE VOOGD *et al.*, 1992; TRUFFERT *et al.*, 1992). The principal scientific problem to address to is wether the Ionian basin has an oceanic crust or a highly attenuated continental crust. The second topic is the nature of the Ionian basin with respect to its margins.

In our multichannel reflection profiles it is clearly recognisable a band of "layered" high amplitude reflections near the base of the crust, which appears to be the characteristic of the basin. This band shows a quasi-monochromatic (ca. 8 to 10 Hz) frequency of the layering. There is some evidence to suggest that the low frequency band dips down, towards the Malta Escarpment (ME) structures, where the crustal image changes and a clear thickening towards the West appears: landward dipping reflectors separate continental and intermediate crust in the central sector of the ME. There are some similarities with the Gulf of Lions deep seismic profile (DE VOOGD *et al.*, 1991).

The time deepening of the lower crust and Moho in front of the margin of the southern Calabria can be partially due to the velocity pull-down of the sedimentary pile of the arc. In fact a true dip of approximately 15% to 18% over 60 km distance is documented. Moreover the reflecting band maintains its characteristics of reflectivity and thickness till its abrupt termination beneath the Ionian extension of the Calabrian crustal structures.

An unexpected thinning of the crust towards the continent has been revealed by the seismic profiles bordering the Sicilian margin (northern sector of the ME). This important feature seems to be directly related to the presence of the volcanic products in the Hyblean plateau and to the actual volcanism of Mt. Etna.

The data were acquired in the frame of the project named STREAMERS with the financial support of EEC. The survey was afterwards completed with the lines acquired in front of Etna (project ETNASEIS) and, thanks to a further project named PROFILES, the data processing was completed and improved. In the data acquisition we used a 7118 cu.in. tuned air-gun source and a 4.5 km streamer giving us the possibility of a high coverage (4500%). In a second time a single-bubble GI-airgun source with a streamer of only 3000 m and a 24 fold coverage was employed (AVEDIK *et al.*, 1994). Equivalent results were obtained, which include: the penetration through the whole crust of the Ionian sea, the resolution of the deep frame of the basin at the margins, hints regarding the sediment/lower crust relations and the accomplishment of coincident and wide-angle acquisition with sea-land connections and landward extension of the marine coverage. Processing advances include the first sea-bottom multiple cancellation by removal of coherent events, the array simulation, an adaptive AGC.

Abyssal plain and central sector of the ME. South of the Alfeo sea-mount we enter into the Ionian Abyssal Plain with the presence of the Messinian salt and thick pre-evaporitic layers. The pinching out of the upper seismic sequences testifies the importance of the post-Tortonian tectonic evolution of the ME and of the facing area with intermediate crustal structures(CASERO *et al.*, 1988). An initial crustal arching may be recognised with a Moho at depths of 16-17 km and newly formed sin-rift basins record the Pleistocene tectonic reactivation: vertical displace ments and transcurrencies.

Messina rise and the northern sector of the ME. The region is largely occupied by the sea extension of the Hyblean foreland. The recent uplift (of the order of 2 mm/y) of the margin is documented by syn-rift basins and vertical faults cutting the whole crust. The extensional tectonic and the pronounced crustal arching have completely obliterated the collisional features of the Calabrian arc in this region. The evidence for tension is consistent with the abundant volcanism of the Mt. Etna occurring preferentially near locations where major fracture zones are thought to transect the crust which thicks only 15 km.

The Ionian margin of southern Calabria. The lines show the sea ward extension of the Calabria block, the internal structures of the crystalline crust down to the base at about 21-22 km depth and the piggy-back basins developed on the arc. The flexures of the Ionian crust in the Spartivento basin area correlate with the deep refraction data. Its abrupt termination, seen in the seismic lines, can be related to a poor signal/noise ratio or is an effect controlled by a sharp velocity increase beneath the overlapping Calabrian crustal structures. Tectonic discontinuities cannot be excluded.

REFERENCES

AVEDIK F., NICOLICH R., HIRN A., MALTEZOU F., McBRIDE J., CERNOBORI L., 1994. Appraisal of a new low frequency seismic pulse generating method on a deep seismic reflection profile in the Central Mediterranean sea. First Break (submitted).
CASERO P., CITA M. B., CROCE M., FRISIA S., HIEKE W. and NICOLICH R., 1988. Malta Esc., Alfeo sea-Mount and Victor Hensen sea-Hill: a key to plate tectonic evolution of the Eastern and Western Med. since Mesozoic. ODP proposal presented at ECOD & CIESM WG.
DE VOOGD B., NICOLICH R., OLIVET J.-L., FANNUCCI F., BURRUS J., 1991. First deep reflection transect from Gulf of Lions to Sardinia. AGU, *Geodyn. Series*, 22, 265-274.
DE VOOGD B., TRUFFERT C., CHAMOT-ROOKE N., HUCHON P., LALLEMANT S. and LE PICHON X., 1992. Two-ships deep seismic soundings in the basin of the Eastern Med. sea (Pasiphae cruise). *Geophysical J. Int.*, 109, 536-552.
FERRUCCI F., GAUDIOSI G., HIRN A. and NICOLICH R., 1991. Ionian basin and Calabrian Arc. *Tectonophysics*, 195, 411-419.
MAKRIS J., NICOLICH R. and WEIGEL W., 1986. A seismic study in the Western Ionian sea. *Annales Geophysicae*, 4, 36, 665-678.
FINETTI I., 1982. Structure, stratigraphy and evolution of Central Mediterranean. *Boll. Geof. Teor. Appl.*, XXIV, 96, 247- 312.
TRUFFERT C., CHAMOT-ROOKE N., LALLEMANT S., DE VOOGD B., HUCHON P. and LE PICHON X., 1993. The crust of the Eastern Med. ridge from deep seismic data and gravity modelling. *Geophysical J. Int.*, 114, 360-372.

G