Contributions to the Geology of Italy
with special regard to the Paleozoic basements.
A volume dedicated to Tommaso Cocozza.
L. Carmignani & F.P. Sassi Editors,
IGCP No. 276, NEWSLETTER Vol. 5, Siena 1992, 339 - 343.

SEISMOTECTONIC IDENTITY OF THE SOUTHERN ADRIATIC AREA

P. Favali *, R. Funiciello *, G. Mattietti *, G. Mele *, P. Montone **, F. Salvini *** & M. Tozzi ****

*Istituto Nazionale di Geofisica, Università degli Studi di Roma, Via di Villa Ricotti, 42 - 00161 Roma, Italy.
**Dipartimento di Scienze della Terra, Università "La Sapienza", P.le A.Moro, 5 - 00100 Roma, Italy.
***Dipartimento di Scienze della Terra, Università degli Studi di Pisa, Via S.Maria,53 - 56100 Pisa, Italy.
****CNR, Centro Studi per la Geologia Tecnica, Via Eudossiana, 18 - 00184 Roma, Italy.

Abstract

The Adriatic microplate is considered in literature as a block relatively undeformed and aseismic with unitary dynamical behaviour. Nevertheless such model is inadequate to justify the recent seismicity of the Adriatic basin. Recent mesostructural analyses are showing a continuous strain boundary all around the Southern Adriatic platform. Several structures were recognized continuously outcropping from the Southern Dalmatian coastline (Kotor zone) to Split-Sibenik area and, across the Adriatic isles, until the Tremiti Islands and the Gargano-Murge regions. Data point out a centripetal trend of the Dinaric and Apenninic units, delimited to the north by ductile and brittle strain belts. These belts seem to set apart the southern block and to allow the release from the northern structures. The agreement between the geological-structural and seismological data allows to identify the Southern Adriatic block as an indipendent crustal structure, divided from the northern one by strike-slip faults. The Southern Adriatic block is able to condition the structural evolution of the neighbouring areas.

Key Words: *Adriatic Sea, Southern Italy, Geodynamics, Seismology, Geodynamics*

1. Introduction

Several microplates are singled out in the Mediterranean area (McKenzie, 1972), following the complex collisional history between the African and European plates. The Adriatic microplate is an elongated continental block including the Po Plain and the Adriatic basin, surrounded by a series of strongly deformed belts. Its collision with the European plate gave rise to the uplift of the peri-Adriatic chains: the Alpine and Dinaric-Hellenic systems during Cretaceous-Eocene, the Western Alps during Eocene-Miocene and the Apenninic chain starting from Upper Miocene.

Among others, the Adriatic microplate, whose margins were identified on the basis of the epicentres distribution (Lort, 1971), has been interpreted also recently as a unitary and nearly aseismic block (e.g. Mantovani et al., 1985; Anderson & Jackson, 1987; Royden et al., 1987). Neverthless this model does not justify either the newly collected structural data in the area (Funiciello et al., 1991) or the recent seismicity localized by the Istituto Nazionale di Geofisica (ING, 1990) in the Central Adriatic basin.

2. Geodynamical Setting

Structural and geological data show that the Southern Adriatic block can be interpreted as homogeneous and brittle (Fig.1) (Funiciello et al., 1988; Montone & Funiciello, 1989), with generally low tectonized areas in its internal part (Salento, Murge) and highly deformed units outcropping along the borders. To the south-west the transition from the Adriatic to the Tyrrhenian domain is marked by a thrust chain (Apennines) derived from the shortening of the sedimentary wedge of a passive margin. This is related to the sinking of the Adriatic lithosphere with its entire thickness (Moretti & Royden, 1988). Several regional geological cross sections (Mostardini & Merlini, 1986), carried out with the contribution of seismic soundings for oil research, confirm this model.

The upper crust structural setting results from a series of mainly in-sequence thrusts according to ramp-flat duplex geometries. Several detachment layers have been recognized. The sole thrust was identified in the Triassic units, as suggested by the age of the oldest involved lithologies (evaporitic sequences) and by their rheology (Ogniben et al., 1975). The development of this chain has been started in Late Tortonian, as suggested by the closing age of the westernmost sedimentary cycles (Bigi et al., 1989).

The central part of the Apenninic chain is structured by NW-SE trending thrust and normal (not shown in Fig. 1) faults that indicate a NE-SW shortening; N-S right-lateral strike-slip faults and NW-SE left-lateral strike-slip faults

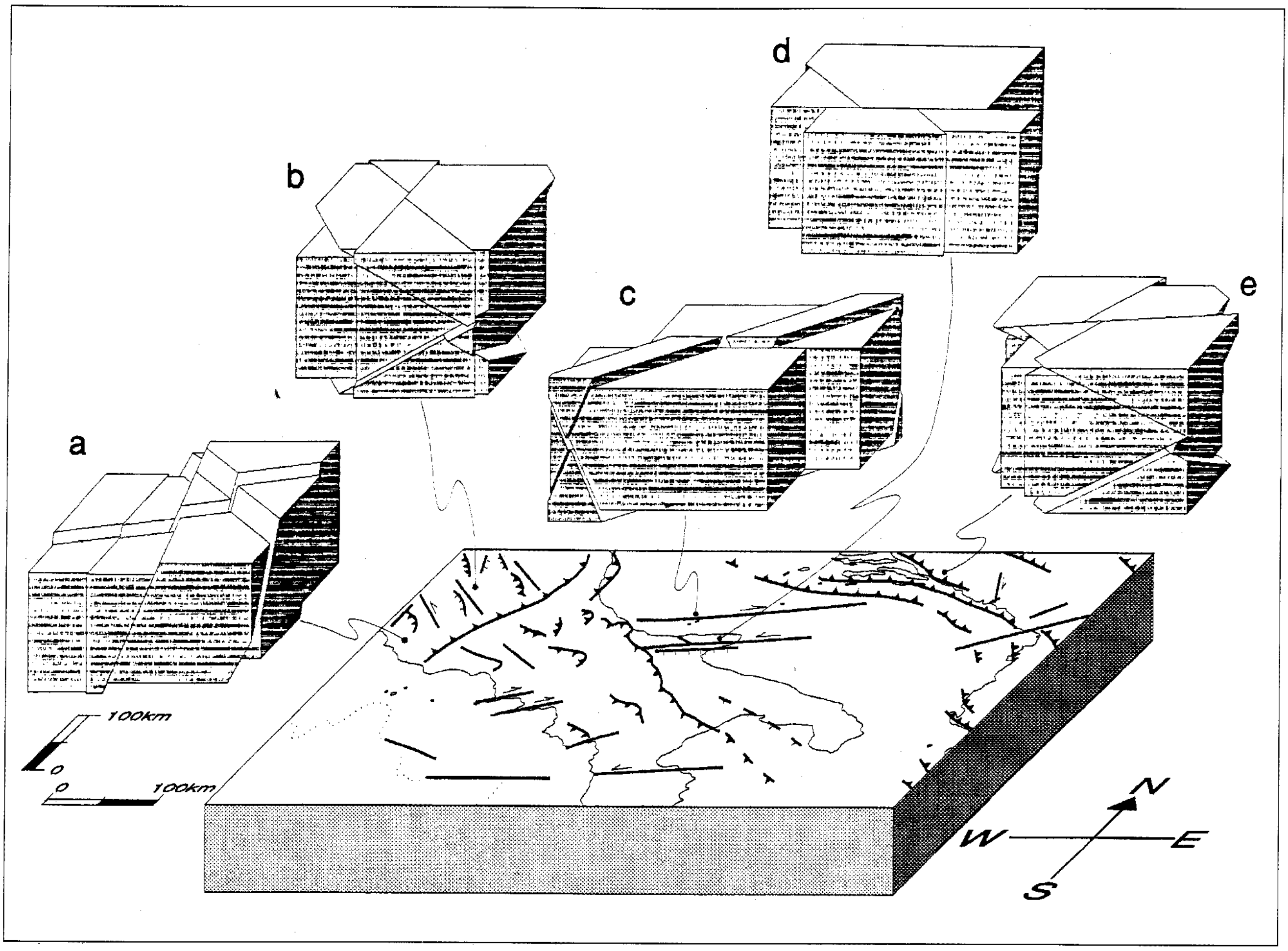

Fig. 1 - Summary of the results from structural data. Blocks show the main fault systems. a) Tyrrhenian margin: it is interested mainly by NW-SE and then N 10°W and N 70°E normal faulting; N-S striking right lateral strike-slip faults with moderate displacement seem to dissect all other features. b) Apenninic chain: this sector is structured by NW-SE trending thrust and normal (not shown) faults that indicate a NE-SW shortening; N-S right lateral strike-slip faults and NW-SE left lateral strike-slip faults dissect all other deformations. c) Tremiti Islands: push-up structure related to E-W right lateral strike-slip faulting. d) Gargano Promontory: NW-SE strike-slip and vertical (not shown) faults; E-W Mattinata fault clearly cut them; E-W normal faulting (not shown) seems to represent the last event. e) Dinarides: NW-SE thrust faults together with a wrench system indicate a NE-SW shortening.

dissect all other deformations (Boccaletti et al.,1982; Alfonsi et al., 1991a; 1991b; Mattei & Miccadei, 1991; Montone & Salvini, 1991). Geological and structural data from the northern margin were collected in the Gargano Promontory and Tremiti Islands. In the Tremiti Islands the deformations can be related to the presence of a push-up structure while in the Gargano Promontory the structural analysis evidenced NW-SE left-lateral strike-slip and vertical faults (not shown in Fig. 1). A regional E-W left-lateral strike-slip faulting clearly displaces all of them. Eventually an E-W faulting (not shown in Fig. 1) seems to represent the last event (Funiciello et al., 1988).

The north-eastern boundary of the Adriatic microplate is also characterized by a thrust chain (Dinarides). The age of deformation is generally considered older than the Apenninic one, while recent offshore data show the involving of terrigenous cycles of Upper Cenozoic age. The strength of the lithologies in the Dinaric units is higher than that of the Apenninic domain, as confirmed by mesostructural data. Fault analysis at outcrop scale pointed out the presence of NW-SE thrust faults together with a wrench system that both indicate a NE-SW shortening. The high percent of wrench tectonic deformations suggests a structural style related to a lithospheric thickening that does not involve subduction.

3. Seismic Activity

The historical earthquakes occurred in the Adriatic Sea are poorly documented and often mislocated. About a hundred earthquakes are known to be occurred in this area from 1000 to 1985 (Postpischl, 1985; ING, 1990), in particular in the Gargano offshore. Starting from 1975 the Seismic Catalogue of the Istituto Nazionale di Geofisica can be considered microseismic, i.e. every hypocentral location is based on the seismogram analysis instead of macroseismic considerations.

We particularly focused on the Central Adriatic basin, where an interesting seismic activity occurred during the last years. In January 1986 a seismic sequence occurred about 50 km to the north of the Tremiti Islands (main shock Mb=4.2). After about one year of quiescence, another sequence has been detected to the east-southeast of Gargano (April 1988, main shock Mb=5.3) and in October 1989 a moderate activity occurred again in the Tremiti Islands (main shock Mb=4.7) until 1990. In figure 2 the 1986-1990 seismic data with 3.0 minimum magnitude threshold and the Centroid-Moment Tensor focal solutions (Favali et al., 1990) relate the main structural features.

The focal solutions are consistent with the regional stress field that is mainly compressive in the eastern side and extensional in the Apennines (e.g. Udias, 1980; D'Argenio, 1988).

4. Discussion

The proposed geodynamical models of the Adriatic microplate as unique, undeformed and aseismic should be improved. The information derived from seismology, structural geology and geophysics singles out at least two domains separated by regional discontinuities at the Gargano latitudes.

The seismic activity occurred in the last years has pointed out the progressive activation of structures, which define the margins of a lithospheric block with unitary geodynamical behaviour. The boundaries of this block are the Southern Apennines to the south-west, the Dinarides-Hellenides to the north-east and the middle Adriatic deformation belt to the north (Mele et al., 1990).

The seismic energy release is different between the two parts of the Adriatic area. In the southern one high magnitude earthquakes (Mb>=6.0) are quite frequent while in the northern part they occur only in the Friuli-Carnia zone, where the compressive interaction between the Northern Adriatic and the European plates is acting (Slejko et al., 1987). In the southern part we modelled the interaction of the Adriatic lithosphere with both the Apennines and the Dinarides-Hellenides, with strong deformations of the sedimentary cover (fig. 3).

In the western sector, a westward lithospheric subduction is coherent with the deep seismicity in Eastern Tyrrhenian coastline (Giardini and Velonà, 1991), while

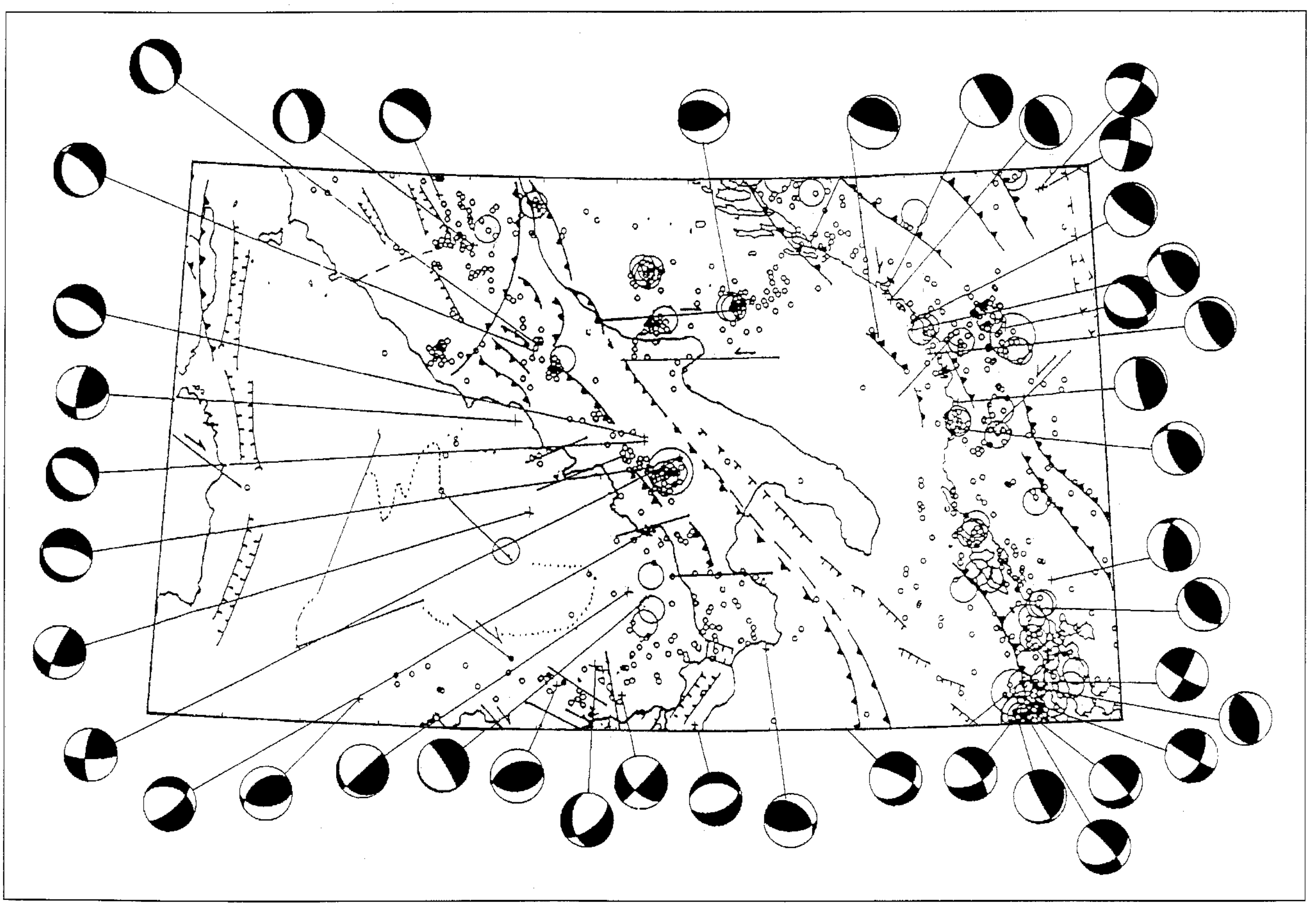

Fig. 2 - 1986-1990 seismic activity (M>=3.0), CMT focal solutions and main tectonic features.

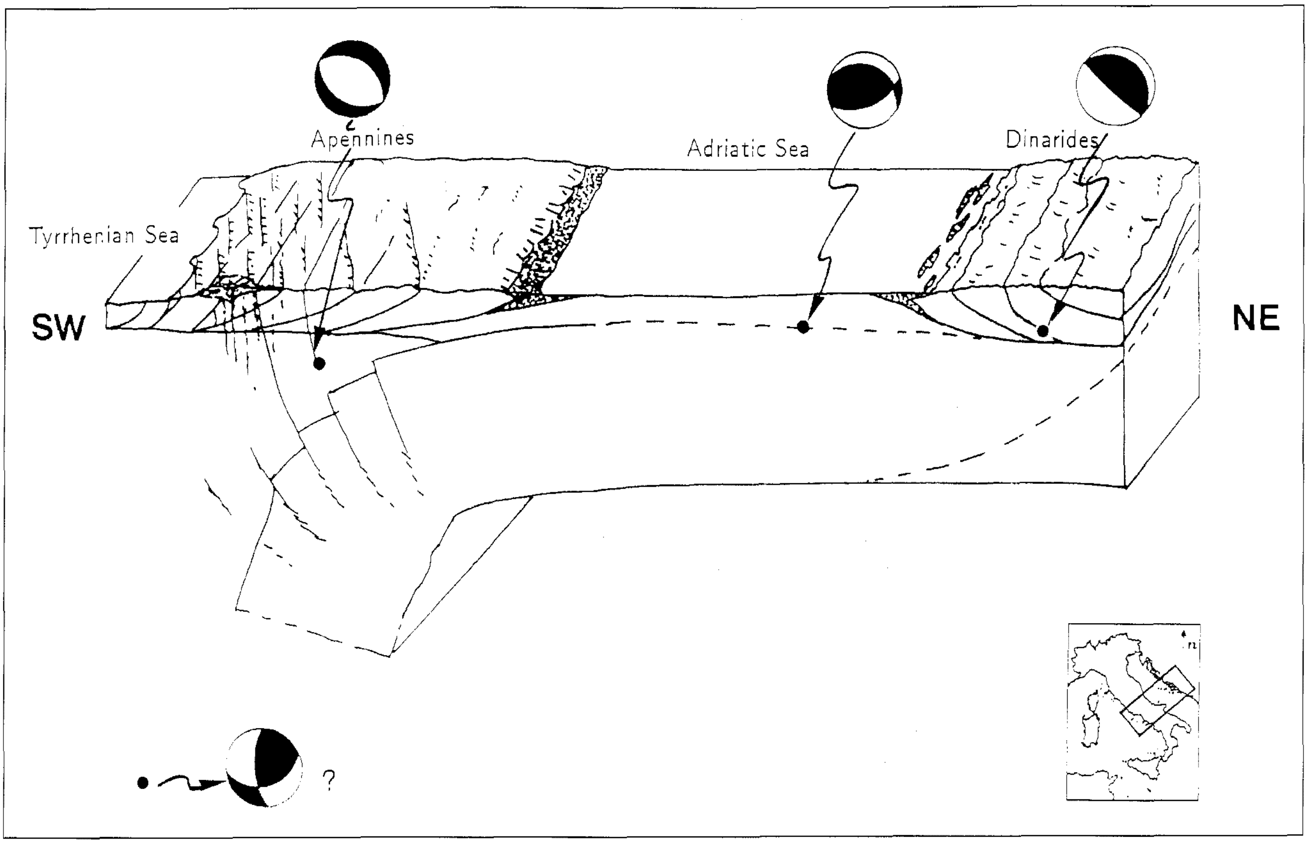

Fig. 3 - Block-diagram showing the interaction between the Adriatic lithosphere and the surrounding chains.

along the eastern margin the upper crust interaction is marked by low angle compressive tectonics. This essentially determined a crustal thickening with the preservation of a dynamical coupling between the basament and the sedimentary cover. This coupling is suggested by the substantial corrispondence between the deep deformations, inferred from the seismological data (see fig. 2), and the superficial ones (see fig. 1). The western margin, on the contrary, presents a clear decoupling between the deep extensional deformations and the intense shortening in the upper crust units.

In the Southern Apennines a sinking lithosphere collapse in the hinge zone could be the seismogenic mechanism, as inferred from the typical focal depths ranging 10 to 30 km. In the eastern margin earthquakes occur near the outermost thrust, in the western one they are located farther whithin the chain.

5. Conclusion

Our new data no longer justify a geodynamical model considering the Adriatic microplate as a unique, undeformed and internally aseismic block. At least two lithospheric domains are identified. The transition zone corresponds to an active deformation belt crossing the Adriatic Sea at the Gargano latitudes, characterized by regional strike-slip discontinuities.

In the southern block, the Dinaric-Hellenic chain marks a crustal thickening that represents its north-eastern margin. A sinking process below the Apennine chain identifies its south-western boundary. The aforementioned transitional zone represents the northern margin of this block, whereas its southern edge is questionable. Some Authors (D'Ingeo et al., 1980; Anderson & Jackson, 1987) tentatively recognized it with the Cephalonia active structure or with the escarpment toward the Ionian Sea.

Acknowledgements

The Authors wish to thank Maurizio Parotto for helpful suggestions and discussions, Enzo Boschi for his encouragement and Daniela Riposati for the drafting of most of the figures.

REFERENCES

ALFONSI, L., FUNICIELLO, R., MATTEI M., GIROTTI O., MAIORANI A., PREITE MARTINEZ M., TRUDU C. & TURI B., (1991a). Structural and geochemical features of the Sabina strike-slip fault (Central Apennines). Boll. Soc. Geol. It., 110, 217-230.

ALFONSI L., FUNICIELLO R. & MATTEI M., (1991b). Strike-slip tectonics in the Sabina area. Boll. Soc. Geol. It., 110, 481-488.

ANDERSON H. & JACKSON J., (1987). Active tectonics of the Adriatic region. Geophys. J. R. Astr. Soc., 91, 937-983.

BIGI G., CASTELLARIN A., CATALANO R., COLI M., COSENTINO D., DAL PIAZ G.V., LENTINI F., PAROTTO M., PATACCA E., PRATURLON A., SALVINI F., SARTORI R., SCANDONE P. & VAI G.B., (1989). Synthetic Structural—Kinematic Map of Italy (1:2,000,000). C.N.R. - P.F.G., Roma.

BOCCALETTI M., CONEDERA C., DAINELLI P. & GOCEV P., (1982). The recent (Miocene-Quaternary) regmatic system of western mediterranean region. Journ. Petrol. Geol., 5, 1, 31-49.

D'ARGENIO B., (1988). L'Appennino campano-lucano. Vecchi e nuovi modelli geologici tra gli anni sessanta e l'inizio degli anni ottanta. In: L'Appennino Campano-Lucano nel quadro geologico dell'Italia meridionale. Proceedings 74 °Congress of Italian Geological Society, 1-13.

D'INGEO F., CALCAGNILE G. & PANZA , G.F., (1980). On the fault-plane solutions in the Central-Eastern Mediterranean region. Boll. Geofis. Teor. Appl., 22, 13-22.

FAVALI P., MELE G. & MATTIETTI G., (1990). Contribution to the study of the Apulian microplate geodynamics. Mem. Soc. Geol. It., 44, 71-80.

FUNICIELLO R., MONTONE P., SALVINI F. & TOZZI M., (1988). Caratteri strutturali del Promontorio del Gargano. Mem. Soc. Geol. It., 41 (in press).

FUNICIELLO R., MONTONE P., PAROTTO M., SALVINI F. & TOZZI M., (1991). Geodynamical evolution of an intra-orogenic foreland: the Apulia case history (Italy). Boll. Soc. Geol. It., 110, 419-425.

GIARDINI D. & VELONA' M., (1991). The deep seismicity of the Tyrrhenian Sea. Terra Nova, 3:57-64.Istituto Nazionale di Geofisica (ING), 1990. Italian seismic catalogue from 1450 b.C. to 1990 a.C. (Internal file). Roma.

LORT J.M., (1971). The tectonics of the Eastern Mediterranean: A geophysical review. Rev. Geophys. Sp. Phys., 9, 189-216.

MANTOVANI E., BABBUCCI D. & FARSI F., (1985). Tertiary evolution of the Mediterranean region: outstanding problems. Boll. Geofis. Teor. Appl., 26, 67-88.

MATTEI M. & MICCADEI E., (1991). Strike-slip tectonics between the Marsica range and the Molisan basin in the Sangro valley (Abruzzo, Central Italy). Boll. Soc. Geol. It., 110, 737-745.

MCKENZIE D., (1972). Active tectonics of the Mediterranean region. Geophys. J. R. Astr. Soc., 30, 109-185.

MELE G., MATTIETTI, G. & FAVALI P., (1990). Sismotettonica dell'area adriatica: interpretazione di dati sismologici recenti. Mem. Soc. Geol. It., 45 (in press).

MONTONE P. & FUNICIELLO R., (1989). Elementi di tettonica trascorrente alle Isole Tremiti (Puglia). Rend. Soc. Geol. It., 12, 7-12.

MONTONE, P. & SALVINI, F., 1991. Evidences of strike-slip tectonics in the Apenninic chain near Tagliacozzo (L'Aquila), Abruzzi, Central Italy. Boll. Soc. Geol. It., 110, 617-619.

MORETTI, I. & ROYDEN, L., 1988. Deflection, gravity anomalies and tectonics of doubly subducted continental lithosphere: Adriatic and Ionian seas. Tectonics, 7, 875-893.

MOSTARDINI F. & MERLINI S., (1986). Appennino Centro Meridionale. Sezioni geologiche e Proposta di Modello Strutturale. Mem. Soc. Geol. It., 35, 177-202.

OGNIBEN L., PAROTTO M. & PRATURLON A. (editors), (1975). Structural model of Italy. Quad. "La Ricerca Scientifica", C.N.R., 90.

POSTPISCHL D. (editor), 1985. Catalogo dei terremoti italiani dall'anno 1000 al 1980. Quad. "La Ricerca Scientifica", C.N.R. - P.F.G., 114 (2B), Bologna.

ROYDEN L., PATACCA, E. & SCANDONE P., (1987). Segmentation and configuration of subducted lithosphere in Italy: an important control on thrust belt and foredeep basin evolution. Geology, 15, 714-717.

SLEJKO D., CARULLI G.B., CARRARO F., CASTALDINI D., CAVALLIN A., DOGLIONI C., ILICETO V., NICOLICH R., REBEZ A., SEMENZA E., ZANFERRARI A. & ZANOLLA C., (1987). Modello sismotettonico dell'Italia nord-orientale. C.N.R. - G.N.D.T., rend. 1, Trieste.

UDIAS A., (1980). Tectonic stresses in the Alpine-Mediterranean region. Rock Mechanics, 9, 75-84.