*Mem. Soc. Geol. It.,*
*44 (1990), 71-80, 6 ff., 1 tab.*

# CONTRIBUTION TO THE STUDY OF THE APULIAN MICROPLATE GEODYNAMICS

PAOLO FAVALI (*), GIULIANA MELE (*) & GIUSEPPINA MATTIETTI (*)

## ABSTRACT

The fragmentation of the collisional border between the African and European plates has also originated the Apulian (Adriatic) microplate. Recent studies show the possibility of a non-unitary geodynamic evolution of this microplate: palaeomagnetic data from North-Western Greece and Southern Apulia indicate a different rotational behaviour. Between 41° and 43° latitude North, regional strike-slip fault systems cut crosswise the Adriatic basin, breaking the Adriatic block in at least two minor elements. The intense seismicity points out an active deformational area. In the same region also other geophysical data identify a transitional zone.

KEY WORDS: *Adriatic microplate, recent seismicity, Mattinata and Tremiti fault systems.*

## RIASSUNTO

Recenti studi hanno messo in luce alcune anomalie nel quadro della evoluzione geodinamica dell'avampaese adriatico. Le misure paleomagnetiche, prima in Grecia nord-occidentale e nella penisola salentina (Puglia meridionale), poi nel Gargano, rivelano un diverso comportamento rotazionale del settore meridionale rispetto a quello settentrionale della microplacca adriatica. Come tale viene identificata l'area sommersa del bacino adriatico e le unità sottostanti le zone di accavallamento degli orogeni terziari periadriatici. La zona di deformazione lungo la quale si sarebbe esplicato lo svincolo è verosimilmente da identificarsi nel sistema di faglie regionali conosciute in letteratura come *Faglia delle Tremiti e Faglia di Mattinata*, con probabile coinvolgimento della fascia circostante.

Il potenziamento della rete sismica nazionale ha da alcuni anni reso possibile l'acquisizione di dati che si riferiscono ad eventi sismici avvenuti all'interno del bacino adriatico, per il quale le fonti storiche davano scarse informazioni. Ne risulta che l'area in cui è stato individuato il prolungamento a mare delle faglie suddette è interessata da un'attività sismica con valori di magnitudo in alcuni casi comparabili con quelli di altre aree circostanti (ad esempio l'Appennino centrale).

La microplacca adriatica sarebbe dunque da inquadrare in un nuovo modello geodinamico, in cui essa risulta composta da almeno due unità a evoluzione differente, a nord e a sud delle latitudini garganiche. L'esame delle mappe gravimetriche, magnetometriche, di profondità della Moho e della batimetria, sembra confermare l'esistenza di una zona di transizione tra domini con assetto morfo-tettonico differente.

TERMINI CHIAVE: *Microplacca Adriatica, sismicità recente, faglie di Mattinata e Tremiti.*

## INTRODUCTION

The Mediterranean area is a very complex system of continental blocks, basins and orogenic belts the tectonic setting of which has been determined by the drift of the African and European plates. Since Upper Cretaceous, the progressive collision of these two plates originated the circum-Mediterranean mountain belts, which are also zones of crustal shortening. Actually the contact zone between the African and European plates is characterized by several microplates originated by the fragmentation of the former collisional border, such as the Iberian, Sardinian-Corsica block, Egean and Anatolian microplates (MCKENZIE, 1972).

This is also the origin of the Apulian (Adriatic) microplate, which played an important role in the evolution of the Mediterranean region: this continental block collided with the European body at different times, during Cretaceous-Eocene in the eastern and northern side giving rise to the uplift of the Alpine and Dinaric-Hellenic systems, and later, during Eocene-Miocene, in the western side forming the Western Alps. The Apennine-Maghrebid system gradually arose since Upper Miocene. The Adriatic microplate margins were identified at first by LORT (1971) because of their seismic activity: nowdays the Apulian microplate is a continental area mostly below sea level and surrounded by greatly deformed orogenic belts (Apennines to the west, Southern Alps to the north, Dinarides and Hellenides to the east-southeast).

(*) Istituto Nazionale di Geofisica, Roma.

## GENERAL OUTLINE

The Apulian (Adriatic) microplate is nowdays in consumption along all its margins, except the Ionian one, in the southern edge: the Ionian crustal characteristics are of great importance in order to understand the relationship between the Apulian microplate and the African body. The Ionian zone seems a tectonically stable area with low heat flow values (≃ 30-40 *mW/m²*, from ERICKSON *et alii*, 1977), a characteristic of old crust portions. The margin is compressional along the northern and eastern sides (Southern Alps and Dinarides), and is extensional along the axis of the Apennine chain (D'ARGENIO *et alii*, 1975; UDIAS, 1980; D'ARGENIO, 1988). The available peri-Adriatic focal solutions, obtained by means of the Centroid-moment tensor method (CMT) recovered by DZIEWONSKI *et alii* (1981), confirm this stress pattern (GIARDINI *et alii*, 1984; FAVALI & MELE, 1989). Fig. 1 shows the CMT solutions with a body magnitude ($m_b$) greater than or equal to 4.8 for events occurring between 1977 and 1987 (further details concerning the focal solutions are contained in table 1). We can observe coherent solutions in the northern part of the peri-Adriatic belt up to the Gargano headland, with extensional and compressional edges along the Apennines and Dinarides respectively; the southern part is characterized by a more complex situation, except for the Sicilian border showing a prevalent N-S compression.

In the same figure we added the focal mechanism of the earthquake which took place on April 26, 1988 ($m_b$ = 5.3) within the Adriatic area at Gargano level. This solution shows a small strike-slip component in an east-west direction.

## SEISMICITY AND MAIN TECTONIC FRAMEWORK

The Adriatic main tectonic trend (faults and fold axis) is NW-SE and NNW-SSE. Fig. 2 shows the main structural elements associated to the seismic activity recorded from 1986 to 1990 (June) with a local magnitude ($M_L$ greater than or equal to 3.0. This magnitude threshold has been chosen after an analysis

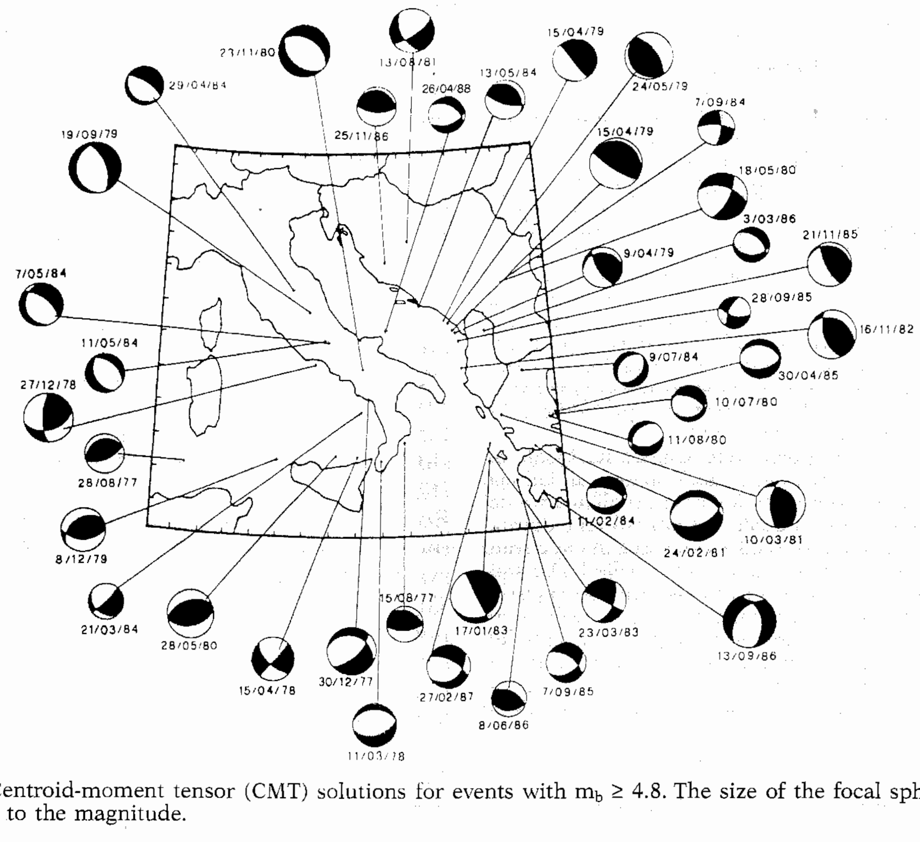


*Fig. 1* - Centroid-moment tensor (CMT) solutions for events with $m_b \geq 4.8$. The size of the focal sphere is proportional to the magnitude.

TABLE 1

*List of the CMT solutions plotted in fig. 1 (T, N, P-axis plunges and azimuths in degrees).*

| Date | $\phi$ | $\lambda$ | $h$ | $m_b$ | P – axis | | N – axis | | T – axis | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | az. | pl. | az. | pl. | az. | pl. |
| 08/15/77 | 38.85 | 16.98 | 54 | 5.0 | 313 | 69 | 102 | 18 | 195 | 10 |
| 08/28/77 | 38.21 | 8.21 | 10 | 5.1 | 314 | 72 | 65 | 7 | 157 | 17 |
| 12/30/77 | 40.00 | 15.42 | 283 | 5.6 | 164 | 19 | 62 | 32 | 279 | 52 |
| 03/11/78 | 38.10 | 16.03 | 33 | 5.6 | 167 | 6 | 76 | 12 | 282 | 77 |
| 04/15/78 | 38.39 | 15.07 | 14 | 5.5 | 93 | 18 | 217 | 60 | 355 | 23 |
| 12/27/78 | 41.11 | 13.58 | 390 | 5.6 | 58 | 45 | 204 | 39 | 309 | 18 |
| 04/09/79 | 41.96 | 19.02 | 10 | 5.3 | 90 | 59 | 320 | 21 | 221 | 22 |
| 04/15/79 | 42.04 | 19.05 | 4 | 6.1 | 31 | 58 | 129 | 5 | 222 | 32 |
| 04/15/79 | 42.32 | 18.68 | 10 | 5.7 | 59 | 45 | 328 | 1 | 236 | 45 |
| 05/24/79 | 42.26 | 18.75 | 8 | 5.8 | 254 | 72 | 150 | 5 | 58 | 18 |
| 09/19/79 | 42.81 | 13.06 | 16 | 5.9 | 79 | 19 | 346 | 9 | 231 | 69 |
| 12/08/79 | 38.28 | 11.74 | 33 | 5.4 | 63 | 74 | 252 | 16 | 162 | 3 |
| 05/18/80 | 43.29 | 20.84 | 9 | 5.7 | 157 | 11 | 52 | 52 | 255 | 35 |
| 05/28/80 | 38.48 | 14.25 | 14 | 5.7 | 98 | 84 | 257 | 6 | 347 | 2 |
| 07/10/80 | 39.31 | 22.92 | 10 | 5.2 | 13 | 17 | 108 | 17 | 239 | 66 |
| 08/11/80 | 39.27 | 22.66 | 17 | 5.1 | 159 | 3 | 250 | 24 | 62 | 66 |
| 11/23/80 | 40.91 | 15.37 | 10 | 6.0 | 39 | 4 | 308 | 6 | 163 | 82 |
| 02/24/81 | 38.22 | 22.93 | 33 | 5.9 | 176 | 10 | 83 | 16 | 299 | 71 |
| 03/10/81 | 39.48 | 20.70 | 31 | 5.6 | 146 | 66 | 352 | 22 | 259 | 10 |
| 08/13/81 | 44.86 | 17.33 | 9 | 5.5 | 109 | 17 | 223 | 53 | 7 | 31 |
| 11/16/82 | 40.98 | 19.54 | 10 | 5.6 | 108 | 65 | 328 | 20 | 232 | 15 |
| 01/17/83 | 38.09 | 20.19 | 9 | 6.0 | 48 | 50 | 152 | 12 | 252 | 38 |
| 03/23/83 | 38.33 | 20.22 | 15 | 5.7 | 348 | 25 | 126 | 58 | 249 | 19 |
| 02/11/84 | 38.38 | 22.07 | 15 | 5.3 | 10 | 19 | 105 | 14 | 229 | 65 |
| 03/21/84 | 39.40 | 15.18 | 278 | 5.0 | 117 | 42 | 227 | 21 | 337 | 41 |
| 04/29/84 | 43.27 | 12.57 | 14 | 5.2 | 39 | 25 | 306 | 6 | 203 | 64 |
| 05/07/84 | 41.77 | 13.89 | 10 | 5.5 | 57 | 19 | 320 | 19 | 189 | 63 |
| 05/11/84 | 41.83 | 13.95 | 13 | 5.3 | 56 | 3 | 326 | 10 | 164 | 80 |
| 05/13/84 | 42.93 | 17.73 | 10 | 5.2 | 10 | 59 | 110 | 6 | 203 | 30 |
| 07/09/84 | 40.69 | 21.82 | 10 | 5.1 | 133 | 8 | 225 | 9 | 2 | 78 |
| 09/07/84 | 43.30 | 20.91 | 10 | 5.1 | 144 | 2 | 46 | 75 | 234 | 15 |
| 04/30/85 | 39.25 | 22.79 | 19 | 5.4 | 179 | 3 | 88 | 12 | 284 | 77 |
| 09/07/85 | 37.48 | 21.24 | 33 | 5.2 | 348 | 14 | 88 | 35 | 240 | 51 |
| 09/28/85 | 41.59 | 22.22 | 20 | 4.8 | 160 | 0 | 250 | 61 | 70 | 29 |
| 11/21/85 | 41.72 | 19.32 | 22 | 5.4 | 76 | 62 | 330 | 9 | 236 | 26 |
| 03/03/86 | 41.95 | 20.27 | 23 | 5.0 | 31 | 13 | 126 | 22 | 273 | 64 |
| 06/08/86 | 36.07 | 21.51 | 29 | 5.1 | 215 | 78 | 113 | 2 | 23 | 11 |
| 09/13/86 | 37.03 | 22.20 | 29 | 5.8 | 287 | 6 | 20 | 28 | 187 | 62 |
| 11/25/86 | 44.14 | 16.41 | 27 | 5.3 | 348 | 64 | 92 | 6 | 185 | 25 |
| 02/27/87 | 38.50 | 20.26 | 10 | 5.4 | 359 | 22 | 105 | 33 | 242 | 48 |
| 04/26/88 | 42.30 | 16.59 | 10 | 5.3 | 279 | 68 | 85 | 21 | 177 | 5 |

$\phi$, $\lambda$ epicentral coordinates
$h$ hypocentral depth (in km)

of completeness from 1986. When $M_L$ was not available we used the duration magnitude ($M_D$).

The structural elements have been recovered from many authors (AA.VV., 1981; AGIP, 1981; PAROTTO & PRATURLON, 1981; FINETTI, 1982; FINETTI & DEL BEN, 1986; KISSEL *et alii*, 1986; FINETTI *et alii*, 1987; REUTHER, 1987; SKOKO *et alii*, 1987; MORETTI & ROYDEN, 1988). The Istituto Nazionale di Geofisica (ING) catalogue and bulletin are source of seismic data (ING, 1989; 1990).

The average stress field of the Adriatic area presents a main compressional axis ($\sigma_1$) in anti-Apennine direction (SW-NE) and perpendicular to the elongation of the Adriatic sea (PHILIP, 1987). Furthermore the progressive deepening of the top of the Mesozoic series along the

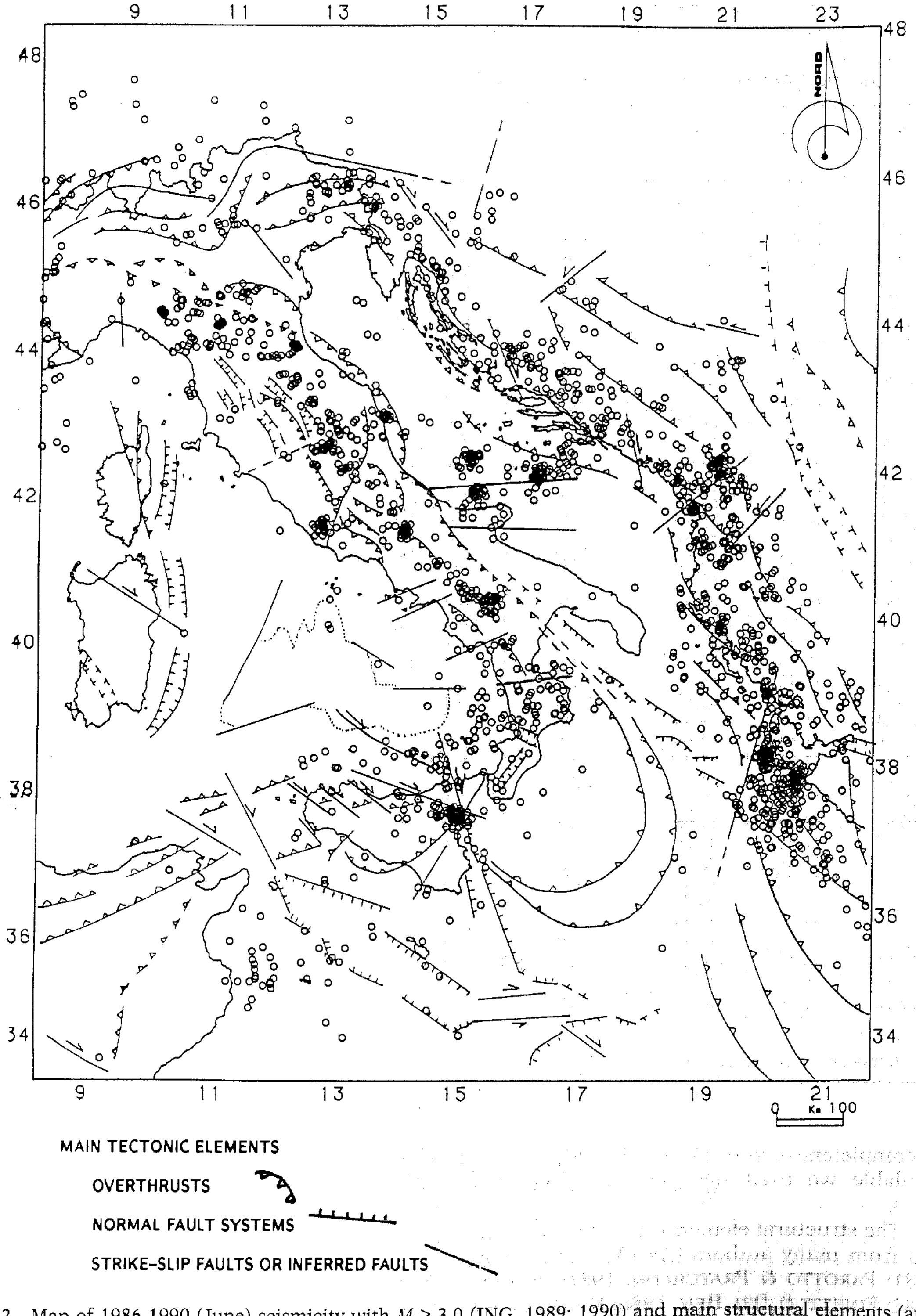


*Fig. 2* - Map of 1986-1990 (June) seismicity with $M \geq 3.0$ (ING, 1989; 1990) and main structural elements (after AA.VV., 1981; AGIP, 1981; PAROTTO & PRATURLON, 1981; FINETTI, 1982; FINETTI & DEL BEN, 1986; KISSEL *et alii*, 1986; FINETTI *et alii*, 1987; REUTHER, 1987; SKOKO *et alii*, 1987; MORETTI & ROYDEN, 1988).

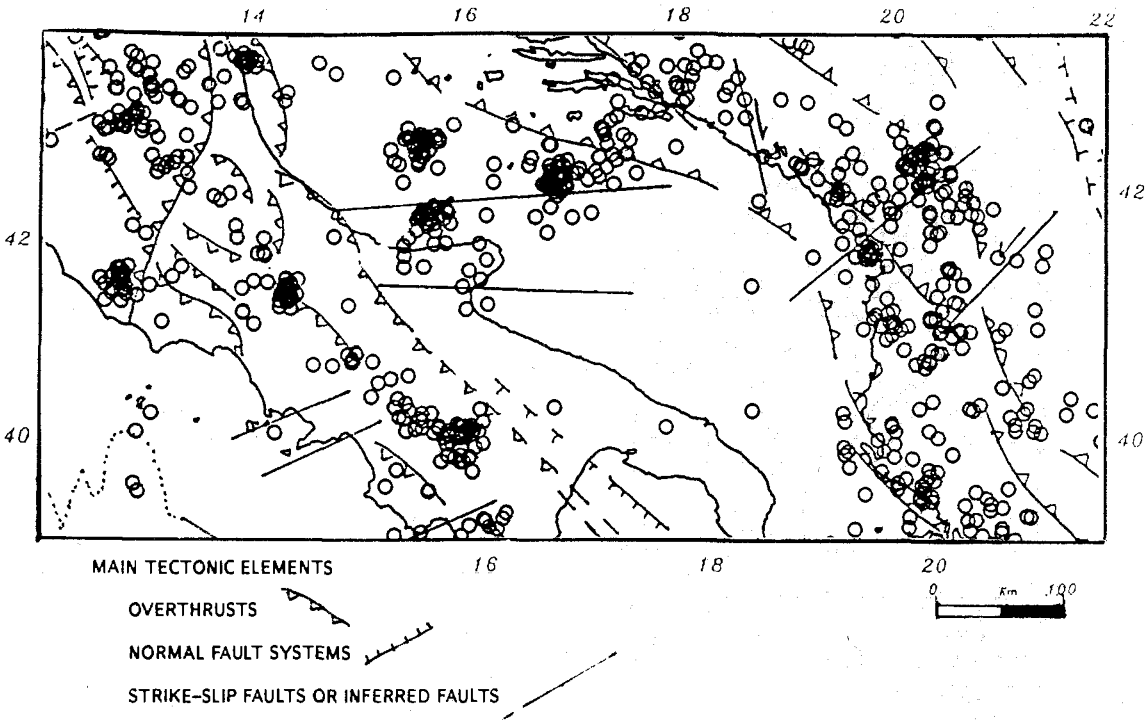


*Fig. 3* - Map of 1986-1990 seismic activity and main tectonic features (detail of the Gargano area).

eastern margin from the Southern Adriatic area towards the Greek coasts (FINETTI & MORELLI, 1973; FINETTI, 1982) indicates that the interaction between the two regions produced an underthrust of the first one with respect to the second one; the main compressional direction is WNW-ESE or NW-SE and this trend is confirmed by the focal mechanisms.

A similar model is hypothesized for the Apennine chain, based on the pattern of the gravity anomalies and on the deflection of the bottom of the Pliocene series. This model involves four different arcs for the Apennines and a lithosphere sinking beneath them (MALINVERNO & RYAN, 1986; ROYDEN *et alii*, 1987; ROYDEN, 1988). MORETTI & ROYDEN (1988) have recently hypothesized a double subduction of the Adriatic continental lithosphere under both margins (Apennines and Dinarides) based on gravity anomalies and tectonic features. BALLY *et alii* (1986) and MOSTARDINI & MERLINI (1986) published results in agreement with such model.

Even if the main tectonic Adriatic trend is NW-SE and NNW-SSE, there are several important tectonic elements crosswise, some of them very large and still active such as the *Mattinata* and *Tremiti* mega-faults, both strike-slip, and located in the Adriatic area in front of the Gargano headland (FINETTI, 1982; FINETTI *et alii*, 1987). Fig. 3 shows the details of the 1986-1990 seismic activity and the main structural elements concerning the geographic strip within the Garganic latitudes. In the last few years the *ING* has improved the Italian seismic network recording since 1986 high quality digital data. Thanks to this improvement we were able to record many reliable data referred to the seismic sequences which occurred within the Adriatic block, close by the Gargano-Molisan coast. The maximum magnitudes of the Adriatic area (January 11,

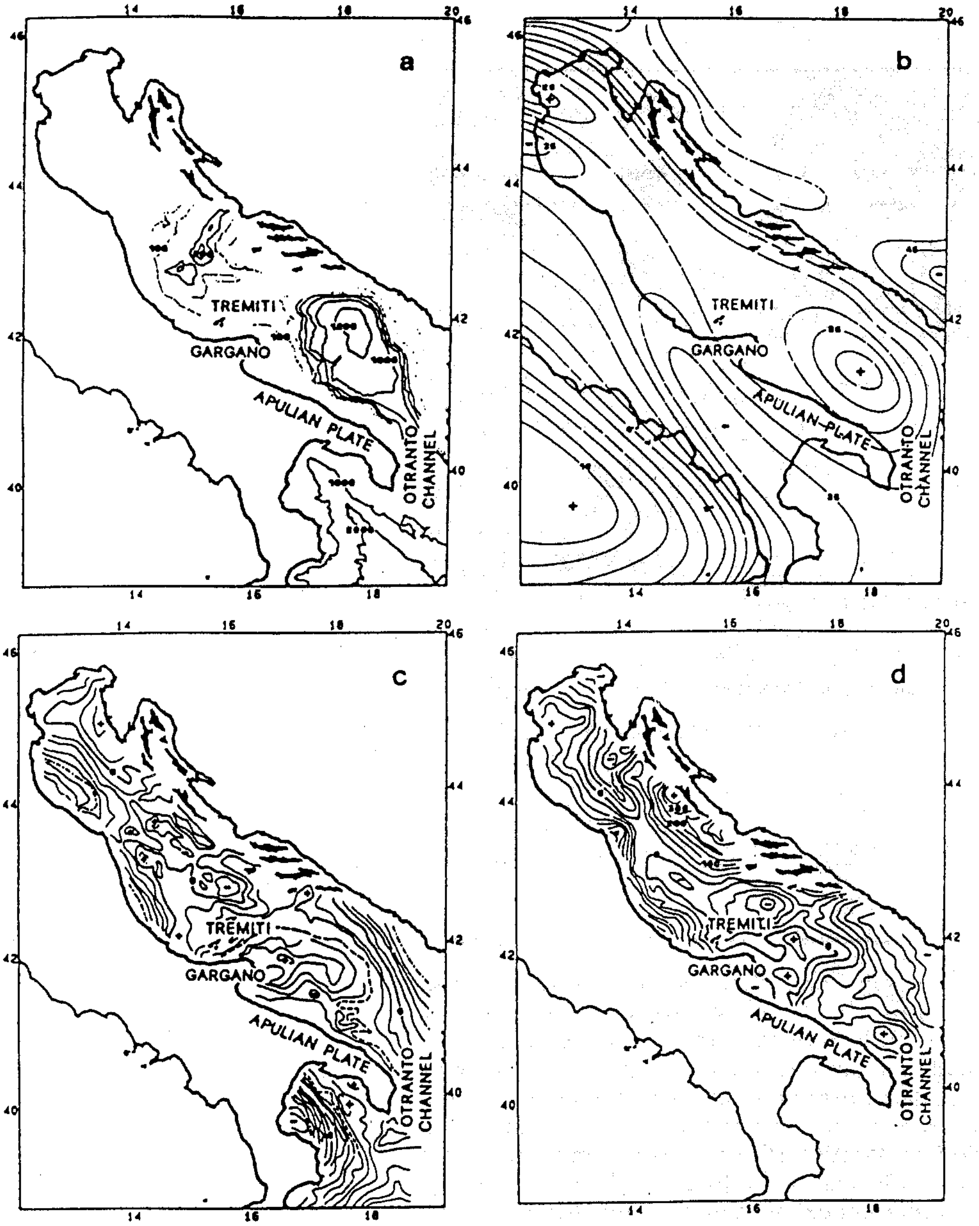


*Fig. 4* - Schematic geophysical maps: *a)* bathimetry of the Adriatic and Ionian seas, the values of isobaths are expressed in metres (after GIORGETTI & MOSETTI, 1969); *b)* Moho depth, equidistance 2.5 *km* (after SKOKO *et alii*, 1987); *c)* Bouguer anomalies equidistance 10 *mGal*, the hatched line represents the +50 *mGal* anomaly, the hatched and dotted line represents the –50 *mGal* anomaly (after FINETTI & MORELLI, 1973); *d)* magnetic field anomalies, equidistance 20 *nT* except near the maximum of 300 *nT* for graphical reasons (after MORELLI *et alii*, 1969).

1986 - $m_b$ = 4.2; April 26, 1988 - $m_b$ = 5.3; October 17, 1989 $m_b$ = 4.7) are comparable with that one of events occurred in seismic surrounding areas (e.g. Central Apennines), thus actually questioning the hypothesis of relative absence of seismic activity within the Adriatic block (LORT, 1971; ANDERSON & JACKSON, 1987).

A joint relocation of the 1986-1988 seismic sequences and the focal mechanism of the two above mentioned major shocks indicate strike-slip movements and a trend of seismic activity in east-west direction possibly related to the previous described fault systems (CONSOLE *et alii*, 1989a; 1989b). This seismic activity at the Gargano-Molisan coast level has an important geodynamical meaning and could prove the existence of an active margin dividing the Adriatic microplate in at least two minor blocks.

### OTHER GEOPHYSICAL DATA

Other geophysical data suggest the difference of the structural framework between the northern and the southern part of the Adriatic area, individuating a transitional zone in the same area within the Gargano latitudes. Figs. 4*a-d* show respectively: (*a*) the bathimetry of the Adriatic and Ionian seas; (*b*) the Moho depth; (*c*) the Bouguer anomalies; (*d*) the magnetic field anomalies. The evidence of the transitional zone between the northern and southern part of the Adriatic microplate and superimposed on an active deformational belt is confirmed by the magnetic basement pattern derived by the AGIP aeromagnetic survey (CASSANO *et alii*, 1986) (fig. 5).

Recent palaeomagnetic studies referring to different sites of the peri-Adriatic region have also pointed out the impossibility to explain the present tectonic pattern with a counterclockwise rotation of a unique relatively undeformed block, as previously hypothesized in the literature (SOFFEL, 1972; 1974; 1975; CHANNELL & TARLING, 1975; LOWRIE & ALVAREZ, 1975; VANDENBERG, 1979; 1983; LOWRIE, 1986). Palaeomagnetic data in Palaeogenic samples of North-Western Greece show a clockwise rotation, coherent with those found in Southern Apulia and in the Garganic promontory (LAJ *et alii*, 1982; HORNER & FREEMAN, 1983; KISSEL *et alii*, 1985; 1986; JONGSMA, 1987; KISSEL & LAJ, 1988; TOZZI *et alii*, 1988a; 1988b; 1989).

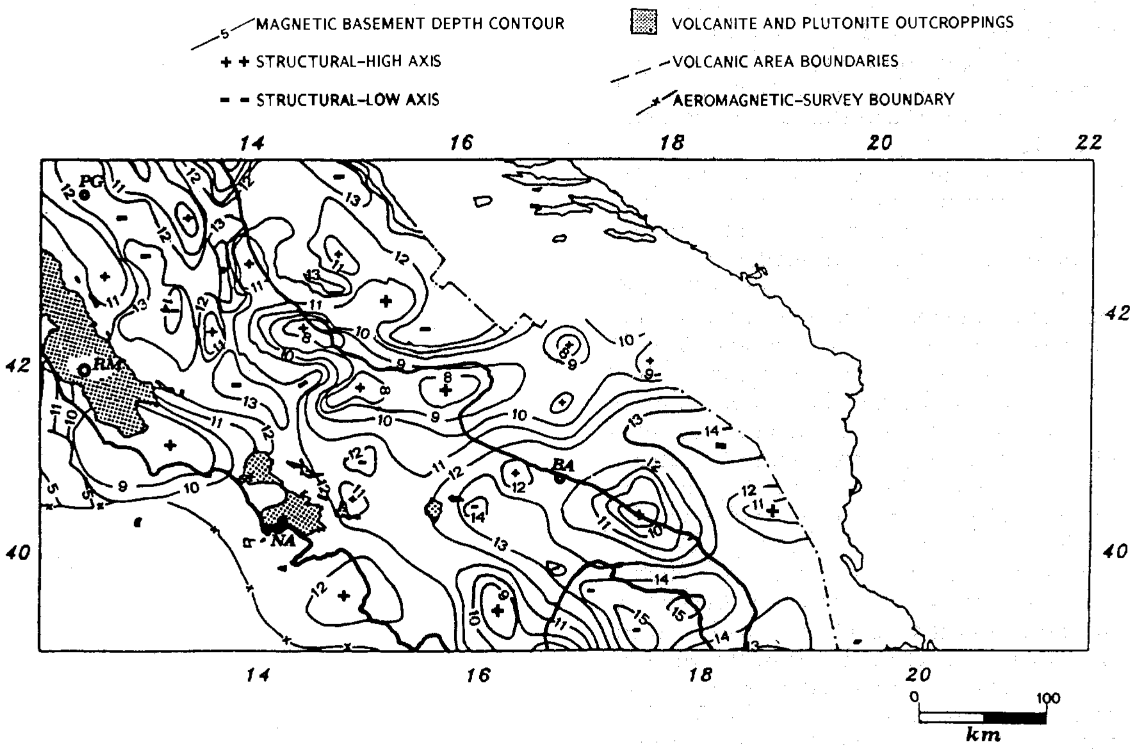


*Fig. 5* - Schematic contour map of the depth of the magnetic basement, recovered and simplified from an aeromagnetic survey carried out by AGIP (after CASSANO *et alii*, 1986).

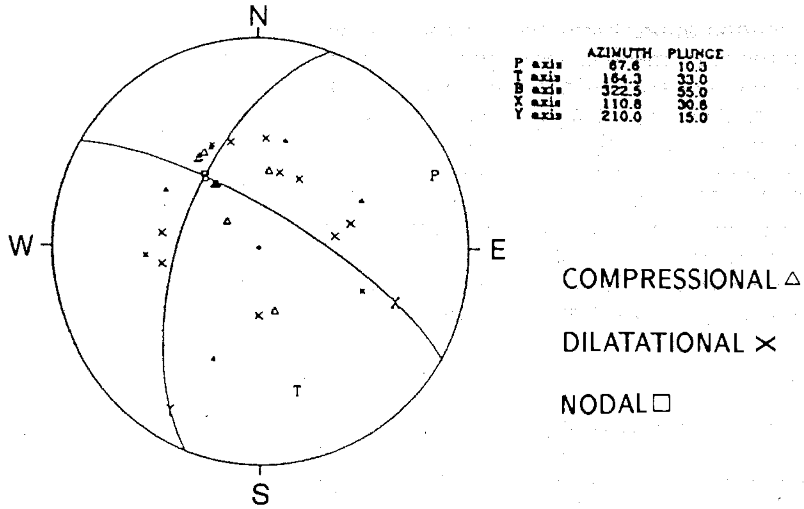


*Fig. 6* - First motion focal mechanism of October 20, 1974 earthquake ($m_b$ = 4.9) occurred in the Otranto channel, using only teleseismic data.

## CONCLUSIONS AND FUTURE PURPOSES

The Apulian (Adriatic) microplate is in consumption along all its margins, except the southern edge (Ionian sea), underthrusting the Hellenides, the Dinarides, the Southern Alps and the Apennines. Recent models hypothesize a double subduction of the Adriatic microplate under the Dinarides and the Apennines.

Geophysical data also confirm the existence of different structural blocks within the Adriatic area with a transitional zone at the latitudes of the Gargano headland.

The recent seismicity (1986-1990) emphasizes this transitional zone as an active deformational belt in which regional important strike-slip fault systems are present. The framework derived from these data contradicts the idea of an aseismic, undeformed Adriatic block with a unique geodynamical behaviour. We suppose that this deformational active belt includes also the peri-Adriatic chains.

Therefore this boundary could be the northern edge of a minor block which presents a different dynamical behaviour with opposite rotation (clockwise) with respect to the northern part of the Adriatic microplate. A hypothetical southern edge can be identified along the bathimetric escarpment in the Otranto channel and the Cephalonia tranform fault. In the Otranto channel a very interesting seismic sequence occurred in October 1974. The main shock (October 20, 1974 - $m_b$ = 4.9) presents a focal mechanism with a strike-slip component and one of the two plane strikes in NW-SE direction, similar to the elongation of the escarpment (fig. 6). D'INGEO *et alii* (1980) hypothesized the existence of a margin between the Adriatic microplate and the African plate in the Otranto channel.

On the basis of our study we wish to point out the importance of clarifying with further investigations the role of the great discontinuities, their time evolution and the structural link between peri-Adriatic and intra-Adriatic margins.

*Manoscritto consegnato il 10 settembre 1990.*
*Testo accettato per la stampa il 15 febbraio 1991.*
*Ultime bozze restituite il 5 luglio 1991.*

## REFERENCES

AA.VV. (1981) - *Tectonic map of Italy, 1:1,500,000.* CNR Italian Geodynamical Project, **269**, G.E.O., Roma.

AGIP Spa (1981) - *Italy, Residual Magnetic Field Synthesis Map, 1:2,000,000.* Reprinted in: Boll. Geofis. Teor. Appl., **26**, 101-102, 1984.

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

BALLY A.W., BURBI L., COOPER C. & GHELARDONI R. (1986) - *Balanced sections and seismic reflection profiles across the Central Apennines.* Mem. Soc. Geol. It., **35**, 257-310.

CASSANO E., FICHERA R. & ARISI ROTA F. (1986) - *Rilievo aeromagnetico d'Italia. Alcuni risultati interpretativi*. Proceedings 5° Meeting Gruppo Naz. Geofis. Terra Solida - CNR, Roma, 939-958.

CHANNELL J.E.T. & TARLING D.H. (1975) - *Palaeomagnetism and the rotation of Italy*. Earth. Planet. Sci. Lett., **25**, 177-188.

CONSOLE R., DI GIOVAMBATTISTA R., FAVALI P. & SMRIGLIO G. (1989a) - *Lower Adriatic sea seismic sequence (January 1986): spatial definition of the seismogenic structure*. Tectonophysics, **166**, 235-246.

CONSOLE R., DI GIOVAMBATTISTA R., FAVALI P., PRESGRAVE B. & SMRIGLIO G. (1989b) - *Seismicity of the Adriatic microplate*. XXV General Assembly IASPEI, Istanbul.

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 Geological Society of Italy, 1-13.

D'ARGENIO B., PESCATORE T. & SCANDONE P. (1975) - *Structural pattern of the Campania-Lucania Apennines*. In: Ogniben L., Parotto M. & Praturlon A. (Editors). Structural model of Italy, Maps and explanatory notes, CNR - Quad. Ric. Scien., **90**, 313-327.

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.

DZIEWONSKI A.M., CHOU T.A. & WOODHOUSE J.H. (1981) - *Determination of earthquakes source parameters from waveform data for studies of global and regional seismicity*. J. Geophys. Res., **86**, 1825-1852.

ERICKSON A.J., SIMMONS G. & RYAN W.B.F. (1977) - *Review of heat flow data from the Mediterranean and Aegean seas*. In: BIJU-DUVAL B. & MONTADERT L. (Editors). The structural history of the Mediterranean basins, Technip, Paris, 263-280.

FAVALI P. & MELE G. (1989) - *Dinamica e margini attivi della microplacca apula: un'ipotesi di lavoro*. Proceedings 8° Meeting Gruppo Naz. Geofis. Terra Solida - CNR, Roma (in press).

FINETTI I. (1982) - *Structure, stratigraphy and evolution of Central Mediterranean*. Boll. Geofis. Teor. Appl., **24**, 247-312.

FINETTI I., BRICCHI G., DEL BEN A., PIPAN M. & XUAN Z. (1987) - *Geophysical study of the Adria plate*. Mem. Soc. Geol. It., **40**, 335-344.

FINETTI I. & DEL BEN A. (1986) - *Geophysical study of the Tyrrhenian opening*. Boll. Geofis. Teor. Appl., **38**, 75-155.

FINETTI I. & MORELLI C. (1973) - *Geophysical exploration of the Mediterranean sea*. Boll. Geofis. Teor. Appl., **15**, 263-341.

GIARDINI D., DZIEWONSKI A.M., WOODHOUSE J.H. & BOSCHI E. (1984) - *Sistematic analysis of the seismicity of the Mediterranean region using the centroid moment tensor method*. Boll. Geofis. Teor. Appl., **26**, 103-121.

GIORGETTI F. & MOSETTI F. (1969) - *General morphology of the Adriatic sea*. Boll. Geofis. Teor. Appl., **11**, 49-56.

HORNER F. & FREEMAN R. (1983) - *Palaeomagnetic evidence from pelagic limestones for clockwise rotation of the Ionian zone Western Greece*. Tectonophysics, **98**, 11-27.

KISSEL C., LAJ C. & MÜLLER C. (1985) - *Tertiary geodinamical evolution of Northwestern Greece: palaeomagnetic results*. Earth Planet. Sci. Lett., **72**, 190-204.

KISSEL C., LAJ C., POISSON A., SAVASCIU Y., SIMEAKIS K. & MERCIER J.L. (1986) - *Palaeomagnetic evidence for Neogene rotational deformations in the Aegean domain*. Tectonics, **5**, 783-795.

KISSEL C. & LAJ C. (1988) - *The Tertiary geodinamical evolution of the Aegean arc: a palaeomagnetic reconstruction*. Tectonophysics, **146**, 183-201.

ISTITUTO NAZIONALE DI GEOFISICA (ING) (1989) - *Italian seismic catalogue from 1450 b.C. to 1988 a.C.* (Internal files), Roma.

ISTITUTO NAZIONALE DI GEOFISICA (ING) (1990) - *Seismic bulletin (1989-1990, June)*, Roma.

JONGSMA D. (1987) - *The geometry and rates of microplate motions in the Eastern Mediterranean sea - quantitative constrains by using anoxic basins as piercing points*. Marine Geology, **75**, 1-29.

LAJ C., JAMET M., SOREL D. & VALENTE J.P. (1982) - *First palaeomagnetic results from the Mio-Pliocene series of the Hellenic sedimentary arc*. Tectonophysics, **86**, 45-68.

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

LOWRIE W. (1986) - *Palaeomagnetism and the Adriatic promontory: a reappraisal*. Tectonics, **5**, 797-807.

LOWRIE W. & ALVAREZ W. (1975) - *Palaeomagnetic evidence for rotation of the Italian peninsula*. J. Geophys. Res., **80**, 1579-1592.

MALINVERNO A. & RYAN W.B.F. (1986) - *Extension of the Tyrrhenian Sea and shortening in the Apennines as result of arc migration driven by sinking lithosphere*. Tectonics, **5**, 227-245.

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

MORELLI C., CARROZZO M.T., CECCHERINI P., FINETTI I., GANTAR C., PISANI M. & SCHMIDT DI FRIEDBERG P. (1969) - *Regional geophysical study of the Adriatic sea*. Boll. Geofis. Teor. Appl., **11**, 3-48.

MORETTI I. & ROYDEN L. (1988) - *Deflection, gravity anomalies and tectonics of doubly subducted continental lithosphere: Adriatic and Ionian sea*. 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.

PAROTTO M. & PRATURLON A. (1981) - *Structural sketch of the Middle-Eastern Mediterranean area*. CNR Italian Geodynamical Project, **269**, G.E.O., Roma.

PHILIP H. (1987) - *Plio-Quaternary evolution of the stress field in Mediterranean zones of subduction and collision*. Annales Geophysicae, **5B**, 301-319.

REUTHER C.D. (1987) - *Extensional tectonics within the Central Mediterranean segment of the Afro-European zone of convergence*. Mem. Soc. Geol. It., **38**, 69-80.

ROYDEN L. (1988) - *Flexural behaviour of the continental lithosphere in Italy: Costraints imposed by gravity and deflection data*. J. Geophys. Res., **93**, 7747-7766.

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.

SKOKO D., PRELOGOVIČ E. & ALJINOVIČ B. (1987) - *Geological structure of the Earth's crust above the Moho discontinuity in Yugoslavia*. Geophys. J.R. Astr. Soc., **89**, 379-382.

SOFFEL H. (1972) - *Anticlockwise rotation of Italy between Eocene and Miocene, palaeomagnetic evidence*. Earth. Planet. Sci. Lett., **17**, 207-220.

SOFFEL H. (1974) - *Palaeomagnetism and rock magnetism of the Colli Euganei volcanites and the rotation of Northern Italy between Eocene and Oligocene*. Boll. Geofis. Teor. Appl., **16**, 333-355.

SOFFEL H. (1975) - *The palaeomagnetism of age dated Tertiary volcanites of the Monti Lessini (Northern Italy) and its implication to the rotation of Northern Italy*. J. Geophys., **41**, 385-400.

TOZZI M., KISSEL C., FUNICIELLO R., LAJ C. & PAROTTO M. (1988a) - *A clockwise rotation of Southern Apulia?* Geophys. Res. Lett., **15**, 681-684.

TOZZI M., KISSEL C., FUNICIELLO R., LAJ C. & PAROTTO M. (1988b) - *Nuovi dati paleomagnetici nella Puglia meridionale*. Proceedings 74° Congress of Geological Society of Italy, vol. **B**, 419-423.

TOZZI M., FUNICIELLO R. & PAROTTO M. (1989) - *Paleomagnetismo ed evoluzione geodinamica del settore settentrionale dell'Avampaese Apulo*. Proceedings 8° Meeting Gruppo Naz. Geofis. Terra Solida - CNR, Roma (in press).

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

VANDENBERG J. (1979) - *Reconstruction of the Western Mediterranean area for the Mesozoic and Tertiary timespan*. Geol. Mijnbouw, **58**, 153-160.

VANDENBERG J. (1983) - *Reappraisal of palaeomagnetic data from Gargano (South Italy)*. In: McClelland Brown E. & Vandenberg J. (Editors). Palaeomagnetism of orogenic belts. Tectonophysics, **98**, 29-41.