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SHALLOW EARTHQUAKE FEATURES IN THE SOUTHERN TYRRHENIAN REGION: GEOSTRUCTURAL AND TECTONIC IMPLICATIONS

Abstract. The locations and mechanisms of the Aeolian Islands seismicity during a period of background activity (March 1988 - March 1990) were analysed using data from the local seismic networks operating on these islands and in northeastern Sicily and Calabria. The results are discussed in a more general framework which also includes the information available on the most intensely active phases of recent decades (1978 and 1980). Both in the low- and high-activity periods, seismicity affected mostly the southern and western sectors of the area investigated, where NW-SE lithospheric fault systems define the southern margin of the Tyrrhenian basin and allow SE lateral dislocation of the southern Tyrrhenian crustal structures with respect to the Sicilian ones. The notable lack of shallow seismicity observed in the northern and eastern sectors is interpreted as due to a lesser stress accumulation in the inner part of the SE migrating crustal mass and at some distance from its highly stretched margins. Even if a rigorous identification of the faults which have generated the earthquakes is often difficult because of the location uncertainties both of fault systems and hypocenters, it can be said that a relevant percentage of the Aeolian Islands seismic events occur in correspondence to the main faults (Sisifo and Vulcano), in the depth range 0-25 km and, especially, 8-16 km. In particular, the two strongest events of recent decades (Gulf of Patti, April 1978, M=5.5 and Alicudi, May 1980, M=5.8) were located near the bottom of the active layer, approximately at the level of the crust-mantle transition. However, while the fault-plane solutions of these two events are coherent with the presumed dynamics of the Tyrrhenian crust, the P-polarity distributions of the smaller and shallower earthquakes occurring in the same fault systems from periods of background activity show some mechanism heterogeneity. This is explained in terms of stress regime complexity and structural heterogeneity at shallow depth for these faults, which is also coherent with the fairly high values of some of the earthquake statistical parameters such as the temporal clustering of shocks and the slope of the frequency-magnitude relationship.

The above data led us to interpret the background activity as being closely related to the tectonic process generating the strongest shocks (the southern Tyrrhenian crust SE migration). Furthermore, bearing in mind a model of seismic energy accumulation-release recently proposed for this area, and considering both the present low seismic rate and the depth distribution of the different magnitude earthquakes, we hypothesize that energy could be presently accumulating in the Aeolian region, possibly at the level of the crust-mantle transition, while a comparatively low release is occurring in the shallower and more fractured structures under a quite complex stress regime due to the high rock fracture and stretch.

INTRODUCTION

In this work, some seismological features of a tectonically important sector (see S in Fig. 1) of the Tyrrhenian region are investigated. In general, sector S corresponds to the Aeolian Islands volcanic archipelago. Seismic activity there is permanently monitored by a short-period network (the Aeolian Islands seismometric network: AISN, Fig. 1) of the Istituto Internazionale di Vulcanologia of Catania, with the principal purpose of reducing the risk associated with local volcanic activity (Vulcano and Stromboli). The same area is also a good observation point for investigations of regional geodynamic processes, being crossed by important fault systems which

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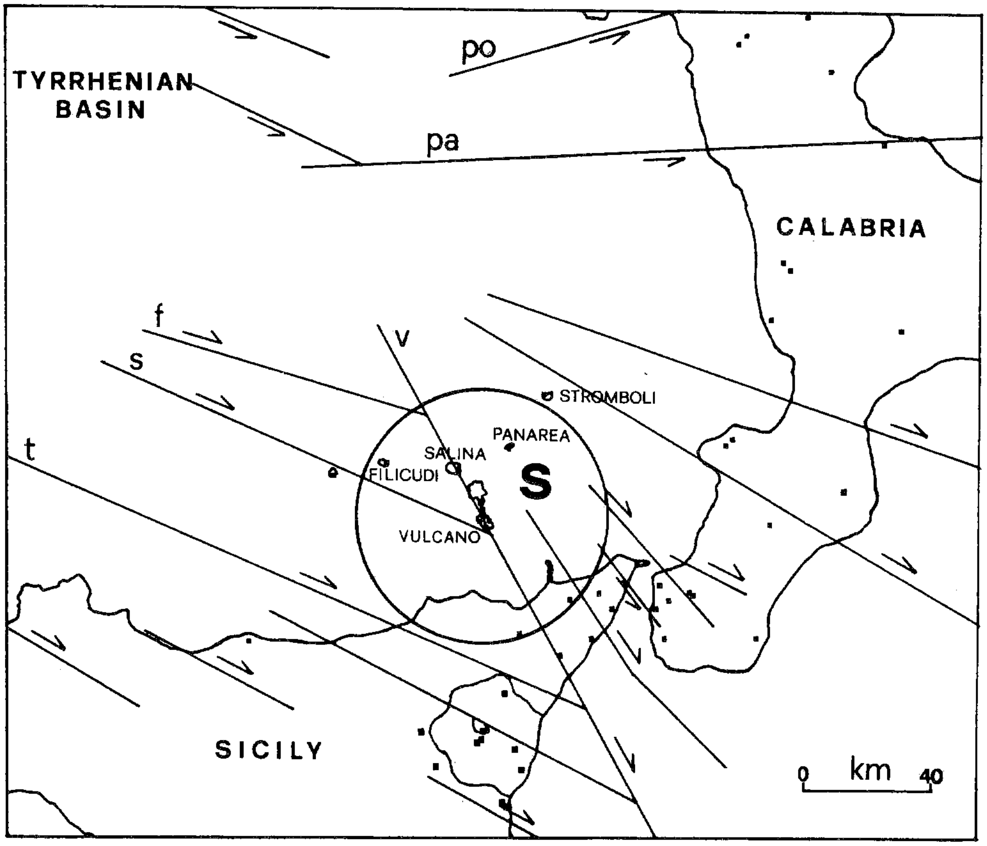

Fig. 1 - Map of the southern Tyrrhenian region with locations of the seismic stations used in the present work, and the main fault systems (t=Taormina, s=Sisifo, f=Filicudi, v=Vulcano, pa=Palinuro, po=Policastro, according to the nomenclature given by Finetti and Del Ben, 1986). S indicates the sector investigated. The AISN includes all stations located on the islands and the one on the southern border of sector S in northern Sicily.

define the southern margin of the Tyrrhenian basin (Fig. 1).

In this research, the space distribution and P-wave polarities of shallow depth (<40 km) and low magnitude (⩽4.2) earthquakes in sector S from March 1988 to March 1990 were analysed and discussed in the light of the available information on fault locations and mechanisms. Data relative to other time intervals in the last two decades were also used for a more general view of the processes. Finally, some tectonic implications of the findings are evaluated.

In the past, the extent of the network geometry problems was too great to allow such an approach to micro-earthquake activity. The increased availability of stations in recent years (Fig. 1) has not yet totally solved these problems, but allows us to be more otpimistic about the possibilty of an initial attempt. Moreover, recent advances in computation algorithms (e.g. hypocenter location methods) have made a remarkable contribution to this type of investigation.

TECTONIC FRAMEWORK

Crustal structure and fault systems in the Aeolian area

The crustal structure is marked by sharp variations in the southern Tyrrhenian region (Fig. 2), from the abyssal plain (oceanic crust) to the Aeolian Islands (thin continental crust) and the inner lands of Calabria and Sicily (continental crust). In the area investigated (Fig. 1), the

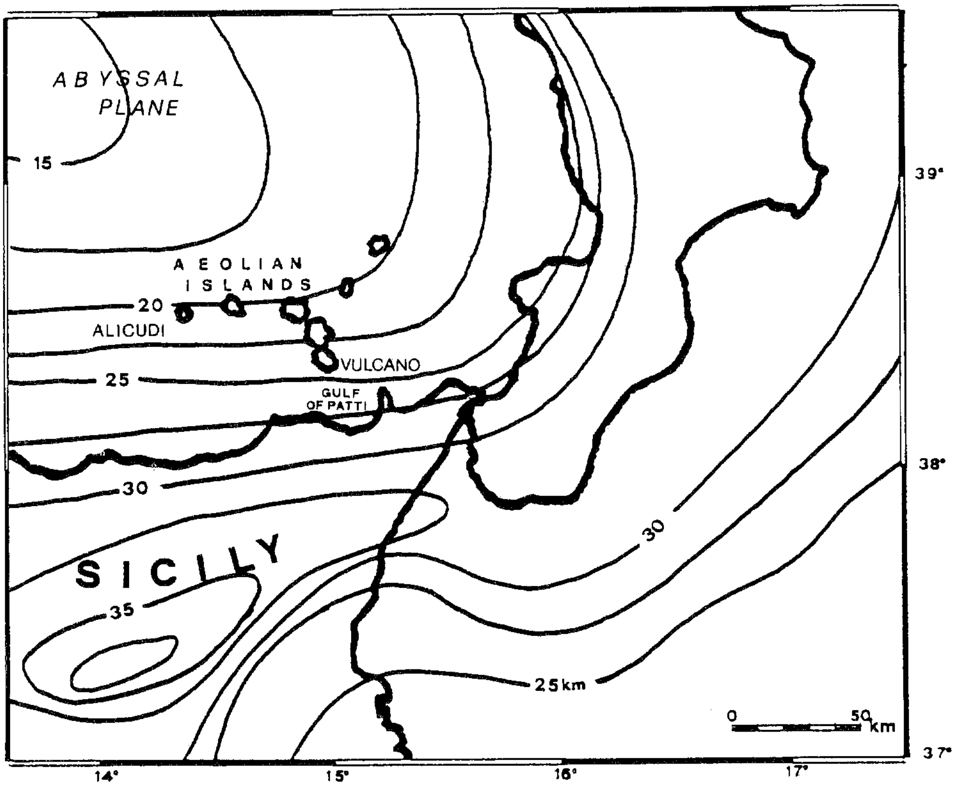

Fig. 2 - Moho depth contours in the southern Tyrrhenian and Calabro - Peloritan Arc region (from Bottari et al., 1986a).

Moho depth ranges from 18-20 km (along the belt joining the islands of Filicudi, Salina and Panarea) to about 30-35 km (northeastern Sicily).

The geostructural framework, defined mainly on the basis of observations both geological (see e.g. Frazzetta et al., 1982) and geophysical (Finetti and Del Ben, 1986), is dominated by approximately NW-SE dextral transcurrent faults of regional character (Taormina, Sisifo, Filicudi and Vulcano, Fig. 1). The situation becomes far more complex in the surroundings and, in particular, in Sicily and the Calabrian Arc. In western Sicily, further NW-SE transcurrent systems (like the Pantelleria and Egadi faults) cut the NW thrusting Maghrebian chain (Fig. 3c, Finetti and Del Ben, 1986). Rotation and torsional components are produced there by the interaction between the two different mechanisms. The Calabrian Arc shows notable mechanism heterogeneity, but, normal faults play a major role, being the most important source of seismic risk for the whole region (Ghisetti and Vezzani, 1982; Bottari et al., 1986a). Northern Calabria is characterized by sinistral transcurrent faults like those of Palinuro and Policastro (Figs. 1 and 3c).

Tectonic models

The literature on the Tyrrhenian region geodynamic evolution and present tectonics shows that the debate is far from being concluded.

According to Barberi et al. (1973), a subduction process is probably active beneath the Southern Tyrrhenian Sea, with a trench zone close to the Ionian coast of Calabria and a WNW slab immersion (Fig. 3a). Among other things, this would explain the location of the intermediate and deep seismicity, the arc structure and the type of volcanism of the Aeolian Islands archipelago. The Etna and Ustica extensional volcanism defines the southern limit of the compressive tectonics sector, while the Tyrrhenian abyssal plain is interpreted as a marginal basin.

Scandone (1979), and Scandone and Patacca (1984) interpret the Tyrrhenian area as a

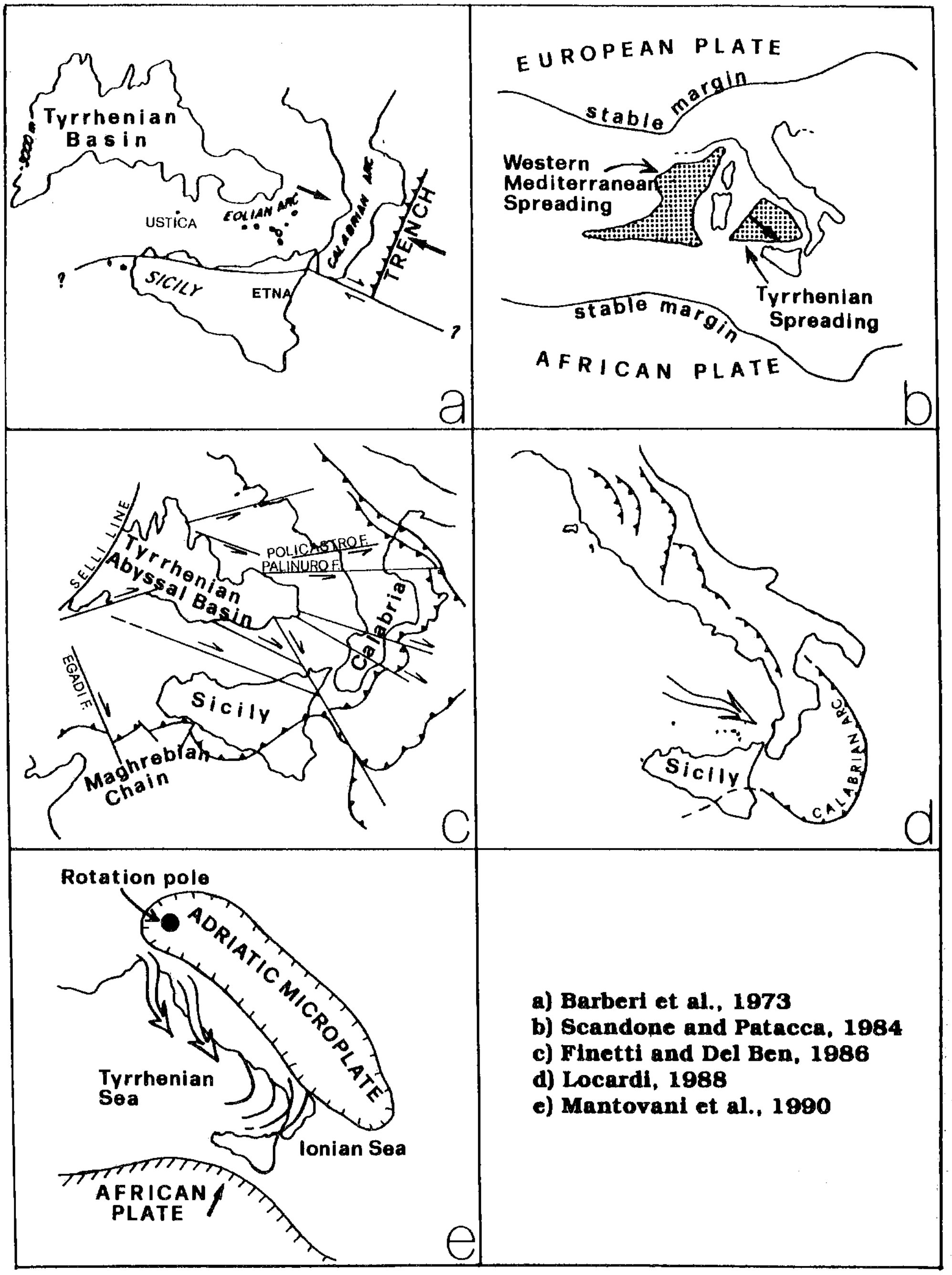

Fig. 3 - Schematic representation of tectonic models proposed in the literature for the southern Tyrrhenian region.

fragment inside a large and partially ductile belt separating the stable margins (South-Atlasic lineament and Pyrenees-Alps chains) of the African and European plates (Fig. 3b). This belt, deriving from the deformation and consumption of the original plate margins, includes many heterogeneous blocks and structures, such as the Iberian and Sardo-Corso microplates, the western Mediterranean and Tyrrhenian basins, the Calabrian Arc, etc. According to these authors, the small ocean-type western Mediterranean and Tyrrhenian basins were generated during subsequent times (Early Miocene and Middle-Upper Miocene, respectively) in this region of severe lithospheric stretching. Spreading mechanisms are probably still acting in the Southern Tyrrhenian region. Subduction processes were active before the above described rifting phases, and subsequently the slab would have been strongly distorted and partially readsorbed. A passive subduction of the residual slab is hypothesized at the present.

An opening in the Tyrrhenian Sea is also central to the model of Finetti and Del Ben (1986). The beginning of this phase is considered to correspond to the Selli line (Fig. 3c) on the basis of (1) magnetic anomalies, (2) seismic data indicating a basement uplift along the same line, and (3) the time coincidence of the Selli line activity, strike-slip movements along the Taormina line, and the Maghrebian chain truncation. The most intense geodynamic activity took place from the end of the Miocene to the end of the Lower Pliocene. At the same time, the southern Apennines rotate anticlockwise with respect to the northern Apennines, sinistral strike-slip faults (e.g., the Palinuro) were very active on the northern side of the Calabrian Arc apex, and dextral strike-slip faults (e.g., the Taormina) were active on the southern side; the Calabrian block moved consistently ESE. During the Middle-Upper Pliocene, arc migration and the consequent back-arc area opening continued at a lower rate than in the Lower Pliocene but still remarkably quickly. The deformation velocity of the accretion front indicates lesser activity in the Late Pleistocene.

Locardi (1988) interprets the main structural features of the Tyrrhenian region and confining sectors as due to diapirism processes. In particular, he claims that the evolution of some mantle domes in the Tyrrhenian region produced stress fields sufficient to generate, in the Apenninic chain (Fig. 3d), various arc structures disconnected by lithospheric transform faults transversally cutting the chain. The strongly arcuated structure of the Calabrian Arc may have been produced by the dynamics of a mantle dome in the southern Tyrrhenian area and by a greater mechanical resistance to arc migration of the Apulian and Iblean borders with respect to the Ionian region.

A quite different model has been proposed by Mantovani et al. (1982, 1985, 1987, 1990). According to them, a key role is played by the kinematics of the Adriatic microplate which is rotating anticlockwise with respect to the European plate, around a pole located in the Alpine region (Fig. 3e). The African plate produces a NE compression, pushing the Adriatic block through a "continental bridge" represented by the Calabrian Arc. The Adriatic block rotation around the Alpine region is the basis of the stretching in the Tyrrhenian Sea. The asymmetry in the opening of the Tyrrhenian basin, the stable position of the Sardo-Corso block, and the extensional processes in the Ionian Sea are thus convincingly explained.

SEISMOLOGICAL FEATURES

Intermediate and deep seismicity

Papers on intermediate and deep seismicity in the southern Tyrrhenian region have been published in recent decades (Peterschmitt, 1956; Ritsema, 1972; Bottari and Federico, 1979; Gasparini et al., 1982; Anderson and Jackson, 1987; etc.). A substantial agreement emerges as to the existence of a Benioff zone, WNW dipping and reaching a depth of about 500 km. The Benioff plane should intersect the earth's surface near the Ionian coast of Calabria. The dip angle depends on depth (about 70° above 250 km and 45°-50° below; Gasparini et al, 1982; Anderson and Jackson, 1987). The earthquake fault-plane solutions show strike-slip movements on the lateral borders of the Benioff zone and down-dip compressions in the inner part.

Shallow seismicity

As opposed to the confining Calabro-Peloritan Arc region characterized by crustal earthquakes of magnitudes up to 7-7.5, in the southern Tyrrhenian area the shallow seismicity does not reach magnitude values above 6. The cumulative seismic energy release over the last 100 years displays (Neri, 1985) medium-term regularity, thus probably indicating the constancy of the tectonic agents producing the stress accumulation; low-activity time intervals may be considered as periods of large stress accumulation.

Since the installation of the local networks in this area (early 70's), only two earthquakes have exceeded magnitude 5 (15 April 1978, Gulf of Patti, M=5.5 and 28 May 1980, Alicudi, M=5.8; both epicenters and aftershock areas are reported in Fig. 5). An interesting feature, which will be relevant to the final discussion, is that the first of these events was preceded (Falsaperla et al., 1989) by notable ground deformation (areal dilatation) in the Lipari-Vulcano area, where systematic geodetic measurements are taken for volcanological investigations. The deformation phase began about two years before the event, showed a sign inversion several months after it, and concluded without a complete recovery. The location and mechanism features of the two respective sequences (Bottari and Neri, 1980; Gasparini et al., 1980; Del Pezzo et al., 1982; Del Pezzo et al.; 1984; Neri, 1985; Bottari et al., 1986a) led Bottari et al. (1986b) to hypothesize a relationship with the Vulcano and Sisifo fault systems (Figs. 1 and 5).

Finally, also the lower magnitude earthquake activity generally affects the sectors of the 1978 and 1980 events, to the south and west of Vulcano island (Neri et al., 1989).

DATA AND METHODS OF ANALYSIS

Data

Forty-seven seismic stations belonging to the short-period local networks operating in northeastern Sicily and Calabria (Fig. 1) have provided data suitable for this investigation. P- and S- wave arrival-times were used for hypocenter locations, P polarities for mechanism studies, and earthquake durations for magnitude estimates. Data are of varying resolution, depending on the recording and playback systems used (1 mm/s to 1 m/s paper recordings), and on the availability of horizontal seismometers for a better S-wave identification.

Starting from the AISN catalogues, earthquakes occurring in a radius of 40 km around Vulcano island with focal depth <40 km were the subject of this investigation. Considering both the quite low activity level in the area over the last 10 years and the improved network geometry in the last 2-3 years, only the earthquakes of the March 1988 - March 1990 time interval (MAR88-MAR90 hereafter) were submitted to both analytical hypocenter locations and polarity distribution studies. Events showing at least 8 well-readable P-wave first arrivals were used. A further selection was done on the basis of the recording station areal distribution.

Methods

Earthquake location has never been a simple operation in the area investigated here (see e.g. Del Pezzo and Martini, 1982; Del Pezzo et al., 1984; Bottari et al., 1986a). The presence of sea (together with the lack of ocean bottom seismometers), and strong lateral heterogeneities affecting both the crustal and upper mantle structures, are the main factors which make hypocenter parameter computation difficult. Limiting the set of stations used to those closest to the epicenter may help to reduce the effects of structural heterogeneities, but it introduces large uncertainties into the calculations due to the small number of data available and inadequate network geometry. On the other hand, using more distant stations can produce biases due to the generally lower compatibility between observed and 1-D computed travel-times when more complex and heterogeneous structures are involved in the wave propagation. In the present investigation, a special effort has been made to find a reasonable compromise among these two factors for each event.

The earth model was chosen from those (Fig. 4) reported in the literature and adopted for locating earthquakes in the southern Tyrrhenian Sea and Calabro-Peloritan Arc regions. Tests and comparisons were done on data from more than 100 local earthquakes and 2 DSS surveys carried out in the southern Tyrrhenian sea in 1984 and 1986. Following a criterion often adopted in the literature (see e.g. Nelson and Vidale, 1990), comparisons among the models (with related station corrections) were done by using the mean RMS estimated over the whole set of events (model residual) as test parameter. In spite of its rather general nature, the Jeffreys and Bullen model (Fig. 4b) showed the minimum model residual. It is likely that the simpler analytical structure of this model with respect to others helped to reduce failures in the iterative procedure.

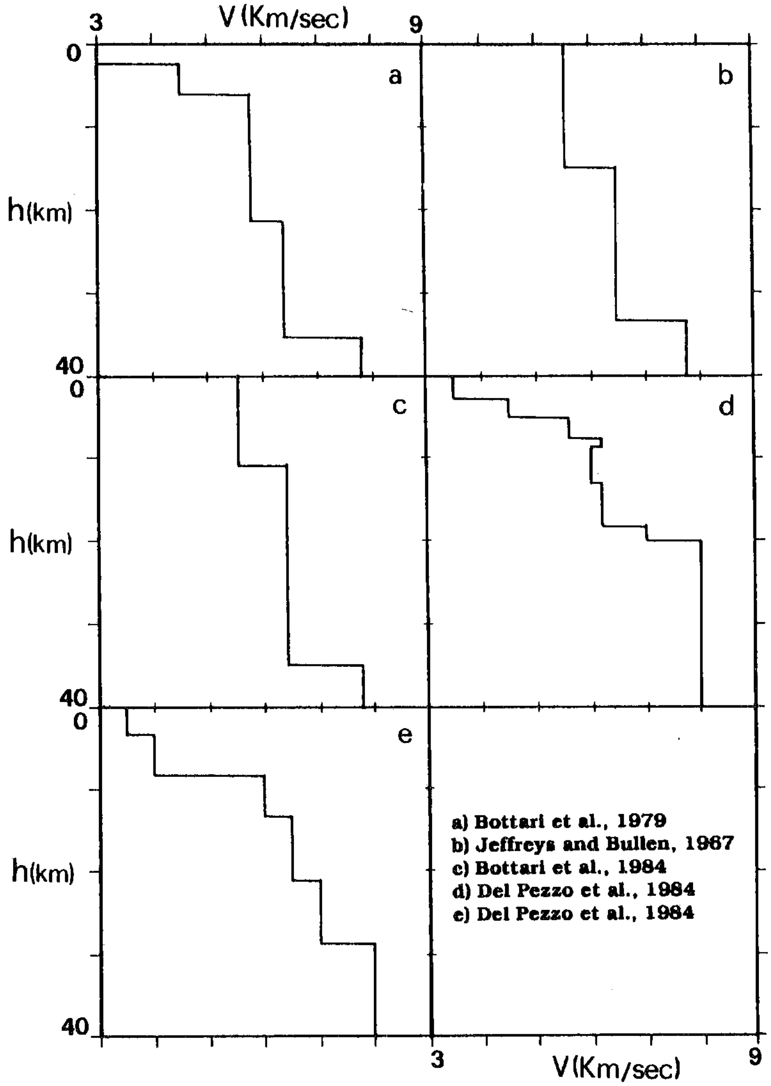

Fig. 4 - P-wave velocity models used in the tests preceding the hypocenter location of the MAR88-MAR90 earthquakes.

Two different location algorithms were applied (EVM, Caccamo and Neri, 1984; HYPOPC, IASPEI Software Library) in order to minimize the effects of near-critical computation conditions. The two methods use formally similar equation systems which, however, differ in the coefficient analytical structure (Caccamo and Neri, 1984, 1985). This difference is the main reason for the different behaviour of the algorithms, observed particularly when location conditions are far from optimal. For each earthquake, the hypocenter solution corresponding to the smaller RMS value was chosen. Finally, magnitudes were estimated by using the empirical magnitude-duration relationships valid for the AISN stations (Di Prima et al., 1985).

RESULTS AND DISCUSSION

Hypocentral parameters for the MAR88-MAR90 earthquakes selected according to the criteria described in the previous section are reported in the Table. For the same events, Figs.

Table - Hypocentral parameters of the MAR88-MAR90 earthquakes.
Mag = magnitude, NP = number of P-wave arrival times used for the location, NO = total number of P and S arrival times, Meth = method leading to the hypocenter with the smallest RMS (E=EVM, Caccamo and Neri, 1984; H=HYPOPC, IASPEI).

N°	Date	h/m	Mag	NP	NO	Lat.	Lon.	Depth	O.T.	RMS	ERH	ERZ	Meth
01	88.03.30	11:19	4.0	14	16	38.43	14.78	18.8	27.7	.54	4.0	2.8	H
02	88.04.06	01:25	3.5	14	19	38.61	14.75	01.7	16.7	.62	6.8	3.4	H
03	88.04.11	01:50	2.9	10	12	38.05	15.01	15.2	57.0	.30	4.2	5.2	E
04	88.04.17	06:05	3.0	13	15	38.31	14.74	13.1	01.3	.50	4.3	3.9	E
05	88.04.17	15:20	3.0	11	12	38.36	14.94	11.8	36.4	.50	5.1	0 3.3	E
06	88.05.28	05:57	3.2	14	16	38.33	14.83	22.5	35.3	.39	4.5	6.2	E
07	88.05.30	10:06	3.9	18	20	38.41	14.67	11.5	36.6	.50	4.0	2.3	H
08	88.06.04	16.28	3.4	15	19	38.32	14.63	11.2	26.7	.31	3.3	3.0	E
09	88.06.06	19.16	3.1	08	11	38.40	14.69	00.9	14.1	.36	3.1	34.0	H
10	88.06.10	01:31	3.0	08	12	38.14	15.03	04.7	43.1	.61	5.5	15.0	H
11	88.10.07	16:22	2.9	09	11	38.40	14.60	13.3	22.2	.29	3.8	3.7	E
12	89.04.13	14:49	2.7	10	14	38.56	15.02	21.5	26.6	.89	8.7	9.0	E
13	89.05.02	11:48	2.8	10	12	38.48	14.73	09.0	09.1	.37	5.4	2.4	H
14	89.05.26	22:19	3.0	10	12	38.05	15.02	27.3	15.6	.21	4.0	4.5	E
15	89.06.21	16:46	2.9	10	13	38.13	14.94	13.6	20.7	.63	11.0	6.0	H
16	89.06.22	16:31	2.7	11	13	38.17	15.03	12.1	30.2	.25	1.7	2.4	E
17	89.07.18	05:08	3.1	22	28	38.51	14.81	11.3	56.0	.71	2.9	1.5	H
18	89.07.24	21:32	2.8	09	10	38.52	14.74	12.1	54.7	.38	10.0	4.5	E
19	89.09.12	01:32	3.0	13	14	38.42	14.72	11.4	57.1	.49	3.6	2.4	H
20	89.09.26	16:38	3.0	14	17	38.57	14.66	12.2	11.9	.56	5.0	1.6	H
21	89.11.05	02:26	2.9	12	13	38.48	14.09	01.1	44.2	.39	4.0	4.0	E
22	90.02.13	09:50	3.0	08	10	38.33	15.05	14.9	28.8	.23	3.5	2.1	H
23	90.02.18	00:28	3.1	15	18	38.12	15.16	18.0	47.0	.40	4.0	3.0	H
24	90.03.28	05:47	4.2	20	21	38.16	14.90	15.1	31.5	.45	3.0	4.6	E

5 and 6 show (circles) the epicentral map and two hypocenter vertical sections. Fig. 5 also displays (squares) the epicenters of shocks located with data from 7 stations. These events are not reported in Fig. 6 because the focal depth values do not appear to be, in general, adequately constrained. Furthermore, Fig. 5 shows the epicenter location of the $M > 5$ earthquakes of 1978 and 1980 (asterisks) and the aftershock areas concerned (dotted zones; basic data from Bottari et al., 1986 b). Finally, the inset indicates the strain release areal distribution around the island of Vulcano during the period July 84-June 89 (data from Neri et al., 1989).

Fig. 5 shows that the MAR88-MAR90 epicenters are mainly located to the south and west of Vulcano island, whereas seismicity is almost absent in the other sectors investigated. In spite of the hypocenter location problems typical of this area (see previous section), and considering both the set of stations used for the investigation (Fig. 1) and the special attention paid to the location methodological aspects, the space distribution of earthquake activity obtained can be considered very significant. This result confirms the general features of the earthquake space distribution already evidenced by investigations both of the most relevant sequences in the Aeolian Islands area in recent decades (Bottari et al., 1986b) and the microearthquake activity in recent years (July 1984 - June 1989, Neri et al., 1989). Focal depth values (Fig. 6) lie generally in the range 0-25 km and show a greater concentration between 8 and 16 km. For a significant percentage of earthquakes, there is an apparent correspondence between the epicenter and a specific structural system (Fig. 5). In the other cases, epicenters are very far from known faults (activity of minor faults?), or the epicenter uncertainty is not small enough to allow us to hypothesize a correlation with the fault system. Even if the seismic rate is low during the background activity periods in the Aeolian Islands and, consequently, our selected earthquake sample is quite modest, some differences in activity among the various fault systems are detectable. In particular, the events located "in correspondence with" a specific structural system lie on the Sisifo and Vulcano faults, the same faults which would have generated (Bottari et al., 1986b) the sequences of 1978 and 1980. This reveals some analogy in the epicenter distribution (and possibly in active fault systems) during periods of intense and modest seismic activity.

The depth range affected by the MAR88-MAR90 activity (0-25 km, Fig. 6) corresponds

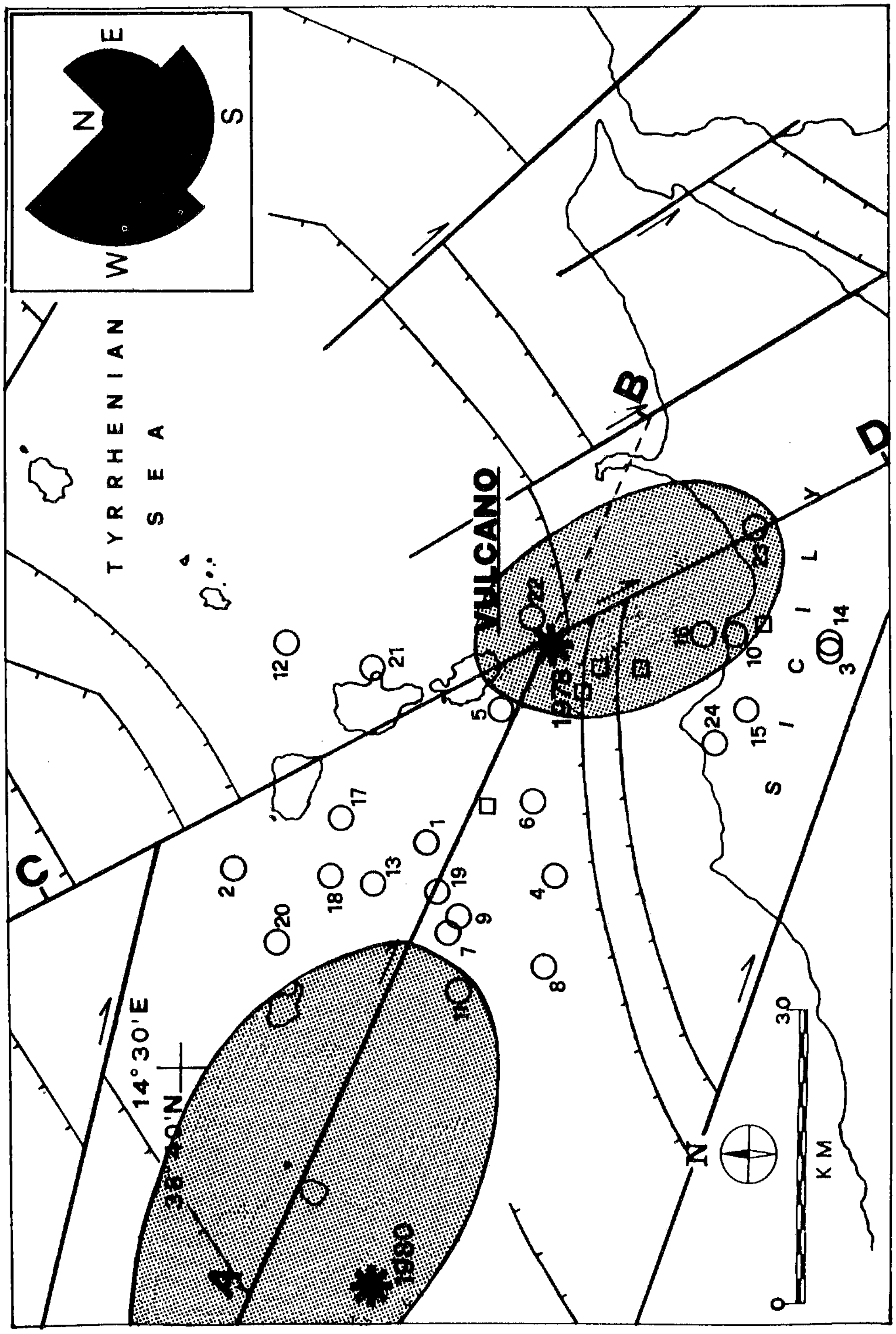

Fig. 5 - Epicentral map (circles) of the MAR88-MAR90 earthquakes. Numbers indicate the time order. Asterisks show the epicenters of the 1978 and 1980 mainshocks, (re-evaluated). The dotted zones are the aftershock areas concerned (from Bottari et al., 1986b). In the inset, the seismic strain release distribution in different sectors around Vulcano during JUL84-JUN89 (Neri et al., 1989) is given.

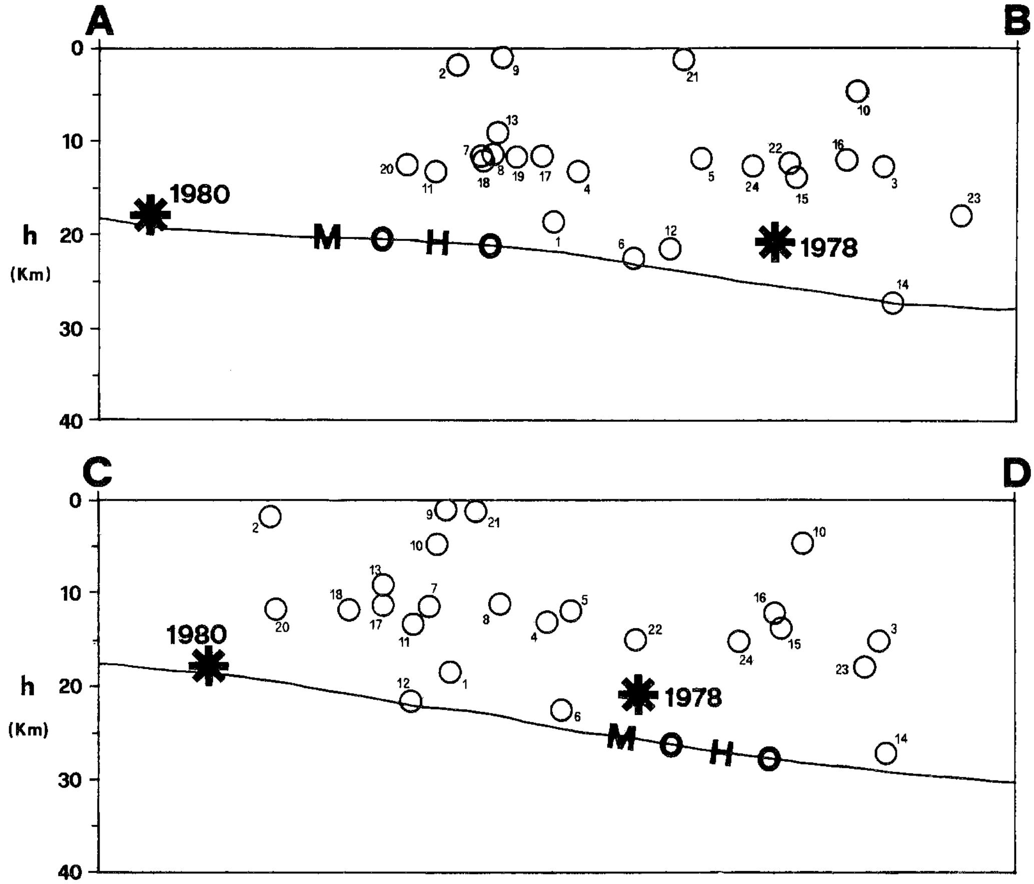

Fig. 6 - Hypocenter vertical section of the MAR88-MAR90 earthquakes along the profiles AB and CD indicated in Fig. 5. Asterisks show the hypocenters of the 1978 and 1980 mainshocks (re-evaluated); the ERZ values are 3.5 km (1978) and 2.2 km (1980).

to the whole crust, since in the most active sectors, the Moho depth (Fig. 2) ranges from 20 km beneath Alicudi, to 25 km beneath Vulcano and the Gulf of Patti. It can also be observed from Figs. 5 and 6 that the recent earthquake activity near the Vulcano fault is shallower than the mainshock of the 1978 sequence, the depth level of which seems to define the lower bound of the depth range active in recent years. A similar observation can be made with respect to the strong shock of 1980, even if in this case greater caution must be used because of the external location of this event with respect to sector S (Figs. 1 and 5).

The polarity distributions (lower hemisphere projection) of some earthquakes located near the Vulcano and Sisifo faults are reported in Fig. 7. For comparison, the focal mechanisms of the main events of 1978 and 1980, respectively, are also shown. These mechanisms are, on the other hand, quite similar to those proposed by Finetti and Del Ben (1986) in their structural investigation based on DSS data. The stability of the polarity distribution when moving the hypocenter within the uncertainty volume has been carefully verified. In general, hypocenter location errors are small enough to make the polarity distribution practically invariant. No correspondence generally appears (Fig. 7) between the hypothesized main mechanisms of the two fault systems and earthquakes in the magnitude range 2.8-4.0 which occurred along the same systems during MAR88-MAR90. The data evidence some mechanism heterogeneity on both structures.

The features discussed of the Aeolian Islands seismicity can reasonably be located within the framework of the available geostructural and tectonic information. The western and sou-

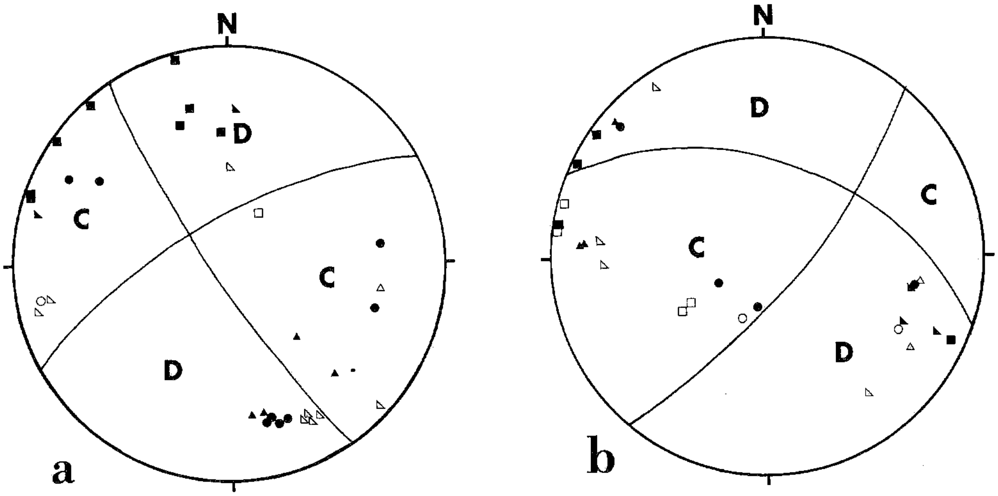

Fig. 7 - Polarity distributions of two small groups of earthquakes located, near the Vulcano (a) and Sisifo (b) fault systems respectively. Each symbol corresponds to an earthquake. For comparison, the fault plane solutions of the 1978 and 1980 mainshocks (Gasparini et al., 1980) are also shown. Full symbols indicate compression; the representation is given in the lower hemisphere.

thern sectors of the area (the most active ones in relation to both the main sequences and the microearthquakes in background activity periods) represent the southeastern margin of the Tyrrhenian basin (Fig. 1); fault systems like those of Vulcano, Sisifo, Filicudi and Taormina, are associated with dextral transcurrent dislocation processes of the Tyrrhenian crustal structures with respect to the Sicilian ones. The northern margin of the Tyrrhenian basin is defined by the Palinuro and Policastro sinistral transcurrent faults. The southern Tyrrhenian crust is SE moving between these fault systems. Within this kinematic framework, which is substantially in common to the different tectonic models (Fig. 3), it would seem reasonable that a higher stress concentration occurs along the borders of the southern Tyrrhenian structure and, in particular, on the southern border (Vulcano, Sisifo, Filicudi and Taormina faults). For this reason, the seismic energy release is more relevant in the southern and western sectors of the Aeolian Islands than in the northern and eastern ones. The focal depth values estimated during both the main sequences and the background activity periods indicate that the main structural systems are seismically active throughout the crustal thickness. The strongest events occur near the crust-mantle transition. A significant feature is that, while the fault-plane solutions of the main events of 1978 and 1980 (Gasparini et al., 1980) are in agreement with fault mechanisms inferred from geological observations and geophysical exploration, the smaller and shallower MAR88-MAR90 earthquakes have P polarity distributions incompatible with the presumed main mechanisms of the structures concerned, revealing structural heterogeneity and rock fracturing at shallower depths on these structures. A significant degree of fracturing in the western sector of the Aeolian Islands area has also been hypothesised by other authors (Del Pezzo and Martini, 1982; Del Pezzo et al., 1984). The above postulated relationship between a significant number of MAR88-MAR90 earthquakes and minor faults to the west of Vulcano island could be further evidence of structural heterogeneity, as well as the fairly high values obtained by Neri et al. (1989) for both the Gutenberg-Richter "b" coefficient and the 1/E temporal clustering of microearthquake activity in July 84 - June 89. This situation is not surprising considering both the strong stretching suffered by crustal and mantle structures in this area during its geodynamical evolution (Scandone, 1979; Scandone and Patacca, 1984) and the present location of structural systems, which in several cases intersect each other or closely interact (Fig. 1).

An attempt to analyse jointly the above described features and the literature data on the earthquake long-term patterns in the same area (linearity of the cumulative seismic energy release, suspected regularity of stressing by tectonic agents, relevant storage of elastic energy during low-seismicity periods; see above and Neri, 1985) has led us to suspect that a large

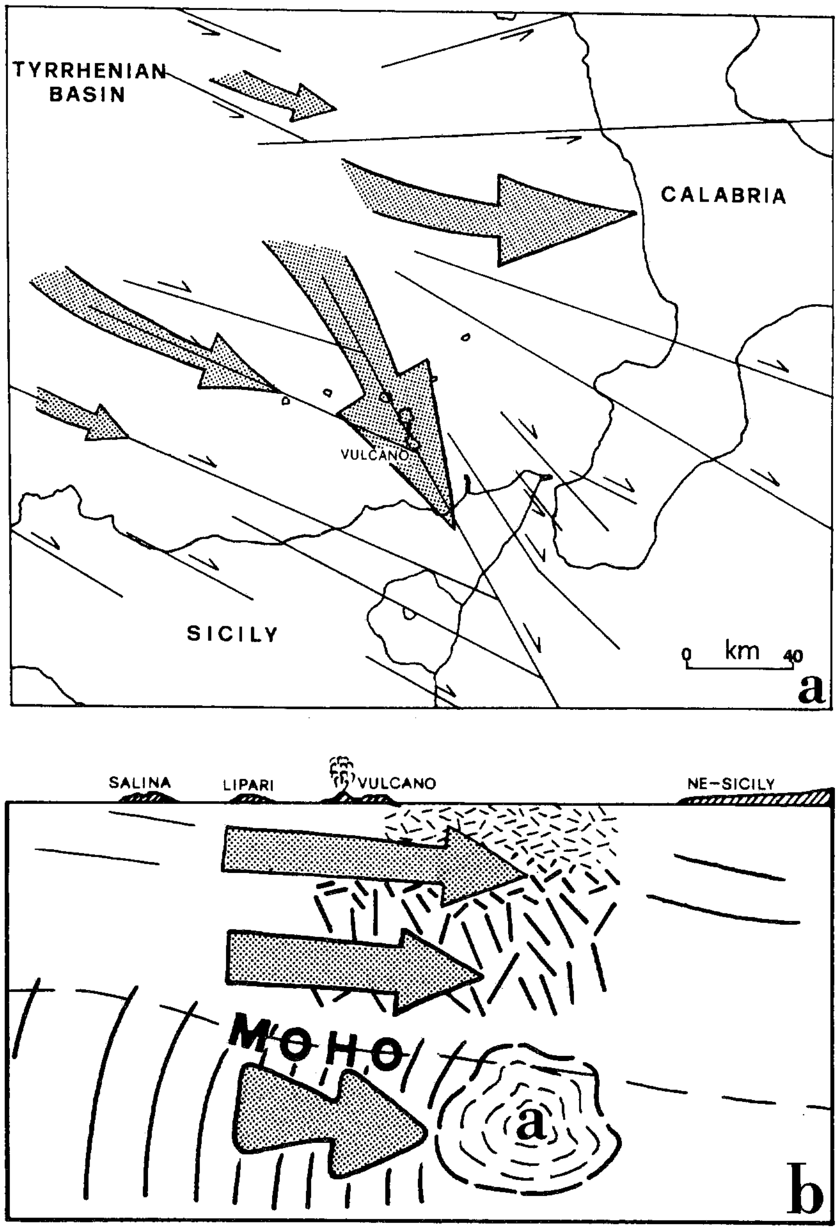

Fig. 8 - a) Simplified representation of the presumed kinematics of the southern Tyrrhenian crustal structures (the structural basis is from Finetti and Del Ben, 1986). b) Vertical section along the main fault systems, with a schematic representation of the hypothesized accumulation process (zone a).

amount of tectonic stress is currently being accumulated, possibly at the level of the Moho along the main structural systems (Fig. 8). Over the last 5 years, only a modest percentage of the energy stored would have been released, in the shallower and more heterogeneous structures of these systems and on close minor faults, under a complex stress regime due to high rock fracturing and stretching. Within this framework, the pre- and post-seismic ground deformation patterns related to the 1978 earthquake (Falsaperla et al., 1989; see section "Seismological features") may also be reasonably explained. The areal dilatation which appeared in the Lipari-Vulcano area about 2 years before the seismic event could be related to a late stage of the stress accumulation process; the depth of the earthquake (27.0 ± 3.5 km), and the shallow crust structural heterogeneity, may have contributed to the observed delay of the deformation sign inversion with respect to the event, and to the anelastic rock behaviour indicated by the only partial recovery of the deformation. No significant deformation was, on the contrary, detected in the Lipari-Vulcano area for the 1980 event which was, however, farther from the area where geodimetric measurements are systematically carried out.

Finally, we would like to stress two basic aspects of the present work. Firstly, the limitations due to the occurrence of only two significant sequences since the installation of local networks, and the intrinsic approximations with regard to the earthquake long-term patterns (Neri, 1985) prevent us from considering the scheme presented in Fig. 8 as more than a working-hypothesis. Secondy, although the southern Tyrrhenian shallow earthquake data proved to be reasonably locatable in the geostructural framework and are consistent with the local crustal kinematics, they are not sufficient for solving the present indeterminacy regarding the large-scale geodynamical processes (Fig. 3) at the root of the generally agreed southern Tyrrhenian kinematics.

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