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Identification of seismogenic areas in the Southern Apennines, Italy

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Abstract
The most available macroseismic and instrumental data concerning seismicity of the Southern Apennines from the XI up to the XX century have been analyzed.
In comparing the concentration of both historical and recent seismic activity the global trend of a seismically active large band is evident, with NW-SE orientation, which stretches from southern Abruzzo to Basilicata region. Inside such a belt a complex structural setting is found which makes difficult a clear identification of surface structures with associated seismic activity.
In this paper, according to historical and recent event concentration, four main seismogenic areas have been distinguished which seem to be marked by a characteristic seismic behaviour:

1) Southern Abruzzo area: both historical and present activity of medium- to low-energy level. Fault plane solutions mainly of normal type.
2) Molise area: high-intensity historical earthquakes ($I \geq$ X MCS). Swarm-type recent events with low magnitude ($M_{max} = 4.0$).
3) Beneventano area: several strong historical earthquakes ($I \geq$ X MCS). Current activity is characterized by frequent and low-energy events except the 1962 earthquake (I = IX MCS).
4) Campania-Lucania area: highest number of damaging historical and recent earthquakes ($I \geq$ X MCS). The last strongest events were the Irpinia-Lucania November 23, 1980 ($M_S = 6.8$ NEIS; I = IX-X MCS); the Potenza May 5, 1990 ($M_S = 5.4$ SEAN; I = VII MSK) and, recently, the Potenza May 26, 1991 ($M_l = 4.7$ NEIC; I = VI-VII MSK). Well-constrained dip-slip focal mechanisms.

1. Introduction

The aim of this study is to recognize and characterize seismogenic areas of the Southern Apennines, in the sector between southern Abruzzo and Basilicata region. Historical earthquakes occurred in the XI up to the XVIII century, having maximum intensity $I \geq$ VIII MCS, have been considered; moreover, precursory shocks and aftershocks related to historical events with $I \geq$ VIII MCS of the XIX century have been first identified in this paper (fig. 1) and detailed macroseismic revisions have been carried out for the main events. Four recent events with magnitude $M \geq 4$ have also been studied making use of macroseismic methods.

As regards instrumentally recorded earthquakes occurred in the Southern Apennines between 23 November 1980 (Irpinia earthquake) and December 1991, accurate hypocentral locations have been computed for events with $M \geq 2.5$ by means of data from the Osservatorio Vesuviano and the Istituto Nazionale di Geofisica seismic networks (fig.2).

2. Seismic zoning

The region under study is characterized by a complex seismotectonic frame; in fact, owing to the complicated structural setting of the Southern Apennines, thick alloctonous nappes hide seis-

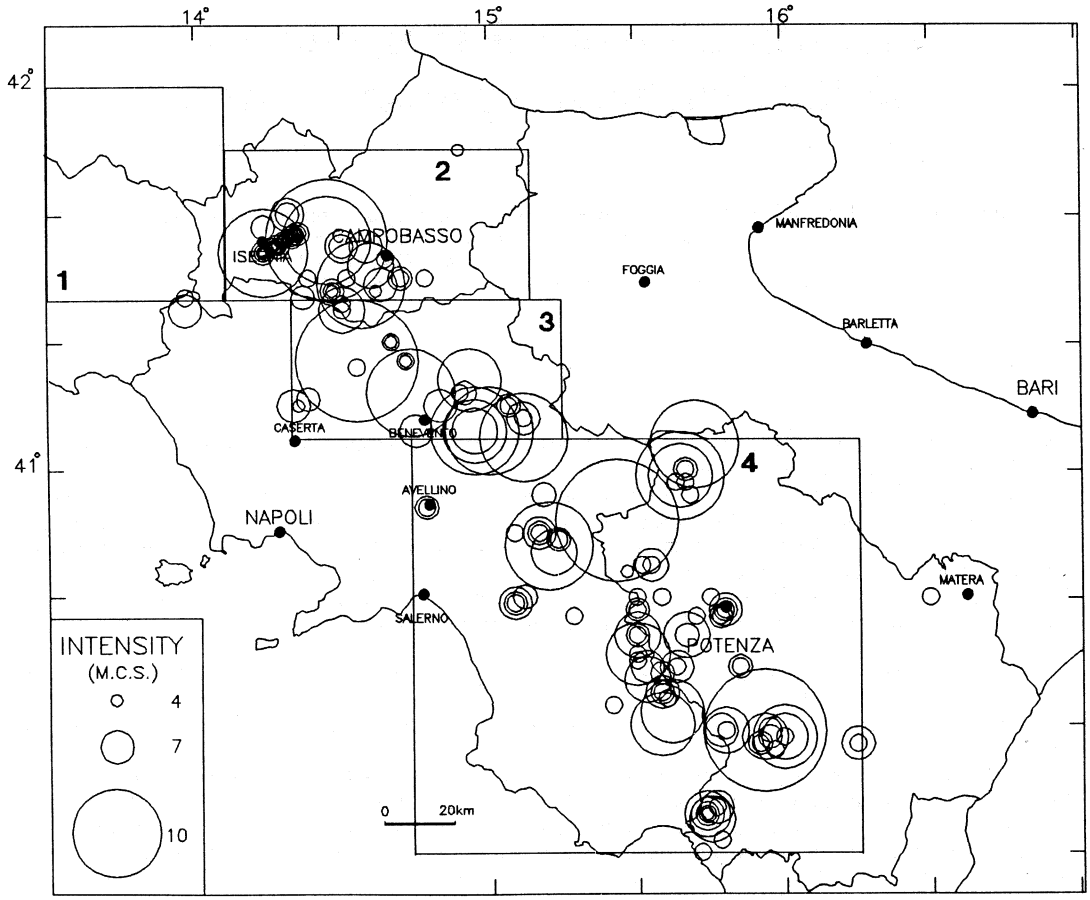


Fig. 1. Distribution of macroseismic epicenters for the events occurred in the Southern Apennines from 1125 to 1962.

mogenic faults (Patacca and Scandone, 1989). Therefore, a study of past and recent seismicity of this region has been carried out in order to get information about local tectonic structures.

According to historical and recent event concentrations as well as a different seismic behaviour, four main seismogenic areas have been distinguished, as shown in fig.1 and 2: 1) Southern Abruzzo area; 2) Molise area; 3) Beneventano area; 4) Campania-Lucania area.

Southern Abruzzo area (41°25′- 42°00 North Lat. and 13°00 - 14°05′ East Lon.)

The Ortona-Roccamonfina line (Locardi, 1982) which clearly separates the Northern Apennines arch from the Southern Apennines one (Patacca and Scandone, 1987) represents an important transversal structural line of this area. Earthquake activity is of medium-to-low level; however, neighbouring big earthquakes have been considerably felt inside this area. The most active region is located inside the site of the Parco Nazionale d'Abruzzo, where several medium-intensity earthquakes have taken place in the last years. Among recent events, the May 1984 seismic sequence which had two main shocks, May 7 (M_S=5.8 NEIS) and May 11 (M_S=5.2 NEIS), has been studied in detail. The macroseismic

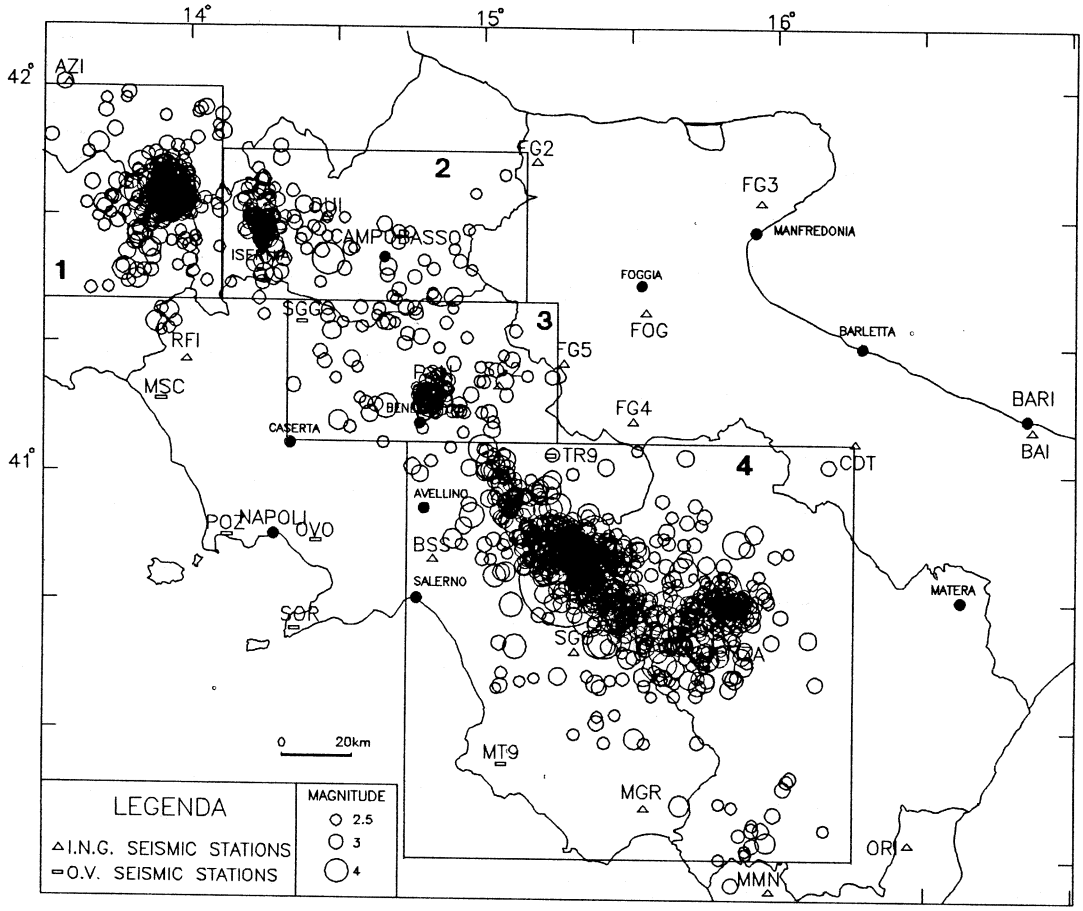
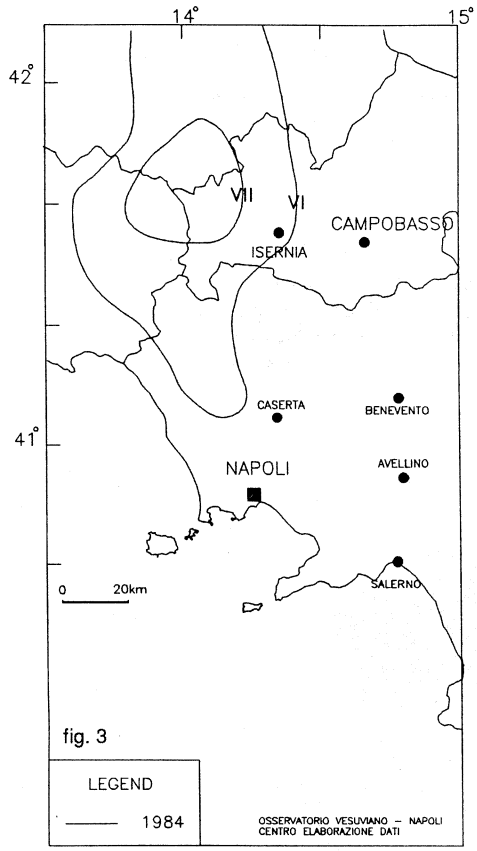


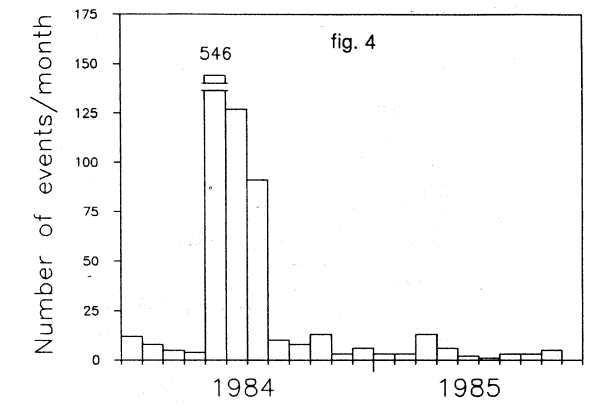
Fig. 2. Epicentral distribution of the seismic events occurred from November 23,1980 to December 1991 in the Southern Apennines. The four seismogenic areas are shown inside the rectangles.

epicenter has been located in the village of Alfedena (L'Aquila); the mesoseismal zone showed a length of about 40 km, with effects of VII MSK and a general lengthening towards N-S (fig.3) and towards the Piana Campana (Branno *et al.*, 1985; Esposito *et al.*, 1989). The space evolution of earthquake activity for this sequence has been analyzed through a temporary seismic network, which was set out in the epicentral area (Del Pezzo *et al.*, 1985; Ferri and Gorini, 1986). The epicentral distribution shows a cluster of events (fig. 2, area n.1); as regards the temporal evolution of the sequence, the seismic frequency and seismic-energy release are shown in fig. 4 and 5.

Molise area (41°25′ - 41°50′ North Lat. and 14°05′ - 15°10′ East Lon.)

This area was hit by the December 1456 and the July 1805 earthquakes, with $I \geq$ X MCS (fig. 6).The December 1456 earthquakes were probably the most powerful in the whole Italian seismic history and destroyed the town of Isernia as well as its neighbourhood (Figliuolo, 1988). The July 26, 1805 earthquake, with intensity equal to XI MCS, mainly hit the village of Frosolone which was entirely razed to the ground (Esposito *et al.*, 1987). The 1805 historical seismic sequence, which lasted until July 1806, shows a concentration of epicenters between Isernia and





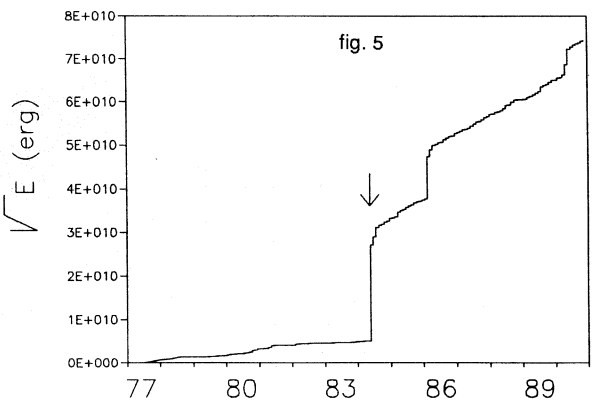


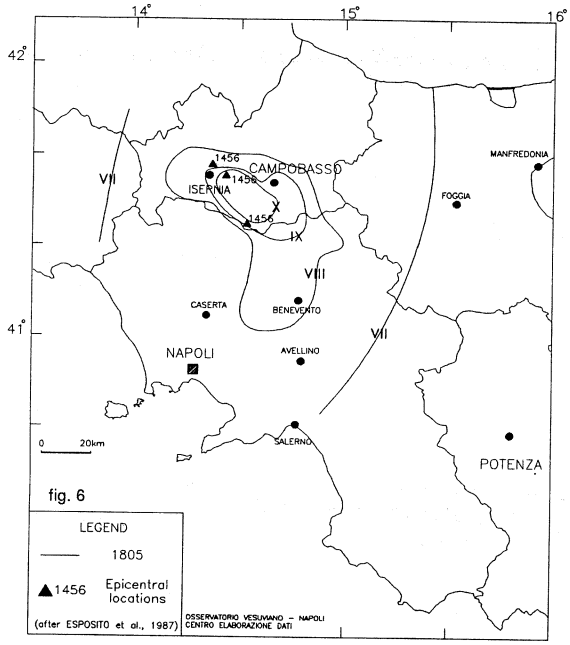
Fig. 3. Macroseismic field of the May 1984 events.

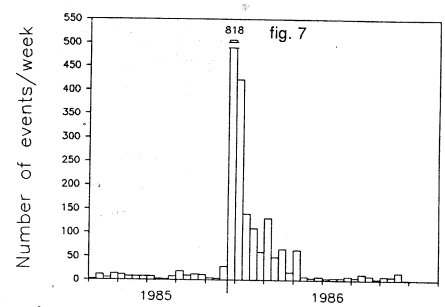
Fig. 4. Monthly seismic frequency at the SGG station from January 1984 to October 1985. The peak relative to the May 1984 seismic sequence is evident.

Fig. 5. Monthly strain release at SGG station. The step relative to the May 1984 seismic sequence is marked by the arrow.

Frosolone; about 150 aftershocks with intensity from IV to VII MCS have first been identified. From 1826 to 1835 about ten events with intensity from IV to VI MCS have also been identified, which have been located between Isernia and Campobasso (Esposito and Porfido, in preparation).

As regards the recent seismicity, the January 1986 seismic sequence has been the most interesting one in the area. The epicenters distribution covered a small area NE of Isernia of about 10 km^2 (Alessio *et al.*, 1990a). The earthquakes had low magnitude (M_{max}= 4.0) and their distribution shows a clustering of events, without any regular geometry (fig. 2, area n.2). A composite fault plane solution indicates that the Isernia sequence was related to a strike-slip failure mechanism with a small dip component. The statistical analysis of the time series associated with this seismic sequence was consistent with a swarm type of seismic activity (Alessio *et al.*, 1990a); the seismic-frequency and seismic-energy release are shown in fig. 7 and 8.





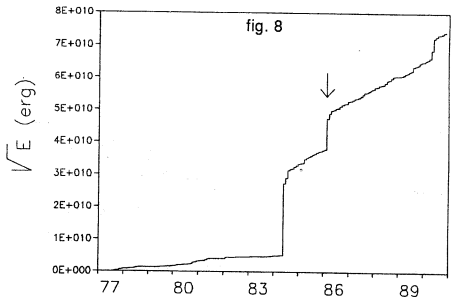


Fig. 6. Macroseismic field of the 1805 earthquake and epicentral locations of the 1456 earthquakes. The isoseismals trend indicates propagation towards the Campanian plain and attenuation towards the Matese mountains.

Fig. 7. Weekly seismic frequency at the SGG station from 1985 to 1986. The peak relative to the January 1986 seismic sequence is evident.

Fig. 8. Monthly strain release at the SGG station. The step relative to the January 1986 seismic sequence is marked by the arrow.

Beneventano area (41°05′ - 41°25′ North Lat. and 14°20′ - 15°15′ East Lon.)

The strongest historical events of this area are the 1688 earthquake (I=X MCS), which destroyed the town of Benevento; the 1702 and 1732 earthquakes, with epicentres located to the east of the town. Another disastrous event was the October 11, 1125 earthquake which was located between Benevento and Ariano Irpino village. As regards the recent seismicity, the August 21, 1962 earthquake was one of the biggest events, with an epicentral intensity of IX MCS (fig. 9). In the last decade, the earthquake activity of this area has had low energy and epicentres appear to be quite scattered. However, in April 1990 a seismic crisis occurred in this area, which has been studied in detail by means of a temporary digital seismic network (Alessio *et al.*, 1990b). Epicentres of this seismic sequence have been located between Benevento and Pescosannita village; the strongest event occurred on April 22, at 11:45 local time, with magnitude M_l=3.6 (fig. 2, area n.3). As regards the time-frequency pattern of occurrence of events, the April 1990 earthquake activity appears to be of swarm type (fig. 10 and 11).

Campania - Lucania area (40°00′ - 41°05′ North Lat. and 14°48′ - 16°15′ East Lon.)

The November 23, 1980 earthquake, one of the most violent events of Southern Italy (I=X MCS), occurred in this area. Moreover, the highest number of disastrous events with $I \geq$ X MCS took place in this area at historical times (fig.12a)). Such events (1694, 1930) appear to be concentrated in the same zone; only one strong

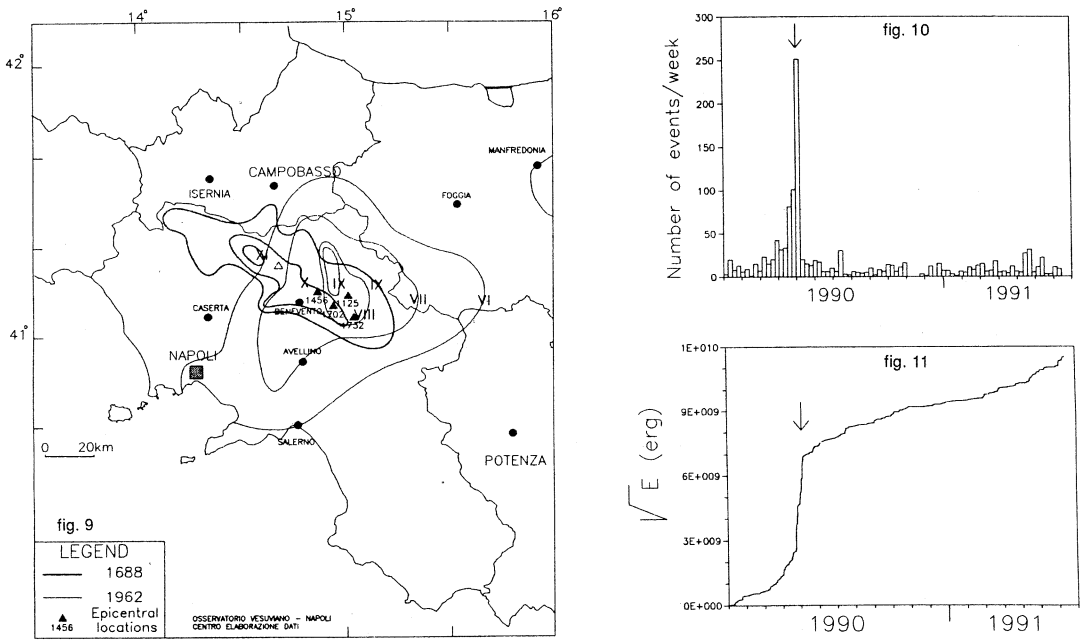


Fig. 9. Macroseismic field for the 1688 and 1962 earthquakes. The isoseismals of the 1688 earthquake show a lengthening parallel to the Apennines chain, while those of the 1962 earthquake show a direction transverse to the Apennines chain.

Fig. 10. Weekly seismic frequency at the SGG station from January 1990 to June 1991. The peak relative to the April 1990 seismic sequence is evident.

Fig. 11. Daily strain release at the SGG station. The step relative to the April 1990 seismic sequence is marked by the arrow.

event, the December 16, 1857 earthquake affected the southern sector of this area; moreover, the 1550 and 1561 earthquakes have been located in the west of the area, in the Vallo di Diano. After the Irpinia earthquake, seismic activity consisted of medium-intensity events ($I \geq$ VII), whose locations are mainly placed near the border between the Lucania and the Campania regions (Porfido *et al.*, 1988) (fig.12b)). The February 2, 1983 earthquake (in fig.12b) marked with a star), the September 2, 1983 and the July 23, 1986 earthquakes have been studied in detail, since they are located in zones which have been already hit by historical events. In the last decade seismicity in this area has still affected the Irpinia epicentral zone (fig. 2, area n.4). Events show higher magnitude than the ones in the other areas, and have been mainly located in the south-east border of the seismogenetic belt (Alessio *et al.*, 1987). Particularly, the July 1986 seismic sequence affected this border; the May 5, 1990 earthquake (M_l = 4.8, M_S = 5.4 (SEAN), I = VII) and the May 26, 1991 earthquake (M_l = 4.7 NEIC, I = VI-VII MSK), the strongest events after the Irpinia earthquake, also affected this zone.

The seismic pattern of this area appears to be of a main shock- aftershocks type (fig. 13 and 14) with quiescence periods and strong isolated events at intervals.

3. Conclusions

In conclusion, the four main seismogenic areas identified in this study seem to be marked by a characteristic seismic behaviour, on the basis of macroseismic and instrumental investigations.

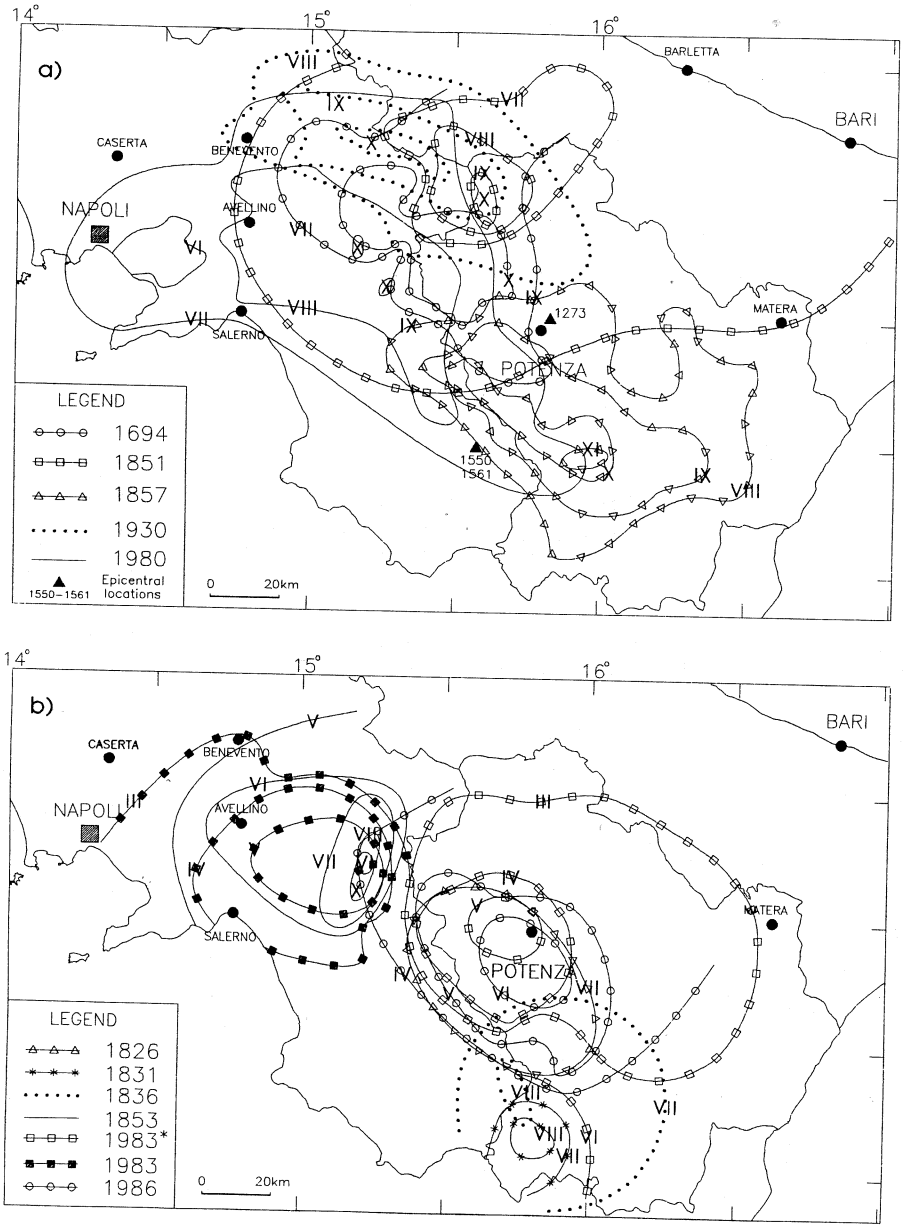


Fig. 12. Macroseismic field of the events with $I \geqq$ X MCS (a)) and VI $< I <$ VIII (b)). A general lengthening of the isoseismals of higher intensity in the NW-SE direction is evident. The isoseismals trend shows:
- Strong attenuation (1857, 1980, 1983*, 1986) in the W direction, towards the Cilento area.
- Efficient propagation (1857, 1980, 1983*, 1986) in the E direction, towards the Puglia region.
- Efficient propagation (1853, 1857, 1980, 1983) in the Campanian plain direction. The isoseismals of the 1831, 1836, 1851, 1853 and 1983 earthquakes show an anti-Apenninic direction probably correlated to transverse tectonic lineaments.

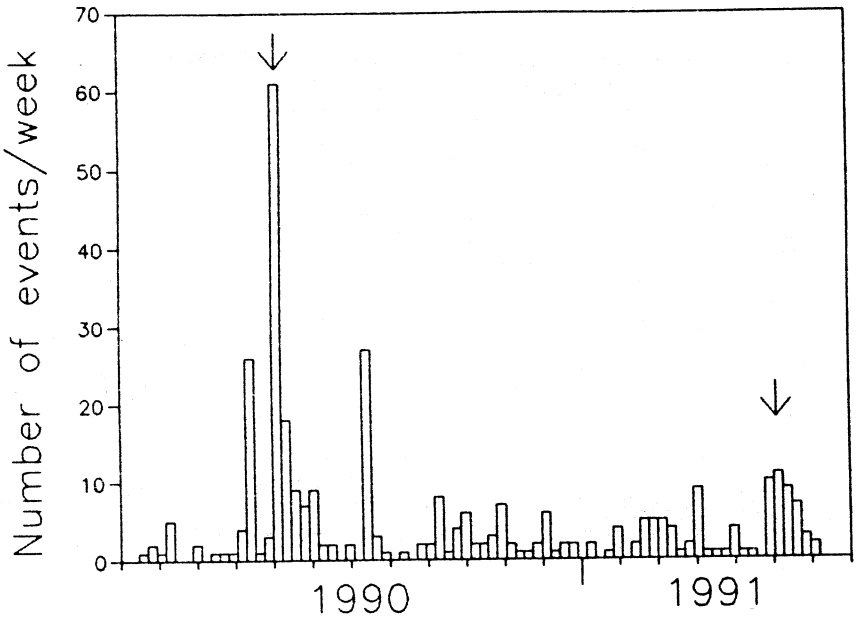


Fig. 13. Weekly seismic frequency at the TR9 station from January 1990 to June 1991. The peaks relative to the May 1990 and the May 1991 seismic sequences are marked by the arrows.

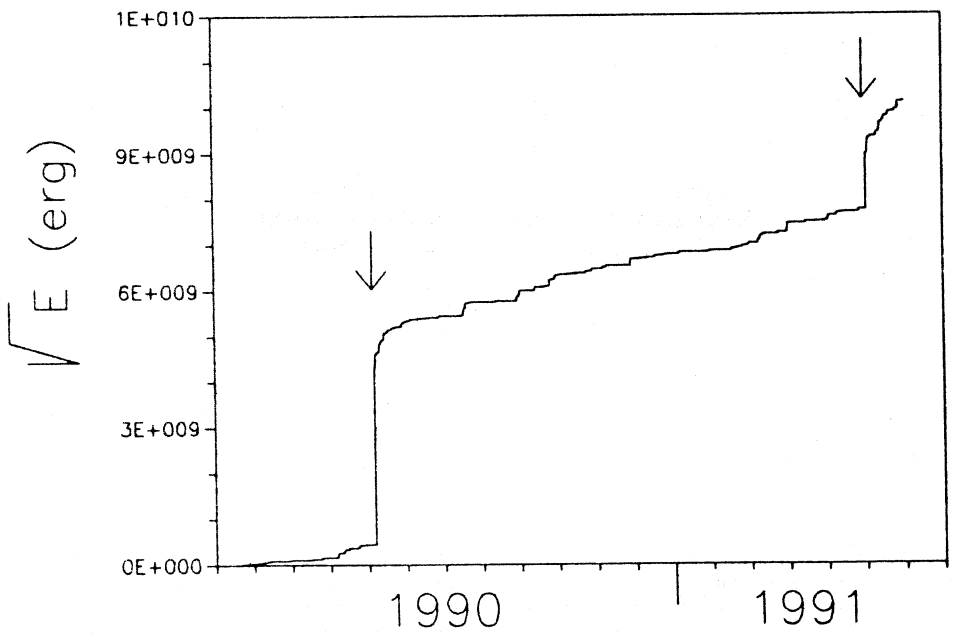


Fig. 14. Daily strain release at the TR9 station. The steps relative to the May 1990 and the May 1991 seismic sequences are marked by the arrows.

As regards recent and current seismic activity, the Campania-Lucania area preferably gives rise to strong sequences of main shock-aftershocks type, while the Molise and Beneventano areas mainly show a swarm-type activity, with sequences of comparable magnitude, which are concentrated in time and space.

As regards historic seismic activity, both the Campania-Lucania and Molise areas give confirmation of the above-mentioned seismic behaviour. In fact, frequent earthquakes with high intensity have occurred in the Campania-Lucania area, while the Molise area has been hit by some high-intensity events and several events of medium-to-low intensity. Further analyses are necessary as regards low-intensity earthquakes of the other two areas under study in order to know how such findings can be used in terms of seismic-hazard evaluation.

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