Relationship between seismicity and eruptive activity at Mt. Etna volcano (Italy) as inferred from historical record analysis: the 1883 and 1971 case histories

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Abstract
In this paper historical and recent seismological data are analysed in order to investigate the relationship between seismicity and eruptive phenomena at Mt. Etna volcano. The 1883 and 1971 case histories have been proposed because they are significant events in the recent history of the volcano regarding volcanic hazard and show very different evolutions of associated seismic activity and eruption dynamics. The first (1883) represents flank eruptions characterised by high seismic release, short duration and moderate effusion rate whereas the second (1971) can be ascribed to eruptions starting as summit or subterminal events and thereafter developing on the flanks with a minor level of seismicity, higher effusion rate and prolonged duration. The pattern of seismic activity during 1883 and 1971, as inferred from historical record analysis, and the different associated type of eruption may be a result of diverse stress conditions acting on the volcanic system. The interpretation of the seismic behaviour by considering historical eruptions in a systematic fashion will contribute to a clearer understanding of volcanic phenomena at Mt. Etna.

Key words *historical earthquakes – seismicity analysis – volcanic eruptions – Mt. Etna (Sicily, Italy)*

1. Introduction

Over the last 10-20 years most of the studies on the volcanic activity of Mt. Etna have focused on geophysical investigations, such as seismological, ground deformation, gravimetric studies. Seismicity has long been considered the most useful tool to monitor the state of an active volcano and recognize possible precursors of volcanic eruptions. Many authors have investigated the statistical relationship between seismicity and eruptions on Mt. Etna using both historical (Sharp *et al.*, 1981; Nercessian *et al.*, 1991; Gresta *et al.*, 1994) and instrumental data (Scarpa *et al.*, 1983; Gasperini *et al.*, 1990; Lombardo and Cardaci, 1994). These studies have identified some problems, such as the incompleteness of catalogues and the selection criteria of both seismic events and time-span sampling. Moreover, a different approach has to be adopted when using either macroseismic or recent instrumental data, the latter being mostly very low magnitude shocks. Consequently, further statistical analyses need more consistent, complete and detailed data on the seismic and volcanic phenomena that have affected the volcano.

Since the last century, eruptions at Mt. Etna have been well reported (Romano and Sturiale, 1982; Chetser *et al.*, 1985). In addition, a large amount of macroseismic and instrumental seismological information is available. Such data, starting from the mid 1800s, have rarely been used and include both eruptive and quiescent stages of the volcano's activity. Extending the period studied by making use of the historical records over the last 150 years – during which 36 main eruptions occurred – will provide a clearer relationship between seismicity and eruption type to emerge. Therefore, a systematic research of historical sources aimed at obtaining a complete data base should be undertaken. The goal of this study is to highlight the potential of historical records in the investigation of the relationship between seismic and volcanic activity.

The 1883 and 1971 case histories have been chosen because these may be representative of particular types of activity related to volcanic hazard. In fact both eruptions represent a high risk condition: i) opening of eruptive fissure at low altitude, a few kilometers away the nearest town (*e.g.*, 1536, 1595, 1651, 1669 and 1883, the last being the most recent eruption of this type); ii) eruptive activity starting near the summit and quickly developing downhill by the opening of fissures issuing lava flows with relevant effusion rate (*e.g.*, 1780, 1809, 1879, 1911, 1928, 1971).

2. Seismological data

In the last three centuries the etnean area has been densely urbanised, thus many earthquakes are felt by the local population. Independently from seismic networks, events can be qualitatively located by the distribution of the perceptibility area (macroseismic information). Moreover the frequent correlation between damage area and coseismic surface faulting also identifies the seismogenic fault (Azzaro *et al.*, 1989).

In recent years the preference given to instrumental seismic data has resulted in non systematic collection of macroseismic information. This has led to a gap between reliable macroseismic information (*e.g.*, data collected at the turn of the XIX century) and reliable instrumental findings, the latter being linked to the development of seismic networks. The case histories examined are typical examples of this problem.

The seismological data here presented come from different sources: scientific papers and bulletins for the 1883 eruption; mainly from newspapers and seismograms for the 1971 event. Although the seismic network operating on Mt. Etna was not yet developed in 1971, the macroseismic data were not systematically collected. Newspaper information is not always complete and fully reliable, but it is a useful source for the most significant shocks that occurred on the volcano, providing that these data are used cautiously.

The macroseismic information was interpreted using the EMS 92 intensity scale (Grünthal, 1993), *i.e.* the most updated MSK version. A macroseismic earthquake catalogue with intensity $I \geq 4$, has been compiled for these two periods (Appendix A and B). Though this threshold implies no completeness of catalogue, some information on seismically active areas of the volcano may be inferred.

The catalogue contains: shock order number; date and time of the event; maximum intensity observed; epicentral area, or maximum intensity area when a precise location is not possible due to lack of information or localities; felt areas or damaged localities with relative estimated intensity; seismic stations recording the shock and, finally, quotation of the main source (more than one reference indicates discrepancies in the reported data). The instrumental data of the 1883 eruption are reported in historical sources, while the 1971 ones are derived from original seismograms for the Catania station and from newspaper reports for the Acireale station, since seismograms are not available.

Comparative analysis between intensity distribution, number and site of stations recording the event and recent earthquakes (Azzaro *et al.*, 1989, 1992) allowed us to qualitatively locate the shocks and to distinguish the following features of seismicity: i) events widely felt on the volcano with low intensity attenuation are interpreted as deep earthquakes ($h \cong$ 5-20 km); ii) events occurring in restricted areas with damage (or higher perceptibility) are interpreted as shallow shocks ($h \leq 5$ km).

3. The 1883 case history

The 1883 eruption is part of the 1874-1892 eruptive cycle and represents an anomalous event in the recent eruptive history of Mt. Etna volcano, because a 3.5 km long fracture issuing a short lava flow opened at low altitude (fig. 1) (Ricciardi, 1883; Silvestri, 1883). After the end of the 1879 eruption, activity was located at the Central Crater and consisted of ash ejection caused by collapse in the vent during the first six months of 1882, followed by strombolian activity until 1883, March 22 when a flank eruption broke out on the south-

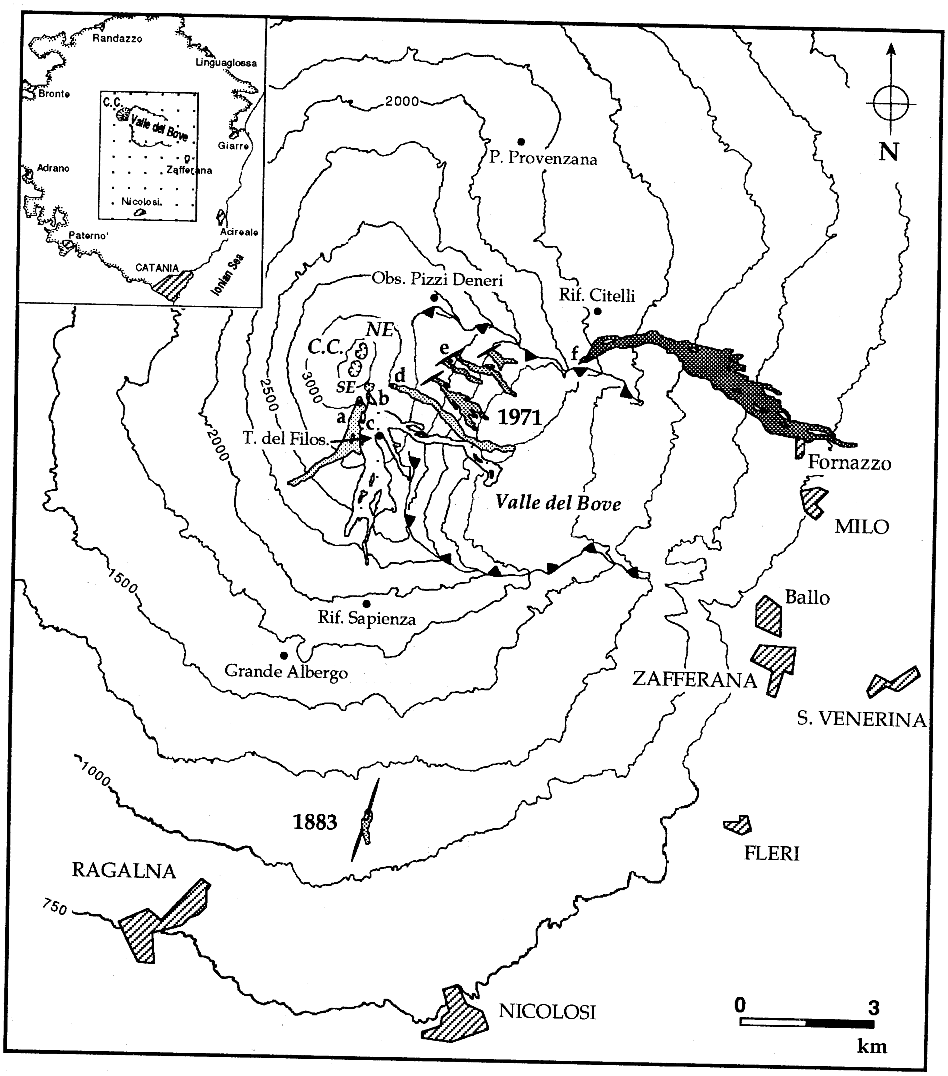

Fig. 1. Map of the lavas produced during the 1883 and 1971 eruptions on the south and east flanks of Mt. Etna (modified after Azzaro and Neri, 1992). Letters (a-f) indicate lava flows issuing from different vents (compare with table II).

Table I. Volcanological parameters of the 1883 eruption. Compiled from information in Silvestri (1883); Romano and Sturiale (1982).

Date		Onset 22-03-1883	End 24-03-1883	Days 3
Eruptive system	Location	*Southern flank*		
	Altitude (m a.s.l.)	1200-950		
	Vent	Eruptive fissure		
	Denomination	*Mt. Leone*		
Flows	Maximum length (km)	0.250		
	Average thickness (m)	2		
	Altitude attained (m a.s.l.)	1060		
	Area (km^2)	0.0252		
	Volume of lava (10^6 m^3)	0.0504		
	Volume of pyroclastics (10^6 m^3)	0.167		
	Mean effusion rate (m^3/s)	0.84		

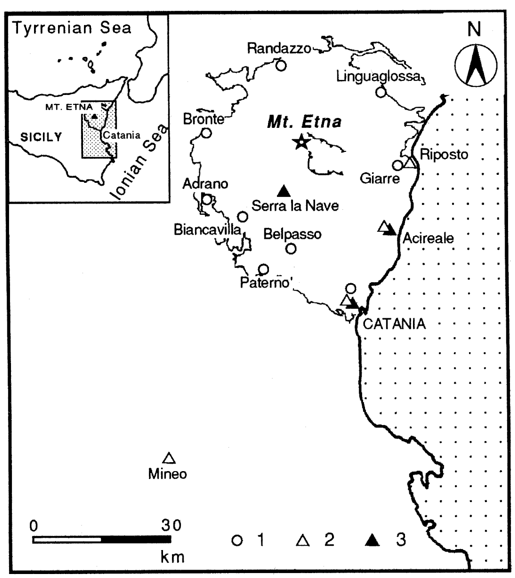

Fig. 2. Location map of seismic stations. Government seismic observatories in 1883 (linked to Catania center by telegraph): 1 = seismoscope, type Galli or Brassart; 2 = seismograph, type Cecchi. 1971 seismic network 3 = one-component, analog station.

ern flank of the volcano. The volcanic unrest was characterised by strong explosive activity (Mercalli, 1883) and lasted only three days with a small volume of erupted lava (table I). Intense seismic activity throughout the eruption affected the whole volcano: in the space of two months over 210 earthquakes were recorded by the seismic network operating at that time (fig. 2) and many of them (about 100 events with intensity $I \geq 3$-4) were felt by people (Appendix A).

During the first months of 1883, there was no evidence of seismic activity except for one shallow earthquake occurring on the lower southern flank. On March 20, two days prior to the eruption, a seismic crisis accompanied by a so called «microseismic agitation» (Silvestri, 1883) which probably refers to a strong tremor signal, was recorded. The seismic sequence started with deep earthquakes widely felt on the volcano slopes and was followed by several shallower shocks felt in restricted areas on the eastern and the south-western flanks (fig. 3). Continuous «tremors» are reported to have shaken the village of Nicolosi and seem to be closely related to the opening of the eruptive fissure on March 22 at 00:15 GMT.

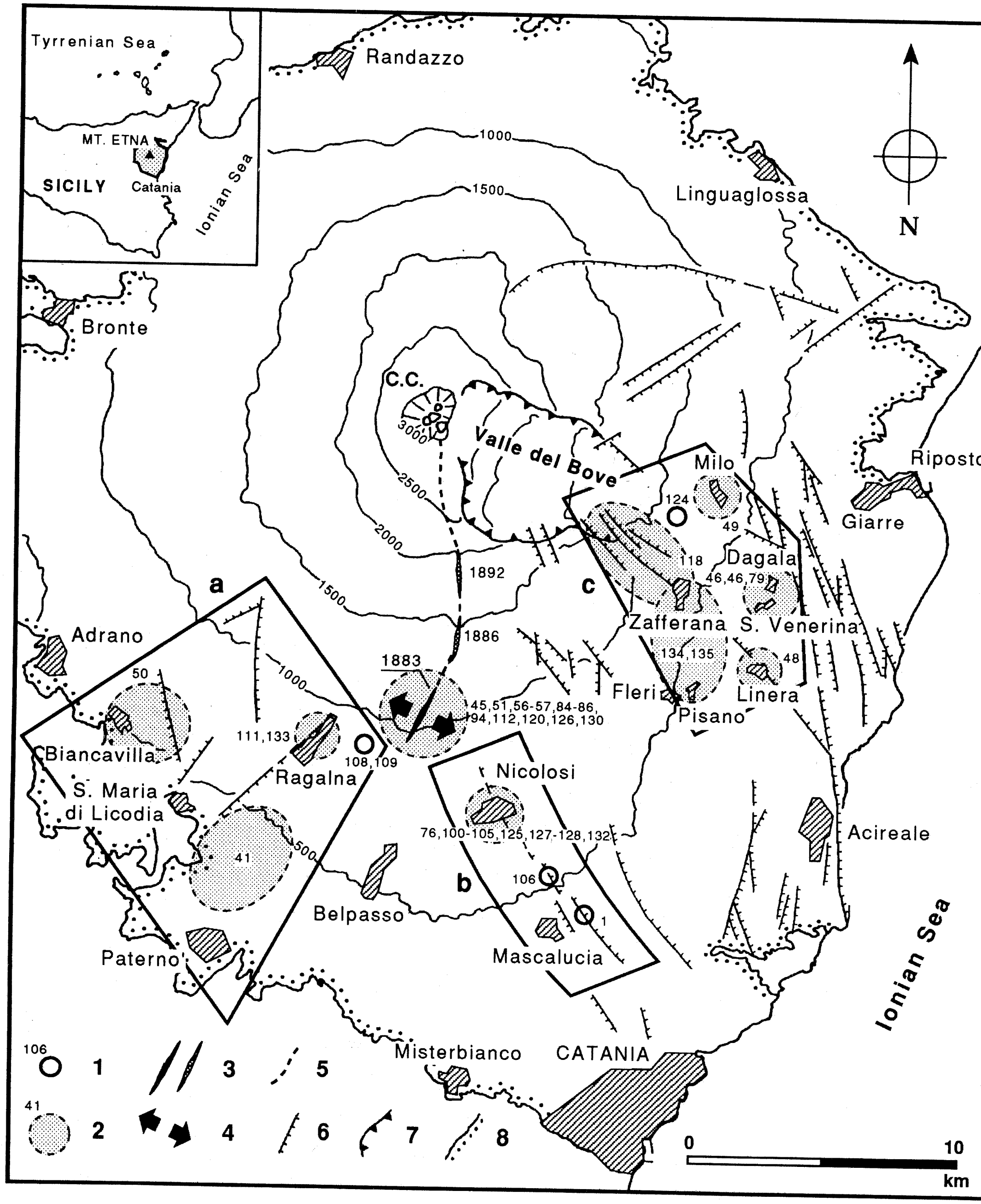

Fig. 3. Epicentral map of the main 1883 macroseismic earthquakes (tectonic sketch map from Rasà *et al.*, 1996). Numbers indicate shocks listed in Appendix A. 1 = Well defined epicentres; 2 = max intensity areas (circles proportional to location uncertainty); 3 = eruptive fissures; 4 = tensile opening related to the 1883 eruption; 5 = long fracture connecting the 1883-1886-1892 vents with the Central Crater (C.C.) (adapted from Silvestri, 1893); 6 = main faults; 7 = Valle del Bove depression; 8 = limit of the volcanics. For the insets (a, b and c) see text.

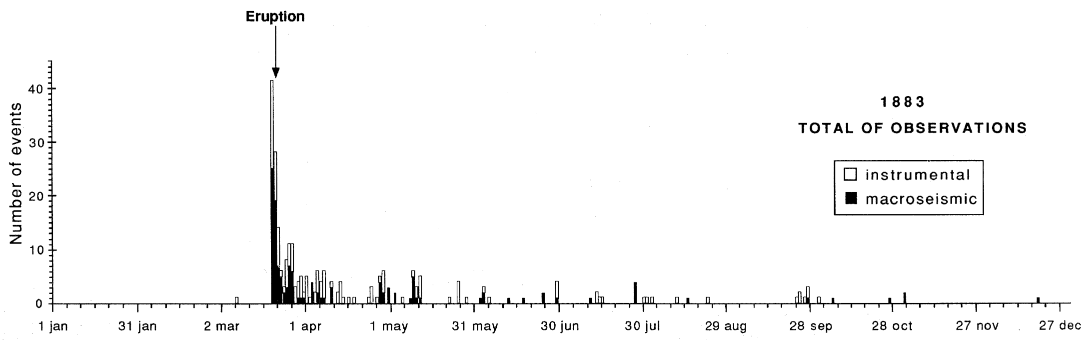

Fig. 4. Daily seismic frequency recorded at Mt. Etna during 1883. Events felt with intensity $I < 4$ are considered instrumental data.

The occurrence and the intensity of earthquakes dropped immediately after the eruption started (fig. 4). At the end of the eruption (March 24) shallow seismicity renewed, and the number of shocks progressively diminished during the following months (May-July). Seismicity mainly affected the areas of Nicolosi, Biancavilla, Linera, Milo (fig. 3) and the macroseismic epicentres showed a tendency to migrate from the eastern to the south-western flank of the volcano, whereas other minor instrumental shocks were mainly located on the south-eastern side (fig. 5, Acireale station). On the whole, some fifteen earthquakes damaged restricted areas during the 1883 seismic sequence.

Less violent emission of fine juvenile material from the Central Crater continued throughout the eruption and renewed at the end of the unrest. Similar activity was sporadically reported from April till the end of the year.

4. The 1971 case history

The 1971 eruption is among the main flank events in this century for duration, volume of lava erupted, and dynamics of the eruptive fissure opening (table II) (Guest and Skelhon, 1973). It followed a period (1966-1971) of persistent activity at the Northeast Crater characterised by strombolian explosions and low rate lava effusion (Rittmann *et al.*, 1971). The unrest began (fig. 1) on April 5 near the summit of the volcano (vents a and b) and then two new vents (c, d) opened on April 22 and May 4 respectively and remained active until May 6. The next day (May 7) the eruptive theatre shifted to the upper eastern flank of the volcano where a set of fractures opened in the Valle del Bove (vent e) and in the Serracozzo area (vent f), remaining active until May 16 and June 12, respectively. Finally a degassing vent (SE) opened in the summit area where the Southeast Crater subsequently formed (Calvari *et al.*, 1994). Lava flows from the 1971 eruption destroyed the Etna cable-way and roads and fields near the village of Fornazzo (fig. 1). During the eruption only two seismic stations (fig. 2) were operating on the volcano (Serra la Nave station was out of order). In the months before the eruption the data collected consisted of a few shocks recorded only at the Acireale station (fig. 6), the Catania one being out of order. The latter recorded some low magnitude events a few days before the eruption and also during the eruptive period, while the Fondo Macchia destructive earthquake (Riuscetti and Distefano, 1971) occurred on the eastern flank on April 21 (fig. 7). The seismic rate increased some days before the end of the eruption and reached a maximum in concomitance with the end of the unrest (fig. 6). However, these data seem to indicate that during the eruption seismicity was mostly characterised by very shallow, low magnitude events with epicentres near eruptive sites. After the end of the volcanic unrest, seismicity continued throughout

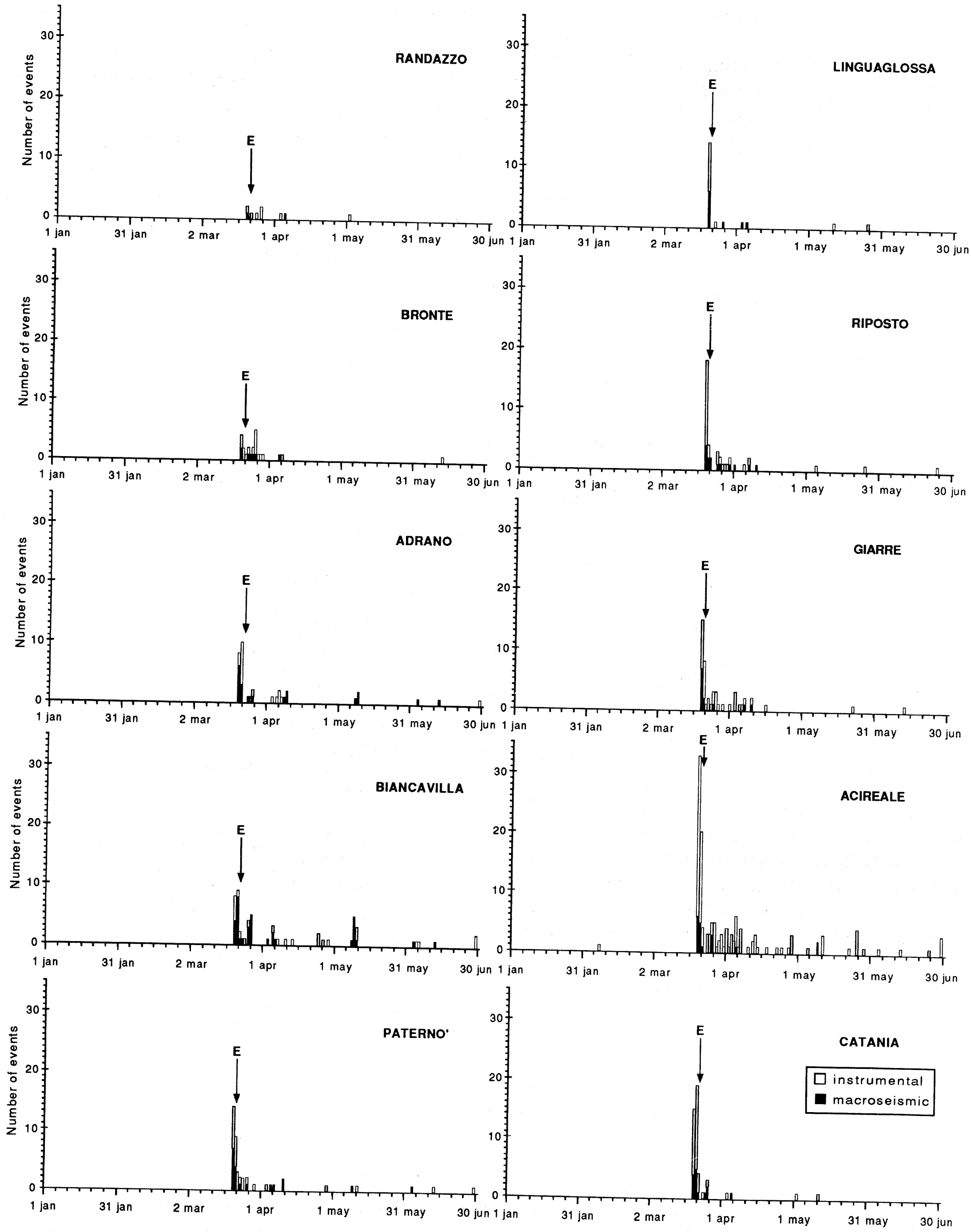

Fig. 5. Daily seismic frequency recorded at different stations from January to June 1883.

Table II. Volcanological parameters of the 1971 eruption. Compiled from information in Azzaro and Neri (1992).

Date		Onset 05-04-1971	End 12-06-1971	Days 69
Eruptive system	Location	*Summit area* (a-c); *eastern flank*: *Valle del Bove* (d-e), *Serra delle Concazze* (f)		
	Altitude (m a.s.l.)	2975 (a); 3050 (b); 3020 (c); 2880 (d); 2680, 2580-2540, 2300 (e); 1840-1800 (f)		
	Vent	Scoria cones (a-d), eruptive fissures (e-f)		
	Denomination	*Mt. Ponte* (a)		
Flows	Maximum length (km)	7.2 {3.3 (a); 3.7 (b); 2.8 (c); 3.3 (d); 1.7, 1.9, 0.8 (e); 7.2 (f)}		
	Average thickness (m)	9.9		
	Altitude attained (m a.s.l.)	600 {2175 (a); 1670 (b); 2325 (c); 1750 (d); 1925, 1930, 2050 (e); 600 (f)}		
	Area (km^2)	7.6 {1.37 (a); 1.23 (b); 0.5 (c); 0.55 (d); 0.4, 0.4, 0.1 (e), 3.05 (f)}		
	Volume of lava (10^6 m^3)	75		
	Volume of pyroclastics (10^6 m^3)	3		
	Mean effusion rate (m^3/s)	13		

the year. It reached its maximum in September, in concomitance with renewal of the explosive activity at the Central Crater (Bottari *et al.*, 1975), but no detailed information is available on the epicentral locations.

5. Discussion

5.1. *The 1883 eruption*

After 4 months' total lack of seismicity (since November 1882), the seismic crisis started on March 20 1883, two days prior to the eruption onset. The earthquake hypocentres were deep beneath the central sector of the volcano and were recorded at all stations (fig. 5). Soon after, weak shocks were felt on the southern, eastern and lower south-western flanks (Appendix A). On March 21, some hours before the eruption started, the seismic rate increased. Shallower shocks occurred in the southern flank, the strongest of which were felt at Nicolosi, Paternò and Biancavilla.

It is suggested that the feeder dyke emplacement occurred on March 20, and was marked by the seismic sequence which started two days prior to the eruption. A change in local stress caused seismic release in shallow faults near the site where the eruptive fracture later opened – «continuous tremors» at Nicolosi and weak shocks felt nearby – and also in the south-western and eastern flanks of the volcano (fig. 3: sectors a and c). These shallow shocks affected NW-SE, NE-SW fault systems and seem to have been directly connected with the vent opening. The tensile stress responsible for the splitting of the 1883 eruptive fissure could have caused a loading of the nearby fault systems (fig. 3, sector a and b). The diffuse seismicity on the volcano stopped during the eruption (March 22 to 24) and local shocks affected mainly Nicolosi and nearby areas.

Accommodation of stresses following magma injection (Lo Giudice and Rasà, 1986) can account of the stronger earthquakes located on the eastern flank of the volcano (fig. 3: sector c). This area, considered a distinct shallow seismotectonic domain gliding eastward by gravitational stresses (Lo Giudice and Rasà, 1992), is where seismic releases occur most frequently, especially during eruptions as testified by recent frequent seismicity felt by people (*e.g.*, 1984, 1986, see Azzaro *et al.*, 1989). From the end of the eruption (March 25) till May, rearrangement of the residual stresses could have renewed the seismicity both near the eruptive site (shocks and continuous «tremors» felt at Nicolosi) and in the nearby faults (fig. 3: sectors a, b).

The NE-SW tectonic trend (fig. 3: sector a), where frequent seismic activity has been reported by both historical (Imbò, 1935) and recent (Azzaro *et al.*, 1989, 1992) macroseismic investigations, is correlated with the regional fault system and seems to play a fundamental role in the eruptive dynamics of Mt. Etna (Ferrucci *et al.*, 1992). In addition to seismicity, secondary volcanic phenomena such as mud volcanoes (*Salinelle*) and mineral springs occur in this sector of the volcano. Silvestri (1883) reported exceptional activity of *Salinelle* at Paternò, consisting of water-spouts ejected by high CO_2 fluxes. Such activity had lasted since 1879 and stopped suddenly just one month before the 1883 eruption. Recently Giammanco *et al.* (1993) detected a similar decrease in the

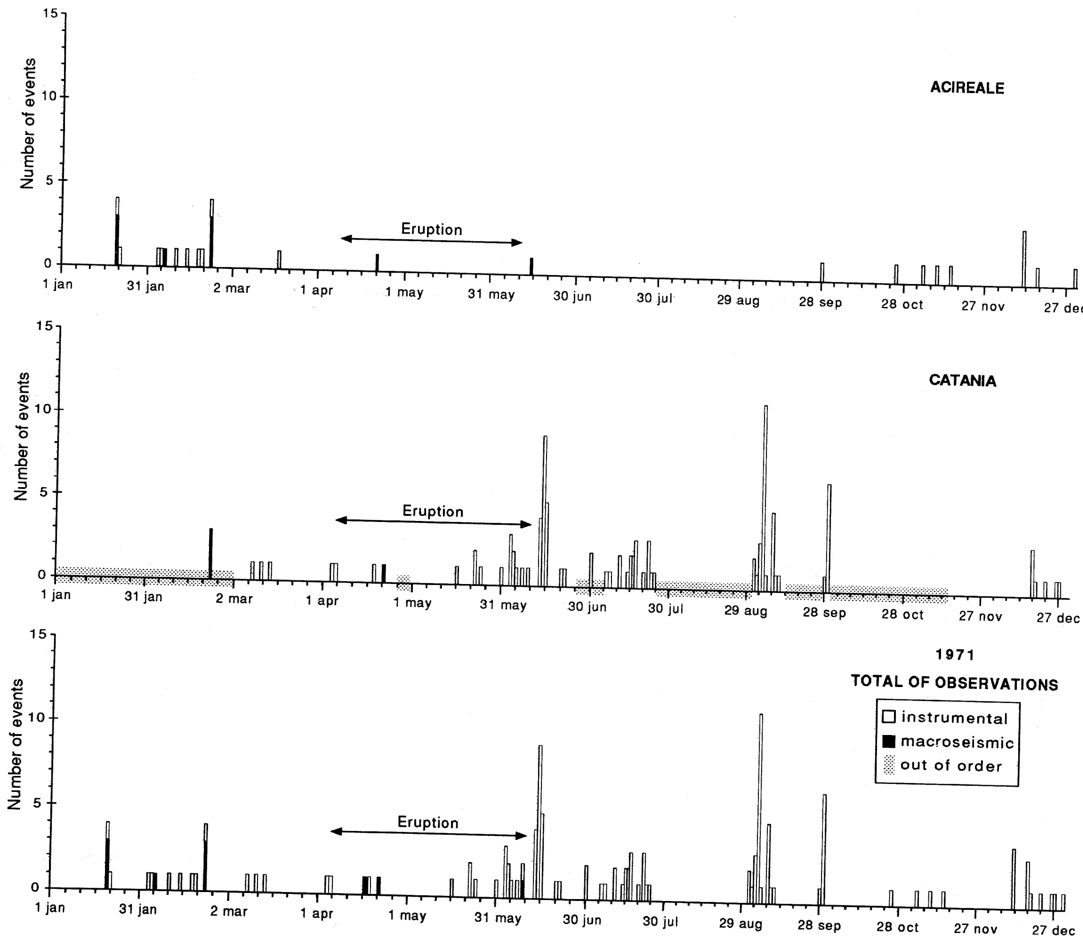

Fig. 6. Daily seismic frequency recorded at Mt. Etna during 1971.

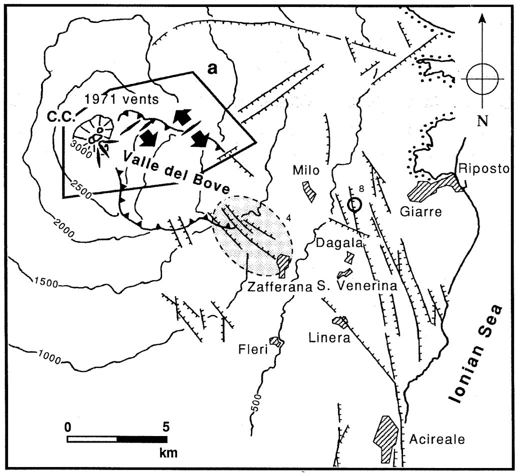

Fig. 7. Epicentral map of the main 1971 macroseismic earthquakes. Symbols as in fig. 2. For the inset (a) see text.

temporal variation of CO_2 fluxes before the 1991-1993 eruption in the same area. These phenomena, somehow related to volcanic and tectonic activity, warrant further investigation.

5.2. *The 1971 eruption*

During 1971 the scant seismological information available seems related to a different seismic behaviour as well as an incomplete data set. There were few earthquakes felt (Appendix B) and instrumental seismicity was recorded by peripheral stations far from the volcano summit (fig. 2). Low magnitude earthquakes detectable only by a local array on the upper flanks (*i.e.*, Barbano *et al.*, 1979; Ferrucci *et al.*, 1993; Ferrucci and Patanè, 1993; Lombardo and Cardaci, 1994), may not have been recorded.

In January, three months prior to the eruption onset some deep earthquakes were recorded, while shallower earthquakes also affected the eastern flank of the volcano in February. These considerations on depth are inferred from the perceptibility area of earthquakes, because no instrumental determination is available. On April 5, the eruption began at the summit without being preceded by any significant seismic activity in a short time interval, as observed in some cases (Lombardo and Cardaci, 1994). The opening of flank fractures (May 7) was not accompanied by recorded seismic activity at remote stations (Rittmann *et al.*, 1971) as it was during the propagation of the 1989 NE system fracture (Ferrucci *et al.*, 1993).

The low number of events and associated seismic release seem to suggest a condition of relatively little change in the stresses acting on the volcano because the magma column was already high in the central feeding system (Guest, 1982). In fact, the volcanic unrest began as a summit eruption and thereafter a set of N65°E fissures opened progressively at lower altitudes on the eastern flank due to a «hydrostatic load» of magma column passively inducing dyke emplacement along a weakness zone (Rittmann *et al.*, 1971).

6. Conclusions

The eruptions analysed showed different seismic behaviour: the 1883 one presented high seismic energy release, while the 1971 one a relatively low level of seismicity. Data analysis identified the following features of seismicity: i) connected to dyke emplacement, deep earthquakes located in the central sector of the volcano before the eruption, and shallower ones with epicentres on faults near the vents during the opening of the eruptive fissures; ii) independent from eruptive activity, shallow shocks located on eastern and southwestern flanks of the volcano, and probably related to general stress accommodation following magma injection.

The high seismicity associated with the 1883 small volcanic unrest meaning a substantial rearrangement of stress at local and large scale, could be explained, according to Silvestri (1893), by considering this eruption as a first forced outbreak of magma along a N-S plane related to a single, large-scale fracturing episode that later gave rise to the 1886 and 1892 eruptive events. These eruptions were characterised by increased duration, greater volume of erupted lava and higher altitude of

Table III. Main parameters of the 1883, 1886 and 1892 eruptions at Mt. Etna. Compiled from information in Arcidiacono (1893, 1903); Silvestri (1893); Romano and Sturiale (1982).

Date (onset)	Duration (days)	Volume of lava (m^3)	Vent altitude (m/a.s.l.)	Fissure length (km)
1883-03-22	3	50.4×10^3	950-1200	3.5
1886-05-19	20	48×10^6	1300-1450	1.2
1892-07-09	173	120×10^6	1750-2050	1.5

vents (table III) which opened upward of each other along the same fracture system (fig. 3). Moreover, it must be stressed that seismic activity preceding the onset of these eruptions (Arcidiacono, 1893, 1902) was progressively lower and affected the same structural systems of the volcano.

Such a single intrusive episode leading to distinct volcanic events does not seem rare on Mt. Etna, as recently observed in the 1989 and 1991-1993 eruptions (Ferrucci *et al.*, 1993). The opening of the 1989 SE fissure system was accompanied by a seismic swarm on the lowermost tip of the fracture, without being followed by effusive activity. The 1991-1993 fissure opened upslope on the same fracture and was preceded by a first seismic swarm that was probably related to the feeder dyke emplacement. A second swarm involving the NE-SW coniugate structural system was interpreted as an elastic response of the medium to the stress applied by the magma push (Ferrucci and Patanè, 1993).

Totally different behaviour was seen during the 1971 eruption when moderate seismic release was associated with high dynamics of eruptive fissure opening and substantial volumes of erupted lava. Very low seismicity all over the volcanic edifice preceding eruptions starting with summit activity, and thereafter developing on the flanks, was also observed at Mt. Etna in 1981 and 1985 (Lombardo and Cardaci, 1994). This behaviour may suggest that the eruption occurred without a significant change of stress as a result of passive emplacement of magma. Most of the posteruptive shocks could be related to stress rearrangement.

Finally, the different features in the rate, space and time evolution of seismicity associated with the 1883 and 1971 eruptions (as emerged also from the greater amount of historical data available for 1883) are consistent with the different stress conditions and dynamics acting on the volcanic system.

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Appendix A. 1883 macroseismic earthquake catalogue. In brackets = epicentres located by comparison with well known events; in italics = probable epicentre location; asterisks = effects due to several indistinguishable shocks. Seismic stations (see fig. 1): AC = Acireale; AD: Adrano; BL = Belpasso; BN = Biancavilla; BR = Bronte; CT = Catania; GR = Giarre; LG = Linguaglossa; MN = Mineo; PT = Paternò; RN = Randazzo; RP = Riposto. Sources: 1 = Silvestri, 1883; 2 = Ricciardi, 1883; 3 = Cafiero and Pennisi, 1883a; 4 = Cafiero and Pennisi, 1883b; 5 = Cafiero and Pennisi, 1883c; 6 = De Rossi, 1883; 7 = De Rossi, 1884.

No.	Date y m d	Time GMT	I_{max}	Epicentral area	Felt area	Instrumental data	Ref.
1	18830207	0917	4-5	(Pizzo Carammo) *(Mascalucia-Tremestieri fault)*	Mascalucia	AC	1
2	18830320	0230	5	*Southern flank*	Nicolosi - other localities (not specified) (F)		1
3	18830320	0320	4		Acireale, Riposto		1, 3, 6
4	18830320	0452	4-5	*Eastern flank*	Catania, Acireale, Giarre, Riposto, Nicolosi, Linguaglossa-Randazzo, Trecastagni, Paternò, Belpasso, Adrano, Viagrande, Bronte, Pedara (3)		1, 3, 6
5	18830320	0703	4	*Central sector*	Riposto, Giarre, Linguaglossa, Paternò, Nicolosi	AC, CT	1, 6
6	18830320	0839	4	*Central sector*	Riposto, Linguaglossa, Adrano, Biancavilla, Paternò, Nicolosi	AC, CT, GR	1, 6
7	18830320	1114	4-5	*Lower SW flank*	Paternò	AC	1
8	18830320	1228	4		Giarre	AC, LG, PT, BN	1
9	18830320	1256	4	*SW flank*	Biancavilla	CT, AC, AD	1
10	18830320	1312	4-5	*Lower SW flank*	Paternò	AC	1
11	18830320	1346	4-5	*Lower SW flank*	Paternò	CT, BN, AD, RP, BR, LG, AC	1
12	18830320	1417	4-5	*Eastern flank*	Riposto - Giarre (4) - Acireale (3)	AC	1
13	18830320	1436	4-5	*Eastern flank*	Acireale		3, 6
14	18830320	1443	4-5	*Southern flank*	Paternò - Catania (4)	AC, RP, LG	1
15	18830320	1501	4-5	*Eastern flank*	Acireale	RP, GR, LG	1
16	18830320	1511	4-5	*Eastern flank*	Acireale	GR, RP	1
17	18830320	1557	4-5	*Eastern flank*	Acireale		1
18	18830320	1753	4	*Central sector*	Giarre	CT, AC, BN, PT	1
19	18830320	1807	4		Catania	AC, PT, BN	1
20	18830320	1937	4-5	*Eastern flank*	Giarre, Linguaglossa, Adrano - Acireale (4)	RP	1, 3, 6
21	18830320	2045	4-5	*SW flank*	Biancavilla - Bronte, Adrano, Catania (4)	AC, RP, LG, RN	1
22	18830320	2053	4		Bronte, Adrano, Acireale	LG, CT	1, 3, 6
23	18830320	2134	4		Linguaglossa		1
24	18830320	2234	4		Acireale, Giarre		1
25	18830320	2325	4-5	*Eastern flank*	Acireale	GR	1
26	18830320	all day	6	*	Nicolosi, Zafferana (5-6) - Linera, Bongiardo, S. Venerina, Dagala, Macchia, Milo (3-4)		1

Appendix A (*continued*).

No.	Date y m d	Time GMT	I_{max}	Epicentral area	Felt area	Instrumental data	Ref.
27	18830320	all day	3-4	*	Castiglione, Francavilla, Calatabiano, Mts. Nebrodi		1
28	18830321	0050	4-5	*Lower E flank*	Riposto - Acireale, Biancavilla (4)		1
29	18830321	0154	4		Riposto		1
30	18830321	0214	4-5	*Eastern flank*	Giarre	AC	1
31	18830321	0305	4		Acireale - Randazzo (3)		1
32	18830321	0504	4-5	*Southern flank*	Misterbianco - Adrano, Biancavilla, Paternò (4)	RP, AC, CT	1
33	18830321	0721	4-5	*SW flank*	Biancavilla	GR, RP, AC	1
34	18830321	1007	4	*SW flank*	Adrano and Biancavilla	AC, PT	1
35	18830321	1127	4	*Southern flank*	Catania, Acireale, Adrano, Biancavilla	MN	1
36	18830321	1307	4		Giarre	AC, BR, AD	1
37	18830321	1338	4		Giarre	AC	1
38	18830321	1446	4		Giarre	CT, AC, AD, PT	1
39	18830321	1546	4		Catania	AC, AD, PT	1
40	18830321	1617	4		Acireale - Biancavilla, Paternò (3)	CT, AD	3, 6
41	18830321	1715	5-6	Lower SW flank	Outskirts of Paternò - Paternò (4-5) - Biancavilla (3)	AC, AD, CT	1, 2
42	18830321	1719	4		Catania	AC, AD	1
43	18830321	1820	4		Paternò, Biancavilla	AC, CT	1
44	18830321	2030	4		Acireale, Giarre, Paternò - Catania (3)		1
45	18830321	2345	5	*Contrada Renazzi*	Nicolosi	CT	1
46	18830321	night	6-7	Lower E flank	Dagala *		3
47	18830321	night	5-6	Lower E flank	S. Venerina *		3
48	18830321	night	5-6	Lower E flank	Linera *		3
49	18830321	night	6-7	Lower E flank	Milo *		3
50	18830321	night	6-7	Lower SW flank	Biancavilla		3
51	18830322	0015	7-8	Contrada Renazzi (*1883 eruptive vents*)	Nicolosi - Zafferana (6-7) - Borrello, Belpasso, Mascalucia, Pedara (5) - Catania (4)		1, 2
52	18830322	0114	4	Eastern flank	Acireale, Giarre, Riposto		1
53	18830322	0430	4		Nicolosi		1
54	18830322	0624	4		Riposto	AC	1
55	18830322	0757	4-5	*Lower SW flank*	Biancavilla	AC, CT	1
56	18830322	2230	6-7	Contrada Renazzi (*1883 eruptive vents*)	Nicolosi, Belpasso - Raccuia (landslide)		6
57	18830323	0030	4-5	*Contrada Renazzi*	Belpasso, Nicolosi		6
58	18830323	0105	4-5		Catania		6
59	18830323	0215	4		Paternò		1
60	18830323	0438	4-5	Eastern flank	Riposto - Giarre (4)	LN	1
61	18830323	1300	4		Giarre		1
62	18830323	1713	4	SW flank	Biancavilla	PT	1
63	18830323	1830	4		Bronte		1
64	18830323	2320	4-5	SW flank	Belpasso, Biancavilla, Adrano, Nicolosi - Catania (4)		6
65	18830324	1051	4	SW flank	Adrano	CT, AC, PT, BN, BR, RN	1

Appendix A (*continued*).

No.	Date y m d	Time GMT	I_{max}	Epicentral area	Felt area	Instrumental data	Ref.
66	18830324	1300	4		Nicolosi		6
67	18830325	1300	4		Giarre - Nicolosi, Belpasso, Zafferana (3-4)		1
68	18830325	1505	4		Giarre - Nicolosi, Belpasso, Zafferana (3-4)		1
69	18830325	1942	4		Bronte		1
70	18830326	0122	4		Riposto	BR	1
71	18830326	0720	4		Biancavilla		1
72	18830326	0754	4	*SW flank*	Biancavilla, Adrano, Paternò	BR, AC	1
73	18830326	0835	4-5	*Contrada Renazzi*	Belpasso, Nicolosi, Riposto - Catania, Acireale, Biancavilla (4)	BR	1
74	18830326	1511	4		Biancavilla, Acireale, Giarre, Bronte	AD, RN	1
75	18830326	2035	4		Catania, Acireale, Giarre, Linguaglossa, Riposto		1, 3
76	18830326	2126	6-7		Nicolosi		6
77	18830326	2345	4		Giarre - Riposto (3)	PT	1
78	18830327	0018	4		Biancavilla		1
79	18830327	0031	4-5	Lower E flank	S. Venerina, Bongiardo	AC	6
80	18830327	0615	4		Biancavilla		1
81	18830327	0700	4		Biancavilla		1
82	18830327	1554	4		Biancavilla - Adrano (2)	AC	1
83	18830327	1630	4		Biancavilla, Giarre	AC	1
84	18830329	night	4-5	*Contrada Renazzi*	Nicolosi, Belpasso *		6
85	18830330	0100	4-5	*Contrada Renazzi*	Nicolosi		1
86	18830330	0315	4-5	*Contrada Renazzi*	Nicolosi		1
87	18830330	1830	4		Riposto		1
88	18830403	1036	4	*Upper eastern flank*	Giarre, Riposto, Linguaglossa, Nicolosi - Randazzo (2)	CT, AC	1
89	18830403	1058	4		Giarre - Pedara, Viagrande (3)	AC	1
90	18830403	1840	4		Giarre		1
91	18830404	night	4-5	*Southern flank*	Pedara *		6
92	18830405	0035	4		Acireale		6
93	18830405	0137	4		Acireale		6
94	18830405	0858	5-6	*Central sector*	Nicolosi - Giarre (5) - Acireale, Riposto, Catania, Biancavilla, Linguaglossa, Randazzo, Paternò (4-5) - Bronte (3) - Adrano (2)		1, 4
95	18830406	1657	4	Lower SW flank	Paternò, Biancavilla	AD, BR	1
96	18830410	1555	4	Eastern flank	Giarre - Riposto (3)	AC	2
97	18830410	2045	4	Lower SW flank	Paternò	BN	1
98	18830410	2240	4		Paternò		1
99	18830413	0631	4		Acireale		1
100	18830427	1830	4-5	Nicolosi			6
101	18830427	1922	4-5	Nicolosi			1
102	18830427	2230	3-4	Nicolosi			6
103	18830427	2245	3-4	Nicolosi			1
104	18830427	2335	3-4	Nicolosi			1
105	18830428	0125	6-7	Nicolosi			1

Appendix A (*continued*).

No.	Date y m d	Time GMT	I_{max}	Epicentral area	Felt area	Instrumental data	Ref.
106	18830428	1530	5-6	Torre di Grifo (*Mascalucia-Tremestieri fault*)	Nicolosi (3-4)		1
107	18830430	all day	3-4		Nicolosi *		1, 6
108	18830502	0630	4-5	Grotta d'Angela	Nicolosi (4)		1
109	18830502	2234	4-5	Grotta d'Angela	Nicolosi (4)		1
110	18830504	0130	3-4		Nicolosi		6
111	18830504	0745	4	Ragalna	Nicolosi (3-4)		6
112	18830504	1015	4-5		S. Leo - Nicolosi (3)		6
113	18830509	0415	4	*SW flank*	Adrano, Biancavilla, S. Maria Licodia, Paternò	AC	1
114	18830509	0450	4	*SW flank*	Biancavilla - Adrano (3)		1
115	18830509	0725	4	*SW flank*	Biancavilla		1
116	18830509	0900	4	*SW flank*	Biancavilla		1
117	18830510	2050	4	*SW flank*	Biancavilla		1
118	18830511	1445	4-5	(Val Calanna)	Zafferana		1
119	18830602	2336	4-5	*Southern flank*	Nicolosi - Biancavilla (4) - Adrano, Paternò (3)	AC, MN	1, 6
120	18830603	0000	4-5	*Central sector*	Nicolosi	RN	1, 6
121	18830603	2346	4-5	*SW flank*	Nicolosi, Belpasso	BN	5, 6
122	18830612	1834	4-5	*SW flank*	Biancavilla - Randazzo, Adrano, Belpasso, Nicolosi, Zafferana (3)	AC, BR, PT, GR	1, 5, 6
123	18830617	0845	4-5		Nicolosi		1, 6
124	18830624	0747	6-7	(Contrada Algerazzi)	Dagala, Zafferana, Milo - Nicolosi (4-5)	AC, RP	1, 5
125	18830624	0930	4-5	Nicolosi			1
126	18830628	2330	5	*Contrada Renazzi*	Belpasso - Nicolosi (4-5) - Pedara, Biancavilla (3-4)		1, 5
127	18830629	0100	4-5	Nicolosi			1, 6
128	18830712	1430	4	Nicolosi			1
129	18830715	1808	4		Randazzo	AC	7
130	18830816	0822	3-4	*Contrada Renazzi*	Nicolosi	PT, AC	2, 7
131	18830928	1400	4	*SW flank*	S.Maria Licodia, Biancavilla		1
132	18831007	0445	4-5	Nicolosi			2
133	18831028	2030	3-4	Ragalna			1
134	18831113	1700	5-6	Zafferana-Pisano	Nicolosi (3)		1
135	18831113	1730	3-4	Zafferana, Pisano			2
136	18831220	0020	4-5	*Central sector*	Nicolosi, S. Maria Licodia - Paternò, Biancavilla (2)	AC, LN	1

Appendix B. 1971 macroseismic earthquake catalogue. Stations: AC = Acireale; CT = Catania; ME = Messina. Sources: 1 = La Sicilia, Catania newspaper, 1971; 2 = Bollettino Sismico, 1971, Istituto Nazionale di Geofisica; 3 = Riuscetti and Distefano, 1971.

No.	Date y m d	Time GMT	I_{max}	M_l	Epicentral area	Felt area	Instrumental data	Ref.
1	19710120	1557	3-4			Acireale, Giarre, Biancavilla, Adrano		1
2	19710120	1656	3-4			Acireale, Giarre, Biancavilla, Adrano	AC	1
3	19710120	1659	3-4			Acireale, Giarre, Biancavilla, Adrano	AC	1
4	19710206	2345	4-5			Zafferana	AC	1
5	19710222	0944	3-4		(37.500N 15.000E) *Southern flank*	Catania - Acireale (3), and other localities (not specified)	AC, ME	1, 2
6	19710222	0953	3-4			Catania - Acireale (2), and other localities (not specified)	AC, ME	1
7	19710222	1431	3-4		(37.800N 15.167E) Upper E flank	Catania - Acireale (2) and other localities (not specified)	AC, ME	1, 2
8	19710421	1630	8	4.0	Fondo Macchia (*Moscarello fault*)	Cerza Spirdo - Sciara, Baglio (7-8) - Rondinella (7) - Monacella di sotto (6-7) - Moscarello (6) - Dagala, Codavolpe, S. Giovanni, Croce (5-6) and other localities (not specified)	CT	1, 2, 3