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H4.SMR/1150 - 31

Fifth Workshop on Non-Linear Dynamics
and Earthquake Prediction

4 - 22 October 1999

Irregular Regularities in Regional Seismicity

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The catalogue of Carrozzo et al. (1973) lists about 10,000 events from the year 0 until 1970 (however, only 94 of them occurred prior to the year 1000). The Baratta (1901) catalogue was compiled at the end of the 19th Century, although it is an important document, it is not as complete as the others, mostly for the smaller events; it does not give intensities nor coordinates of the events but important detailed description of the locations and the damages which occurred there. In the ENEL catalogue (1978) the epicentral coordinates of the events which were recorded instrumentally have been recomputed using the most updated models of the Italian territory, where this was not possible the epicenters were estimated from the isoseismals or assuming it where the largest damage was recorded or, in case of the smaller events, where the event was felt. In most cases we may assume the accuracy of the epicentral coordinates is less than 10 km.

A comparison of the two catalogues made by Caputo (1981) shows that the most frequent disagreement between the catalogues of ENEL (1978) and Carrozzo et al. (1973) concerns the intensity of historic earthquakes which had to be inferred from the description of the events in very old books or cronicles; the disagreements between the intensities of the events of the areas considered in this study is limited to at most one degree of intensity; in all Italian earthquakes with $I \geq$ IX, for 38 events I is larger in the Carrozzo et al. (1973) catalogue, for 5 events I is larger in the ENEL catalogues. The ENEL catalogue is not only the most complete but apparently it is also more accurate in the epicentral coordinates and intensity of the events. For this study we therefore used the ENEL catalogue.

Assuming that the statistical density distribution of the number of earthquakes does not change with time in 1000 years and provided reasonably long time intervals for the statistics are considered, we obtain for the completeness of the ENEL catalogue the time windows listed in Table I; as in most catalogues of earthquakes, the completeness is increasing with time. Table I was obtained by considering time windows at 10 and 25 years which gave the same results. The distribution of events in time windows of 25 years is shown in Table II.

The time T_I, after which the catalogue was tentatively considered complete for the intensity I, was estimated assuming that the average number of events $n(I, \Delta, t)$ in

TABLE I

Completeness of the ENEL (1978) Catalogue of Italian Earthquakes

Intensity, I	Completeness of the catalogue
$\geq$ VI	1885–1975
$\geq$ VII	1775–1975
$\geq$ VIII	1700–1975
$\geq$ IX	1600–1975
$\geq$ X	1550–1975
$\geq$ XI	1000–1975

seismic network and/or the macroseismic service were such to secure the completeness of the catalogue. For instance, one may assume that from the beginning of the century the seismic network and macroseismic service would detect all events of intensity VII or larger, or that all events with intensity XI and XII were reported in the cronicles from year 1000.

Given a Δ_I which secure $n(I, \Delta, t) \geq 10$ (note that for all Δ_I considered and $I < IX$ there is one exception, namely for $I = VIII$ and $\Delta_{VIII} = 1774-1750$) one compares $|\langle n_{\Delta I}\rangle - n(I, \Delta, t)|$ with $\sigma_{\Delta I}$; the catalogue is then considered complete after the year T_I if $|\langle n_{\Delta I}|\rangle - n(I, \Delta, t)| < \sigma_{\Delta I}$ for $t \geq T_I$. It has always been verified that for time windows prior to T_I one finds $|\langle n_{\Delta I}\rangle - n(I, \Delta, t)| > \sigma_{\Delta I}$. For $I = VI$ we used $\Delta_I = 10$ years, for $VI < I < IX$ we used $\Delta_I = 25$ years; for $I = IX$ we used $\Delta_I = 50$ years; in this case $n(I, \Delta, t) \geq 9$.

It has also been verified that for $I = VII$ the windowings with $\Delta_I = 10$ years and $\Delta_I = 25$ give the same results, taking into account the lower resolution of $\Delta_I = 25$; and also that for $I = VIII$, the windowing with $\Delta_I = 25$ and $\Delta_I = 50$ give the same results. Moreover the initial time of the windowing with $\Delta_I = 10$ has been shifted by 2 years, that with $\Delta_I = 25$ has been shifted by 5 years, and that with $\Delta_I = 50$ has been shifted by 25 years verifying that one obtains for T_I the same results.

The $I = X$ deserves special attention because the number of events per century in the last five centuries in general is less than 10, for instance the number of events in the interval 1875–1975 is 4; considering the historic conditions of Italy prior to 1500 and that between 1400 and 1500 only one event was recorded, after applying the above mentioned criterion we tentatively assumed $T_x = 1500$ verifying that $\sigma_{\Delta x} > |\langle n_{\Delta x}\rangle - n(x, \Delta, t)|$ for $t < T_x$. However, we cannot rule out that the large fluctuation prior to 1500 be real.

Another test of completeness has been done by comparing the a_1 and b_1 values of the law:

$$\log n = a_1 - b_1 I$$

for time windows beginning at different times in the past. The results of this test are in agreement with those of the previous tests.

In this study we consider two areas: the circle of 140 km radius centered in the Messina Strait (area B) (see Fig. 1) and the portion of the Southern Apennines between latitudes 39°N, 41.8°N (area A) (see Fig. 2). Both areas have been very seismic in the past. For the area A, the ENEL (1978) catalogue lists 38 earthquakes with intensity IX or more occurring after 1448. For the area B, the ENEL (1978) catalogue lists 16 events with intensity X or more occurred after the year 1100. It is worth noting that both areas include a large or complete portion of the D (dangerous) areas defined in southern Italy by a pattern recognition study of earthquake-prone areas of Italy (Caputo et al., 1980). Area A includes the epicenter of the November 23rd 1980 earthquake ($M_s = 6.9$) which coincides with intersection 77 of Fig. 2.

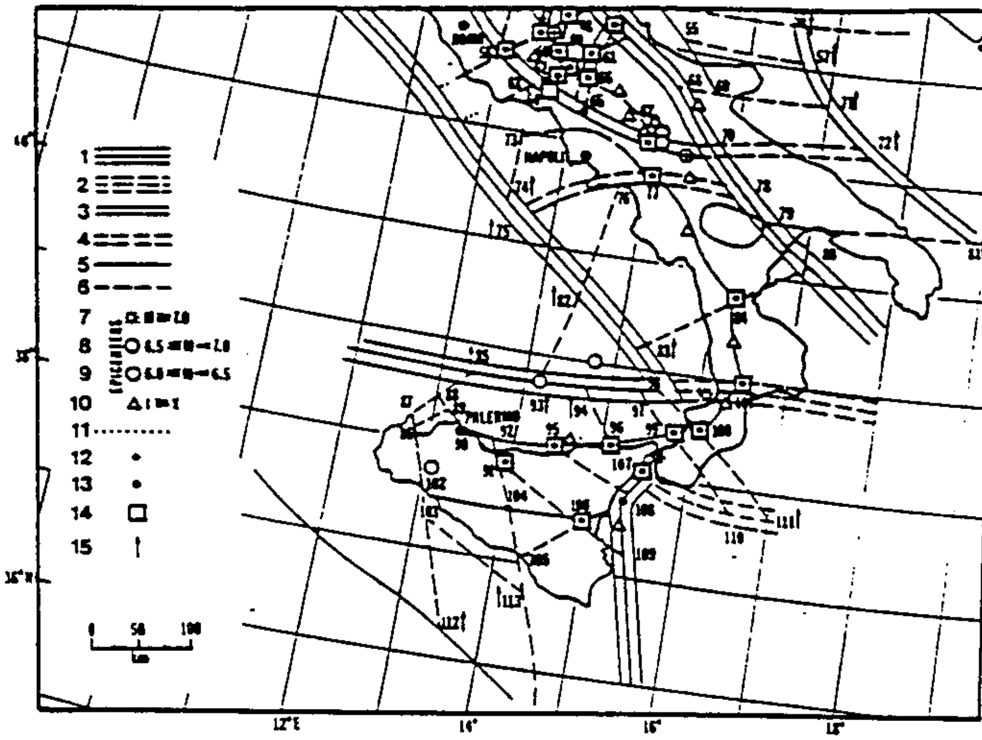

Fig. 2. Map of the major lineaments of the Italian region, and of the intersections of the lineaments considered as potentially dangerous. Numbers in the key refer to the following classification of lineaments, epicenters, boundaries and intersections. Lineaments: *1*, *2* = first order; *3*, *4* = second order; *5*, *6* = third order; *1*, *3* and *5* longitudinal, *2*, *4* and *6* are not expressed in topography. *7*, *8*, *9*, *10* = epicenters, *11* = uncertain lineaments (covered by sediments or sea). Intersections: *12* = recognized as D in the basic variant; *13* = recognized as uncertain in the basic variant; *14* = recognized as D in the earthquake future experiment; *15* = not used because the intersections are on the outer boundaries of the regions.

THE MESSINA STRAIT AREA

The 16 earthquakes shown in Fig. 2 have intensity X or more in one of the catalogues of Carrozzo et al. (1973) and ENEL (1978). The probability that 16 events distributed over 980 years are agregated in 8 pairs, and that the two events of each pair are separated by at most 25 years, is less than $7 \cdot 10^{-5}$.

Let E_i be the earthquake that occurred at time t_i ($t_{i+1} > t_i$; $i = 1{,}16$). We shall consider a pair of two earthquakes E_{2j}, E_{2j-1} ($j = 1{,}8$); the time ($t_{2j} - t_{2j-1}$) separating the two elements of each pair (see Fig. 1) is less than 23 years. $\langle t_{2j} - t_{2j-1} \rangle = 10$ years. The time separating two successive pairs, $t_{2j+1} - t_{2j}$, has an average value of about 100 years.

TABLE III

Sequences of large earthquakes in the Southern Apennines (between the latitudes 39°N and 41° 50'N)

Time window	Events (intensity, year)	Number of events	Time to second event of sequence (years)	Length of time window of each sequence (years)	Gap between successive sequences (years)
1448–1456	IX, 1448; XI, 1456; IX, 1456	3	8	8	94
1550–1561	IX, 1550; IX, 1560; IX, 1561; X, 1561	4	10	11	66
1627–1627	IX, 1627; X½, 1627;	2	0	0	11
1638–1638	X, 1638; IX, 1638	2	0	0	8
1646–1654	IX, 1646; X, 1654; IX, 1654	3	8	8	34
1688–1702	X, 1688; X, 1694; IX, 1702	3	6	14	29
1731–1732	X, 1731; IX, 1732	2	1	1	23
1755–1767	IX, 1755; IX, 1767	2	12	12	29
1796–1805	IX, 1796; X½, 1805	2	9	9	21
1826–1836	IX, 1826; IX, 1828; X, 1832 IX, 1835; IX, 1836; IX, 1836	6	2	10	15
1851–1858	IX, 1851; IX, 1854; IX, 1857; X, 1857; X, 1858	5	3	7	12
1870–1883	X, 1870; IX, 1883	2	13	13	27
1910–1913	IX½, 1910; IX, 1913	2	3	3	67
1980–?	X, 1980	?	?	?	
Average		3	5.7	7.4	33

33 years in average. The total alarm time between the first and the second event of each sequence is 75 years or about 16% of the total time for 13 pairs from the first event of the first pair.

In all of these sequences of events except those after the years 1550, 1646, 1796, 1851, the first event of the sequence has the largest intensity.

The statistical distribution of earthquakes was studied since the beginning of seismology; some early studies (AKi, 1956; Knopoff, 1964) concluded that the main sequence events were non-Poissonian. However, it has been noted (Gardner and Knopoff, 1974) that the California earthquakes with $M \geqslant 3.8$ between 1952 and 1971, after properly removing the aftershocks have a Poissonian distribution, that the same property is valid also for $M \geqslant 4.3$, $M \geqslant 4.8$, $M \geqslant 5.3$, but for $M \geqslant 5.8$ the number of events is not sufficient to draw any conclusion. Also the number of events considered in Table III is insufficient to draw any conclusions as to their statistical distribution law; however, assuming tentatively that their distribution is Poissonian, we find that the probability that 38 events distributed over 532 years are aggregated in 13 sequences, such that in each sequence there are at least two events and the time

TABLE IV

Average successive inter-arrival time in each sequence of Table III

	1st–2nd	2nd–3rd	3rd–4th	4th–5th	5th–6th
Inter-arrival time in years	5.9	2.8	1.2	0.63	0.57
Number of cases	13	6	3	2	1

The pattern recognition study of the earthquake prone areas in Italy does not necessarily forecast the location of the expected earthquakes in area B because the intensity of these events is anticipated to be IX or more which in turn could imply a magnitude less than 6.5 which escapes the possibilities of the pattern recognition study aiming to magnitudes $M \geqslant 6.5$. The same reasoning applies to the swarm precursors which generally aim at magnitudes $M \geqslant 6.5$. However, other precursors such as variation of radon content in subterranean waters of tilts or deformations of the ground, may indicate the time and location of the future epicenters; the presence of these signals prior to some earthquakes has been already proven possible in the Apennines (Alessio et al., 1980).

CONCLUSIONS

According to this study the two areas considered may experience a large earthquake in the near future.

Concerning the area around the Strait of Messina the earthquake may occur in one of the points of that area indicated as D in the pattern recognition study of the Italian region made by Caputo et al. (1980) shown in Fig. 2.

If we focus our analysis to the period after 1783 we see that the groups of earthquakes are regularly separated by about 40 years and the present gap of 73 years is very significant. But if we consider also the preceding period, we see that larger gaps have occurred and the present gap would be significant only if the seismic regime after 1783 will be continued. Also we must consider that we cannot firmly exclude that some large earthquakes which occurred prior to the year 1500, are not listed in the catalogue.

In the Southern Apennines the earthquake expected may not occur in one of the points indicated as D in the pattern recognition study of Caputo et al. (1980) because this aims to earthquakes with magnitudes $M \geqslant 6.5$ while the earthquake expected here may have a smaller magnitude.

The catalogue used in this study (ENEL, 1978) should be complete for intensities $I \geqslant$ IX only after the year 1550. Therefore the incompleteness could affect only the first sequence of Table III. The gap of 67 years recorded before the last event is then very significant. If the past experience is repeated, the earthquakes which will

Revista Geofísica, 28, 1988

The forecast of the magnitude 5.8, May 7th 1984, earthquake in Central Italy

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Resumen

El 23 de noviembre de 1980 un terremoto de magnitud M=6.5 ocurrió en la parte sur de los Apeninos a la latitud 40°55' y longitud 15°22'. Siguiendo la tradición del análisis estadístico del catálogo italiano de terremotos que condujo en el pasado al desarrollo de algunos métodos de predicción a largo plazo de grandes terremotos (Caputo et al., 1977; Caputo et al., 1983), aquel catálogo fue examinado a efectos de investigar modelos de sismicidad con los cuales fuera posible estimar la probabilidad, a su vez, de una fuerte réplica. El análisis del catálogo de terremotos italiano con intensidades mayores de VIII desde el año 1448 reveló que, entre las latitudes 39°N y 41°57'N (excluyendo Apulia), los sismos ocurrieron en 15 secuencias, cada una compuesta promedialmente de tres eventos dentro de un período de siete años. A su vez, dentro de cada secuencia, el tiempo promedio entre el primer y segundo evento, es de cinco años.

Este modelo de secuencias de grandes terremotos condujo a una tentativa de predicción de nuevos terremotos con una magnitud moderada, a seguir unos pocos años después al evento del 20 de noviembre de 1980 (Caputo, 1983). Estos terremotos realmente ocurrieron en mayo 7 y en mayo 11 de 1984 con magnitudes 5.8 y 5.2, respectivamente.

Los últimos sismos mencionados indicaron que la predicción era correcta y que, por lo tanto, era apropiado estudiar con mayor detalle el conjunto de secuencias de terremotos, así como las secuencias de todos los eventos y la distribución de eventos dentro de aquellas secuencias, a efectos de encontrar posibles leyes físicas que pudieran regular el comportamiento de los terremotos dentro de las secuencias y la agregación de los mismos para formar aquellas. Un análisis más refinado reveló que la distribución de los tiempos entre las secuencias era exponencial, lo que implica que no es posible prever

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ción porque han pasado 80 años desde la última concentración en el intervalo 1905-1908.

Abstract

Analysis of the catalogue of Italian earthquakes with intensities larger than VIII from the year 1448 reveals that, between the latitudes 39°N and 41°57'N (excluding Apulia), the earthquakes occurred in 15 sequences, each composed of an average of 3 events within an average time of 7 years. The average time between the 1st and 2nd events of each sequence is 5 years, which led to the tentative prediction of new earthquakes with moderately large magnitude to follow a few years after the event of November 20, 1980 (Caputo 1983). These earthquakes actually occurred on May 7th and May 11th, 1984 with magnitudes 5.8 and 5.2. A more refined analysis reveals that the distribution of the times between the 15 sequences is exponential; while the times between all the events, or between the events of one sequence have a non-exponential distribution. This implies that after the first earthquake of a sequence, as in the case of the 1980 earthquake, one may foresse the occurrence of other earthquakes after few years, while it would be difficult to foresse the occurrence of a future sequence of earthquakes.

The data do not allow us to foresse the occurrence of the third event of the sequence with acceptable confidence. These occur with about 46% probability. On average, they occur within 7 years from the first earthquake of their sequence and within 2 years from the second.

Introduction

The statistical distribution of earthquake parameters has been studied since the beginning of modern seismology. Work by Ishimoto and Iida (1939), who discovered that the log of the density distribution of the magnitude M is a linear function of M, which led to the definition of the now well-known b value.

Aki (1956) and Knopoff (1964) studied sequences of events in catalogues of earthquakes and concluded that they are not Poissonian; however Gardner and Knopoff (1974) found that California earthquakes with $M > 3.8$ between 1952 and 1971, after proper removal of aftershocks, have a Poissonian distribution. The same is true also for $M > 4.3$, $M > 4.8$, and $M > 5.3$; but for $M > 5.8$ the number of events is not sufficiently large to draw any reliable conclusion.

Caputo (1980a, 1982, 1981b) and Caputo and Console (1980) studied the statistical distribution of the scalar moments M_o as a function of the length of the fault l and of the stress drop p and found that their density distributions $n_o(M_o)$, $n_l(l)$, and $n_p(p)$ are powers of M_o, l and p respectively, as predicted theoretically (Caputo 1976, 1980), and that some of the exponents of power laws are related.

Benvenuti and Caputo (1982), to be prone to events with M ≥ 6.5 (see Fig. 1). It was preceded by a swarm precursor (Caputo et al, 1983); for a detailed discussion of the precursors of this event see Del Pezzo et al, (1983).

A detailed analysis of the catalogues of earthquakes (ENEL 1978, Carrozzo et al, 1973) of the portion of the Appennines between latitudes 39°N and 42°N, from the year 1448 through 1964 (Caputo 1983), indicates that the events with intensity larger than or equal to IX tend to cluster in time. These events are listed in Table 2.

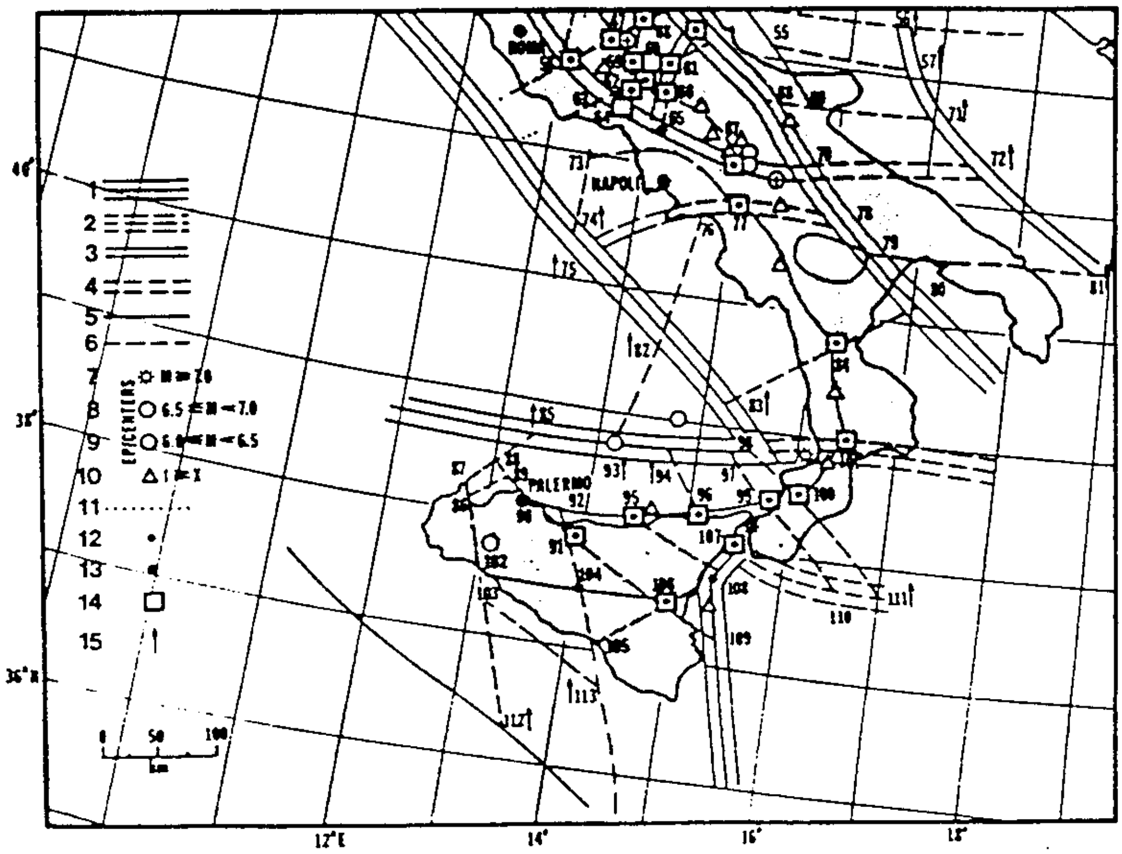

Figure 1. Map of the major lineaments of the Italian region, and of the intersections of the lineaments considered as potentially dangerous. Numbers in the key refer to the following classification of lineaments, epicenters, boundaries and intersections. Lineaments: 1,2 = first order; 3,4 = second order; 5,6 = third order; 1, 3 and 5 longitudinal, 2, 4 and 6 are not expressed in topography. 7, 8, 9 and 10 = epicenters, 11 = uncertain lineaments (covered by sediments or sea). Intersections: 12 = recognized as D in the basic variant: 13 = recognized as uncertain in the basic variant; 14 = recognized as D in the earthquake future experiment; 15 = not used because the intersections are on the outer boundaries of the regions.

Table 2
(continued)

YEAR	MON	DA	HO	MI	SE	LONG	LAT	INT	MAG	MAG
1835	10	12	12			39 25	16 15	9.0	5.6	5.4
1836	4	24	23	15		39 40	16 45	9.0	5.6	5.4
1836	11	20	7	30		40 0	15 45	9.0	5.6	5.3
1851	8	14	13	22	35	41 0	15 40	10.0	6.1	5.7
1854	2	12	17	30		39 20	16 10	9.0	5.6	5.4
1857	12	16	21	15		40 37	15 17	9.0	5.6	5.3
1857	12	16	21	18		40 17	15 55	10.0	6.1	5.7
1858	8	6	10	30		40 37	15 17	9.0	5.6	5.5
1870	10	4	16	55		39 17	16 17	10.0	6.1	5.8
1883	7	28	20	25		40 45	13 54	9.0	5.6	5.0
1910	6	7	2	4		40 54	15 27	9.5	5.8	5.3
1913	6	28	8	53	2	39 37	16 9	9.0	5.6	5.3
1962	8	21	18	10	30	41 8	15 7	9.0	5.6	5.8
1962	8	21	18	19	30	41 8	15 7	9.0	5.6	5.8
									M_L	M_s
1980	11	23	18	34	54	40 55	15 22		6.5	6.9
1984	5	7	17	49	42	41 46	13 54		6.0	5.8
1984	5	11	10	41	50	41 50	13 58		5.4	5.2

Coordinates, time of occurrence, intensities and magnitudes of the events considered in the region between latitudes of 30°N and 41°50'N in Italy (Apulia excluded). The intensities are those reported in the ENEL Catalogue. The magnitudes of the events until 1968 are those listed in the ENEL catalogue and estimated from the intensities according to empirical formulae of Karnik (1969). The events occurred after 1962 have M_L computed at Observatorio Geofisico of Trieste, while M_s is taken from Preliminary Determination of Epicenters Bulletin of U.S. Geological Survey lists.

first and the second event of all sequences is 75 years, or about 14% of the total time since 1448; these periods will be called "alarm times".

In Figure 2 one may see that there is no correlation between the number of events in the sequence and their duration. One may also see in Figure 3 that there is no correlation between the number of events in a sequence and the time to the preceeding or following sequence.

In 60% of the sequences (exceptions are those which began in the years 1638, 1688, 1731, 1870, 1910, 1980) the first event of the sequence is not that with the largest intensity. All sequences except those which began in 1755 and 1962 include an event with intensity larger than IX. The average time between the events with I ≥ IX½ and the preceeding event is 11 years; the average time to the following event is 10 years. Comparing these averages with the average interval time of all the events, 12.5 years, one may infer that there is no evidence for either the time- or slip-predictable models.

Table 3
(Continued)

Time window	Events (intensity, year)	Number of events	Time to second event of sequence (years)	Length of time window of each sequence (years)	Gap between successive sequences (years)
1796.211-1805.570	IX,1796.211; X½,1805.570	2	9.359	9.359	20.518
1826.088-1836.888	IX,1826.088; IX,1828.090 X,1832.186; IX,1835.781; IX,1836.315; IX,1836.888	6	2.002	10.800	14.731
1851.619-1858.597	IX,1851.619; IX,1854.021; IX,1857.962; X,1857.962; X,1858.597	5	2.511	6.978	12.165
1870.762-1883.575	X,1870.762; IX,1883.575	2	12.813	12.813	26.858
1910.433-1913.490	IX½,1910.443; IX,1913.480	2	3.057	3.057	49.148
1962.638-1962.638	IX,1962.638; IX,1962.638	2	0.000	0.000	18.258
1980.896-?	X,1980.896; 1984.351; 1984.359	3	3.455	?	?
Average		2.87	5.24	7.00	31.01
		(3.07)	(5.63)	(8.35)	(32.59)

Sequences of earthquakes formed with the events of Table 2 and discussed in the paper. In brackets is also indicated the sequence substituting the two sequences beginning on 1627 and 1638 respectively; the discussion of this new set of sequences does not alter the conclusion of the paper, only the average interarrival times of Fig. 7 change slightly, those pertinent to this new set of sequences are indicated by a dashed line. Time is in years.

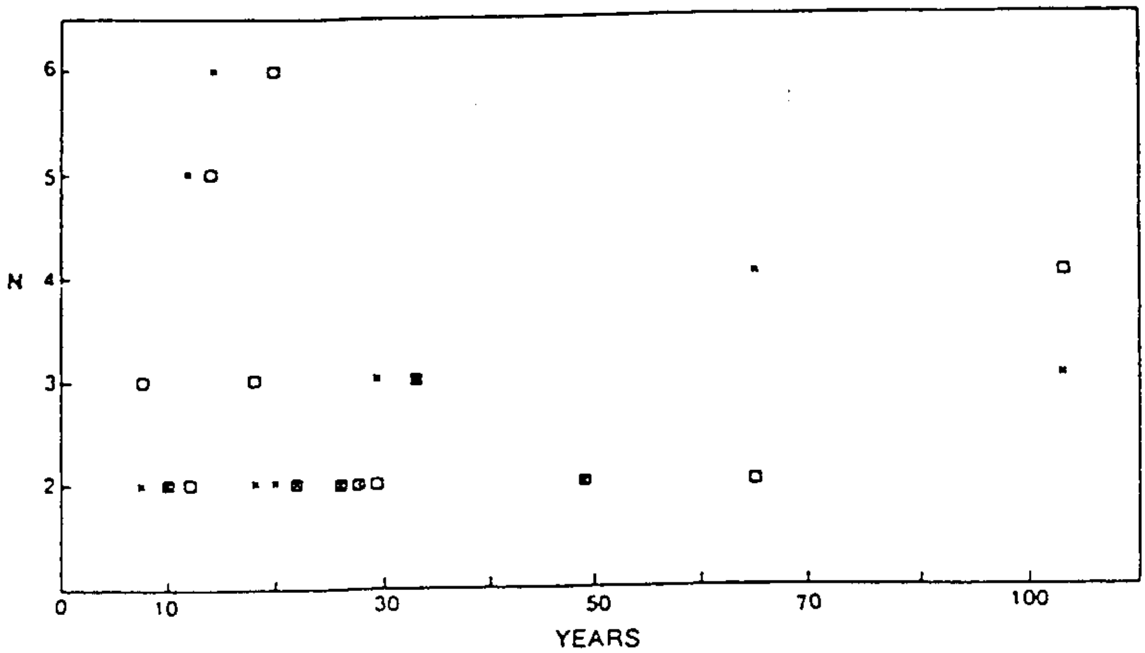

Figure 3. Number of events in each sequence as function of the interarrival time to previous sequence (squares) or to the following sequence (crosses).

the density distribution n of the interarrival times of the events should be a power law of the time. However, we know that the process of accumulation of the energy for the next earthquake, begins before last occurrs. To take into account both phenomena, we will tentatively add a constant c, to the time t, to represent an average time elapsed from the beginning of the accumulation of the stress until the new regime installed at the previous earthquake. Then

$$\ln(n) = a + b \ln(t + c) \tag{2}$$

which implies that after each large earthquake, time has a new role depending on the local geologic environment, (particularly the asperities), on the mechanism of the earthquake which triggered the new energy accumulation regime, as well as on the mechanism of the earthquake to be released.

The same could also be tentatively applied to the sequences of events, considering them as bursts of earthquakes preparing for a successive burst, although the mechanism involved would probably be different from that triggering the single earthquakes.

Before discussing the fit of the three sets of data to equation (2), in order to test the randomness of the data, we consider also the fit of the three sets to the function representing the Poisson distribution

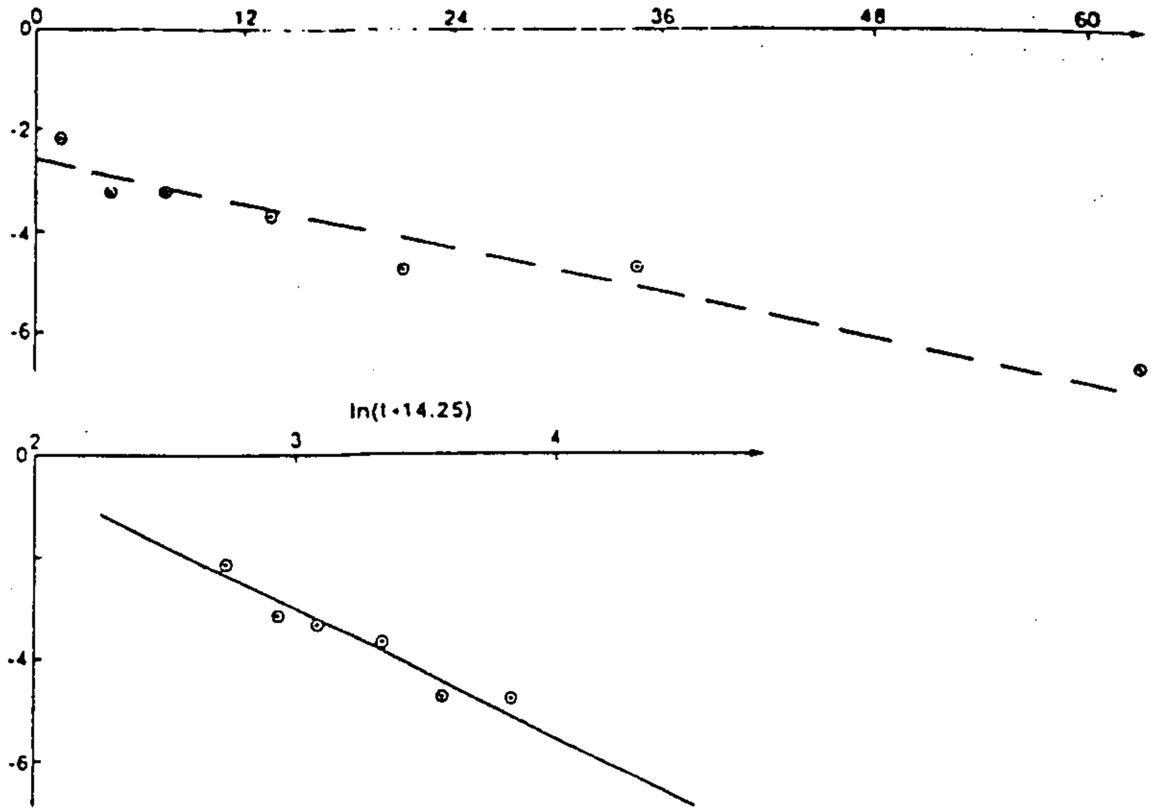

Figure 5. Best fit of (2) (continuous line bottom $\ln n = -4.65 - 2.58 \ln (t + 14.25)$) to the density distribution of the interarrival times of all events. The dashed line is (3) with $\mu = 13.1$ interarrival time of events.

Since the average of the magnitudes estimated for each event considered differ from 5.9 by at most 0.6, we may tentatively consider that the earthquakes of the set have released energies of the same order of magnitude.

One may also check that there is no correlation between the intensity of each earthquake and the time from the previous one in sets I and II; te same applies to set III, considering the correlation between the energy released in each sequence and the time to the sequence preceeding it.

The results of the fit of the three sets of data to the three density distributions laws, shown in Table 4 and Fig. 4, 5, and 6 indicates that the law (2) always has the smallest σ^2 and is the closest to the data, which in turn seems to indicate that the process of release of the elastic energy in this region, through earthquakes of comparable order of magnitudes, is not random. The σ^2 of the fit of n_{c1} and n_{e2} to set I is relatively small and we could also infer that the interval times of the sequences have a nearly exponential distribution.

which represents a tentative physical model; however n [illegible] contains three arbitrary parameters to fit the data and therefore has a higher [illegible] probability of giving a smaller σ².

The catalogues of earth[illegible] otherwise [illegible] to be exponential (Gardner and Knopoff, 19[illegible]) whether the process of release of seismic energy may be [illegible] therefore [illegible] sets of events from an experimental distribution [illegible] an exponential distribution may always be considered [illegible] of the distribution which are not necessarily all exponential [illegible] that [illegible] the catalogues of

Table 4

SET	a	b	c	σ^2	lnA	−B	σ^2	μ	−lnμ	$-\mu^{-1}$	σ^2
I					−3.335	−0.032	0.042	31.02	−3.435	−0.032	0.047
II	−0.739	−1.132	0.75	0.010	−1.709	−0.173	0.035	3.76	−1.325	−0.265	0.211
III	4.653	−2.585	14.25	0.069				13.07	−2.570	−0.077	0.285

Numerical values of the parameters of the density distributions n, n_{e1}, n_{e2} defined by (2), (3) and (4), obtained with least square method fit to the data sets I, II and III. σ² is the variance of the data with respect to the lines fitted.

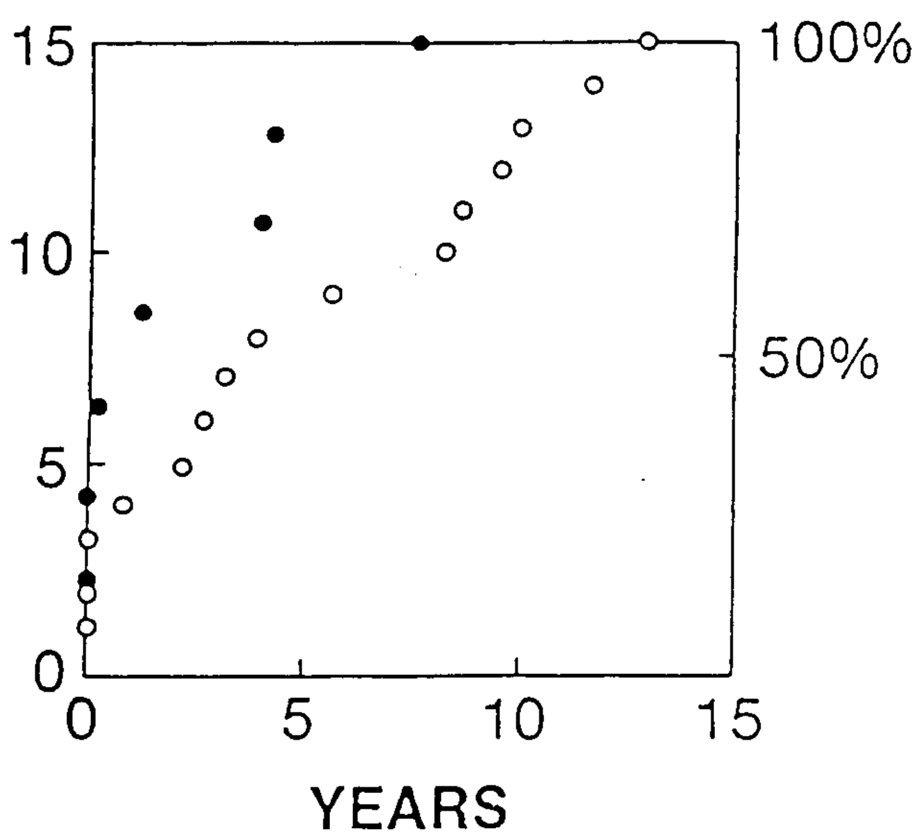

Figure 8. Cumulative distribution of the interarrival times between the first and the second event (open circles) and between the second and the third events (solid circles) in the sequences.

earthquakes of large regions: they may be the result of the sum of several different non-exponential processes.

Since in no case was it possible to prove that a regional catalogue of large events has an exponential distribution, it seems reasonable to consider that sets I and II have density distribution represented by n, rather n_{e1} or n_{e2}, on the basis of their σ^2.

We may thus suggest that it should be possible to predict the interval time between the successive events in the sequences.

Figure 7 shows the average interval time between the successive events of the sequence. It is clear that the events cluster towards the last one of each sequence.

Figure 8 shows the cumulative distribution of the interval times between the first and second events of each sequence and between the second and third events of each sequence, which reflects a property of Fig. 7. This may imply that each shock alters the distribution of stress, releasing it in the

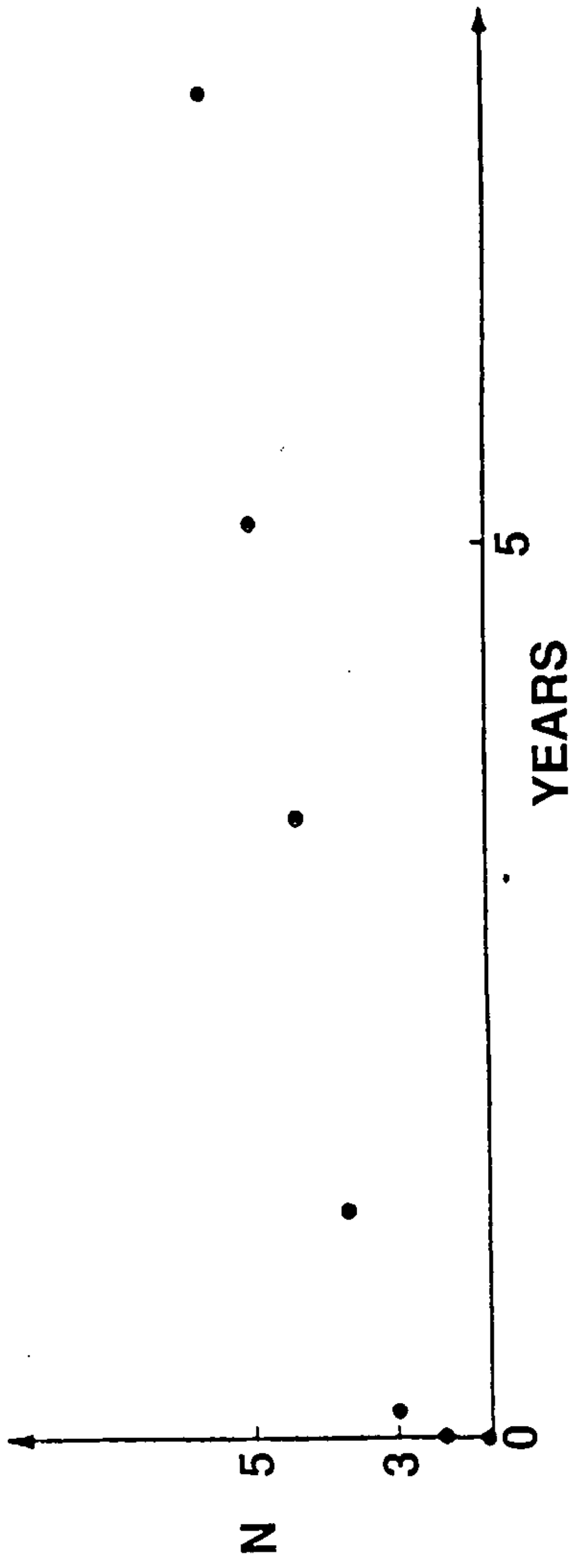

Figure 9. Cumulative distribution of the length of the time windows of the sequences.

ENEL Catalogue of Italian Earthquakes from the year 1000 through 1975, in tape form.

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tensity $I \geq X$, which has some similarity with that of the Parkfield area, and occurred in an area A of 140 km radius around the Messina Straits.

Concerning the intensisties $I \geq X$ the catalogues of Italian earthquakes are considered complete since 1550. Between 1550 and 1783, in the area A around the Messina Straits there are 4 earthquakes which seem randomly distributed in time and the last occurred in 1693.

However beginning in 1783 there seems to be an almost regular pattern of occurrence in which the events occur in sets of two or more in a limited time interval T_1, each set being separated from the following by a time interval T_2 much larger than the duration of the set as shown in figure 1.

The average value of T_1 is 5 yr with a standard deviation of 2.2 years and that of T_2 is 35 yr with standard deviation of 7.5 yr.

The cumulative distribution with mean 1905 + 35 = 1940 and standard deviation 7.5 is given by the t distribution with two degrees of freedom and implies that the following sequence had 3.2% probability to occur after the years 1993 and 3.0% probability to occur after the year 2000.

Since no earthquake with intensity $I \geq IX$ occurred in the area A until 1993, it is reasonable to assume that the regularity presumed between 1783 and 1908 has ceased and that another regime of energy release may have begun.

The same hypothesis may be considered also for the Parkfield sequence. The tectonic energy which accumulates in that area will eventually be released, however it is difficult to estimate when a new pattern of regularity will possibly be established because at the moment have been studied only the sequence of Parkfield and that of the Messina Strait and the latter indicates that the setting of a new pattern of events occurring at regular intervals may take more than 230 yeras as was the length of the quiesence before the pattern begun in 1783.

Abstract. Great attention has been given to the 6 moderate ($M > 6$) earthquakes sequence which occured at Parkfield (California) about one every 20 years. It was noted that this regularity implied that a moderate earthquake should occur no later than March 1992. With a new hypothesis Savage (1993) estimates that there is a 9% probability that the next event occurs after 1993.0 and 5% probability that it occurs after 1996.0. However there is also the hypothesis that the regularity of the sequence of 6 earthquakes is limited in time. We present here a set of 4 sequences of earthquakes with intensity $I \geq X$, similar to that of the Pakfield area, occurred around the Messina Straits, began in 1783 and ended in 1908. It is estimated that the following