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# THE SEISMIC SEQUENCE OF COMINO VALLEY (CENTRAL ITALY)- MAY 7 1984

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## Abstract

In this paper some remarks about the Comino Valley seismic sequence, occurred in central Italy on 7 May 1984 with a main shock of $M_d = 5.4$, are presented. The sequence, occurred in a seismic zone, was characterized by absence of foreshocks. Some characteristics of the sequence underline the coupling between the cumulative frequency vs time trend and the modality of a Kelvin's solid strain release which has a time relaxation of about 30 days. Furthermore we analyse *b*-value and *Gutenberg* relation to evaluate the energy release.

## Introduction

The Central Italy Appennines chain has been historically affected by many strong earthquakes, some of them very destructive. We can mention the towns of Cassino, Sora, Atina, Alvito, S. Elia, Isernia often damaged and destroyed by earthquakes during their history. From the I.N.G. Catalogue an intense distribution of seismicity comes out, surrounding the epicentral area, with strong earthquakes. The main of these ones are the Sora earthquake (IX-X MCS) July 23 1654, which caused over 400 deads and destructions in the whole region (Baratta, 1901) and the 1349 earthquake (X MCS) which involved a large area in Central Italy but whose localization is uncertain because of the incompleteness of informations (Baratta, 1901; Postpschil et alii, 1983). The last important event occurred on November 5 1973 (VI-VII intensity degree, $M_l = 4.2$) with an epicentre very closed to the May 7 1984 one (fig. 1).

The tectonic context of the area is dominated by the evolution of the Apennines chain, which suffers the Tyrrhenian rifting from the Messinian. The zone is characterized by carbonatic platform formations which are typical of the Lazio-Abruzzi sequence, and by the Transition sequence, which have been interested by an intense deformation beginning from the Miocenic compression. The layers are generally overthrusted to NE. The actual feature of the area derives from relaxation phases active since the late Pliocene (fig.2). The profile, (*Mostardini and Merlini, 1986*) crossing the Apennines coast to coast, shows thrust faults deforming the strong thickness of the platform, and normal faults which contributed to its disarticolation (fig.3).

## Seismic sequence characteristics

A data set from ING Bulletin has been collected about the period May- September 1984. Events with $M_d \geq 2.3$ have been considered in statistical treatment. On the basis of seismic sequences Mogi's classification (1963), we can identify the Comino Valley sequence in the first kind, consisting in a master event followed by an aftershocks serie (fig.4).

We can also observe a first phase of the of the sequence, the early 4 days, with a quick decreasing in aftershocks number and in magnitude values, and a second longer phase starting with the main aftershock ($M_d = 5.1$).

In order to define a characteristic parameter of the strain and energy modalities of release, we have considered two kinds of theoretical trends that can approximate the real trend of the aftershocks sequence.

It has been shown in previous studies that both the aftershocks sequences and the rock mechanics submitted to a constant stress follow two main behaviours depending on the rheological characteristics of the materials (*Scheidegger, 1970*).

The first of these is better known as logarithmic creep or Omori's law (*Omori, 1902*) and has the form

$$log\ n(t) = log\ k - p\ log\ t \tag{1}$$

where $n$ is the number of aftershocks, $k$ and $p$ are constants. In our case we obtain a very low agreement between this theoretical behaviour and the experimental data, infact

$$log\ n(t) = (1.4 \pm 0.1) - (0.62 \pm 0.07)\ log\ t \tag{2}$$

with correlation coefficient $R = -0.66$

To the Omori's law corresponds the rheological relationship (*Lomnitz, 1966*) valid for a constant acting stress $\sigma_0$

$$\epsilon = \frac{\sigma_0}{\mu} + q\ ln(1 + Bt) \tag{3}$$

where $\epsilon$ is the strain $\mu$ is the material rigidity, q and B are constants.

The second one may be written as

$$N(t) = N_{max} + (1 - N_{max})e^{-\frac{t}{\tau}} \tag{4}$$

where N is the cumulated aftershocks frequency (fig.5), $N_{max}$ its asymptotic value and $\tau$ is the time constant of the sequence (*Riguzzi et alii, 1989*). This relationship corresponds, under a few hypothesis, to a Kelvin's solid equation

$$\epsilon(t) = \frac{\sigma_0}{\mu}(1 - e^{-\frac{\mu}{\eta}t}) \tag{5}$$

Where the ratio $\tau = \eta/\mu$ is the time relaxation of the material and corresponds to the time constant of the sequence. Generally, it ranges between 1 and 16 days, depending on the characteristics of the medium (*Scheidegger, 1970; Scheidegger, 1982*). We have estimated $\tau$ by a linear regression on the first 131 days of the sequence, as follows

$$ln\frac{N(t) - N_{max}}{1 - N_{max}} = -(0.033 \pm 0.001)t \tag{6}$$

where has been imposed the zero point as costraint to the linear regression. The correlation coefficient is $R = -0.96$ and $\tau$ value, which is the inverse of slope, is $(30 \pm 1)$ days

(fig.6). This $\tau$ value results higher than the other ones reported in literature; however we can't reject it because the Kelvin's model seems better to approximate this aftershocks sequence than the logarithmic-creep model.
The availability of previously mentioned hypothesis are the following:
1) the mean stress is indipendent of time (*Valle, 1969; Scheidegger, 1982*).
2) the aftershocks mean magnitude is stable in time, as reported by *Lomnitz* (1966) and *Ranalli and Scheidegger* (1969). This implies that, on average, each aftershock of the sequence contributes for the same amount to the cumulative strain release. This condition is satisfied, at least in first approximation, when the cumulated magnitude of the events is a linear function of the number of aftershocks. The Comino Valley seismic sequence linear regression is :

$$M_{cum} = (3.27 \pm 0.37) + (2.789 \pm 0.001)n \tag{7}$$

with correlation coefficient 1.00 (fig.7).

From *Gutenberg* relation (1956)

$$logE = 11.8 + 1.5M$$

the energy released during the sequence has been calculated. Looking at the fig.8, which shows the distribution of the cumulated energy vs time, we note that most of the released energy is gathered on the early 6 days of the seismic period, while it increases slowly for the rest of the sequence.
Then frequency-magnitude relationship has been studied (*Gutenberg and Richter, 1944*)

$$logN = a - bM$$

where N is the cumulate frequency of n earthquakes with $M \leq M_s$ ($M_s$ is the main shock magnitude). Using the least squares method with magnitude values within 2.3 and $M_s$, we have obtained the following relationship:

$$logN = (4.77 \pm 0.09) - (0.91 \pm 0.03)M \tag{8}$$

with a correlation coefficient R= 0.99 (fig.9).
Furthemore it has been computed the b-value according to the Utsu's relationship (*Utsu, 1967*) that represent a more general point of view

$$b_{Utsu} = \frac{N \ \ log \ e}{\Sigma_i M_i - N M_t} \tag{9}$$

where N is the number of aftershocks with $M \geq M_t$ where threshold magnitude $M_t = 2.3$. In our case $b_{Utsu} = 0.89 \pm 0.40$.
Other authors have computed quite similar $b - values$ of this sequence, like *Console et alii* (1984), $b = -0.93$ for the May 1984, and *Achilli et alii* (1984), $b = -0.91$. From literature it is evinced that the b-value is related to the tectonic structure of the region (*Mogi, 1962; Drakopoulos and Shrivastava, 1970*), in fact it decreases in inverse proportion to the symmetry degree of applied stresses. According to *Scholz*, (1968) it is the regional state of stress, rather than the materials heterogeneity, which influences b-value variability. The b-value of the studied zone (0.91 ± 0.03) would be, from the structural point of view, characteristic of a quite inhomogeneous region, and with a not uniform stress distribution

## Conclusion

We conclude observing that the strain release modalities seem to point out a rheological behaviour in analogy with a Kelvin's solid, with a relaxation time of about 30 days. This relatively high value, sign of a slow recovery of equilibrium conditions, characterizes a zone where tectonic stresses are not recent and therefore, its seismicity is high and spread in time. This opinion is confirmed by b-estimation . These considerations about the dynamic behaviour of the sequence seem to be in agreement with structural aspects, which are typical of regions with a principal tensional tectonic.

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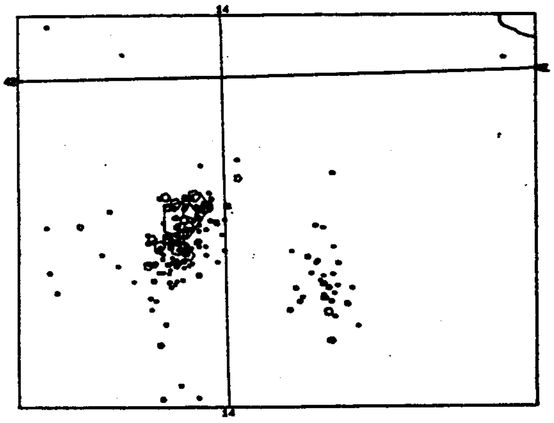


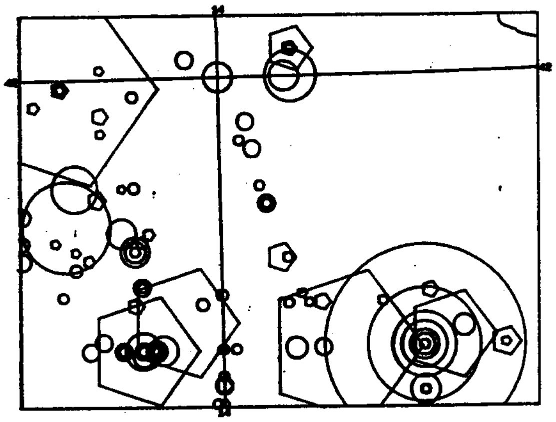


**fig.1a - Events occurred from 1000 A.C. to 1983 A.C..Magnitude $\geq 4.0$.**

**fig 1b - Events occurred from 1984 to 1988. Magnitude $\geq 3.0$ . Symbols :* main shock of 5 May 1984; ○$h < 5km$; ⬠ $5 < h < 30$; □$30 < h < 60$; △$h > 60$; dimension are proportional to the magnitude.**

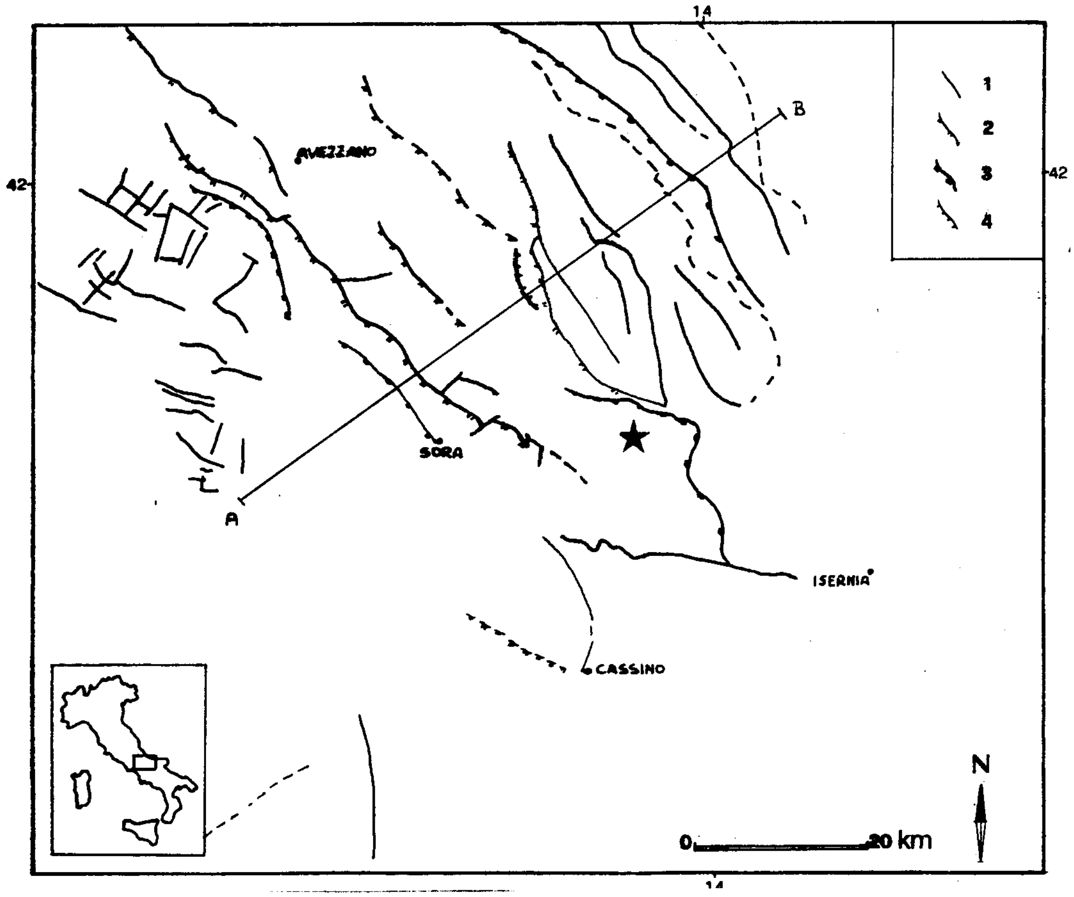


fig.2 - Structural allignements in the area. a): 1 - undeterminated faults; 2 - normal faults; 3 - thrusts; 4 - reverse fault ; Yellow star is the May 7 1984 epicentre. (Semplified from structural model of Italy, 1986.)

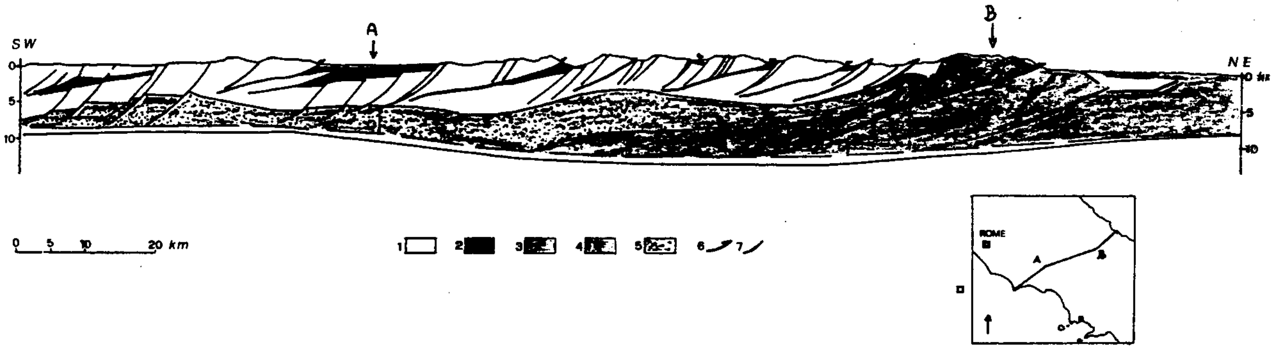
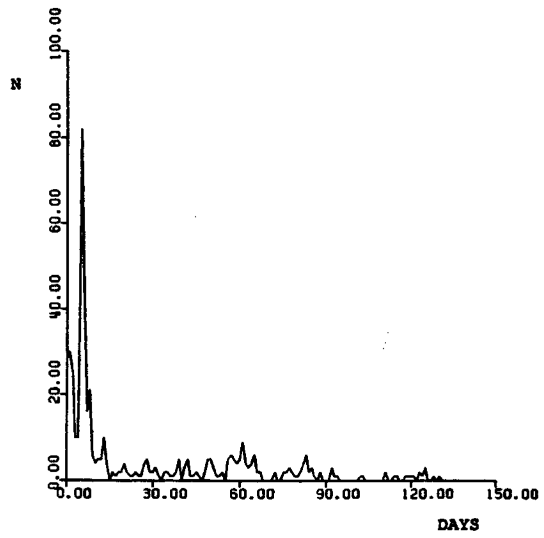


fig.3 - Cross section SW-NE; semplified from Mostardini and Merlini 1986. 1 - Lazio-Abruzzi carbonatic platform; 2 - Miocenic flysch; 3 - Apulia basin; 4 - Outer Apulia platform; 5 - Lagonegro basin.



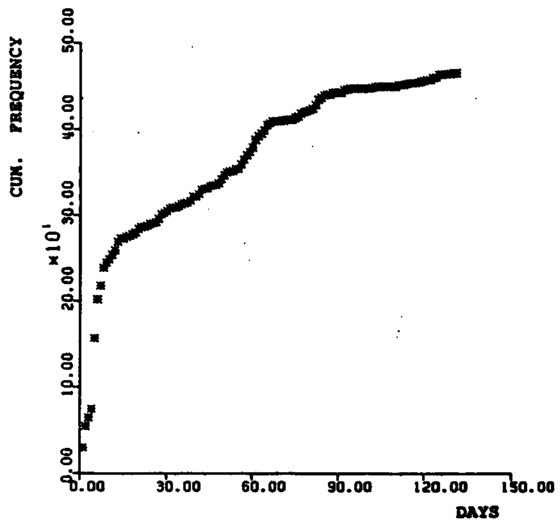
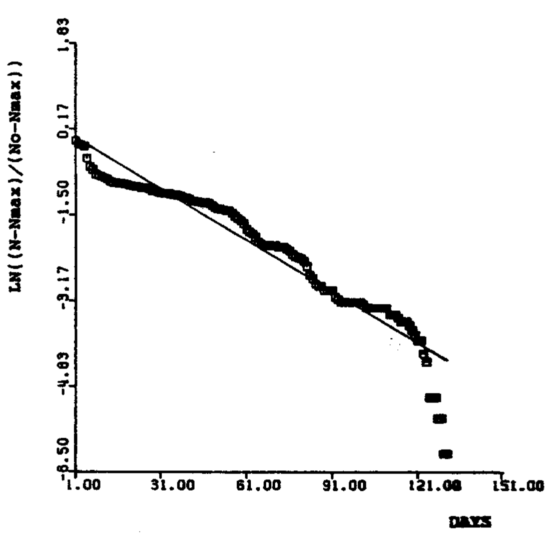


fig.4 - Time-frequency distribution of the sequence.

fig.5 - Time-cumulated frequency distribution of the shocks of the sequence.



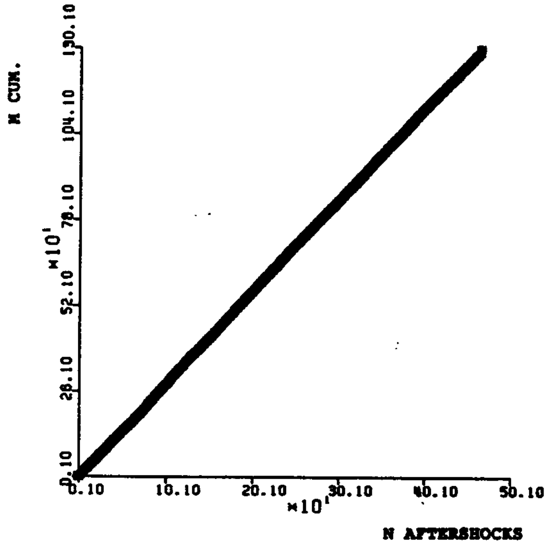
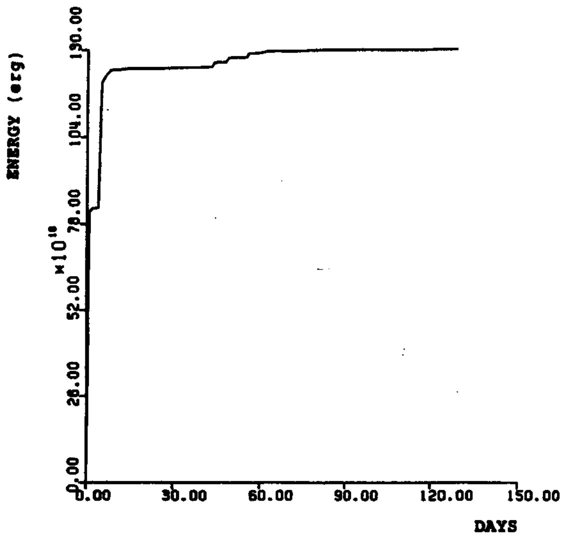


fig.6 - $ln\frac{N(t)-N_{max}}{1-N_{max}}$ vs time linear regression on the first 5 months.

fig.7 - Cumulated magnitude (Md) - number of aftershocks distribution.



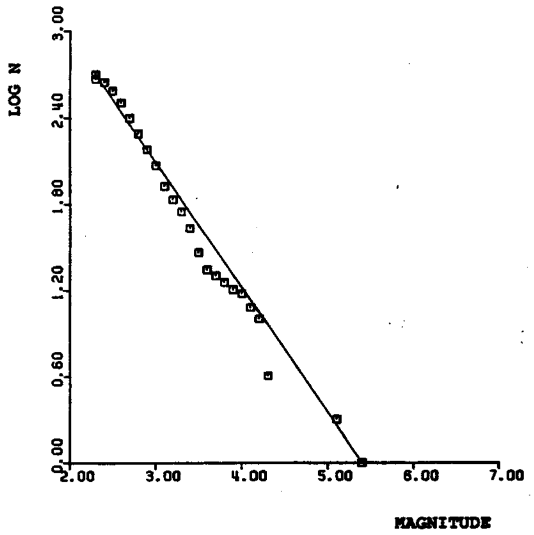


**fig.8** - Distribution of released energy from Gutenberg relation.

**fig.9** - Md frequency distribution.