Happy New Year & Welcome to our (fantastic) Reading Group!

Paper of the day [Jones and Molnar 1979]

SOME CHARACTERISTICS OF FORESHOCKS AND THEIR POSSIBLE RELATIONSHIP TO EARTHQUAKE PREDICTION AND PREMONITORY SLIP ON FAULTS [Jones and Molnar 1979]

Interest of studying foreshocks

- Most obvious premonitory phenomenon before major (Mw > 7) earthquakes.

- Can we use foreshocks to predict (major) earthquakes?

As prediction time-scale : Short-term prediction!

- Better understand the mechanical behavior.

Overview

What did they do?

1) They observed the temporal and spatial distribution of foreshocks.

2) They studied the relative magnitudes of foreshocks and mainshocks.

3) They compared the data with mathematical expression derived for accelerating premonitory fault slip

Database

All earthquakes are computed with teleseismic data.

How to define foreshocks?

Criteria (double event, background seismicity...)

Temporal distribution :

Three groups of foreshocks before mainshocks.

- $M_w > 7$ with depth < 100 km in the world from 1914 to 1949
- $M_w > 7$ with depth < 100 km in the world from 1950 to 1964
- $M_w > 7$ with depth < 100 km in the world from 1965 to 1973

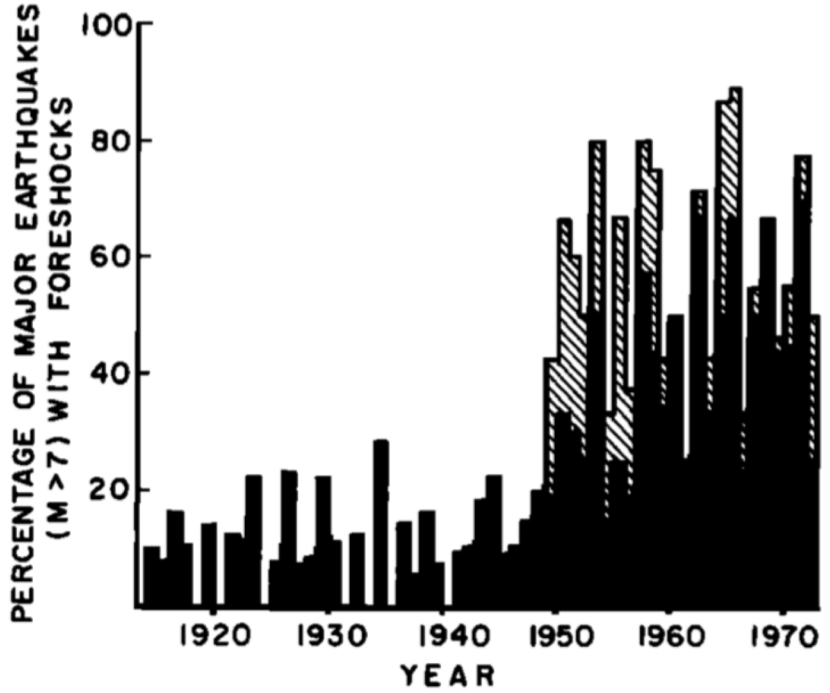

Fig. 1. Percentage of major earthquakes ($M \geq 7$) in each year from 1914 to 1973 that were preceded by recorded foreshocks. For 1950 to 1973 the hatched area is the percentage of earthquakes that had at least two aftershocks recorded by NOAA and that were preceded by foreshocks.

Possible phases of foreshock activity

Number of foreshocks in function of days before the mainshock, for 3 groups sorted by the distance between the computed foreshock and mainshock epicenters.

- Very large number of foreshocks near the epicenter for the last day.
  It's a culmination of an increasing that starts several days earlier.

- Far from the mainshock epicenter, an increasing of the activity starts about 3 months before the mainshock.

The increase of the activity could be a a premonitory?

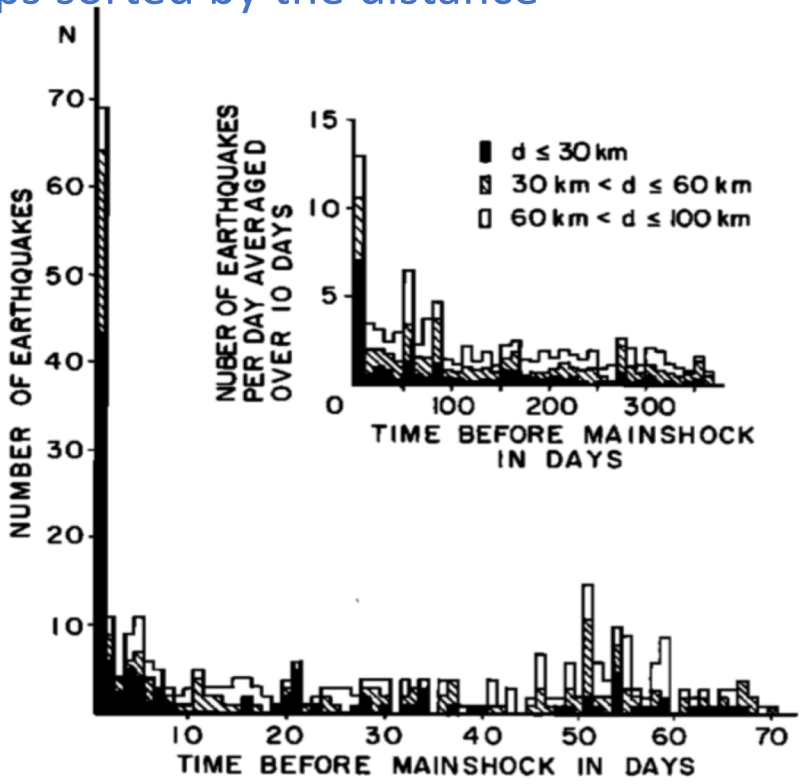

Fig. 2. Foreshock activity as a function of time before main shocks occurring between 1950 and 1973. The number of foreshocks are given separately for three different ranges of distance between the computed foreshock and main shock epicenters. Inset shows the number of foreshocks averaged over 10-day periods for a 1-year period preceding the main shocks.

Study of the background seismicity

The mislocation of earthquakes could contaminate the data then a relocation was done.

Maybe a large number of foreshocks for some shocks : a few shocks could be contaminated the data too.

Previous observations are not due to an abundant seismicity before a small number of earthquakes.

«artefacts »

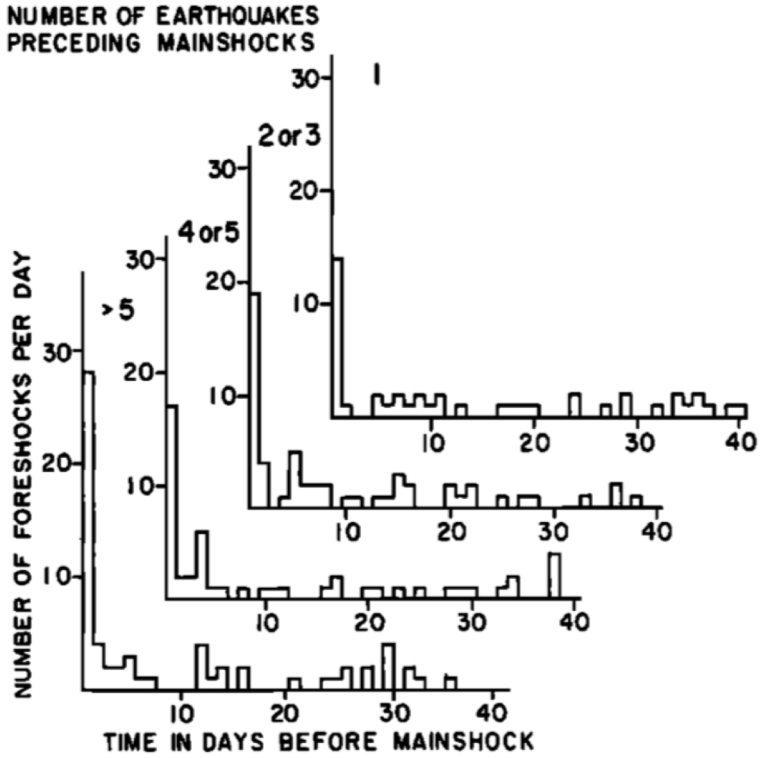

Fig. 4. Number of foreshocks per day as a function of number of the foreshocks recorded for different earthquakes. Separate plots are shown for foreshock sequences consisting of only 1 event, 2 or 3, 3 or 4, or greater than 5 events. Note that the increase about 5 days before the main shocks and the peak on the last day do not depend upon how many foreshocks preceded each event.

Study of the background seismicity

Spatial observation :

Three groups of foreshocks in function of the location.

- New Hebrides (A)
- Solomon Islands (a)
- Rest of the world (C)

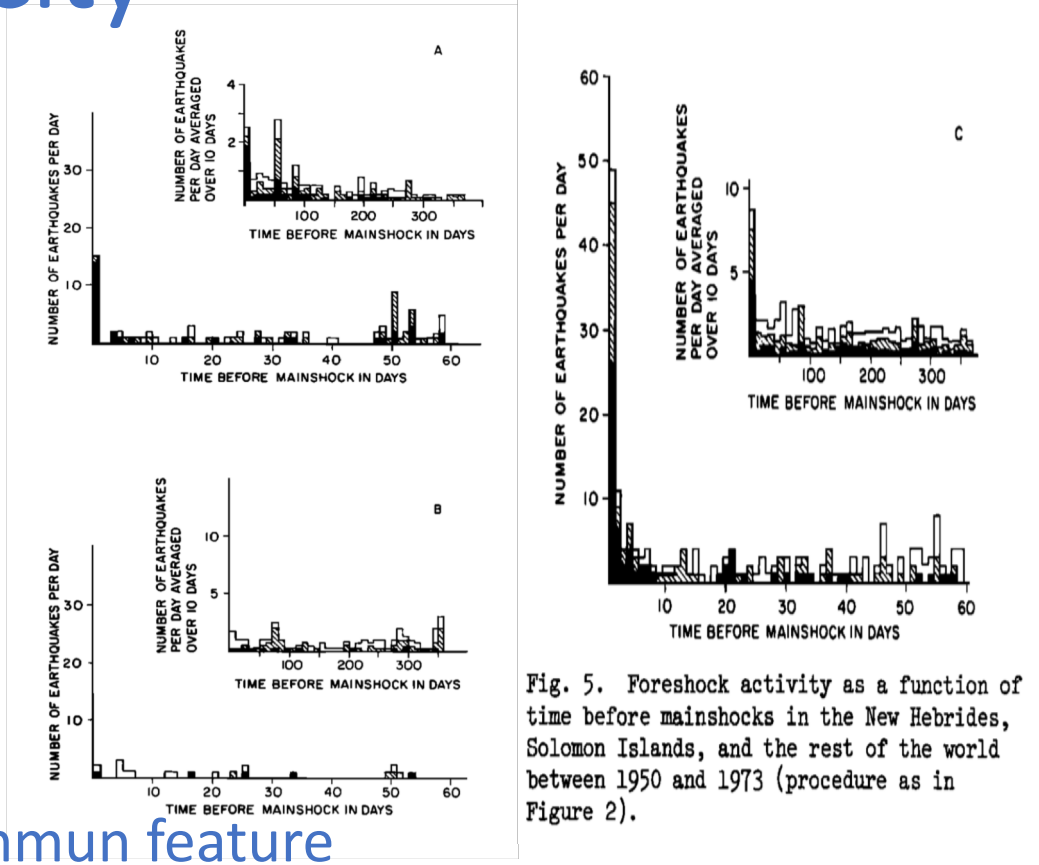

Fig. 5. Foreshock activity as a function of time before mainshocks in the New Hebrides, Solomon Islands, and the rest of the world between 1950 and 1973 (procedure as in Figure 2).

- The peak on 90 days before the mainshocks is not a commun feature

- Unable to detect any clear dependence of the temporal pattern of foreshock activity on the tectonic setting of the main shocks

Study of the very short term premonitory seismicity

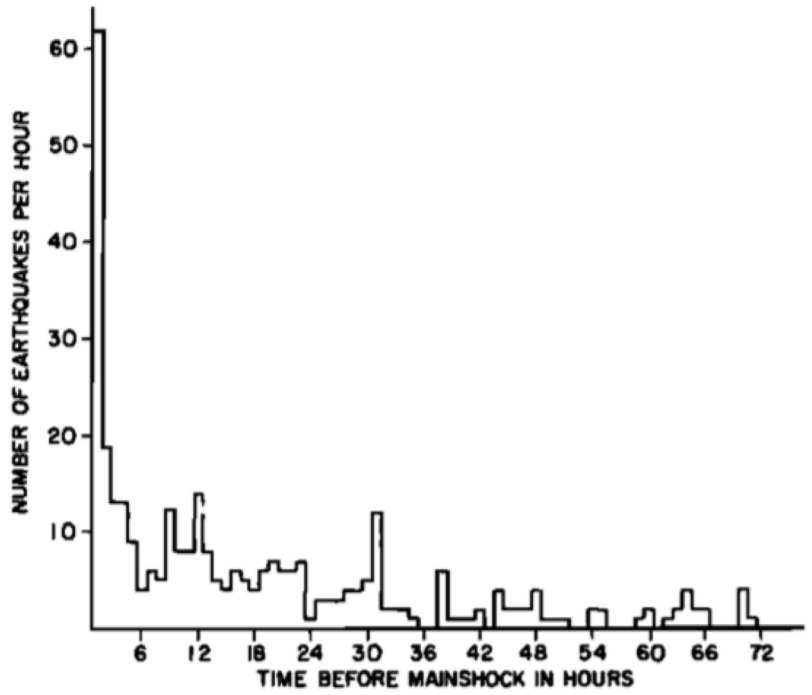

Fig. 8. Foreshock activity as a function of time before main shocks for the 3 days before the main shocks.

Gap during the last 5-8 hours before the earthquake.

[Wu et al., 1976] reported a drop in foreshock activity 4-8 hours before earthquakes.

Study of the dependence on magnitude of the mainshock

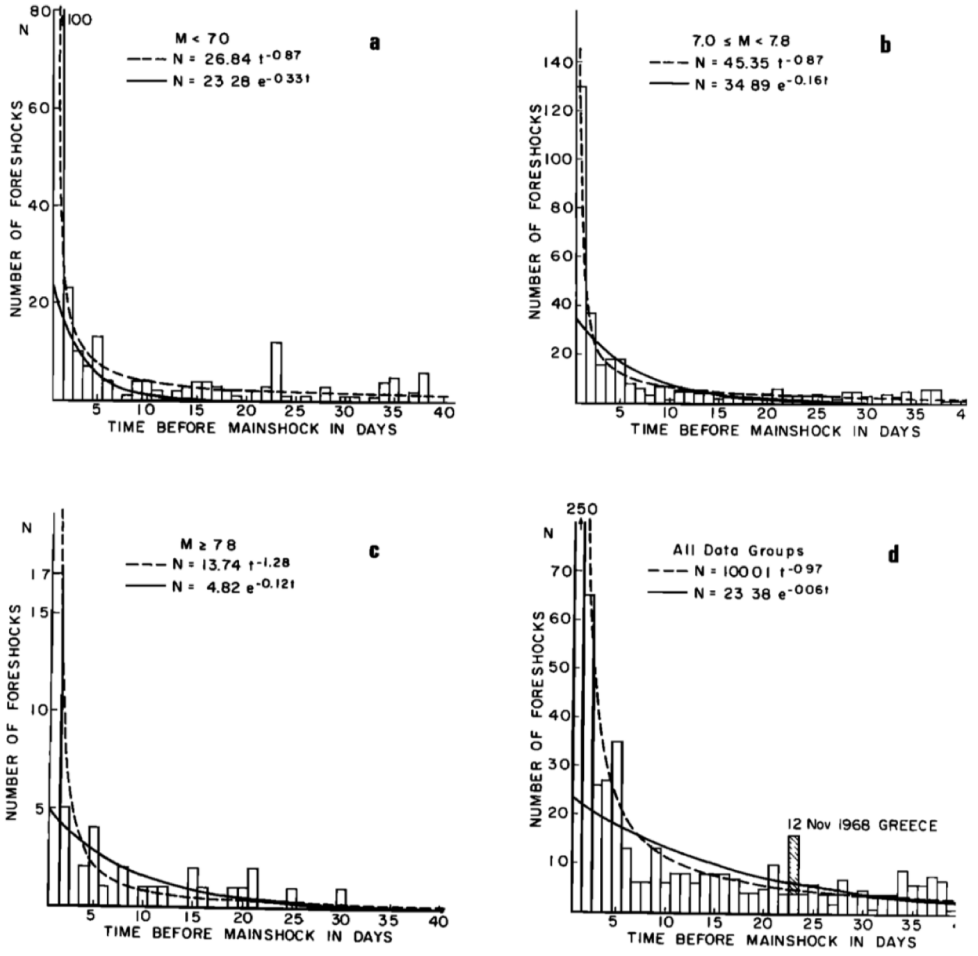

Fig. 7. Foreshock activity (a-c) as a function of time before main shocks of different magnitudes and (d) for all main shocks from all three data sets. Also shown are the exponential (solid line) and power law (dotted line) equations that best fit these data. Note that the temporal variation does not depend upon the magnitude of the main shock.

Foreshocks are sorted by magnitude of the mainshock.

They observed the same pattern of seismicity, an increase in activity a few day before the earthquake with a culminant peak for the day before the mainshock.

No dependency with the magnitude of the mainshock.

Power-law fitting, testing values on paper.

Study of the dependence on magnitude of the mainshock

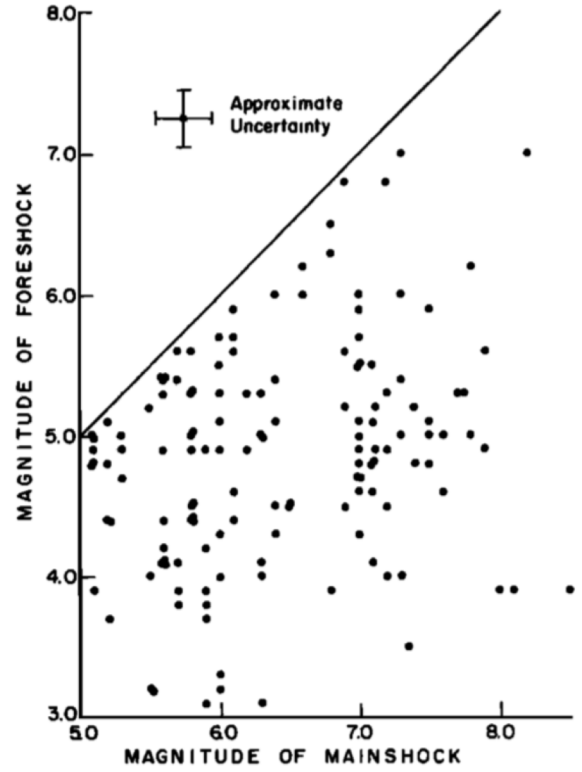

Fig. 9. The magnitudes of the largest foreshocks as a function of the magnitude of their main shocks. No pattern is obviously discernible. This is the only figure in which data from written reports of foreshock activity are used.

- There is not a dependency between the foreshocks and mainshock magnitude.
- There is not a dependency between the frequence of the activity and the magnitude of the mainshock.

Amplitude Ratios of P and S Waves

- Most foreshocks are too small for determination of **a fault plane solution** : compare amplitudes of P and S waves at one station

- Ratio depends on propagation path, **fault plane solution** and position of the station

- Plot Amplitude of S Wave versus Amplitude of P Wave for different regions

(Phillipine, Greece and Turkey)

Amplitude Ratios of P and S Waves

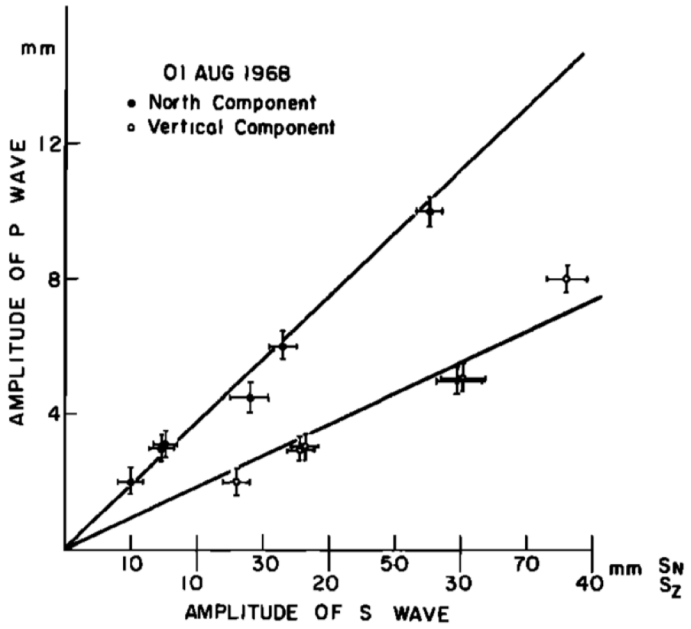

Fig. 10. The maximum amplitude of the P wave versus the maximum amplitude of the S wave of both the vertical and north-south records of the August 1, 1968, earthquake in the Philippines recorded at Baguio (BAG).

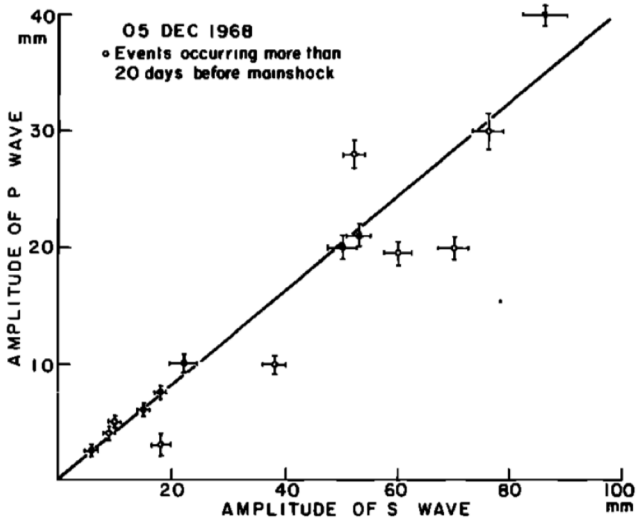

Fig. 11. The maximum amplitude of the P wave versus the maximum amplitude of the S wave of the December 5, 1968, earthquake near Greece recorded at Athens University (ATU). The solid circles are foreshocks that occurred within 4 days of the main shock, while the open circles are foreshocks occurring more than 20 days before it.

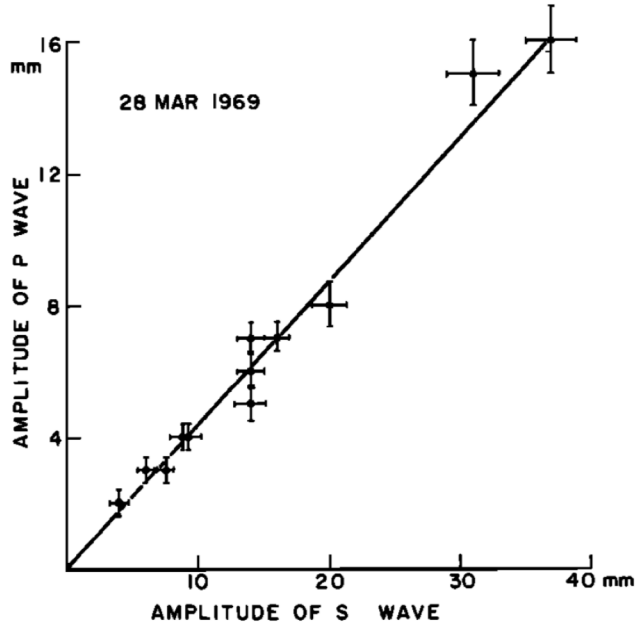

Fig. 12. The maximum amplitude of the P wave versus the maximum amplitude of the S wave of the March 28, 1969, earthquake in western Turkey recorded at Athens University (ATU).

The amplitude ratio is not the same for the different cases.
Let's talk about the Greece case.

Amplitude Ratios of P and S Waves

The amplitude ratio is not the same for the different cases.
Let's talk about the Greece case.

- The only points that deviate from the lines are those for a few foreshocks occurring more than 3 weeks before the earthquake
- Data seems shown an **identical fault plane solution** for the foreshock occuring on the 1-4 days range before the mainshock.

Discussion

- Temporal distribution seems to show wherever the slip is, it is accelerating.

- There is not correlation between the magnitude of mainshock and foreshocks : that's means the slipping area is not constant.

- Slip occured on some segments of the fault, the stress on remaining unslipped segments increased untill a probably further slip.

Eventually the rate of asperity increase, the instability lifetime depends on upon stress acting on it.

If static fatigue is a random process N_{asp} break proportionnal N_{asp} non break.

Conclusions

- 5-10 days before the mainshock the activity increase rapidly near the future epicenter with a culminant peak the last day.

- Culminant peak untill the shock except for certains cases with a gap for the last hours.

- Not finding relations between the magnitude of the mainshock and the magnitude of the foreshock or the foreshock activity.

Only foreshocks are insufficient for earthquake prediction.

Frequency of foreshock occurrence shows that precursory deformation does occur before many major earthquakes.