A MICROSEISMICY PRECURSOR BEFORE THE DECEMBER 21, 1990 EARTHQUAKE (M_s=5.9, NORTHERN GREECE)

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A B S T R A C T

By examining the small magnitude seismicity rate in a seismic source in northern Greece, where a strong earthquake occurred in December 1990 (M_s=5.9), it was found that a significant increase of the seismicity rate had started since May 1988, that is, 2.6 years before the main shock. This result strengthens recent observations on the behaviour of the seismic activity during the seismic cycle, which revealed that the second main shock of the cycle is preceded by a period of increased activity with a duration of about 2.7 years.

ΠΡΟΔΡΟΜΗ ΜΕΤΑΒΟΛΗ ΤΟΥ ΡΥΘΜΟΥ ΓΕΝΕΣΗΣ ΜΙΚΡΩΝ ΣΕΙΣΜΩΝ ΠΡΙΝ ΑΠΟ ΤΟ ΣΕΙΣΜΟ ΤΗΣ 21 ΔΕΚΕΜΒΡΙΟΥ 1990. (M_s=5.9, ΒΟΡΕΙΑ ΕΛΛΑΔΑ).

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Π Ε Ρ Ι Λ Η Ψ Η

Στην εργασία αυτή εξετάζεται ο ρυθμός γένεσης μικρών σεισμών σε σεισμική πηγή της Βόρειας Ελλάδας, στην οποία έγινε σεισμός το Δεκέμβριο του 1990 με μέγεθος M_s=5.9. Βρέθηκε, ότι από το Μάιο του 1988 ο ρυθμός σεισμικότητας είχε αρχίσει να αυξάνεται σε σχέση με το ρυθμό του προηγούμενου χρονικού διαστήματος. Το γεγονός, ότι η διάρκεια της περιόδου ψηλού ρυμθού σεισμικότητας ήταν ίση με 2.6 χρόνια, ισχυροποιεί τα αποτελέσματα πρόσφατης έρευνας πάνω στη μεταβολή της σεισμικότητας κατά τη διάρκεια του σεισμικού κύκλου, σύμφωνα με τα οποία παρατηρείται μιά περίοδος αυξημένου ρυθμού σεισμικότητας πριν τον κύριο σεισμό ίση με 2.7 χρόνια, κατά μέσο όρο.

INTRODUCTION

The behaviour of the seismic activity during a single seismic cycle has been being the subject of many seismicity studies. Recent work on the nature of the seismic cycle resulted in the refinement of the different phases of the cycle, which actually reflect time variations of earthquake occurrence frequency (Mogi, 1981; Ellsworth et al., 1981; Karakaisis et al., 1991).

The most recent results (Karakaisis et al., 1991), which are depicted in Fig.1 and concern shallow main shocks, show that the post-shock activity follows the first main shock of the seismic cycle and lasts up to several years, with its duration being dependent on the magnitude of the main shock. Then, the seismicity drops to the background level. During the last one-fourth of this phase, the seismicity exhibits a tendency to increase gradually. This phase, with a duration depending on the magnitude of the first main shock, is followed by a period of increased activity with an average duration of about 2.7 years, which culminates before the second main shock, while its duration does not depend neither on the first nor on the second main shock magnitudes.

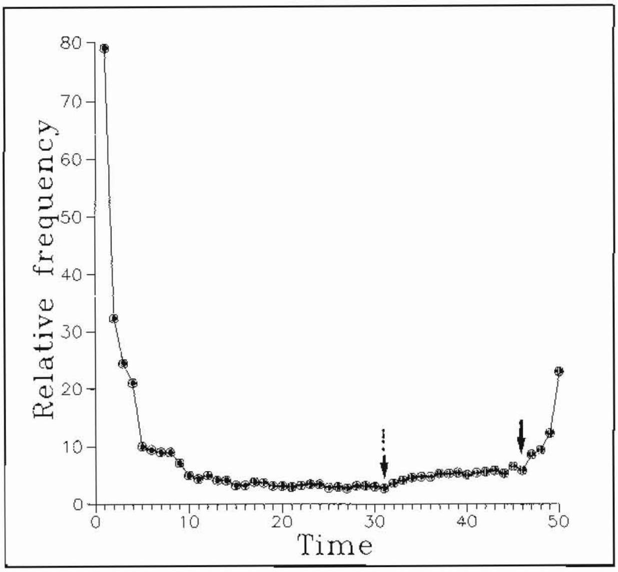

Fig.1. Temporal variation of the seismic activity during a single seismic cycle.

It is the purpose of the present paper to present a case history of such precursory increase of the small magnitude seismic activity by analysing the seismicity rate before the December 21, 1990 earthquake (M_S=5.9, Northern Greece).

DATA AND METHOD

On December 21, 1990 a M_S=5.9 earthquake occurred in Northern Greece, in one of the seismogenic sources into which Greece and the surrounding areas have been divided (Fig.2). This separation has been obtained on the basis of geomorphological criteria, of spatial clustering of epicenters of strong earthquakes, on the seismicity level, on the maximum earthquake observed and on the type of faulting (Papazachos and Papaioannou, 1993).

Since we are interested in the small-magnitude seismicity variations, we took advantage of the data of Scordilis (1985) for the period 1981-1984, of Scordilis et al. (1989) for the period 1985-1986 and of Scordilis et al.(1992) for the period 1987-1990. These catalogues concern earthquakes which occurred in the broader area of N.Greece and have been recorded by the telemetry seismological network of the Geophysical Laboratory of the Aristotelian University of Thessaloniki.

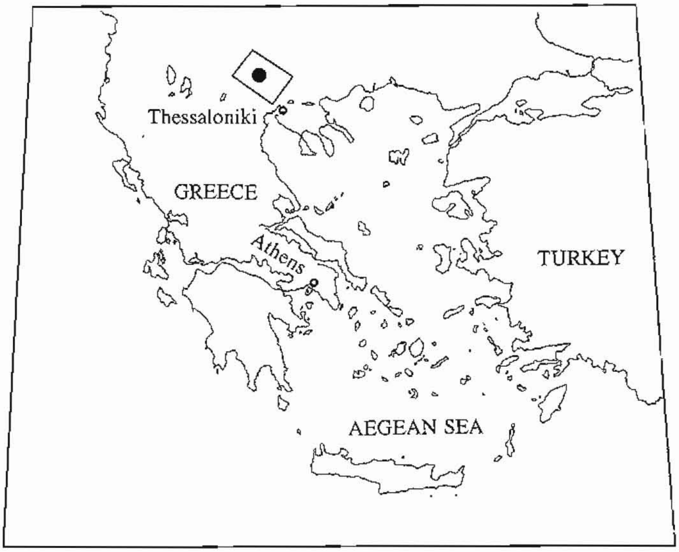

Fig.2. The seismogenic source, into which the M_s=5.9 earthquake occurred (December 21, N.Greece).

As it is known, the main problem in treating earthquake catalogues for the determination of seismicity rate changes, which might reflect changes in tectonic processes, is the recognition and the elimination of changes which may have been introduced during the compilation of the catalogues. These man-made changes have been described in detail by Habermann (1987a) and concern changes that are related to the detectability of the seismological networks which monitor and locate events (detection changes), changes that are related to lack of reporting of magnitudes for detected events (detecting changes) and changes in the magnitude determination (magnitude shifts).

Studies on the detectability of the seismological network of the Geophysical Laboratory showed that every earthquake that occurrs in the broader area of N.Greece, with $M_L \geq 2.1$, is recorded and can be accurately located. On the other hand, the seismological network that monitored the earthquakes has been being continuously in operation since 1981. Furthermore, the magnitude determination procedure has been based on measurements of the recordings of these stations, remaining unaltered during the last ten years. For these reasons, the data used are complete and homogeneous and probable variations will be the manifestation of ongoing tectonic process.

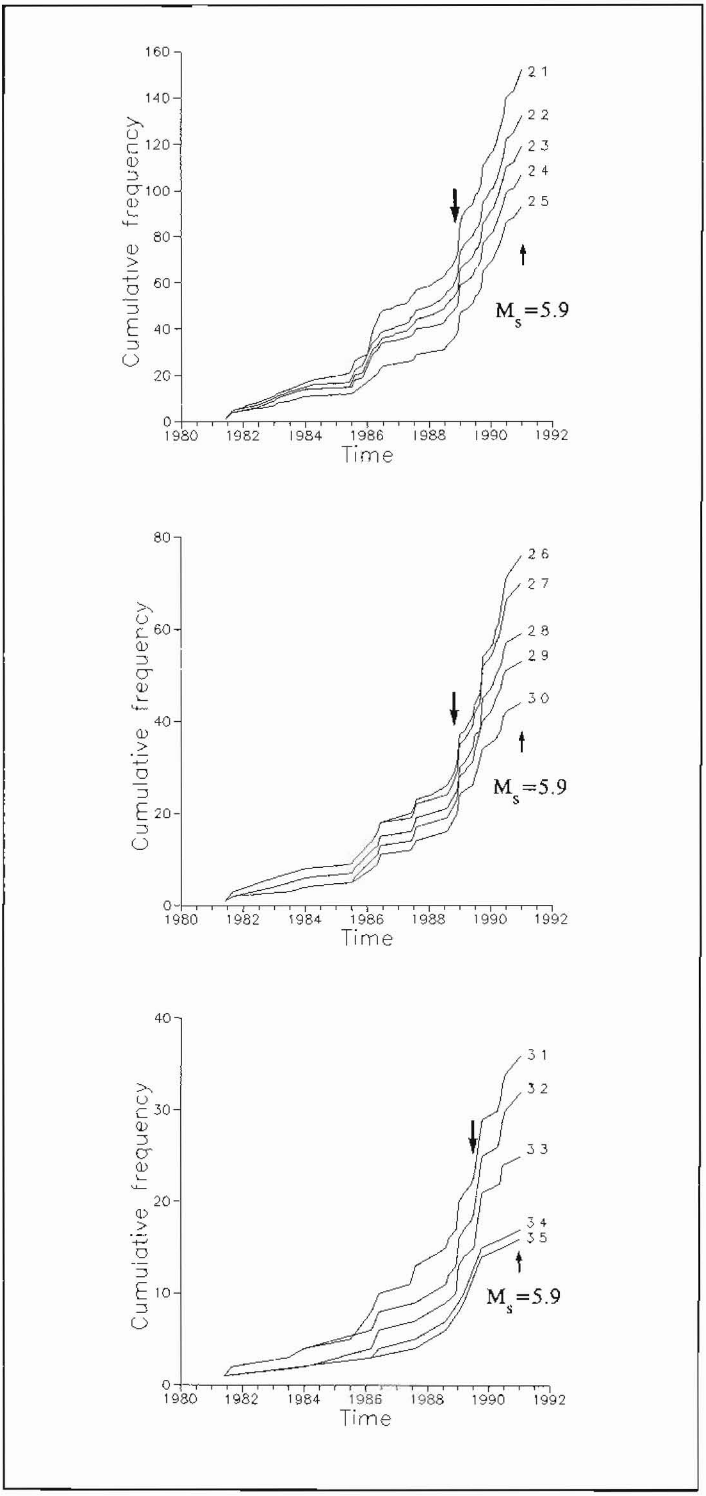

Fig.3. Seismicity rates for different cut-off magnitudes.

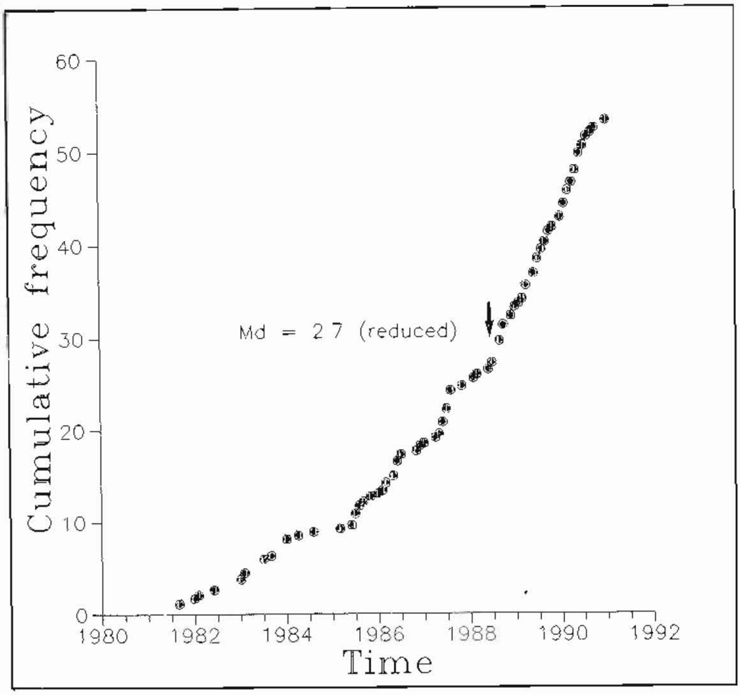

Fig.4. Seismicity rate of the earthquakes of Fig.3 with cut-off magnitudes M_L=2.1-3.3, which were reduced to M_L=2.7

RESULTS

Figure 3 shows the cumulative earthquake occurrence frequency in the seismogenic source of Fig.2 since January 1981 until December 20, 1990, that is, one day before the main shock, for different cut-off magnitudes. It is observed that the seismicity rate was slowly increasing until April 1988. Since May 1988 the seismicity rate became higher and remained almost constant until the main shock occurrence. It seems, however, that for larger cut-off magnitudes ($M_L \geq 3.4$), the seismicity rate decreased after August 1989.

For a better representation of the increasing trend of the seismicity rate, the magnitudes of all the earthquakes that followed this trend (M_L=2.3-3.3) were reduced to M_L=2.7. The result of this procedure is depicted in Figure 4.

It has been pointed out (Habermann 1987b; Matthews and Reasenberg, 1986) that visual evaluation of seismicity data is not adequate for recognition of anomalies of seismicity rate, and some sort of quantitative tools must be used for examining these data. The test which has been most extensively used and tested for comparing seismicity rate changes is the z-test for a difference between two means (Habermann 1987b).

Seismicity rate changes are defined in terms of the rates during the two time periods which procede and follow the changes.

In order to compare those rates, the mean rates during the two periods (M_1 and M_2), the standard deviations of those rates (S_1 and S_2) and the number of samples in each period (N_1 and N_2) have to be determined. Then, the z-statistic for the change is calculated by the formula:

$$z=\frac{M_1-M_2}{\left(\frac{S_1^2}{N_1}-\frac{S_2^2}{N_2}\right)^{\frac{1}{2}}}$$

The z-statistic was applied on the data of Figure 4 and it was found that the z-value is equal to 3.73. This value is comparable with those found by several authors, who detected significant rate changes before strong earthquakes (Wyss et al.1984; Wyss and Habermann 1986).

CONCLUSION

The temporal variation of the small magnitude seismicity before a M_S=5.9 main shock is examined. It was found that a significant increase (z=3.73) started 2.6 years before the main shock. During these years, the seismicity rate was about 3 times higher than the rate of the previous time interval. This observation reconfirms previous results (Karakaisis et al. 1991). The same procedure was applied on the earthquakes of several other sources of Greece with data from the recently published yearly earthquake catalogues that have been compiled by the Geophysical Laboratory of the University of Thessaloniki. The results seemed encouraging but more work is needed, since the minimum cut-off magnitudes of the earthquakes considered are higher ($M_L \geq 3.1$) than those of the present study and it has been suggested that the friction law between earthquakes with magnitudes greater than 3 and smaller than 3 has distinctly different parameters (Aki;1986).

The above mentioned results, in combination with the results of the application of the time predictable model proposed by Papazachos and Papaioannou (1993), as well as a denser network of seismological stations, might enhance our ability towards intermediate-term earthquake prediction.

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