550. 34 (520)

ON THE EXCEPTIONAL EARTHQUAKE SWARM ACTIVITY AT MATSUSHIRO, JAPAN

by

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Abstract

A general description of the earthquake swarm at Matsushiro is presented. From August 1965 through June 1966, almost 400 000 shocks were registered.

Some remarks and discussion on the activity course and on the energy release problem in relation to medium structure are given.

Finally, attention is called to the importance of studies of microearthquake activities.

1. *General description of phenomena*

Matsushiro, a small town located near Nagano city in central Japan, recently became famous. Since September 1965, almost every day the Japanese daily papers contained news of tremors that shook the area. Indeed, the termor activity began in August, but at that time the shocks were only detectable with very sensitive seismographs. Later, the daily number of these microearthquakes increased and a few of them were strong enough to be felt. In accordance with the general rule, here once again confirmed, an increase in the intensity of a relatively small number of shocks accompanies the increase in the number of shocks.

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Until November 1965, the increase of activity continued at Matsushiro, by which time a daily figure of 1 000 unfelt shocks and several hundreds of felt shocks was reached. Until March 1966, the daily numbers of shocks fluctuated around these values. Starting in March, however, a new and unusual increase of activity began, soon reaching several thousands of shocks daily. This time, the space distribution also changed; the earthquake foci spread out from the very confined region of a few kilometers. The depths of the shocks still remained very shallow, around 2—5 km only.

The intensity of individual tremors did not exceed V of the Japanese seven-degree scale, that is a magnitude of less than about 5 and energy release of about 10^{20} erg. Up to June 17, 1966, according to the Japan Meteorological Agency, 400 000 shocks had been registered. Almost 40 000 of these shocks were felt, and of these 7 were of intensity V, 35 reached intensity IV, and over 300 intensity III.

2. *Energy release problem*

Earthquake phenomena result from accumulation of internal strain energy inside the Earth's crust and upper mantle. This accumulation increases, probably steadily with time, and when a certain critical value in a volume is reached, at least part of the accumulated energy is released, *i.e.* an earthquake occurs.

Some investigations and field observations indicate that the mode of energy release depends on the local structure of the medium. The tremor swarm at Matsushiro seems to demonstrate that in some volumes almost continuous energy release could occur through many very small shocks, whilst in some other volumes the energy could be released only in one earthquake at a time. The structure of the medium, its internal characteristics, geological history, failures and inhomogeneities are responsible for these differences.

In homogeneous material energy accumulates without any discharge process up to a certain moment, at which a major release occurs. In very inhomogeneous material almost simultaneously with the accumulation process the discharge of energy through small shocks will occur. It should be added here that in the former case the properties of originally homogeneous material would gradually be changed, as a result of cracks and failures that arose during the first shock, so that the next discharge, called replicas, would then be expected with high probability.

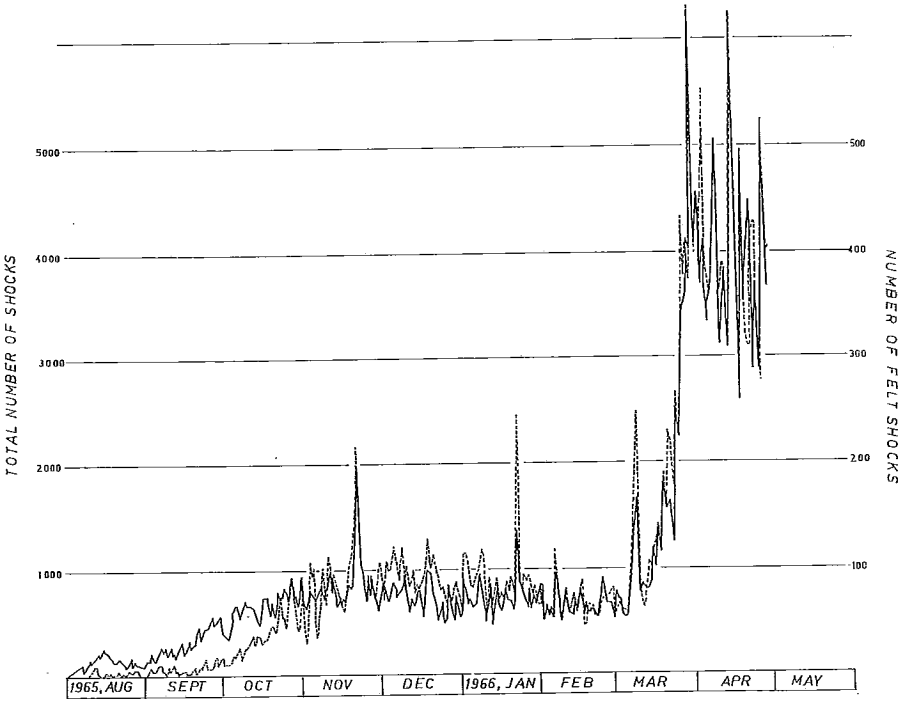

Fig. 1. Total number of shocks at Matsushiro from the beginning of August 1965 till May 1966 according to data given by JMA. Broken line = number of felt shocks.

In this paper we are discussing an almost continuous sequence of Matsushiro swarm earthquakes. This is, of course, an extreme case of an earthquake group sequence. More usually, in seismological papers we find discussions and research on the aftershock sequence which follows a major earthquake.

Different cases were described in the paper on multiple shocks [1] occurring almost simultaneously and revealed on seismograms by overlapping impulses. In the paper quoted the authors were trying to prove that two kinds of multiple shocks could be distinguished: the first kind represented by shocks directly related to each other and with foci forming a series within the same volume, and the second kind represented by the case in which the following shocks occurred in nearby blocks or volumes but were also related — by sudden changes of stress due to energy release — to the first shock. In the case of multiple shocks of the second

kind, it is evident that the distances between individual foci may be detectable.

Coming back now to the shock swarm in Matsushiro, we could apply the above argument to a long-term phenomenon. Thus the beginning of the swarm in August 1965 and the following remarkable increases in activity, like those in October, November and January, could each be treated as a group of phenomena corresponding to the first kind of multiplicity. We could also regard the new different activity period from March as an earthquake phenomenon of the second kind of multiplicity; the activity increases in August, October, November, January and March would thus correspond to first impulses of different individual activities. It should be added here that up to March 1966 the region of the Matsushiro foci was restricted within a defined volume. In March 1966, however, a new activity increase (the main phenomenon?) was observed and at the same time the foci spread out into a larger volume, outside the Matsushiro region.

3. *Seismological observations at Matsushiro*

At Matsushiro, just above the activity volume, the central seismological observatory of the Japan Meteorological Agency is located. The observatory is equipped with several sets of up-to-date seismographs, including standard ones. In addition, very long quartz strain meters (100 m long) are installed there. The observatory has been operating since 1950 [2].

The sensitive equipment of the seismological observatory made it possible to detect the many ultra-small tremors of the activity at its very beginning. Later, the Earthquake Research Institute of the University of Tokyo also installed many field seismograph stations there during the continuation of the recent swarm activity. Besides, the International Institute of Seismology and Earthquake Engineering took part in the investigations in Matsushiro, carrying out several field observations with very sensitive instruments during different periods of activity.

Among other investigations in the Matsushiro area it should be pointed out that geodetic measurements were also made by triangulation with the aid of precise light theodolites. These repeated measurements clearly revealed slight changes in distances which corresponded to the usual pattern of earthquakes in the area.

Our personal observations in Matsushiro in the beginning of December 1965 made a very deep impression on us. The shocks which we felt were similar to very short rapid movements accompanied by a deep sound. The phenomenon also reminded one of the authors of his experiences in Silesia, Poland. In this mining region rock bursts and small tectonic tremors frequently occur. The shocks which are sometimes felt there are also like sharp movements of short duration. Perhaps the small depths of these events are responsible for the similarity. Phenomena like the »Lapinjärvi shots» over ten years ago and some single shot-like noises noticed in certain parts of Finland might also be recalled here. Such phenomena might result from microearthquake swarms, even in stabile masses, and encourage studies in this important field.

Acknowledgment: The authors are indebted to Dr. S. OMOTE, Acting Director of the International Institute of Seismology and Earthquake Engineering, for his invaluable support of their work at the Institute.

Great appreciation is also expressed to the Japan Meteorological Agency for kindly offering the whole of their available observation data for the purpose.

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