Letters to the Editor

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EARTHQUAKE RECORDINGS ON THE ANNAMALAINAGAR MAGNETOGRAMS

During the IGY period two field magnetic observatories were started, one at Annamalainagar (Geo. Lat. 11°22′N, Long. 79°41′E) and another at Trivandrum (Geo. Lat. 8°29′N, Long. 76°57′E). Between 1958 to 1963, there were 63 occasions during which the Annamalainagar magnetograph had recorded earthquake shocks. The exactly similar magnetograph at Trivandrum had not recorded even a single earthquake. The different types of magnetographs at the Alibag Observatory also did not record a single earthquake during this period. The earthquake records are analysed and discussed in this note.

Earlier work — A brief reference to the earlier work is made before presenting the analysis of the earthquake records at Annamalainagar. The first recorded earthquake on a magnetogram was in 1887 during the earthquake in Liguria. An earthquake on 12 June 1897 caused similar disturbances at many observatories in Europe and Asia. It was at first thought that earthquakes were responsible for causing magnetic disturbances. But soon it had to be given up when it was known that the disturbances on the magnetograms were not simultaneous and the waves that cause these disturbances travel at the same speed as that of the earthquake waves. A satisfactory theory was lacking for long time to explain how an earthquake tremor could produce a rotary motion of the suspended magnet. Professor Harry Reid of Johns Hopkins University tackled the problem from the mathematical side and showed (1914) in his paper "The free and forced vibrations of a suspended magnet" that under conditions that exist in magnetic variometers a rotary motion would be given to the suspended magnet by earthquake waves, due primarily to the fact that the centre of gravity of the magnet system does not lie in the axis of rotation.

It was also thought that during certain phase of the earthquake, electric currents were set up and they were responsible for the perturbations caused on the magnetograms during the period of the earthquake. There were others too like Charles Davison who believed that it was entirely due to mechanical effect and the explanation offered by them was that one end of a compass needle would receive a greater effective impulse than the other at the time of an earthquake shock on account of its greater mass. There were still others who believed that it is partly electrical and partly mechanical. The period of the magnetographs and the seismic waves also drew the attention of the early workers in this field. They were surprised to find magnetographs having vast difference in periods from the period of the seismic waves recording the earthquakes. The phenomenon of magnetographs recording earthquakes was so exciting during the beginning of the 20th century that detailed study was instituted in many countries by establishing side by side magnetic as well as seismological instruments to determine whether or not the movement of the magnets was entirely mechanical. These investigations under Bauer of United States Coast and Geodetic Survey, showed that some earthquakes are recorded on the magnetograph and not on the seismograph and *vice versa*. It was also noticed that a magnetograph which was recording earthquake shocks stopped recording the same when shifted to another station hardly 50 miles apart. Magnetographs which had recorded

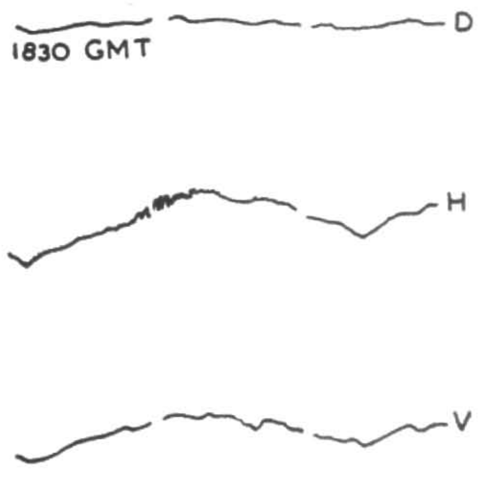

Fig. 1. Iranian earthquake of 1 September 1962 recorded on *H* only

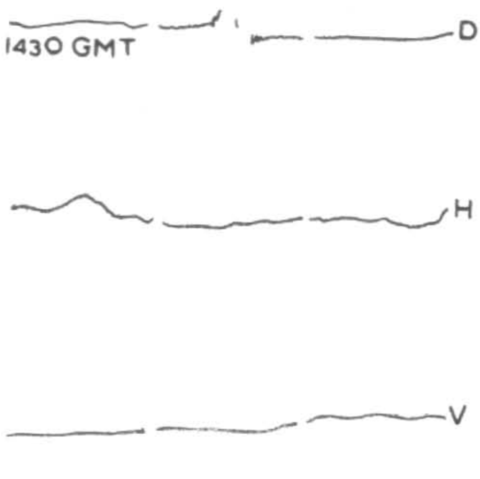

Fig. 2. Hindukush earthquake of 2 March 1959 recorded on *D* only

slight earthquakes, sometimes did not respond to very great earthquakes. These and many other points were examined but the problem has remained unexplained fully.

The existence of a correlation between magnetic disturbance and seismic activity, suspected ever since the first record of the earthquake on the magnetogram, is more and more believed especially during the last decade. The Japanese scientists are conducting magnetic surveys before and after earthquakes and they attribute the difference in the magnetic values as due to seismic activity. It is explained by them that due to thermal changes accompanying the earthquakes, demagnetization in the magnetic mine takes place in a certain volume of rock and this causes a change of field at the surface. Russian scientists especially Kalashnikov (1954) has explained these perturbations on the magnetograms during earthquakes as due to seismo-magnetic effects. He has initiated laboratory experiments to consider the piezomagnetic properties of rocks, and he explains the seismo-magnetic effects as due to the piezomagnetic properties of rocks, the magnetizations of which change reversibly with the stress applied to them. It is in the light of the fresh thinking given to this subject of earthquake recordings by the magnetographs that the recordings at Annamalainagar are interesting.

Analysis of the Results

The Annamalainagar Observatory is equipped with the Askania type *H*, *V* and *D* instruments. But the earthquake recordings are made in the traces of *H* and *D* only and not in *V*. There are occasions when only *D* or *H* has responded to earthquakes though in majority of cases both have responded. In their degree of response too *H* and *D* have differed from earthquake to earthquake (Figs. 1 to 3).

The instruments *H* and *D* have responded to near as well as distant shocks. They have responded to a tremor near Delhi in 1963 as well as the great shock near Chile (S. America) in 1962. They have also recorded shocks from all directions. In all cases, the starting time of perturbations at Annamalainagar magnetograms has coincided practically with the *P* time of earthquake as tabulated at Colaba Observatory.

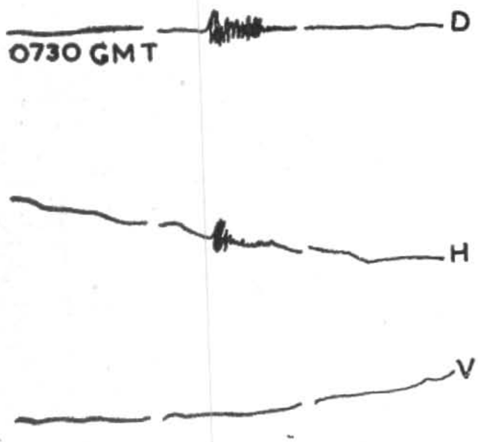

Fig. 3. Kurile Island shock of 16 March 1963 recorded on H and D only

The traces of the magnetograms affected by the earthquakes can be broadly classified into two categories. To the general category belong the traces where there are a broadening or blurring or even interruption, of the photographic traces indicating oscillations too rapid to be recorded separately. In the second category of traces we find as if a magnetic disturbance is associated with the earthquake. Here the oscillations have longer period, say one or two minutes.

Mention has been made that some of the shocks were prominent in H while others were prominent in D. This depends mainly on the resultant ground motion produced by the seismic waves. North and south ground motion will have good impact on H magnet which is oriented east-west while east-west ground motion will produce prominent perturbations in D, where the magnet is oriented north-south. Generally the duration of the perturbations have a bearing on the nearness and the intensity of the shock waves passing over the station, though this is not always the rule.

From a few of the magnetograms, especially from those where the recordings are sharp, it is possible to discern the preliminary phases, the long waves and several after shocks. Because of the slow rotation of the drum (20 mm per hour) accurate timing of the phases is impossible.

A study of the earthquake recordings by the magnetographs at Annamalainagar will not be complete without providing suitable explanations for the following.

(1) The non-recording of earthquakes by the exactly similar instruments at Trivandrum, (2) The non-recording of earthquake by the Vertical Force Magnetograph at Annamalainagar and (3) The random recordings of earthquakes unconditioned by any general criteria such as néarness, intensity etc.

A detailed study of the structure of the soil, its conductivity and the magnetic anomaly at the places, are being looked into before explanations are offered on the above.

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