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An account of short period microseisms recorded during three Indian cyclones

B. P. SAHA

Central Seismological Observatory, Shillong

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ABSTRACT. The microseisms in the range of period 4 to 10 secs have been observed and studied in great detail. The microseisms in the range of period one second or less were studied by the author previously. It was concluded that the short period microseisms are associated with the passage of cold fronts over or near the station. A few interesting observations of short period microseisms immediately after the passage of cyclonic storms into the land area are presented. The mechanism of generation of these microseisms in relation to the existing theories is discussed.

1. Introduction

With the discovery of fairly sensitive seismographs the seismologist could observe microseisms in the period range 4 to 10 secs and they were attributed to disturbances over the surface of the ocean. The microseisms in this period range have the maximum amplitude and hence they are detected very easily. Extensive studies have been carried out partly because of their easier detection and partly because these are connected with the meteorological disturbances far out in the sea and it might be possible to use them for tracking and predicting cyclonic storms in the distant ocean. Most of the existing theories on microseisms are related to some effects of sea waves either on a steep coast or to the sea bottom and the theories may be summarised as (1) effect of the surf on the steep coast, (2) effect of the atmospheric oscillations on the surface of the sea and (3) effects of the standing waves on the sea bottom. Accordingly these theories are suitable for explaining microseisms of sea origin only but they have no application to the short period microseisms of land origin proposed for study in this paper. Recently the author (Saha 1962) observed some microseisms in the period range of one second or less on the records of the short period Benioff seismograph at Shillong. Before him it was Walsh (1955), Wilson (1953) and Akamatu (1961) who made a detailed study of microseisms of period 0·3 to 0·4 sec. Walsh (1955) concluded from his study that these short period microseisms are associated with some convective activity over the recording station. The present author has, however, concluded that these microseisms are induced by the passage of cold fronts associated with low pressure waves of the western disturbances. Chakrabarty and Sarkar (1958) have also observed similar short period microseisms of period 0·4 sec in the records of the Benioff seismographs at Howrah when the Nor'wester disturbance was near the station just before its passage into the Bay of Bengal. Soon after its passage, they, however, observed microseisms in the period range of 2 to 3 seconds. The present study is due to observations of similar short period microseisms when the cyclonic storms originating in the Bay of Bengal move towards Assam as low pressure wave; although these storms did generate 4 to 6 sec microseisms recorded at Shillong when the cyclonic storms were in the Bay of Bengal. It is very remarkable that the meteorological disturbances over continental area could induce microseisms having comparatively shorter period than those observed when meteorological disturbances are over the nearby ocean or large bodies of water.

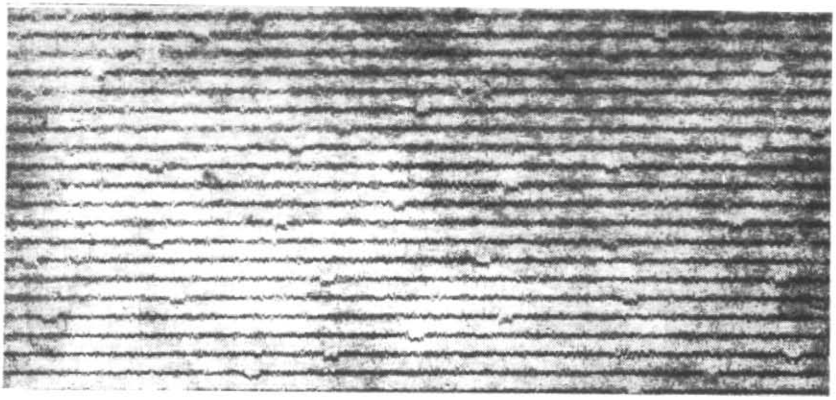

Fig. 1. Section of Shillong Vertical Benioff (S.P.) record of 9 May 1961
Time scale 60 mm/min. Time interval between corresponding points on consecutive line is 15 min (approx.)

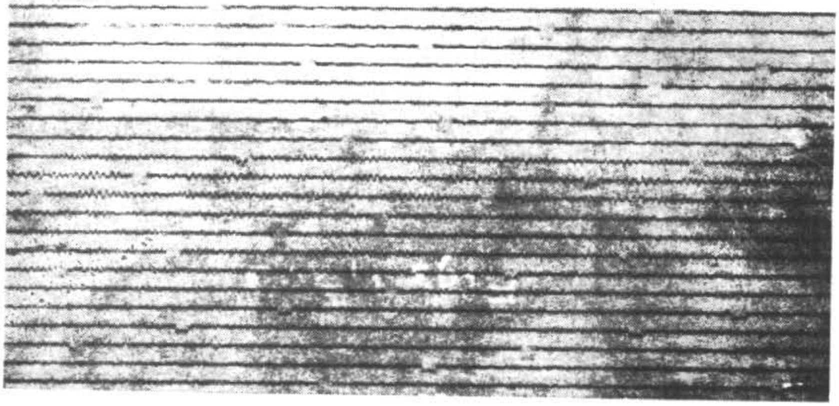

Fig. 2. Section of Shillong Vertical Benioff (S.P.) record of 30 May 1961

2. Experimental data

Three cyclonic storms originated in the Bay of Bengal during the month of May (1961 and 1963) and gave rise to storm microseisms of period 3-5 sec which were recorded at Shillong at a distance of 400 km from the nearest coast. These cyclonic storms after crossing near the east coast of Pakistan moved as low pressure wave towards Assam. On all occasions short period microseisms were recorded by the short period Benioff vertical seismograph ($To=1\cdot0$ sec and $Tg=0\cdot18$ sec) at Shillong. These microseisms are very similar to those studied by the author (Saha 1962) previously. The short period microseisms recorded at Shillong are reproduced in Figs. 1–4.

Fig. 1 represents the trace of the short period microseisms recorded when the cyclonic storm which originated in the Bay of Bengal on 7 May 1961, crossed coast on the morning of 9th and moved away as low pressure wave across Assam. The short period microseisms commenced at about 1500 IST of 9 May 1961 and continued till the morning of the following day. During this period the low pressure wave was over continental area of Assam and East Pakistan. The microseisms of 3-4 sec period continued till the appearance of the short period microseisms under study. Figs. 2 and 3 represent the trace of microseisms recorded when another cyclonic storm which originated in the Bay of Bengal on 28 May 1961, crossed coast near Chittagong on 30th and moved away as low pressure wave towards Assam. The microseismic waves of $1\cdot5$ cycles/sec (Fig. 2) appeared at about 2130 IST of 30th and attained maximum amplitude in short time and became very weak in course of a couple of hours. On this occasion also the microseisms of 3-4 sec period continued till the appearance of the first spell of short period microseisms (Fig. 2) at 2130 IST of 30 May 1961. On the weak back ground of microseisms of the first spell (Fig. 2), the microseisms reproduced in Fig. 3 commenced appearing at about 1400 IST of the following day and attained maximum phase at about 1600 IST and continued till the morning of 1 June 1961.

The manuscript of the present paper was prepared and sent for publication in August 1961. In April 1963, the instrumental set up at the observatory was replaced by U. S. C. G. S. world wide network of standard seismographs. The short period Benioff seismometers (three components) have the constants $To=1\cdot0$ sec $Tg=0\cdot75$ sec and peak magnification of 200 k at one cycle/sec. During the month of May 1963, one severe cyclonic storm originating in the Bay of Bengal, crossed coast near Chittagong on the night of 28 May 1963. The short period microseisms of similar type commenced appearing in all the three components of the records of the above instrument at about 0500 GMT of 29 May 1963. The amplitude of the recorded microseisms is large on account of increased magnification of the new set up. A section of the recorded trace from the east component is reproduced in Fig. 4. The microseisms with increased amplitude continued for about 6 hours and then began to decrease. It would be seen from Fig. 4 that the microseisms of longer period on account of the cyclonic storm when it was over the oceanic area have not completely disappeared and the short period microseisms have commenced appearing.

On a comparison of the recorded microseisms reproduced in Figs. 1-4, it is apparent that the frequency structure of these waves are not exactly same. Although the exact measurement of the frequency is extremely difficult partly because of the higher value of the frequency of the waves and partly because of the complicated structure of the waves on account of the super-imposition of waves having different frequencies, it might be possible to indicate, in a general way, the range of the predominating frequencies inspite of the variability of the frequency of the microseismic waves recorded. On an examination it is noticed that the waves of 3 to 4 cycles/sec are predominating

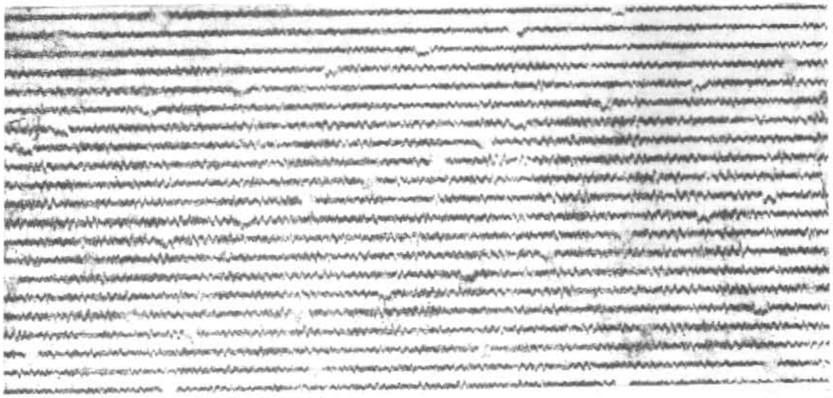

Fig. 3. Section of Shillong Vertical Benioff (S. P.) record of 31 May 1961

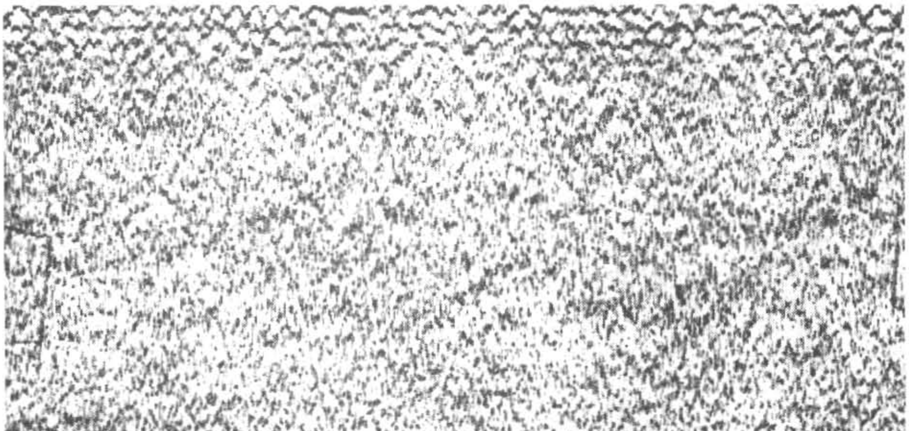

Fig. 4. Section of Shillong (N-S) Benioff (S.P.) record of 29 May 1963

in the case of microseism reproduced in Fig. 1. In the case of microseisms reproduced in Fig. 2, it is noticed that at first there are waves of 1·5 cycles/sec with higher frequency waves of smaller amplitudes superimposed on them. Afterwards the waves having higher frequency of 3 to 4 cycles/sec began to predominate on account of the increased amplitude of the higher frequency waves. The existence of the waves of 1·5 cycles/sec, although perceptible, became unimportant on account of decreased amplitude. The frequency structure of the microseisms reproduced in Figs. 3 and 4 appears to be still more variable and there is preponderance of waves of 1·5 to 4 cycles/sec. The amplitudes of waves having different frequencies appear to be equally strong. The observed variability of the frequency of the microseismic waves might suggest that area over which the low pressure wave moved has plural layers.

Similar microseisms of short periods were also recorded when cold fronts in association with secondary western disturbances move over Assam area. These western disturbances are extra-tropical depressions from the Mediterranean Sea travelling along the middle latitudes of Asian countries from west to east. From the synoptic situation it is concluded that the microseisms under study are due to the low pressure waves resulting from three cyclonic storms mentioned above. From meteorological standpoint, there is very little difference between the two types of disturbances mentioned above. The present situation is due to the low pressure waves resulting from the tropical cyclones while the secondary western disturbances are due to the low pressure waves resulting from the extra-tropical depression of the middle latitudes. The broad synoptic situation prevailing over Assam and adjoining area are shown in Figs. 5—8. It will be seen from the synoptic situation that there was a fairly deep low pressure area over Assam and adjoining country and that the synoptic situations on all the occasions are very similar. The tracks of the two cyclonic storms in Fig. 9 have been reproduced from page 502, Vol. 12 of this Journal. The track of the third cyclonic storm is also very similar.

3. Discussion

The above observation of short period microseisms could not be explained by the wave interference theory due to Longuet-Higgins (1950). The only theory that can be regarded as a serious rival to the stationary wave theory is due to Ewing and Press (1948). The recent study on microseisms at the bottom of the Baltic Sea by Monakhov (1962) also suggests that depending on the character of the layering we should expect the presence of prevailing vibrations with definite periods in the microseisms spectrum. The idea that microseisms are Rayleigh waves is an old one and the above theory of the authors could be easily extended to explain the frequency spectra of the microseisms of continental origin under study. We may have certain period set up between the superficial sedimentary rocks and the solid rock and these frequencies are associated with the stationary values of the group velocity. Theory predicts that large amplitudes should be associated with minimum of the group velocity of the dispersion curve. These frequencies are probably excited by the atmospheric oscillations of the same frequency. The theory is not, however, very advanced quantitatively as the stationary wave theory. Recently Mitra (1957), taking into consideration the presence of sedimentary layer under the water layer, could account for the observed periods of microseisms associated with Nor'westers over the head Bay of Bengal. It might be possible to explain the observed frequencies of the microseismic waves if we take into consideration the thickness of the different layers of the sedimentary rocks with appropriate seismic wave velocities.

The author (Saha 1962) had shown previously that atmosphere sedimentary layer coupling is possible and a significant transfer of energy can take place from air to rock.

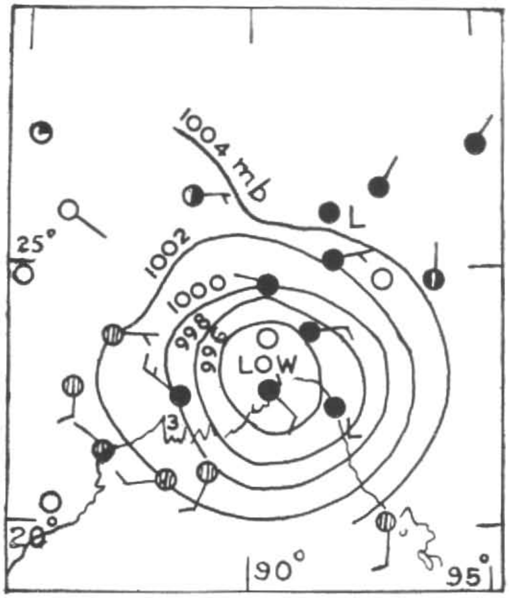

Fig. 5. 9 May 1961 (0830 IST)

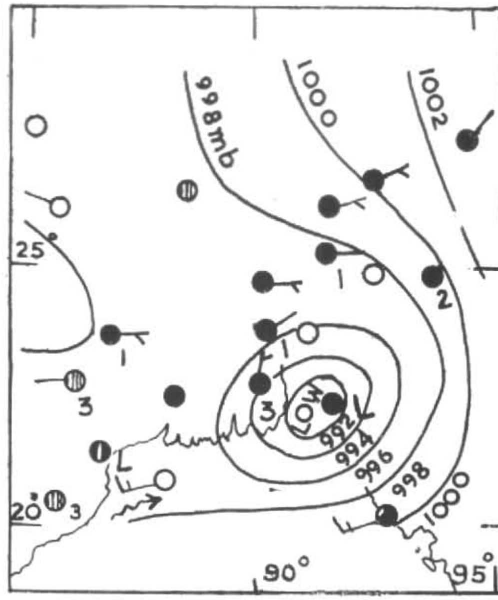

Fig. 6. 30 May 1961 (0830 IST)

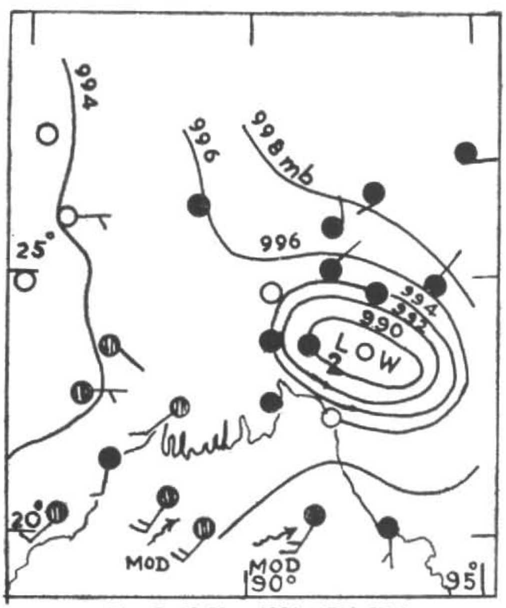

Fig. 7. 20 May 1961 (1730 IST)

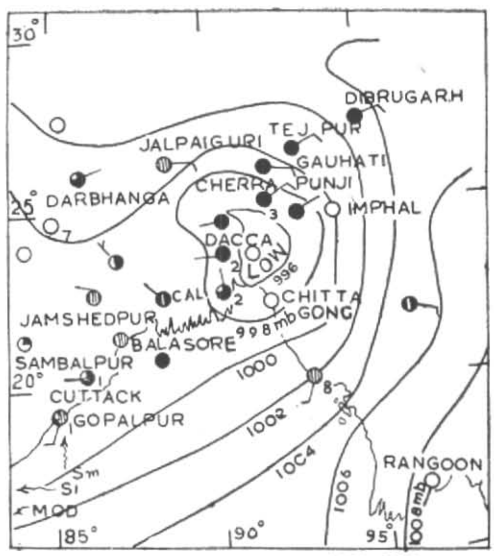

Fig. 8. 29 May 1963 (0830 IST)

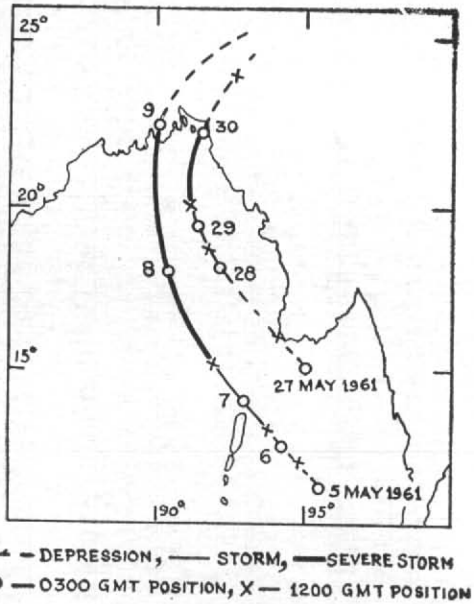

Fig. 9. Track of severe cyclonic storm, May 1961

This agrees with suggestion of Pomeroy and Oliver (1960) that the transfer of energy from atmosphere into seismic waves in the earth is possible at least without the intervening process of interfering gravity wave trains that has been discussed extensively in the current literature on microseism of oceanic origin. In many respects the microseisms of oceanic and continental origin are, however, very similar, specially in respect of selective transmission of certain frequencies. The frequency spectrum due to the microseisms of continental origin is likely to be variable because the structure of the crust particularly the upper surface layers would vary very widely. The periods and the amplitudes of microseisms under study are smaller as compared to those due to microseisms of sea origin. On account of higher attenuation of shorter period waves, the short period microseisms constitute noise level of extremely local and occasional nature while the ordinary microseisms of sea origin constitute noise level of much widespread nature. The water layer including sediments in the case of microseisms of oceanic origin or the surficial sedimentary layer in the case of microseisms of continental origin acts like some kind of filter and the dispersion curve appropriate to the structure may be regarded as a characteristic frequency proper to the layer.

4. Conclusions

1. The same meteorological disturbance moving over different structure can induce microseisms of different periods proper for that structure, provided there is sufficient potential in the spectrum of the exciting source.

2. Information on the layer parameters like the density and seismic wave velocity of the sedimentary rocks will be very useful to verify the hypothesis suggested in the paper. It is easier to determine the parameters of the sedimentary layers as compared to the structure of the ocean bottom.

3. From the above consideration the author is of opinion that it might be possible to work out a mechanical theory which would explain all observed facts of microseisms of both sea and land origin.

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