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Microseisms at Madras associated with disturbances in the Bay of Bengal

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ABSTRACT. Microseisms recorded at Madras associated with nearly all depressions and storms in the Bay of Bengal during the five-year period 1955 to 1959 have been examined. Mean characteristics of microseisms in different months are described. Case history of four microseismic storms are given.

Regions in the Bay favourable for production of microseisms at Madras and otherwise are located and probable explanation for the existence of such regions offered.

1. Introduction

Microseisms recorded at stations in India in association with meteorological system in the Indian Seas have been studied by Banerji (1930, 1935), Pramanik *et al.* (1948) and Tandon (1957). Mostly these studies were made with microseisms recorded on seismographs usually intended to record earthquakes. In 1952, Sprengnether microseismograph was installed at Madras. As this instrument has a high magnification and particular sensitivity in the period range of microseisms the records are specially suited for their study. The author has examined the data from 1955 to 1959 for the periods and amplitudes and their relationships with depressions and storms in the Bay of Bengal. The free period of the seismograph is $T_o = T_g = 7 \cdot 5$ sec and the magnification about 5000.

2. Mean amplitudes and periods

In this paper, wherever mentioned, amplitude refers to double amplitude. It is given in millimeters as measured without reducing it to its actual value. The amplitudes and periods are tabulated as a routine at Madras for the hours 00, 03, 06, 12 and 18 GMT. The mean values for different months have been worked out from these tabulations based on the five-year data. They are given in Table 1 and shown in Fig. 1.

The amplitude shows great variation during the course of the year being maximum in July and minimum in February. There is a second maximum in November. Relatively, variation in period is smaller. The minimum period occurs in January and maximum in August, though a secondary maximum is noticed in March and minimum in June. Corresponding to November maximum in amplitude there is no peak in period. From March to June the decrease in period is associated with an increase in amplitude.

The means, will represent conditions of days disturbed by depressions and storms and undisturbed periods. The total number of depression/storm days in different months in the five-year period are shown in Fig. 2 to indicate their relative effect.

The secondary maximum of amplitude in November coincides with maximum of depression/storm days. The large amplitudes from June to September cannot apparently be due to the effect of depressions and storms particularly due to the relatively lower intensity of these disturbances and greater distance from Madras as compared with those of October and November. While the winds in July in the Bay of Bengal and Arabian Sea are stronger than in February neither the difference in mean speed nor the more frequent strong winds can account for the five fold amplitude in July. Banerji (1930) has classified the microseisms of these

Fig. 1

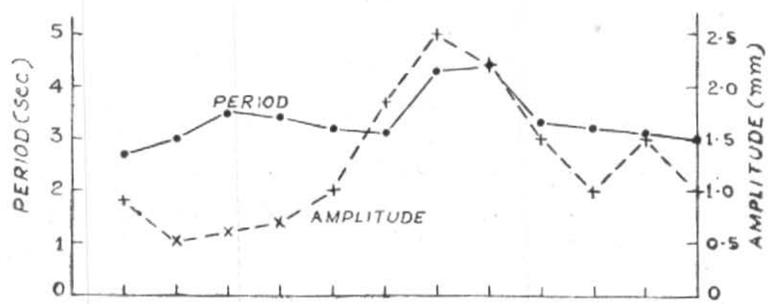
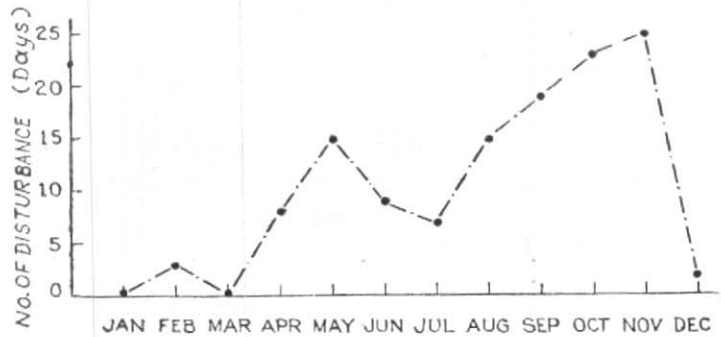


Fig. 2



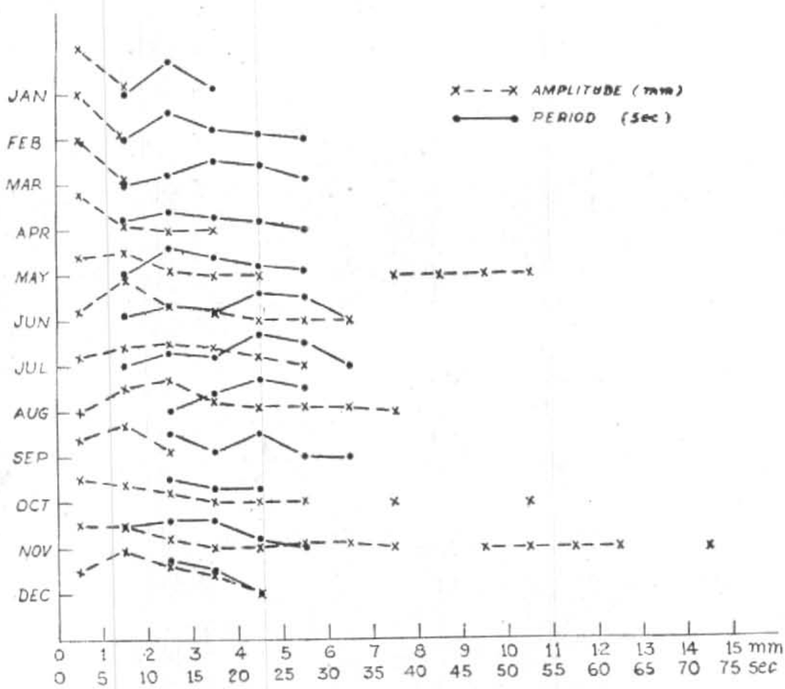


Fig. 3. Frequencies of amplitude and period

Frequency scale arbitrary

TABLE 1

Mean values of period and amplitude

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Period (sec)	2·7	3·0	3·5	3·4	3·2	3·1	4·3	4·4	3·3	3·2	3·1	3·0
Amplitude (mm)	0·9	0·5	0·6	0·7	1·0	1·9	2·5	2·2	1·5	1·0	1·5	1·0

TABLE 2

Date	Nearest hour (GMT)	Amplitude (mm)	Average amplitude prior to formation (mm)	Increase in amplitude (mm)	Percentage increase in amplitude
6-11-55	06 14	12·8 13·2	1·0	11·8 12·2	1180 1220 } Double Maxima
29-4-56	06	13·5	0·8	12·7	1589
29-10-56	03	11·8	0·7	11·1	1587
20-11-58	20	16·0	0·8	15·2	1900

months separately as monsoon type. Greater amplitude and period appears to be their characteristic.

3. Frequency distributions of periods and amplitudes

Frequency distributions of periods and amplitudes in different months are shown in Fig. 3.

The greater frequency of higher periods during the southwest monsoon months is seen strikingly in the diagram. The highest amplitudes are due to severe cyclones of pre-monsoon and post-monsoon months.

4. Storm microseisms

Striking changes in microseisms, particularly in amplitudes have been observed by different workers in association with formation, intensification, movement and weakening of depressions and cyclonic storms in the Indian Seas. For illustrating these changes microseisms associated with four storms which formed during the period of study are listed in Table 2.

The average amplitude prior to formation of the disturbance and the highest mean amplitude during the life period of the disturbance are given in Table 2. The highest mean amplitude is twelve to nineteen times that of the preceding undisturbed periods.

4.1. *Storm during 3 to 9 November 1955*—Shown in Fig. 4 are the variations in amplitude and period with successive positions and intensities of the disturbance. The track of the storm and its isobaric configuration at the synoptic hour nearest to the maximum amplitude of microseisms are also shown as insets.

The disturbance started as an easterly wave in south Andaman Sea on 2 November, intensified into a cyclonic storm by

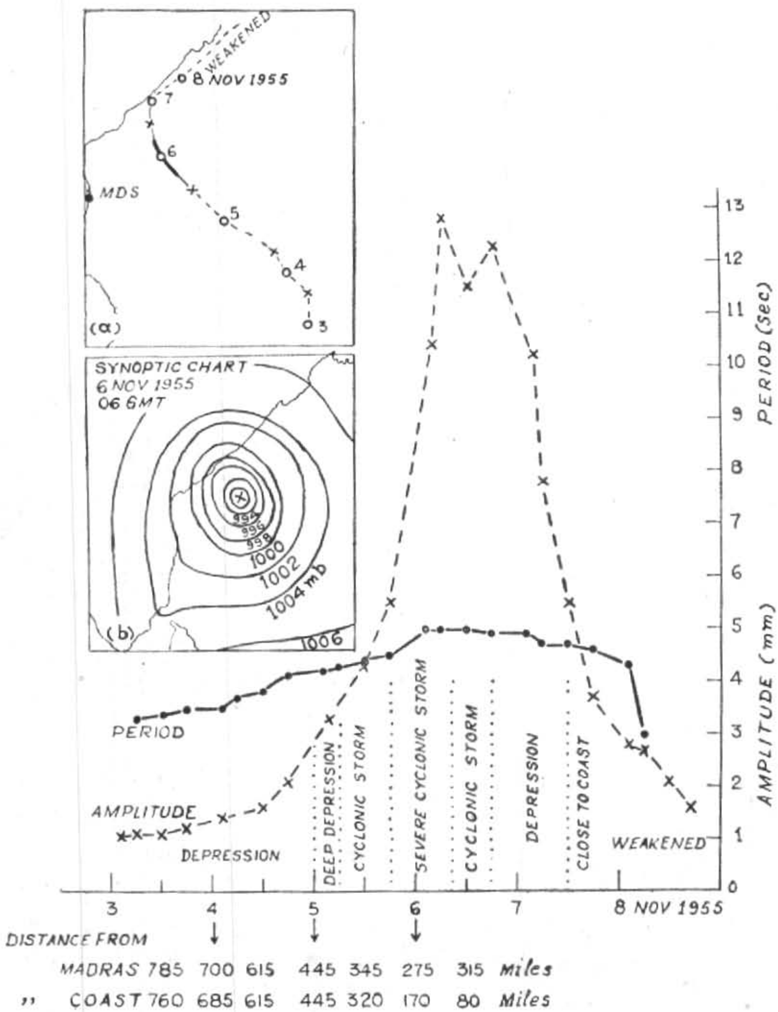


Fig. 4

the evening of 5th, and further intensified into a severe cyclonic storm by the early morning of 6th. The storm weakened as it approached the coast so that its maximum intensity was when it was at about 270 miles from Madras and at about 170 miles from the coast. The amplitude increased with the increase in intensity of the pressure system.

It is interesting to notice another maximum some hours after the first maximum even after the pressure system commenced weakening. The first maximum in amplitude is associated with maximum intensity

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NOTE—In the graphs showing the variation of microseismic amplitude and period 03, 06, 12 and 18 GMT values only are plotted

In the storm tracks given as insets in Figs. 4-7, circle and cross indicate 03 and 12 GMT positions of the disturbance respectively. Broken line, thin continuous line and thick continuous line indicate depression, cyclonic storm and severe cyclonic storm respectively

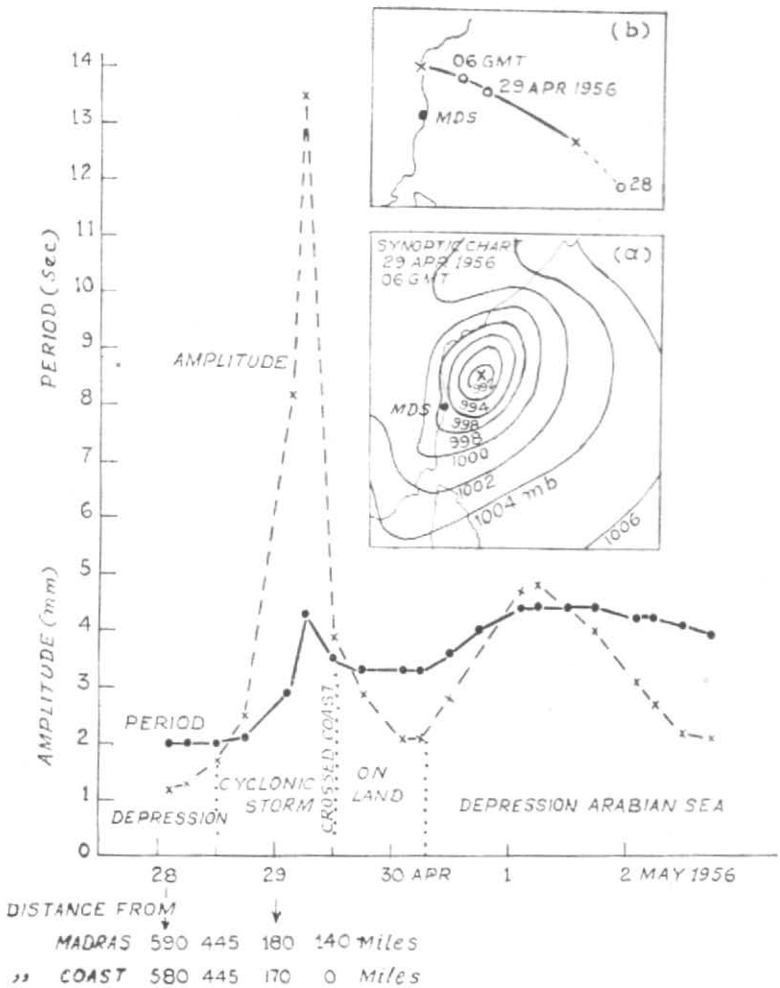


Fig. 5

of the pressure system when it was severe cyclonic storm, the amplitude thereafter falling with the weakening of the system. The second maximum probably occurred, as will be seen later, when the cyclonic storm was near the optimum depth of the sea, the amplitude falling thereafter with the further weakening of the system.

4.2. *Storm during 27 April to 2 May 1956*—All features relating to the storm are shown in Fig. 5. As the depression intensified into cyclonic storm, the amplitude shot up and reached maximum by about 0600 GMT of 29th when also the storm was most intense. Thereafter the amplitude fell rapidly, even though the system was coming closer to the coast. The maximum amplitude was definitely recorded 5 to 6 hours before the pressure system crossed the coast.

After crossing the coast the disturbance travelled across the Peninsula and entered the Arabian Sea. The changes in amplitude and period when the disturbance is on land and as it entered the Arabian Sea are also shown in Fig. 5.

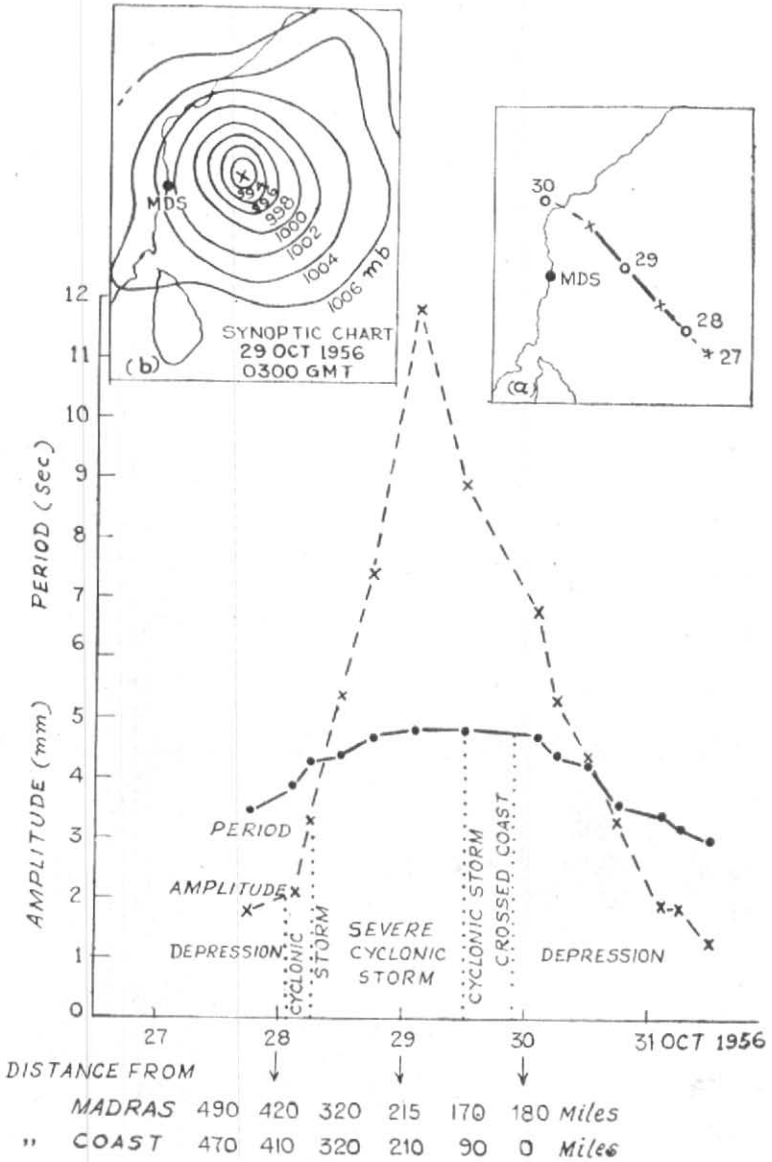


Fig. 6

4.3. *Storm during 27 to 31 October 1956*—The disturbance which started as an easterly wave over Andaman Sea on 26th gradually intensified into a cyclonic storm by the morning of 28th. From about 12 GMT of 28th to 00 GMT of 29th, this was a severe cyclonic storm but was already weakening by 03 GMT of 29th. The amplitude of microseisms continuously increased upto 03 GMT of 29th, under the combined influence of increasing intensity and decreasing distance from Madras. Thereafter even though the system was coming closer to the coast the amplitude decreased rapidly with the

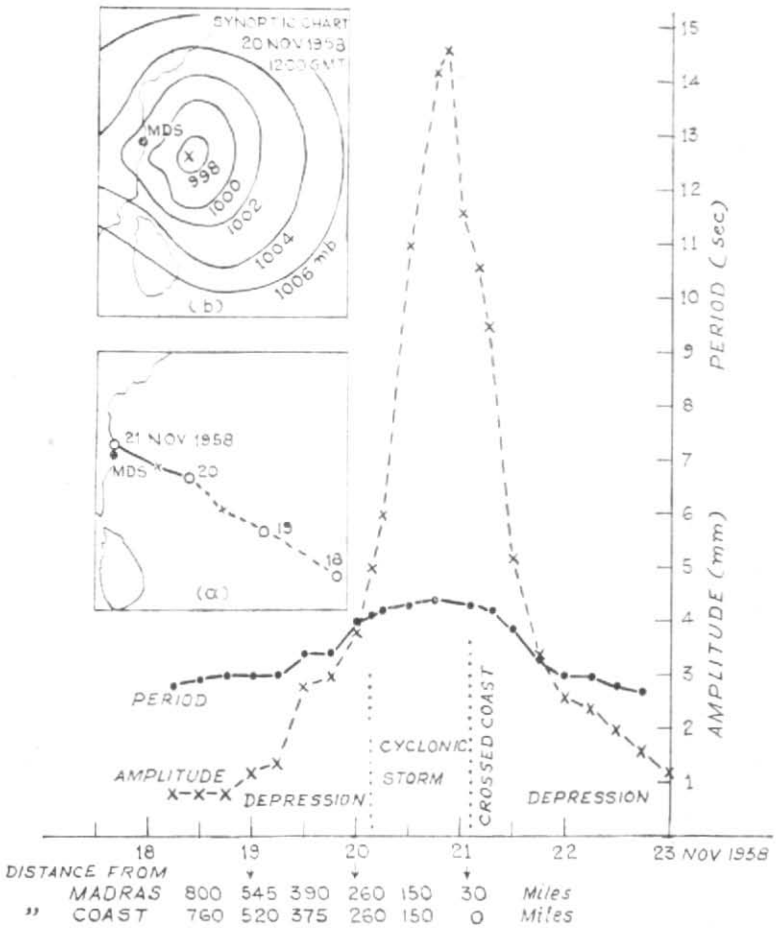


Fig. 7

weakening of the system. The maximum amplitude was recorded much before the system crossed the coast.

The variations in amplitude and period during the life period of the disturbance are shown in Fig. 6.

4.4. *Storm from 18 to 23 November 1958*—An easterly wave which was moving westwards across Tennaserim on the morning of 16th, caused the formation of a well marked trough of low in southeast Bay by the morning of 18th. It intensified into a depression by the same evening and further intensified into cyclonic storm by the morning of 20th and struck coast by 03 GMT of 21st by which time it had commenced weakening. The amplitude of microseisms was maximum at about 20 GMT of 20th when it was about 100 miles away at sea. Thereafter the amplitude fell rapidly. All features relating to the storm are shown in Fig. 7.

5. Deductions

From the above four and other similar cases of disturbances studied in relation to microseisms the following inferences could be drawn.

(1) As long as the depression or storm is intensifying and moving closer to recording station the amplitude increases.

(2) Decrease in amplitude even when the system is moving closer to the station is a definite indication of the weakening of the system.

(3) The time of occurrence of maximum amplitude is apparently not related to the system striking the coast but to the variations in intensity of the system as the intensity appears to be the most predominating factor in controlling the amplitude.

However, the amplitude seems to start decreasing some hours before the disturbance crossing the coast at an average distance of about 100 miles from the coast. This may be due to the decrease in the generating area due to a part of the strong wind field coming over land in combination with other factors mentioned above.

The maximum amplitude appears to occur when the system is still well over the sea at a distance form the coast which appears to more or less coincide with the position of 1000 fathom line, the amplitude falling rapidly thereafter even though it is approaching the coast. Thus there appears to be an optimum depth of the sea for the maximum amplitude to occur apart from the intensity and the distance of the disturbance, the maximum occurring neither in too shallow waters nor in the deep sea.

(4) The period appears to have a tendency to rise and fall with the amplitude but the changes in period are relatively smaller.

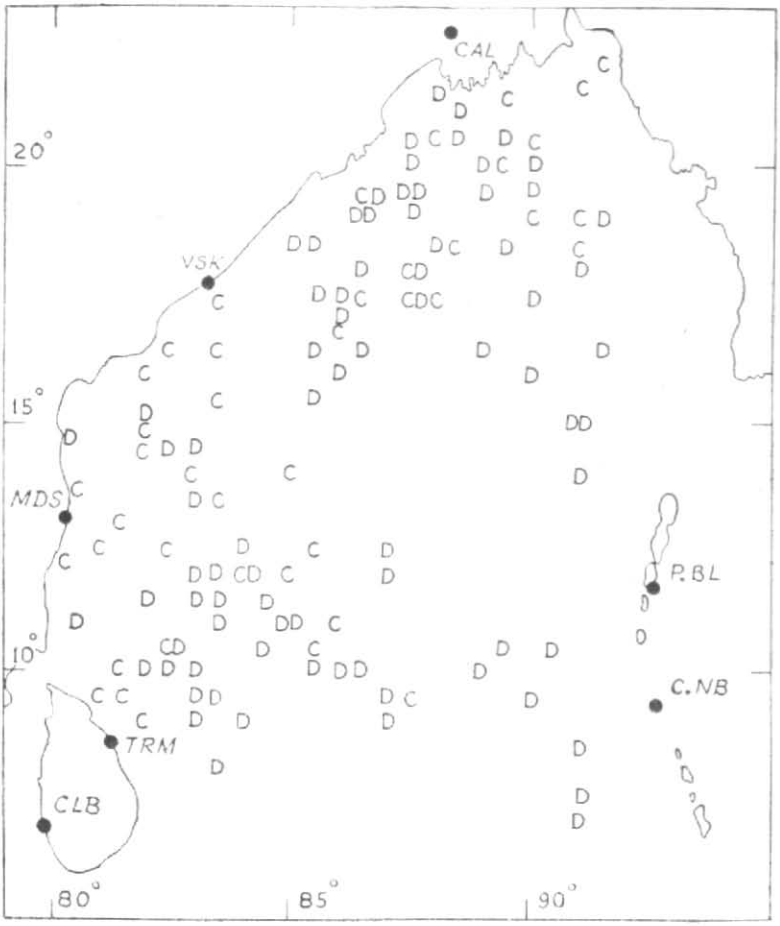
(5) The amplitude shows a marked increase when there is intensification to storm stage from depression. This can be of use in forecasting when ships data are meagre to indicate the intensification.

(6) There appears to be a primary difference between microseisms associated with disturbances in the Bay in pre-monsoon and post monsoon months from those in the head Bay during monsoon months. While the microseisms associated with storms in non-monsoon months show an abrupt decrease in amplitude as the storm weakens or crosses the region of optimum depth and much more so after crossing the coast falling down to original value, the microseisms associated with storms in monsoon months neither show an abrupt fall with decrease in intensity nor with the system approaching the coast. The amplitude remains fairly high till the system crosses the coast and continues to be so for a considerable period even after the system moves inland. This indicates that microseismic amplitude in monsoon months is not only associated with the storms but also with the attendant strengthening of monsoon not only when the system is in the Bay, but also for a considerable time even after the system moves inland.

6. Regions in the Bay favourable for production of microseisms at Madras

As has been shown above studies in microseisms associated with tropical disturbances in the seas show that these disturbances always cause an increase in amplitude of microseisms when near enough to the recording station. But, however, some changes appear to take place. In some cases a cyclone causes large microseisms at a distant station while there is no noticeable increase in microseisms at another station not so far from it. In this respect there is good evidence to show that propagation of microseisms is affected by deep geological discontinuities and that their strength gets modified due to changes in geological condition. In this connection, mention may be made of the observation of Pramanik *et al.* (1948) that microseisms are not recorded at Calcutta when storm was positioned in certain regions in the Bay.

Attempt has been made by the author to locate regions in the Bay of Bengal which are favourable for the production of microseisms at Madras and otherwise.



D — Depression C — Disturbance of a higher intensity than depression

Fig. 8

Fig. 8 shows the scatter of all the 03 GMT and 12 GMT positions of depressions (D) and more intense disturbances (C) after their formation and before crossing coast during the five-year period of study. On an average of four positions during the life period of each disturbance in Bay 160 centres have been obtained. After elimination of cases of simultaneously more than one disturbance either in the Bay or in the Arabian Sea about 120 centres were obtained.

The percentages of increase in microseismic amplitudes over the average prior to the formation of disturbances have been plotted at their respective centres separately for depressions and for more intense disturbances. The isopleths of equal percentage increase in amplitude were drawn. Figs. 9 and 10 show the isopleths for depressions and for more intense disturbances respectively.

Two regions of low index appear to be present in the Bay. The first is region from Andaman Sea to Sundarbans coast. This is noticed both in charts for depressions and more intense disturbances. It is interesting to note that depressions and storms

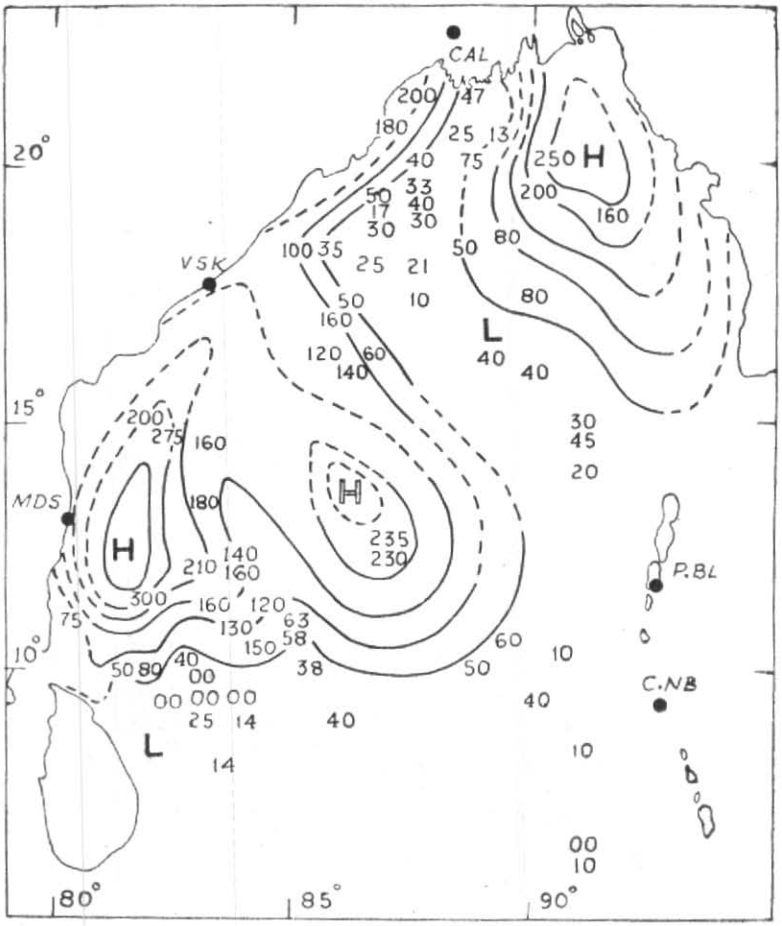


Fig. 9

off Arakan Coast even though farther from Madras than the region of low index referred to above caused greater increase in microseismic amplitudes.

The region of low index may have some association with the crevesses and slopes in the sea bed in the region of the so-called "Ganges Submarine Canyon" and its associated submarine channels reported by the Swedish Oceanographic Expedition in "ALBATROSS" and more recently by the Danish Sea Expedition round the world led by Dr. A. Fr. Brunn in "H.M.S. Galthea". But the width of the canyon reported is too small. This cannot however, be confirmed until a similar study as this is made with the data of another station say Calcutta or Port Blair.

The second region of low index is off east coast of Ceylon which is also noticed in both the charts for depressions and for more intense disturbances. This may be due to refraction and hence dissipation microseismic energy due to any steeply sloping region in the sea bed or due to any lithological discontinuity in its basement*.

*The Soviet Oceanographic Expedition has since reported the discovery of a conspicuous submarine ridge undersea mountain with several peaks off east coast of Ceylon (*Sci. & Cult.*, **27**, **3**, p. 108)

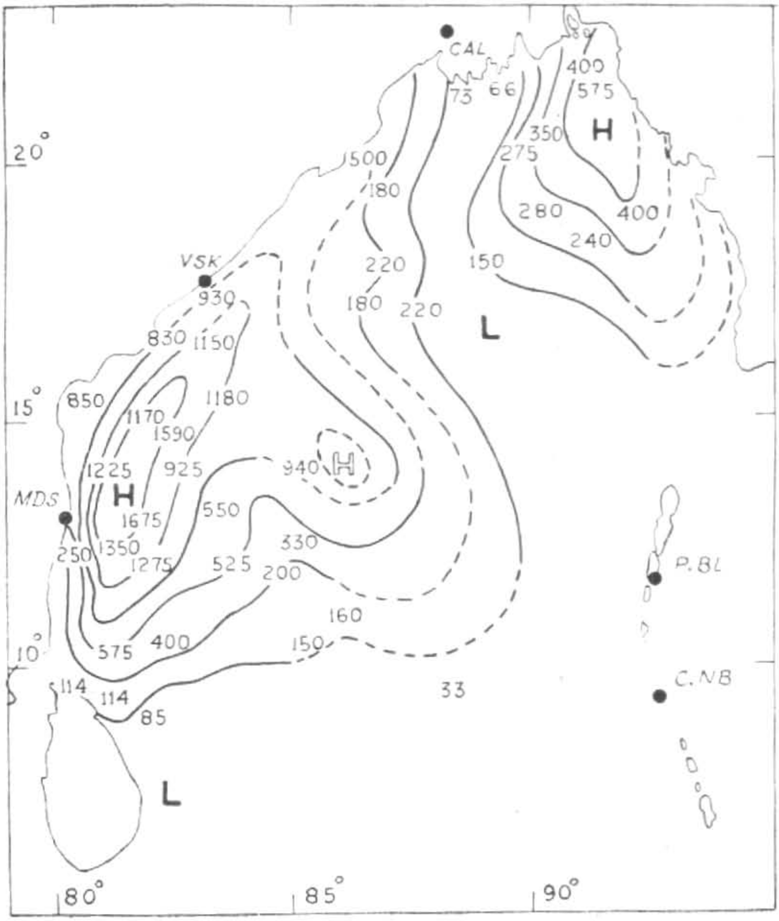


Fig. 10

However, the topography responsible for this low index is not clear.

It is seen from the map "Indian Ocean —Bay of Bengal" published by Hydrographic Office, British Admiralty, London that this region of low index is also the deepest region in the Bay. The large depth of the sea in this area of the Bay may be responsible for this low index.

It is interesting to note that a cyclonic storm in this region during December 1957 did not cause large increase in microseismic amplitudes even though near to Madras. Also a depression in October 1958, did not cause any perceptible increase in microseismic amplitude when in the same area.

Region east of Madras has been found to show high index in both the charts for depressions and disturbances of higher intensity. There seems to be yet one more region of high index present in the Bay to the east of the first high but due to paucity of observations in that area its existence cannot be claimed to be definite.

7. Correlations

On a cursory examination of the data, it appeared that some sort of relationship

TABLE 3

No. of sets of observation N	r_{12}	r_{13}	r_{14}	r_{34}	$r_{1\cdot 23}$	$r_{13\cdot 2}$
100	+0·4806	−0·4203	−0·2617	+0·0627	+0·5613	−0·5208

Multiple Correlations

$R_{1\cdot 23}$	$R_{1\cdot 234}$
0·6658	0·6838

exists between the amplitude of microseisms, intensity of the disturbance and its distance from the recording station. It was also thought that the nearest distance from the coast may also have some effect on the amplitude.

So a multiple correlation between the percentage increase in amplitude over the average (X_1) against intensity of the disturbance (measured in terms of pressure gradient from the synoptic charts X_2, the distance of the centre of the disturbance from Madras X_3 and the nearest distance from the coast X_4) has been worked out.

As has already been shown monthly means of amplitudes vary very much from month to month from 0·5 mm in February to 2·5 mm in July, as such it was considered better to take percentage increase in amplitude over the average prior to formation of the disturbance than the actual value of the amplitude or the difference from the average. It has also been found to be more convenient from the point of identifiability of increase over the average. The inter-correlations, the partial correlations and the multiple correlations are shown in Table 3.

The inter-correlations show that the amplitude increase with increasing intensity and with decreasing distance, both of which are physically understandable. The maximum amplitude probably occurs due to the combined effect of the distance from Madras and intensity of the disturbance with the combination of some other factors, connected with the bottom topography of the sea, the most dominating factor being the intensity of the system. (A high inter-correlation of +0·6630 is obtained between the amplitude and the intensity when disturbances in the region of high index only were utilised for another correlation).

It is interesting to see that the distance of the disturbance and the nearest distance from coast show that they are independent and unrelated.

A multiple correlation of 0·6658 is obtained between amplitude, the intensity and the distance from Madras. The introduction of the fourth variable, *i.e.*, nearest distance from the coast could only increase the multiple correlation slightly raising it to 0·6838.

The values of multiple correlation $R_{1\cdot 23}$ and $R_{1\cdot 234}$ have been tested and F-test showed that they are highly significant.

The correlation between the nearest distance and the amplitude even though negative is low. This indicates that as the distance from the coast decreases amplitude increases. If that were the most predominant factor the maximum amplitude should occur at the time of the system crossing the coast. The low value of correlation does not justify this. The higher correlation co-efficient with the other parameters would suggest that the nearest distance from the coast has a relatively lower effect on amplitude. This actually supports the conclusion that the maximum amplitude occurs much before the disturbance crosses the coast.

From the above data it can be inferred that the depression can cause perceptible increase in microseismic amplitude even at a distance of 500 miles. A depression of average intensity (1·8 mb/100 miles) can cause an average increase of 106 per cent in amplitude. A cyclonic storm can cause perceptible increase in microseisms even at a distance of 900 miles. A cyclonic storm of average intensity (3·4 mb/100 miles) can cause an average increase of 495 per cent in amplitude.

A detailed study of microseism will doubtless increase the importance of microseismic method as an aid to forecasting formation, movement, intensification and weakening of meteorological systems in seas, where data are meagre and at times practically absent. However, there are many hurdles in the way as the microseismic energy is very much modified by complicated phenomena as refraction, diffraction etc, due to topographical variations in the sea bed.

8. Acknowledgements

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