ON THE NATURE OF MICROSEISMIC WAVES AND THE LOCATION OF THE SOURCE OF MICROSEISMS

by L. N. Rykunov, *Physical Faculty, Moscow State University, Moscow B-234*

(Communicated by S. K. Chakrabarty, F.N.I.)

(*Received November 12, 1965*)

Records of microseisms produced by cyclones in the Bay of Bengal have been analysed to examine the possibility of precise determination of the location and size of the source. It appears that the microseisms are not pure Rayleigh waves and that the Love waves contribute about 25 per cent of the total disturbance. The analysis presented shows that the variation of the correlation coefficient with distance of the source can be explained by assuming a finite size for the source, and also gives a possible method of locating the position of the source.

Introduction

Different authors have analysed the horizontal components of the microseismic waves produced by cyclones, with a view to locating the position of the storm centre, but the results have yet to be fully satisfactory. The basic ideas underlying most of their works are that the source of the microseisms has a very small size in comparison to its distance from the station recording them and that the microseismic waves are Rayleigh waves only. If, however, these assumptions are true then the magnitude of the coefficient of correlation between the N–S and the E–W components of displacements in the records of all microseisms must be near one.

In the present paper we have critically examined these points by analysing the records of microseisms associated with fourteen cyclones which had developed either in the Bay of Bengal or in the Arabian Sea during the last ten years and which were recorded at the Geophysical Laboratory, Howrah, by two horizontal seismometers of the Benioff variable reluctance type. In a later section we have also examined the degree of correlation between the amplitudes of the two horizontal components assuming that the microseisms are a mixture of Love and Rayleigh waves and have tried to explain the discrepancy between the actual records and those expected on the above assumptions about the source and structure of the microseisms. We have also tried to explain the effect of the size of the source and its azimuth on the degree of correlation between the two components.

METHOD OF ANALYSIS

We have selected parts of the two seismograms of E–W and N–S components which were recorded simultaneously and have measured the magnitudes of the series of amplitudes which were recorded at intervals of 6 sec, during a continuous period of 20 min at a time. We have represented by X'_i and Y'_i the simultaneous amplitudes of the E–W and the N–S components respectively at the ith interval where i thus takes values from 1 to 200 in any particular group of observations. We then have calculated the correlation coefficient r according to the relation

$$r = \frac{m\sum_i^m X_i Y_i - \sum_i^m X_i \sum_i^m Y_i}{\left\{m\sum_i^m X_i^2 - \left(\sum_i^m X_i\right)^2\right\}^{\frac{1}{2}} \left\{m\sum_i^m Y_i^2 - \left(\sum_i^m Y_i\right)^2\right\}^{\frac{1}{2}}}, \quad \cdots \quad \cdots \quad (1)$$

where X_i and Y_i are the deviations from the working mean which is taken as zero, so that

$$X_i = \left|X'_i - \frac{1}{m}\sum X'_i\right|; \quad Y_i = \left|Y'_i - \frac{1}{m}\sum Y'_i\right|. \quad \cdots \quad \cdots \quad (2)$$

The details of the method of analysis has been given in earlier papers (Rykunov 1961 and Rykunov and Mishin 1961). The dates and times during which the amplitudes of the microseisms were measured and used in the analysis have been given in Table I. The positions of the cyclone centres

TABLE I

No.	Cyclones		$\alpha°$	Δ (km)	r	$\sqrt{\overline{X}^2+\overline{Y}^2}$ (mm)	$\beta°$	L* (km) ($\approx 2\Delta \tan\beta/2$)
	Date	Time						
1	31-10-60	0900	−60	200	−0·04	3·5		
2	09-05-61	0230	−75	250	0·07	3·5		
3	30-05-61	0300	−75	300	−0·09	2·8		
4	29-05-61	0300	32	470	0·23	2·5	37	300 (400)
5	11-10-55	0230	48	670	0·45	2·2	30	340 (290)
6	08-05-61	0230	−33	670	0·35	3·0	31	350 (375)
7	09-10-55	1200	−26	800	0·45	1·8	20	280 (240)
8	30-04-53	1200	−35	900	0·50	1·7	23	350 (300)
9	06-11-55	0230	35	930	0·55	2·5	19	300 (280)
10	29-10-56	1700	52	1000	0·66	2·1		
11	29-10-56	0000	25	1200	0·65	2·1		
12	24-05-61	0300	62	1900	0·63	3·2		
13	11-11-57	2230	70	2140	0·67	1·8		
14	11-11-57	0300	70	2400	0·63	2·2		

---

* The diameter of the largest closed isobar or that of the 1000 mb isobar of the corresponding cyclone as recorded in the I.D.W.R. has been given in parenthesis.

producing the microseisms were taken from the India Daily Weather Reports published by the India Meteorological Department. The values of r were obtained for some different distances of the centre of cyclones from the recording station ranging from 200 km to 2400 km. For closer distances the noise level of the records was high and the analysis became liable to large error and was therefore not taken into consideration. The values of r as a function of Δ, where Δ is the distance of the cyclone centre from the station, ($r = f(\Delta)$) have been plotted in Fig. 1. It shows that in the range $0 < \Delta < 1000$ km, r increases linearly with Δ but for $\Delta > 1000$ km, r retains a steady value of about 0·65.

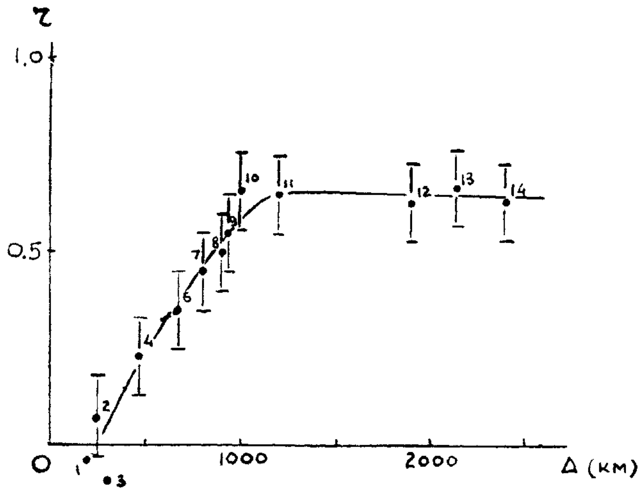

FIG. 1.

The significant departure of the value of r from 1·0, even when it is steady at $\Delta > 1000$ km, suggests that the microseisms are not pure Rayleigh waves and that they are possibly produced by the superposition of Love and Rayleigh waves. The influence of background noise cannot explain this steady departure as it has been observed that this feature is independent of the intensity of the microseism. The influence of the background noise on the analysis of the records of microseisms of different intensities would, however, be different, but this was not observed.

Assuming that the microseisms are produced by the superposition of Rayleigh and Love waves, we can estimate their relative contribution in the following way:

Let $\vec{R}(t_i)$ and $\vec{Q}(t_i)$ be the displacement vectors in Rayleigh and Love waves respectively at time t_i at the recording stations. The magnitudes and signs of the corresponding displacements can then be taken as

$$(-1)^{k_i}\left|\vec{R}(t_i)\right| \text{ and } (-1)^{p_i}\left|\vec{Q}_i(t_i)\right|. \qquad (3)$$

We then have easily the E–W and the N–S displacements given by X'_i and Y'_i, where

$$\left.\begin{aligned} X'_i &= \left|(-1)^{k_i}\left|\vec{R}(t_i)\right|\sin\alpha+(-1)^{p_i}\left|\vec{Q}(t_i)\right|\cos\alpha\right| \\ Y'_i &= \left|(-1)^{k_i}\left|\vec{R}(t_i)\right|\cos\alpha+(-1)^{p_i}\left|\vec{Q}(t_i)\right|\sin\alpha\right| \end{aligned}\right\} \qquad (4)$$

where α is the azimuth of the storm centre relative to the station, measured from the south through west. Selecting the random system of values for $\left|\vec{R}(t_i)\right|$, $\left|\vec{Q}(t_i)\right|$, k_i and p_i where i takes the values 1, 2, 3 . . . m, subject to the condition that

$$\sum_{i}^{m}\left|\vec{Q}(t_i)\right| \Big/ \sum_{i}^{m}\left|\vec{R}(t_i)\right| = C \qquad (5)$$

we can obtain different sets of values for X'_i, Y'_i for different values of C, viz. 0·1, 0·2, 0·3, . . . 1·0. The sets of values of X'_i, Y'_i thus determined are then used in equations (1) and (2) for obtaining r, the correlation coefficient between the E–W and the N–S components of the displacements for different values of α and C. The variation of r for $\alpha = 30°$ with Q/R has been plotted in Fig. 2. It shows that the coefficient of correlation is 0·65 when C is 0·25.

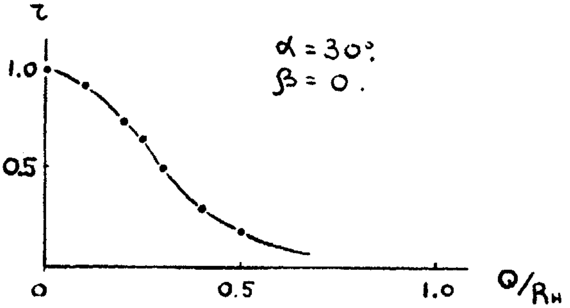

FIG. 2.

This shows that for a source which is at a large distance ($\Delta > 1000$ km) and having an azimuth of about 30° West of South the displacements produced by the Love waves is about a quarter of that produced by the Rayleigh waves.

It is also possible to explain the observed linear increase in the value of r with Δ when $\Delta < 1000$ km by assuming that the source of microseisms has a finite size and that it consists of a system of partial incoherent sources. One can then find the approximate connection between the angle size of the source β, the azimuth of the mean position of the source α and the correlation coefficient r assuming a fixed value of C. In Fig. 3 we have plotted r as a function of β for some discrete values of α. Using these curves along with the values of r obtained as a function of Δ, as shown in Fig. 1, it is possible to get an approximate estimate of the dimension of the source. The values of β thus determined in some cases together with an estimate of the linear dimension of the source have been obtained and incorporated in Table I.

CONCLUSIONS

The results of observation analysed in the present paper indicate that about 25 per cent of the microseismic disturbances associated with the cyclones generated in the Bay of Bengal must be Love waves and that a reference to Fig. 1 may give the distance of the centre of the cyclone from a measure of the correlation coefficient r between the displacements recorded by the E–W and the N–S seismographs. The value of r obtained from records when referred to Fig. 3 will then give an estimate of the possible combinations of the azimuth of the source and its angle size. The azimuth and the precise position of the source can be fixed up from similar records of the two different stations. The details of this method will be discussed in another paper.

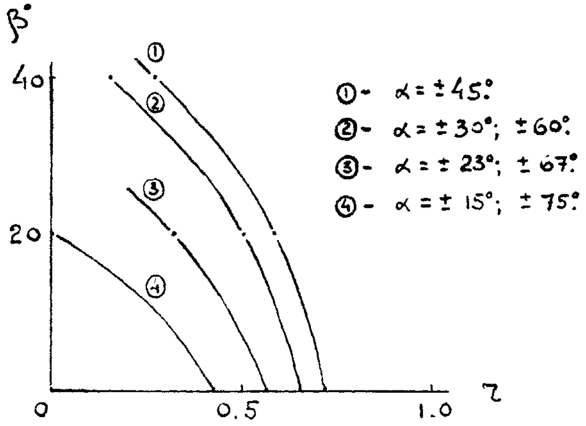

FIG. 3.

ACKNOWLEDGEMENTS

I am very much grateful to Professor S. K. Chakrabarty for his kind help during the progress of this work.

I am also indebted to the Ministry of Education, Government of India, for granting me a Visiting Fellowship for working at the Geophysical Laboratory of the Bengal Engineering College, Howrah, India.

REFERENCES

Rykunov, L. N. (1961). *Bull. Acad. Sci. USSR Geophys. Ser.*, **7**, 686–687.

Rykunov, L. N., and Mishin, S. V. (1961). *Bull. Acad. Sci. USSR Geophys. Ser.*, **6**, 529–533.