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Direction of approach of Microseism

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ABSTRACT. By using three component records of Shillong an attempt has been made to determine the direction of approach of microseism from the Bay of Bengal on account of a cyclonic storm which originated there during the month of May 1963. Three methods, *viz.*, amplitude method, slope method and particle trajectory method, were employed for the determination of the direction of approach of the microseism and a consequent determination of the direction of the centre of the storm. The relative merits of all the methods are discussed.

1. Introduction

Earlier investigations of microseism from the Bay of Bengal were based on records of horizontal component seismograph in operation at various Indian Observatories. The notable authors are — Banerji (1930), Chakrabarty and Sarkar (1958), Pramanik, Sen Gupta and Chakravortty (1948), Tandon (1957) and Saha (1960). But practically no work has so far been done in India regarding the direction of approach. In the present communication an attempt has been made by the author to find out the direction of approach of microseisms, from a study of the seismograms of Shillong, using three different methods.

With the installation of three component long period seismograph of the Press-Ewing type under the Worldwide network of Standard Seismograph of the U.S.C.G.S. at Shillong it might be of interest to use single station data to determine the direction of approach of microseism. The matched three component system has the following instrumental constants —

Seismometer period $= T_0 = 30$ sec

Galvanometer period $= T_0 = 100$ sec

These seismometers have not only the same constants but their magnifications are also the same which is 3000 at 30 sec period.

Many authors have used elaborate technique to study the direction of approach of microseism. Bath (1962) has used much simpler conventional methods to study the direction of approach from the records of the matched seismographs at Upsala. The author also proposes to use the amplitude and slope method as used by Bath. He also proposes to use the ground particle trajectories as was used by Donn (1954) and discuss the relative merits of the methods.

2. Theory

The method assumes the microseisms to be a composite wave motion, consisting of Rayleigh and Love waves. The notations used are as follows —

x, y, z = rectangular co-ordinates

H = horizontal

α = direction of approach of microseisms counted from north over east

R, Q = Rayleigh and Love wave amplitudes respectively

t = time

ω = angular frequency (assumed to be the same for R and Q)

u = displacement with components U_x, U_y, U_z

γ = phase displacement between R and Q waves

n = number of observations included in one direction determination

The x and y components of R and Q can then be written as follows —

$$\left.\begin{aligned} R_x &= R_H \sin\alpha, \quad Q_x = Q\cos\alpha \\ R_y &= R_H\cos\alpha, \quad Q_y = Q\sin\alpha \end{aligned}\right\} \quad (1)$$

The displacements at time t along the co-ordinate axes are —

$$\left.\begin{aligned} U_x &= R_x \sin\omega t + Q_x \sin\,(\omega t+\gamma) \\ U_y &= R_y \sin\omega t + Q_y \sin\,(\omega t+\gamma) \\ U_z &= R_z \sin\,(\omega t - \pi/2) \end{aligned}\right\} \quad (2)$$

Derivation with regard to time gives —

$$\left.\begin{aligned} dU_x\,/\,dt &= (dR_x\,/\,dt)\sin\omega t + \omega R_x\cos\omega t + \\ &\quad + (dQ_x\,/\,dt)\,\sin\,(\omega t+\gamma) + \\ &\quad + (\omega + d\gamma\,/\,dt)\,Q_x\cos\,(\omega t+\gamma) \\ dU_y\,/\,dt &= (dR_y\,/\,dt)\sin\omega t + \omega R_y\cos\omega t + \\ &\quad + (dQ_y\,/\,dt)\,\sin\,(\omega t+\gamma) + \\ &\quad + (\omega + d\gamma/dt)\,Q_y\cos\,(\omega t+\gamma) \end{aligned}\right\} \quad (3)$$

As moments for measuring the slopes on the horizontal records, Jensen chooses —

$|U_z| =$ Max., *i.e.*, $t = 0$, then equation (3) becomes —

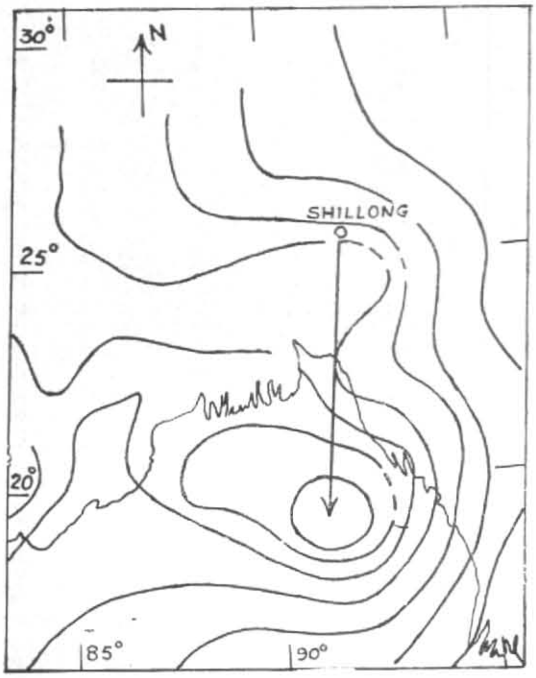

Fig. 1. Synoptic chart showing the direction of the centre of the storm in respect of the station Shillong at 1200 GMT on 28 May 1963

$$\left.\begin{aligned} dU_x / dt &= \omega R_x + (dQ_x / dt) \sin \gamma + (\omega + d\gamma / dt) Q_x \cos \gamma \\ dU_y / dt &= \omega R_y + (d Q_y / dt) \sin \gamma + (\omega + d\gamma / dt) Q_y \cos \gamma \end{aligned}\right\} \quad (4)$$

As we have good reason to assume the R and Q waves to be uncorrelated with each other, the phase angle assumes all values between $-\pi$ and $+\pi$, we then have—

$$\left.\begin{aligned} &\Sigma_n \sin \gamma = \Sigma_n \cos \gamma = 0 ; \\ &\Sigma_n (dU_x / dt) = \omega R_x ; \Sigma_n (dU_y / dt) = \omega R_y \end{aligned}\right\} \quad (5)$$

and finally

$$\Sigma_n (dU_x /dt)/ \Sigma_n (d U_y /dt) = R_x / R_y = \tan \alpha \quad (6)$$

It is immediately obvious that this development is valid also for different angular frequencies of R and Q. The method is valid if the microseisms consist of uncorrelated R and Q waves.

In the amplitude method the measuring moments correspond to $U_z = 0$ in well-developed wave groups on the vertical component and the horizontal amplitudes are measured. If we put $U_z = 0$ in equation (2) we find that—

$$\left.\begin{aligned} U_x &= R_x + Q_x \cos \gamma \\ U_y &= R_y + Q_y \cos \gamma \end{aligned}\right\} \quad (7)$$

Again if γ is arbitrarily distributed the mean ratio U_x / U_y of a sufficiently large number of observations will give the direction of the source.

Regarding the last method, by using particle motion trajectories, Donn (1954), from a study of microseisms recorded at Palisades due to the passage of hurricanes that the inclination of particle motion trajectories of the microseisms recorded gives approximately the direction of the source.

Teisseyre and Siemek (1960) have also given a theory for another method for determining the direction of approach of microseisms in their paper. They also use R waves, and as measuring moments they select $U_z = 0$ in well-developed wave groups on the vertical component and arrive at a vector equation, which corresponds to a straight line in a co-ordinate system with U_x / R_z and U_y / R_z as axes. The arrival direction is perpendicular to this straight line. But the existence of Q waves is necessary for a successful application of Teisseyre-Siemek's method, whereas they are not required in the first two methods. As it is not definitely known whether microseisms from Bay of Bengal contain Q waves or not, because no such study has so far been made, till the preparation of this manuscript, Teisseyre-Siemek's method has not been attempted in the present communication.

A severe cyclonic storm originated in the Bay of Bengal during the month of May 1963 and gave rise to a microseismic storm which were recorded by Shillong seismographs of 28 May 1963. The distance of the station, Shillong, is approximately 400 km from nearest sea-shore. Fig. 1 represents the synoptic chart of 1200 GMT of 28 May 1963 as reproduced from *I.D.W.R.*, which shows the position of the centre of the storm at 1200 GMT on 28 May 1963. In Fig. 2, a portion of the long period vertical and horizontal seismogram recorded at Shillong at about 1200 GMT on 28 May 1963 is reproduced.

(1) *Amplitude method*—A number of observations were taken by this method on either side of 1200 GMT. The amplitudes U_x and U_y from the two horizontal components were measured at moments $U_z = 0$ from vertical component. The amplitudes U_x and U_y were then plotted and shown in Fig. 3. The mean direction is found to point towards the centre of the storm (Barometric low).

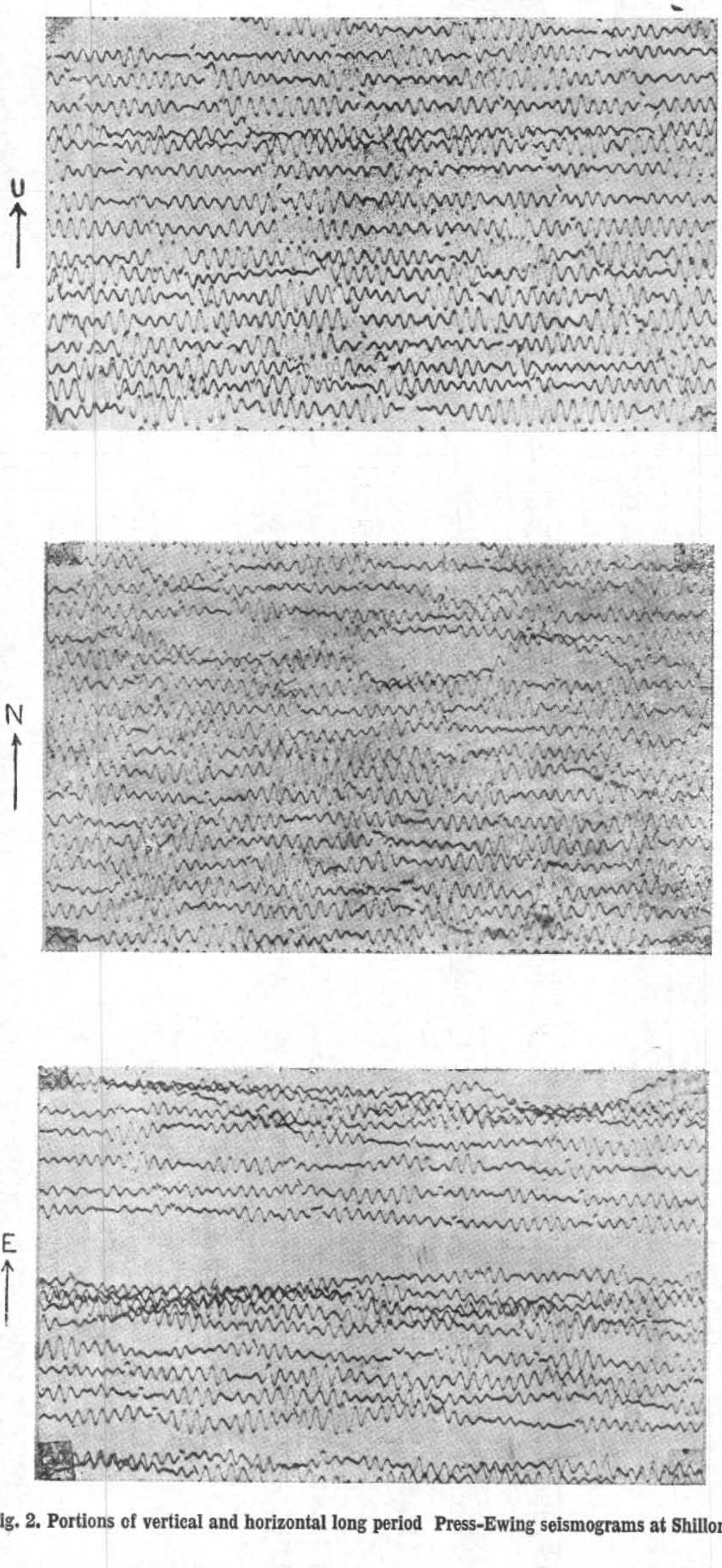

Fig. 2. Portions of vertical and horizontal long period Press-Ewing seismograms at Shillong

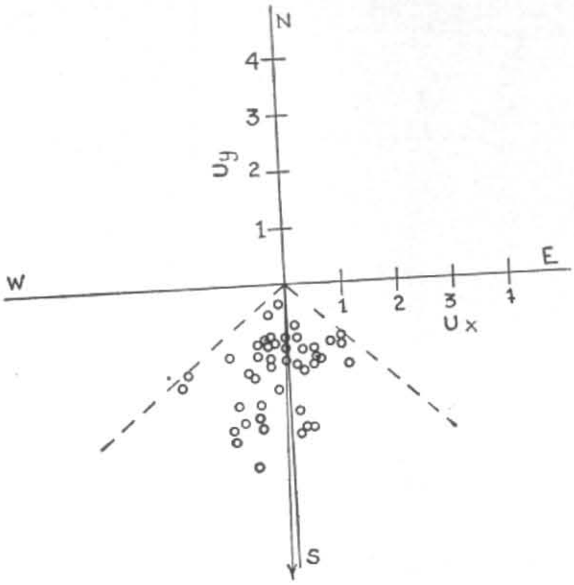

Fig. 3. Direction determination by amplitude method

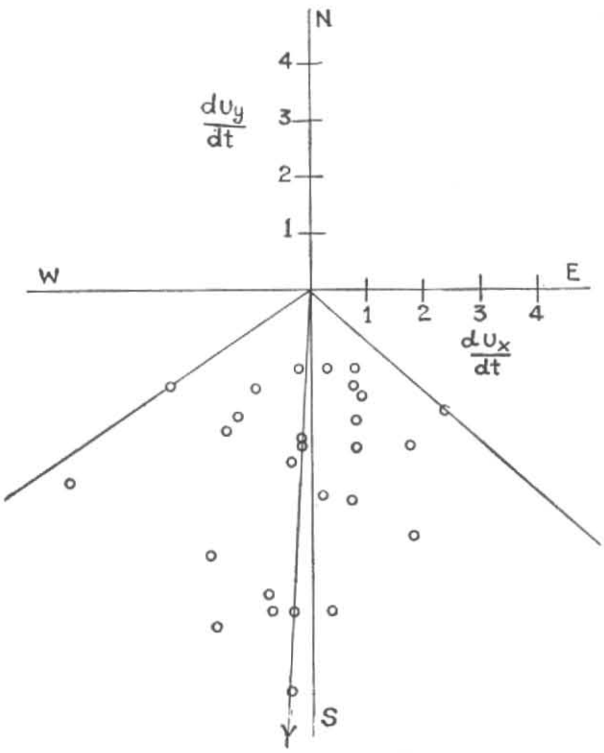

Fig. 4. Direction determination by slope method

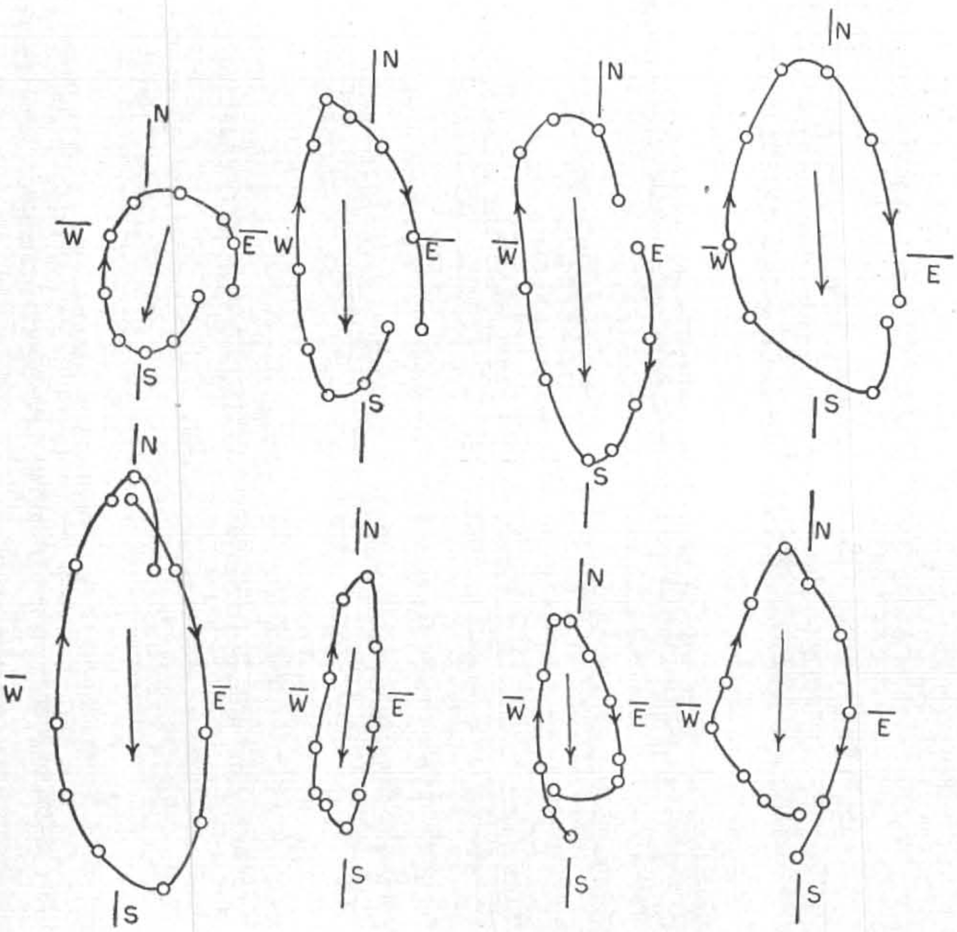

Fig. 5. Direction determination by particle motion trajectory method

(2) *Slope method* — Similarly a number of observations were again taken by this method on either side of 1200 GMT. The quantities dU_x / dt and dU_y / dt, *i.e.*, the slopes were measured from the two horizontal components at moments U_z = maximum in the vertical component. These quantities dU_x / dt and dU_y / dt were plotted and shown in Fig. 4. It may be seen from Fig. 4 that the mean direction is approximately the same as found in the previous method.

(3) *Ground particle motion trajectory method* — Several well-developed microseism groups (on either side of 1200 GMT) which were coherent and prominent on vertical records and which were readily identifiable on the horizontals were selected for the measurement of particle motion trajectories. Horizontal particle motion trajectories were then plotted for these selected groups and shown in Fig. 5. From the figure it would be seen that the inclination or the axis of the trajectories more or lese points towards the direction of the storm.

3. Discussion and conclusion

The above three methods can be utilised for determining the direction of approach of microseisms from a single station three component records. But to the author the amplitude method appears to be the simplest. Also the method could be utilised in day-to-day work to study the direction of approach. The other two methods involve lot of complicated computation and do not appear to be suitable for any routine type of analysis in determining the direction of approach.

The fact that the inclination of horizontal ground particle trajectory could indicate the direction the approach goes to suggest that the microseisms from the Bay of Bengal are predominantly Rayleigh type of waves. This will probably justify why the author did not try the Teisseyre-Siemek's method which requires the existence of Q waves for its successful application.

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