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Determination of Sedimentary Thickness in the Shillong plateau by Microseisms

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ABSTRACT. The observed periods of microseisms of land origin recorded by short period Benioff seismograph at Shillong are used in an effort to make an estimate of the low velocity superficial sedimentary rock thickness in the Shillong plateau. The estimate of thickness of the sedimentary layer if verified by some direct methods will provide an answer for the hypothesis that microseismic periods are dependent on the structure of the crust. The use of period characteristics on account of microseisms of land origin has a superiority over the use of microseisms of sea origin because the structure of the sedimentary crust in a continental area could be explored with much certainty as compared to the structure of the sea bed under the oceans.

1. Introduction

The type of short period microseisms which the author wishes to use here has not been reported and investigated in great detail. It was Walsh (1956) who first pointed out the existence of this type of microseisms of period 0·3 to 0·4 sec. The present writer (1961) observed similar microseisms with slightly different period characteristics with period very close to one second recorded by the short period vertical component Benioff seismograph at Shillong. It is observed that the short period microseisms are recorded when the local weather condition is appreciably disturbed and these are not in any way related to the passage of the meteorological disturbance over the ocean area at a distance of 400 km from Shillong. Chakrabarty and Sarkar (1958) in their study on microseisms associated with Nor'-westers have noticed similar microseisms of 0·4 sec in the records of the Benioff seismograph at Howrah when the Nor'wester disturbances were near their station just before the passage of the disturbances into the Bay of Bengal. After the passage of the disturbance into the Bay of Bengal, they, however, observed microseisms with period between 2 and 3 sec.

The idea that microseisms are Rayleigh waves is an old one and the propagation of Rayleigh waves in many types of crustal structure has been studied by many investigators. These may be classified in general into two types, continental and oceanic. Ewing and Press (1948, 1950, 1952) have made use of the Rayleigh wave propagation of study of crustal structure under the oceans. There is general agreement between observations and the theoretical dispersion curve in the range of periods greater than 12 sec observed in natural earthquakes. There is, however, serious disagreement in range of periods observed in microseisms. Mitra (1957) attributes this to the neglect of the presence of a sedimentary layer which exists below the ocean and accounts for the observed periods of microseisms associated with Nor'-westers. Theory predicts that large amplitudes should be associated with the minimum of the group velocity of the dispersion curve and Mitra could obtain a minimum group velocity to account for microseisms of 2 to 3 sec period observed by Chakrabarty and Sarkar (1958) when the Nor'wester disturbance was over the surface of ocean from the consideration of the normal mode propagation. In this paper the author proposes to use the same method to account for the observed periods of microseisms of land origin from the consideration of a double layered continental structure.

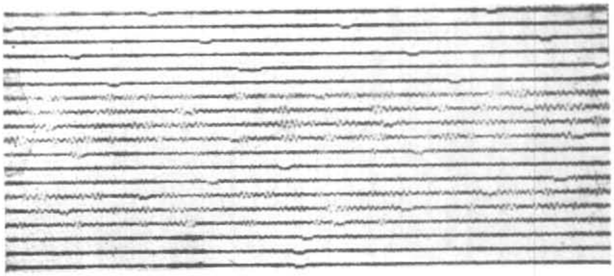

Fig. 1

Section of Shillong vertical short period, 11-12 April 1959; Time scale 60 mm/min; Time interval between corresponding points on consecutive time is 15 min

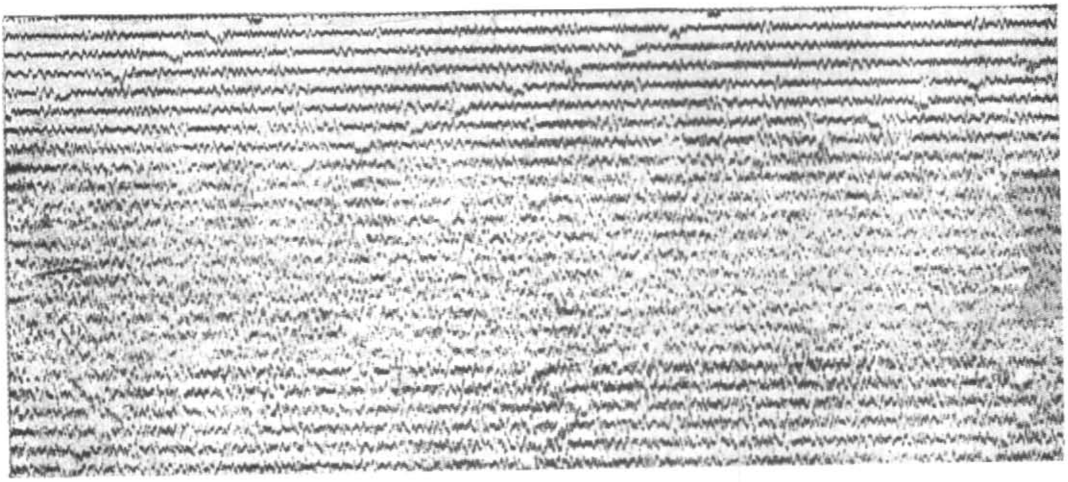

Fig. 2

Section of Shilling vertical short period Benioff record of 17-18 July 1960

2. Nature of microseisms

Before the discussion of the problem proper, the author proposes to present some sample of typical records of the short period microseisms. During the pre-monsoon months these microseisms appear as a fine pattern of regular waves displaying a pronounced group of beat effect with characteristic period close to one second with usually small amplitudes which at times rise to 2 mm. On the most occasions the amplitudes gradually increase and attain a maximum value in the middle of the train and then decrease gradually. The duration of these microseisms varies from one hour to several hours; on some occasions they appear in 2 or 3 spells separated by intervals of one to several hours. During the monsoon season the microseisms of one second period commence on a quiet background and during the maximum phase of the storm there is a superimposition of smaller period oscillations. In this type the maximum amplitude and the duration of the microseisms storm is much greater than those recorded during the pre-monsoon months; maximum amplitude reaches about 3 to 4 mm. The trace amplitude has been expressed in mm as no calibration curve is available for the Benioff seismograph at Shillong. Typical examples of these two types are reproduced in Figs. 1 and 2.

All records are from vertical component seismograph ($T_0=1\cdot0$ sec; $T_g=0\cdot18$ sec) and it is remarkable that observed peak period is nearly one second on all occasions in the case of microseisms of the type shown in Fig. 1. The period is, however, much smaller in the case of superimposed microseisms as shown in Fig. 2. This remarkable consistency of the periods of microseims together with the observation of different period microseisms elsewhere is suggestive of the fact that the periods are dependent on the structure of the local sedimentary crust.

3. Discussion

The author has already presented in his previous study the type of meteorological disturbance responsible for generation and the mechanism by which the atmospheric disturbance is transmitted to crust inspite of great contrast in the acoustic impedance. Stoneley (1953, 1954, 1955) made use of the theory of Rayleigh wave propagation in a multilayered medium for study of the continental structure of the crust. Recently Shurbet (1961) in his study on the determination of sedimentary thickness in the Mexican Geosyncline has made use of the theoretical dispersion curves in the short period range using the calculations of Stoneley (1955). The dispersion curve is reproduced in Fig. 3. In the model the two surface layers are treated as sedimentary layers over a granitic layer as was done by Oliver and Ewing (1958) who showed that the velocity of Rayleigh waves in the short period range is strongly affected by sedimentary layers of average thickness. It is certain that the two layer crustal model is certainly inadequate to give minimum group velocity that will exactly compare with the observed periods of microseisms but it will certainly make available semiquantitative information which may be compared with the observed periods.

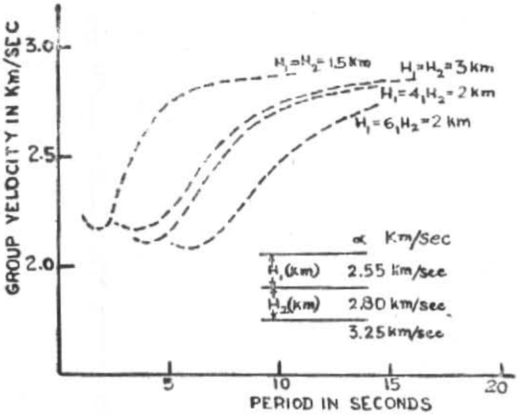

Fig. 3

Rayleigh wave dispersion curves

From Fig. 3 it will be seen that the minimum or stationery value of the group velocity gradually shifts towards the shorter period side when the thickness of the layers gradually decreases. It is apparent that the total thickness of the sedimentary layer corresponding to a value close to one second period for the minimum group velocity will be much less than 3 km. In the absence of any data on the thickness of the low velocity layers at Shillong, it has not been possible to verify the above finding of the author. But it is felt that the value appears to be too high for Shillong. It may be that the value of compressional wave velocity considered is too low for the granitic layer (6·0 km/sec.). We have considered that the predominant period of microseisms of short period will correspond to the minimum group velocity for the ground. In that case the ground layer is equivalent to some kind of filter and the dispersion curve inherent to the ground structure may be regarded as characteristic frequency curve of the filter. Assuming the so called quarter wave length low asserted by Tazime (1957) to hold good, we have for the periods T for waves transmitted to crystalline basement are given by

$$T = \frac{4H}{V_P}$$

where H=thickness of the sedimentary layer and V_P = seismic wave velocity for P waves; taking $T=1 \cdot 0$ sec and $V_P=3250$ m/sec the thickness H works out to be 800 meters. It is also possible that short period microseisms of 1 sec period recorded at Shillong might be due to disturbance at a distance where there is thicker section of the sedimentary

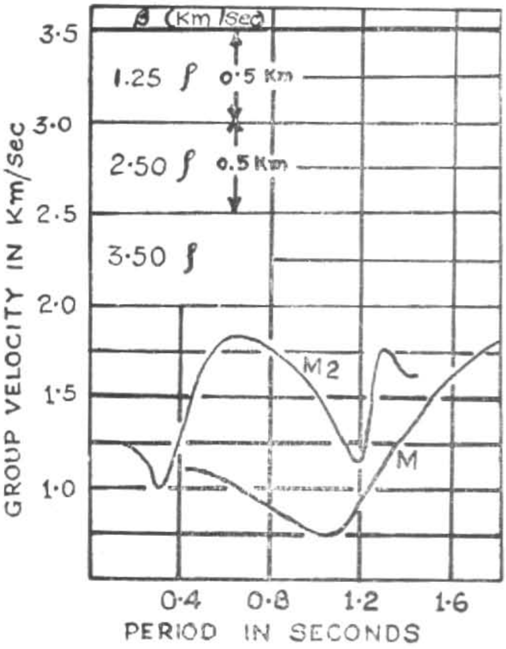

Fig. 4
Theoretical dispersion curve for **M2** and **M** mode (after Nagamune)

crust and the preponderance of shorter period oscillation (Fig. 2) would correspond to the structure proper for Shillong plateau. In that case the thickness of the sedimentary layer may be even less than half of the above value. It is not possible to rule out the above possibility because it will be seen from Fig. 2 that the microseism of 1 sec period commences first when it is followed by shorter period microseisms of comparatively larger amplitudes. On some occasions only microseisms of 1 sec period are observed without being followed by shorter period oscillations. It might be that on such occasions the disturbance did not affect the Shillong plateau proper where the thickness of the sedimentary layer is smaller as compared to the plains in the neighbourhood.

Alternatively the preponderance of shorter period oscillation (much shorter than the usual period of about one second) in microseismic record (Fig. 2) during the monsoon season could also be explained from the consideration of M2 mode dispersion curves for an appropriate crustal structure. Nagamune (1956) computed dispersion curves for M2 waves for two cases for one of which Homma had already computed the Rayleigh mode. The rigidity ratios chosen for this case corresponds more closely to the conditions in the crust mantle system while in the other case the rigidity ratios corresponds more closely to the sedimentary granite system although choice of equal densities and so the shear velocities for the individual surface sedimentary layers are not as close to accepted values as one might prefer. However, the complexity of calculation is great. So no additional curves have yet been computed. In fact Nagamune's computations are the only ones, for M2 for double surface layer case. Theoretical dispersion curves for M2 and Rayleigh mode for a two layered sedimentary crust is reproduced in Fig. 4.

It is observed from the above curve that Rayleigh mode has one single value for the minimum group velocity. For the M2 waves there are two minima. Accordingly the shorter period oscillations (Fig. 2) superimposed on the waves of 1 second period will correspond to the shorter wave length minimum of the M2 mode dispersion curve while the microseisms of 1 sec period will correspond to the fundamental Rayleigh mode or longer wave length minimum as there is very little difference in the period of the two minima. But the velocity of propagation of over 1 km observed by Akamatu (1961) will suggest a correspondence with M2 mode. The value of the sedimentary layer of the order of 1 km is slightly higher than the previous value probably because much higher value for the velocity of shear wave in the intermediate layer was taken. The author had no choice because he had to take a value of 3·50 km for granitic layer and the values of velocity figure for other layers were fixed by the conditions of the model considered by Nagamune (1956).

4. Conclusions

It is not possible to obtain directly from the above study a quantitative estimate about the thickness of the low velocity sedimentary layer but the method can certainly provide some comparative estimate of sedimentary thickness from the observed microseismic periods. The observation of 0·3 to 0·4 second period observed by Walsh (1956) and Chakarbarty and Sarkar (1958) will certainly suggest a thinner sedimentary layer at the places of observation. The above two methods suggest a sedimentary thickness of the order of 800—1000 metres if the microseisms of period 1 second period is considered to be due to structure proper for Shillong plateau. The value of the thickness of the layer may be even much less than the above value if the actual velocity of the seismic waves is much less than the value taken into consideration. The method however, does illustrate a rather simple economical method providing semiquantitative estimate of sedimentary thickness in different parts of the world.

Although it has not been possible to verify the findings by other methods of determining sedimentary thickness, it is suggested that an agreement of data will certainly provide material to verify the hypothesis of the dependence of microseismic periods on the structure of the crust. The present method of testing the above hypothesis has a superiority because the sedimentary layers in continental areas could be explored without much uncertainty by direct methods while in the case of the exploration of the structure of the sea bed there is always a certain amount of uncertainty which renders critical examination of the dependence of the microseismic periods on the structure of the sea bed extremely difficult in the case of microseisms of ocean origin.

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