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SOME THEORIES OF MICROSEISMS IN THE LIGHT OF MORE RECENT FINDINGS

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ABSTRACT

A review of a few recent discussions concerning different theories of generation and propagation of the 2–10 sec. microseisms is given and it is shown that Dr. Jensen's (1961) large number of determinations of direction of approach confirms some of the older findings, e.g. the microseismic barrier in the eastern North Sea. Furthermore it is shown that the dependence of microseisms on air temperature in the source area can be explained satisfactorily in terms of Longuet-Higgins theory.

After a short discussion about correlation between microseisms and meteorological data, including wave height observations, a discussion is given of an attempt to correlate microseisms in Greenland with observed waves at a certain weathership. The result was negative as far as the variation from day to day is concerned, but the characteristics of the seasonal variation of the two variables give some support to the Longuet-Higgins theory of the origin of microseisms.

Microseisms and Oceanic Disturbances

One of the arguments used by Donn (1957) in favor of his theory that breaking of waves is responsible for the generation of microseisms is that cold winds are more turbulent than warm ones and thus produce more random noise; this is in accordance with observations made by Jones (1949), Donn (1951), and Båth (1953) that cold winds have greater efficiency in generating microseisms. This effect, however, can also be explained by means of the Longuet-Higgins theory since Fleagle (1956) showed that significantly higher wind-produced waves are generated by cold air than by warm air, the difference amounting to roughly ten percent of the warm air values per degree centigrade.

One thing is common for the source mechanism suggested by Longuet-Higgins and Donn, namely that waves are the primary source. There are several findings which indicate that the system, water plus bottom, is not sufficient in itself to produce microseisms. One of them is that the determination of directions of approach at Nord, northeastern Greenland, (Jensen, 1961) indicated no microseisms coming from the Polar Basin which is permanently covered with ice. From his study of antarctic microseisms at Scott Base, Hatherton (1960) arrived at the same conclusion.

An example of large attenuation differences was given by Jensen (1961) who considered the distribution of directions determined at Nord. He found that the sector containing the ocean between Greenland, Iceland and Norway contained practically no arrivals, although source conditions favourable for generation of microseisms were known to exist, at least at the coastal area of Norway. The oceanic path, or some other microseismic barrier, attenuated the microseisms far below the level of those arriving from other directions.

It is interesting to note that in the distribution of directions found in Copenhagen (Jensen, 1961), the western sector contained almost no arrivals, although storms and interfering waves are not less likely to appear in the North Sea and in the

Atlantic beyond Great Britain than they are in the Baltic and in the northeastern Atlantic. The relative lack of arrivals in this sector, however, confirms the microseismic barrier found by Gutenberg (1921) in the eastern North Sea (see figure 1). As mentioned by Westerhausen (1954) this barrier has been used by the geologist

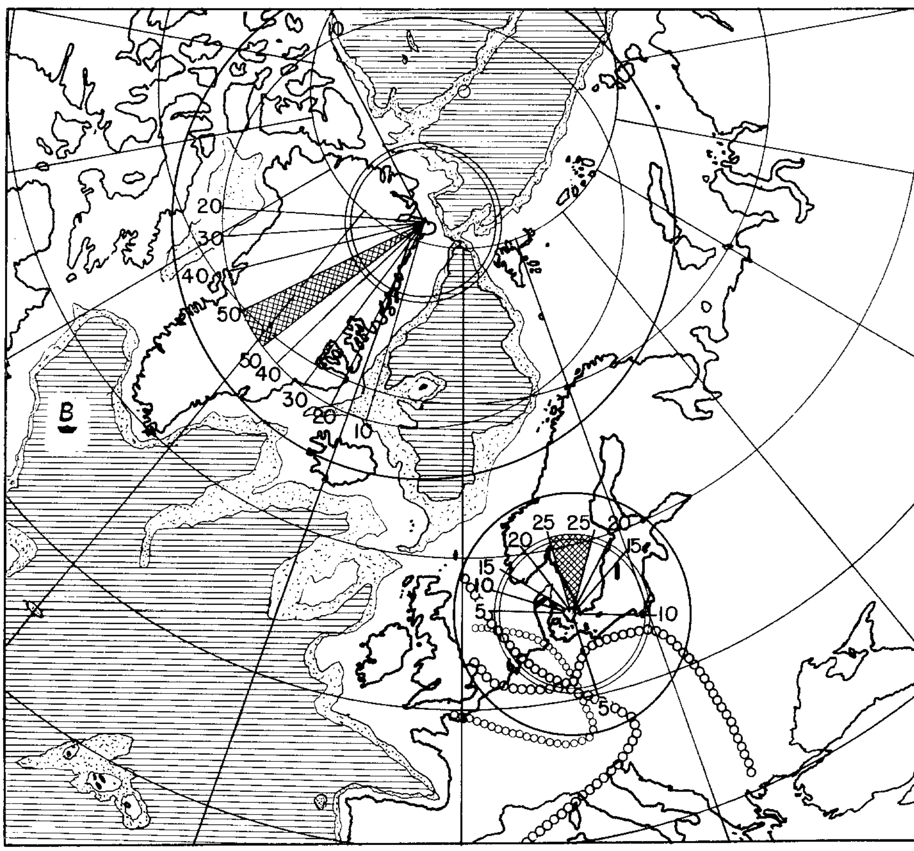

Fig. 1. Map showing the location of the seismic stations Copenhagen and Nord, and distribution of the directions of approach; unit of numbers marked are per cent per 40°. Position of the weathership *B* and the contours for the 3000 ft. and 6000 ft. ocean depths are shown. In addition the microseismic barriers as drawn originally by Gutenberg (1921) are indicated. Lambert's azimuthal, equal area projection.

Schwinner as one of the arguments for the discontinuity of Caledonian folding between northern Scotland and Norway, in contrast to the continuation of Norwegian folding beneath Jutland to northwestern Germany. This connection is called "die Pompeckjsche", and the western boundary of this is assumed to form a microseismic barrier. Thus one of the possible uses of microseisms may be to determine the location of deep faults and other irregularities, and also zones of transition from oceanic to continental structure. The shallowness of the North Sea rules out the possibility that the effect is due to variation of Rayleigh-wave velocity with water depth.

Although it is generally accepted that microseisms are generated by disturbed weather at sea, it is very difficult to determine the source of a given microseism. Even isolated microseismic storms may not uniquely correspond to a low pressure or a front system at sea; not even when the direction of approach is determined is

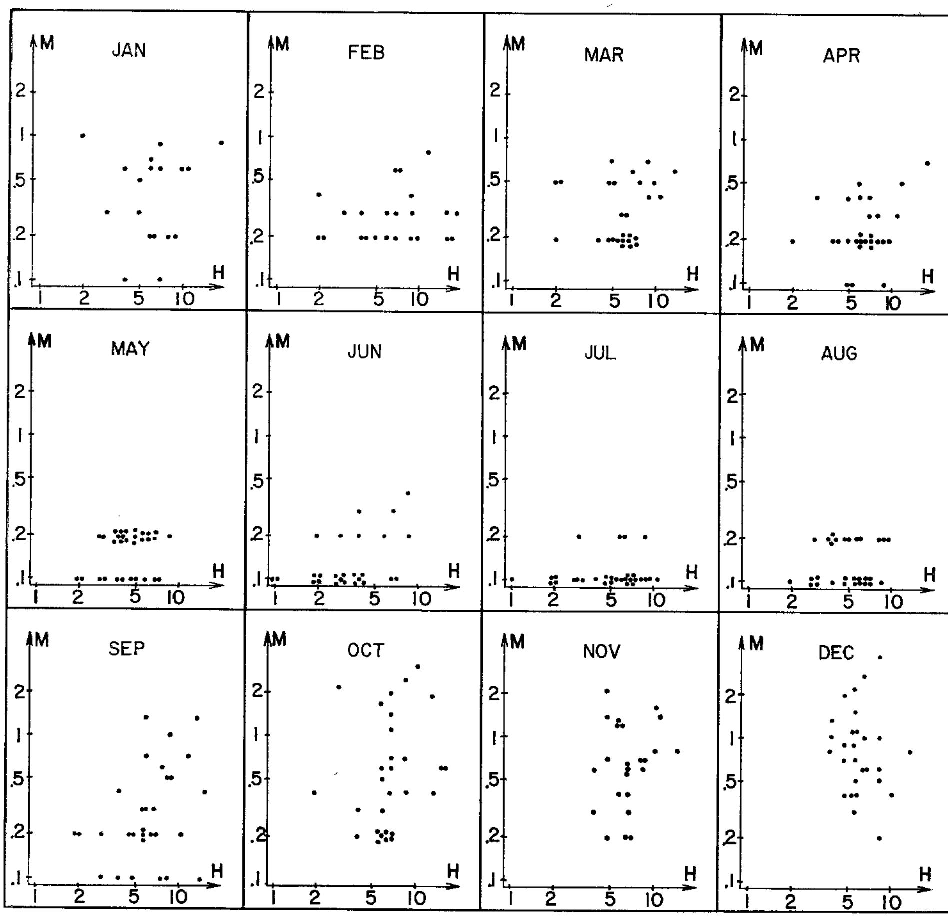

FIG. 2. Dot diagram showing the N-component of the microseismic amplitude M at Nord, measured in microns, plotted against wave height at weathership B, measured in half-meters, one dot per day.

it always obvious what the meteorological cause is. The reason for this is, probably, that the wave conditions at a given place is a complicated function of the weather during the previous few days throughout a large area. Even with known wave conditions throughout any possible source area the problems involved in the propagation of microseisms make it impossible at present to predict the resulting microseisms.

In their studies of microseisms, Dinger and Fisher (1955) found at Guam a definite relationship between amplitudes of wave heights and of microseisms; and Gutenberg's comparison of Norwegian surf with German microseisms is an example of a successful attempt to find correlation between microseisms and water waves at a distant point.

Analysis of Microseisms at Nord

Because Jensen (1961) found a narrow angle from which a large number of microseisms approached station Nord, the frequency being 1.3 per cent of all determinations per degree, it was decided to make a comparison between the wave heights at the weathership *B* and the *IGY*-readings of microseisms at Nord covering the period Jan.–Dec. 1958. The weathership *B* had the position (56N, 50W) in the

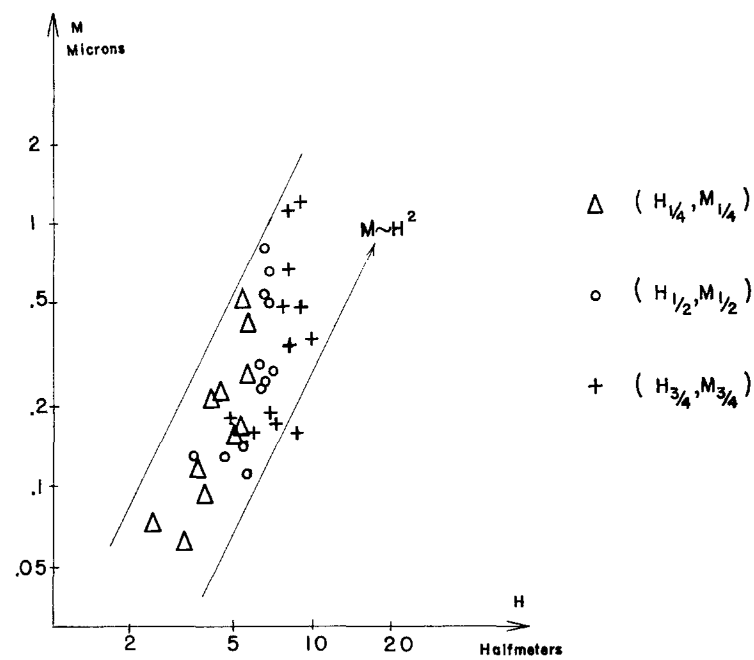

Fig. 3. The quarter, half, and three-quarter fractiles of the monthly distributions of the daily observations of the microseismic amplitudes at Nord, plotted against corresponding parameters of the wave heights reported from weathership *B*.

narrow angle mentioned, and was 500 km from the coast of Greenland. The comparison was made by making dot diagrams, figure 2, one dot per day, and one diagram per month. To make the distribution of the points more even, a logarithmic scale was chosen. A statistical non-parametrical test (which did not allow, however, for the stochastical dependence between two consecutive days) was applied. It was concluded that only October showed a significant positive covariation, whereas an unsophisticated glance at the diagram shows slight trends towards positive covariation in September and October. This trend probably does not indicate any common source for the daily variation of the two variables; first because it is not continued in the two other high-activity months, November and December, second because September and October are months with rapidly increasing microseisms from the small summer level to the high autumn level, so that a spurious covariation would show if the range of each variable is bounded by large values of each variable at the end of each month as compared with the beginning. This is the kind of long periodic variations which often causes covariation among variables having no causal interrelation. In this case the only common factor that can be demonstrated is the season.

A diagram showing this seasonal variation is given in figure 3, plotting different fractiles from the monthly distributions of observed values. The value of the fractiles are obtained by linear interpolation of the accumulated number of observations between successive observed values. A marked covariation is present, and it is worth noting that if the seasonal variation of the wave heights in the source areas is similar to their variation at weathership B, the monthly parameters of microseisms would, according to the Longuet-Higgins theory, be proportional to the product of the waveheights of the two interfering waves. A representative estimate of this product may be obtained by taking the square of the monthly parameter of the wave height (H). Hence the amplitude of microseisms (M) should, apart from a certain scatter, be proportional to H^2. The lines drawn on figure 3 confirm this, although the very highest values of the microseisms are somewhat higher than expected. This, however, is easily explained by the fact that the high amplitudes almost invariably are associated with longer periods, propagated with less attenuation.

Conclusions

The position of weathership B was not at the most prominent source area for the microseisms observed at Nord, possibly due to attenuation during the 400 km of the path on which the ocean depth exceeds 6000 feet. Alternately, the narrow ray of most frequent approach may not originate in the suggested area, but the ray, which has the direction of the long axis of Greenland, may receive microseisms refracted into it from the sides, in particular from the north Atlantic. Although the relationship between the monthly parameters of microseisms and wave height could be coincidental, it can be concluded that support has been given to the theory of Longuet-Higgins, as it is the only theory available that predicts a linear relationship between microseisms and square of water wave height.

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