

ART. XXXIX.—*One Phase of Microseismic Motion*; by
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SEISMOLOGISTS generally include in the term *microseismic motion* all pulsations and movements of the earth's crust which are not attributable to earthquakes or to motion of a more or less violent and abrupt nature.

Microseisms may be due to local causes, as industrial operations and ordinary traffic, storms and waves on adjacent shores, frost action, and possibly by wind, tide, and waves on distant shores. The kind and number of microseisms recorded at any place will naturally be limited by the adjustment and damping of the pendulum and the nature of the record, as a photographic registering seismograph with high magnification will record microseisms when a mechanically registering seismograph would give only a smooth straight line. Moreover, with mechanical registration the recording surface may not always be uniformly coated with lampblack and hence will offer varying resistance to the lateral movement of the writing stylus. The mechanical registration with low magnification offers a distinct advantage in studying certain microseisms, since it does not give such a large mass of detail, in which it is often difficult to identify a particular type of motion.

At the Cheltenham Magnetic Observatory we have been studying the relation between *microseismic motion* and the variations in atmospheric pressure since 1906. Our seismograph is a two-component, 10 kilogram, horizontal pendulum, of the Omori type, with mechanical registration and magnification of ten times. The periods of the pendulums have been kept between 24 and 29 seconds. With the seismograph operating under these conditions, only the more pronounced microseisms are recorded, yet it is an interesting fact that during nearly five years record there have been not more than 25 cases of moderate barometric changes in connection with which microseisms might have been expected and were not found on the seismograph traces.

The microseisms accompanying atmospheric pressure variations have a remarkably regular wave-like motion which almost always shows a rhythmical increase and decrease of amplitude indicating interference. The waves occur in groups of from 6 to 12, and vary in amplitude with the intensity of the barometric variation. The most pronounced cases indicate a movement of the earth particles at this place amounting to about 0.05 millimeters on each side of their mean position.

The results of our observations from September 1, 1906, to

January 31, 1908, were published* in tabular form, with full notes on the atmospheric pressure conditions. These results showed that the most pronounced microseisms were almost invariably connected with the passage of deep lows across the coast line from land to sea, or vice versa. It was also pointed out that the water area under the pressure disturbance would be in hydrostatic equilibrium, while the land area would be subject to a stress which would be greatest at the shore line, hence we should expect the greatest microseismic motion when the center of a low area moves rapidly over the coast line.

This reasoning has been confirmed by approximately 100 well-defined cases during the past 5 years. In fact, during the period under investigation there has not been a single case of a well-defined low area which has crossed the coast line between Maine and Florida which has not been accompanied by well-defined microseisms. It was also noted in the above paper that a rapid rising or falling pressure over the coast was accompanied by microseisms.

This type of microseisms has been studied by Dr. Otto Klotz of Ottawa, Canada, who finds that the most marked cases at Ottawa are connected with the passage of low areas down the St. Lawrence and into the Gulf. He considers the microseisms due to difference in pressure, which is in agreement with our conclusions.

The movement of a low area down the St. Lawrence and into the Gulf should be regarded as a passage across the coast line, although Dr. Klotz makes the statement† that such passage is not marked by microseisms. This statement is not in agreement with our results at Cheltenham, which is peculiarly well located geographically for the study of such phenomena. Of 300 microseisms recorded here between September 1, 1906, and June 30, 1911, all but 32, about 10 per cent, have been definitely connected with some change of pressure occurring over the coast line between Labrador and Texas.

That a change of pressure over land areas alone, although of considerable intensity, does not produce appreciable tremors is borne out by the following observations; in many cases intense depressions have developed over the Mississippi valley and over the Lakes and have moved northward and eastward entirely unaccompanied by microseisms until they had approached sufficiently near the ocean to cause a steep pressure gradient over the coast. Another small group in which a low develops over the Gulf or the lower Mississippi valley and moves rapidly northeastward, passing out to sea over the middle Atlantic

* *Journal Terrestrial Magnetism*, vol. xiii, pp. 1-20, March, 1908.

† Department of the Interior, Canada, Report of Chief Astronomer, 1908, pp. 24-40.

states,—in such cases no appreciable microseisms occur until it approaches the coast, when they begin and reach their greatest intensity while the center is passing out to sea. Another very rare condition is when a low develops over the Gulf states and moves northeastward along the Allegheny mountains, passing into Canada without producing any great pressure changes along the coast line; in such cases no microseisms are recognizable. Still another very rare case is when a low develops over the ocean east of Florida and recurves northwestward, passing inland over the South Atlantic coast. The microseisms rapidly decrease after the center passes inland, although it may still be of considerable intensity.

Of the 268 microseisms recorded here during the last 5 years and which appear connected with atmospheric variations, approximately two-thirds occur in the period October to April, when pressure changes are more frequent and abrupt; they occur very rarely during June, July, and August, when pressure gradients are very small. During these winter months these microseisms often continue for several days, diminishing and increasing in intensity as a succession of abrupt pressure changes from low to high sweep over the coast into the Atlantic Ocean.

A detailed study of all these cases confirms the general conclusions already set forth in connection with my earlier paper; hence the tabulation and detailed notes are omitted from this paper, and only conclusions stated.

Of the 268 microseisms above mentioned, 74 were connected with lows moving over the Gulf of St. Lawrence; 20 of these were of sufficient amplitude to determine the period, which varied from 2.8 to 3.5 seconds, with 4 cases of 3.6, 4.6, 5.0, and 6.0 seconds respectively—68 lows moved wholly or in part over the coast of New England; of these 21 showed periods ranging from 3.0 to 3.5 seconds, with one 3.8, one 4.0, and two 5.0 seconds, the remainder being too ill-defined to allow determination of period—73 microseisms were connected with pressure changes occurring over the Middle Atlantic coast between New York City and Cape Hatteras; nearly all of these were lows and show periods ranging from 3.0 to 3.5 seconds, with 5 cases ranging from 3.8 to 5.0 seconds. There were 20 cases connected with the South Atlantic coast, nearly all being due to lows passing northeastward into the ocean and often moving northward parallel to the coast with decreasing intensity; most of these gave intense microseisms with the usual period, one case having a period of 5.0 seconds; in addition to these were 13 cases of lows forming in the Gulf, or the ocean east of Florida, also including hurricanes which approach the Florida peninsula or the Gulf coast; these show the usual periods

with one marked exception: on October 16-17 a hurricane, with pressure about 29.05 inches, was in the Gulf southwest of Florida and the microseisms had a period from 5.0 to 5.8 seconds; on the 18th, when the center had approached the Florida coast and was passing inland, the period had decreased to 3.5 seconds and the amplitude greatly increased.

In general the period of the microseisms is from 3.0 to 3.5 seconds regardless of the part of the coast under strain. Periods greater than 3.6 seconds apparently occur only when the low is of great extent and the center almost wholly over the ocean. It would appear from this that the period of the microseisms varies with the extent of the disturbed water area.

In general, pressure changes due to high areas are too gradual and widespread to produce microseisms of appreciable intensity, although about 40 cases have been noted, nearly all being cases in which a depression was closely followed by a high area of marked intensity.

In my earlier paper it was suggested that the microseisms might be connected with the movements of large masses of water set in motion by the wind accompanying the pressure changes. This assumption is not borne out by a comparison of the winds, normal to the coast line, and the microseisms occurring during the period January 1 to June 30, 1910. During this period there were strong microseisms on days when there was little or no wind along the coast, and also days when there were high winds without any well-marked microseisms. In general, high areas are accompanied by winds when they approach the coast, although they are rarely accompanied by microseisms.

Another point of interest is that the period of the microseisms does not appear to be conditioned by the geological nature of the part of the coast line over which the low is passing, as all parts of the coast give essentially the same periods. It seems probable that this period is a characteristic of the locality in which the seismograph is mounted, although the change of period during different microseisms is difficult to explain on that basis. Klotz at Ottawa observed periods of 5 to 6 seconds with occasional changes to 3 seconds.

The above conclusions by no means preclude the probability of microseisms being produced by the movement of lows and highs wholly over the land area; in fact it is extremely probable that they do occur, and could be readily recorded by a sufficiently sensitive seismograph, but it is evident that, at least for the eastern part of the United States, the most marked microseisms are those related to the variations of pressure along the coast line.