

ROYAL OBSERVATORY, HONG KONG.

TECHNICAL NOTES NO.9.

STORM MICROSEISMS IN HONG KONG.

Preliminary Report.

1. Introduction. Microseisms are recorded on most days by the seismograph at the Royal Observatory, and the purpose of this preliminary study is to ascertain their relationship with meteorological disturbances in the area, and in particular to discover whether the records of a single seismograph provide any information about tropical cyclones which would aid the storm warning service. The distance and bearing of a cyclone centre cannot be determined from the microseismic records of a single station, but an empirical method of analysing such records developed by the U.S. Naval Aerological Service (1952) promises results which may be useful in forecasting, and is adopted here. This method employs "equal-amplitude charts", on which isopleths are drawn through the positions of the centres of all known cyclones of given intensity which produced microseisms of given amplitude at the station. Provided the analysis of past storms gives consistent results, these charts should enable the intensity of a cyclone to be estimated from the amplitude of the microseisms when its approximate position is known. The microseisms should also give an indication of any sudden development or intensification of a cyclone within the area covered by the charts.

2. Analysis of Seismograms. The instrument in use is a Sprengnether series H seismometer recording E-W movements; the pendulum period is 14 seconds, the galvanometer period 13.6 seconds, and the magnification approximately 3,500. No change has been made in the magnification since May 1952, and the records throughout the period June 1952 to December 1953 were accordingly analysed for microseisms. Various types of microseisms have been classified by Gutenberg. Attention was confined to the more or less regular microseisms with a period of about 4 or 5 seconds, corresponding to Gutenberg's types 5-9. These often show fluctuations in amplitude suggestive of beats. They are very frequently recorded in Hong Kong, and are easily distinguished from the irregular microseisms of longer period (types 10-11), which are attributed to local causes.

The maximum range (double amplitude) occurring within 30 minutes of each synoptic hour was measured and tabulated on all occasions when the recorded range exceeded 2mm. The periods of the microseisms were not measured. Microseisms of range 2mm. will be termed "enhanced microseisms" for brevity.

3. Analysis of Weather Charts. The charts for the whole period were examined, together with all available aircraft reconnaissance reports, and on each occasion of enhanced microseisms a note was made in the table of any meteorological disturbance known to exist in the area extending from  $10^{\circ}$  to  $30^{\circ}$  N and from  $105^{\circ}$  to  $125^{\circ}$  E, which might have accounted for the increased microseismic activity. The maximum winds in the disturbance, if known, and the position of the centre of a cyclonic disturbance were also noted. In addition, all disturbances producing winds of gale force or more within the area, but which were not associated with enhanced microseisms, were entered in the table.

4. Meteorological Disturbances associated with Microseisms. It was found that on almost every occasion when enhanced microseisms were recorded a meteorological disturbance of one of the following types existed in the given area:-

Winter monsoon winds  
Troughs of low pressure  
Typhoons  
Tropical storms  
Tropical depressions and "Kona" storms.

The converse does not hold; as we shall see, a disturbance may exist within the area without producing enhanced microseisms.

There were only three instances of enhanced microseisms which did not appear to be associated with any of the above types of disturbance. On one of these occasions microseisms of 2.4mm. range were recorded when a stationary depression over Tonkin was producing S'ly winds of up to 25kts. off the S. China coast. On the other two occasions extra-tropical depressions with winds of gale force were centred in the region of S. Japan; these were associated with microseisms of ranges up to 2.4 and 2.8 mm respectively.

5. Winter Monsoon Winds. Microseisms of small amplitude almost invariably make their appearance when strong monsoon winds are blowing along the China coast or across the northern part of the China Sea. It is rare, however, for microseisms of range greater than 2mm. to be associated with monsoon winds alone. There were 99 occasions during the period of analysis when monsoon gales were reported in this area, and on only 11 of these were enhanced microseisms recorded which could be attributed solely to the monsoon; the maximum range recorded was 3.0mm. There were, however, a number of occasions when enhanced microseisms, attributed at first sight to monsoon gales blowing at the time, were found on further examination to be the tail end of a series of microseisms of gradually decreasing amplitude associated with a tropical cyclone which had

already filled up in the area. There seems little doubt that in certain cases the microseisms produced by a tropical cyclone can persist for a day or two after the storm has filled up.

6. Troughs of Low Pressure. Enhanced microseisms were recorded on 4 occasions when troughs lay to the south of Hong Kong, extending from the neighbourhood of Hainan to S. Formosa or Luzon Strait. On three of these occasions no strong winds were reported from the troughs, and the maximum range of the resulting microseisms was between 2 and 3mm. On the remaining occasion there were 25kt. winds in the trough, and the maximum range of the microseisms was 4.2mm.; a tropical depression subsequently developed in this trough.

7. Typhoons and Tropical Storms. In order to construct the "equal amplitude charts" referred to above, we must know the positions and intensities of past typhoons at the times when they were producing microseisms at the recording station. Although the positions of typhoon centres in the China Seas are usually known with reasonable accuracy, there is no certainty about their intensities; even if reports are available from ships or reconnaissance aircraft in the central region of a storm, the observations of surface wind speeds are at best only estimates. It was found possible, however, to obtain fairly consistent results by dividing typhoons into two classes, one consisting of mature and severe typhoons probably with maximum winds of over 100kts, the other of less severe typhoons with maximum winds between 64 and 100kts. For example typhoon "Susan", whose centre passed within some 30 miles of Hong Kong in September 1953, but which had only reached typhoon intensity three days earlier, produced smaller microseisms than did several mature typhoons crossing the China Sea at a much greater distance from Hong Kong.

Provisional equal-amplitude charts for severe typhoons, less severe typhoons, and tropical storms are shown in Figs. 1 - 3. In these charts the lines of equal amplitude are very far from symmetrical about the recording station, the largest microseisms being registered when storm centres were situated to the S and SW of Hong Kong. Severe typhoons (Fig. 1) approaching from the Pacific did not produced enhanced microseisms until they had crossed the Philippines, although enhanced microseisms appeared on occasions when severe typhoons were centred to the east of Bashi Channel or off the East China coast as far north as Shanghai. As might be expected the amplitude of the microseisms increased as a typhoon approached Hong Kong, but it often continued to increase after a centre had passed to the south and was moving on westward across the China Sea. No severe typhoons passed within 150 miles to the south of Hong Kong during the period, so the isopleths in this region are conjectural.

It is remarkable that the largest microseisms recorded, with a range of 12 or 13mm., occurred when typhoons "Trix" and "Wilma" were entering the coast of Annam in October 1952. On each of these occasions the centre of the typhoon was at least 500 miles from Hong Kong at the time the greatest microseismic activity was taking place. All typhoons which entered the coast anywhere between Shanghai and Central Annam during the period continued to give enhanced microseisms of diminishing amplitude after the centre had moved inland. This tail end of the microseismic disturbance lasted anything between 6 hours and 30 hours.

The lines of equal amplitude for less severe typhoons (Fig.2) and for tropical storms (Fig.3) show the same general features, but the smaller the intensity of the storm, the less the distance at which it produced microseisms of a given amplitude. The centre of a less intense typhoon may almost reach Pratas before it begins to produce enhanced microseisms in Hong Kong. The largest microseisms produced by such typhoons had a range of 10mm., and occurred when "Susan" was centred 60-100 miles to the SE of the Colony. Of tropical storms, "Charlotte" produced the largest microseisms, with a range of 8mm., when centred 150 miles to the SW of Hong Kong.

A tentative explanation of the unsymmetrical distribution of the amplitude lines will be given in a later section.

8. Tropical Depressions and "Kona" Storms. The effects of these were irregular, and it was not possible to draw lines of equal amplitude. This was not due to lack of data, for 16 such depressions occurred in the China Sea during the period. Depressions seldom produced enhanced microseisms when centred east of  $115^{\circ}$  E or south of  $14^{\circ}$  N, and again the largest microseisms were usually recorded when the centres were to the SW of Hong Kong - often at a considerable distance. An extensive depression of the kona type, with winds of 30 knots on its periphery, produced microseisms of over 7mm. range when centred nearly 300 miles to the SSW of Hong Kong on 27th September, 1953. These were the largest microseisms associated with tropical depressions or kona storms, and were comparable with those produced by a typhoon of moderate severity centred in the same neighbourhood. On the whole, however, these depressions produced only slightly enhanced microseisms, the range of which seldom reached 4mm.

9. Conclusions. The foregoing results were obtained by means of a single E-W seismograph, and it should not be forgotten that the pictures presented by analysis of the N-S or vertical components might be very different. Until records of all three components are available at the Observatory, no serious contribution to the theory of microseisms can be made. It has been suggested

that storm microseisms are due to vibrations transmitted to the ocean floor beneath the centre of a circular storm. Even from the limited data so far available in Hong Kong, it is obvious however that there must be other causes, since microseisms are generated by monsoon winds, troughs and kona-type storms, none of which are associated with well-defined centres. Moreover circular storms continue to produce microseisms after their centres have filled up or moved inland.

Again, the peculiar shape of the lines of equal amplitude may be partly due to the fact that only E-W movements are recorded, and partly to irregularities in the geological structure of the area. Yet the south-westward extension of the isopleths, corresponding with a continued increase in the amplitude of the microseisms as a storm passes to the south of Hong Kong and moves on towards Indo China, strongly suggests that the microseisms are not wholly due to earth waves travelling at high speed from directly beneath the storm centre, but rather to slower-moving swell. The largest microseisms of all were recorded when typhoons were approaching or crossing the coast of central Annam; at this stage a southerly or south-easterly swell of long fetch was presumably arriving at the South China coast from a direction at right angles to the coastline.

A further investigation when 3 - component seismograms are available will be needed to confirm the relation between swell and microseisms. Meanwhile the equal-amplitude charts may be used in conjunction with the E-W seismograms to obtain additional information on tropical cyclones in the area. The following routine is suggested. The daily seismogram should be examined immediately after the sheet has been developed. Assuming the magnification of the seismometer is unchanged, microseisms of maximum range greater than 2 mm. indicate a meteorological disturbance of some kind in the area. If no strong monsoon winds are blowing along the China coast at the time, it is highly probable that the disturbance is a tropical cyclone (weak or intense), which may well be situated within the China Sea. If the approximate position of the centre of this disturbance is already known from weather reports, it will often be possible to estimate its intensity by measuring the maximum range of the microseisms and applying this to the amplitude charts. During the typhoon season the occurrence of enhanced microseisms when no meteorological disturbance has yet been detected on the weather map should be regarded as a warning that a tropical cyclone is probably developing in the China Sea.

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References:

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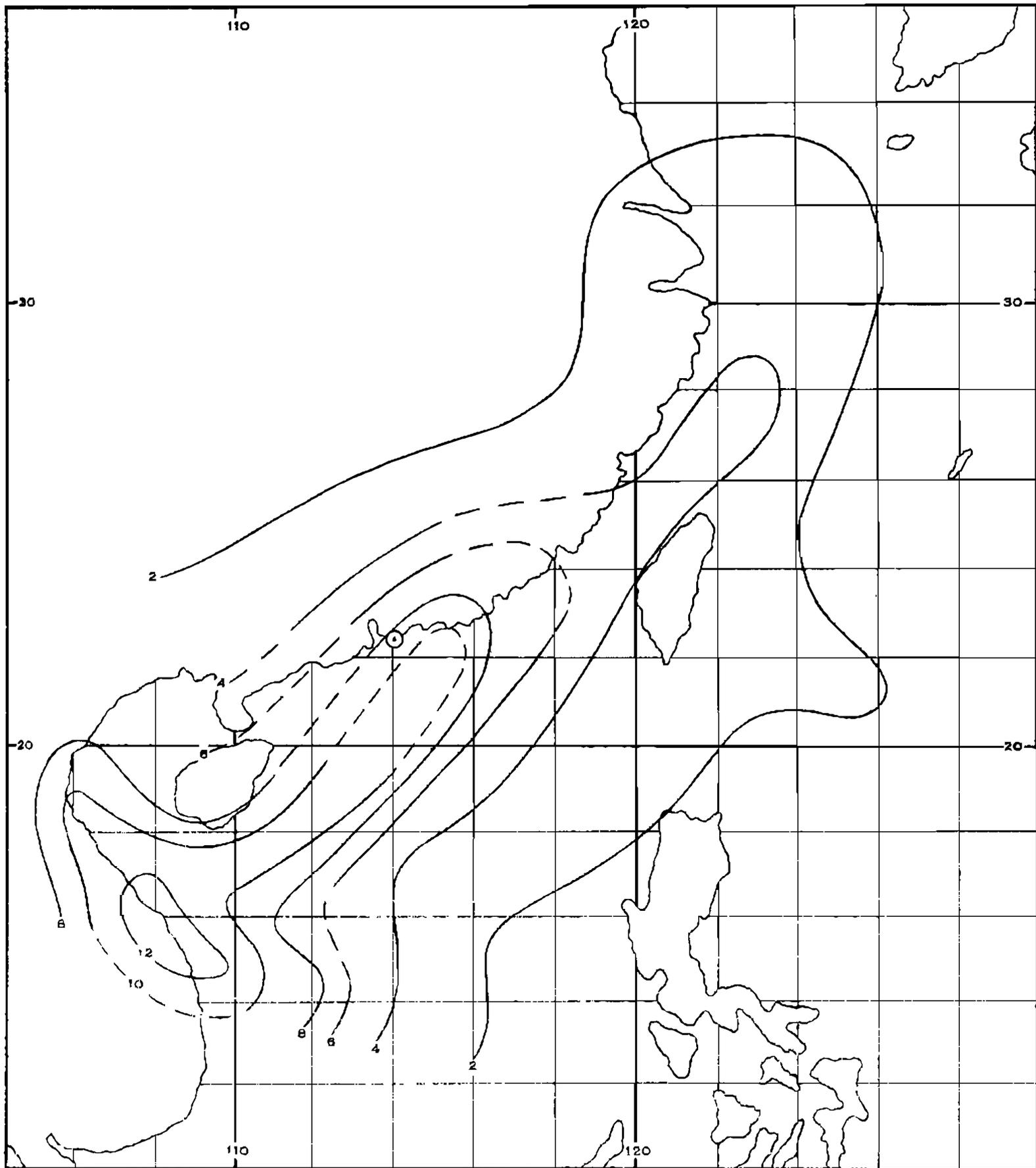


FIG. 1 - EQUAL-AMPLITUDE CHART FOR SEVERE TYPHOONS.

ISOPLETHS SHOW MAXIMUM RANGE OF E - W MICROSEISMS IN MM.

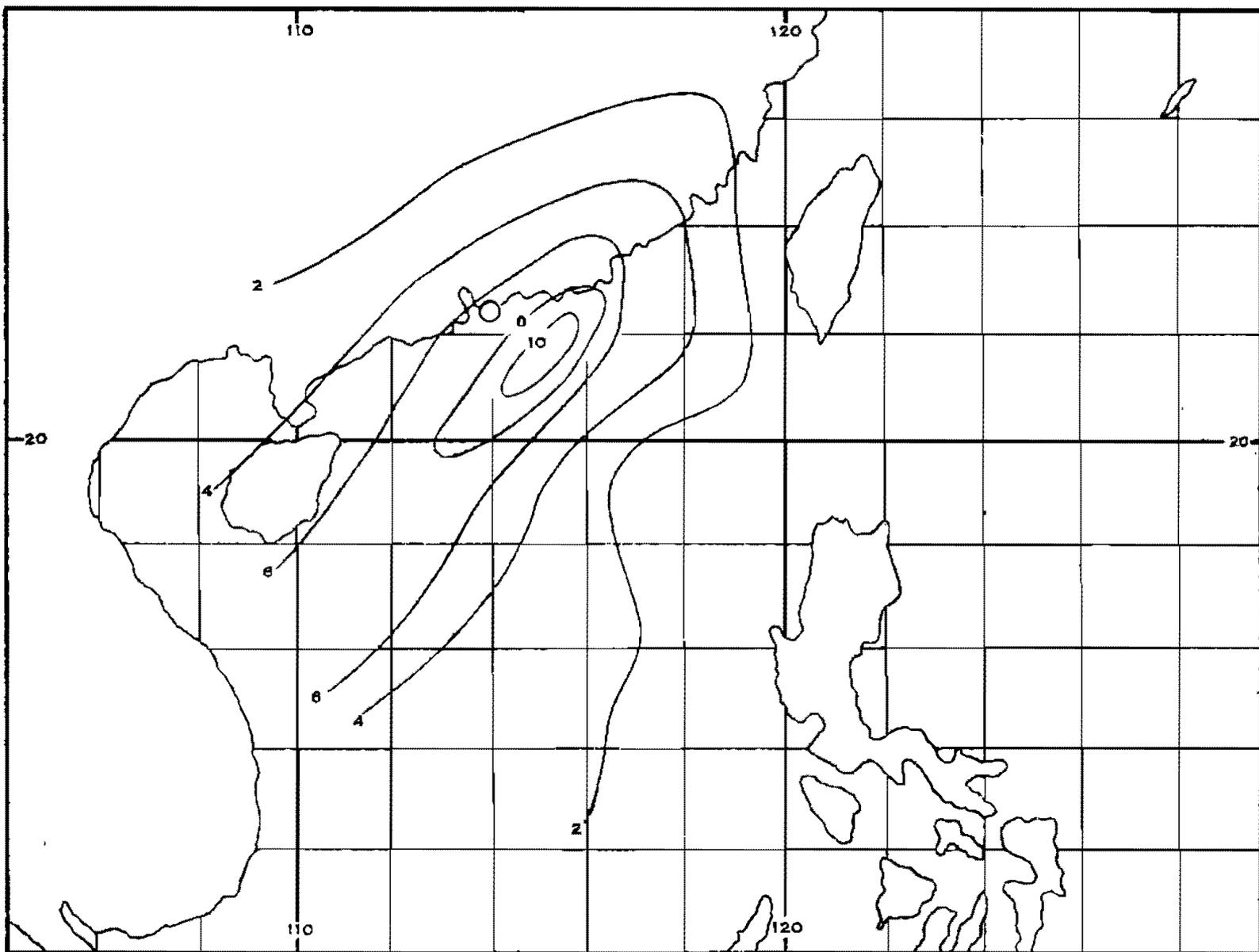


FIG. 2 -- EQUAL-AMPLITUDE CHART FOR LESS SEVERE TYPHOONS.

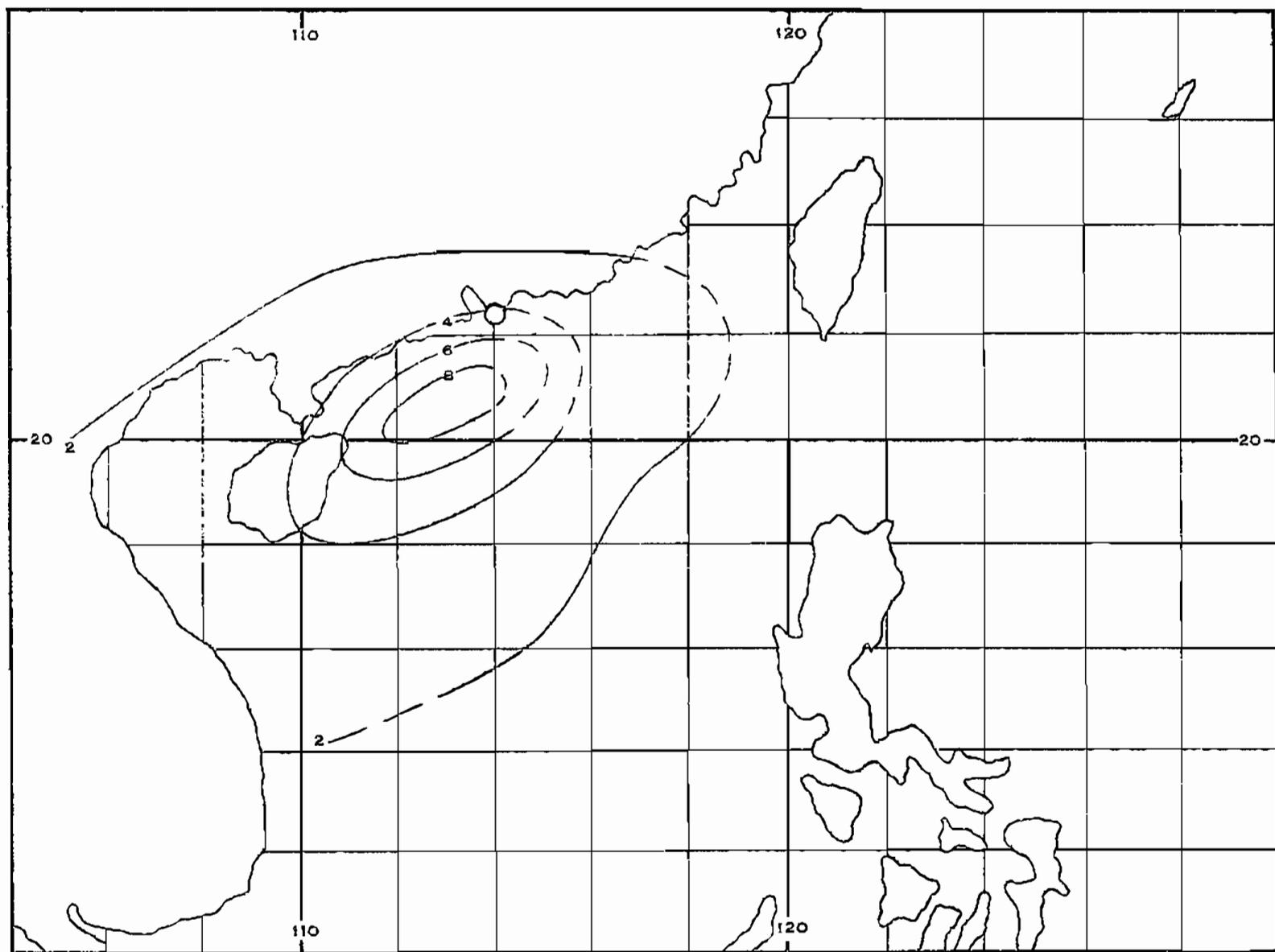


FIG. 3 - EQUAL-AMPLITUDE CHART FOR TROPICAL STORMS.