COMPUTATIONS OF THE DIRECTIONS OF MICROSEISMS AT TRIPARTITE STATIONS*

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The direction from which microseisms reach a tripartite station is computed from the differences in the times at which an individual wave reaches the instruments at three locations A, B, C. In bearings so determined troublesome inaccuracy is frequently remarked and criticized but never satisfactorily explained.

Without debating how much error is contributed by uncertainty regarding the exact point of origin of the microseisms, the effect of geologic barriers, and the effect of cold fronts, let us see whether ordinary principles of measurement theory are being properly followed in current techniques and, if not, what can best be done to minimize the component of error which is introduced by such shortcoming.

Though mainifestly it is necessary to identify them in the three records, there are few detailed discussions of the best ways of identifying individual or "unmodified" waves. How much better this might be done with three-component instruments at A, B, C remains uncertain. But it is clear that the arriving microseisms crossing a tripartite station do not comprise a single coherent wave train and that this may result in the derivation, from any single observation, of markedly false directions and velocities.[1]

The obvious recourse is to average the largest practical number of independent observations (as one does in navigation), because measurement theory indicates that the accidental error of the mean of 4, 9, 16, 25 . . . entirely independent observations is only ½, ⅓, ¼, ⅕ . . . of the accidental error of a single observation.

One finds, however, even with many criticisms of the accuracy of bearings from tripartite stations, that in tracking hurricanes four- to six-hour intervals between successive bearing computations are not at all uncommon. Perhaps some component of the bearing error is systematic rather than accidental; but it nevertheless strongly suggests itself that bearing computations about every twenty minutes, giving perhaps sixteen times as many fixes, and about one-fourth as large an accidental error as we now have in the mean of those fixes, might be well worth attempting. (Nothing in the foregoing is intended to discourage using an average of a series of intervals in making a single computation. That is helpful; but it is not, I believe, a satisfactory substitute for a multiplicity of independent computations and fixes at shorter, regular intervals.)

In addition to the present undesirably low frequency of making bearing computations there is the further difficulty that on each occasion only one bearing computation is made (using one pair of arrival-time intervals) instead of making three bearing computations (using the three possible pairs of arrival-time intervals) and averaging the three results. In its own way this seems just as unsound as having three triangulation lines but being satisfied with a fix at the intersection of only two of the lines, instead of using for the fix the center of the small triangle which the three lines form by not all crossing in a single point.

The present computations of bearings seem to total only about one-fiftieth as

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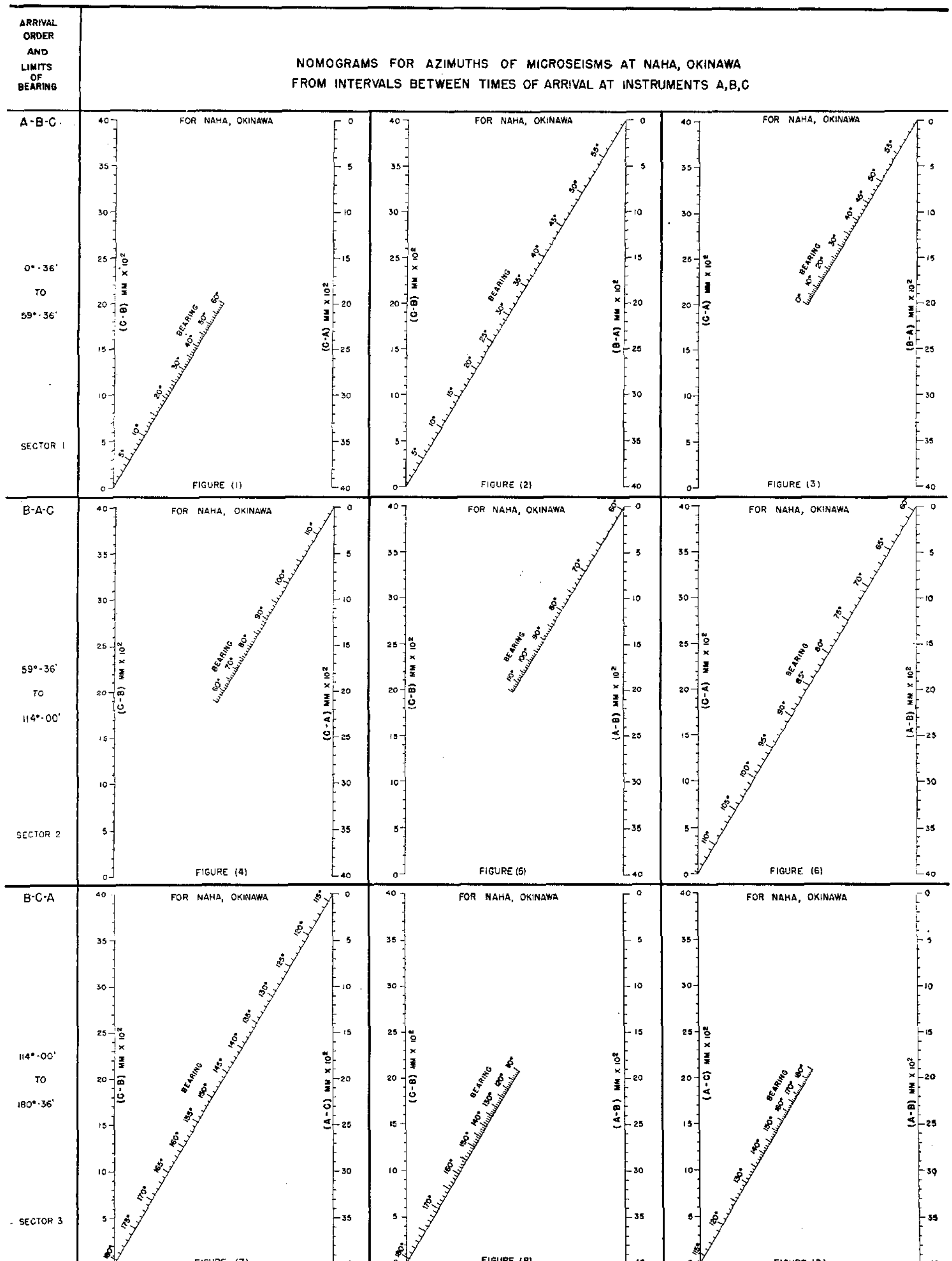
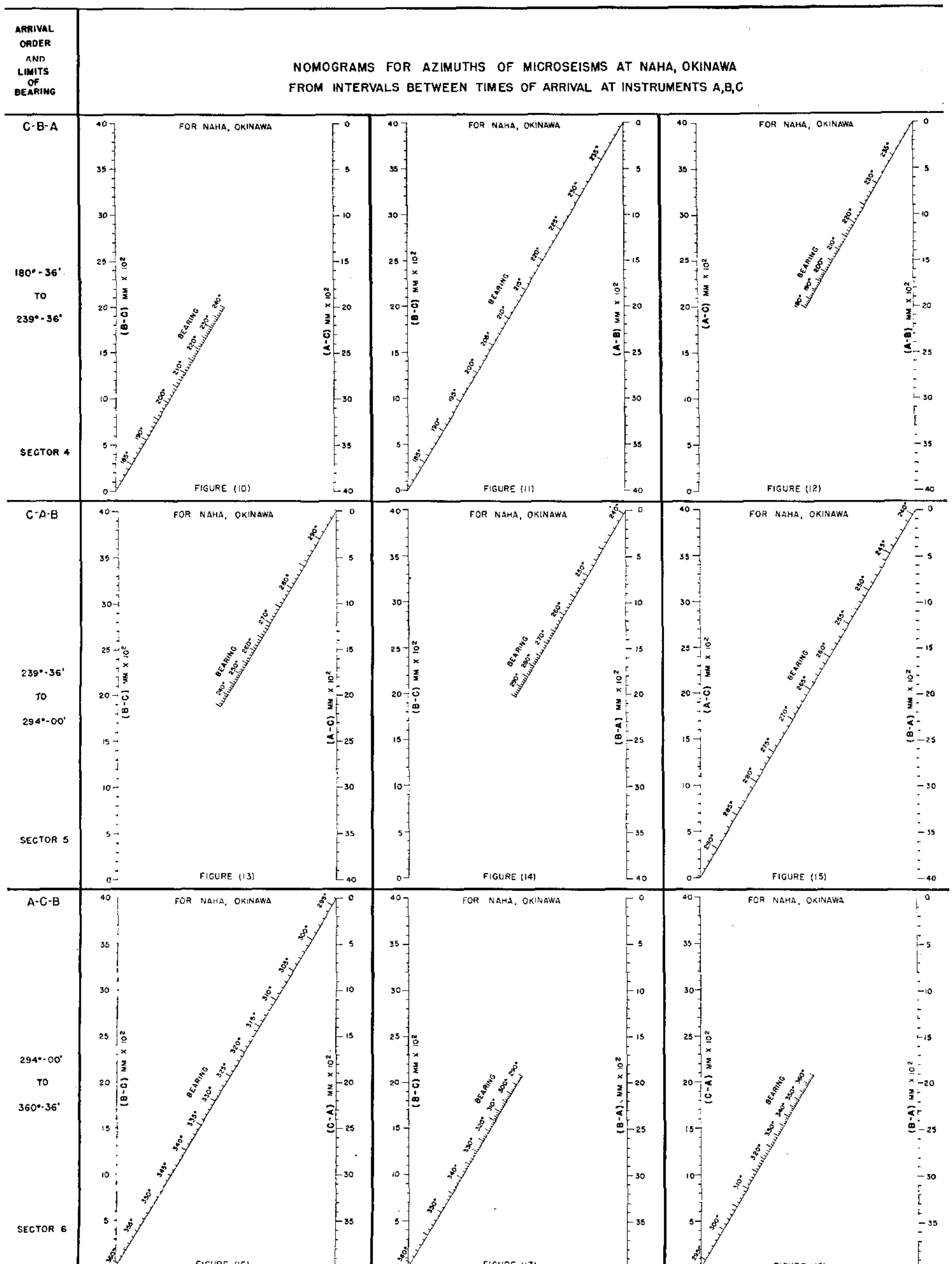
[1] J. E. Dinger, discussion at Symposium on Microseisms, September, 1952, National Academy of Sciences—National Research Council, *Publication 306*, pp. 12–16 (1953).



Figs. 1–9 (sheet 1).



Figs. 1–9 (sheet 2)

many as we might well like to have, but perhaps this is at least partly explained by the extraordinarily clumsy and laborious current computation techniques, which date back to pioneers in this field.[2]

For practical routine work let us therefore supply each tripartite station with a separate set of eighteen nomograms by means of which it can work out bearings with no computation at all.[3]

There are six possible orders in which a wave may arrive at the three instruments, namely, ABC, BAC, BCA, CBA, CAB, ACB. Each of these corresponds to a different bearing sector. As an example, let the arrival order be BCA, and the measurements of the intervals C − B = 25, A − C = 10, A − B = 32 mm. × 10^2.

From the arrival order the accompanying figures show the bearing to be in sector 3, or between bearings 114° 00′ and 180° 36′, and that figures 7, 8, 9 apply. As the longest interval is not exactly the sum of the two others the indicated bearings must be somewhat "discordant."

In figure 7, aligning 25 on the left scale and 10 on the right scale makes the straightedge cut the diagonal scale at a bearing of 130°.5. In figure 8, using 25 on on the left scale and 10 on the right scale, we have a bearing of 126°.5. In figure 9, using 10 on the left scale and 32 on the right scale, we have a bearing of 132°.5. Taking the average of these three bearings, or better yet and more quickly the median value of 133°, we in this way obtain the bearing in a matter of seconds after measuring the three arrival-time intervals. The full-size nomograms measure 6 by 10 inches and are best printed on heavy chart paper. After some experience one does not find it necessary to draw a line all the way across the nomogram, but only to draw a short mark where the straightedge crosses the diagonal scale.

It is not claimed that this method necessarily will make fixes from tripartite stations better than those had by other methods (e.g., by micro-ratio networks). The purpose is merely to point out that the potentialities of tripartite stations are unlikely to be fully realized unless and until the computation techniques now commonly employed by them are drastically modernized in some such way as the one here indicated.

Added Note on Velocity Determinations

It should be remarked that the bearings have in effect been determined from the *ratios* of intervals in which the velocity cancels out, so that the accuracy of the bearings is independent of any error in estimating the microseisms' horizontal velocity v.

To determine v one may, for each of the sides, develop from observation an ordinary sinusoidal plot of times versus bearings. However, the following polar plot is suggested, instead.

If t is the interval required for a wave to pass from one end to the other end of side c, and θ is the corresponding obliquity between side c and the direction of travel of the microseisms, the observed points of the polar plot of t versus θ will develop circles of diameter c/v, which, it is suggested, determines v more neatly and more accurately than can be done by any sinusoidal plots.

[2] J. Emilio Ramirez, "An Experimental Investigation of the Nature and Origin of Microseisms at St. Louis, Missouri," *Bull. Seism. Soc. Am.*, 30: 35–84, 137–178 (1940); Marion Gilmore, "Microseisms and Ocean Storms," *Bull. Seism. Soc. Am.*, 36: 89–119 (1946); V. F. Jennemann, "Microseisms at Corpus Christi," Saint Louis University, Institute of Technology (1948); B. Gutenberg, "Microseisms and Weather Forecasting," *Jour. Meteor.*, 4: 21–28 (1947).

[3] G. L. Schuyler, O.N.R. publication *Navexos*, January 1, 1949, p. 598.