BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 49, PP. 653-658, 3 FIGS. APRIL 1, 1938

LOCAL AREAL VARIATION OF BEACH SANDS

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INTRODUCTION

Several years ago the writer collected a series of sand samples from the shore of Lake Michigan, at Waverly Beach, about 10 miles west of Michigan City, Indiana. The samples were mechanically analyzed, and the data were used in a study of the probable error of sampling sediments for mechanical analysis (Krumbein, 1934). The paper was also presented at the Chicago meeting of the American Association for the Advancement of Science in June, 1933, at which time a map of the areal variation of average grain size was shown. The map itself was not published, however. During 1936 the writer, in collaboration with J. Scott Griffith (Krumbein and Griffith, 1938), studied the areal variation of beach deposits at Little Sister Bay, Wisconsin. The results of the latter study showed certain similarities to the earlier map prepared on the Waverly Beach samples, and the writer believes it pertinent to supplement the Little Sister Bay report with the data from the earlier study.

In the original analyses of the Waverly samples, the median grain size was used, but for present purposes the phi mean, M_ϕ, the phi standard deviation, σ_ϕ, and the geometric mean diameters, GM_ξ, of the samples were computed (Krumbein, 1936), to make the results more directly comparable to the measures used at Little Sister Bay. For purposes of orientation, Figure 1 shows the nature of the grid pattern on which the samples were collected. The samples were spaced in three rows along

the beach, each sample in a given row 60 feet apart, and the rows 30 feet apart. The mechanical analysis data are given in the original paper; Table 1 lists the phi mean, the phi standard deviation, the geo-

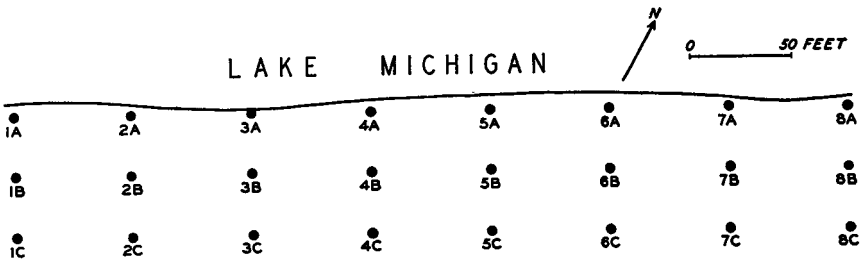

FIGURE 1.—*Map showing location and number of samples*

AREAL VARIATION OF AVERAGE GRAIN SIZE

metric mean size in millimeters, and, for purposes of comparison, the median diameters as given in the earlier paper.

Figure 2 is a map of the areal variation of the geometric mean diameter in millimeters of sand grains at Waverly Beach. (Compare with Figure 2 of Plate 3 of the Little Sister Bay study.) The numbers have been rounded to two decimal places. The map discloses that there is a linear trend to the variation of average size here as well as at Little Sister Bay, and, in addition, there are suggestions of tongues of coarser material which cut across the linear pattern of contours. As in Little Sister Bay also, the linear pattern shows a "trough" of finer material above the water line and parallel to the beach. There is no topographic depression present in the surface of the beach itself, however.

At Little Sister Bay the nests of coarser material along the beach are attributed to ice shove; in the present study the writer's conclusions were, and are, that waves which carried coarser material across the beach modified the essentially linear pattern of lines. About a year before the samples were collected at Waverly, a great storm had torn out much of the beach along the southern shore of Lake Michigan, and had exposed material from some depth below the previous level. At the time the map was first presented, the writer had concluded that the result of the large storm had been to expose the linear size variation pattern of the off-shore bars which had been formed when the shore line was farther south. Since the stripping effect of the first storm, it was postulated that subsequent minor storms modified the pattern by carrying tongues of coarser material across the beach here and there.

In view of the findings at Little Sister Bay, the linear pattern may be due merely to the fact that more than a single year's beach was covered

by the sampling grid, so that the inner portion may represent earlier accumulations. The essential similarity of the patterns in the two studies, involving pebbles in the one, and sand in the other, suggests that linear patterns may be the rule in size variations along beaches.

In connection with changes in the average size of the sand grains along

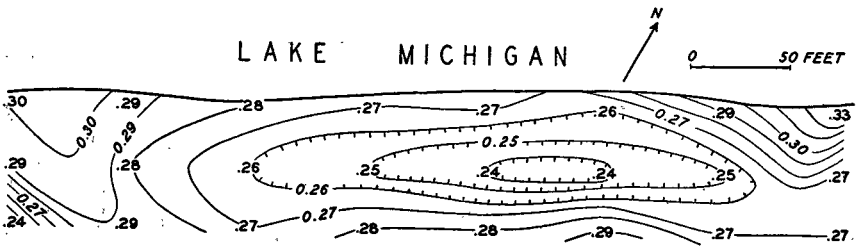

FIGURE 2.—*Map of areal variation of geometric mean diameter of sand grains*

the beach, it may be noted from Figure 2 that, although the western portion of the beach shows a decrease in average size toward the east, the size increases again in the eastern end of the grid area. It seems likely that over the small stretch of beach involved here, no definite tendency can be established. Pettijohn (1931) showed that the average size decreases toward the southern end of the lake, along both the eastern and the western shores, but the rate of change of size is too small to be indicated by a stretch of beach 500 feet long.

The contour interval in Figure 2 is probably smaller than the data justify, but the interval was chosen to bring out more clearly the linear pattern. The earlier study of the probable error showed that the laboratory error was only about one-half of one percent, so that the data have been used directly, without any attempt at correction.

AREAL VARIATION OF THE PHI STANDARD DEVIATION

Figure 3 is a map of the areal variation of the phi standard deviation of the sands on Waverly Beach. (Compare with Figure 4 of Plate 3 of the Little Sister Bay study.) The phi standard deviation, σ_ϕ, is a measure of the average spread of the curves about their mean values, expressed directly in terms of Wentworth grades. (For the geometrical significance of σ_ϕ see Krumbein, 1936.) The individual values of Figure 3 are distributed more or less at random over the beach. No definite linear trend is present, although the average value of the samples in each row increases inward from the shore line. The several contour lines on the map were drawn to indicate as much the absence of any definite trend, as to show a pattern which seems to fit the points.

The range of values of σ_ϕ is from 0.48 to 0.61. The average value is 0.53, which means that, on the whole, the average spread of the grains about their mean values is about half a Wentworth unit on either side of the mean.[1] The relatively small range of values here, combined with the apparently random pattern of the lines, bears on the question raised

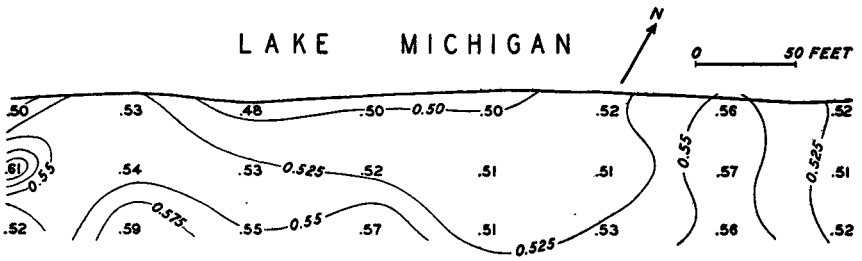

FIGURE 3.—*Map of areal variation of phi standard deviation,* σ_ϕ

in the Little Sister Bay study, in connection with the tendency for the standard deviation to represent fluctuations about some fixed value throughout the environment. The present study seems to support the hypothesis that beaches may tend toward a fixed spread of their size frequency in a given stretch of beach, but, as in the previous paper, the question should be left open until more data accumulate. In any given stretch of beach the average action of the waves may be approximately uniform, so that selective processes, on which the spread of the curve depends in part, may be fairly constant. Local fluctuations in the value of the spread may arise in part from slight changes in the slope of the beach, as well as from the accidental variation in the last large waves to strike any given point during a storm period.

SUMMARY

The present paper seeks to supplement part of the findings in the study of the beach deposits at Little Sister Bay, by showing that there are certain underlying similarities on widely different beaches, which may point to generalizations which are valid for beach environments in general. It is interesting to note that, whereas the size variations of the deposits at Little Sister Bay could be detected with the eye, and the sampling grid modified to bring out the abrupt changes, at Waverly Beach, where the sand appeared homogeneous to the eye, a simple rectangular grid was adequate to develop the pattern of the deposits.

[1] Where the frequency curves are symmetrical on the phi scale, there is about 68 percent of the distribution in the range $(M_\phi - \sigma_\phi)$ to $(M_\phi + \sigma_\phi)$.

TABLE 1.—*Statistical constants of Waverly samples*

Sample	Phi Mean M_ϕ	Geometric Mean Diameter in mm. GM_ξ	Phi Standard Deviation σ_ϕ	Median Size (mm.) Md_ξ
1A	1.73	0.302	0.50	0.290
1B	1.77	0.294	0.61	0.278
1C	2.04	0.243	0.50	0.238
2A	1.77	0.294	0.53	0.281
2B	1.85	0.277	0.54	0.270
2C	1.81	0.285	0.59	0.272
3A	1.83	0.281	0.48	0.273
3B	1.96	0.258	0.53	0.251
3C	1.90	0.268	0.55	0.261
4A	1.88	0.272	0.50	0.266
4B	2.06	0.245	0.52	0.234
4C	1.83	0.281	0.57	0.272
5A	1.89	0.270	0.50	0.263
5B	2.04	0.243	0.51	0.240
5C	1.86	0.276	0.51	0.270
6A	1.95	0.259	0.52	0.254
6B	2.04	0.243	0.51	0.240
6C	1.81	0.285	0.53	0.277
7A	1.81	0.285	0.56	0.273
7B	2.00	0.250	0.57	0.239
7C	1.88	0.272	0.56	0.262
8A	1.61	0.328	0.52	0.310
8B	1.90	0.268	0.51	0.263
8C	1.89	0.270	0.52	0.262

WORKS TO WHICH REFERENCE IS MADE

Krumbein, W. C. (1934) *The probable error of sampling sediments for mechanical analysis,* Am. Jour Sci., 5th ser., vol. 27, p. 204-214; also, corrigenda, p. 399.

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MANUSCRIPT RECEIVED BY THE SECRETARY OF THE SOCIETY, FEBRUARY 23, 1937.
ACCEPTED BY THE COMMITTEE ON PUBLICATIONS, 1937.