Ohio Sea Grant

PRELIMINARY EVALUATION OF SAND RESOURCES IN WESTERN LAKE ERIE

Project R/MR-1

Final Report Prepared for
The Ohio Sea Grant Program
and Kuhlman Corporation

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PREFACE

Sand and gravel for beach nourishment, the construction industry and glass manufacturers are becoming increasingly scarce along the south shore of Lake Erie. Many land-based deposits have been depleted or lie in environmentally sensitive areas. Offshore deposits in Lake Erie offer promising locations for commercial extraction. The following report presents the preliminary findings of an investigation of sand deposits in the Michigan and Ohio waters of western Lake Erie.

The study was originally conceived by Professor Lester J. Walters, Jr., of Bowling Green State University and eventually conducted by Dr. Robert W. Anderhalt of the same institution. Support for the project was provided by the Ohio Sea Grant Program (Project R/MR-1) and by the Kuhlman Corporation of Toledo, Ohio. Without the assistance of Mr. M. S. Bartholomew, President of Kuhlman Corporation, in organizing and financing the investigation, this project would not have been possible.

Charles E. Herdendorf
Director

ABSTRACT

The percentages of quartz, potassium feldspar, and plagioclase in the sand fractions of western Lake Erie surface sediments were determined by semi-quantitative x-ray diffraction analyses. A majority of the sampling area which, consisted of 300 stations, is contained within a triangle with one apex at West Sister Island and the other two apices along the Michigan shore about 8 km. northeast and 12 km. southwest of the River Raisin.

Sands collected immediately offshore of the major tributaries adjacent to the study area show a general trend in which the northern streams are relatively enriched in plagioclase, while the more southern streams have a more nearly equal distribution of plagioclase and potassium feldspar. The distribution of sand mineralogy in the lake sediments can be interpreted in terms of dispersal patterns from these tributaries, although this does not rule out other possibilities for the origin of the sand. The quartz content of most of the sand fractions range from 50 to 80% with most samples collected near the tributaries having slightly less quartz than the more offshore sand fractions. This trend of quartz contents is as would be expected due to the increasing maturity of the sands reworked by the lacustrine hydraulic regime.

The general conclusions of the study are that:

1. *There are several areas and linear trends within the study area which are enriched in sand.*

2. *The sand in these sand-rich areas is of suitable coarseness for beach nourishment.*

3. *The mineralogical composition of the sand indicates that substantial beneficiation would be required to produce a glass-grade sand.*

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INTRODUCTION

Large volumes of sand are needed in northwest Ohio for use in the glass industry, construction, and to replenish beaches along the Ohio shore of Lake Erie. Sand is currently being dredged from the Maumee River, Maumee Bay, and Lake Erie off Cleveland for use in the construction industry. Pure quartz sand is also needed for use in the glass industry. Technology is currently available to beneficiate many naturally occurring sand deposits up to the stringent specifications of the glass industry. Because of shipping costs, a large supply of sand which met or could be upgraded to the specifications of the glass industry and construction industries could be utilized in the Toledo industrial area. Water transport, because of its low cost, is a desirable means of moving large amounts of sand. Therefore, if an adequate supply of sand could be delineated in Lake Erie, it could be readily used.

Earlier investigations suggest that a large deposit of sand exists in western Lake Erie between Monroe, Michigan and West Sister Island, Ohio. In order to document the magnitude and utility of the deposit, the present study was undertaken. Objectives of the study included

1. Delineate the surface extent of this sand body in moderate detail.

2. Develop a jetting technique for obtaining sediment samples through the sand body at low cost.

3. Determine the mineralogical, textural and chemical character of the sand.

BACKGROUND

Numerous researchers have observed sand in the surficial sediments of Lake Erie in the region between Monroe, Michigan and West Sister Island. Thomas et al (1976) suggested the presence of a sand concentration in the study area. We also observed and abundance of sandy sediments along the west shore of Lake Erie (Walters, 1978; Przywara et al, 1977; Walters and Herdendorf, 1975). The data compiled by Herdendorf et al (1978) is consistent with the outline of sand distribution shown by Nwankwo (1979). However, none of these studies provides adequate detail to delineate the sand distribution in the surficial sediments.

The mineralogical composition of the sand is an important factor in determining its suitability for use in the glass and construction industries. Przywara (1977) examined seven samples from the proposed study area for heavy minerals. These samples averaged 5.1 percent total heavy minerals and contained magnetite (0.85%), hornblende (1.62%), garnet (0.66%), augite (0.67%), diopside (0.22%), tourmaline (0.40%), ilmenite (0.13%), hematite (0.07%) zircon (0.13%), and others (0.31%). Most of these heavy and refractory minerals can be removed by froth flotation (Brown and Redeker, 1980) to a level below the 0.2 g 100 lbs. limit of LOF (1974). Pre-sizing of the sand to a range of 0.425-0.106 mm prior to flotation will remove a major portion of the heavy minerals because they are concentrated in the fine fraction (Przywara, 1977).

Yahney (1978) examined the mineralogical composition of the sand fractions of three surface sand fractions within the proposed study area by x-ray diffraction. These sand fractions had generally consistent mineralogy and contained quartz (78%), orthoclase (8%), plagioclase (11%), calcite (1%), and dolomite (2%). The quartz content of the Western Basin sand samples ranged between 61 and 80 percent on a carbonate free basis. Yahney (1978) concluded that the area between Monroe, Michigan and West Sister Island has been enriched in resistive minerals, mainly quartz, through solution, physical reqorking and selective removal of most of the smaller silt and clay-sized fractions in a high energy zone.

Nwankwo (1979) proposed that the Monroe-West Sister Island sand body was of glacio-fluvial origin with subsequent modification by beach processes. Przywara (1977) and Yahney (1978) noted the influence of modern lake currents on the reworking and enrichment of this sand deposit. They also concluded the modern Raisin River which enters Lake Erie at Monroe, Michigan could not have deposited the sand. Recent work by Grube (1980) on the Oak Openings sand belt, which is a glacial beach-dune sand area in Ohio and Michigan, suggests that the Monroe-West Sister Island sand deposit and the Oak Openings sand belt are related. Grube (1980) concluded that the development of the Oak Opening sand belt began with sand moving southward by longshore drift from deltaic sources near Ypsilanti and Plymouth, Michigan at the time of glacial Lake Warren I (690 feet). Subsequent lowering of the lake level from Warren I (690 feet) to Warren II (682 feet) and to Wayne (660 feet) provided the opportunity for the sand to dry out and become wind-blown. Glacial Lake Warren III (675 feet) represents a rise in lake level from glacial Lake Wayne and thus is believed to have helped to thicken the sand by sweeping sand up-slope and creating a well-developed beach feature along the length of the Oak Openings sand belt (Grube, 1980). The sand in the study area may represent the offshore facies of the sand presently found in the Oak Openings sand belt and may not have been subjected to extensive subareal exposure.

APPROACH

During 1981, 224 samples were collected in the study area and were each analyzed for the percentage of sand, silt, and clay. In order to use the available ship time in the most cost-effective manner possible, the original sample positions (of which there were approximately 300) were categorized as either high- or low-priority stations based on the probable sandiness of the region using existent data (Nwankwo, 1979). The high-priority stations were each sampled, although a sample was not recovered from five stations due to the rockiness of the substrate. The available ship time was not adequate to sample the low-priority stations. Due to the elimination of some of the low-priority and probably muddy samples there is a small area to the southeast which is not continuous with the main group of samples.

The stations and samples were assigned two sets of numbers separated by a hyphen according to their position in the grid pattern. The first set of digits corresponds to the relative east-west position with '1' being the most western row of stations and '25' being the easternmost row of stations. The second set of digits corresponds to the relative north-south position, with '1' being the most southern row of stations and '25' being the most northern row of stations.

Other analyses performed on the samples were x-ray diffraction analysis to estimate the mineralogy of the 94 samples riches in sand and a seiving analysis of the sand fractions of 22 samples from various sand-rich areas. The sieving analysis was conducted to enable a comparison with some existing, stable, sandy beaches. A study of the geochemistry of the feldspar minerals present in the western portion of Lake Erie was also undertaken and a manuscript of these results is being prepared for submission to the Ohio Journal of Science. The results of this study, in a preliminary form, were also presented at a meeting of the Ohio Academy of Science in April, 1982, at the Ohio State University. (Anderhalt et al, 1982).

RESULTS

Sediment Grain Size

The results of the sand-silt-clay data are reported in the Appendix and summarized graphically as a trivariate plot in Figure 1. The sample was washed with a sieve having a mesh size of 63 microns. The material which was retained on the sieve was sand-sized material. The material that passed through the sieve was the combined silt- plus clay-sized sediment. The silt/clay determination was made by pipet analysis and is based upon the discrimination of the weight of the material having a settling velocity greater than that of a 4 micron sphere of quartz-density material (silt) and that which has a lesser velocity (clay).

Of all the samples analyzed, 35% were classified as "sand" (i.e., greater than 75% sand) using the classification scheme presented in Figure 1 (Shepard, 1954). If the clayey sands and silty sands are included, then 62% of all of the analyzed samples are sands.

It is commonly expected that the sediment closest to the shore will be the coarsest sediment and that progressively finer sediment will be found with increasing distance from the shore. Although the most shoreward group of samples were among the coarsest samples analyzed (16 of the 22 stations closest to shore contained more than 75% sand), there were some anomalously coarse areas that

GRAIN SIZE DISTRIBUTION of LAKE ERIE SANDS

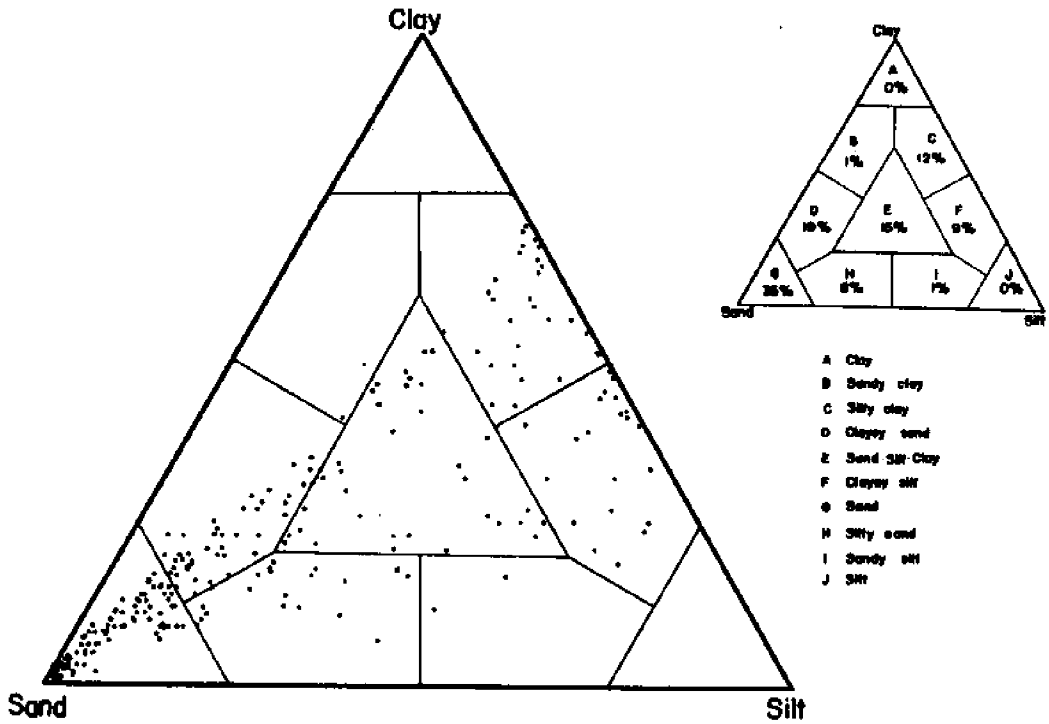

Figure 1. Distribution of samples by the percentages of sand, silt and clay. Classification of sediment is derived from Shepard (1954).

SAND DISTRIBUTION IN WESTERN LAKE ERIE

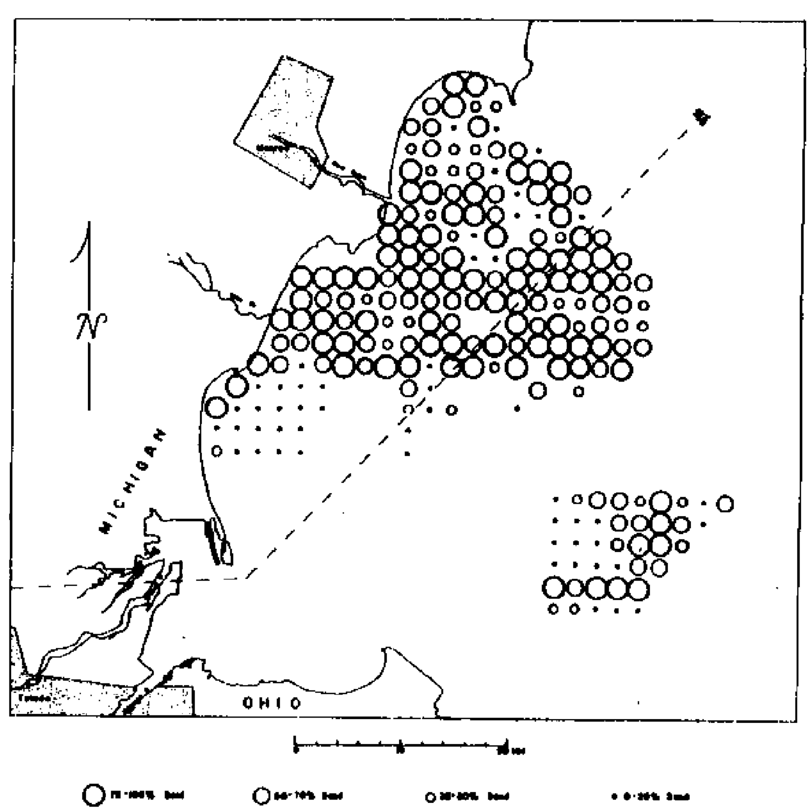

Figure 2. Map of the sand distribution in the study area.

were as much as 10 to 20 km from shore (Figure 2). Two such locations were found: one consisted of six stations in a triangular arrangement in the northeastern portion of the study area (location A on Figure 2); and, another contained 10 stations in the eastern part of the area just south of the first location (B on Figure 2). Each may each have a considerable supply of sand. If these bodies of sand are each continuous within themselves, then they may each have a surface area of 6 and 10 square kilometers, respectively. Some other sand-rich trends appear to be present as narrow, near-linear arrangements of stations which are situated perpendicular to shore just north and south of the extension into the lake of the course of the River Raisin and perhaps along the extension of Otter Creek (Figure 2).

Sand Analysis

The sand fractions of some of the samples from the sand-rich areas just described were sieved to test if these sand resources have suitable size characteristics for beach nourishment and replenishment. This test was enabled by a comparison of the sand-size distribution of these sands with the same distribution for two sandy Lake Erie beaches at Sterling State Beach near the River Raisin and a beach near the Cedar Point Amusement Park. Both of these beach sands have their most prominent mode in the fine sand grade (between 2 and 3 ϕ, or 0.25 and 0.125 mm, or 60 and 120 grade mesh). They are also quite poor in the very fine sand grade (between 3 and 4 ϕ, or 0.125 and 0.063 mm, or 120 and 230 mesh), and each contain less than 3% in this size range (Figure 3). Much of the very fine sand consists of high density minerals such as ilmenite, hornblende, and garnet. The lack of low-density minerals in the very fine sand grade is one of the most typical traits of beach sands (Komar, 1976, p. 350) and indicates that this size is too fine to be stable on beaches just as is the case for silt-sized particles.

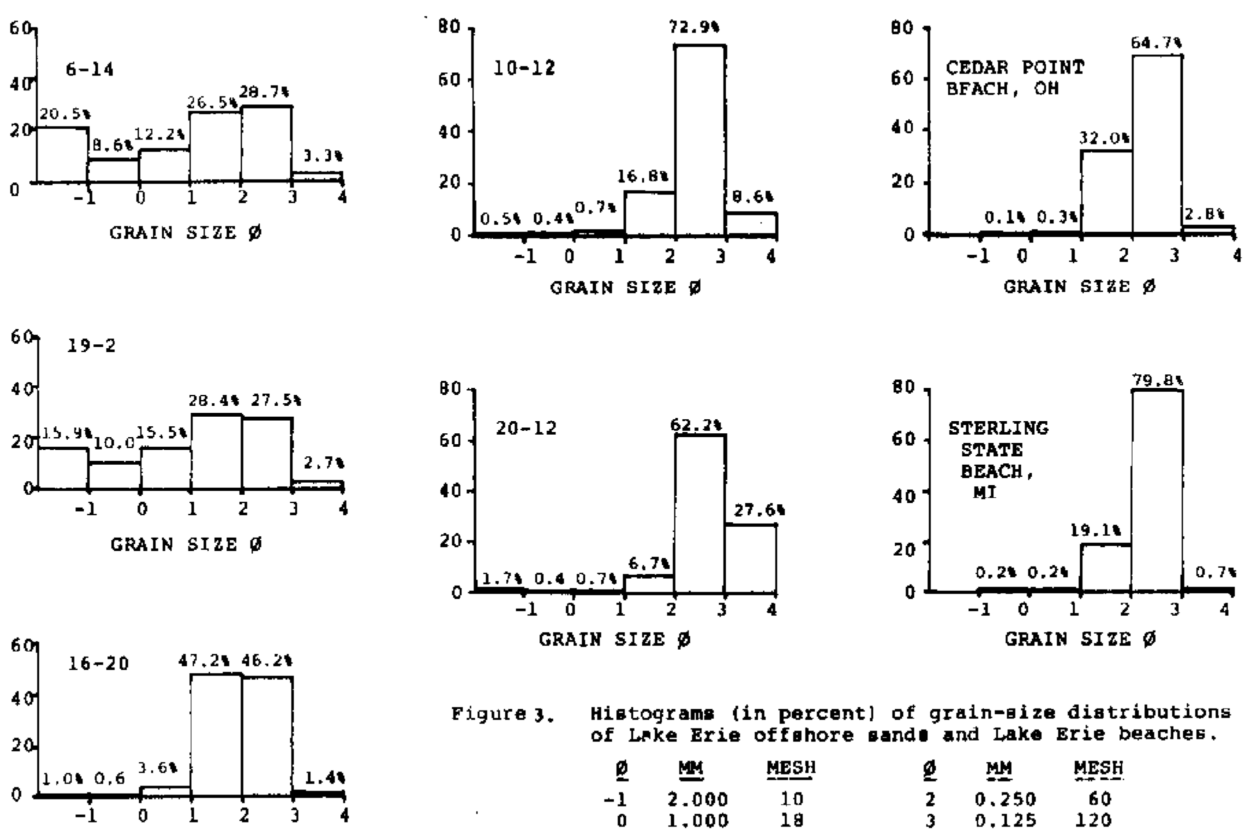

Figure 3. Histograms (in percent) of grain-size distributions of Lake Erie offshore sands and Lake Erie beaches.

Ø	MM	MESH	Ø	MM	MESH
-1	2.000	10	2	0.250	60
0	1.000	18	3	0.125	120
1	0.500	35	4	0.063	230

An examination of the histograms for sands from the relatively coarse areas show they are also relatively poor in the very fine sand-size material with several samples containing less than 5% (Figure 3). A substantial minority of sand in this size grade (i.e., 20-25%) is probably still tolerable for beach nourishment as this very fine sand will probably be selectively winnowed on the beach face and transported into deeper water. The two sand-rich, offshore areas also appear to be favorable accumulations of sand for beach replenishment based upon their histograms from the sieving analysis (Figure 4).

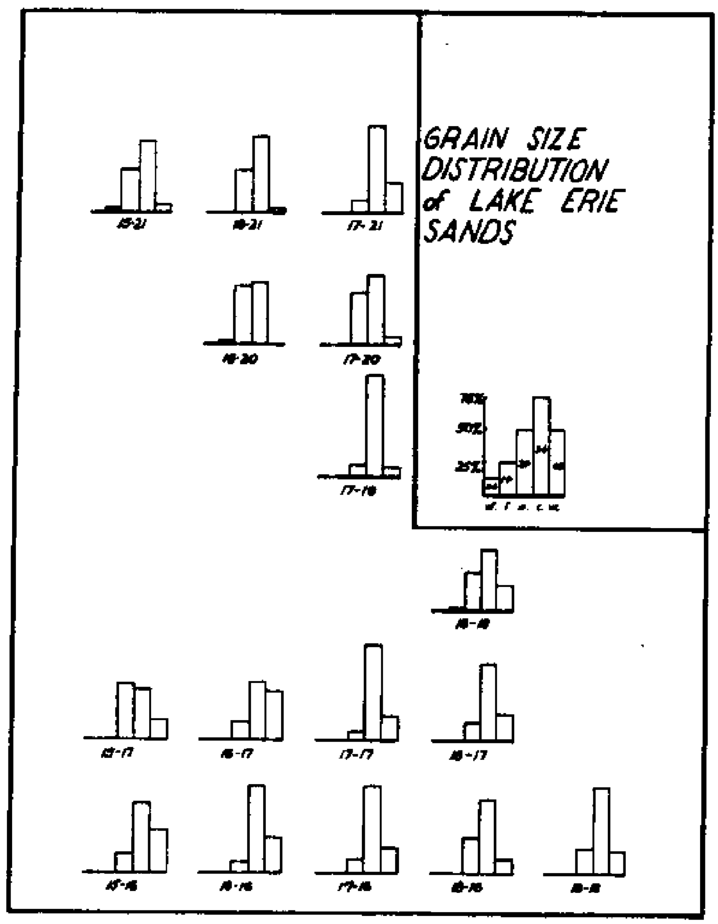

Figure 4. Histograms of the sand fraction for an offshore sand-rich area. Histograms are plotted by position.

Mineralogy

The mineralogy of 94 samples was determined by x-ray diffraction. The purpose of this analysis was to determine if any of the sand-rich areas contain sand suitable for the glass industry which requires sand aproaching 100% quartz (LOF, 1974; Brown and Redeker, 1980). Of the 94 samples analyzed, none contained more than 90% quartz and 68 samples (or 72% of all the samples analyzed) contained less than 70% quartz when only quartz and the two feldspars, plagioclase and potassium feldspar, were considered (Figure 5). Most x-ray diffractograms actually contained at least five components rather than the three just mentioned. Prominent peaks for calcite (from limestone fragments) and dolomite were also quite common (Figure 6). The peak heights of characteristic peaks for each mineral is multiplied by a factor and these products are summed for each mineral. The percentage of each product relative to the sum gives that mineral's percentage (Cook et al, 1975). A few samples contained illite peaks from shale and slate fragments, and a few also contained hornblende. Nevertheless, if the nine relatively quartz-rich samples

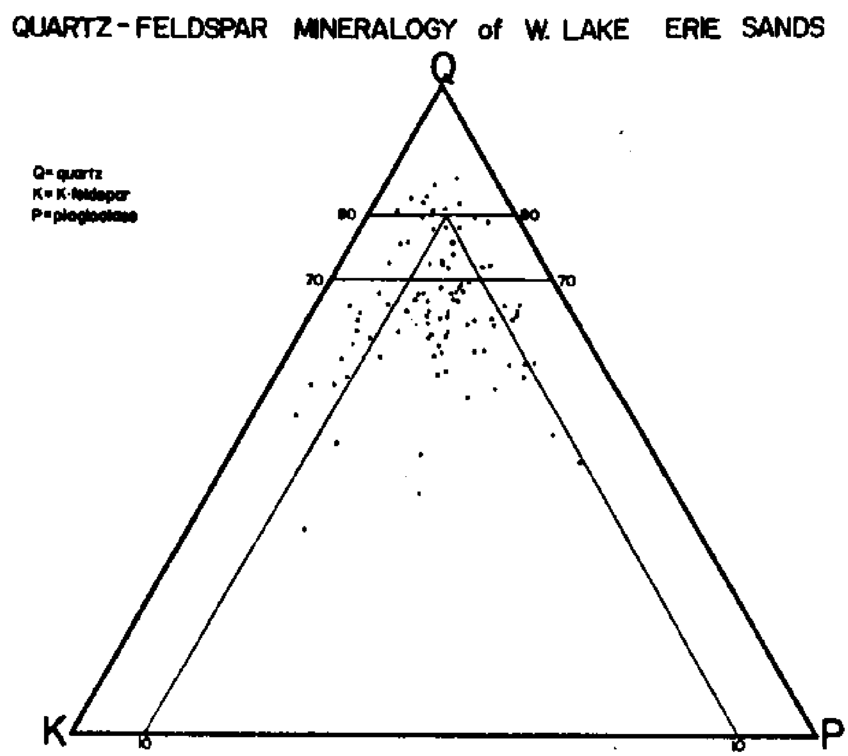

Figure 5. Trivariate plot of the mineralogy of 94 of the samples from the study area.

requiring some beneficiation may be a possibility. Unfortunately, the distribution of the sands by mineralogy is nearly random and no pattern was discernible (Figure 7). If these sands were to be utilized by the glass industry, they would require substantial beneficiation.

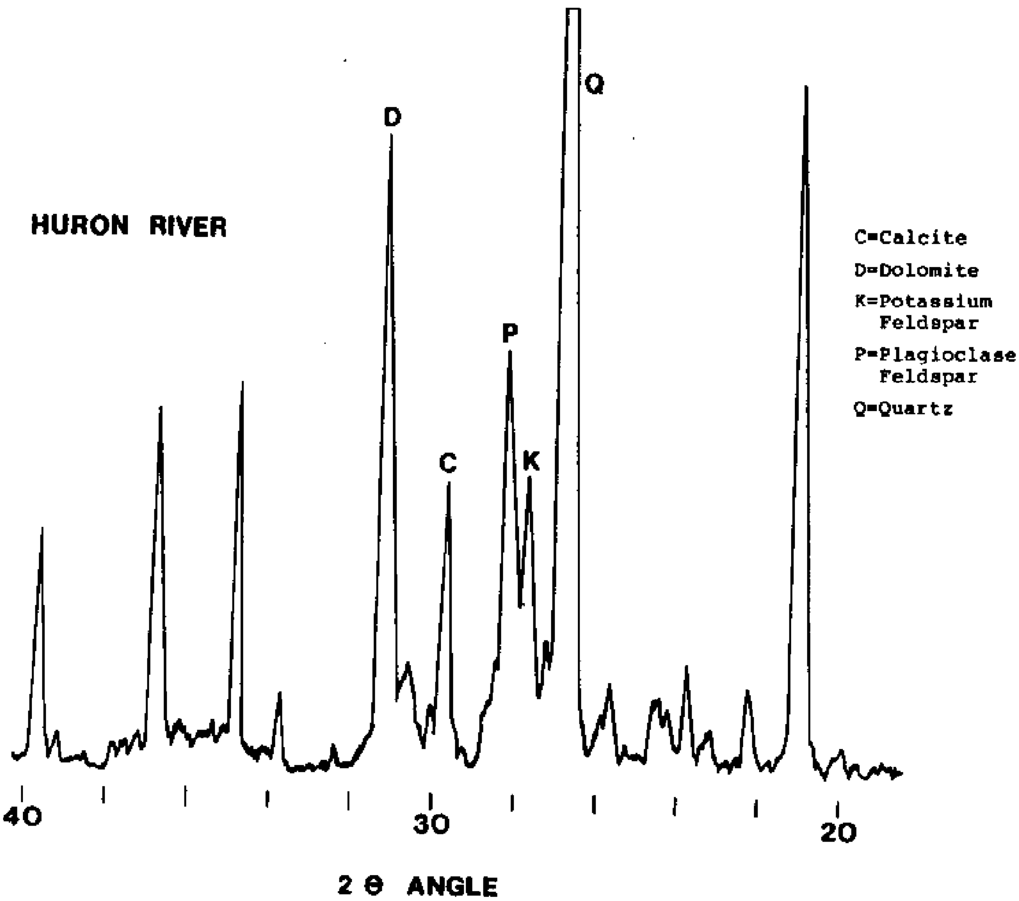

Figure 6. X-ray diffractrogram of sample collected near the Huron River.

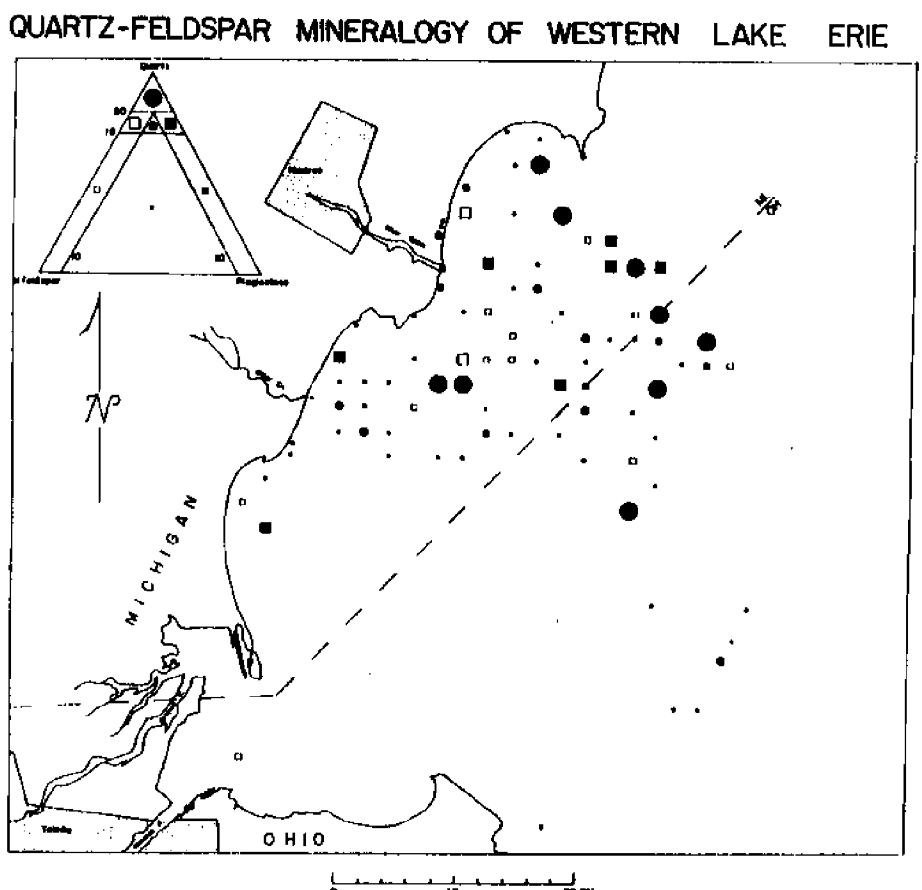

Figure 7. Map showing the distribution of mineralogy in the study area. Some additional samples are also plotted.

Thickness of Sand Deposit

Due to the reduced budget made available to us during the investigation, it was not possible to conduct primary research concerning the maximum thickness of the sand. However, given the existing data and the geological history for the region, it is possible to place some rather speculative constraints on the sand thickness. Work by the Ohio Geological Survey in areas adjacent to the study area indicated sand thicknesses of as much as six feet (Fuller, 1981). This may well be a regional thickness maximum that can be applied to the study area as well, but there are at least two reasons that still allow the speculation that the total thickness might exceed this value. For one, the level of Lake Erie was considerably lower approximately 4,000 to 12,000 years ago (Herdendorf and Braidech, 1972, and Forsythe, 1973). During those times, the River Raisin, Otter Creek and perhaps several other streams in the area, may have incised channels into what was previously, and what is now the lake bottom. These channels may now be mostly filled with coarse river-derived sediment. The thickness of such a deposit might be considerably more than six feet. The offshore sand areas may be bodies of sand similar in origin to that of the Oak Openings area which has a maximum thickness of 30 feet (Grube, 1980). Most likely, the offshore sand deposits would not be as thick as the Oak Openings sand even if their origins were similar, due to the limited areal extent of the offshore sands.

CONCLUSIONS

Although little firm data on the thickness of the sand-rich areas is available, there are several other conclusions which can be stated:

1. There are several areas and linear trends within the study area which are enriched in sand.

2. The sand in these sand-rich areas is of suitable coarseness for beach nourishment.

3. The mineralogical composition of the sand indicates that substantial beneficiation would be required to produce a glass-grade sand.

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APPENDIX

GRAIN SIZE ANALYSIS

SAMPLE	SAND (%)	SILT (%)	CLAY (%)	SAMPLE	SAND (%)	SILT (%)	CLAY (%)
17- 1	43.91	23.25	32.84	1- 8	29.72	52.82	17.46
18- 1	28.02	25.01	46.97	2- 8	6.74	67.81	25.45
19- 1	23.57	26.06	51.37	3- 8	2.95	63.93	33.12
20- 1	10.58	28.85	60.57	4- 8	2.09	56.93	40.99
21- 1	19.92	26.21	53.87	5- 8	2.29	96.19	1.52
17- 2	82.94	3.88	13.18	10- 8	11.05	37.22	51.73
18- 2	65.18	9.86	24.96	1- 9	17.22	58.40	24.38
19- 2	89.95	2.22	7.83	2- 9	22.19	51.27	26.55
20- 2	77.71	6.15	16.13	3- 9	1.09	59.22	39.69
21- 2	91.48	2.36	6.16	4- 9	7.58	53.26	39.16
17- 3	23.09	26.20	50.71	5- 9	1.49	44.55	53.97
18- 3	4.12	30.25	65.63	10- 9	8.44	44.57	46.99
19- 3	2.22	28.61	69.17	1-10	81.25	11.99	6.76
20- 3	8.90	29.42	61.68	2-10	16.16	62.91	20.93
21- 3	65.16	12.40	22.24	3-10	1.68	58.16	40.17
22- 3	59.16	12.98	27.86	4-10	0.95	51.67	47.39
17- 4	2.23	32.64	65.13	5-10	1.13	48.11	50.76
18- 4	2.70	33.66	63.64	6-10	3.04	52.17	44.78
19- 4	6.12	34.73	59.15	10-10	28.58	25.08	46.34
20- 4	32.28	21.32	46.41	11-10	1.86	42.37	55.77
21- 4	77.67	6.98	15.35	12-10	43.59	22.42	33.99
22- 4	81.24	7.79	10.97	15-10	19.42	38.01	42.57
23- 4	34.15	21.10	44.75	2-11	94.00	2.63	3.37
17- 5	0.67	31.74	67.59	3-11	14.26	67.15	18.59
18- 5	0.81	28.78	70.41	4-11	7.53	67.79	24.68
19- 5	10.62	29.86	59.52	5-11	1.28	47.52	51.20
20- 5	71.70	9.92	18.38	6-11	3.67	51.85	44.48
21- 5	74.59	8.14	17.28	10-11	66.66	16.47	16.87
22- 5	75.77	8.87	15.36	11-11	13.17	39.59	47.24
23- 5	50.06	16.34	33.60	16-11	63.22	17.67	19.11
24- 5	2.05	34.17	63.78	18-11	28.26	40.03	31.71
17- 6	0.80	30.68	68.52	3-12	99.81	0.04	0.15
18- 6	28.06	23.77	48.17	4-12	60.42	27.94	11.64
19- 6	17.29	9.47	19.24	5-12	22.88	53.96	23.16
20- 6	74.37	5.51	20.13	6-12	70.76	9.60	19.63
21- 6	39.57	18.86	41.57	7-12	96.83	1.24	1.93
22- 6	80.36	5.78	13.86	8-12	71.63	5.40	22.97
23- 6	46.90	18.15	34.96	9-12	81.21	5.91	12.88
24- 6	4.78	39.20	56.02	10-12	81.70	6.77	11.53
25- 6	55.40	14.69	29.91	11-12	9.54	33.81	56.65

APPENDIX, continued

GRAIN SIZE ANALYSIS

SAMPLE	SAND (%)	SILT (%)	CLAY (%)	SAMPLE	SAND (%)	SILT (%)	CLAY (%)
12-12	96.00	1.88	2.12	19-14	65.71	10.72	23.57
13-12	77.05	6.34	16.61	21-14	48.73	19.29	31.98
14-12	27.38	26.61	46.01	22-14	30.02	28.65	41.34
15-12	76.37	8.74	14.89	5-15	97.77	0.74	1.48
17-12	90.31	4.49	5.20	6-15	73.16	15.87	10.97
18-12	98.68	1.40	0.92	7-15	65.83	13.17	20.99
19-12	72.19	9.70	18.11	8-15	46.62	20.83	32.54
20-12	99.82	0.05	0.13	9-15	52.27	20.89	26.84
4-13	51.60	40.61	7.80	10-15	59.51	17.14	23.35
5-13	60.97	25.30	13.73	11-15	57.92	14.72	27.35
6-13	97.24	0.86	1.90	12-12	63.19	14.01	22.81
7-13	95.39	1.97	2.64	13-15	74.59	9.59	15.87
8-13	73.77	8.46	17.77	14-15	84.78	4.02	11.20
9-13	48.08	20.28	31.64	15-15	79.87	8.07	12.06
10-13	68.06	10.53	21.42	16-15	70.01	6.99	23.00
11-13	84.57	5.66	9.77	17-15	46.93	18.95	34.12
12-13	85.73	4.40	9.87	18-15	47.37	20.01	32.62
13-13	71.87	8.00	20.13	19-15	52.58	17.56	29.87
14-13	94.19	0.49	5.32	20-15	70.98	10.19	18.83
15-13	56.66	14.78	28.56	21-15	45.03	25.12	29.85
16-13	79.54	6.97	13.48	5-16	97.81	0.82	1.32
17-13	85.70	4.65	9.66	6-16	75.21	16.00	8.79
18-13	84.54	6.37	9.09	7-16	93.72	2.14	4.14
19-13	88.98	3.03	7.99	8-16	97.15	0.42	2.43
20-13	74.11	9.08	16.82	9-16	52.09	32.21	15.70
21-13	56.38	20.65	22.97	10-16	77.03	9.08	13.88
22-13	94.53	1.51	3.96	11-16	87.61	4.70	7.69
4-14	97.27	0.57	2.16	12-16	80.85	8.64	10.51
5-14	96.15	0.99	2.86	13-16	76.25	9.77	13.98
6-14	96.07	1.23	2.70	14-16	72.34	9.36	18.30
7-14	69.69	14.84	15.47	15-16	80.85	8.02	11.12
8-14	84.59	4.31	11.11	16-16	83.24	6.79	9.96
9-14	33.87	27.31	38.81	17-16	79.41	7.67	12.92
10-14	47.47	19.92	32.61	18-16	92.07	2.27	5.66
11-14	76.75	9.99	13.26	19-16	89.97	3.63	6.40
12-14	69.83	13.50	16.67	20-16	58.25	13.21	28.54
15-14	88.39	4.25	7.36	21-16	62.20	18.42	19.38
16-14	59.60	21.12	19.29	9-17	95.31	1.10	3.59
17-14	76.72	7.97	15.31	10-17	97.64	0.61	1.76
18-14	47.72	20.34	31.94	11-17	73.05	13.17	13.77

GRAIN SIZE ANALYSIS

SAMPLE	SAND (%)	SILT (%)	CLAY (%)	SAMPLE	SAND (%)	SILT (%)	CLAY (%)
12-17	76.99	10.80	12.21	12-21	41.22	59.46	0.32
13-17	21.46	54.08	24.46	13-21	55.55	24.96	19.49
14-17	16.26	41.15	42.59	14-21	11.44	51.75	36.81
15-17	92.12	2.69	5.19	15-21	77.02	10.59	12.39
16-17	77.14	7.54	15.31	16-21	98.30	0.01	1.70
17-17	81.83	5.87	12.30	17-21	90.56	3.09	6.35
18-17	78.45	6.03	15.52	10-22	42.01	45.66	12.33
19-17	29.08	23.18	47.75	11-22	54.77	27.49	17.74
20-17	71.13	11.29	17.58	12-22	44.17	48.00	7.83
9-18	92.32	5.80	1.88	13-22	44.53	29.21	26.27
10-18	79.40	12.02	8.58	14-22	53.01	25.11	21.88
11-18	80.29	10.63	9.08	15-22	61.31	20.72	17.97
12-18	33.16	28.03	38.82	16-22	15.86	35.21	48.93
13-18	21.58	39.59	38.83	10-23	42.91	39.96	17.13
14-18	80.48	10.59	8.93	11-23	56.25	27.20	16.55
16-18	50.36	19.02	30.63	12-23	17.37	51.21	31.41
17-18	42.46	35.00	22.54	13-23	98.98	0.01	1.01
18-18	87.82	4.14	8.03	14-23	7.87	60.14	32.01
19-18	72.44	12.12	15.44	11-24	73.24	14.53	12.23
9-19	84.44	5.31	10.25	12-24	80.69	11.31	8.00
10-19	55.59	33.52	10.90	13-24	44.03	37.71	18.26
11-19	40.23	38.34	21.43	14-24	27.82	45.53	26.65
12-19	83.40	7.27	9.32	12-25	92.96	3.93	3.12
13-19	92.83	2.21	4.96	13-25	79.60	11.40	9.00
14-19	53.83	21.53	24.63				
15-19	12.12	38.96	48.92				
16-19	5.72	35.68	58.61				
17-19	77.74	6.59	15.67				
18-19	17.13	32.34	50.52				
10-20	97.68	0.70	1.62				
11-20	95.39	1.86	2.75				
12-20	72.62	12.75	14.63				
13-20	92.92	2.78	4.29				
14-20	61.32	21.38	17.30				
15-20	16.26	44.29	39.45				
16-20	93.36	1.21	2.43				
17-20	92.06	2.95	4.99				
18-20	55.85	17.12	27.04				
10-21	76.46	14.74	8.80				
11-21	36.00	43.36	20.64				