CHAPTER 6

SOURCE MATERIALS FOR LAKE MICHIGAN BEACHES

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The extensive wave erosion which has occurred in many parts of the Lake Michigan shoreline since 1943 has centered interest on the materials composing the bluffs above the water line and on the amount and grain size of beach sediments yielded by wave erosion of these bluffs. The present study grew out of a preliminary mapping of the landform types and shore materials of the Lake Michigan basin carried out in 1952-53 for the Beach Erosion Board of the United States Army Corps of Engineers. The report prepared for the Beach Erosion Board summarized the geology of the Lake Michigan shoreline. Types of bedrock were indicated not only where such rocks form cliffs or reefs above water level but also beneath the unconsolidated materials which form three-quarters of the actual shoreline. Such unconsolidated materials were also mapped as to type and present form, and on these bases the shoreline was divided into physiographic units. These physiographic units and materials will be evaluated with respect to the total proportion of each type along the shoreline and the sediments yielded to the beach zone by wave erosion.

COMPLEXITY OF LAKE MICHIGAN SHORE MATERIALS

Bedrock forms about twenty-five per cent of the Lake Michigan shoreline, almost entirely in the northern third of the lake basin. Although the Lake Michigan basin and Green Bay lowland are eroded mainly along the outcrop of shale formations, the latter are generally covered by unconsolidated deposits, and rocks exposed along the shore consist almost wholly of dolomites of Ordovician, Silurian, Devonian, and Mississippian geologic age. Although these dolomites differ considerably in thickness of individual beds and amount of interbedded shale, they all retreat but slowly under wave attack and yield coarse slabby gravel or large stone blocks which effectively resist the waves. Such bedrock forms cliffs or reefs along the east shore of Door Peninsula north of Jacksonport and the western coast of the same peninsula, most of the shores of the Stonington and Garden Peninsulas north of Green Bay, considerable stretches of the north shore of the lake between Manistique and St. Ignace, much of the shore from Mackinaw City westward to Waugoshance Point, and the south shore of Little Traverse Bay. Other scattered exposures of bedrock include reefs at Sheboygan, Wind Point north of Racine, and Fifty-first and Seventy-ninth Streets in Chicago. No exposures are known to occur on the east coast between Chicago and Grand Traverse Bay, but reefs are present near Norwood and Charlevoix farther north.

Three-fourths of the Lake Michigan shoreline consists of unconsolidated deposits resting on and concealing the bedrock. Such deposits belong to three groups: those of glacial origin, those of lacustrine origin deposited when the lake waters stood at higher levels, and sands dropped by wind action along both the present lake shore and the shorelines of former higher stages of the lake.

Surface glacial deposits belong to the Cary and Valders-Port Huron substages of the last, or Wisconsin, glacial stage. Deposits of the three pre-Wisconsin glacial stages may and probably do underlie the Wisconsin, but such older glacial materials have not yet been positively identified along the present shoreline. During the Wisconsin glacial stage, glacial lobes from eastern Canada advanced down the Lake Michigan and Green Bay lowlands. Along the Door Peninsula, a dolomite ridge, these two opposing glacial lobes merged. Unstratified glacial till and washed deposits of sand and gravel were dropped by these glaciers as, through melting, they shrank back through the Lake Michigan and Green Bay lowlands to some position north of the Lake Michigan basin. While receding, they impounded a glacial lake which stood sixty feet above present Lake Michigan in the Chicago area. Later the same two glacial lobes readvanced as far as Fond du Lac south of Green Bay, and in the Lake Michigan basin as far as Milwaukee and Muskegon. These deposits mark the Valders-Port Huron glacial substage and consist also of glacial till, sand, and gravel. These glacial lobes also receded or melted back toward their source region northeast of the Great Lakes.

As the glaciers last receded, water was impounded between the shrinking ice front and the glacial drift deposits forming the margins of the Lake Michigan basin. These lake waters like the earlier pre-Valders lake overflowed first southwest of Chicago to the Illinois River. During and following the glacial episode, the region northeast of the Great Lakes was lower than now, and the waters of the post-glacial lakes submerged extensive areas in the northern part of the Lake Michigan basin. At an earlier lake stage, the Algonquin, the lake waters stood 220 feet higher than Lake Michigan in the Straits of Mackinac area, and at a later lake stage, the Nipissing, more than 50 feet higher in the same area. Deposits made in these former lakes are extensive in the northern part of the Lake Michigan basin area, and consist of sand and gravel where the water was shallow, clay and silt in deeper off-shore areas.

Sand dunes line long stretches of the present shoreline and are also associated with the sandy plains and shores of the higher lake stages. Such dune areas are extensive along the east shores of Lake Michigan from Gary northward to Sleeping Bear Point and at a few places on the north shore of the basin. Sand dunes occur at very few places along the west shore of Lake Michigan and Green Bay. Their absence on the west and presence on the east of the lake basin is attributed to the fact that strongest and driest winds in this region commonly blow from the west.

PHYSIOGRAPHIC UNITS OF THE LAKE MICHIGAN SHORE

Physiographic units of the Lake Michigan shore have been established on the basis, first, of shore materials and, second, of coastal landform types. Shore materials consist of the following:

Table 1. Materials Composing Lake Michigan Shores Above Beach Zone.

Glacial till — clayey
Glacial till — sandy
Sand and gravel — either glacial or lacustrine
Gravel -- either glacial or lacustrine
Dune sand — eolian
Silt and clay — lacustrine
Bedrock

Glacial till is an unstratified glacial deposit consisting of boulders, gravel, sand, and grit distributed through a matrix of fine ground-up rock. Where the matrix is sticky when damp, the glacial till is described as clayey. Where the matrix is sandy and has less coherence when damp, the till is classified as sandy. Stratified sand and gravel deposits may be of either glacial or lacustrine origin. Although the two may be readily distinguished by such properties as their bedding, a distinction between them in the present study serves no purpose. Gravel with most particles above four millimeters in size may also be either glacial or lacustrine in origin. Dune sand is remarkable for its very large proportion of particles between one millimeter and one-fourth millimeter in size. Silt and clay deposits are thinly stratified and represent the deeper water sediments of the lake at its former higher stages.

The landform types above the beach zone may be classified as follows:

Table 2. Landform Types Of Lake Michigan Shores, Other Than Beaches.

High bluff composed of (clayey till
(sandy till
(sand and gravel
(gravel
(dune sand
(silt and clay
Low bluff composed of same six materials
Low plain composed of (sand and gravel
(gravel
(silt and clay
Dune, no bluff
Steep cliff composed of bedrock
Low rock reefs in water, below inland plain composed of sand and gravel
Sand bar or spit, associated with beach

Where the bluff is not more than twenty feet high, it is classed as Low Bluff; if higher than twenty feet, as High Bluff. Bluffs, both the high and low, are associated with wave erosion and recession of the shore. Low Plain, on the contrary, generally marks areas that are stable or aggrading. Sand bars or spits are dominant elements of the shore at a few places where they have closed off lagoons or inland lakes. They mark aggradation of the shore.

Although the above table lists nineteen physiographic types on the basis of form and material, some are too limited in extent to appear on a small scale map of the lake basin. However, thirteen of the types occur frequently and comprise extensive proportions of the shoreline as listed in Table 4 of this report. On the basis of these thirteen types of physiographic units, 196 shoreline units were recognized and indicated on a map of scale 1:500,000 for the Beach Erosion Board. By using appropriate combinations of symbols, it was possible to indicate on the map both the coastal landform type and the nature of the underlying materials for each of these 196 units.

SEDIMENTS YIELDED BY SHORE EROSION OF THE SEVEN TYPES OF SHORELINE MATERIALS

Bedrock cliffs commonly shed coarse rock fragments varying from flat platy shingle fragments a few inches in size to massive blocks several feet in dimension. All these materials remain on the beach and effectively protect the cliffs behind from rapid erosion inasmuch as the wave energy is largely expended in chewing these rock fragments. Where gravel forms the shoreline practically all of the gravel remains on the beach where it also effectively retards wave erosion. No analyses were made of the large fragment sizes composing such gravel and bedrock rubble.

The other five types of shore materials form extensive portions of the shoreline and in many places are undergoing erosion. Grain size analyses were run on representative samples from these five types of materials in order to determine the proportions likely to remain in the shore zone and thus contribute to the beach. A summary of these grain size analyses is given in Table 3 below:

Table 3. Sediments Yielded by Wave Erosion Of Shore Materials:

MATERIAL	NO. OF SAMPLES	SIZE, IN MM. ABOVE 4	4-1	1-¼	¼-1/16	BELOW 1/16
CLAYEY TILL	5	2.4%	2.9	8.7	11.4	74.7
SANDY TILL	3	23.4	7.8	16.3	17.7	34.6
SAND & GRAVEL	11	0.9	2.1	77.8	17.2	2.0
DUNE SAND	5	0.0	0.0	73.3	25.1	1.7
CLAY & SILT	2	0.0	0.2	0.6	2.8	96.5

The results summarized above indicate that sandy till contains a large proportion of sediment above four millimeters in size. Clayey till, on the contrary, consists predominantly of matrix material below one-sixteenth millimeter. Both sand and gravel and dune sand consist predominantly of particles between one millimeter and one-fourth millimeter with most of the remainder between one-fourth and one-sixteenth

millimeter. Clay and silt are composed almost entirely of particles of less than one-sixteenth millimeter in size. During disintegration and sorting by wave erosion, most of the clay and silt and three-fourths of the clayey till may be expected to be removed by the lake waters in suspension. Sand and gravel and dune sand, although relatively fine, consist mainly of particles that will remain on the beach.

PROPORTION OF SHORELINE FORMED BY EACH OF THE THIRTEEN PHYSIOGRAPHIC UNIT TYPES

The shoreline of Lake Michigan and Green Bay is approximately 1,216 miles in length. The proportion of this shore composed of each of the thirteen principal types of physiographic units is indicated in the following table:

Table 4. Proportion Of Lake Michigan Shoreline Formed By Each Principal Type Of Physiographic Unit:

	TOTAL LENGTH, MILES	% OF TOTAL
HIGH BLUFF OF CLAYEY TILL	193.0	15.9
HIGH BLUFF OF SANDY TILL	16.5	1.4
HIGH BLUFF OF SAND AND GRAVEL	43.1	3.5
HIGH BLUFF OF CLAY AND SILT	11.8	1.0
HIGH BLUFF OF DUNE SAND	127.5	10.5
LOW BLUFF OF CLAYEY TILL	18.1	1.5
LOW BLUFF OF SAND AND GRAVEL	162.0	13.3
LOW BLUFF OF CLAY AND SILT	8.6	0.7
LOW PLAIN OF SAND AND GRAVEL	258.7	21.3
DUNES, NO BLUFF	61.2	5.0
BAR OR SPIT OF SAND OR GRAVEL	6.3	0.5
CLIFF OF BEDROCK	257.1	21.8
LOW BEDROCK REEFS IN FRONT OF SANDY PLAIN	52.2	4.3
	1,216.1 MILES	100.7 %

It will be noted that about 32 per cent of the shoreline consists of high bluffs, mainly of clayey till and dune sand. More than 15 per cent

of the shore is low bluffs, mainly of sand and gravel marking ancient lake bottom. More than 21 per cent of the shore is a low plain of sand and gravel. This landform type is most extensive along the west shore of Green Bay and in the Chicago area. Dunes without a bluff and thus indicating more or less stable shore conditions form only 5 per cent of the shoreline. Bedrock cliffs and low reefs are present along more than 26 per cent of the shoreline.

SIGNIFICANCE OF BEACH MATERIALS YIELDED BY EROSION OF BLUFFS

The grain size distribution of the unconsolidated materials forming three-fourths of the Lake Michigan shoreline is significant with respect to the proportion of such material likely to remain in the beach zone. Material remaining on the beach builds up the latter and retards erosion of the bluffs behind. Particles less than one-sixteenth millimeter in diameter are suspended by wave agitation and float out into deeper portions of the lake where they settle. Particles within this grain size, therefore, contribute almost nothing to the beach. Only materials greater than one-sixteenth millimeter will stay on the beach to protect the shore. Table 3 indicates what the principal types of unconsolidated shore materials are likely to contribute to the beach under wave erosion and sorting in the beach zone.

In November, 1952, and September, 1953, 139 shore localities along Lake Michigan shores were visited; and at most, samples of shore materials were collected. At 90 of the 139 localities, shore erosion appeared to be in progress; and in a number of cases, rapid retreat of the bluffs was indicated. 34 localities appeared to be stable; and at 14 localities, the shore seemed to be aggrading. At those many points where erosion is occurring under present conditions, protection of the shore from further destruction must be based on an intelligent utilization of beach materials furnished by the waves themselves in their attack on the shore.