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GEOPHYSICAL EVIDENCE THAT THE HAEGER TILL MEMBER UNDERLIES SOUTHERN WESTERN LAKE MICHIGAN

by

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ABSTRACT

While developing methodology for underwater sand and gravel exploration (western Lake Michigan, 1976 to 1978), we collected evidence that a till unit which was not seen in previous geophysical investigations overlies the bedrock under the lake. Interpretation of the newly-detected till sheet was based upon data gathered by electrical resistivity and acoustic reflection profiling at Wind Point, north of Racine, Wisconsin. The till is postulated to be the Haeger, which crops out onshore in southern Wisconsin and northern Illinois. It is an older and more gravelly till than any previously reported under Lake Michigan.

INTRODUCTION

A major goal of the 1976 to 1978 Western Lake Michigan Sand and Gravel Assessment project sponsored by the University of Wisconsin Sea Grant Program was to test and apply promising geophysical methods for delineation of the lateral extent and thickness of possible offshore deposits of sand and gravel (Welkie, 1980). Six test sites along the western Lake Michigan shoreline were selected as promising for sand and gravel exploration based upon previous studies, or extrapolation of onshore geology to offshore shallow-water areas. Four geophysical methods (acoustic profiling, seismic refraction, electrical resistivity profiling, and resistivity sounding) were chosen on the basis of the following criteria: (1) previous successful application of the method; (2) applicability in shallow water where sand and gravel are likely to be exploited; (3) possibility of modification for rapid data acquisition and interpretation; and (4) ability to distinguish sand and gravel from other sediments. Methods were tested singly and in combination, and our interpretations were verified by obtaining samples at locations suggested by the geophysical data.

As a result, a more accurate assessment of offshore deposits was possible than by previous blind surficial sampling or coring programs, and interpretation of geologic structure was possible also at depths that could not be reached by sampling. Indeed, an estimate of sediment texture, compressional velocity, resistivity, and thickness could be obtained for geologic units between the lake floor and Paleozoic rock.

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As an auxiliary result of our investigations at a test site north of Racine at Wind Point, Wisconsin (fig. 1), a previously unreported till unit under the lake was inferred to overlie the Paleozoic rock. This interpretation was based on data collected by acoustic profiling followed by sampling, although the till unit itself could not be sampled because it did not crop out.

SUBSURFACE GEOLOGY AND GEOPHYSICS OF THE 1977 TEST SITE

Along the western shore of Lake Michigan, the Paleozoic rock (depth 0 to 100 m) is mostly reef and interreef dolomite of the Racine Formation, Niagaran Series, Silurian System (Alden, 1918). Exposures of dense reef rock, which contain a variety of invertebrate fossils, are known throughout the Silurian sequence and are present in Chicago, off Waukegan Harbor, and off Wind Point, (Alden, 1918).

Some of the major topographic relief on the Paleozoic rock surface was caused by preglacial stream erosion (Horberg, 1950). Ancient stream valleys were buried by glacial till of Wisconsin age (100,000 to 10,000 years B.P.) (Hough, 1958; Mickelson and others 1977a). Compressional velocity of about 1.7 km/s and electrical resistivity of about 100 ohm-metre of the tills are considerably lower than those of the bedrock (Woollard and Hanson, 1954). Therefore, we expected that the till-bedrock boundary would be definable on the basis of both seismic and resistivity methods.

Four major till units are exposed in a north to south sequence under the lake (fig. 1). These till units have been named under the lake by Lineback and others (1974), and numbered in bluff exposures by Mickelson and others (1977a). In their detailed study of till outcrops along the western shore of Lake Michigan, Mickelson and others (1977a) found that the major till units contained sub-units that were distinguishable because of lithology and interbeddded lake sediment. From oldest (south) to youngest (north) their names and corresponding numbers are the Wadsworth Till Member (2), Shorewood Till Member (3A), Manitowoc Till Member (3C), and Two Rivers Member.

A still older till unit, known as the Haeger, crops out 40 km to the west of the present lake shore in northern Illinois and in southern Wisconsin. By projection, the Haeger should underlie the others under the lake, but geophysical evidence for this has been missing so far. Mickelson and others (1977a) have divided one equivalent of the Haeger Member into subunits 1A and 1B (fig. 2). The 1A till is coarse and sandy, containing over 40 percent sand, pebbles, cobbles and boulders. The 1B till is gray, is sandy and silty, and contains fewer cobbles, pebbles and boulders. At an outcrop, the thickness of the 1B unit was measured to be 2 to 3 m; the 1A unit was thicker, but its thickness is not yet determined.

The next-younger overlying till unit, the Wadsworth of Illinois (2A, 2B, and 2C of Mickelson and others 1977a), which extends southward to beyond the present lake basin (fig. 1), is more fine grained than the Haeger. The 2A and 2B subunits are similar lithologically, gray and clayey, containing greater than 70 percent illite in the clay fraction and more dolomite than calcite in the carbonate fraction (Lineback and others 1974). Occasional lenses of granular outwash are enclosed in the till (State of Illinois, 1958). The maximum known thickness of the Wadsworth under the lake is 18 m, found in the southwest corner (Lineback and others 1974).

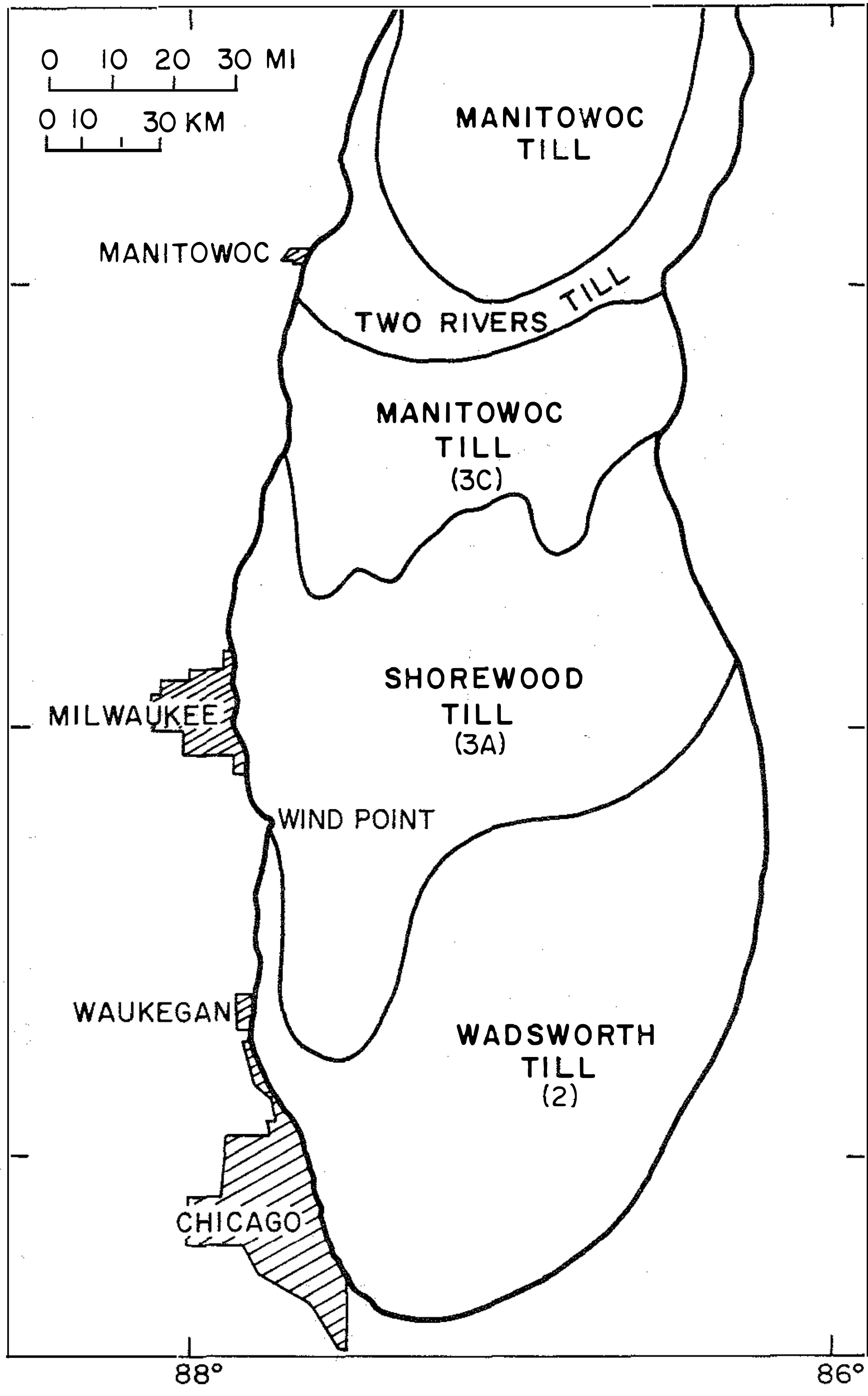


FIGURE 1.--Glacial tills underlying Lake Michigan. The location of the study site along the western shore north of Wind Point is indicated.

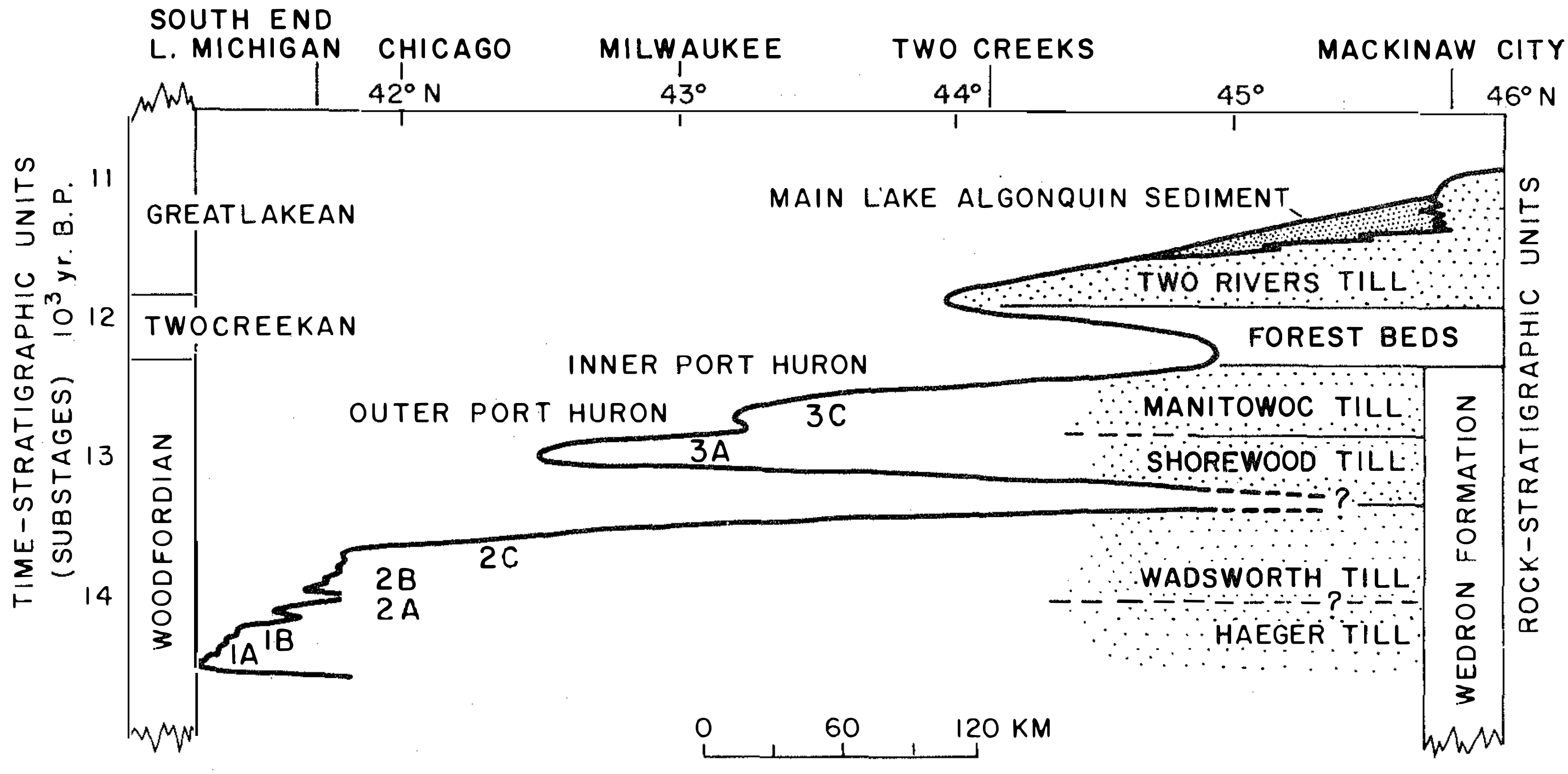


FIGURE 2.--Time-sequence, rockstratigraphic units, and extent of glacier ice in the Lake Michigan basin in Wisconsin time. The distances of advance are at the center of the lake and are somewhat less on the western shore. The numbered units are those used for till units found in the bluffs in Wisconsin by Mickelson and others (1977a). The terminology on the right is that used in Illinois for till units under the lake (Lineback and others 1974) except for the Two Rivers Member which has been formally named in Wisconsin.

Onshore and in the nearshore, the Shorewood Till member (3A) overlies the Wadsworth only as far south as Milwaukee, north of the study area; but it extends farther south under the center of the lake (fig. 1).

We expected that the units and subunits would be distinguishable geophysically by the nature of the interfaces between them. Three types of divisions between till units are possible. First, most of the units exposed onshore are separated physically from the others by a layer of lake sediment deposited during minor glacial retreats (D. Mickelson, oral communications). Second, gravel is commonly found on the top surfaces of till units (Flint, 1964). Finally, predecessors of the present lake are known to have receded after episodes of glaciation causing some till surfaces to be exposed to the air. Drying of the clay at the surface of the till should have occurred, and because the clay has low permeability, it should not quickly become saturated when covered again with water. The dry part of the till should provide yet another physical discontinuity (D. Mickelson, oral communication).

Because a difference in grain size, age, and history exists between the Wadsworth and the Haeger, some differences in seismic velocity, density, and resistivity are reasonable expectations. The fine-grained lake sediment, gravel, or dried clay that may exist between till units should provide reflective interfaces. A velocity contrast on the order of 1:2 between the Haeger and the Paleozoic rock could be expected.

SURFICIAL GEOLOGY OF WIND POINT

The offshore sediments north of Wind Point have not been examined previously in detail. An onshore surficial sediment map (fig. 3) (Alden, 1918) shows the locations of onshore sand, stratified clay, and gravel deposits that may extend into the offshore. North of Wind Point, onshore gravel deposits that have been mined intersect the shore. This sediment is thought to have been deposited along the shores of predecessors to the present lake (Alden, 1918).

METHODS

The instruments used in this study have been described in detail in a previous paper (Welkie and Meyer, 1982). A brief summary of methods follows.

The position of the boat was determined to within 5 m of its true position with a Motorola Miniranger II active radar system.

A Shipek sampler of 10 cubic centimeter capacity was used to obtain surficial samples. Locations of sample stations were selected from the acoustic profiles.

For acoustic profiling, the modified EDO Western Corporation Model 248A/TVG sonar transceiver used has been previously described (Lineback and others 1971; Nebrija, 1979). A streamlined depressor-body containing a transducer that transmitted pulses at 5 kHz was towed from the stern A-frame of the boat about 3 m below the surface and was decoupled from the vessel's pitch by elastic shock cords. A pulse length of 0.3 milliseconds (1 cycle) was used for greatest resolution. The maximum vertical resolution of the complete system is 0.5 milliseconds (determined by measurements from the records).

Electrical resistivity profiling was used in conjunction with acoustic reflection profiling (Nebrija, 1979). The Schlumberger configuration rather than the Wenner was used because the shorter separation of potential electrodes allows greater resolution along traverses (Bhattacharya and Patra, 1968; Dobrin, 1976). A surface-towed current electrode spacing (AB) of 120 m and potential-electrode spacing (MN) of 15 m were selected from the standard two-layer Schlumberger curves using the anticipated water depth and expected contrast in resistivity between the water and the sediments. The AB spacing used was approximately 10 times the water depth, and MN was 1/5 or less than the AB separation.

RESULTS

North of Wind Point, near Racine, the area where onshore gravel deposits appeared to extend offshore was examined by combining the techniques of acoustic and resistivity profiling and sampling (fig. 4).

The eastern-most acoustic profile measured perpendicular to the shore (C-D, figs. 5 and 6) shows humps 1 to 2 m high on the lake bottom that stop where a subsurface reflector begins to outcrop (fig. 6). Samples were not recoverable over the ridges, (sample stations 4 and 5, fig. 4), but hard clay was found on the sampling tool. Over the outcropping material, closer to shore, samples were also difficult to obtain (sample stations 1 to 3, fig. 4), but small amounts of sand were recovered. Because the sampling attempts suggested a hard bottom, erosion may be taking place here. Shore erosion rates are 3 m/yr at the northern part of Wind Point (Mickelson and others, 1977); therefore, offshore erosion is also likely here.

The material that outcrops close to shore is interpreted as dolomite because of its high resistivity (fig. 5). It is covered in places by sand which was probably derived from eroding onshore deposits.

The irregular-surface material that is truncated at the dolomite outcrop is probably till covered with gravel. The gravel possibly is a lag deposit resulting from removal of the fine-grained components of the lake sediment or the till. Clay was sampled here, so the gravel is probably thin or intermingled with the clay. A further indication that the gravel is thin or patchy is that acoustic penetration was achieved into the till. If the gravel was thick, penetration should not have been possible because most of the acoustic energy would have been returned as reflected energy. Subsurface reflectors indicate that there is layering within the till. Because three till units are expected here but at least five subsurface reflectors are seen, the till units appear to have been deposited in several episodes, as numbered by Mickelson and others (1977). By examining those places where the subsurface reflectors outcrop, connecting them between profiles, and projecting the trends to outcrops of known till units onshore, the subsurface reflectors can be identified and mapped (figs. 5 and 6).

Schneider and others (1977) have prepared a cross-section of the bluff stratigraphy along the shore to the north of Wind Point (from A to B, fig. 5). In the cross-section, a layer of lake sediment consisting mostly of silt and clay with some fine sand lies between till units 2A and 2B; one of the subsurface reflectors corresponds to this layer of lake sediment. Another of the subsurface reflectors can be mapped to where the 2B till outcrops onshore (b, fig. 5). All of the other reflectors can now be mapped by their spatial

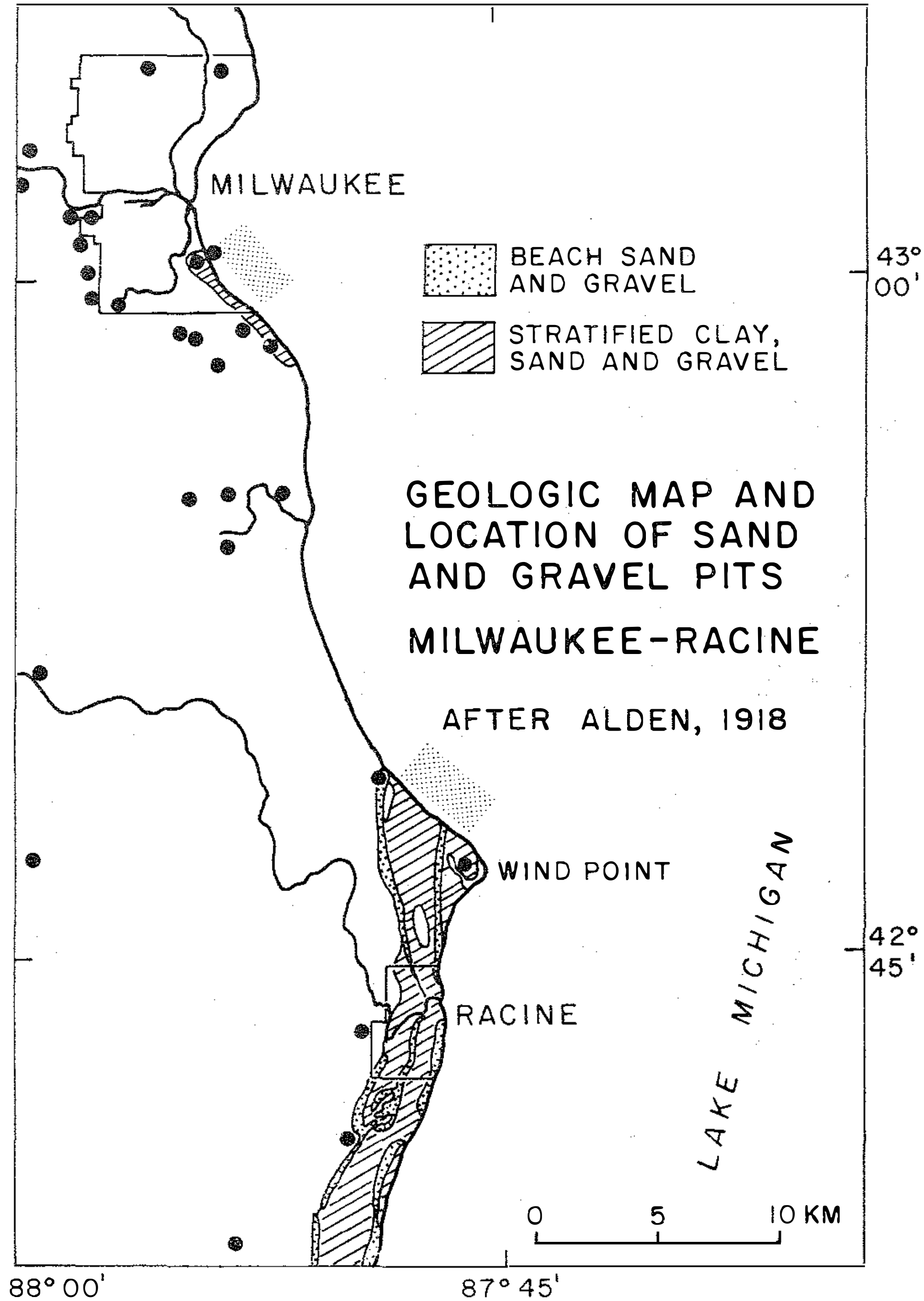


FIGURE 3.--Surficial sediment map in the vicinity of Milwaukee and Racine, Wisconsin, showing only the sandy and gravelly sediments nearshore. Locations of sand and gravel pits are indicated by black dots (Alden, 1918). The offshore areas examined in 1977 and 1978 are shaded. The southernmost area, north of Wind Point, is a subject of this paper.

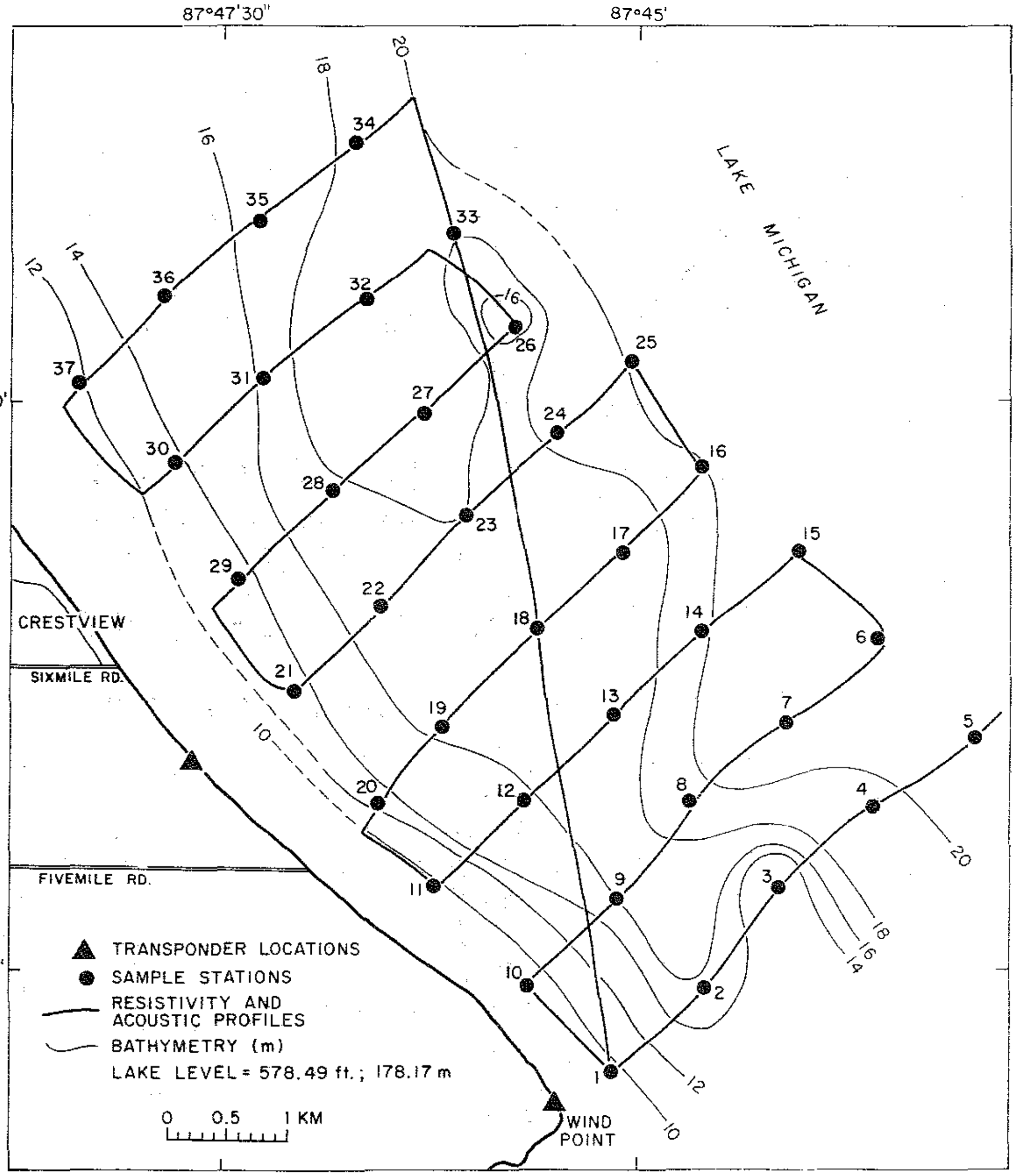


FIGURE 4.--Bathymetry based upon the 1977 acoustic profiles north of Wind Point. Sample station locations are also shown.

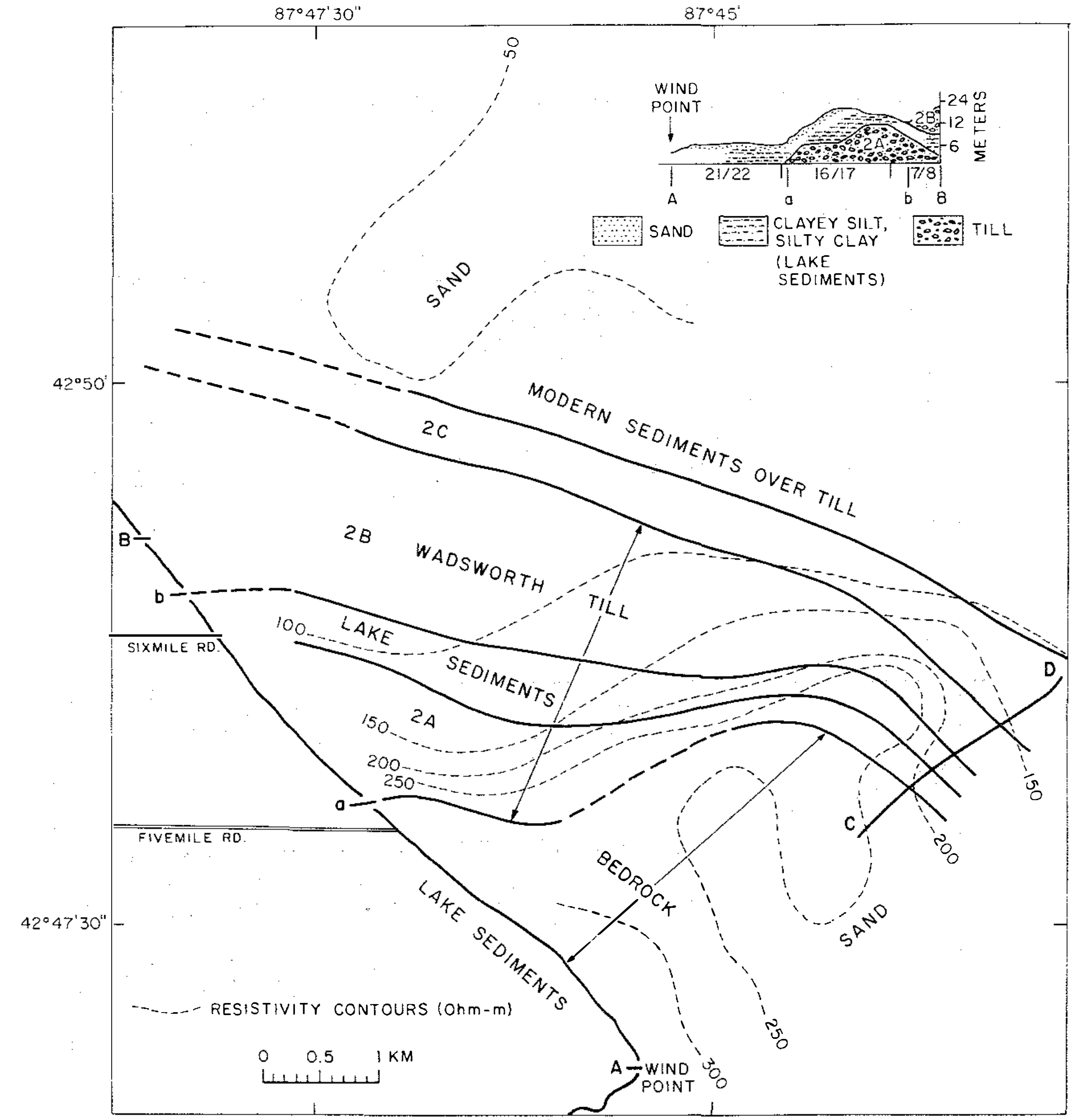
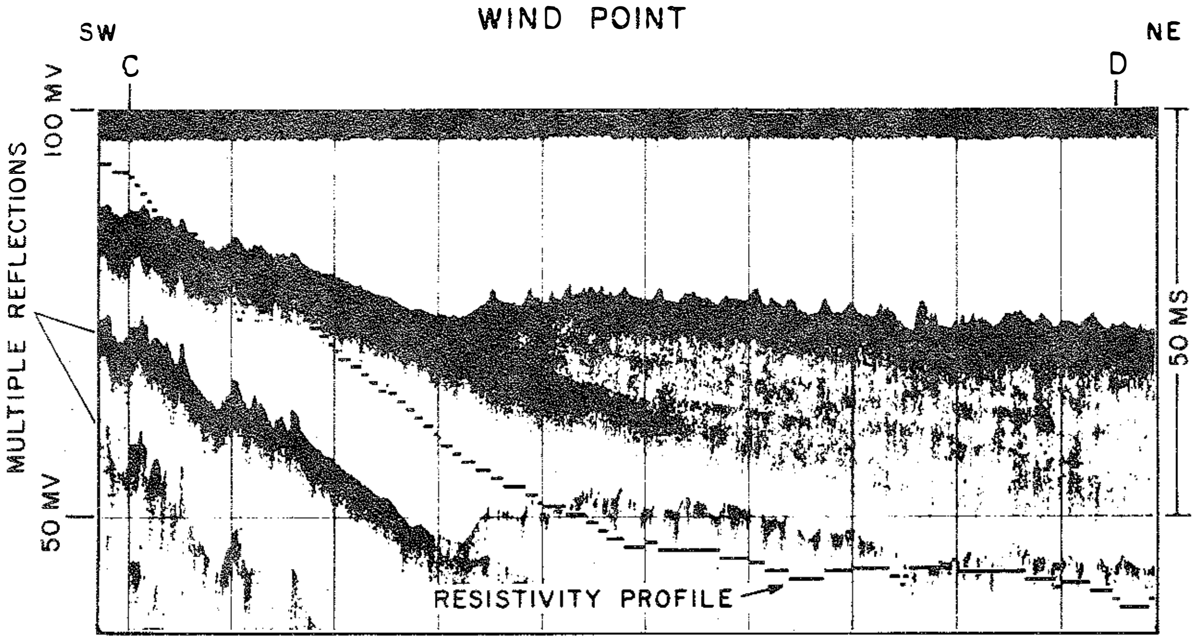


FIGURE 5.--Interpretation north of Wind Point. Because of erosion, till units are exposed on the lake floor and can be traced to shore, where they can be identified. A gravel lag overlies most of the area surveyed. High resistivity measured near Wind Point reflects the rock outcrop. Dotted lines are isoresistivity contours.



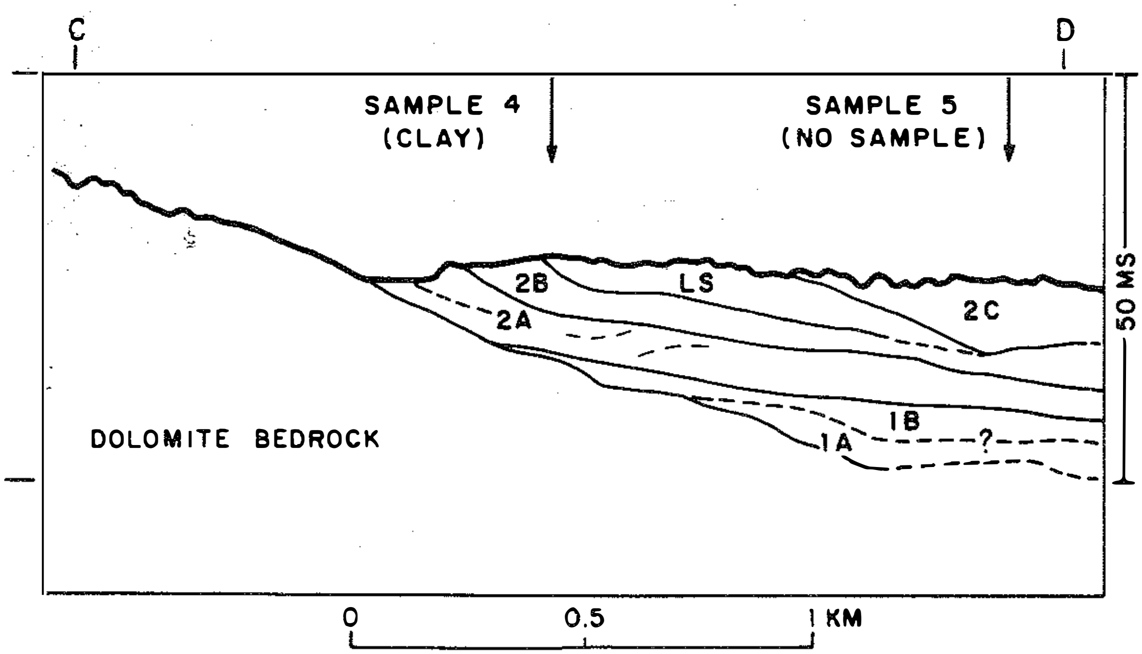


FIGURE 6.--Acoustic profile and interpretation along C-D of figure 5. The sub-units of till were identified by extrapolating to their outcrops in the nearshore bluffs except for till units 1A and 1B which do not outcrop, but lie roughly 7 m below the lake bottom at the location of sample 4.

relationships to the three reflectors that were tentatively identified. Thus, at least two other reflectors of acoustic energy lie under the Wadsworth Till Member (2A). These are most probably the two subunits of the Haeger Till Member. The Haeger Till Member does not outcrop on the lake bottom but is truncated at the dolomite outcrop (fig. 5). The layer of lake sediment pinches out about 3 km from shore (fig. 6).

The reconnaissance surficial sampling tool (Shipek) could not sample the till because the till did not outcrop. Vibratory coring should be able to provide positive identification of the till units. The Haeger Till Member, previously not sampled under the lake (Lineback and others 1974), can be cored most easily near the dolomite outcrop, where the overlying till units are thin. At its shallowest, the hypothesized Haeger lies 7 m below the lake bottom at a water depth of about 18 m.

Resistivity contours (fig. 5) indicate that the resistivity of the lake bottom is controlled by the shape of the Paleozoic rock surface, as expected, because the dolomite is much higher in resistivity than the till and is shallow. Near Wind Point, there is a small depression in the rock which is filled with sand. Sand was also sampled offshore northwest of Wind Point. Because mobile surficial sand at Waukegan has the same resistivity as the bottom water (Welkie and Meyer, 1982), sand at Wind Point probably also has a lower resistivity than the till and rock on which it lies. Another sand deposit at the tip of Wind Point could be responsible for the lower (than rock) resistivity values there.

The elevation of the rock where it outcrops on the lake floor is 160 m, consistent with the projected elevation of the rock surface predicted by Alden (1918).

SUMMARY

Offshore of Wind Point, erosion appears to be taking place. Identification of stratigraphic units exposed on the lake floor was possible by extrapolating to bluff deposits onshore. Two till layers underlying the Wadsworth Till Member were seen on the acoustic records. These layers may be two subunits of the Haeger Till Member. Coring would positively identify these units, and they may be cored most easily off Wind Point, where they lie only 7 m below the lake floor. North of Wind Point, the topography of the rock surface is manifested in the resistivity data because the rock is shallow and an order of magnitude higher in resistivity than the till.

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