Illinois State Geological Survey

Hydrogeology, Geology and Engineering Aspects of Surficial Materials on the Lake Michigan Shore in Illinois

ILLINOIS COASTAL ZONE MANAGEMENT DEVELOPMENT PROJECT

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GEOLOGIC, HYDROGEOLOGIC, AND ENGINEERING ASPECTS OF LAKE MICHIGAN SURFICIAL DEPOSITS

Paul B. DuMontelle, Keith L. Stoffel, and James J. Brossman

ABSTRACT

The basic characteristics that determine erosion susceptibility, foundation stability, weathering qualities, slump resistance, and drainage performance of the Illinois Lake Michigan shore bluffs were studied in detail.

Groundwater data (hydrologic data) were gathered from weather records, from piezometer installations at Lake Bluff, and from bluff-line seep studies along the entire shore. These indicate the presence of drainage problems at many places along the shore. Most, but not all, are related to above-average rainfall conditions.

Geologic data were derived from numerous bluff exposures and fourteen research boreholes in addition to records from earlier boreholes. From these, the stratigraphic sequence is described in detail along with sediment characteristics and clay mineralogy. These last values permit calculation of sediment loading and littoral drift budgets in the lake.

Foundation strengths, unconfined compressive strengths, moisture content, liquid limits, plasticity indices, shear strengths and wet and dry densities were measured on samples collected from 12 bluff outcrops and 14 boreholes. In general, low water content (<15%), high strength (>30 blows per foot) and high unconfined compressive strengths (>3 tons per square foot) contribute toward increased stability. Materials are unstable where water content is greater than 20%, strength less than 30 blows per foot and unconfined compressive strength less than 1.5 tons per square foot.

Slope failure is related to groundwater pore pressure which correlates directly to maximum annual groundwater levels but not directly to regional precipitation - annual fluctuation in pore pressure being partly dependent on the effects of vegetation.

Bluffs near Glencoe and Highland Park, which are relatively stable, have a low level of groundwater activity because the glacial till contains few discontinuous layers of silt and sand. Bluffs at Lake Forest and Lake Bluff consist of alternating tills and water-laid deposits that have a high level of groundwater activity and a comparable high recession rate.

INTRODUCTION

The hydrogeologic, geologic and engineering characteristics of materials that constitute the shore directly determine the natural stability and strength of the bluffs and beaches. Erosion rates, landslide and weathering phenomena, foundation stability, land drainage, distribution of vegetation and shore sediment resources are all dependent on these characteristics. Previous studies have investigated the sediment characteristics of the Zion Beach Ridge and Dune Plain (Fraser and Hester, 1974) and its sediment dynamics (Badal, 1975). Berg and Collinson (1975) examined bluff erosion, recession rates and volumetric losses of the bluff-lined part of the shore, whereas DuMontelle, Stoffel and Brossman (1975) studied the geology and earth material characteristics of the bluffs from the engineering viewpoint.

The present study is a continuation and expansion of the last study in that it incorporates the data gathered for it and combines them with a large number of new engineering determinations from 20 bluff sections and six additional boreholes extending from North Chicago southward to Winnetka (Figs. 1-3). In addition, new surficial geologic field mapping in Lake County by Keith L. Stoffel and Jean I. Larsen (1976) and in Cook County by Jean E. Bogner (1976) has been utilized to supplement engineering measurements.

Information about the duration and location of bluff groundwater seeps was used along with data gathered from two borehole piezometers at Lake Bluff to identify areas with potential drainage and stability problems.

The engineering data are summarized by cross sections and geologic columns. Appendix A records the engineering, sedimentologic and mineralogic properties of materials found in surface exposures and boreholes. Appendix B presents ten cross sections that summarize surface and subsurface conditions in ten areas ranging from Waukegan into Evanston. Three of the cross sections are essentially unchanged from the FY1975 report whereas all of the others are significantly revised or are entirely new.

ACKNOWLEDGEMENTS

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Fig. 1 - (Opposite) Map showing locations of the Lake Border moraines.

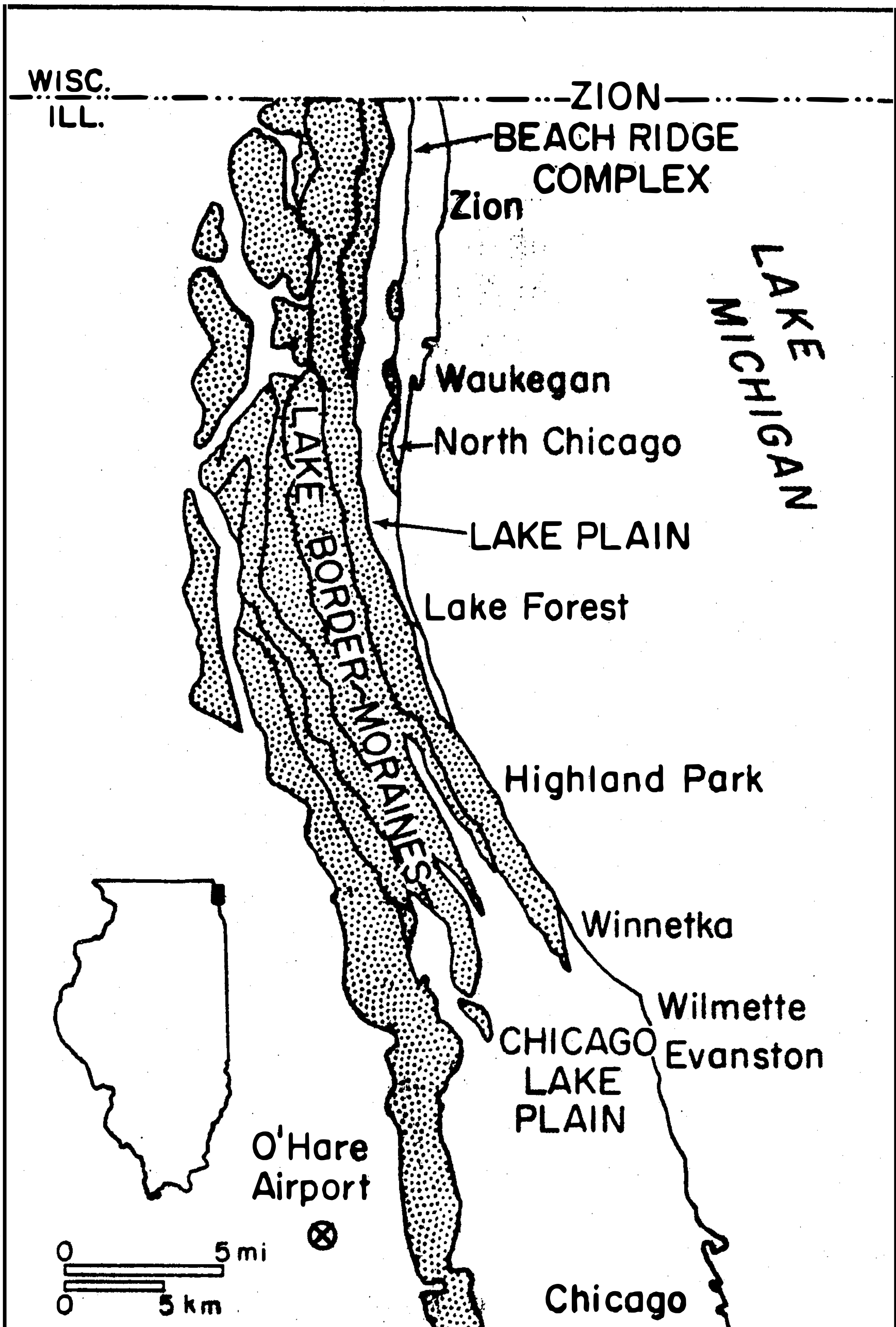
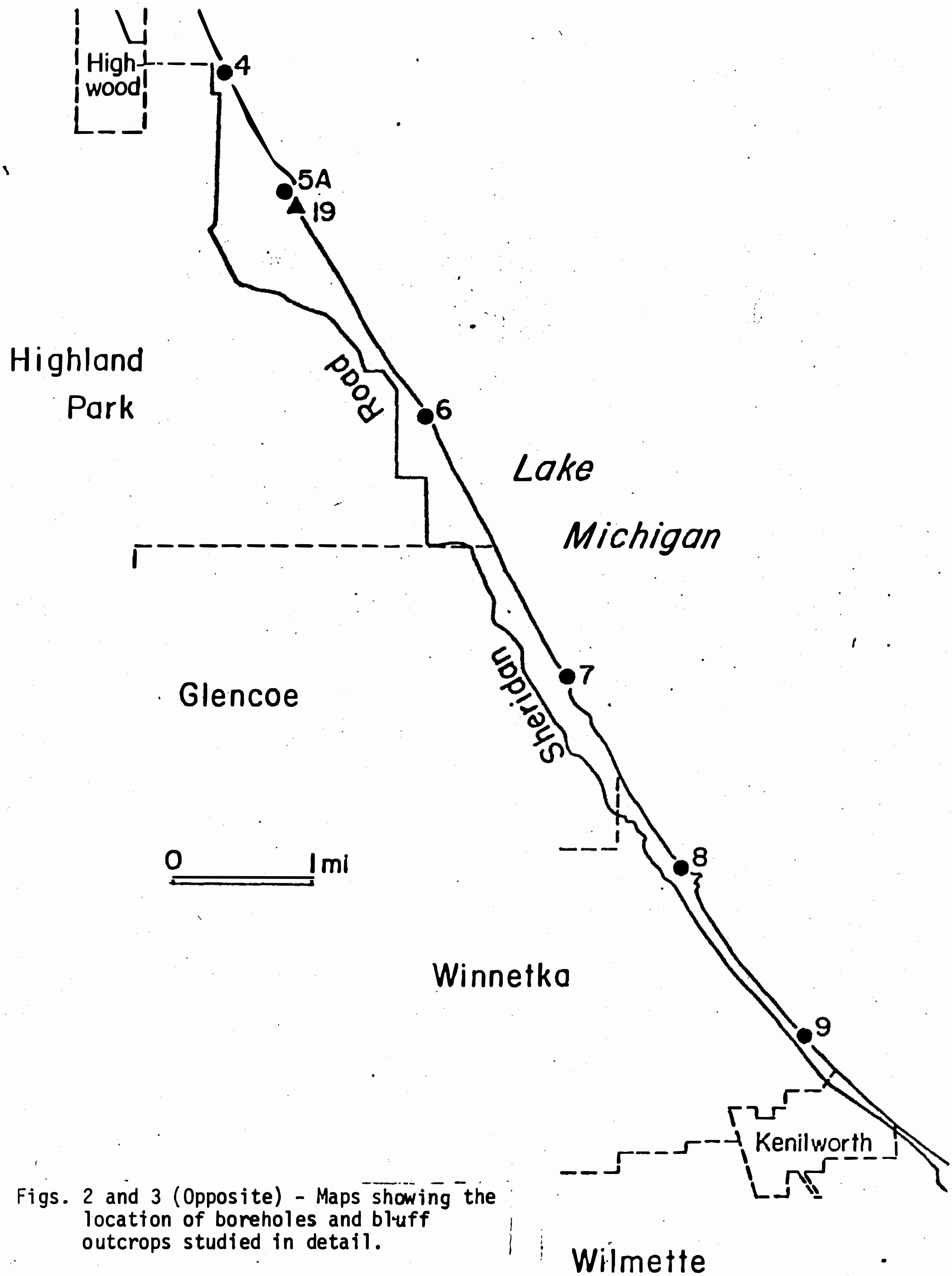
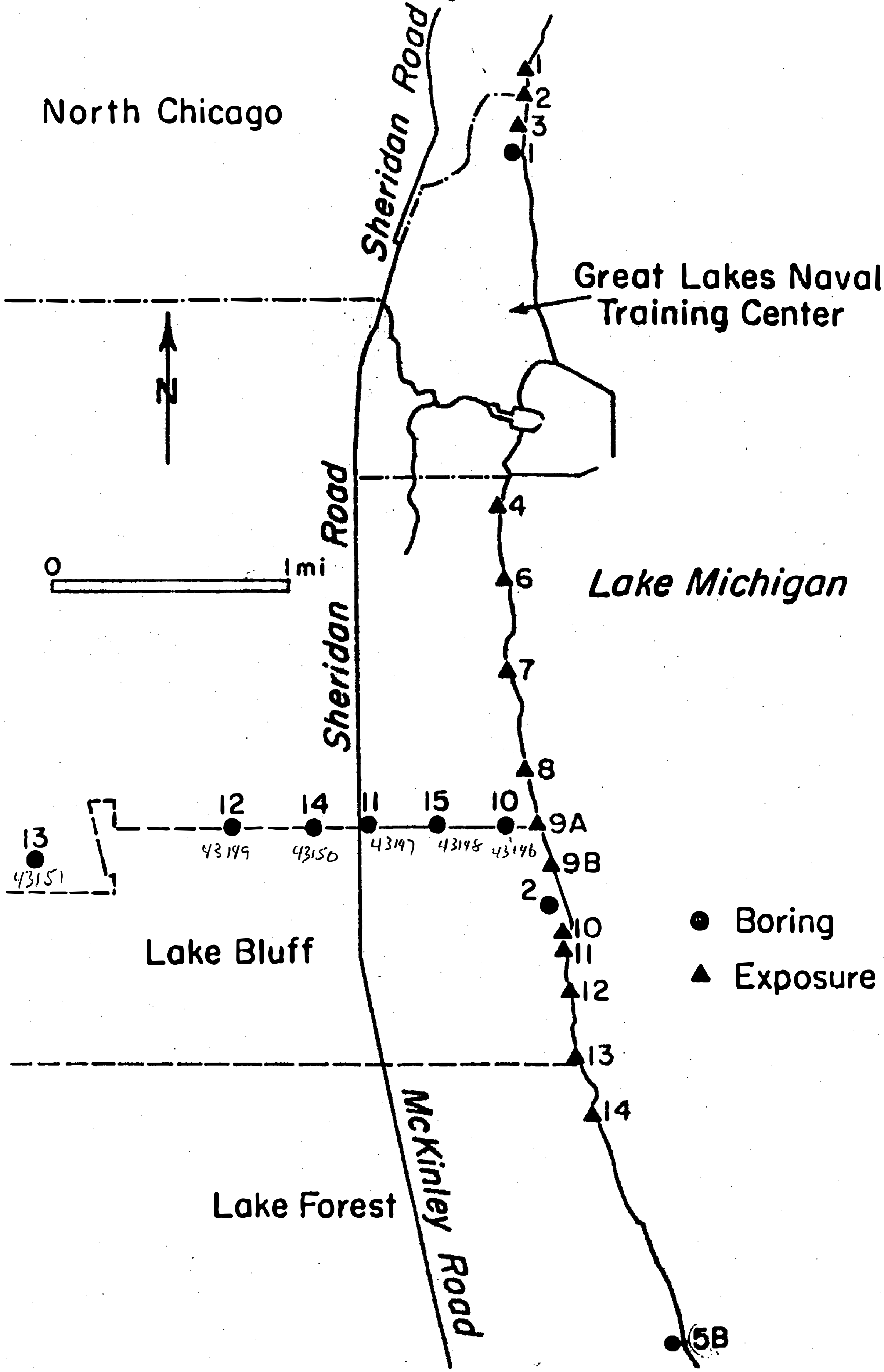

WISC.
ILL.
ZION
BEACH RIDGE COMPLEX
Zion
LAKE MICHIGAN
Waukegan
North Chicago
LAKE PLAIN
LAKE BORDER MORAINES
Lake Forest
Highland Park
Winnetka
Wilmette
Evanston
CHICAGO LAKE PLAIN
O'Hare Airport
Chicago
0
5 mi
0
5 km

Fig. 1



Figs. 2 and 3 (Opposite) - Maps showing the location of boreholes and bluff outcrops studied in detail.


North Chicago
Sheridan Road
Great Lakes Naval Training Center
N
0
1 mi
Sheridan Road
Lake Michigan
1
2
3
1
4
6
7
8
12
14
11
15
10
9A
13
43149
43150
43147
43148
43146
43151
9B
2
10
11
12
13
14
Lake Bluff
Lake Forest
McKinley Road
5B
Boring
Exposure

GEOLOGIC HISTORY

During late Woodfordian time, glacial ice in the Lake Michigan Lobe flowed southwestward into Illinois and deposited the Wadsworth Till Member of the Wedron Formation. Development of the successive moraines of the Lake Border Morainic System (Fig. 1) was achieved by minor readvances in the general retreat of the Wadsworth ice sheet. The uniform composition of the till of the five Lake Border moraines is attributed to the homogeneous nature of the ice. The two principal moraines in the study area are the Highland Park Moraine and the Zion City Moraine, the two youngest moraines in Illinois.

Upon deposition of the Zion City Moraine the ice retreated into the Lake Michigan Basin. Stagnation of the ice in the Lake Michigan Basin produced an ice marginal lake, which extended west to the Highland Park Moraine. Deposits of this glacial lake have been found from Lake Forest to Great Lakes Naval Training Center (GLNTC), on a wave-cut bench composed of Wadsworth Till, at elevations as high as 680'. This lake probably extended north into Wisconsin, although no direct evidence of this has been found. The lake deposits that occur in the north could have been deposited at a later time.

Subsequent readvance of the ice from the basin deposited another till layer upon the lacustrine deposits. This lobe of a minor readvance only occupied the area from Lake Forest to GLNTC. Advancement by the ice sheet in this area displaced the ice-marginal lake northward. Beach and bar deposits indicate that lake levels were at least 675' in elevation. There is no evidence that the ice sheet advanced into the area north of GLNTC. Upon deposition of the upper till, the ice retreated into the Lake Michigan Basin for the final time, concluding glaciation in Illinois.

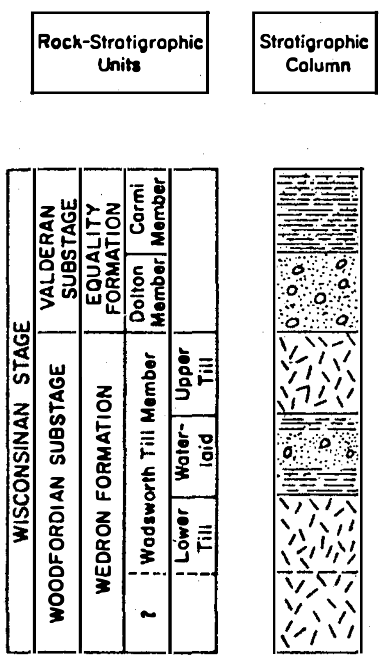
Accompanying retreat of the ice was drainage of the ice-marginal lake. The lake leveled off at 640' in elevation, forming the Glenwood stage of glacial Lake Chicago. At this time, beaches and bars formed in the southern part of the study area near Wilmette. Subsequent lower levels formed similar features in Evanston and farther south. Lowered lake levels have since produced the Zion Beach Ridge and Dune Plain from Waukegan north to Kenosha, Wisconsin.

GEOLOGY

The principle geologic unit comprising the till bluffs is the Wadsworth Till Member of the Wedron Formation (Fig. 4). The Wadsworth Till is geomorphically expressed in the Lake Border Morainic System, as a set of five parallel moraines and intermorainal ground moraine. The principal Lake Border moraines in the Lake Bluff area are the Highland Park Moraine, which intersects the shoreline in Lake Forest, and the Zion City Moraine in the North Chicago area. The Wadsworth ground moraine is the surficial unit throughout most of Lake County, and is found as far west as the McHenry-Lake County line.

The till is a massive, gray, silty clay with traces of sand and gravel. It ranges from tough or very stiff to hard, and contains only discontinuous seams of silt and sand. Texturally, the till is generally uniform in character as shown by the textural variation of the unit shown in Figure 4. Silt and clay are nearly equal in amount but a slight shift in their percentages is common. Sand is generally 10% or less, and only a trace of gravel is characteristic. Only minor variations occur in the mineralogic properties of the till. Figure 4 illustrates the typical composition of Wadsworth Till. When unaltered, the till contains 10% expandable clay minerals, 70% illite, and 20% chlorite+kaolinite. The Vermiculite Index ranges from 4 to 12, and carbonates average approximately 55 to 70 counts per second of calcite and dolomite, respectively.

The compositional similarities of the till are reflected by their index properties (Fig. 4). Inorganic silt and clay of slight to medium plasticity make up a high percentage of the materials composing the Wadsworth Till. Natural moisture content averages 16% while dry densities are approximately 120 lbs/ft^3. Unconfined compressive strengths from 3.0 to 4.5+ TSF characterize the till as very tough to hard. A liquid limit average of about 27% and a plasticity index of about 8% are indicative of slight to medium plasticity.



Matrix Grain Size (%)			Clay Mineral Composition (%)		
Sand	Silt	Clay	Expandable Clay Minerals	Illite	Chlorite and Kaolinite
7	65	28	33	52	15
44	44	12	5	79	16
16	45	39	17	72	11
Varies from silty clay to coarse sand and gravel			8	76	16
9	48	43	11	70	19
12	31	57	6	77	17

Fig. 4 - Geologic column and index properties of stratigraphic units of the Lake Michigan bluffs and shore.

TABLE 1 - SYMBOLS USED IN THE TEXT AND IN THE APPENDICES

Symbol	Meaning
Spl No.	Sample number
INDEX PROPERTIES	
N/BPF	Number of blows per specified distance
Qu/TSF	Unconfined compressive strength in tons per square foot
W	Natural moisture content in percent
LL	Liquid limit
PI	Plasticity index
SS/TSF	Shear strength in tons per square foot
DD/PCF	Dry density in pounds per cubic foot
DW/PCF	Wet density in pounds per cubic foot
GRAIN SIZE	
Gvl	Percent of gravel in sample
Sd	Percent of sand in sample
St	Percent of silt in sample
Cl	Percent of clay in sample
X-RAY DATA	
DI	Diffraction intensity
M	The clay mineral montmorillonite in percent of the clay fraction
I	Illite (clay mineral) in percent of the clay fraction
C-K	Chlorite-kaolinite (clay minerals) in percent of the clay fraction
Cal	Calcite in percent of the carbonate fraction of the clay-size minerals
Dol	Dolomite in percent of the carbonate fraction of the clay-size minerals
Verm. Index	Vermiculite Index

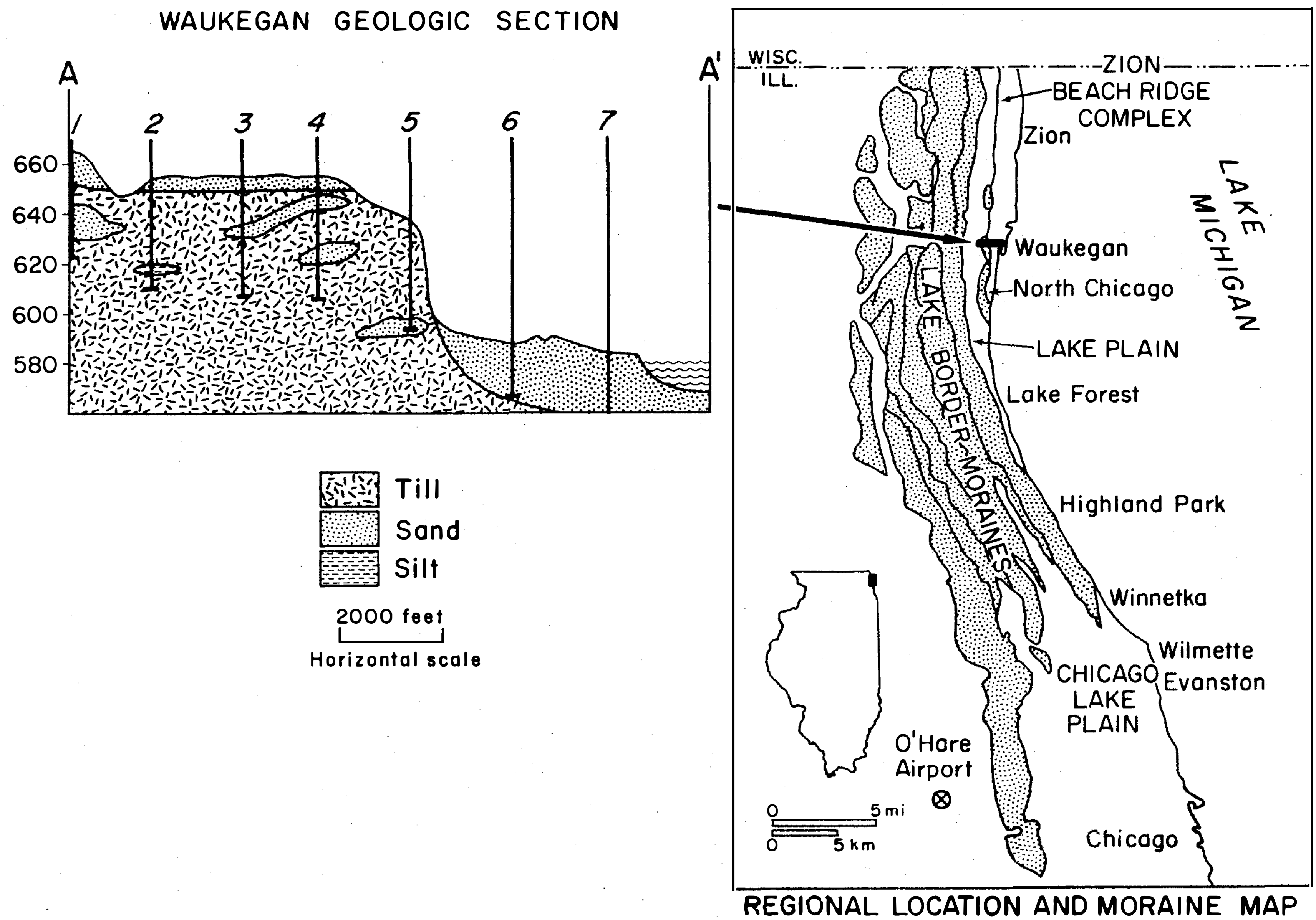


Fig. 5 - Geologic section at Waukegan showing the Zion Beach Ridge and Dune Plain in Boreholes 6 and 7.

The high till bluffs bordering Lake Michigan in Illinois extend from Wilmette on the south to Waukegan on the north (Fig. 1). North of Waukegan, the Zion Beach Ridge and Dune Plain separates the bluffs from the present-day shoreline. South of Wilmette, sand and gravel deposits of prehistoric glacial Lake Chicago comprise low bluffs.

At the extreme southern end of the study area in Evanston, boreholes have passed through the Wadsworth Till and penetrated a gray silty clay till unit of extremely low unconfined compressive strength (Figs. 4-6). This soft till is characterized by Qu/BPF (Table 1) generally <1 TSF and moisture contents as high as 47%. This is the northernmost occurrence of the soft till unit which extends in the subsurface southward towards Chicago (Peck and Reed, 1954).

The till bluffs bordering Lake Michigan can be divided into three geologically distinct areas: Waukegan to Great Lakes Naval Training Center, GLNTC to Lake Forest, and Lake Forest to Evanston.

Waukegan to Great Lakes Naval Training Center

Wadsworth Till and overlying high-level lake deposits of glacial Lake Chicago comprise the bluffs along the shoreline from Waukegan to GLNTC (Figs. 4-6). In places, the water-laid material is thin or absent, and the bluffs are principally till. In other places, these deposits attain a thickness of up to 40 feet (12 meters). Sand and gravel shoreline and bar deposits (Dolton Member of the Equality Formation), and silt and sand lacustrine deposits (Carmi Member of the Equality Formation) rest on the till (Fig. 4). A ridge of these materials is indicated by boreholes shown in cross-sections B-B' and B-B" of Figure 6. This ridge represents a bar or spit deposited in an ice marginal lake of high elevation. The reach of 80 foot (24 meter) high bluffs from GLNTC to North Chicago is exposed to wave erosion. From North Chicago to Waukegan, however, the bluffs are protected from Lake Michigan by man-made land. North of Waukegan, the Zion Beach Ridge and Dune Plain separates the bluff from the shoreline. Adjacent to the bluff, sand and gravel of the beach ridge plain occur at the 600 foot (183 meter) elevation, reducing the bluff height to approximately 50 feet (15 meters).

Great Lakes Naval Training Center to Lake Forest

Two tills separated by up to 33 feet (10 meters) of lacustrine deposits comprise the 80 foot (24 meters) high till bluffs along the Great Lakes to Lake Forest reach of the shoreline (Figs. 7-12). The upper till is locally overlain by thin water-laid deposits.

The lower till is the Wadsworth Member of the Wedron Formation. The granulometric, mineralogic, and index properties are all similar to those cited previously for the till of the Wadsworth. A wave-cut bench has been incised into the lower till, and up to 33 feet (10 meters) of lacustrine deposits occupy it. This transgressive-regressive sequence of water-laid materials resulted from a proglacial lake of the retreating Wadsworth ice. As these deposits occur at elevations as high as 680 feet (207 meters),

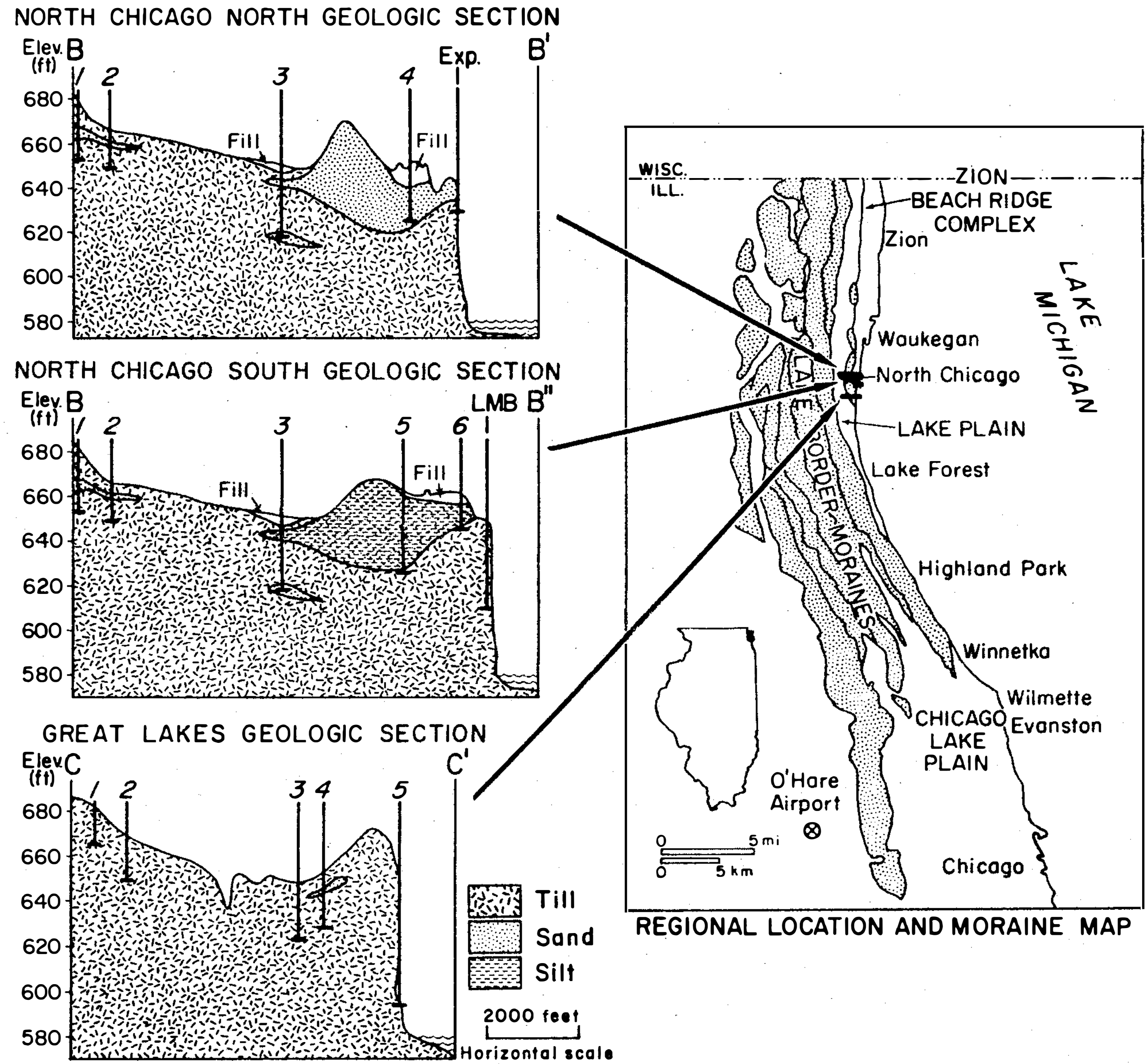


Fig. 6 - Geologic sections at North Chicago and at Great Lakes Naval Training Center showing high lake level deposits overlying the glacial till.

which is 40 feet (12 meters) higher than the highest recorded level of glacial Lake Chicago, it was an ice-marginal lake. The lacustrine deposit from bottom to top grades from coarse-grained to fine and back to coarse. This represents a shore to nearshore to offshore to nearshore cycle of events--a transgressive-regressive lake deposit sequence. The sedimentary assemblages of each zone are:

shore - medium- to coarse-grained sand and gravel with rounded, gray silty clay till inclusions; cross-bedded;

nearshore - fine- to medium-grained sand with some silt; laminated; cross-bedded;

offshore - dense clayey silt and silty clay; laminated.

A minor readvance of the waning late Woodfordian ice flowed out of the Lake Michigan Basin into the Great Lakes-Lake Forest area and deposited the upper till which is uniformly 7 feet (2 meters) thick. The physical properties of this upper unit are different from those of the lower till. Texturally, the upper till is more sandy than the lower (Fig. 8). This is to be expected, as the ice overrode and incorporated some of the lacustrine deposits below. Average texture of the upper till is 16% sand, 45% silt, 39% clay. The mineralogic composition is also different from typical till of the Wadsworth. Expandable clay minerals are more abundant than in the typical till, chlorite+kaolinite is less, vermiculite is substantially greater, and carbonates substantially less. The upper till rarely exceeds 7 feet (2 meters) in thickness and is never found unaltered; therefore, mineralogic comparison of the upper and lower tills is difficult. The lacustrine material was largely reworked by wave action prior to incorporation by the overriding ice which deposited the upper till. This accounts for mineralogical differences between the tills. Although some minor compositional differences exist between the upper and lower tills, they do not significantly affect the index properties. Despite the present discrepancies, the composition of the ice that deposited the upper till was probably very similar to that for the lower till. Incorporation of lacustrine material and post-depositional weathering have served to mask the original composition.

Lake Forest to Evanston

The bluffs from Evanston to Lake Forest are composed of massive, gray silty clay till of the Wadsworth Member, with physical properties as cited previously. Only discontinuous seams of sand and silt are present within the till unit. To the south, near Glencoe and Winnetka, the till of the Wadsworth becomes slightly more clayey, with a typical texture of 9% sand, 33% silt and 58% clay. The bluff height decreases to the south from 80 feet (24 meters) at Lake Forest to only 33 feet (10 meters) in Evanston. At Northwestern University in Evanston, the 40-foot (12 meters) high bluff is composed largely of sand and silt of the Graceland spit formed during the Toleston stage of glacial Lake Chicago (Bretz, 1955).

In the southern portion of this reach, near Winnetka, boreholes have encountered at depth a gray silty clay till of a character slightly different

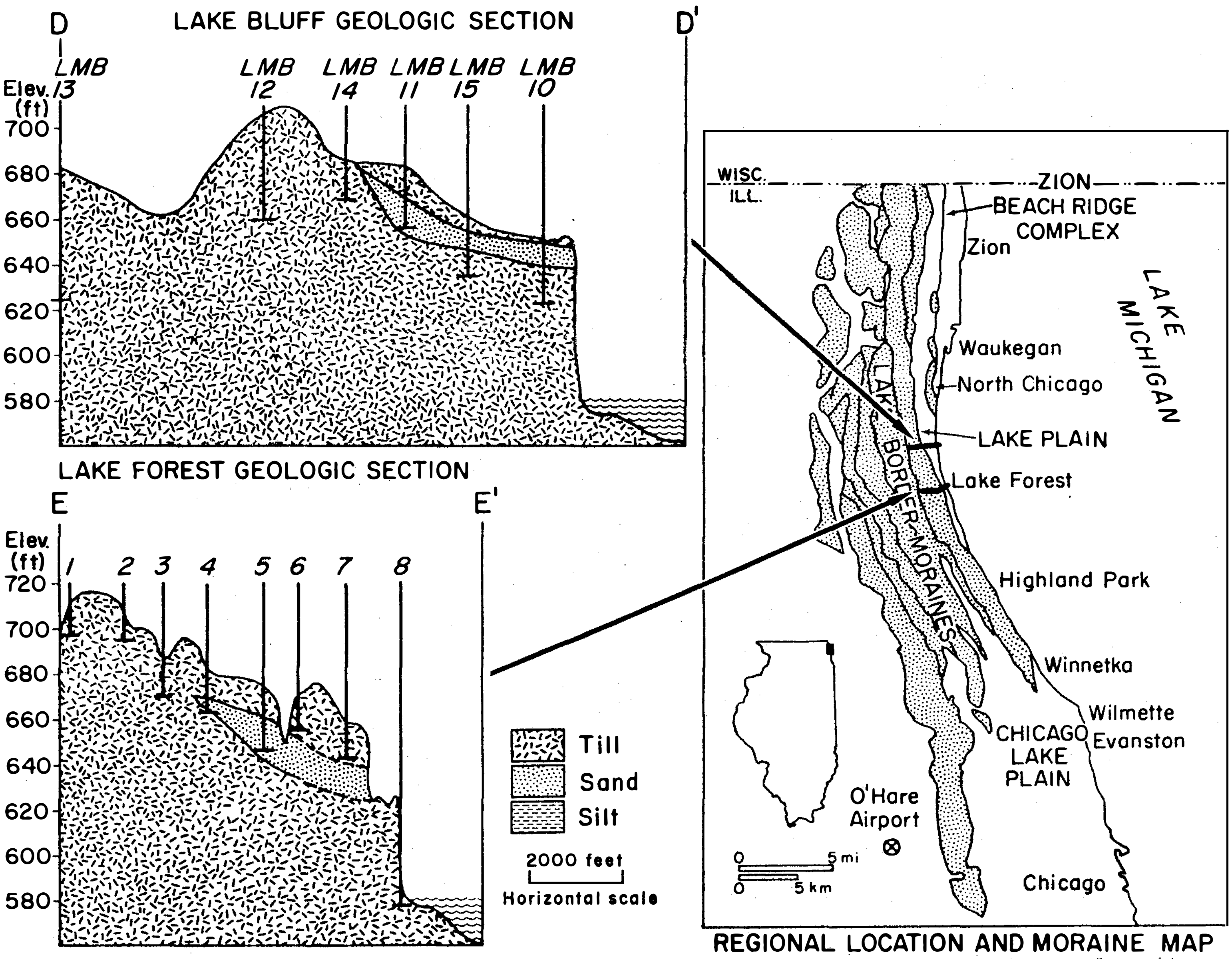


Fig. 7 - Geologic sections at Lake Bluff and at Lake Forest showing two glacial tills separated by glacio-lacustrine sediments.

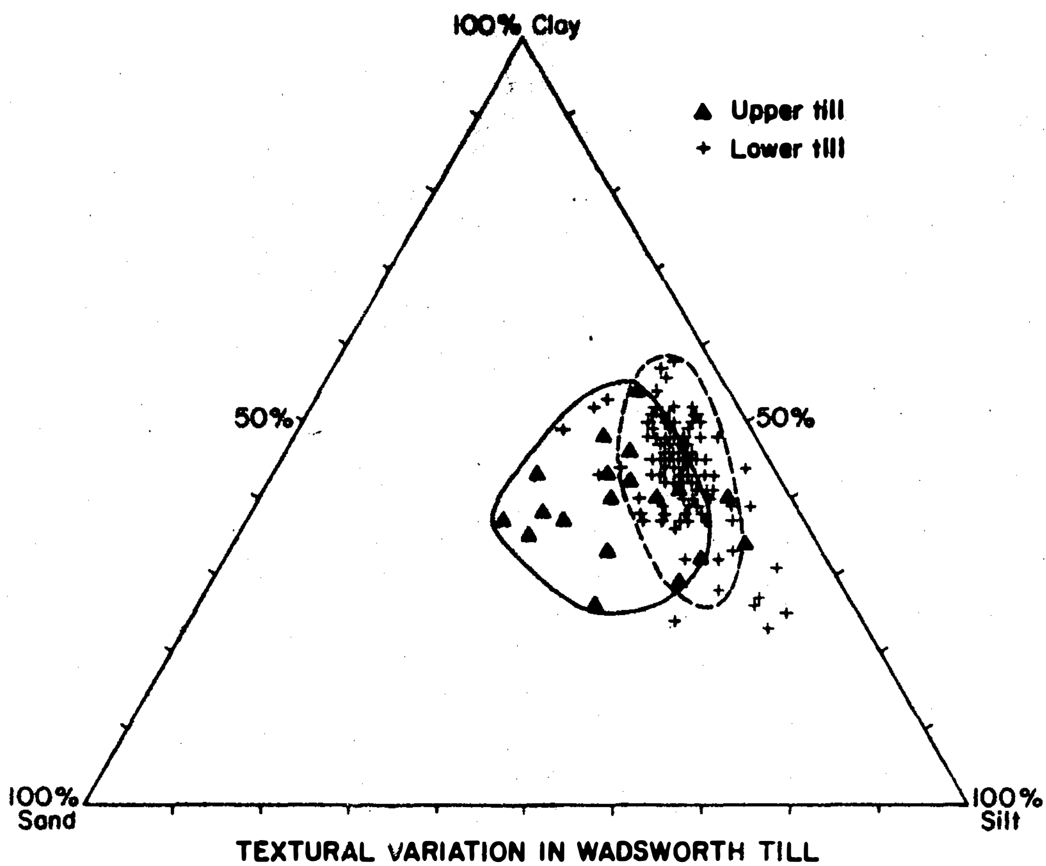


Fig. 8 - Ternary diagram based on sieve analyses. Textural variations within the Wadsworth Till Member of the Wedron Formation are shown. The upper till is differentiated from the lower by its greater silt content. All samples were collected at Lake Bluff.

LAKE MICHIGAN BLUFFS — BORING 12

Lake Bluff Central Elementary School

SE cor. SE-SE-SW Sec. 17, T.44 N., R.12 E.

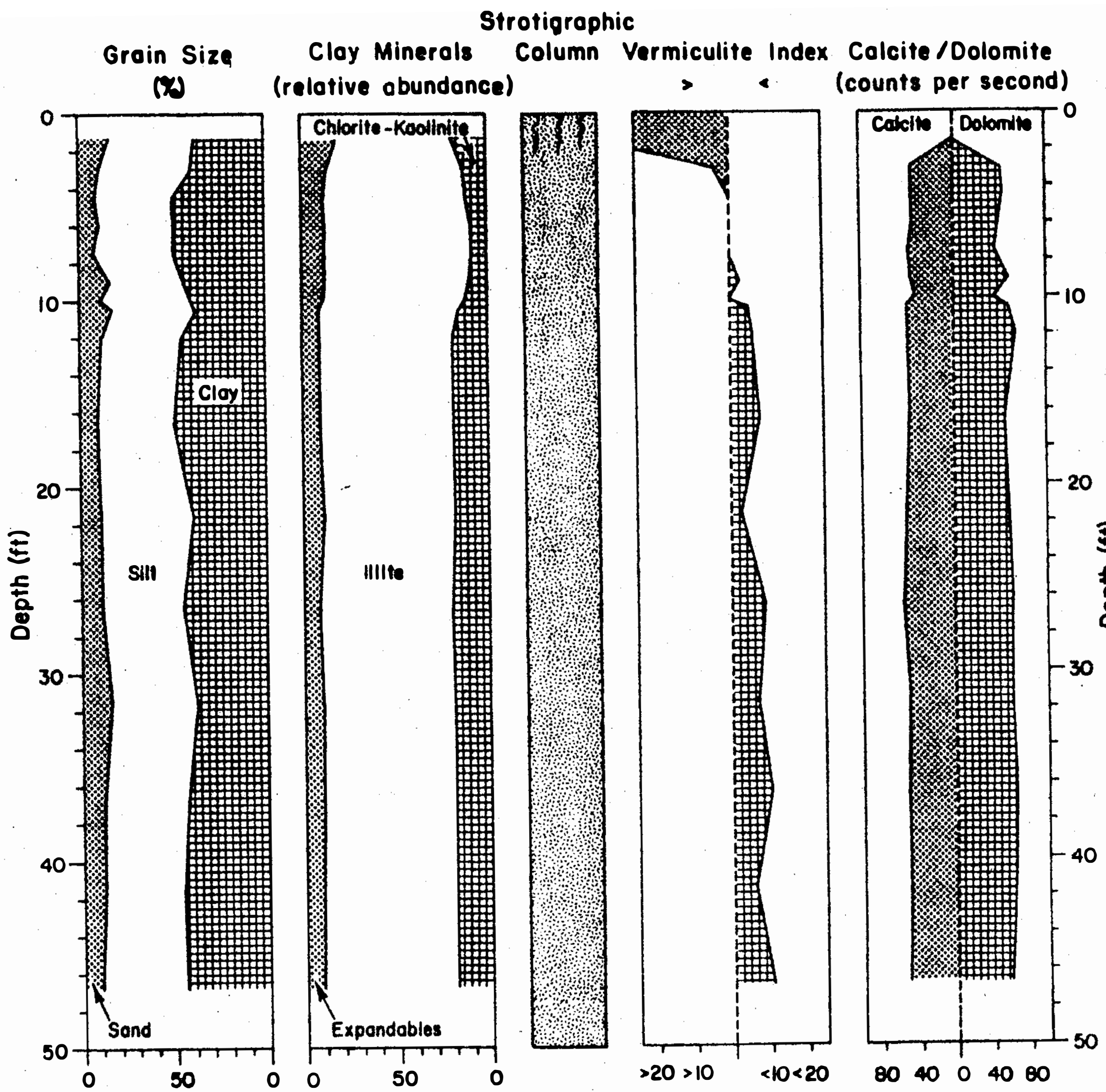


Fig. 9 - Diagram illustrating the composition of Wadsworth till in Borehole LMB-12 (Fig. 7) at Lake Bluff. The upper till, which extends down to ten-foot depth, is distinguished from the lower till by the high amount of expandable clay minerals and by high Vermiculite Index values. Both indicate that the till has been weathered and is relatively porous. Low calcite and dolomite counts reenforce the interpretation. Because of these characteristics the upper till, especially the upper 1 1/2 feet (see Appendix A), is relatively weak and subject to failure by slump during periods of high rainfall and during spring thaws.

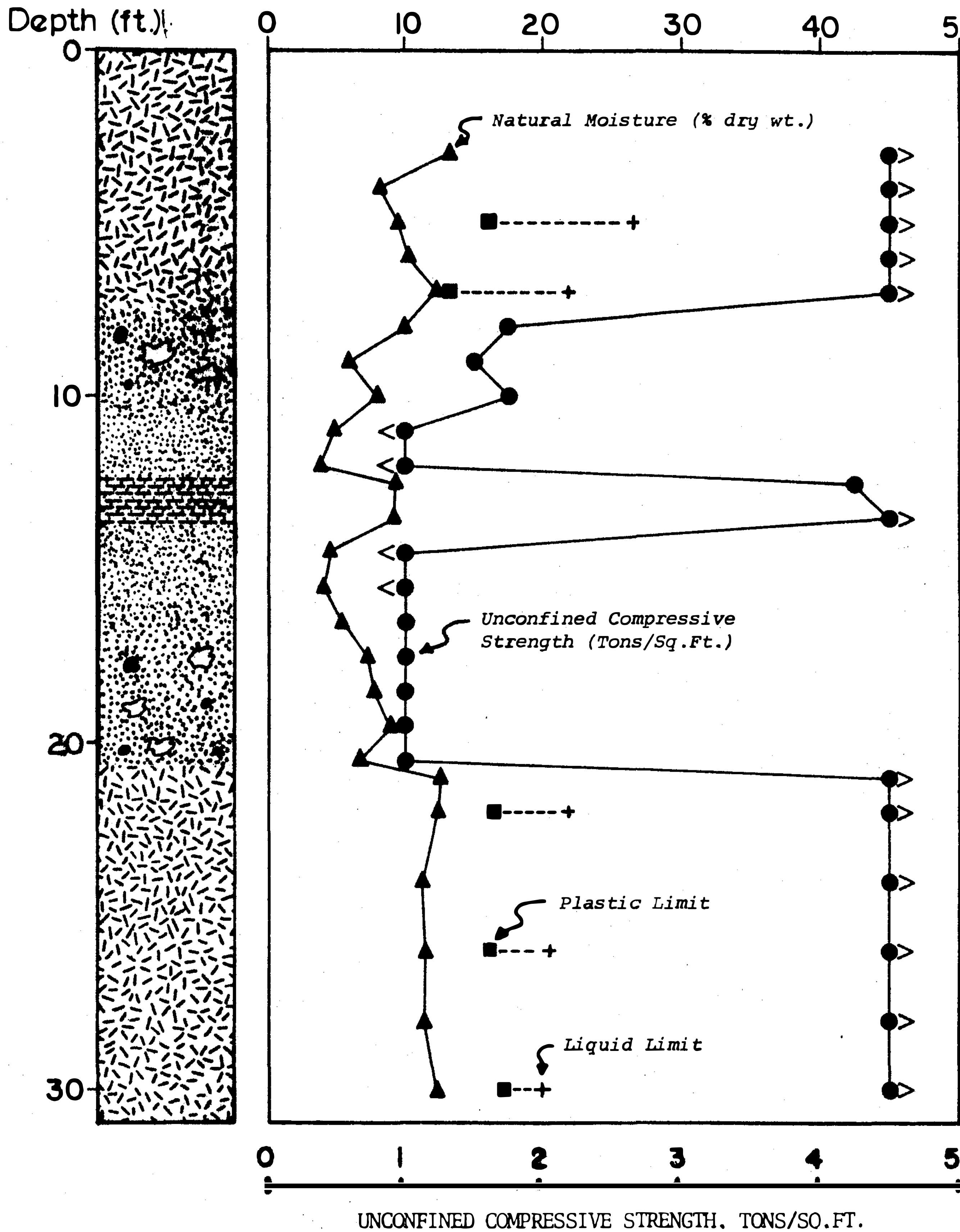


Fig. 10 - Diagram illustrating the compositions of the upper and lower tills and the interlayered lacustrine sediments at Exposure 6 in Lake Bluff. This site is one with an excessively high rate of recession.

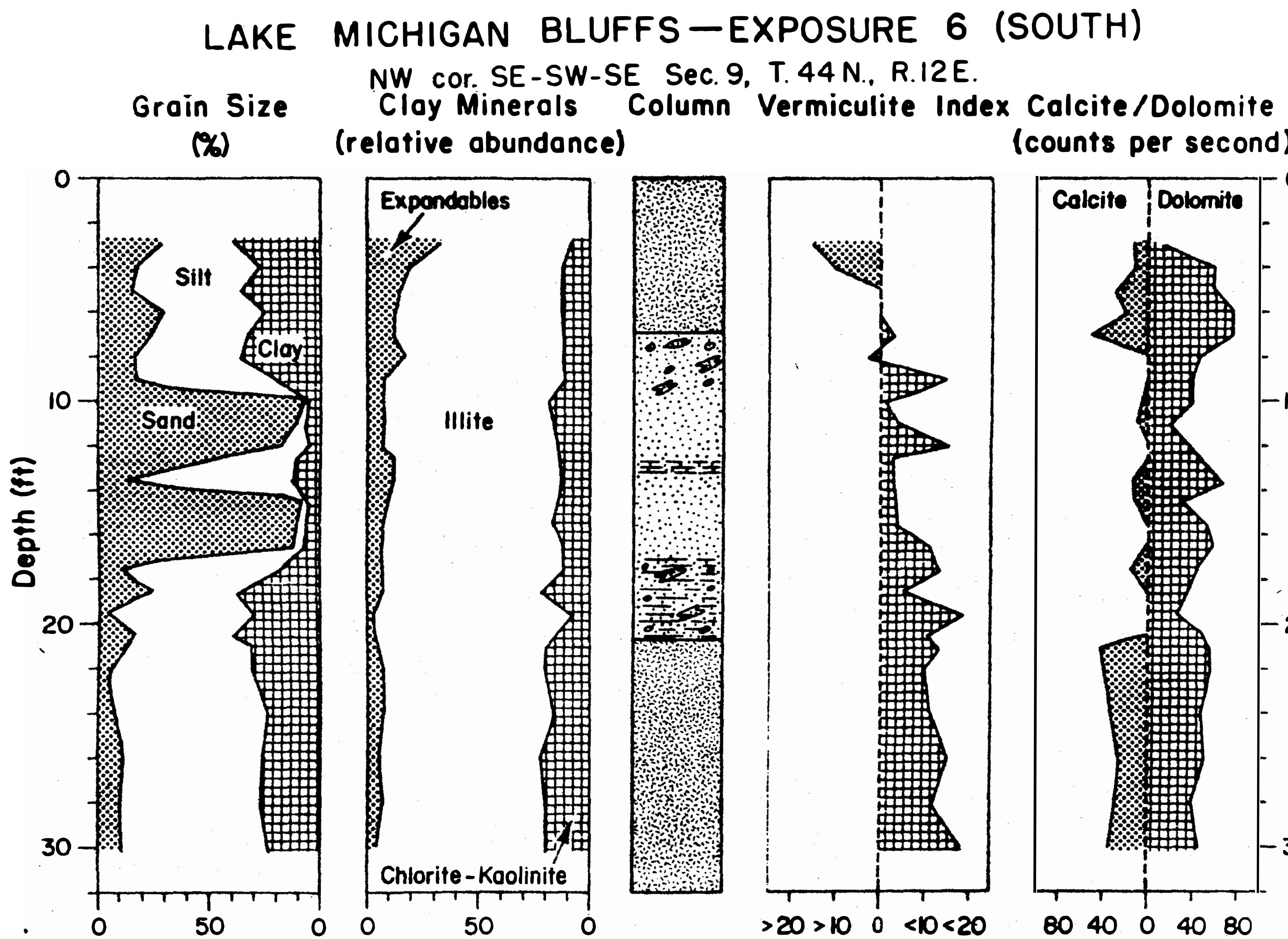


Fig. 11 - Diagram illustrating index properties of the upper and lower tills and the interlayered lacustrine sediments at Exposure 6 in Lake Bluff.

Fig. 12 - Photo of bluff shore in Lake Forest showing slump failure in weak glacio-lacustrine materials underlying the upper till.

from that of the overlying till. The average texture of the deep till is 12% sand, 31% silt, and 57% clay. The expandable clay mineral content is about 5% less than in the overlying whereas the illite content is relatively high (75-80%) and the Vermiculite Index is low. Carbonates are measured at only 25 counts per second of calcite and 35 of dolomite. Only the top of the deep unit has been penetrated, and few tests have been run on the till. Due to insufficient data, assignment of this till unit to a specific member of the Wedron Formation would be presumptuous.

METHODS OF STUDY

Fourteen research boreholes, drilled by the Illinois State Geological Survey, are located in the study area (Figs. 1-3). Lake Michigan bluff boreholes LMB-1 through LMB-9 were drilled near the crest of the bluff. All samples in this series were collected at tive-foot intervals using a split tube designed by Dames and Moore, Consulting Engineers, of Park Ridge, Illinois. A set of brass rings was inserted into the tube and the tube driven, with a drop hammer, into the bottom of a drilled hole. Once filled, the sampler was brought to the surface and the rings containing the sample were removed. This method obtained a relatively undisturbed sample that was then carefully sealed in an air-tight container for laboratory testing. Excess sample was described and retained for grain size and X-ray analyses, as well as for engineering tests that do not require an undisturbed sample. Samples from boreholes LMB-10 through LMB-15 (Fig. 3) were obtained by similar drilling methods using a standard split-spoon sampler.

Bluff face samples were collected by digging a trench into the face of the bluff to expose fresh material. Where the slopes were steep and inaccessible, rappelling methods were used to sample the upper bluff. A Soiltest hand-sampler was used to remove samples of bluff materials.

Grain-size distribution was determined by the sieve and hydrometer method of separation. Each sample was analysed to obtain percentages of gravel, sand, silt, and clay present. This information is useful for calculations to determine the amount of material available for beach nourishment and sediment loading in the lake. Granulometric data are useful for slope stability studies and soil classification.

The <2 micron portion of the samples was analysed by X-ray diffraction methods to determine the mineralogy. The results of these analyses are presented in Appendix A. The percents of montmorillonite (M), illite (I), and chlorite+kaolinite (C+K) in a sample are useful for making geologic correlations. The relative amounts of calcite (Cal) and dolomite (Dol), measured as counts per second, aid in identifying specific units when used in conjunction with other mineralogic parameters. The <u>Diffraction Intensity Index</u> (DI) compares the percentage of illite with that of chlorite+kaolinite. An unweathered unit will have a characteristically low DI. The weathering process breaks down chlorite more readily than illite or kaolinite. Weathering increases the DI so it is useful in recognizing buried soils. The difference in height (measured in millimeters) between the first-order chlorite and the first-order illite peaks is the <u>Vermiculite Index</u>. Weathering causes an increase in height of the first-order diffraction peak for chlorite while the first-order illite peak remains unchanged in

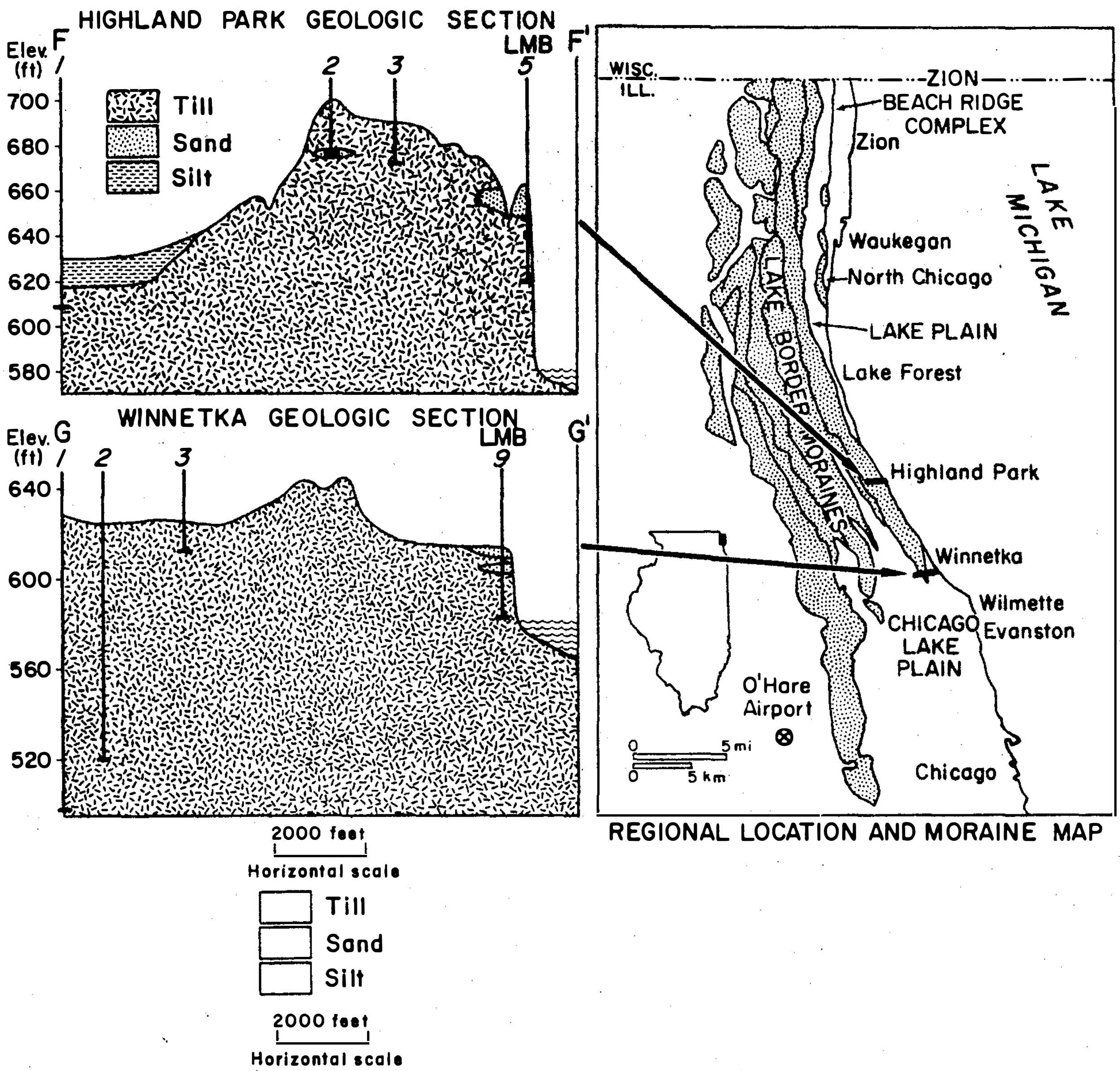


Fig. 13 - Geologic sections at Highland Park and Winnetka showing the presence of discontinuous lenses of sand and silt that cause local areas susceptible to shore recession.

Woodfordian age deposits. Vermiculite Index values increase with increased weathering. (Glass, personal communication)

Index properties were measured at the Illinois State Geological Survey, at the laboratories of Dames and Moore, Consulting Engineers, and at the Soil Testing Services laboratory. Engineering tests were performed as prescribed by the American Society For Testing Materials (ASTM). The materials were classified on the basis of texture and plasticity in accordance with the Unified Soil Classification System. The estimated group symbol is given in parentheses following the soil description in the borehole logs (Appendix A). N/BPF indicates the number of blows (from a standard 140 pound hammer, dropped 30 inches) needed to drive the sampler one foot into a material. Unconfined compressive strength (Qu/TSF) is the axially applied force required to cause failure of an undisturbed sample. Shear strength (SS/TSF) was measured by a Soiltest, Inc. "Torvane" tester. Values are given in tons per square foot. The dry density of the material is measured in pounds per cubic foot (DD/PCF). Wet density is denoted by DW/PCF in pounds per cubic foot. Natural moisture content (W) is calculated as percentage of dry weight. The liquid limit (LL) is the water content at which the soil has such a small shear strength that it flows to close a groove of standard width when jarred in a specified manner. The water content at which the soil begins to crumble when rolled into threads of specified size is defined as the plastic limit. The amount of water that must be added to change a soil from its plastic limit to its liquid is an indication of the plasticity of the soil. The plasticity is measured by the plasticity index (PI), which is equal to the liquid minus the plastic limit.

Groundwater piezometers were installed in two borings at Lake Bluff. In the open boring, pea gravel was placed around the perforated end of a small diameter plastic tube extending to the surface. The pea gravel cell was sealed with dry bentonite to prevent distortion of measurements of head pressures due to leakage from above. Measurements were made periodically by means of a dip stick.

The distribution of groundwater seeps on the fork of the bluff was plotted by means of low-level oblique aerial photographs taken in August 1974 when groundwater levels were near record heights, in May 1976 when levels were near their peak for 1976 (Fig. 15) and in August 1976 when groundwater levels had fallen substantially due to decreased precipitation (Fig. 15). In addition, field examinations and ground photographs were used. The locations of seeps, their size and their position in the bluff were recorded.

GEOHYDROLOGY OF THE BLUFFS

Data regarding the effect of hydrogeologic factors on bluff materials include piezometer records of boreholes, observations of groundwater seeps along the bluff face and the detailed stratigraphy of exposures and borings.

Two piezometers were installed along the Lake Bluff cross section in boreholes LMB-12 and LMB-15. Readings taken since October of 1975 are shown in Table 2. In Figure 15, a graph of water levels in Borehole LMB-15 is shown with a graph of the monthly precipitation totals.

Slope failure that is caused by high pore pressures in bluff materials is related to high annual groundwater levels (Fig. 15) but the rise of ground water is not directly related to regional precipitation. Annual fluctuation of water levels is more dependent upon the changes in balance due to vegetation than water infiltration. Vegetation takes up increasing amounts of water beginning with the first growth each spring. In fall, when cool weather and frost cause a cessation of water-use by plant life, ground waters rise.

GROUNDWATER SEEPS

Groundwater seeps generally are direct evidence of groundwater levels and where they occur on the till bluffs, are indications of reduced shear strengths, increased penetration values, lowered unconfined compressive strengths and increased weathering rates. Significant groundwater seepage on the bluff face was mapped in seven areas: (1) North Chicago, (2) northern Lake Bluff, (3) southern Lake Bluff, (4) southern Lake Forest, (5) southern Fort Sheridan, (6) Highland Park, (7) Glencoe.

North Chicago

Several seeps occur near the middle of the bluff in the vicinity of the North Chicago sewage plant. The seeps result from the fact that several feet of clayey sand and gravel overlying clayey till occur at the top of the bluff. Where the porous sediments meet the impervious till seeps occur. In addition, sandy zones in the till occur near the middle of the bluff face. These sandy beds are relatively unstable and contribute to erosion in progress there.

Lake Bluff

Seeps are widespread along the bluff extending from the Great Lakes Naval Training Center southward to North Avenue. The uppermost seeps occur between 2 1/2 and 6 1/2 feet (3/4 and 2 meters respectively) below the top of the bluff and are controlled by silt beds in the upper till. Between 7 and 20 feet (2 and 6 meters) below the top, the bluff is composed of weak gravel, sand and silt beds that contain numerous seeps and represents the most important area of instability on the entire Illinois bluff shore. Seeps low in the bluff are attributable to silt beds in the lower till.

Reentrants in the bluff can be directly correlated with specific seeps (Fig. 16). Comparison of photos taken in August 1974, when record high groundwater levels existed, and in August 1976, when levels had fallen several feet (Fig. 17), shows a significant reduction in flow from the seeps. Nevertheless, they represent the continuation of surface instability.

Along the reach the bluff extending from the Lake Bluff sanitary pumping station at Sunrise Park to just south of the Lake Forest water treatment plant, seeps are common in the upper parts of the bluff. The uppermost ones occur from 4 to 15 feet (1 1/4 to 4 1/2 meters) below the

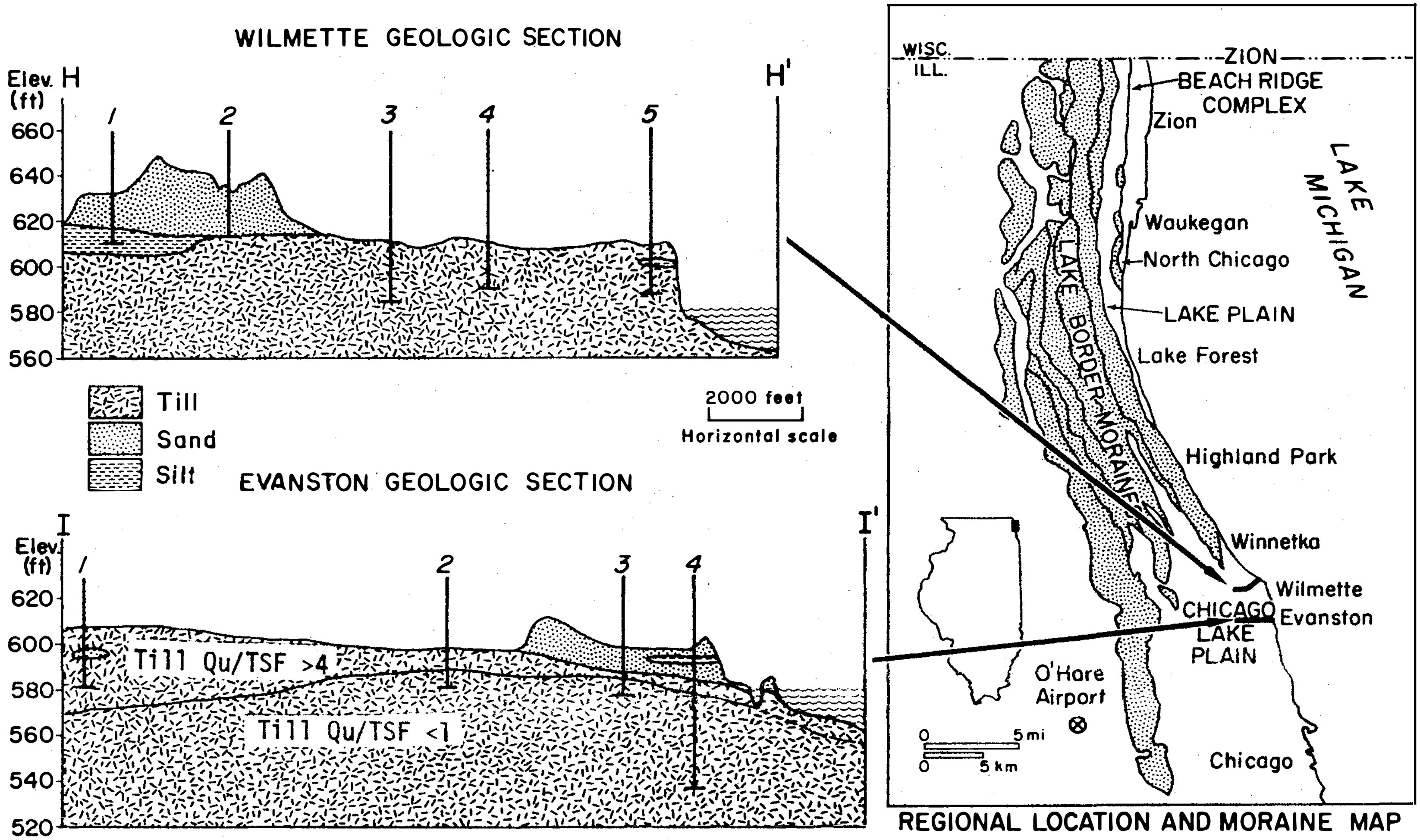


Fig. 14 - Geologic sections at Wilmette and Evanston showing sandy deposits from the Toleston stage of ancient Lake Chicago lying on glacial till. Cross section I-I' shows the presence of a weak deep till underlying the lower till of sections to the north.

bluff edge, at the base of the upper glacial till. Beneath the till is a series of cobble, gravel, sand and silt beds which extend down to 36 feet (11 meters) below the top of the bluff and contain seeps throughout their extent. A few seeps are also found in silt layers within the underlying lower till. In August 1976, after considerable lowering of the water table, seeps remained in many places along this reach of shore.

Lake Forest

Seepage occurs in several places in Lake Forest. North of Stonegate Lane in the central part of the reach, seeps are common in the middle and upper parts of the bluff giving rise to loss of vegetation and serious sheet-type slope failures. Drilling records indicate that the upper few feet of glacial till that form the lip of the bluff in Lake Forest are weathered to the extent that it retains surface waters and conducts them to the bluff face. Slumping of these uppermost few feet is common.

In southernmost Lake Forest, near the former site of Villa Turicum, seeps were abundant from 1973 until August 1976 when groundwater levels fell and seeps dried up.

Fort Sheridan

Along the southernmost half mile of bluff at Fort Sheridan, seeps occurred in the upper half of the bluff during the 1973-1976 high precipitation period. With the drop in rainfall during summer 1976, the seeps entirely disappeared.

Highland Park

Although most of the bluff in Highland Park is well-vegetated, seeps were common in the uppermost 20 feet during the period 1973-1976. Most resulted from surface water penetration of the weathered portion of the till at the top of the bluff. The water moved lakeward to the bluff face as seeps when it encountered the unweathered gray till. In addition, sand layers are not uncommon 15 to 35 feet (5 to 11 meters) below the top of the bluff and cause seeps at those levels. In several locations, one of them near Central Park, sand comprises the uppermost part of the bluff. Seeps occur at the base of the sand. Most seeps in Highland Park had ceased flowing by August 1976.

Glencoe

In northernmost Glencoe, weathered till at the top of the bluff and sand layers near the middle give rise to seeps causing serious instabilities in the area adjacent to the North Shore Congregation Israel Temple.

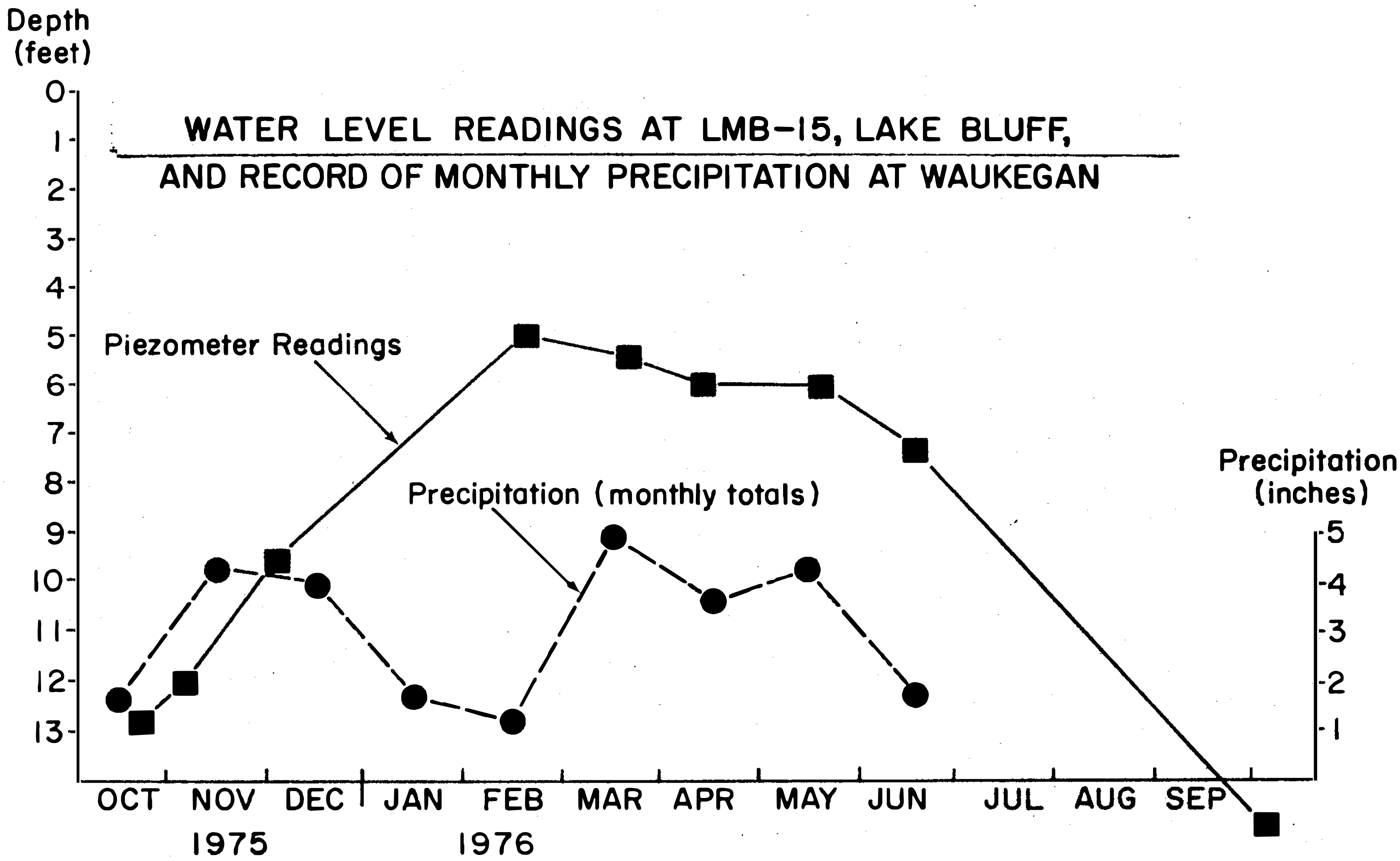


Fig. 15 - Graph comparing water levels in Boring LMB-15 (Fig. 7) at Lake Bluff with the total monthly precipitation measured at Waukegan during the period from October 1975 to June 1976.

TABLE 2 - GROUNDWATER LEVELS AT TWO PIEZOMETER LOCATIONS IN LAKE BLUFF, CROSS SECTION D-D', FIG. 7

Date	LMB-13 (Piezometer at 40 ft.)	LMB-15 (Piezometer at 15.5 ft.)
October 23, 1975	>30.0 ft. (>10.0)	12.8 ft.
November 5, 1975	>35.5 (15.0)	12.0
December 2, 1975	No Reading	9.5
February 17, 1976	36.3 (16.3)	4.9
March 17, 1976	35.0 (15.0)	5.4
April 14, 1976	34.6 (14.6)	5.9
May 18, 1976	33.8 (13.8)	5.9
June 17, 1976	34.7 (14.7)	7.2
August 5, 1976	36.9 (16.9)	11.2
September 3, 1976	38.9 (18.9)	>15.3

All measurements are given as depths in feet from the land surface. Figures in parentheses are corrected to the elevation of LMB-15. LMB-13 is located at a land elevation of 682.5 feet, 11,000 feet west of the lakeshore and 870 feet west of LMB-15, along Blodgett Avenue or its extension in Lake Bluff. LMB-13 is entirely in homogeneous Wedron till more than two miles from the lake in the Skokie River drainage area whereas LMB-15 is less than a half mile from the lakeshore (Fig. 7).

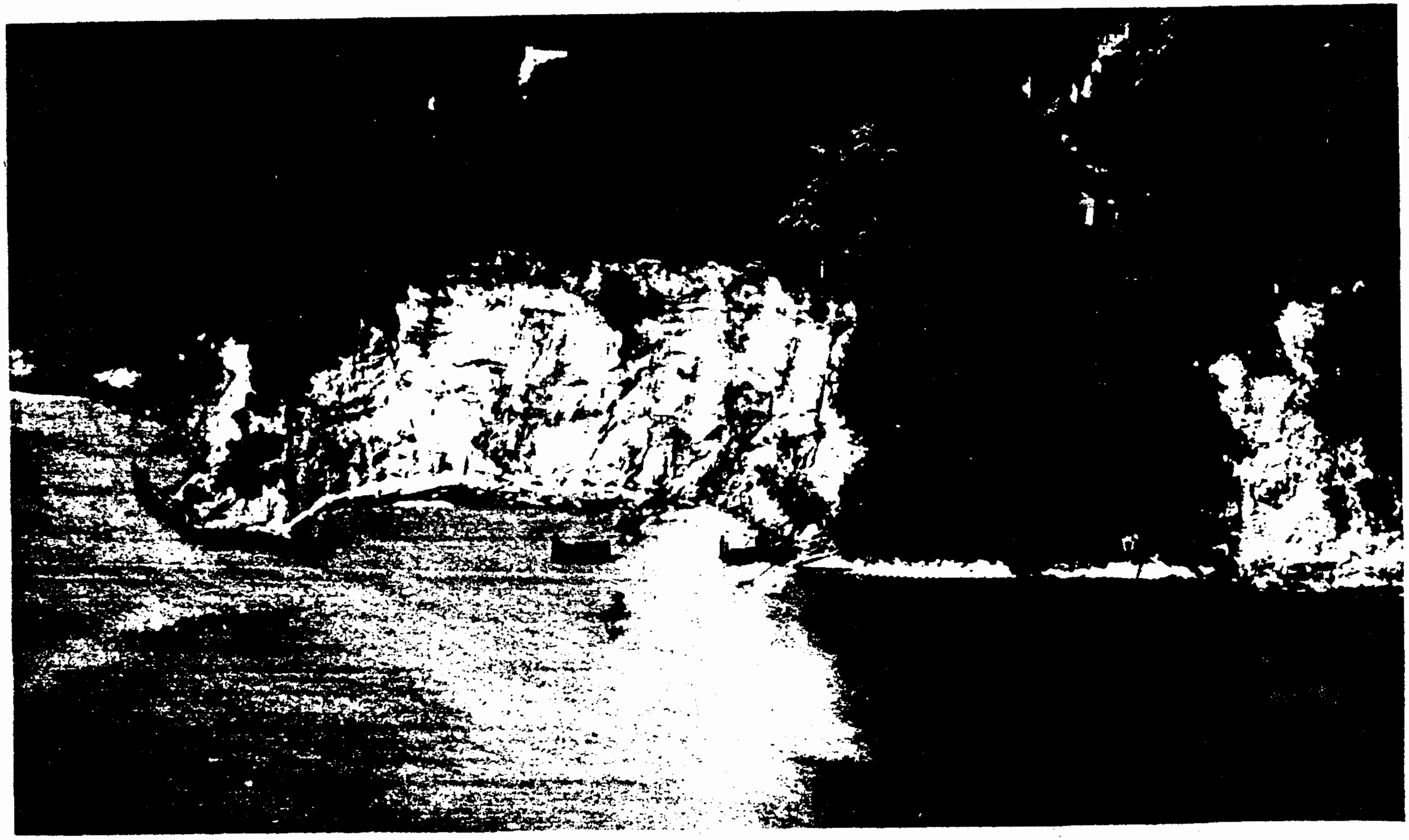


Fig. 16 - The till bluff in south Lake Bluff showing numerous groundwater seeps in glacio-lacustrine sediments distributed over most of the bluff. The photo was made in August 1974 when groundwater levels were near record heights.

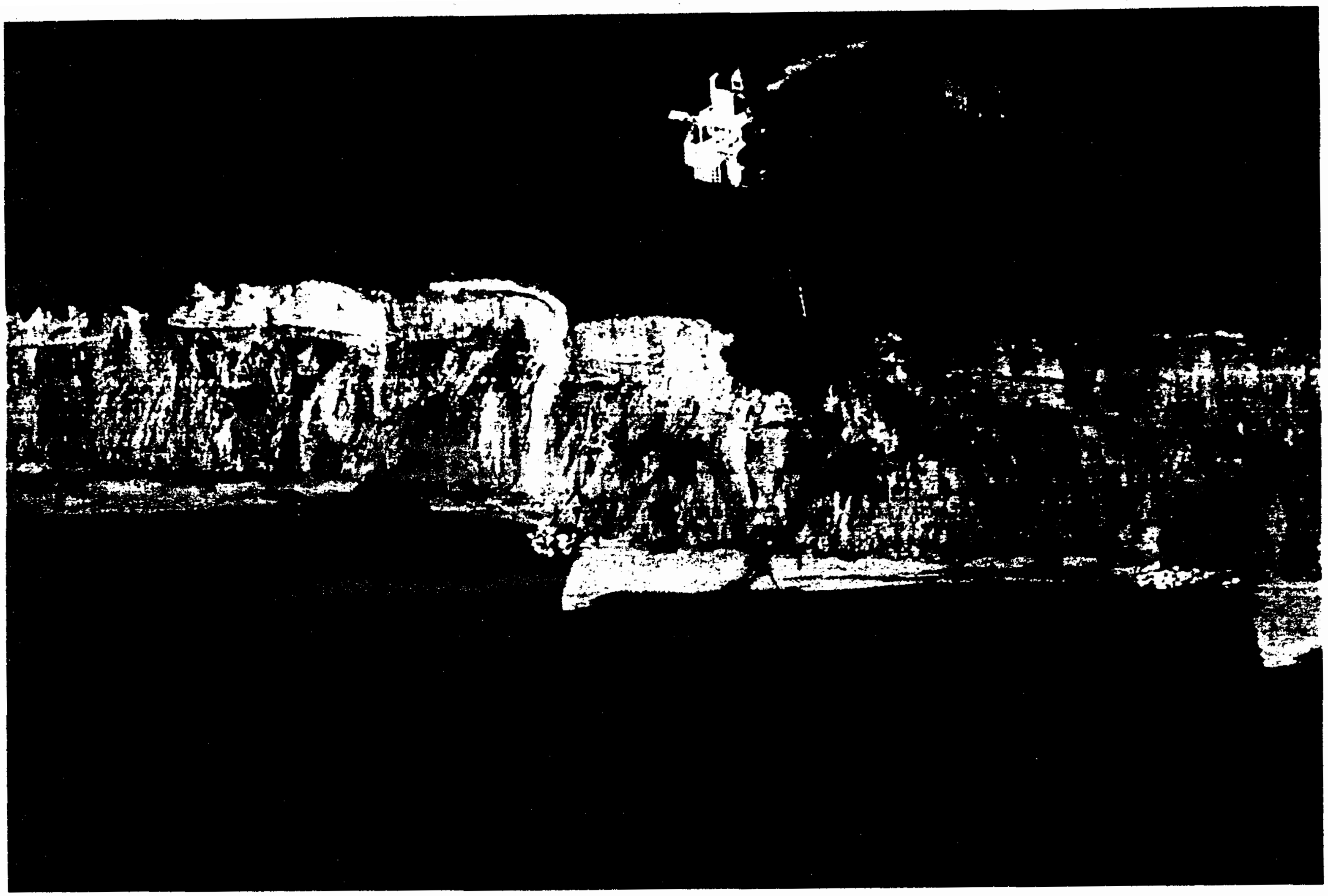


Fig. 17 - The till bluff in south Lake Bluff during August 1976 when groundwater levels were falling. The thin upper till can be identified directly in front of the house. The thirty-six feet (11 meters) of interbedded lake sands and silts that underlie it contain numerous seeps. Each seep correlates to a reentrant, whether large or small. Large seeps occupy major reentrants in the bluff.

CONCLUSIONS

This study is concerned with part of the total system of erosion along the shoreline of Lake Michigan. The geology, hydrogeology, and engineering properties are supportive of the work by Berg and Collinson, 1976. For example, bluff erosion rates and volumetric losses were higher in less competent sections of the shoreline. Bluffs near Glencoe and Highland Park have a low level of hydrogeologic activity and are composed of massive till containing only a few discontinuous seams of silt and sand. They are relatively stable, having a recession rate of about 13 meters in 100 years. In contrast, bluffs near Lake Forest and Lake Bluff consist of alternating tills and water-laid deposits and have a high level of hydrogeologic activity. Consequently they are relatively unstable, having a recession rate of about 81 meters in 100 years.

Texture analyses from geologic studies are used to determine the kind and quality of materials fed to the deposits found in beach areas. Erosion of homogeneous till of the Wadsworth provides very little sand for beach nourishment. However, the total volume of sand contributed to the system can be determined by knowing the recession rates of each area (Berg and Collinson, 1976).

Observations of numerous slope failures during field work indicate that thick sequences of till fail as slumps rather than as particle-by-particle erosion. A fluctuation of head pressure of 10 feet in water-laid deposits as indicated in borehole LMB-15 (Fig. 15) leads us to expect much higher head pressures in sections of homogeneous till. Our hydrogeologic work indicates that although vegetation is an important part of any program of stabilization of the surface materials of the bluffs, unstable slopes likely will continue to fail from high pore pressures during the winter unless other means such as structural support, slope reduction or dewatering are used to increase stability. As slumps develop, care should be taken to avoid further loading of slump units and accelerating movement along already failed planes of weakness. The tops of these slopes should be sealed to prevent increased infiltration, because the records show that infiltration continues even when the ground is frozen. Sodding tends to increase infiltration and should be avoided. Drainage systems should be designed and constructed to intercept the base of slide planes. Graded material or permeable membranes should be placed with the drains to prevent subsurface erosion.

Each geologic unit encountered in the field exhibits a range of engineering properties. The range reflects the mode of deposition of the material and the hydrogeologic and mechanical stresses within the system as it now exists. Engineers and geologists should look together to attempt to categorize the unit properties so that the stable or unstable condition of bluff materials can be determined.

In general, low water contents, of less than 15 percent water and high strengths of greater than 30 blows per foot and unconfined compressive test results greater than 3 tons per square foot indicate a high degree of stability. Values of more than 20 percent water, less than 10 blows per foot, and unconfined compressive test results ranging less than 1.5 tons per square foot indicate a low degree of stability. Local conditions and inter-unit relationships may affect the stability of the total sequence of materials. For example, stability of a till unit may be increased if the till is underlain by a well-drained sand. In contrast, a dense, sandy till unit may exhibit a strength of 4 to 5 tons per square foot and yet failure may occur along a joint surface having very low strength qualities or fail due to undercutting of loose underlying sand beds.

Interpretation of all factors of engineering geology and hydrogeology is necessary to answer the question of the stability of each particular slope.

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EXPLANATION OF APPENDICES

Along the Lake Michigan bluff fourteen research boreholes, twelve outcrop sections and ten subsurface cross-sections provided more than 370 samples from which 6 to 18 properties were measured for comparison with the stress stability, weathering characteristics and erosion resistance of materials in the lake bluffs. Combined, the boreholes and geologic sections cover the Illinois shore from south Waukegan on the north to Evanston on the south.

Figures 2 and 3 show their locations. Appendix A includes tables that present the geologic and engineering data from these boreholes and geologic outcrop sections. The tables are arranged in numerical order. The tables give descriptions of each sample, followed by a graphic log, index properties, grain-size fractions and X-ray data. Up to eight index properties are presented (Table 1). N/BPF represents the values from a standard penetration test given as number of blows per foot. Qu/TSF refers to the Unconfined Compression Strength in tons per square foot. SS/TSF refers to shear strength in tons per square foot. Moisture Content is given in percent under the symbol W. The Liquid Limit is given under LL as percent. The Plasticity Index is presented under PI as percent. DD/PCF presents dry density in pounds per cubic foot. DW/PCF refers to wet density.

Four size fractions--gravel (Gvl), sand (Sd), silt (St) and clay (Cl)--are presented as percentages. Seven X-ray characteristics are given. DI, the Diffraction Index, is a measurement of diffraction intensity. M represents the percent composition of the clay mineral montmorillonite. I refers to the percent of the clay mineral illite present. C-K refers to the clay minerals chlorite and kaolinite as a combined percent. Cal refers to calcite (percent) and Dol refers to dolomite. Verm. Index, the Vermiculite Index, is a sensitive index of the amount of weathering experienced by the sample. The index is derived by comparing the X-ray diffraction graph peak of first-order chlorite to that of illite. Negative values, such as 5<, indicate fresh materials whereas positive values, such a 5> represent weathered materials.

Appendix B includes engineering measurements made of samples available from cross-section boreholes. The tables are arranged in numerical order.

APPENDIX A

Stratigraphic descriptions, graphic logs, index properties, grain-size data and clay mineralogy from fourteen boreholes and twelve outcrop sections. See Figures 2 and 3 for locations.

Lake Michigan Bluff Exposure 1 (North)
NE/C of NE, SW, SE, Sec. 33, T. 45N, R. 12E,
Waukegan Quadrangle

Elevation: 640' Est.

110' North of 4th groin South of U.S. Steel Plant in Waukegan

				Index Properties				Grain Size				X-Ray Data						
Spl. No.	Depth of Sample	Unit Description	Graphic Log	Qu TSF	W %	LL %	PI %	Gvl % total	Sd %	St %	Cl %	DI	M %	I %	C-K %	Cal	Dol	Verm. Index
1- 1	1.5	Brn sand and slt with grvly cly mtx (SC)		4.5+	8.63	--	--	37	38	32	30	--	--	--	--	--	--	--
1- 2	2.5			4.5+	12.29	--	--	23	50	18	32	2.6	35	52	13	--	--	--
1- 3	3.5			4.5+	10.81	--	--	42	33	25	42	4.7	28	63	9	--	--	--
1- 4	4.5			4.5+	11.01	--	--	39	48	16	36	4.2	28	62	10	--	--	--
1- 5	5.5	Brn cly fn grvl		3.0	25.65	55.4	22.1	52	34	21	45	5.0	28	63	9	14	15	--
1- 6	6.5	Brown clayey silt till (CL-ML)		4.5+	14.37	--	--	4	11	47	42	4.5	8	80	12	21	45	10 <
1- 7	7.5			4.5+	14.54	22.7	6.7	5	15	49	36	4.6	8	80	12	36	56	9 <
1- 8	8.5			4.5+	14.43	--	--	13	10	57	33	3.7	7	79	14	45	54	5 <
1- 9	9.5	Gray clayey silt till with shale inclusion (CL-ML)		3.5-4.0	14.80	--	--	2	14	58	28	2.6	8	73	19	50	72	11 <
1-10	10.5			3.5-4.0	13.31	20.2	5.5	5	16	54	30	2.8	7	75	18	42	62	15 <

Lake Michigan Bluff Drilling Project, Boring 13
SW/C of NE, NW, NE, Sec. 19, T. 44N., R. 12E

Waukegan Quadrangle

Core file number : 10529

Elevation: 682' Est.

Spl. No.	Depth of Sample	Unit Description	Graphic Log	N BPF	W %	Grain Size: Gvl % total	Sd %	St %	Cl %	X-Ray Data: DI	M %	I %	C-K %	Cal	Dol	Verm. Index
15	45.5-46	Gr, Sty, fn.Sd (SM)		32/18"	-	1	24	60	16	3.0	8	75	17	27	38	13<
16	46-47	Gray silt (CL-ML). (ML)			18.0	1	1	50	49	2.5	6	74	20	31	57	16<
17	50.5-52	Gray silty clay till (CL)		55/18"	-	1	7	32	61	2.4	6	73	21	51	54	9<
18	55.5-57	Gr, md, cy, sd. & gr. SW		40/18"	-	19	87	5	8	3.4	5	80	15	15	39	19<
		Total Depth	57.0'													

Lake Michigan Bluff Exposure 19 (Main)
NE/C of NW, NW, SW, Sec. 24, T. 43N, R. 12E
Highland Park Quadrangle

Elevation: 659'+

242' south of bench mark on east end of Laurel Avenue
Highland Park

				Index Properties				Grain Size				X-Ray Data						
Spl. No.	Depth of Sample	Unit Description	Graphic Log	Qu TSF	W %	LL %	PI %	Gvl % total	Sd %	St %	Cl %	DI	M %	I %	C-K %	Cal	Dol	Verm. Index
-																		
-		Brown & gray																
4	4.5	clayey silt		4.5+	12.6	23.0	6.6	3	12	43	45	4.8	16	74	10	41	49	1½ >
5	5.5	till		4.5+	14.5	25.5	9.6	3	11	46	43	4.7	16½	73½	10	45	55	2½ >
6	6.5	(CL-ML)		3.75	13.8	22.9	6.1	8	11	46	43	5.5	15½	75½	9	37	65	3½ >
7	7.5			4.25	14.2	22.4	6.1	13	10	49	41	6.4	15	77	8	32	66	2½ <

Lake Michigan Bluff Exposure 6 (North)
SW/C of NE, SW, SE, Sec. 9, T. 44N, R. 12E,
Waukegan Quadrangle

Elevation: 650' Est.

391' North of Service drive seawall at Shore Acres Country Club

Spl. No.	Depth of Sample	Unit Description	Graphic Log	Index Properties: Qu TSF	W %	LL %	PI %	Grain Size: Gvl % total	Sd %	St %	Cl %	X-Ray Data: DI	M %	I %	C-K %	Cal	Dol	Verm. Index
		Lt yellow-brn																
		to gray till,																
		colluvium,																
6N-1	3.5	water laid		4.5+	18.55	29.3	7.0	0	2	47	51	--	--	--	--	--	--	--
6N-2	4.5	(CL-ML) ?		4.5+	18.90			--	--	--	--	--	--	--	--	--	--	--
6N-3	5.5	Brn clayey		4.25	14.49			11	17	41	42	--	--	--	--	--	--	--
6N-4	6.5	silt till		4.25	12.49	24.8	9.1	1	13	50	37	--	--	--	--	--	--	--
6N-5	7.5	(CL)		4.5+	13.42			0	6	50	44	--	--	--	--	--	--	--
6N-6	8.5	Brown clayey		4.5+	18.89	37.9	17.1	4	0	48	52	--	--	--	--	--	--	--
		silt																
		(CL)																

Lake Michigan Bluff Exposure 6 (Main)
SW/C of NE, SW, SE, Sec. 9, T. 44N, R. 12E,
Waukegan Quadrangle

Elevation: 650' Est.

329' North of service drive seawall at Shore Acres Country Club

Spl. No.	Depth of Sample	Unit Description	Graphic Log	Index Properties: Qu TSF	W %	LL %	PI %	Grain Size: Gvl % total	Sd %	St %	Cl %	X-Ray Data: DI	M %	I %	C-K %	Cal	Dol	Verm. Index
		Yellow-brown																
		and gray mot-																
6-26	4.5	tled clayey		4.5	6.40	--	--	3	12	47	41	--	--	--	--	--	--	--
6-27	5.5	silt till		4.5+	7.61	--	--	2	14	49	37	--	--	--	--	--	--	--
		(CL-ML)																
6-28	6.5	**Lt tan slt fn sd**		4.5+	2.70	--	--	0	44	45	11	--	--	--	--	--	--	--
6-29	7.0	Yellowish tan		1.5-2.0	2.86	--	--	0	60	35	5	--	--	--	--	--	--	--
6-30	8.0	to brown		<1.0	3.61	--	--	0	94	2	4	--	--	--	--	--	--	--
6-31	9.0	fine to		<1.0	3.47	--	--	0	96	1	3	--	--	--	--	--	--	--
6-32	10.0	medium cross		2.5	4.18	--	--	0	94	1	5	--	--	--	--	--	--	--
6-33	11.0	bedded sand		2.5	4.40	--	--	0	90	5	5	--	--	--	--	--	--	--
6-34	12.0	(SP)		1.0	4.41	--	--	0	84	11	5	--	--	--	--	--	--	--
6-35	13.0			1.5-2.0	13.40	--	--	0	14	80	6	--	--	--	--	--	--	--
6-36	14.5			1.5-2.0	9.51	--	--	0	66	28	6	--	--	--	--	--	--	--
6-37	16.0			1.5-2.0	3.25	--	--	0	93	1	6	--	--	--	--	--	--	--
6-38	17.0	Massive gray		4.5+	17.24	--	--	0	3	77	20	--	--	--	--	--	--	--
6-39	18.5	clayey silt,		--	16.30	--	--	0	0	83	17	--	--	--	--	--	--	--
6-40	20.0	sand lenses		--	13.93	--	--	0	1	59	40	--	--	--	--	--	--	--
		near base																
		(ML)																

Exposure 6 south (Continued)

Spl. No.	Depth of Sample	Unit Description	Graphic Log	Qu TSF	W %	LL %	PI %	Gvl % total	Sd %	St %	Cl %	DI	M %	I %	C-K %	Cal	Dol	Verm. Index
6-23	26.0	(CL-ML)		4.5+	11.5	20.5	4.3	6	11	63	26	2.2	6	72	22	27	52	15<
6-24	28.0	Gray clayey		4.5+	11.3			5	10	63	27	2.4	7	73	20	30	40	12<
6-25	30.0	silt till		4.5+	12.4	20.0	2.9	3	11	66	23	2.4	4	75	21	35	45	18 <
		(CL)																

Lake Michigan Bluff Exposure 13 (South)
SE, SE, SE, Sec. 21, T. 44N, R. 12E,
Waukegan Quadrangle

Elevation: ≈ 650'

Spl. No.	Depth of Sample	Unit Description	Graphic Log	Index Properties: Qu TSF	W %	LL %	PI %	Grain Size: Gvl % total	Sd %	St %	Cl %	X-Ray Data: DI	M %	I %	C-K %	Cal	Dol	Verm. Index
--	1- 2	Dark yellowish brown clayey silt till (CL)																
--	3- 4																	
--	5- 6	Intbed. sand & gravel, silt, boulders, till inclusions (SM)																
--	7- 8																	
--	9-10																	
13_g-1	11-12			1.75	6.9	--	--	0	70	22	8	3.2	13	72	15	19	32	4 <
13_g-2	13-14			4.5+	14.7	--	--	0	15	70	15	2.5	13	69	18	31	58	2 <
13_g-3	15-16	Grayish-brown silty clay till (CL)		4.5+	13.3	--	--	0	10	42	48	2.6	10	72	18	54	84	11 <
13_g-4	17-18			4.0	16.4	--	--	2	10	42	48	2.9	11	73	16	50	57	8 <

Lake Michigan Bluff Exposure 13 (North)
Southernmost shore, Lake Bluff
SE, SE, SE, Sec. 21, T. 44N, R. 12E,
Waukegan Quadrangle

Elevation: ≈650'

Spl. No.	Depth of Sample	Unit Description	Graphic Log	Index Properties: Qu TSF	Index Properties: W %	Index Properties: LL %	Index Properties: PI %	Grain Size: Gvl % total	Grain Size: Sd %	Grain Size: St %	Grain Size: Cl %	X-Ray Data: DI	X-Ray Data: M %	X-Ray Data: I %	X-Ray Data: C-K %	X-Ray Data: Cal	X-Ray Data: Dol	X-Ray Data: Verm. Index
--	1- 2																	
13N-1	3- 4			3.5	16.9	33.2	13.9	5	17	41	42	4.6	24	65	11	--	42	18 >
13N-2	5- 6	Dark yellowish		3.0	18.2	31.1	10.3	12	27	30	43	4.1	29	61	10	--	16	21 >
13N-3	7- 8	brown clayey		4.0	18.5	33.2	12.9	2	15	39	46	4.9	19	71	10	--	15	9 >
13N-4	9-10	silt till		2.75	19.7	30.9	11.9	5	17	35	48	4.6	19	70	11	--	16	10 >
13N-5	11-12	(CL)		2.5	20.8	34.2	13.8	4	17	35	48	4.8	21	69	10	--	--	16 >
13N-6A	13-14	14'		--	21.0	36.5	15.3	12	19	38	43	4.0	37	54	9	--	--	27 >
13N-6	14.0	Dark brown		1.0	5.5	--	--	5	80	7	13	5.2	6	83	11	16	47	17 <
—Inclusions—		sand & gravel		—till inclusions—				2	10	45	45	4.4	16	73	11	42	60	=
		with boulders																
		and till. (SW)																
		inclusions																

Lake Michigan Bluff Exposure 13 (Main)
SE, SE, SE, Sec. 21, T. 44N, R. 12E.
Waukegan Quadrangle

Elevation: ≈650'

Spl. No.	Depth of Sample	Unit Description	Graphic Log	Index Properties: Qu TSF	W %	LL %	PI %	Grain Size: Gvl % total	Sd %	St %	Cl %	X-Ray Data: DI	M %	I %	C-K %	Cal	Dol	Verm. Index
		Dark yellowish																
--	1- 2	brown clayey																
--	3- 4	silt till																
--	5- 6	(CL-ML)																
13- 5	7- 8	8.0		4.5+	15.8			1	11	46	43	4.4	13	75	12	10	54	7 <
13- 6	9-10			3.0	13.1			8	59	16	25	5.0	27	64	9	18	12	12 >
13- 7	11-12	Fine to coarse		2.25	9.9			1	72	17	11	3.6	9	77	14	--	21	7 <
13- 8	13-14	sand; silts		3.0	9.0			3	75	14	11	3.3	6	78	16	--	30	7 <
13- 9	15-16	interbedded		4.5+	18.2			0	15	72	13	3.4	18	68	14	--	60	4 >
13-10	17-	sands and		4.5+	16.4			0	11	75	14	2.7	13	70	17	19	63	=
13-11	18-19	silts; with		3.0	6.5			12	66	20	14	4.0	7	80	13	11	40	13 <
13-12	20-21	coarser sand		3.0	7.8	26.0	8.8	0	89	5	6	3.8	8	79	13	15	46	12 <
13-13	22-23	and gravel		3.25	11.0			0	59	33	8	2.6	14	68	18	12	60	=
13-14	24-25	with cobbles		1.75	8.1			0	85	10	5	2.5	8	73	19	--	29	8 <
13-15	26-	and boulders		3.5	17.5	16.9	--	0	14	72	14	2.2	11	68	21	40	70	5 <
13-16	27-28	and till		2.0	8.3			0	86	8	6	2.7	5	76	19	10	29	14 <
13-17	29-30	inclusions		4.0	14.2			0	62	31	7	3.6	5	80	15	17	36	19 <
13-18	31-32	at top and		4.5	18.4			0	10	82	8	2.5	13	69	18	18	54	4 <
13-19	33-34	bottom		3.5	20.0			0	43	49	8	2.4	5	74	21	22	31	8 <
13-20	34.5	(SM)		4.25	18.3	17.5	--	0	12	81	7	2.0	10	68	22	16	31	3 <
13-21	35-	36.0		1.5	6.0			5	90	4	6	3.6	6	80	14	19	66	15 <
13-22	36-37	Dark grayish-		4.5+	13.4			2	11	44	45	2.5	9	72	19	65	75	10 <
13-23	38-39	brown clayey		4.0	15.3			3	10	44	46	2.5	11	70	19	52	59	8 <
13-24	40-41	silt till		4.5+	15.7	28.8	11.2	4	8	44	48	3.0	10	74	16	58	77	11 <
13-25	42-43			--	15.5			19	4	48	48	2.7	11	72	17	59	78	10 <
13-26	44-45			4.5+	14.4	29.5	11.8	1	11	44	45	2.2	7	71	22	65	90	12 <
13-27	46-			4.5+	15.9	31.5	13.5	2	10	42	48	2.6	7	74	19	46	70	10 <
		(CL)																

Lake Michigan Bluff Exposure [illegible] (North)
NE/C of NW, NW, SW, Sec. 24, T. 43N, R. 12E,
Highland Park Quadrangle

Elevation: 663' Est.

101 South of bench mark on east end of Laurel Avenue
Highland Park

				Index Properties				Grain Size				X-Ray Data						
Spl. No.	Depth of Sample	Unit Description	Graphic Log	Qu TSF	W %	LL %	PI %	Gvl % total	Sd %	St %	Cl %	DI	M %	I %	C-K %	Cal	Dol	Verm. Index
		Gray & brown																
8	4.0	clayey silt		4.5+	14.5			4	11	44	45	5.0	14½	75½	10	25	55	1½ >
9	5.0	till		3.75	14.3	25.2	7.1	2	11	42	47	5.3	12½	78	9½	31	53	2 >
10	6.0	(CL)		4.5+	14.7			1	11	44	45	4.3	14½	74	11½	41	52	2 >
11	7.0			3.5	14.5	25.8	9.4	4	21	38	41	4.1	22	67	11	57	61	8½ >
12	8.0			4.5+	14.5			6	12	44	44	5.7	11	79½	9½	50	61	=
12A	8.8	Yellow-br silt		4.5+	19.0	21.0	0.9	3	7	70	23	2.8	8½	74	17½	18	85	5 <
13	9.0			4.5+	14.2	26.6	11.4	3	12	44	44	2.7	6½	75	18½	40	82	13 <

Exposure 4 (Continued)

Spl. No.	Depth of Sample	Unit Description	Graphic Log	Qu TSF	W %	LL %	PI %	Gvl % total	Sd %	St %	Cl %	DI	M %	I %	C-K %	Cal	Dol	Verm. Index
19	28.0	(CL)		4.5+E	12.2	23.2	7.3	0	1	66	33	2.5	11	71	18	60	61	7 <
20	30.0	Grayish-brown clayey silt		4.5+E	12.2	20.1	--	0	1	66	33	2.3	9	71	20	58	58	7 <
21	32.0			4.5+E	18.6	--	--	0	8	84	8	2.9	9	74	17	36	62	8 <
22	34.0	(CL)		4.5+E	17.6	--	--	0	4	78	18	2.2	9	70	21	44	59	6 <
23	36.0			4.5+E	14.3	23.9	7.9	0	0	63	37	2.4	10	71	19	45	60	4 <
24	38.0	Contact at 39.0'		4.5+E	16.9	--	--	0	0	69	31	2.3	8	71	21	59	75	6 <
25	40.0	Gray clayey silt till		4.5+E	13.6	20.3	3.7	2	12	51	37	2.3	8	72	20	70	76	11 <
26	42.0	(CL)		4.5+E	10.7	19.2	3.1	8	20	50	30	2.6	3	77	20	42	34	21 <
		Bottom of hole at 42.0'																

Lake Michigan Bluff Drill Hole No. 1, Foss Park, North Chicago
SE, NW, NE, Sec. 4, T. 44 N., R. 12 E.,
Waukegan Quadrangle

Elevation: 650 (est.)

				Index Properties						Grain Size					X-Ray Data					
Spl No.	Depth of Sample	Unit Description	Graphic Log	N BPF	Qu TSF	W %	SS TSF	DD PCF	DW PCF	Gvl % Total	Sd %	St %	Cl %	Dl	M	I	C-K	Cal	Dol	Verm Index
1	5.0	D(W)=137		20/19	6.9	15.0	3.5	119	137	3	10	47	43	4.2	18	71	11	41	63	1½ >
2	10.0	D(D)=120 W=14.8%		20/20	45/3E	14.5	2.3	121	139	4	12	48	40	4.6	11½	77½	11	37	59	2½ <
3	15.0	Qu=3.5/3E		6/11	1.9/3E	14.5	1.0	121	138	2	14	49	37	3.1	10	74	16	49	72	8 <
4	20.0	Gray silty till (CL)		10/13	1.7/3E	14.9	0.8	119	136	5	10	46	44	2.7	12	70½	17½	55	80	9 <
5	25.0			11/13	--/ 3E					3	9	46	45	2.3	10½	69½	20	58	71	7 <
6	30.0	D(W)=138 D(D)=124		16/17	1.9/3E	12.9	1.0	124	140	12	10	49	41	2.6	12½	69½	18	52	67	6 <
7	35.0	W=12.6% Qu=2.8/3E		17/36	3.9/3E	12.5	1.9	124	139	2	8	55	37	2.4	10½	70	19½	60	67	10 <
8	40.0			11/13	2.5/3E	12.2	1.2	122	137	9	19	53	28	2.3	10	69½	20½	50	76	12 <
		Liquid Limit	25.5%																	
		Plastic Index	8.6%																	

*E-Field Estimate

Lake Michigan Bluff Drill Hole No. 2, Lake Park, Lake Bluff
NW, SE, NE, Sec. 21, T. 44N. R. 12E.
Waukegan Quadrangle

Elevation: 650' (est.)

				Index Properties							Grain Size			X-Ray Data						
Spl No.	Depth of Sample	Unit Description	Graphic Log	N BPF	Qu TSF	W %	SS TSF	DD PCF	DW PCF	Gvl % Total	Sd %	St %	Cl %	Dl	M	I	C-K	Cal	Dol	Verm Index
1	2½	Gray silty clay till (CL)		6/12	3.1/2.5E	22.1	1.6	98	120	3	34	29	38	3.0	81	15½	3½		21	
2	5.0			5/5	0.5/2.5E	27.2	0.3	96	123	1	15	44	40	3.0	53½	37½	8½	11		
3	10.0	Gray sands and silts (SM)		5/5	–/.5E					0	2	67	31	2.6	11½	70	18½	32	41	5<
4	15.0			6/7	–/.5E					0	67	21	12	2.7	11½	71	17½	41	58	7<
		Brown-gray till																		
5	20.0	Gray silt (ML)		13/12	0.9/4+E	19.6	0.4	109	131	0	0	49	51	2.9	10½	72½	17	53	74	11<
		Gray, silty clay till (ML-CL)												2.5	10½	70½	19	57	68	
6	25.0			20/18	0.1/.5E	17.1	0.2	115	135	0	5	62	33	2.5	13	68½	18½	59	67	5½<
7	30.0			17/20	0.9/3.5E	15.2	0.5	117	134	0	3	53	44	2.4	12½	68½	19	56	83	7 <

Lake Michigan Bluff Drill Hole No. 7, Glencoe Park, Glencoe

SW, SW, SW, Sec. 5, T. 42N., R. 13E.
Highland Park Quadrangle

Elevation: 662 (est.)

				Index Properties						Grain Size						X-Ray Data			
Spl No.	Depth of Sample	Unit Description	Graphic Log	N BPF	Qu TSF	W %	SS TSF	DD PCF	DW PCF	Gvl % Total	Sd %	St %	Cl %	Dl	M	I	C-K	Cal	Dol	Verm Index
1	2.5	Mottled Soil		28/50+	5+P					1	5	40	56	4.0	15	73	12½	40	51	2>
2	5.0			28/47	5+P					2	9	38	53	3.7	11	75½	13½	35	61	9<
3	7.5			30/44	5+P					3	4	38	58	3.5	10½	75½	14½	37	52	4<
4	10-11	Gray clay		13/18	3.7/5+P	17.8	1.9	113	134	1	6	37	57	3.2	8	76	16	36	53	8<
5	15-16	silty till(CL)		7/13	2.2/3.5P	15.8	1.1	111	129	3	8	38	54	2.6	8	73	19	32	54	7<
6	20-21	D(W)=133		7/10	2.4/3P	19.4	1.2	113	135	2	9	43	47	2.5	8	72½	19½	29	45	9<
7	25-26	D(D)=112 W=18.2%		10/12	2.2/3P	16.6	1.1	111	130	2	9	40	52	2.2	8	71	21	39	42	2<
8	30-31	Qu=2.3		6/10	1.9/3P	21.2	0.9	111	135	4	9	40	52	2.5	9	71½	19½	41	56	6<
9	35-36			7/10	2.1/3P	18.5	1.1	112	132	4	10	39	51	2.6	10½	71½	18	39	46	10<
10	40-41			8/12	4.0P					2	17	39	44	2.4	9	71½	19½	28	40	8<
11	45-46			10/15	2.4/4P	18.5	1.2	114	135	3	16	32	53	2.6	5½	75½	19	24	30	14<
12	55-56			10/15	4.5P															

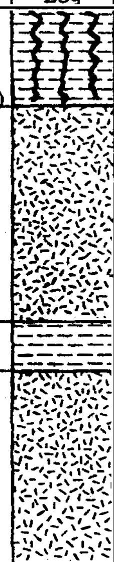
Liquid Limit 29.2%
Plastic Index 10.9%

*E=Field Estimate

Lake Michigan Bluff Drill Hole No. 8, Tower Park, Winnetka

SE, SE, NE, Sec. 17, T. 42N., R. 13E.
Evanston Quadrangle

Elevation: 653 (est.)

				Index Properties						Grain Size				X-Ray Data						
Spl No.	Depth of Sample	Unit Description	Graphic Log	N BPF	Qu TSF	W %	SS TSF	DD PCF	DW PCF	Gvl % Total	Sd %	St %	Cl %	Dl	M	I	C-K	Cal	Dol	Verm Index
1	2.3-3.5	Red-brown silty clay		14/16	4.0P/2.1	18.6	1.0	112	133	1	2	40	58	6.3	18	74	8	45	61	3 >
2	5.0	Colluvium (CL)		15/16	5+P/4.1	17.6	2.1	112	132	0	2	31	67	5.3	18	73	9	41	49	2 >
3	10.0	Gray-Brown silty till (CL)		15/16	5+P/1.0	10.7	0.5	120	132	9	21	30	49	3.7	12½	74	13½	24	39	5 <
4	15-16	W=13.4%		11/11	5+/2.4	17.0	1.2	113	132	3	5	31	64	2.5	11½	70	19	45	48	6 <
5	20-21	Qu=2.3/5P		13/15	4.5P/3.1	12.6	1.5	124	140	3	14	33	53	2.5	10	71	19	29	44	3½<
6	25-26	Silt (ML)		10/14	3P/2.2	16.0	1.1	118	137	1	8	35	57	2.8	9	73	18	41	51	7½<
7	30-31	Gray-brown silty till		9/11	5+P/1.3	17.8	0.7	111	130	2	6	28	66	3.1	10	74	16	33	50	5 <
8	35.0	(CL)		4/9	2P/1.6	15.9	0.8	116	134	5	8	30	62	2.3	8½	71	20½	38	48	3½<
9	40.0	D(W)=132 D(D)=114		5/10	4.5P/--					2	8	25	67	3.3	6½	78	15½	38	38	15 <
10	45-46	W=17% Qu=1.5/3.5P								2	8	30	61	2.6	7½	73½	19	30	48	6½<

Liquid Limit 26.6%
Plastic Index 8.6%

*E=Field Estimate

Lake Michigan Bluff Drill Hole No. 9, Elder Park, Winnetka

SW, NE, SE, Sec. 21, T. 42N., R. 13E. Elevation: 610 (est.)
Evanston Quadrangle

Spl No.	Depth of Sample	Unit Description	Graphic Log	N BPF	Qu TSF	W %	SS TSF	DD PCF	DW PCF	Gvl % Total	Sd %	St %	Cl %	Dl	M	I	C-K	Cal	Dol	Verm Index
				Index Properties						**Grain Size**				**X-Ray Data**						
1	2.5	Fine gr. sand (SM)		14/16						0	91	4	6					20	36	
2	5.0			10/10	2.5/3.5E	15.9	2.4	116	134	2	70	23	7							
		Gray silt till (CL)																		
3	7.5	Med. gr. sand (SM)		12/13	5+P					9	3	27	70	2.6	12	70	18	55	51	6 <
4	10-11			14/16	4.9/5+P	16.1	4.8	117	136	0	3	28	68	2.6	11	71	18	56	56	7 <
5	15-16	Gray silty clay till (CL)		10/12	2.8/3P	19.9	2.6	111	134	0	3	29	68	3.0	13	71	16	56	52	6½<
6	20.0			12/13	2.8/3.5E	19.7	2.8	111	132	1	4	25	71	2.6	11	70½	18½	49	57	8 <
7	25-26			10/12	1.8/3.5E	15.5	1.7	120	139	2	8	35	57	2.2	11½	68	20½	62	58	8 <
8	30-31	D(D)=116 W=17.1% Qu=2.7/3P		10/12	2.4/2.5E	14.8	2.4	121	138	2	7	26	67	2.6	8	73	19	45	51	13½<
9		Gray silty till (CL)		10/24	3.4/5+P	10.7	3.4	127	141	4	8	36	56	2.8	10	73	17	50	59	8½<
10				12/13	1.8/3P	17.8	1.7	112	132	11	14	36	49	3.6	3+	81½	15+	22	35	31 <
		D(D)=112 W=17.8% Qu=1.8/3P																		

*E=Field Estimate

Lake Michigan Bluff Drill Hole No. 4, Old Sheridan Rd., Edgecliff, Highland Park

NW, NW, SE, Sec. 14, T. 43N., R. 12E.
Highland Park Quadrangle

Elevation: 657 (est.)

Spl No.	Depth of Sample	Unit Description	Graphic Log	N BPF	Qu TSF	W %	SS TSF	DD PCF	DW PCF	Gvl % Total	Sd %	St %	Cl %	Dl	M	I	C-K	Cal	Dol	Verm Index
					Index Properties						Grain Size				X-Ray Data					
1	5-5½	Brown-gray		20/24	20.7	12.7	10.3	125	141	3	12	46	41	3.8	13½	73½	13	48	70	½<
2	10-10½	To gray till (CL)		20/16	3.6	13.9	1.8	122	139	9	10	48	42	2.6	9½	72½	18½	50	64	11 <
3	15-15½	D(D)=121 W=14.1%		14/16	2.3	14.1	1,1	120	137	3	9	51	40	2.5	12	69½	18½	49	68	8 <
4	20.0	Qu-2.9		10/14	2.8	14.2	1.4	116	133	1	8	51	41	2.4	11	70	19	61	55	4½<
5	25.0	Gray silty till (CL)		13/14	4.9	11.9	2.4	127	142	5	13	49	38	2.7	11	71½	17½	52	72	8½<
6	30-30½			12/18	3.1	14.1	1.5	122	139											
7	35-35½	D(W)=139 D(D)=122 W=14.5%		12/21	3.4	14.7	1.7	121	139	1	7	54	39	2.5	9	72	19	72	74	8 <
8	40-41½	Qu=3.2		13/16	1.6	14.6	0.8	119	136	5	5	56	39	2.4	10	70½	19½	66	77	9½<
		Liquid Limit	24.8%																	
		Plastic Index	7.3%																	

Lake Michigan Bluff Drill Hole No. 5B, Forest Park, Lake Forest
SW, NE, NW, Sec. 34, T. 44 N., R. 12 E.,
Waukegan Quadrangle

Elevation: 650 (est.)

						Index Properties					Grain Size				X-Ray Data					
Spl No.	Depth of Sample	Unit Description	Graphic Log	N BPF	Qu TSF	W %	SS TSF	DD PCF	DW PCF	Gvl % Total	Sd %	St %	Cl %	Dl	M	I	C-K	Cal	Dol	Verm Index
1	4½-5	Brown-gray		6/12	0.8	21.7	0.4	103	125	2	8	44	48	5.2	27	64½	8½	25	60	10 >
2	7½-8	Silty till		9/28	5.1	14.0	2.5	118	135	1	9	46	46	5.4	13½	77	9½	32	67	3 <
3	10-10½	(CL)		14/16	3.4	15.9	1.7		133	3	10	43	47	3.1	9½	74½	16	60	75	8 <
4	15-15½	D(W)=134 D(D)=116		14/11	2.2	16.9	1.1	115	134	2	10	43	46	2.8	11	72	17	61	80	10 <
5A	20/20½	Qu=2.8		10/11	0.8	16.8	0.4	115	134	3	9	41	51	2.6	10	72	18	42	64	6½ <
5B	20½-	Sand (SC)								1	78	7	15	2.6	8	73	19	42	64	8½ <
		Liquid Limit	30.1%																	
		Plastic Index	8.9%																	

Lake Michigan Bluff Drill Hole No. 10
NE, Corner of Birch Street extended
& Blodgett Avenue, Lake Bluff

Core file number: C10526

Elevation: 647' Est.

SW/C of SE, SW. SE, Sec. 16, T. 44N., R. 12E

Waukegan Quadrangle

Spl. No.	Depth of Sample	Unit Description	Graphic Log	N BPF	W %	Grain Size: Gvl % total	Sd %	St %	Cl %	X-Ray Data: DI	M %	I %	C-K %	Cal	Dol	Verm. Index
1	0-1.5	Gray-brown mottled clayey silt with sand seams (ML)		–	–	2	1	45	54	2.8	18	66	16	–	43	4 <
2	1.5-3.0			–	18.5	0	10	54	35	2.5	16	67	17	24	38	1 <
3	3.0-4.5			–	–	1	12	55	33	2.3	15	66	19	23	63	2 <
–	4.5-5.5			–	–											
4	5.5-7.0			–	–	0	23	44	33	3.1	11	73	16	40	53	6 <
5	7.0-8.5			–	–	–	–	–	–	3.4	11	74	15	8	40	5 <
6	8.5-10.0			–	23.5	0	1	31	68	3.4	11	70	19	33	48	5 <
7	15.0-16.5	Gray silty clay till (CL)		–	–	4	8	49	43	2.3	7	72	21	44	55	6 <
8	20.0-21.5			–	17.0	10	8	46	46	2.6	10	71	19	50	63	8 <
9	25.0-26.5			–	–	1	9	44	47	2.7	9	73	18	46	61	6 <

Total Depth 26.5'

Lake Michigan Bluff Drill Hole No. 11
NE, Corner of Sheridan Road
& Blodgett Avenue, Lake Bluff

SE/C of SW, SW, SW, Sec. 16, T. 44N., R. 12E

Core file number: C10527

Elevation: 678' Est.

Spl. No.	Depth of Sample	Unit Description	Graphic Log	N BPF	W %	Grain Size: Gvl % total	Sd %	St %	Cl %	X-Ray Data: DI	M %	I %	C-K %	Cal	Dol	V I
1	0-1.5	Brown clayey silt till (CL)		-	-	2	10	36	54	5.4	14	76	10	18	17	4
2	1.5-3.0			-	17.0	1	10	44	46	4.7	16	73	11	10	18	8
3	3.0-4.5			-	-	1	11	50	39	5.3	16	74	10	8	36	4
4	4.5-6.0			-	-	4	7	53	40	5.9	11	80	9	22	47	3
-	6.0-7.0	Brown and gray silt sand and gravel (SM)														
5	7.0-8.5			-	19.0	21	47	28	25	7.8	3	89	8	16	29	19
-	8.5-10.0															
6	10.0-11.5			-	-	1	23	66	11	3.5	5	80	15	-	34	15
7	15.5-17.0			-	-	1	26	58	16	2.6	5	75	20	32	67	10
8	20.5-22.0			-	-	8	39	47	14	2.7	3	78	19	13	49	20
9	25.5-27.0			-	-	8	29	54	17	2.8	5	77	18	24	42	1
		Total Depth 27.0'														

Lake Michigan Bluff Drill Hole No. 12
Lake Bluff Central Elementary School, Lake Bluff

Core file number: 10528

Elevation: 705' Est.

SE/C of SE. SE, SW, Sec. 17, T. 44N., R. 12E

Waukegan Quadrangle

Spl. No.	Depth of Sample	Unit Description	Graphic Log	N BPF	W %	Grain Size: Gvl % total	Sd %	St %	Cl %	X-Ray Data: DI	M %	I %	C-K %	Cal	Dol	Verm. Index
1	0-1.5	Yellow-brown clayey silt till, oxidized (CL)		-	-	9	18	45	37	2.4	19	63	18	-	-	30 >
2	1.5-3.0			-	17.0	8	12	49	39	3.7	14	73	13	45	54	4 >
3	3.0-4.5			-	-	1	10	42	48	4.5	12	76	12	42	54	<
4	4.5-6.0			-	17.5	4	11	41	48	5.8	14	77	9	43	50	=
5	6.0-7.5			-	19.0	6	9	43	48	7.1	14	78	8	48	45	<
6	7.5-9.0			-	17.5	4	17	43	40	5.0	13	76	10	46	60	3 <
7	9.0-10.0			-	-	5	12	49	39	4.3	12	76	12	42	46	=
8	10.0-10.5	Gray clayey silt till (CL-ML)		-	-	6	18	45	37	3.2	9	75	16	51	60	5 <
9	10.5-12.0			-	16.5	2	12	44	44	2.5	10	71	19	47	67	6 <
10	15.0-16.5			-	18.5	3	10	42	48	2.7	10	72	18	47	55	8 <
11	20.0-21.5			-	-	5	11	51	38	2.5	12	70	18	52	61	3 <
12	25.0-26.5			-	16.5	6	11	45	44	2.4	9	71	20	56	64	9 <
13	30.0-31.5			-	-	7	16	47	37	2.6	10	71	19	50	59	7 <
14	35.0-36.5			-	-	6	11	46	43	2.6	10	71	19	51	66	11 <
15	40.0-41.5			-	17.5	3	12	43	45	2.5	11	70	19	51	63	6 <
16	45.0-46.5			-	17.5	6	10	46	44	2.5	9	72	19	52	60	11 <

End of Boring @ 46.5'

Lake Michigan Bluff Drilling Project, Boring 13
SW/C OF NE, NW, NE, Sec. 19, T. 44N., R. 12E, Knollwood

Waukegan Quadrangle

Core file number: 10529

Elevation: 682' Est.

Spl. No.	Depth of Sample	Unit Description	Graphic Log	N BPF	W %	Grain Size: Gvl % total	Sd %	St %	Cl %	X-Ray Data: DI	M %	I %	C-K %	Cal	Dol	Verm Index
1	0-1.5	Yellow-brown silty clay till, Oxidized (CL)		49/18"	-	9	9	41	50	5.2	8	81	11	30	55	11 <
2	1.5-3			120/18"	-	2	8	41	51	4.8	10	79	11	13	50	5 <
3	3-4.5			37/18"	11.2	3	5	43	52	4.8	10	79	11	30	49	6 <
4	4.5-6			98/18"	13.4	2	7	41	52	3.8	11	76	13	38	63	1 <
5	6-7			42/12"	15.2	1	9	40	51	5.4	9	81	10	41	50	3 <
-	7-8															
6	8-9.5			66/18"	12.8	4	9	41	50	4.0	7	80	13	49	71	10
	9.5-10.5															
7	10.5-12			43/18"	16.5	2	9	42	49	4.8	5	83	12	36	46	12
-	12-13	Gray, silty clay till with some seams of silt and fine sand (CL) (CL-ML)														
-	13-14.5			42/18"	16.6	-	-	-	-	-	-	-	-	-	-	-
-	14.5-15.5															
8	15.5-17			50/18"	-	3	9	40	51	3.2	6	78	16	33	80	15
-	17-18															
9	18-19.5			40/18"		2	6	44	50	2.9	5	77	18	29	45	16
-	19.5-20.5															
10	20.5-22			33/18"	17.6	2	8	42	50	2.4	4	75	21	43	70	16
11	25.5-27			34/18"	-	2	8	41	51	3.6	5	75	20	63	60	12
12	30.5-32			54/18"	17.0	3	8	42	50	2.6	5	76	19	46	63	17
13	35.5-37			50/18"	-	3	9	35	56	2.5	6	75	19	53	61	16
14	40.5-42			53/18"	-	2	6	46	48	2.4	8	72	20	60	61	11

Lake Michigan Bluff Drilling Project, Boring 13
SW/C of NE, NW, NE, Sec. 19, T. 44N., R. 12E

Waukegan Quadrangle

Core file number : 10529

Elevation: 682' Est.

						Grain Size				X-Ray Data						
Spl. No.	Depth of Sample	Unit Description	Graphic Log	N BPF	W %	Gvl % total	Sd %	St %	Cl %	DI	M %	I %	C-K %	Cal	Dol	Verm. Index
15	45.5-46	Gr, Sty, fn. Sd (SM)		32/18"	-	1	24	60	16	3.0	8	75	17	27	38	13<
16	46-47	Gray silt (CL-ML), (ML)			18.0	1	1	50	49	2.5	6	74	20	31	57	16<
17	50.5-52	Gray silty clay till (CL)		55/18"	-	1	7	32	61	2.4	6	73	21	51	54	9<
18	55.5-57	Gr, md, cy, sd. & gr. SW		40/18"	-	19	87	5	8	3.4	5	80	15	15	39	19<
		Total Depth	57.0'													

Lake Michigan Bluff Drill Hole No. 14
Northwest Corner of Intersection of
W. Blodgett Ave. & Rockland Ave., Lake Bluff

Core file number: 10530

Elevation: 687' Est.

SE/C OF SW, SE, SE, Sec. 17, T. 44N., R. 12E

Waukegan Quadrangle

						Grain Size				X-Ray Data						
Spl. No.	Depth of Sample	Unit Description	Graphic Log	N BPF	W %	Gvl % total	Sd %	St %	Cl %	DI	M %	I %	C-K %	Cal	Dol	Verm. Index
1	0-1	Brown and		45/18"	-	6	15	44	41	4.3	9	79	12	17	21	1<
2	1-1.5	gray mottled			-	1	14	36	50	4.7	17	72	11	-	10	14>
3	1.5-3	clayey silt		53/18"	-	4	11	49	40	5.8	17	74	9	38	37	8>
4	3-4.5	till		22/18"	-	7	16	45	39	5.5	16	75	9	39	41	3>
5	4.5-6	oxidized		23/18"	-	8	15	45	40	7.2	16	77	7	36	46	3>
6	6-7.5			37/18"	-	4	14	46	40	6.7	11	81	8	30	61	1<
-	7.5-8.5	(CL-ML)		-	-											
7	8.5-9.5			45/18"	-	2	12	47	41	5.2	9	80	11	36	59	4<
8	9.5-10				-	10	16	51	33	4.5	10	79	11	26	60	2<
-	10.0-10.5	Gray clayey		-	-											
9	10.5-12	silt till		24/18"	-	13	11	56	33	2.9	7	76	17	43	64	10<
		(CL-ML)														
10	15.5-17			21/18"	-	3	10	45	45	3.1	10	74	16	51	52	8<
		Bottom of Hole @ 17.0'														

Lake Michigan Bluff Drill Hole N. 15 — Core file number: 10531

30 ft. west of west side of 247 E. Blodgett Ave.
and 8 ft. north of Blodgett, Lake Bluff — Elevation: 659' Est.

SE/C of SW, SE, SE, Sec. 16, T. 44N., R. 12E

Waukegan Quadrangle

Spl. No.	Depth of Sample	Unit Description	Graphic Log	N BPF	W %	Grain Size: Gvl % total	Sd %	St %	Cl %	X-Ray Data: DI	M %	I %	C-K %	Cal	Dol
1	0-1.5	Brown		21/18"	-	4	20	40	40	5.8	50	45	5	-	-
2	1.5-3	silty clay		23/18"	-	6	32	33	35	3.3	73	22	5	-	-
3	3-4.5	till,		21/18"	-	5	11	41	48	5.8	17	74	9	-	-
4	4.5-6	oxidized (CL)		30/18"	-	1	14	54	32	5.4	21	70	9	-	-
-	6-8	Brown & gray,		-	-										
5	8-9.5	clayey silt,		31/18"	-	17	33	44	23	4.7	8	80	12	-	31
-	9.5-10.5	some sand &		-	-										
6	10.5-11.5	gravel		26/18"	-	1	4	72	24	3.2	6	78	16	35	63
7	11.5-12	(SM)				3	11	51	38	-	-	-	-	-	-
8	15.5-17	Gray		27/18"	-	2	13	50	37	2.8	8	74	18	54	72
		Clayey													
		silt till													
9	20.5-22			21/18"	-	4	11	45	44	3.2	8	76	16	44	63
		(CL-ML)													
10	25-26.5					-	-	-	-	2.9	9	74	17	41	58
		Total Depth 26.5'													

ake Michigan Bluff Exposure 1 (South)
E/C, NE, SW, SE, Sec. 33, T. 45N., R. 13E.
aukegan Quadrangle

Elevation: 640'

5' North of 4th Groin
outh of U. S. Steel Plant at Waukegan

				Index Properties				Grain Size				X-Ray Data						
l. .	Depth of Sample	Unit Description	Graphic Log	Qu TSF	W %	LL %	PI %	Gvl % total	Sd %	St %	Cl %	DI	M %	I %	C-K %	Cal	Dol	V In
		Dark brn.																
-11	3.5'	clayey gravel		4.5+	11.94			36	29	26	45	5.1	27	60	13	--	11	-
-12	4.5'	& sand (SC)		4.5+	13.28	45.3	18.6	8	60	12	28	5.4	35	58	7	17	15	-
-13	5.5'	Brown		4.5+	18.28			2	11	52	37	6.8	12	80	8	9	23	
-14	6.5'	clayey silt		4.5+	14.03			3	9	44	47	5.4	11	79	10	34	46	
-15	8.5'	till (CL)			13.67	23.1	7.5	6	11	51	38	5.4	9	81	10	28	50	
-16	10.5				12.34			3	21	55	24	5.3	11	79	10	33	46	

Lake Michigan Bluff Drill Hole No. 5A, Central Park, Highland Park

SW, SW, NW, Sec. 24, T. 43N., R. 12E. Elevation: 665 (est.)
Highland Park Quadrangle

				Index Properties						Grain Size					X-Ray Data					
Spl No.	Depth of Sample	Unit Description	Graphic Log	N BPF	Qu TSF	W %	SS TSF	DD PCF	DW PCF	Gvl % Total	Sd %	St %	Cl %	Dl	M	I	C-K	Cal	Dol	Verm Index
1	5-5½	Tan and gray fine-medium gr. sand (SM)		13/13						0	33	52	15		13½	75	11½	16	39	4
2	10-10½			12/13						0	72	15	14		7½	77	15½	14	68	10½
3	15-15½	Gray silty till (CL) D(W)=138 W-15.0 Qu=2.7		9/11	2.3/–	14.3	1.2	121	139	3	11	46	42		9½	70	20½	64	75	11½
4	20-20½			10/14	1.6/3P	14.8	0.8	118	136	5	11	49	40		11½	70	18½	73	72	10½
5	25-25½			11/11	2.5/4P	15.7	1.3	119	137	6	13	45	42		8	73½	18½	50	64	[illegible]
6	30-30½			11/13	4.2/–	15.0	2.1	120	138	4	10	44	45		10	70	20	67	84	[illegible]
7	35-35½			12/14	2.6/–	14.8	1.3	120	138	6	10	45	45		11½	70	18½	54	65	[illegible]
8	40-40½			16/14	3.2/–	15.6	1.6	119	138	5	9	45	46		17½	72	20½	63	77	[illegible]
		Liquid Limit	22.2%																	
		Plastic Index	3.6%																	

Lake Michigan Bluff Drill Hole No. 6, Roger Williams Park, Highland Park

NW, NW, NW, Sec. 31, T. 43 N., R. 13E. Elevation: 640 (est.)
Highland Park Quadrangle

				Index Properties						Grain Size					X-Ray Data					
Spl No.	Depth of Sample	Unit Description	Graphic Log	N BPF	Qu TSF	W %	SS TSF	DD PCF	DW PCF	Gvl % Total	Sd %	St %	Cl %	Dl	M	I	C-K	Cal	Dol	Verm Index
1	5-5½	Reddish-brown		17/19	4.1/–	15.2	2.1	117	135	3	11	40	49	5.2	15	75½	9½	49	62	-
2	10-10½	silty till (CL)		11/26	1.9/–	14.9	1.0	115	132	5	11	43	46	4.1	11	76½	12½	42	58	-
3	13-15½			7/7	1.3/–	16.0	0.6	112	130	3	11	44	44	2.2	6½	71½	22	46	79	13<
4	20-20½	Gray-brown silty till		8/9	0.3/–	20.7	0.1	110	133	2	8	46	46	2.2	10	69	21	72	85	7<
5	25-25½	D(W)=134		12/15	2.2/–	16.7	1.1	111	130	5	8	45	47	2.3	11	69	20	72	77	7<
6	30-30½	D(D)=116 W=16.8%		14/17	2.1/–	17.0	1.0	116	136	2	5	45	50	2.5	8½	72	19½	78	71	7<
7	35-35½			17/14	2.5/–	17.4	1.3	121	142	1	5	44	51	2.3	11	69	20	66	73	6<
8	40-40½			18/16	3.4/–	15/9	1.7	118	136	1	16	52	31	2.4	12	69	19	66	86	5<
		Liquid Limit	28.3%																	
		Plastic Index	9.1%																	

ake Michigan Bluff Exposure 19 (South)
E/C of NW, NW, SW, Sec. 24, T. 43N, R. 12E,
ighland Park Quadrangle

83 South of bench mark on east end of Laurel Avenue
ighland Park

Elevation: 658' Est.

				Index Properties				Grain Size				X-Ray Data						
pl. No.	Depth of Sample	Unit Description	Graphic Log	Qu TSF	W %	LL %	PI %	Gvl % total	Sd %	St %	Cl %	DI	M %	I %	C-K %	Cal	Dol	Verm Index
		Brown & gray clayey silt till (CL-ML)																
1	3.0			4.5+	14.1	27.5	8.7	3	11	44	45	4.0	16	72	12	36	59	5
2	4.0			4.5+	13.6	23.4	6.6	7	18	44	38	4.8	13½	76	10½	45	52	1
3	5.5			3.0	14.0	23.3	7.1	5	15	47	38	4.2	14	74	12	28	63	2

CROSS SECTION A-A'

Borehole #1
SW/c of SW, NW, SE, Sec. 17, T. 45N., R. 12E.
Waukegan Quardrangle, Elevation 665' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-5'	Fill	-	-	-	-
5-12'	Brown, silty fine sand, trace to some gravel, medium dense (SM)	-	-	13	-
12-20'	Gray silty clay, trace sand and gravel, very tough, (CL)	25	2.3	13	-
20-27.5'	Gray, silty fine to coarse sand, trace gravel very dense (SM)	73	-	8	-
27.5-34'	Gray fine to coarse sand and gravel, trace silt, very dense (SW-GP)	90	-	8	-
34-40'	Gray, silty clay, trace sand and gravel, hard, (CL)	-	-	15-26	-
	End of Boring 40'				

CROSS SECTION A-A' (continued)

Borehole #2
SW, NE, SE, Sec. 17, T. 45N., R. 12E.
Waukegan Quadrangle, Elevation 654' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-4'	Clayey fill and topsoil	-	-	-	-
4-33'	Gray, silty clay till, (CL) (CL-CH)	-	-	-	-
33-37'	Gray silt, (ML)	-	-	-	-
37-43"	Gray, silty clay, (CL-ML)	-	-	-	-
	End of Boring 43'				

CROSS SECTION A-A' (continued)

Borehole #3
NW/c of NE, SW, SW, Sec. 16, T. 45N., R. 12E.
Waukegan Quadrangle, Elevation 655' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-2.5'	No sample	-	-	-	-
2.5-3.5'	Light brown and gray silty clay, trace sand, pockets of light gray silt, very tough, (CL-CH)	-	3.2-3.7	25	-
3.5-4'	Light brown silty fine sand, some gravel, trace clay, (SM)	-	-	15	-
4-18'	Gray and slightly brown, silty clay till, trace to some sand, trace gravel, hard, (CL)	-	3.8-5.3	13-18	-
18-23'	Gray, fine to coarse sand, trace silt and gravel, dense, (SW)	51	-	14	-
23-47'	Gray brown to gray silty clay till, trace to some sand, trace gravel and shale, hard, (CL)	-	5.2-7.0	11-13	-
	End of Boring 47'				

CROSS SECTION A-A' (continued)

Borehole #4
NE, SE, SW, Sec. 16, T. 45N., R. 12E.
Waukegan Quadrangle, Elevation 655' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-3.5'	Dark brown, sandy clay, topsoil	-	-	-	-
3.5-5.5'	Brown and gray, silty clay, (CL)	-	-	-	-
5.5-12.5'	Brown and gray, silty sand, (SM-ML)	-	-	-	-
12.5-29'	Gray, wilty clay till, trace sand and gravel	-	-	-	-
29-36.5'	Gray, clayey sand, (SC)	-	-	-	-
36.5-50'	Gray, silty clay till, (CL)	-	-	-	-
	End of Boring 50'				

CROSS SECTION A-A' (continued)

Borehole #5
NW/c of NW, SE, SE, Sec. 16, T. 45N., R. 12E.
Waukdgen Quadrangle, Elevation 645' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-1'	Misc. fill	-	-	-	-
1-38'	Gray silty clay till, horizontal seams of silt and fine sand tough to hard, (CL)	11-28	4.2-7.0	11-19	-
38-41'	Gray, silty, very fine sand, (SM)	-	7.0	9	-
	End of Boring 41'				

CROSS SECTION A-A'

Borehole #6
NW/c of NE, SW, SW, Sec. 15, T. 45N., R. 12E.
Waukegan Quadrangle, Elvevation 585 ' (est.)

Depth	Description	V/BPF	Qu/TSF	W%	Dry Density
0-8'	Gray fine, sand, fill trace clay (SC)	-	-	-	-
8-16'	Gray, fine sand, trace clay (SC)	-	-	-	-
16-21'	Gray brown, fine sand, trace silt and gravel, medium dense, (SP)	29	-	-	-
	End of Boring				

CROSS SECTION A-A' (continued)

Borehole #7
SW/c of NW, SW, SE, Sec. 15, T. 45N., R. 12E.
Waukegan Quadrangle, Elevation 685 (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-1'	Black, sandy silty topsoil	22	-	-	-
1-31'	Brown and gray fine to medium sand trace gravel, dense to very dense (SP)	16-84	-	-	-
31-43'	Gray silty clay, trace to some gravel, very tough to very hard, (CL)	106	2.5-7.3	11	133
	End of Boring 43.0'				

CROSS SECTION B-B'

Borehole #1
NE, SW, NW, Sed. 32, T. 45N., R. 12E.
Waukegan Quadrangle, Elevation 680' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry DENSITY
0-5'	Dark brown, topsoil (OL-OH)	-	18	29	-
.5-2'	Brown and gray, silty clay till, trace to some sand, trace gravel, very tough to hard, (LL-ML)	-	3.8-4.5	20	-
2-9'	Same, irregular silt seams, hard, (CL)	-	4.1-4.5	16-20	-
9-14'	Gray and brown, clayey silt till, trace sand, dense, (ML-CL)	-	2.5-4.5	20	-
14-18'	Gray, fine to coarse sand, some gravel, trace silt, medium dense, (SW-SP)	29	-	-	-
18-27'	Gray, silty clay till, trace sand and gravel, tough, (CL)	29	1.8	18-20	-

Borehole #2
NE/c of SW, SE, NW, Sec. 32, T. 45N., R. 12E.
Waukegan Quadrangle, Elevation 665' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-1.25'	Black, silty clayey, topsoil, (OL-OH)	-	-	44	-
1.25-5.5	Brown and gray, silty clay till, trace sand, gravel and roots, (CL-CH)	-	1.5-2	22-31	93.5
5.5-6.75'	Clayey, silt, some very fine sand (ML-CH)	-	.7	25	101

Borehole #2 (continued)
NE/c of SW, SE, NW, Sec. 32, T. 45N., R. 12E.
Waukegan Quadrangle, Elevation 665' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
6.75-7.25'	Brown and gray, silty fine to medium sand, trace clay (SM)	-	-	16	-
7.25-9'	Brown and gray silty clay till, trace sand and gravel (CL-ML)	-	-	22	-
9-13'	Brown, sandy silty clay till, trace gravel, very tough (CL)	-	3.2	14	124
13-17'	Gray, silty clay till, trace sand and gravel, hard	-	4.5	15	125

Borehole #3
NW, NW, SW, Sec. 33, T. 45N., R. 12E.
Waukegan Quadrangle, Elevation 650' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-2'	Fill	-	1.5-3.4	17-23	-
2-4'	Brown to dark gray, silty sandy clay till, trace gravel, hard (CL)	-	7.0	20	105
4-6'	Light brown and gray, silty clay till, trace sand and gravel very tough, (CL)	-	2.7-3.6	17	110
6-9'	Brown and slightly gray fine sand, trace to some silt, trace gravel and clay, dense, (SP-SM)	-	-	12	-
9-16.5'	Gray, silty clay till, trace sand and gravel, hard, (CL)	-	4.5	12	-

Borehole #3 (continued)
NW, NW, SW, Sec. 33, T. 45N., R. 12E.
Waukegan Quadrangle, Elevation 650' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
16.5-18'	Brownish gray, fine sand, trace silt, dense, (SP)	-	-	6	-
18-28.5'	Gray, silty, sandy clay till, irregular silt seams and pockets, trace sand, hard (CL)	-	5.5-7.0	14	-
28.5-31'	Gray, clayey, sandy silt till, horizontal seams and pockets of fine sand, hard, (ML-CL)	-	5.8	12	-
31-32'	Brownish gray, fine sand, trace silt, (SP)	-	-	16	-

Borehole #4
NW, SW, SE, Sec. 33, T. 45N., R. 12E.
Waukegan Quadrangle, Elevation 650' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-10'	Misc. fill	-	-	-	-
10-15'	Gray clayey sand (SC)	-	-	-	-
15-20'	Brown and gray clayey sand (SC)	-	-	-	-
20-25'	Gray clayey sand (SC)	-	-	-	-

Exposure #1
NE/c of NE, SW, SE, Sec. 33, T. 45N., R. 12E.
Waukegan Quadrangle, Elevation 640' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-4.5'	Brown, gravelly sand silt and clay Brown, gravelly, silty, clayey, sand (SC)	-	4.5+	1.05	-
4.5-5.5'	Brown clayey gravel (GC)	-	3.0	25.7	-

Exposure #1 (continued)
NE/c of NE, SW, SE, Sec. 33, T. 45N., R. 12E.
Waukegan Quadrangle, Elevation 640' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
6.5-8.5'	Brown, clayey silt till (CL-ML)	-	4.5+	14.4	-
8.5-10.5	Gray, clayey silt till (CL-ML)	-	4.5	14.1	-

CROSS SECTION B-B"
Lake Michigan Bluff

Boring #1
SW, NW, NE, Sec. 4, T. 44N., R. 12E.
Waukegan Quadrangle, Elevation 650' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-5'	Gray silty till (CL)	20/19"	6.9	15	119
5-10'	Gray silty till (CL)	20/20"	4.5/3E	14.5	121
10-15'	Gray silty till (CL)	6/11"	1.9/3E	14.5	121
15-20'	Gray silty till (CL)	10/13"	1.7/3E	14.9	119
20-25'	Gray silty till (CL)	11/13"	-	-	-
25-30'	Gray silty till (CL)	16/17"	1.9/3E	12.9	124
30-35'	Gray silty till (CL)	17/36"	3.9/3E	12.5	124
35-40'	Gray silty till	11/13"	2.5/3E	12.2	122

CROSS SECTION B-B" (continued)

Borehole #5
NW/c of NE, NE, NW, Sec. 4, T. 44N., R. 12E.
Waukegan Quadrangle, Elevation 660' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
1-2'	Brown, silty clay till ? trace to some sand, trace gravel, soft, (CL)	8	.5	-	-
2-6'	Brown fine sand, some silt, trace clay, medium dense to dense, (SM)	28-57	-	-	-
6-13'	Brown, fine sand trace silt and gravel, dense, (SP)	45	-	-	-
13-23.5'	Brown, fine to medium sand, trace silt and clay, very dense, (SP)	68-87	-	-	-
23.5-36'	Fine sand, trace silt and clay	127-176	-	20	-
36-36.5'	Gray silty clay till, trace sand, tough (CL)	-	1.8	-	-

CROSS SECTION B-B" (continued)

Boring #6
SW, NW, NE, Sec. 4, T. 44N., R. 12E.
Waukegan Quadrangle, Elevation 660' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-1'	Black, silty and clayey topsoil, (OL)	-	-	22	-
1-4'	Brown and gray silty clay till, trace sand and gravel, very tough to hard, (CL-Possible fill)	-	3.0-4.5	10-18	-
4-6'	Brown, silty sand, trace gravel, intermittent seams of sand, medium dense, (SM)	-	2.5-3.0	10	-
6-9'	Brown and gray, silt, trace clay, sand, and gravel, medium dense, (ML)	-	2.0-3.0	16-18	-
9-11.5'	Brown and gray, silty and clayey sand and gravel, medium dense, (SC-GM)	-	2.2-2.8	11	-
11.5-12.5'	Gray, silty clay till, trace to some sand and gravel (CL-ML)	-	4.6	10	-
12.5-14'	Gray, sandy silt, trace clay and gravel, medium dense, (ML-SM)	-	4.1	14	-
14-15'	Gray, silty clay till, trace sand and gravel, very tough (CL)	-	2.5-3.3	14	-

CROSS SECTION C-C' (continued)

Borehole #2
NW/c of NE, NW, SE, Sec. 5, T. 44N., R. 12E.
Waukegan Quadrangle, Elevation 670' (est.)

Depth	Description	N/BPE	Qu/TSF	W%	Dry Density
0-3'	No samples	-	-	-	-
3-4.5'	Fill	-	.5-2.3	18.5-26	93.5
4.5-5'	Topsoil	-	1.3	34	-
5-19'	Brown and gray, silty clay till, trace sand and gravel, tough to hard, (CL) (CL-CH)	-	1.3-4.5	15-22.5	99-120
	End of Boring 19'				

Borehole #3
SW, SE, NW, Sec. 4, T. 44N., R. 12E.
Waukegan Quadrangle, Elevation 648' (est.)

Depth	Description	N/BPE	Qu/TSF	W%	Dry Density
0-4'	Misc. fill	-	4.6	13-22	97
4-7.5'	Brown and gray, silty clay, till, trace sand and gravel, tough, (CL) (CL-CH)				
7.5-9.5'	Gray, silt, trace clay, medium dense, (ML)	-	4.1	20	-
9.5-25'	Gray silty clay till, trace sand and gravel, (CL)	18	2.5-4.5	14-15.5	-
	End of Boring 25'				

CROSS SECTION C-C' (continued)

Borehole #4
SE, SE, NW, Sec. 4, T. 44N., R. 12E.
Waukegan Quadrangle, Elevation 650' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-1'	Fill and topsoil (CL-OH)	-	3.6	25	-
1-7.5'	Brown and gray, silty clay till, trace sand and gravel, hard, (CL)	-	4.5-7.0	15-17	-
7.5-9.5'	Sand and gravel	-	-	-	-
9.5-25'	Gray silty clay till, trace sand and gravel	50.109	4.6	11-13.5	-
	End of Boring 25'				

Borehole #5
NW/c of NW, NE, SE, Sec. 4, T. 44N., R. 12E.
Waukegan Quadrangle, Elevation 600' (Est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-8.5'	Misc. Sandy fill, (ML-CL) (SP)	4-61	-	18-20	-
8.5-10	Brown, fine to coarse, sand some gravel, trace silt, very dense (SW)	67	-	-	-
	End of Boring 10'				

CROSS SECTION D-D'
Lake Michigan Bluff

Boring #10
SW/c of SE, SW, SE, Sec. 16, T. 44N., R. 12E.
Waukegan Quadrangle, Elevation 647' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-10'	Gray-brown mottled clayey silt, trace to some sand, (ML-CL)	-	-	18.5-23.5	-
14-26.5'	Gray, silty clay till, trace sand and gravel, (CL)	-	-	17.0	-
	End of Boring 26.5'				

Boring #11
SE/c of SW, SW, SW, Sec. 16, T. 44N., R. 12E.
Waukegan Quadrangle, Elevation 678' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-6'	Brown, clayey silt till, (CL)	-	-	17	-
6-27"	Brown and gray silt, sand, and gravel (SM)	-	-	19	-
	End of Boring 27.0'				

Boring #12
SE/c of SE, SE, SW, Sec. 17, T. 44N., R. 12E.
Waukegan Quadrangle, Elevation 705' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-10'	Yellowish brown clayey silt till, trace to some silt, trace gravel, (CL)	-	-	17.0-19.0	-
10-46.5'	Gray, clayey silt till, trace to some sand, trace gravel (CL-ML)	-	-	16.5-18.5	-
	End of Boring 46.5'				

CROSS SECTION D-D' (continued)
Lake Michigan Bluff

Boring #13
SW/c of NE, NW, NE, Sec. 19, T. 44N., R. 12E.
Waukegan Quadrangle, Elevation 682' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-1.5'	Topsoil	49/18"	-	-	-
1.5-12'	Yellow-brown, silty clay till, trace sand and gravel (CL)	37-120/18"	-	11.2-16.5	-
12-37'	Gray, silty clay till, trace sand and gravel (CL)	33-54	-	16.6-17.0	-
37-45.5'	Gray, silty clay till, some seams of silt and fine sand (CL-ML)	50-53/18"	-	-	-
45.5-46'	Gray, silty fine sand (SM)	32/18"	-	-	-
46-47'	Gray silt and clay (ML-CL), (ML)	-	-	18.0	-
47-55.5'	Gray silty clay till, trace sand and gravel (CL)	55/18"	-		-
55.5-57'	Gray, medium to coarse sand and gravel, trace silt and clay (SW)	-	-	-	-
	End of Boring 57.5'				

Boring #14
SE/c of SW, SE, SE, Sec. 17, T. 44N., R. 12E.
Waukegan Quadrangle, Elevation 687' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-10'	Brown and gray mottled, clayey silt till, oxidized, occasional silt seams (CL-ML)	22-45/18"	-	-	-
10-17'	Gray, clayey silt till (CL-ML)	21/45/18"	-	-	-
	End of Boring 17.0'				

Boring #15
SE/c of SW, SE, SW, Sec. 16, T. 44N., R. 12E.
Waukegan Quadrangle, Elevation 659' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-6'	Brown, silty clay till, trace to some sand, trace gravel (CL)	21-30/18"	-	-	-
6-13'	Brown and gray, clayey silt, trace to some sand and gravel, (SM)	26-31/18"	-	-	-
13-26.5'	Gray clayey silt till, trave to some sand, trace gravel, (CL-ML)	21-27/18"	-	-	-
	End of Boring 26.5'				

CROSS SECTION E-E'
Lake Forest, Illinois

Borehole #1
SE/c, NE, NW, SW, Sec. 33, T. 44N., R. 12E.
Highland Park Quadrangle, Elevation 710' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-7'	Brown, silty clay till, trace sand gravel, (CL)	-	-	-	-
7-11'	Brown and slightly gray, silty clay till, trace to some sand, trace gravel, irregular silt seams, very tough, (CL)	-	3.8	16	121
11-14'	Same	-	2.8	13	124

Borehole #2
SE/c, NE, NE, SW, Sec. 33, T. 44N., R. 12E.
Highland Park Quadrangle, Elevation 710' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-5'	Brown, silty clay till, trace sand and gravel, (CL)	-	-	-	-
5-12'	Brown and gray, silty clay till, trace to some sand and gravel, irregular silt seams, hard, (CL)	-	5.7-7.0	15	121

Borehole #3
NE/c, SW, NW, SE, Sec. 33, T. 44N., R. 12E.
Highland Park Quadrangle, Elevation 710' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-1'	Black, clayery and silty topsoil (OL-OH)	-	-	31	-
1-5'	Brown, silty clay till, trace sand and gravel, very tough, (CL)	-	2.5-3.0	17	-

Borehole #3 (continued)
NE/c, SW, NW, SE, Sec. 33, T. 44N., R. 12E.
Highland Park Quadrangle, Elevation 710' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
5-13.5'	Brown, silty clay till, trace to some sand, trace gravel, horizontal silt seams, hard, (CL)	-	4.5	17	119
13.5-17'	Gray and brown, silty clay till, trace sand and gravel, very tough (CL)	-	2.2-2.8	16	118

Borehole #4
SW, NE, SE, Sec. 33, T. 44N., R. 12E.
Highland Park Quadrangle, Elevation 685' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-.5'	Dark brown, topsoil, loose	-	-	34	-
.5-7'	Brown, clayey silt till, trace sand and gravel, dense, (ML-CL)	-	1.9-3.7	17	103-130
7-13.5'	Brown and gray clayey silt till, trace sand and gravel, dense to very dense, (ML-CL)	-	5.6-7.3	17	120
13.5-15.5'	Gray, silty clay till, trace sand and gravel, dense, (ML-CL)	-	4.2	16	130
15.5-18.5'	Brown, fine to coarse sand, some silt, trace gravel, dense, (SM)	30	4.2	8	-
18.5-19'	Gray, silty clay till, trace to some sand, dense, (ML-CL)	38	3.0	-	-

Borehole #5
NW/c, SW, NW, SW, Sec. 34, T. 44N., R. 12E.
Highland Park Quadrangle, Elevation 675' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-1.5"	Dark brown, topsoil, loose (OL)	-	-	25	-
1.5-4.5'	Brown, clayey silt till, trace sand and gravel, very dense, (ML-CL)	-	7.8-8.6	16	112-117
4.5-13.5'	Brown and gray, clayey silt till, trace sand and gravel dense to very dense, silt seams, (ML-CL)	-	2.9-7.6	16-18	115-118
13.5-18.5'	Gray, fine sand and silt, trace clay, dense, (SM)	-	1.3	13	129
18.5-28'	Gray, fine to coarse sand, some silt, trace gravel, dense, (SM)	39-82	-	-	-

Borehole #6
N/2, SE, NW, SW, Sec. 34, T. 44N., R. 12E.
Highland Park Quadrangle, Elevation 672' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-.5'	Black, silty and clayey, topsoil, (OL-OH)	-	-	-	-
.5-8'	Brown and gray, silty clay till, trace sand and gravel, very tough, (CL)	-	3.1	17	-
8-12'	Brown and slightly gray, silty clay till, trace to some sand, trace gravel, horizontal silt seams, hard, (CL)	-	4.5	15	121

Borehole #6 (continued)
N/2, SE, NW, SW, Sec. 34, T. 44N., R. 12E.
Highland Park Quadrangle, Elevation 672' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
12-15'	Gray clayey silt till, trace to some clay and sand, trace gravel, dense, (ML-CL)	-	3.3	11	122
15-16'	Gray, silty clay till, trace sand and gravel, tough, (CL)	-	1.9	14	119

Borehole #7
SW, SE, NW, Sec. 34, T. 44N., R. 12E.
Highland Park Quadrangle, Elevation 658' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-1'	Dark brown, clayey and silty topsoil (OL)	-	-	-	-
1-8'	Brown to dark gray silty clay till, trace sand and gravel, tough, (CL-CH)	-	1.8	22	-
8-12'	Brown and slightly gray, silty clay till, trace to some sand, trace gravel, hard, (CL)	-	4.6	18	117
12-16'	Gray and brown, silty clay till, trace sand and gravel, very tough, (CL)	-	2.2-2.8	17	118

Borehole #8
NE, SE, NW, Sec. 34, T. 44N., R. 12E.
Highland Park Quadrangle, Elevation 625' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-10.5'	Fill	-	2.5-9.9	13-16	112-122
10.5-13.5/	Brown and gray, clayey silt till, trace sand, gravel, and roots, dense, (ML-CL)	-	5.5	17	115
13.5-16'	Gray, silt and clay till, trace sand and gravel, dense, (ML-CL)	-	4.4	19	115

CROSS SECTION F-F'

Borehole #1
NE/c of NE, SW, SW, Sec. 22, T. 43N., R. 12E.
Highland Park Quadrangle, Elevation 630' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-1.5'	Topsoil, (OL-OH)	-	-	-	-
1.5-3.5'	Lt. brown and gray silty, sandy clay tough (CL-CH-SC)	-	1.1	21	108
3.5-8.5'	Brown and gray, fine sand, trace to some silt (SM)	26-46	-	-	-
8.5-13'	Gray silt, trace fine sand, dense, (ML)	32	-	-	-
13-16'	Gray, sandy and silty clay, trace gravel, very tough (CL)	-	2.9	18	118
16-18'	Gray silt and very fine sand, trace clay, (ML-SM)	-	-	-	-
18-27'	Gray silty clay till, trace sand and gravel, tough (CL)	-	1.0-1.6	18	115
	End of boring 27'				

CROSS SECTION F-F' (continued)

Borehole #2
SE/c of NW, SE, SW, Sec. 23, T. 43N., R. 12E.
Highland Park Quadrangle, Elevation 700' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-1'	Topsoil (OL-OH)	-	-	26	-
1-2"	Brown, silty clay till, trace sand and gravel, very tough (CL-CH)	-	3.0-3.6	20	-
2-21.5'	Brown and gray silty clay till, trace sand and gravel, horizontal silt seams, tough to very tough, (CL)	-	1.8-7.0	15-18.5	117.5
21.5-22'	Gray, silty fine sand, trace clay lumps, (SM)	-	-	10	-
	End of boring 22'				

Borehole #3
SE /c, NW, SE, Sec. 23, N. 43N., R. 12E.
Highland Park Quadrangle, Elevation 687' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-2.5'	Topsoil, (OH-OL-fill)	-	1.5	25-35	105
2.5-7.5'	Lt. gray silty clay, trace of sand and gravel (CL)	-	8.1	15	123
7.5-10.0'	Lt. gray silty clay (CL)	-	7.2	15	121
10.0-14.5'	Lt. gray silty clay (CL)	-	11.5	15	122
14.5-17.0'	Lt. gray silty clay with pockets of gray silt (CL)	-	5.2	15	123
	End of Boring 17'				

CROSS SECTION F-F' (continued)

Lake Michigan Bluff Boring #5
SW, SW, NW, Sec. 24, T. 43N., R. 12E.
Highland Park Quadrangle, Elevation 665 (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-5.5'	Tan and gray fine to medium sand, (SM)	12/13	-	-	-
5.5-40.5'	Gray, clayey silt till, trace to some sand and trace gravel	10-16/14"	2.3-4.2	14.315.8	136-139
	End of Boring 40.5				

CROSS SECTION G-G'

Borehole #1
SW, NW, SW, Sec. 20, T. 42N., R. 13E
Evanston Quadrangle, Elevation 628' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-130'	Gray clayey silt till (CL)	(no engineering data available)			

Borehole #2
NE, SW, SW, Sec. 20, T. 42N., R. 13E
Evanston Quadrangle, (Elevation 625' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-104	Gray clayey silt till (CL)	(no engineering data available)			

Borehole #3
NE/c of SW, SW, SE, Sec. 20, T. 42N., R. 13E.
Evanston Quadrangle, Elevation 625' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-13	Gray clayey silt till (CL)	(no engineering data available)			

CROSS SECTION G-G' (continued)

Lake Michigan Bluff Boring #9
SW, NE, SE, Sec. 21, T. 42N., R. 13E
Evanston Quadrangle, Elevation 610' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-5.0'	Fine graine sand (SW)	30	2.5/3.5	15.9	116
5.0-7.5'	Gray, silt till	-	-	-	-
7.5-10.0'	Med. grained sand	25	75	16.1	117
10.0'	Gray, silty clay till	30	4.9/7.5	-	-
		22	2.8/3	19.9	111
		25	2.8/3.5	19.7	111
		22	1.8/3.5	15.5	120
		22	2.4/2.5	14.8	121
		34	3.4/>5	10.7	127
-31.0		35	1.8/3	17.8	112

End of boring 31'

CROSS SECTION H-H'
Wilmette-Kenilworth

Borehole #1
SE, NE, SE, Sec. 32, T. 42N., R. 13E.
Evanston Quadrangle, Elevation ± 633

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-4'	Fill, silty clay (CL)	22	4.6	8-12	-
5-14'	Brown, gray, well-sorted, fine sand (SP)	16-30	-	16-22	-
15-21.5'	Gray, brown, dense moist silt, trace of clay (ML)	28-32	3.5-4.5	15-20	119

Borehole #2
SW/c of NE, NE, SW, Sec. 33, T. 42N., R. 13E.
Evanston Quadrangle, Elevation ± 640'

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-10'	Misc. fill	-	-	20-31	-
10-20.5'	Brown, fine sand, trace silt at bottom (SM)	4-14	-	18-28	-
20.5-21'	Gray, hard, silty clay, (CL)	38	4.5	25	-

Borehole #3
NW/c of SW, SW, SE, Sec. 20, T. 42N., R. 13E.
Evanston Quadrangle, Elevation 610'

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-7'	Fill (CL-CH)	-	2.5	21	108
7-13'	Gray and brown, silty clay, hard ICL)	-	4.1-5.8	18-20	109-113
13-25.5'	Brownish gray, silty clay till. Very tough. (CL)	-	2.7-3.6	20-22	111-113
25.5-26.5'	Gray clayey silt till, trace to some sand and gravel, tough (ML-CL-CM)	-	1.6	18	112
26.5-27'	Gray silty clay till, trace sand and gravel	-	1.8	26	-

Borehole #4
NW, NE, NW, Sec. 34, T. 42N., R. 13E.
Evanston Quadrangle, Elevation ± 611 feet

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
1-2'	Topsoil	-	-	10	-
2-21'	Brown to gray, tough to hard, silty clay, trace sand and gravel (CL)	-	2.0-5.4	18-23	103-104

Borehole #5
SW, SW, NE, Sec. 27, T. 42N., R. 13E.
Evanston Quadrangle, Elevation ± 610 feet

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-4'	Fill, silty clay (CL)	15-16	-	14	-
4-6.5'	Brown, gray, tough, silty clay, w/gravel (CL)	28	3.8-4.2	20	112
6.5-7'	Organic silt (OM)?	-	1.0	30	95
7-21.5'	Brown, gray, hard, silty clay with gravel (CL)	-	4.2-6.2	18-23	108-119

CROSS SECTION I-I'
Lake Michigan Bluff

Boring #1
NE, SW, SW, Sec. 11, T. 44N., R. 13E.
Evanston Quadrangle, Elevation 608' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-2'	Topsoil, fill	-	-	29	-
2-5'	Brown and gray silty clay till, trace sand, tough, (CL)	-	.8	22	101
5-10'	Brown and gray, silty clay, trace sand and gravel, hard, (CL)	-	4.1	17-21	104-111
10-13.5'	Brown and gray, silty sand, trace clay, dense, (SM)	-	4.5	14	-
13.5-18.5'	Gray, silty clay, till, trace to some sand, trace gravel, tough, (CL)	-	1.0	17	113
18.5-23.5'	Gray, clayey silt till, some sand, trace gravel, dense, (ML-CL)	-	4.8	14	123
23.5-27.0'	Gray, silty clay till, some sand, trace gravel, hard, (CL)	-	7.0	13	122
	End of Boring 27.0'				

CROSS SECTION I-I' (continued)
Lake Michigan Bluff

Boring #2
SE, SW, SE, Sec. 12, T. 41N., R. 13E.
Evanston Quadrangle

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-1.5'	Dark brown, topsoil	-	-	29	-
1.5-9.0"	Brown and gray silty clay till, trace sand and gravel, very tough to hard (CL)	-	2.7-5.9	12-22	102-105
9-17'	Gray silty clay till, soft (CH)	-	.3	38-46	72-86
	End of Boring 17'				

Boring #3
NE, NE,NW, Sec. 18, T. 41N., R. 14E.
Evanston Quadrangle, Elevation 600' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-2'	Black sandy topsoil fill	-	-	23	-
2-4'	Dark gray silty sand, trace clay, probable fill (SM-SC)	-	2.3	18	104
4-6'	Brown, silty, sand, trace clay, red-brown silty clay seams, loose (SM-SC)	2	-	-	-
6-11'	Gray, fine sand and silt, trace clay, loose to medium dense, (SM-ML)	8-15	-	-	-
11-13.5'	Gray, silty clay till, trace sand, hard, (CL)	30	4.1	-	-
13.5-22.0'	Gray silty clay, trace sand, soft to stiff (CL-CH)	-	.6	23-41	-
	End of Boring 22.0'				

CROSS SECTION I-I' (continued)
Lake Michigan Bluff

Boring #4
SE, NE, NW, Sec. 18, T. 41N., R. 14E.
Evanston Quadrangle, Elevation 600' (est.)

Depth	Description	N/BPF	Qu/TSF	W%	Dry Density
0-1.5'	Topsoil	5	-	18	-
3-4'	Silty, fine sand (SM)	8	-	16	-
4-5.5'	Brown and gray, silty clay till, stiff to tough, (CL)	5	-	27	-
5.5-11'	Brownish gray to gray clayey silty sand, medium dense to loose, (SM-SC)	4-8	-	25-36	-
11-13.5'	Gray, silty fine sand, trace clay, medium dense, (SM)	22	-	26	-
13.5-18	Gray silty clay till, with seams of silt, very tough (CL)	-	2.6	20	110
18-62'	Gray, silty clay till, trace sand and fine gravel, very soft to stiff (CL-CH)	3-8	.2-.7	24-41	79