DEPARTMENT OF THE INTERIOR

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Late Quaternary stratigraphy and sedimentary features along the Wisconsin shoreline, southwestern Lake Michigan

by

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INTRODUCTION

This report is a summary of observations made during field work along the southwestern shoreline of Lake Michigan between August 23 and August 30, 1989. Selected late Quaternary stratigraphic sections were examined and described along the lakeshore between Racine and Port Washington, Wisconsin. In addition, notes on synsedimentary deformational features at several of the sections measured and a summary of previous stratigraphic work within the region are included in this report. The main goal of this field work was to provide a detailed stratigraphic framework for the research being conducted on processes controlling cliff erosion.

Acknowledgements

Randall W. Jibson introduced me to the geology of the region and many of the sections described herein. Helpful comments by Curtis E. Larsen and David Soller substantially improved the content and organization of this report.

Previous work

Up-to-date summaries of the glacial stratigraphy in the Lake Michigan area are presented in Mickelson and others (1984) and in Monaghan (1988). The earlier paper provides type and reference sections for the mappable late Quaternary units in Wisconsin; the latter paper documents the characteristic clay mineral compositions of the Michigan glacial deposits and provides a correlation chart for the till sheets in the Great Lakes region. The sequence of tills in southeastern Wisconsin and northern Illinois includes deposits below and above the mid-Woodfordian interstade dated at about 15,500 y BP. These are the New Berlin (older) and Oak Creek (younger) tills in Wisconsin (see Schneider, 1983; Mickelson, and others, 1984; Schneider and Need, 1985); the Wadsworth Till Member of the Wedron Formation is the corresponding unit along the lakeshore in northern Illinois (Willman and Frye, 1970). A till between the Mackinaw (13,000 y BP) and the Two Creeks (11,800 y BP) interstades termed the Manitowoc-Shorewood is also present in northern Illinois (Willman and Frye, 1970; Johnson and others, 1985); in Wisconsin, tills of this interval are the Ozaukee, Haven, Valders, and Two Creeks Members of the Kewaunee Formation (Acomb and others, 1982; Mickelson and others, 1984).

Monaghan (1988) described a section just south of Milwaukee at St. Francis that shows the New Berlin and Oak Creek tills separated by sediments of proglacial Lake Milwaukee; this same section is referenced in Christensen and Schneider (1984) and Schneider and Need (1985). Mickelson and others (1984) have used the St. Francis, also known as the Sheridan Park section, as the reference section for the Oak Creek Formation. Detailed stratigraphic information on an equivalent section immediately to

the south at Cudahy is contained in this report.

The section at Shorewood in the northern suburbs of Milwaukee also contains two tills; the lower being equivalent to the Oak Creek Formation and the upper being the Ozaukee Member of the Kewaunee Formation, equivalent to till comprising the Port Huron moraine of Mickelson and others (1983). The Shorewood section was located during an aerial reconnaissance of the coastline. Although no detailed section was measured at Shorewood, largely equivalent sections, such as the Virmond Park section, a few kilometers to the north are equally extensive and more traceable along the shoreline. The type and reference sections of the Ozaukee Member of the Kewaunee Formation (Mickelson and others, 1984) are the Port Washington and Virmond Park sections of this report respectively.

Studies of Lake Michigan coastal erosion and bluff recession have been ongoing for over 100 years, beginning with Lapham (1847) and Andrews (1870). Powars (1958) classified coastal terranes and calculated recession rates for the entire Lake Michigan shoreline. The most recent studies on bluff recession in Illinois are by Larsen (1973), and Berg and Collinson (1976); similar studies for the shorelines of Wisconsin are found in Mickelson and others (1977). Buckler and others (1988) indicate that the most extensive coastal erosion takes place during intense singular storms when lake level is above 580 feet. During this study, lake level was at about 579.9 feet (National Geodetic Vertical Datum or NGVD)*, significantly below the maximum lake levels of 1986-87 (582.9 feet in October, 1986).

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* The National Geodetic Vertical Datum (NGVD) is 1.3 feet (1 m) higher than the International Great Lakes Datum and equivalent to Mean Sea Level (MSL).

STRATIGRAPHIC SECTIONS

A photo reconnaissance of the northeastern Illinois and southeastern Wisconsin shoreline of Lake Michigan began at the northern end of Fort Sheridan, IL and continued north to Port Washington, WI. A number of field observations were made in poorly exposed, partially slumped sections along the highly altered shorelines in northern Illinois, but stratigraphic sections were not described because the sections, dominated by dark gray, silty clay, were quite uniform lithologically. Detailed stratigraphic correlation and material properties of the glacial deposits in northern Illinois are being interpreted from cone penetrometer test borings (Jibson and others, 1990).

Most of the sections from the southeastern Wisconsin shoreline discussed below were measured in detail. Figure 1 shows the location, the main lithologies, and the approximate position of synsedimentary deformational features contained in these sections. Table 1 gives locality information, by 7 1/2-minute quadrangle, section, township and range.

South Racine

This section includes till of the Oak Creek Formation overlain by interbedded fine sand and silty clay beds interpreted as sedimentary deposits of glacial Lake Chicago. A 12 m section was measured from lake level (579.9 feet NGVD) to the top of the bluff (620 feet). The section can not be traced either to the north or south because the shoreline has been altered. The relationship of the lower part of the section to the dark gray silty clays in northern Illinois is unclear, but there do not appear to be any major differences in lithology or age, based on available information.

Sixmile Road section-Crestview

An actively eroding bluff (fig.2) about 12 m high was visited but not measured. The bluff exposes, in its upper part, a possible contact between two tills in the Oak Creek Formation. The lower part of the bluff is obscured by slumped section. The section is fronted by a 20 m wide pebbly beach.

Fitzsimmons Road

This section (fig.3) is immediately north of the type section of the Oak Creek Formation (Mickelson and others, 1984). Only a generalized stratigraphic section was measured here because of pervasive slumping and uniformity of the stratigraphic section. The lower 25 m of the section is a massive till, composed of medium gray, calcareous, pebbly silty clay to clayey silt. The top 1 meter of the section is weathered and contains some distinctive textural units. From base to top, these are: 60 cm of very pebbly clayey sand grading upward into smaller pebbles and granules, 20 cm of sandy clay, and 20 cm of clay to silty clay with well defined peds (mm-scale blocky structures associated with the soil zone).

Slump blocks appear to be actively moving down the cliff face. The site was revisited following several hours of heavy rain to evaluate active processes without detectable change.

Grant Park, South Milwaukee

Several small sections are exposed north of the boat ramp and public beach in Grant Park. Although outcrop on either side of the point is limited, most of the lower part of the section can be reconstructed. Better access to bluffs is from Grant Park picnic areas 5-6. The most complete section (fig.4) is about 16 m thick, including abour 4.5 m of slumped debris near the toe of slope. The section is actively retreating by sapping and headward erosion by ground water emanating from two spring zones on the bluff face.

Overall, the section coarsens upward from a compact, massive to laminated till (Oak Creek) with relatively few pebbles and cobbles through

crossbedded clayey silt into well bedded pebbly, fine to medium grained, quartz sand lenses.

Cudahy

This section (fig. 5) is just south of the reference section of the Oak Creek Formation at Sheridan Park (Mickelson and others, 1984). It is considered the best exposure of multiple tills in southeastern Wisconsin. A total thickness of 30.9 m was measured from lake level with only the basal 5.5 m covered. Overall, the section is much sandier throughout than the sections measured to the south. The blocky, brick-red, sandy to pebbly clay in the lower part of the section is considered to be a till in the New Berlin Formation (Mickelson and others, 1984; Monaghan, 1988). Beginning with the overlying lag of large, well rounded cobbles, the section alternates between very coarse sediment and very finely laminated silt and clay. Thin tills considered part of the Oak Creek Formation constitute a minor part of the total section.

Synsedimetary deformational features are especially notable in the upper part of this section. Fine to very fine grained quartz sand intervals contain oversteepened and contorted bedforms. A massive, blocky pebbly clay bed is injected and broken by the underlying well sorted fine to medium quartz sand. The extensiveness of deformational features in the upper part of the section, which lacks a thick till, suggests a possible tectonic origin for these structures.

Bayview Park

A comparatively thin section (12.3 m) is present along a low bluff facing downtown Milwaukee approximately 2 miles north of the Cudahy section (fig.6). This section is notable only in that about 7.0 m of till is exposed at the base of the section, possibly the thickest section of New Berlin exposed along Lake Michigan. The till contains some large cobbles set in a massive, silty clay.

Virmond Park

This section (fig.7) exposes about 30.4 m of glacial deposits, with only the basal 3.5 m partially covered by loose debris. The lower part of the section is dominated by deformational structures similar to those in the upper part of Cudahy section. At least 19.5 m of pebbly clay at the top of the section is the reference section for the Ozaukee Member of the Kewaunee Formation. The thickness both here and at the Shorewood section to the south are the maximum attained by the unit (Mickelson and others, 1984).

Concordia College

On the southeastern margin of the Concordia College campus, is an area of two active landslides/debris flows. Slump blocks and water-saturated

debris is moving from headward eroding bluffs to lake level (fig.8). The upper part of the section consists of brick red sandy clay; it overlies a water soaked clayey sand interval. No stratigraphic section was measured but numerous photos (see figs. 9, 10, 11) show the nature of slope failure.

Grafton

Between the Concordia College section and the Lake Park section in Port Washington, an extensive area east of Grafton exposes a 2 to 5m-thick interval of coarse cobbles and pebbly sand between an upper pebbly, red clayey till and a lower pebbly, clay till. The lower till is red toward the top and brown to gray below. The lower till is locally deformed along the contact with the overlying coarse pebble-cobble interval. The section is cut by several small drainages emanating from springs at the gravel-lower till contact.

Port Washington

A composite 28.5m thick section was measured northward from construction along the sewage treatment plant at the eastern margin of Lake Park. The upper 17m of red pebbly clay to silty clay till overlies thinly alternating clay clast conglomerates, very fine sand, and silty clay beds. Many of the beds contain deformational features including truncated bedforms, contorted-wavy bedforms, and small-scale offsets. This section is the type section for the Ozaukee Member of the Kewaunee Formation (Mickelson and others, 1984). According to Acomb and others (1982), clays within the unit contain 20 to 30 percent expandable clay minerals, 50 to 63 percent illite, and about 20 percent kaolinite plus chlorite.

DISTRIBUTION OF DEFORMED STRATA

Deformed strata within glacial deposits are abundant and have generally been considered to be synsedimentary load phenomena. In other cases, faulting in glacial deposits has been attributed to collapse following melting of ice blocks buried within outwash sequences (MacDonald and Shilts, 1975). Certain aspects of a simple loading model either from rapid outwash sedimentation or glacial loading associated with a readvance do not seem consistent with all of the sedimentary features within the glacial deposits exposed in the bluffs along the southwestern shore of Lake Michigan. This section describes the nature and stratigraphic position of deformed strata. Deformed strata are described from the top to the bottom of the sections shown on Figure 1.

Cudahy

The section at Cudahy shows the largest deformational feature and the most extensively deformed stratigraphic interval of any section described in this study. The finely laminated silty clay intervals show only moderate deformation (fig. 12, 13). In contrast, two medium-to-very fine sand

intervals, between 7 and 9m from the top of the section, on either side of a 80cm-thick reddish pebbly clay are highly contorted. The upper sand bed consists of alternating very fine and medium quartz sand; the very fine-to-medium sand is rippled and highly contorted (fig. 14). The sand below the clay bed has injected and broken through the compact clay. The upper part of the sand below the clay is structureless to chaotic and flow lines delineate the path of sand movement through the neck disrupting the overlying clay bed (fig. 15). Although the pebbly clay bed is cut out of the section laterally, the correlative stratigraphic interval shows deformational features along the cliff face to the north.

About 3m lower in the section, a highly polymict bed contains deformed very fine sand interbeds within a clay clast conglomerate. The deformation appears to be the result of differential compaction within the heterogeneous bed.

Virmond Park

Deformational features are present throughout much of the lower 11m of section at Virmond Park, which underlies about 20m of red pebbly clay comparable to the upper till section at Port Washington. Several different lithologies, including fine sand, very fine sand, and clayey silt, are deformed (fig. 16); locally, the bedding is chaotic (fig. 17). Distorted primary structures as well as injection features are abundant throughout the intimately interbedded and interlaminated section of sand, silt, and clay. In contrast to other sections containing deformed strata, described in this report, sheared beds and small offsets between the strata are not present.

Port Washington

Immediately below a 17m section of red, pebbly clay is an interbedded sequence of fine quartz sand and laminated silty clay. Primary sedimentary features are well preserved within these finely laminated and interbedded lake sediments. The only deformation seen immediately below the till consists of small offsets in rippled silty clay. Other deformational features include contorted and wavy bedding in fine to very fine sand beds; rippled tops of small sandy bedforms are locally domed (fig.18). The lower part of the section at Port Washington consists of interbedded clay, pebbly clay and very fine sand. The entire interval displays considerable internal deformation, mostly as offsets along shear surfaces. Sand beds and individual laminae are detached (fig. 19).

SUMMARY

This report provides stratigraphic information about late Quaternary glacial deposits exposed along the southwestern shoreline of Lake Michigan. Based on correlation with dateable deposits elsewhere, the oldest deposits are more than 15,500 years old and the youngest are between 11,800 and

13,000 year old. The nature and distribution of these deposits influences the pattern of landsliding and consequently recession of the bluffs, especially during high lake levels.

Sedimentary features in the glacial deposits record intervals of rapid deposition associated with glacial outwash sedimentation alternating with lake sedimentation and the deposition of sediment by ice. Synsedimentary deformational features are found most commonly in fine grained deposits and are thought to result from loading and differential compaction of the deposits. Locally, however, large-scale injection structures, such as the feature preserved in the Cudahy section, may result from paleoseismicity in the region.

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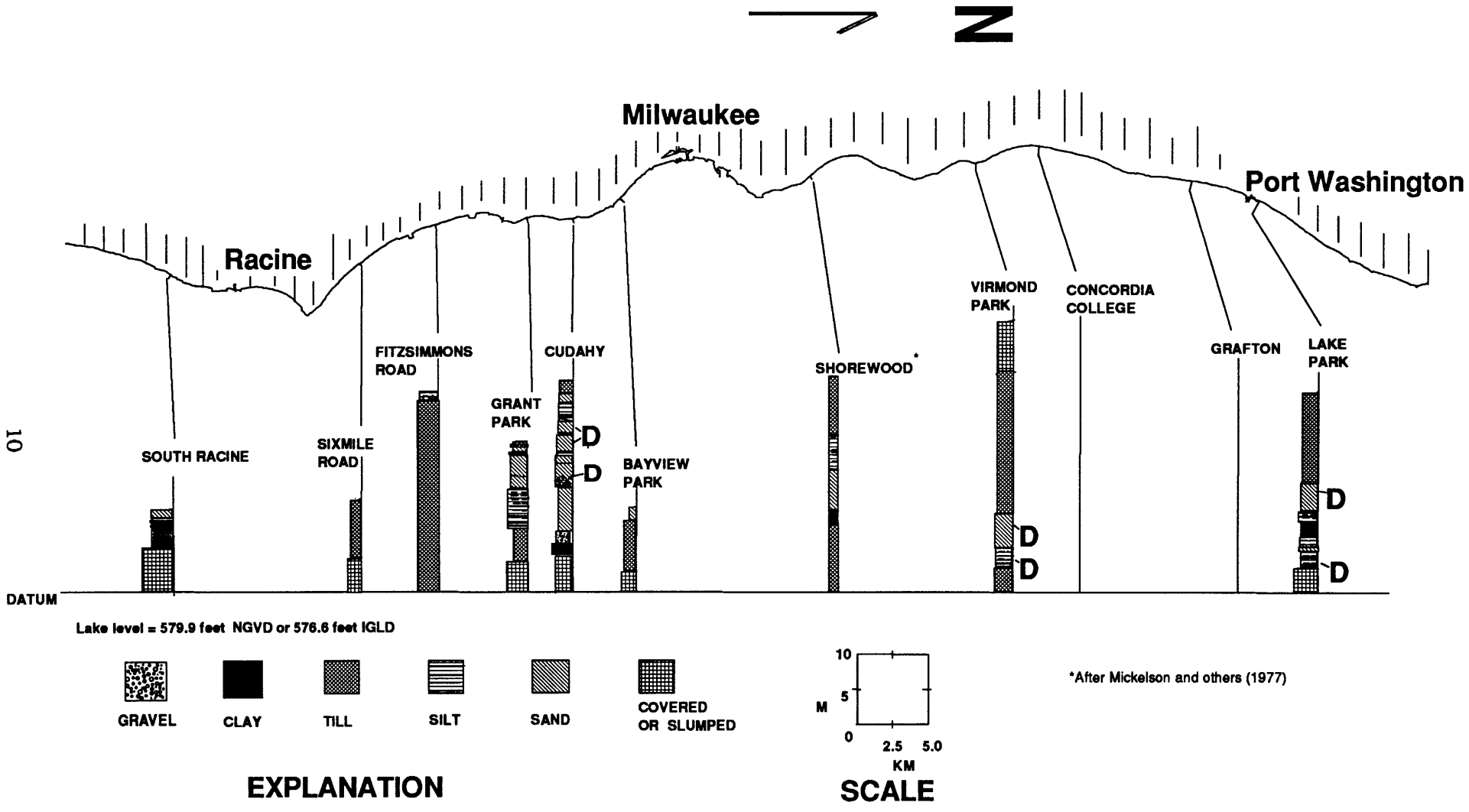

Figure 1. Map of the shoreline in southeastern Wisconsin showing the location of measured sections discussed in this report. Stratigraphic sections are highly generalized and show the approximate positions of deformed sedimentary beds (**D**) in the sections.

Figure 2. Oblique aerial view showing location of the Sixmile Road section, northern suburbs of Racine, Wisconsin. House in the foreground is abandoned, and shows minor damage due to ground failure.

Figure 3. Oblique aerial view of the Fitzsimmons Road area showing the pattern of slope failure along the cliff face. Slump blocks show lateral continuity and relatively little rotation as they move down the cliff face.

Figure 4. Oblique aerial view of the Grant Park area of South Milwaukee, Wisconsin, shows access from picnic area on right side of photograph. Slightly gullied section in left center of the photo is the measured section; note the sharp contrast between the lower clayey and the upper sandy parts of the section.

Figure 5. Oblique view of the section at Cudahy along the southeastern margin of Sheridan Park. The measured section is at the extreme left side of the photo.

Figure 6. Oblique aerial view of the Bayview Park section showing a low bluff, partially slumped, composed of New Berlin Formation.

Figure 7. Oblique aerial view of the highly gullied section at Virmond Park. Deposits composed of uniformly red, pebbly till from north of Milwaukee to Port Washington, Wisconsin are locally interrupted by pods of coarse glacial outwash.

Figure 8. Oblique view of section along the southeastern margin of Concordia College showing two areas of recent slope failure. Note older slumps on the right side of the photo.

Figure 9. Photograph of headward part of smaller slump at Concordia College section. Note: 1) upright posture of trees in slump blocks and 2) rills from surface water runoff.

Figure 10. Photograph of upper part of the large slump at Concordia College showing failure of the upper surface of the cliff. Note wet slipface surface exposed at margins of block.

Figure 11. Base of the Concordia College slump composed of small blocks and wet debris carried down a chute to the lakeshore. Plume of muddy water shows contribution of local cliff failures to the nearshore sediment budget.

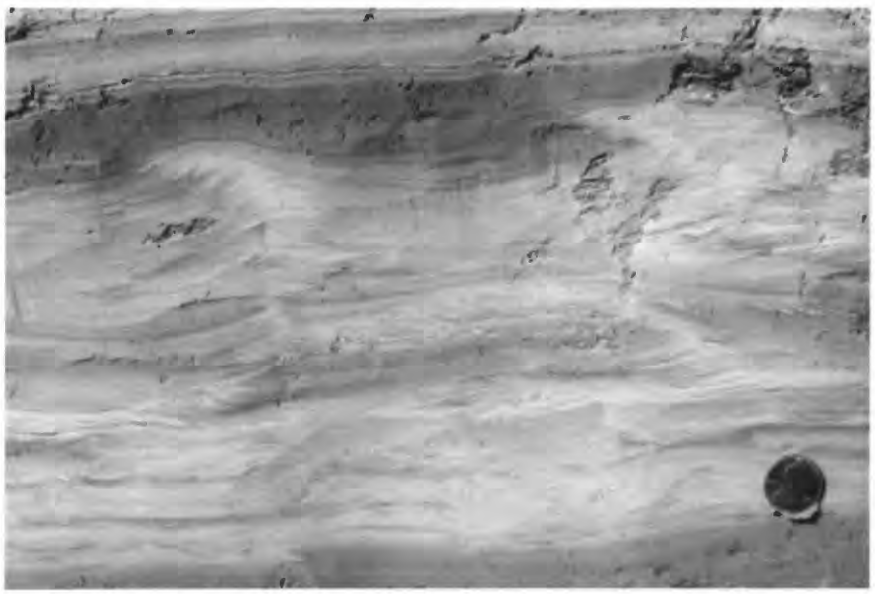

Figure 12. Mildly deformed, ripple cross-laminated very fine sand and planar laminated silt in the upper part of the Cudahy section.

Figure 13. Interbedded silty clay and very fine to medium sand showing moderate internal deformation in a very fine sand interval, closely associated with structure shown in figure 12.

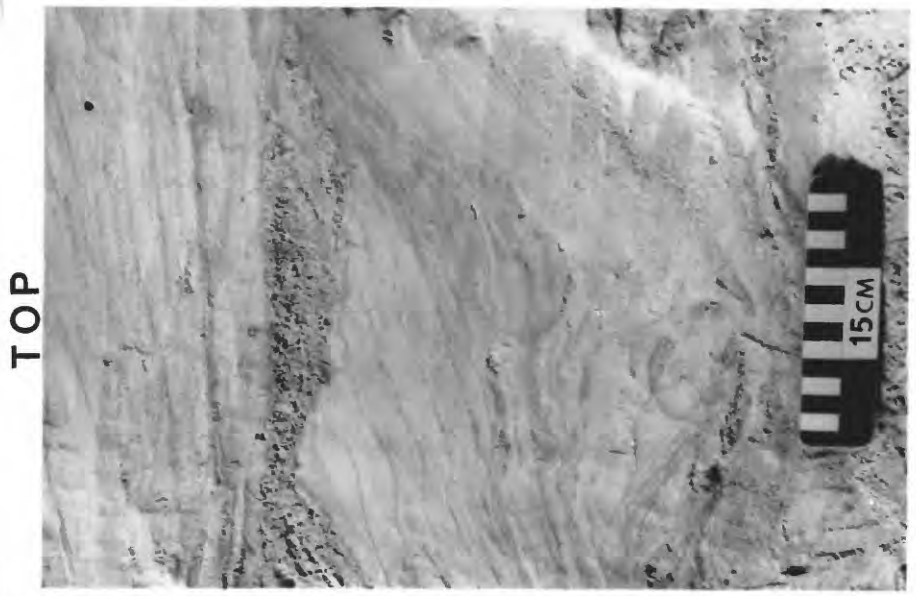

Figure 14. Highly contorted fine sand interbedded with medium to coarse sand lenses and pods in the Cudahy section stratigraphically above the interval in Figure 15.

Figure 15. Injection structure consisting of 80cm-thick pebbly clay deformed along its base and cut through by very fine to very coarse sand. Injection of sand appears to have been concentrated along the right side of the structure with subsequent collapse of sediment in the middle and along the lower left of the structure.

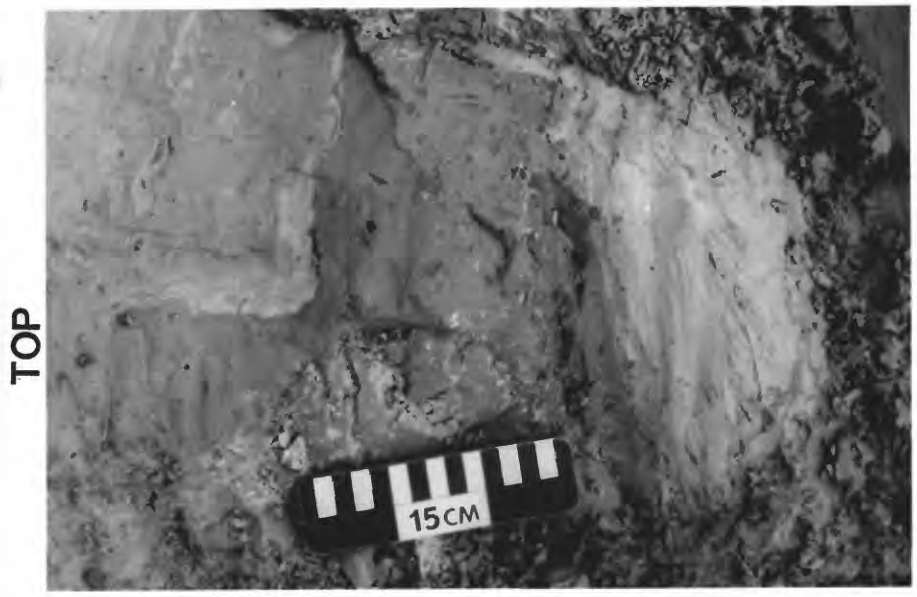

Figure 16. Lower part of the Virmond Park section showing sheared, cross laminated, very fine sand at the base overlain by massive, pebbly till, and highly contorted silty clay.

Figure 17. Chaotic bedding in pebbly till at Virmond Park section.

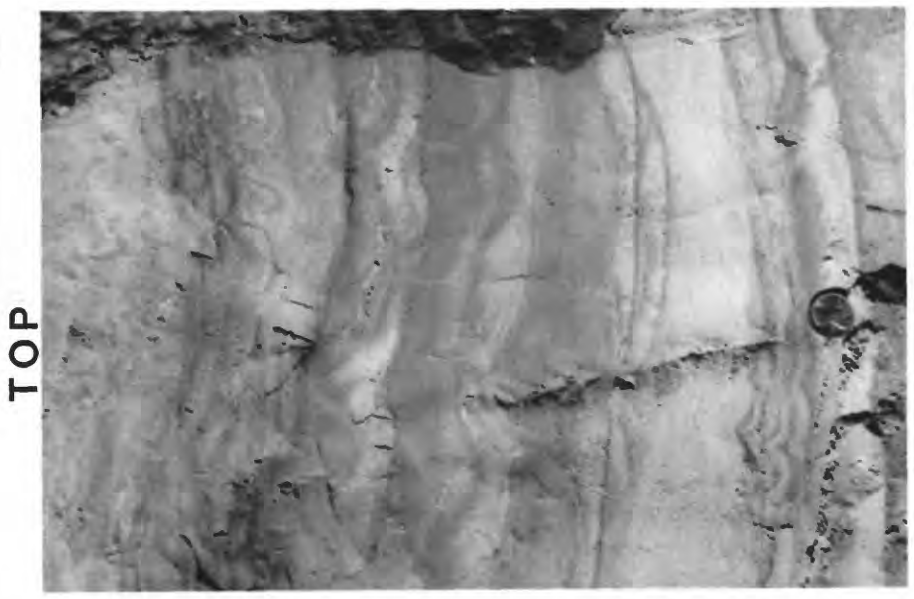

Figure 18. Deformed strata in the upper part of the Lake Park section are interbedded, ripple cross-laminated, fine sand and silty clay. Note unnaturally sharp peaks and U-shaped troughs to bedforms.

Figure 19. Brittle deformation of an internally deformed silty clay bed in the lower part of the Lake Park section. Surrounding medium sand is massive.

Table 1: LOCATION OF STRATIGAPHIC SECTIONS

Section name	**7 1/2' Quadrangle**	**Section**	**Township/Range**
Racine South	Racine South	28	T3N/R23E
Sixmile Road	Racine North	8	T4N/R23E
Fitzsimmons Rd.	Racine North	25	T5N/R22E
Grant Park	South Milwaukee	1	T5N/R22E
Cudahy	South Milwaukee	25	T6N/R22E
Bayview	South Milwaukee	14	T6N/R22E
Shorewood	Milwaukee	34	T8N/R22E
Virmond Park	Thiensville	28	T9N/R22E
Concordia College	Cedarburg	8	T9N/R22E
Grafton	Cedarburg	10	T10N/R22E
Lake Park	Port Washington	28	T11N/R22E