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THE WADSWORTH TILL MEMBER OF ILLINOIS AND THE EQUIVALENT OAK CREEK FORMATION OF WISCONSIN

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ABSTRACT

The Wadsworth Till Member of the Wedron Formation is the youngest till unit in Illinois and was deposited during the last advance of the Lake Michigan Lobe to reach the southern part of the lake basin. The equivalent unit in Wisconsin is called the Oak Creek Formation (Mickelson and others, 1983).* Around the southern margin of the lake the Wadsworth till is found at the surface in the Valparaiso, Tinley, and Lake Border Moraines. In the subsurface it lies beneath the Lake Chicago plain and beneath nontill sediments under Lake Michigan. The composition and texture of the gray, clayey illitic Wadsworth till reflects incorporation of Paleozoic rock and lacustrine sediment from the Lake Michigan basin. Variation in composition is present in vertical profile and in lateral distribution. Whereas some variation is clearly associated with separate depositional events (Valparaiso and Lake Border), other variation appears to reflect differences in length of flow path in the Lake Michigan basin. On the basis of the available data in the study area, the Wadsworth till is a clearly distinguishable stratigraphic unit that can be subdivided further on textural and compositional characteristics related to geographic and stratigraphic positions.

INTRODUCTION

The tradition of Pleistocene stratigraphy in Illinois has been to distinguish rock-stratigraphic units by their physical characteristics and stratigraphic position. Many till units, including the Wadsworth Till Member of the Wedron Formation, first became a part of the stratigraphic nomenclature in 1970 when Willman and Frye presented their classification scheme for Quaternary depostis in Pleistocene Stratigraphy of Illinois. At that time Willman and Frye saw no need to define groups consisting of several formations, but they recognized (p. 45) that future work might distinguish additional subdivisions and groupings.

At the present time, Quaternary researchers in Illinois are considering further revision of the Wedron Formation based on material characteristics. As presently defined, the Wedron Formation consists of those deposits of till and outwash that extend upward from the contact with the top of the Morton Loess to the top of the till below the Two Creeks deposits in Wisconsin, thereby including all till deposits of Woodfordian age. Among the revisions being considered are (1) elevation of the Wedron in rank to group status, (2) differentiation of formations within the group, and (3) differentiation of members within these formations wherever there is a lithologic basis to do so. These revisions have been proposed because the American Code of Stratigraphic Nomenclature recognizes the formation as the working field unit and the Wedron Formation is not a working field unit in this sense. Instead, the working field units in northeastern Illinois are distinguished within the

* To avoid unnecessary use of names and to reduce confusion, Wadsworth till is used in this paper to include the same unit in Wisconsin (Oak Creek Formation) unless reference is made specifically to the Wisconsin unit.

Wedron Formation at the member rank (the Tiskilwa, Malden, Yorkville, Haeger, and Wadsworth Till Members). Elevating these till members to formation rank would be in compliance with the Code guidelines and would at the same time allow for more flexibility at lower levels of classification.

Inasmuch as the Wadsworth till was originally defined as a member of the Wedron, an evaluation of its appropriateness as a formation in the proposed group is required. At least two clay-mineral subdivisions within the Wadsworth till have been recognized and it is important to decide whether or not these clay-mineral subdivisions are accompanied by other lithostratigraphic parameters and therefore merit distinction as separate members of the Wadsworth unit. The present research was initiated in order to respond to such questions and to improve understanding of the deglaciation history of retreating Woodfordian ice in the Lake Michigan basin.

The primary objectives of the paper are to (1) evaluate the status of the Wadsworth till in the rock-stratigraphic hierarchy of Illinois, (2) determine prospects for its subdivision, and (3) discuss the genesis and depositional history of the unit. The study area does not include the entire extent of the Wadsworth till; it covers only northern Illinois and southern Wisconsin as shown in figure 1.

METHODS AND DATA

Sample data were obtained from approximately 75 water-well and 60 test-boring sites. Samples collected from surface exposures and the lake bluffs in Wisconsin and Illinois were another important data source. Other samples used in this study were contributed by A. F. Schneider and D. M. Mickelson.

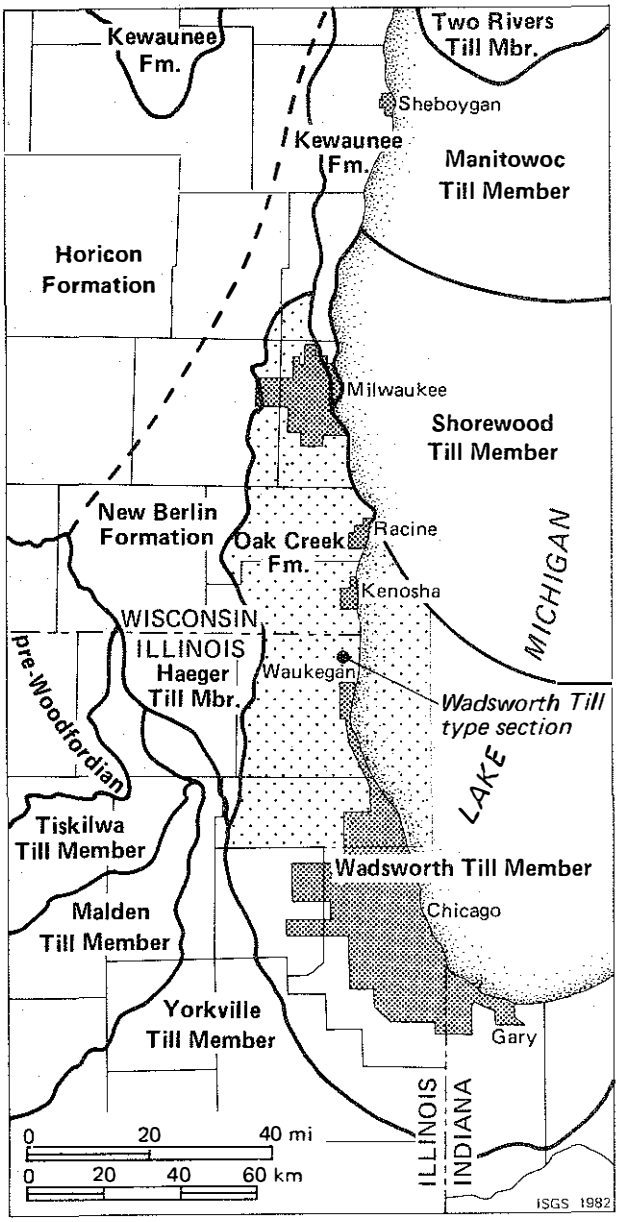

FIGURE 1.--Study area and surficial till units in eastern Wisconsin and northeastern Illinois. (Wadsworth Till Member of Illinois equivalent to the Oak Creek Formation of Wisconsin; Haeger Till Member to the New Berlin Formation; Manitowoc Till Member to part of the Kewaunee Formation.) (Study area stippled.)

Samples were described and analyzed for texture and clay-mineral composition. Textural analysis was determined by R. Bianchini of the Illinois State Geological Survey (ISGS), who used sieve and hydrometer methods to fractionate and determine the weight percentage of gravel (larger than 2.00 mm) in the whole sample and the weight percentages of sand (0.062 to 2.00 mm), silt (0.004 to 0.062 mm), and clay (smaller than 0.004 mm) in the matrix (smaller than 2.00 mm).

Clay mineral identification was done by H. D. Glass (ISGS) from x-ray diffraction data by using oriented aggregate techniques on the smaller-than-0.002 mm material. The clay minerals are separated into three groups, and the percentages of each group are calculated using peak height intensities. The percentage of illite was used to demonstrate variability in clay-mineral content. The calculated value represents a relative index of the amount of illite present. Although relative, the percentage serves as a sensitive measure for discriminating change in clay composition. Other characteristics of the clay-mineral diffraction analyses were also used to help evaluate the clay-mineral composition of weathered samples.

HISTORY OF THE INVESTIGATION OF THE WADSWORTH TILL

The distinct morainic character and trough-shaped configuration of the topography hordering Lake Michigan were noted by Chamberlin in 1878. In 1882 he referred to these deposits as "moraine of the Lake Michigan Glacier." Leverett (1899) was likewise impressed by the striking parallelism of the moraine configuration to the Lake Michigan shore. On the basis of the topography and distribution of the deposits around the lake, he differentiated two morainic systems: the Valparaiso and the Lake Border. Alden's detailed work (1904, 1918) extended Leverett's mapping of the Valparaiso and Lake Border Morainic Systems into Wisconsin.

The glacial deposits of the moraines in the study area have been described by many (Leverett, 1897, 1899; Alden, 1904, 1918; Powers and Ekhlaw, 1940; Bretz, 1955; Willman and Frye, 1970; Willman, 1971; Lineback and others, 1974; Mickelson and others, 1977; and Acomb and others, 1982), but it was not until 1970 that the term "Wadsworth Till Member" was applied to these deposits. At that time, Willman and Frye differentiated the Woodfordian moraines and their related drifts in Illinois and, on the basis of observable physical characteristics, classified materials into rock-stratigraphic units of the Wedron Formation. The exceedingly clayey, gray tills of the Valparaiso Morainic System, the Tinley Moraine, and the Lake Border Morainic System were included in the Wadsworth Till Member of the Wedron Formation.

In 1974 Linehack and others differentiated four till units under Lake Michigan on the hasis of core sampling and seismic profiling. The three oldest units were assigned to the Wedron Formation of the Woodfordian Suhstage and the youngest till was assigned to an unnamed formation of the Valderan Suhstage. The oldest of these units was the gray, illitic Wadsworth Till Member found in the southern portion of the lake. Two new till members were defined in the central portion of the lake: the Shorewood Till Member and the Manitowoc Till Member. The post-Two-creekan Two Rivers Till of Evenson (1973) was identified in thin patches on the lake floor north of Sheboygan. Analytical data from x-ray diffraction studies of clay minerals and carbonates provided the hasis for separating these tills. Their distribution and stratigraphy were determined primarily from seismic profiles. Figure 1 shows the distribution of these four tills in the western part of Lake Michigan.

Shore erosion studies along Lake Michigan in Wisconsin (Mickelson and others, 1977) and Illinois (unpublished reports) have examined the lithology

and stratigraphy of the materials that constitute the lake bluffs. In Wisconsin three pre-Twocreekan till units were differentiated along the Lake Michigan bluffs: Unit 1, coarse-textured bouldery till; Unit 2, gray, clayey till; and Unit 3, red, clayey till. In some places these units were further subdivided on the basis of stratigraphic breaks. The Wadsworth till is the only till unit exposed in the lake bluffs in Illinois.

STRATIGRAPHIC RELATIONS OF THE WADSWORTH TILL

Stratigraphic Nomenclature

The Wadsworth Till Member of the Wedron Formation was named for Wadsworth, Lake County, Illinois (Willman and Frye, 1970). The type section is a roadcut exposure at the intersection of Illinois Highway 131 and Wadsworth Road, 2 miles east of Wadsworth (fig. 1). In Wisconsin the equivalent unit is being defined as the Oak Creek Formation (Mickelson and others, 1983).

A stratigraphic column for the study area is shown in figure 2. Because the study area includes portions of both states, both Illinois and Wisconsin nomenclature are given. The placement of Units 1, 2, and 3 of the Wisconsin shore erosion study (Mickelson and others, 1977) in the rock-stratigraphic framework is also indicated. The Illinois nomenclature is used in this paper except where reference is made to units studied by Wisconsin researchers.

Distribution and Topography

In the southwestern Lake Michigan area the Wadsworth till occurs at the surface in the Valparaiso Morainic System, the Tinley Moraine, and the Lake Border Morainic System, at the surface or beneath lacustrine sediment in the Lake Chicago plain, and in the subsurface beneath nontill sediment in southern Lake Michigan (fig. 3). Till samples that have been analyzed from the Valparaiso and Lake Border Moraines outside the study area in Illinois, Indiana, and Michigan are similar in composition to samples from the Wadsworth Till Member in the study area.

In 1970 Willman and Frye identified 13 separate morphostratigraphic units, called "drifts," on the basis of moraines in the area of the Wadsworth till in Illinois. They did not differentiate the Valparaiso Morainic System into separate ridges in Lake and northern Cook Counties, Illinois, where the morainic area is about 15 km wide and is characterized by numerous knobs, kettles, and lakes. To the south where lakes are much less common, the Valparaiso Morainic System can be separated into seven recognizable ridges or crests.

The first moraine younger than the Valparaiso Morainic System is the Tinley Moraine. It has a hummocky surface similar in topography to that of the Valparaiso but it is only 5 to 7 km wide. Extending from Wisconsin to Indiana, it adjoins the next younger morainic system (Lake Border) in the northern half of the study area.

The Lake Border Morainic System consists of five ridges, each a mile or so wide, that rise 10 to 15 m above narrow valleys. The ridges are generally smooth and lack the hummocky topography characteristic of the Valparaiso and Tinley Moraines. In the vicinity of Chicago the Lake Border Moraines are buried by lacustrine sediment of the Lake Chicago plain, an exceptionally flat surface that was formerly the floor of glacial Lake Chicago (fig. 3). In Cook County, Illinois, where the Lake Chicago plain is scoured of lake sediment, the Wadsworth till occurs at the surface.

Lineback and others (1974) found that the Wadsworth till forms a relatively smooth surface in the southern end of Lake Michigan and is generally overlain by thin gravel and sand. No submerged moraines related to the Wadsworth till were found.

Thickness

The thickness of the Wadsworth till in Illinois ranges from a few meters to more than 50 m. The western margin of the Wadsworth till lies east of the Fox Lake Moraine, the western margin of the area mapped as Valparaiso (undifferentiated) by Willman and Frye (1970); the Wadsworth till was not found to extend into the Chain O'Lakes lowland (fig. 3 and 4). In the area east of the Chain O'Lakes the thickness of the Wadsworth till increases from a few meters to more than 45 m in the distance of a few kilometers. In the hummocky topography of northern Lake County, lacustrine sequences are common and occur in close proximity to thick till sequences. The average thickness of the Wadsworth till in the Valparaiso Morainic System of Lake and northern Cook Counties, Illinois, is 22 m.

Average thicknesses of the Wadsworth till in the Lake Border Moraines, in the Lake Chicago plain, and beneath Lake Michigan have not been estimated

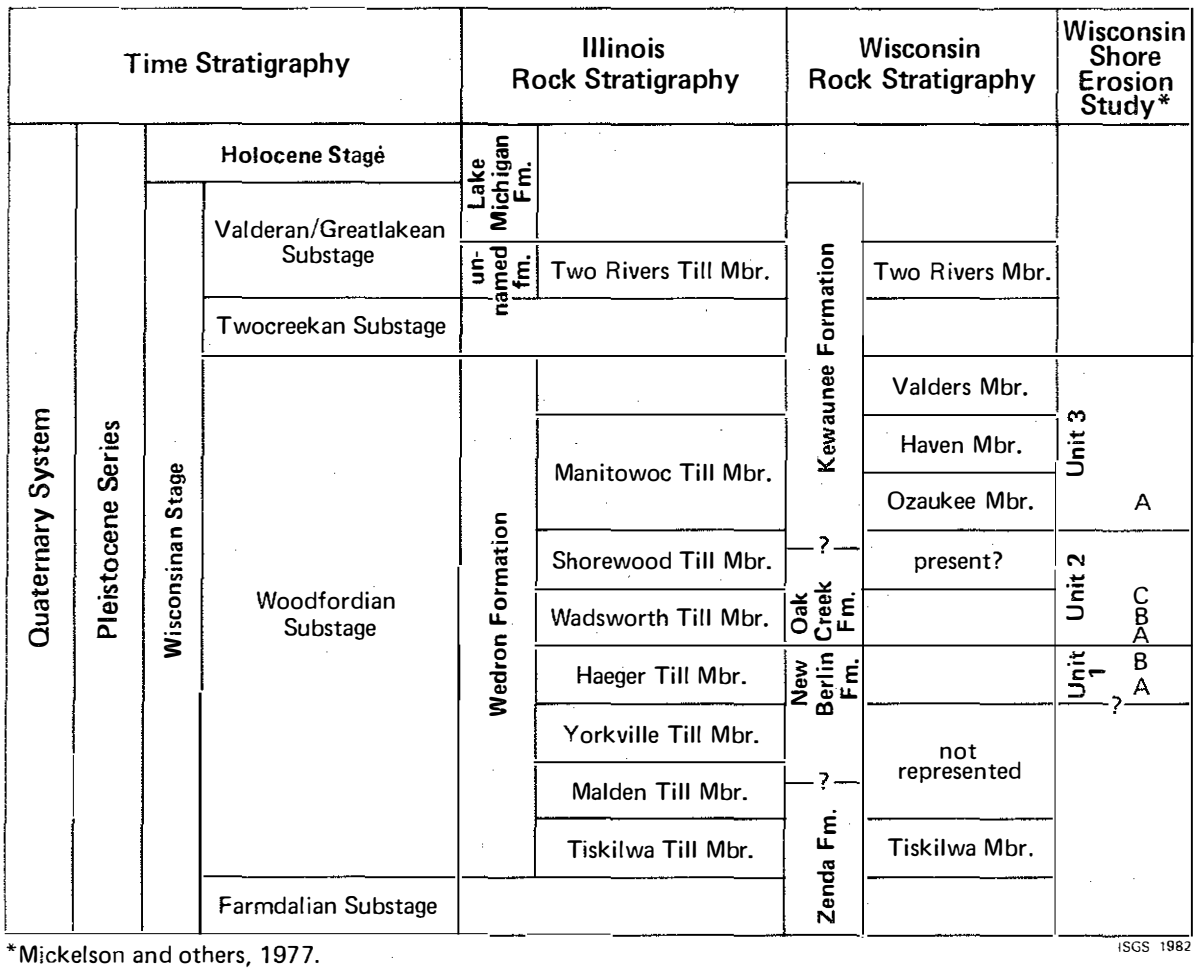

FIGURE 2.--Time and rock stratigraphy for till units in the study area. (Illinois rock stratigraphy from Lineback and others, 1974; Wisconsin rock stratigraphy from Mickelson and others, 1983.)

because of a lack of data. Along the Wisconsin portion of the lake bluffs, 30 m of Wadsworth till and interbedded lacustrine sediment has been found. Thicknesses of up to 50 m occur in the Lake Border Moraines and up to 23 m in the Lake Chicago plain. Up to 18 m of Wadsworth till have been reported in the southwest corner of Lake Michigan (Lineback and others, 1974).

Stratigraphic Position

In Illinois the Wadsworth till lies older Woodfordian tills of the Wedron Formation (fig. 1 and 2). In Wisconsin the Wadsworth till (Oak Creek Formation) overlies the Haeger till (New Berlin Formation). The contact between the Oak Creek Formation of the Valparaiso Moraines and the New Berlin Formation can he seen in quarry exposures in Racine and Waukesha Counties, Wisconsin (Mickelson and others, 1983). Along the lake hluffs south of Milwaukee, the Wadsworth till overlies Unit 1 of Mickelson and others (1977), the bouldery coarse-textured till they suggest may he correlative with the Haeger Till Memher of Illinois.

In Illinois, Wadsworth till is not known to overlie Haeger till. Examination of test-boring and water-well samples from Lake and Cook Counties failed to produce a stratigraphic relationship between these tills, but Wadsworth till was found to overlie outwash of Haeger composition in Cook County. Subsurface data show that the Wadsworth till of northeastern Illinois is usually underlain by a reddish-gray, silty till containing 70 percent illite that is known to occur ahove peat. The silty till also occurs above Tiskilwa till. Peat occurring below Tiskilwa till in northern Cook County is dated at 23 000 radiocarbon B.P. (Kempton and Gross, 1971); hence, the reddish-gray till

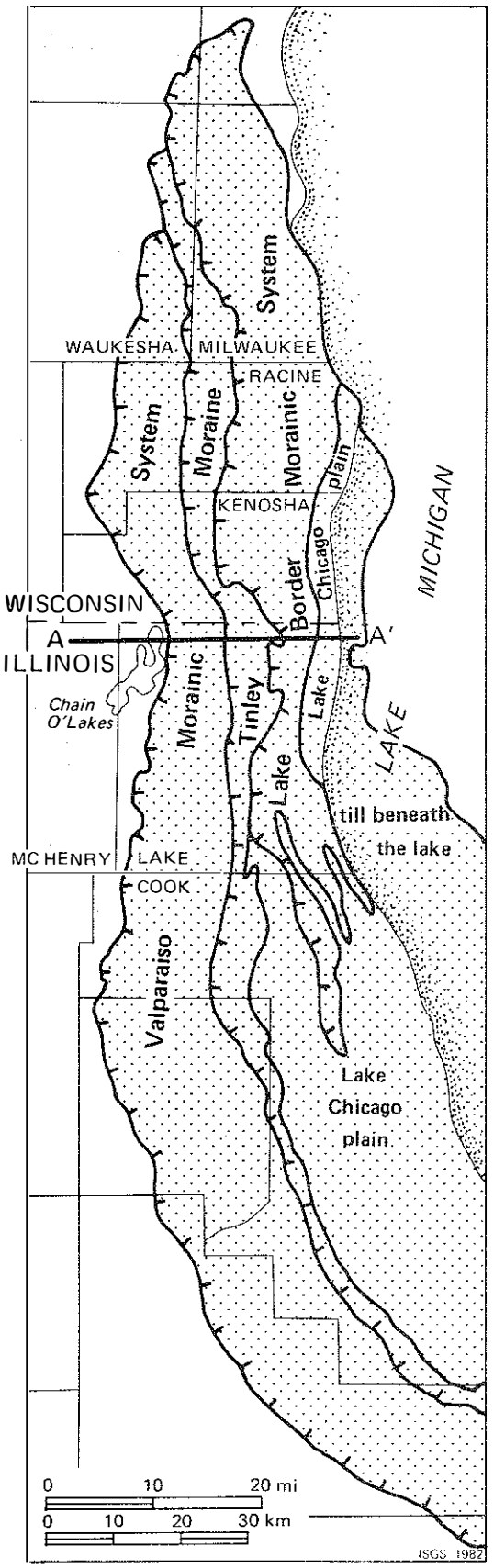

FIGURE 3.--Distribution of the Wadsworth Till Member in the southwestern Lake Michigan area.

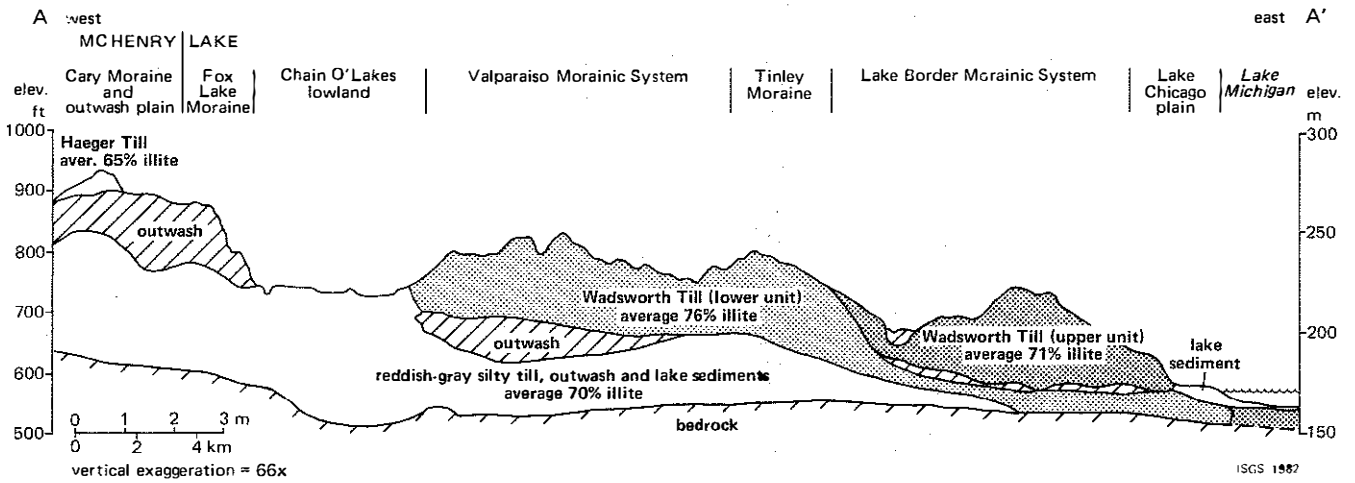

FIGURE 4.--Typical cross section west-east across northern Illinois. Line of section (A-A') is shown in figure 3.

found beneath the Wadsworth till is of Woodfordian age. This same till occurs in the Chain O'Lakes lowland and beneath Haeger till and outwash in McHenry County, Illinois, west of the Chain O'Lakes (fig. 4); it is redder and finer textured than the Haeger till. Although the reddish-gray, silty till is thought to be equivalent to older Wedron units that occur at the surface west and south of the study area (fig. 1) no definite correlation has been established. In the southern part of this study area the Wadsworth till is underlain by either the clayey Yorkville Till Member or the sandy Lemont drift, which Bogner (1974) has correlated to the Malden Till Member.

The stratigraphic relationship of the Wadsworth till and the next younger till is not clear. Lineback and others (1974) state that the Shorewood Till Member overlies the Wadsworth Till Member along the mid-lake high in Lake Michigan. This relationship is based on interpretation of a north-south seismic profile in which a subsurface boundary between the Wadsworth and the Shorewood units can be traced for several miles north of a prominent moraine front in southern Lake Michigan. No samples of the two tills in stratigraphic position have been recovered from the lake. Neither has the Shorewood till been traced on land at the surface in Wisconsin (fig. 1). Unit 2C of the shore erosion study (fig. 2) occurs at the surface along the bluffs south of Milwaukee and has been suggested as a possible equivalent of the Shorewood till (Acomb and others, 1982); however, it contains more illite (usually 70 percent or more) and is less red than the Shorewood till (63 percent illite) as defined by Lineback and others (1974). In the bluffs north of Milwaukee, the Oak Creek Formation which here has the clay-mineral composition of the Shorewood till, is overlain by the red-brown Ozaukee Member of the Kewaunee Formation (Acomb and others, 1982; Mickelson and others, 1983). Surface samples of Wadsworth till from the area mapped as Tinley Moraine west of Milwaukee are compositionally similar to the Shorewood till, but the Tinley morainic ridge appears to mark an ice margin position that is clearly traceable from Wisconsin to Indiana.

This discrepancy between the stratigraphy in the lake basin and the stratigraphy on land remains to be resolved. The Shorewood till is not considered a separate unit in Wisconsin as it is in Lake Michigan. Tills of Shorewood and Wadsworth composition (as defined by Lineback and others, 1974) have not been found in stratigraphic contact.

Stratigraphic unit	Average matrix texture (%)				Average Illite (%)	N
	Sand	Silt	Clay	N		
Shorewood Till Member						
Wickham and others, 1978	--[a]	--	--	--	63	4
Wadsworth Till Member						
Wickham and others, 1978	--	--	--	--	72	15
Willman and Frye, 1970	11	38	51	--	67	--
	12	37	51	--	77	--
This study[b]	11	43	46	98	70	83
Haeger Till Member						
Wickham, 1975	45	39	16	32	62	35
Willman and Frye, 1970	39	39	22	--	63	--
Yorkville Till Member						
Killey, 1982						
upper (Dwight mineral zone)	10	43	47	48	76	49
lower	13	43	44	132	81	141
Wickham, 1975	15	42	43	84	77	94
Willman and Frye, 1970	12	38	50	--	78	--
Malden Till Member						
Wickham, 1975	32	46	22	28	76	33
Willman and Frye, 1970	22	44	34	--	77	--
Tiskilwa Till Member						
Wickham, 1975	35	39	26	850	66	918
Willman and Frye, 1970	31	37	32	--	65	--

N = Number of samples

[a] No data

[b] Includes all data from area mapped as Wadsworth Till Member and Oak Creek Formation in Figure 1.

TABLE 1.--Characteristics of the Wadsworth and adjacent till members of the Wedron Formation.

TEXTURE AND COMPOSITION

Mean values for texture and clay mineral composition for the Wadsworth till are given in table 1. Typical values of these parameters cited by other researchers who have studied the Wadsworth and adjacent tills of the Wedron Formation are also shown.

The Wadsworth till of Illinois is characterized by its gray color, clayey texture, high illite content (generally greater than 70 percent) and low percentage of larger-than-2-mm clasts (average 3 percent). It can be distinguished from the "overlying" Shorewood till in Lake Michigan by its higher illite content and grayer color. The Wadsworth till is readily differentiated from the adjacent and subjacent Haeger till hy its finer texture and grayer color. The clayey Yorkville till is very similar to the Wadsworth till; these tills are not easily distinguishable, but the Wadsworth till is sandier at its western margin. Although the lower Yorkville till of Killey (1982) has more illite (80 percent) than the Wadsworth, her upper Yorkville (Dwight mineral zone) is nearly identical in clay mineral composition (76 percent illite) to that of the lower part of the Wadsworth. The Malden till is generally sandier and more often oxidized than is the Wadsworth Till; the Tiskilwa has a distinctive red-brown color and a sandy texture, and it is lower in illite.

Location	Sand (%)			Silt (%)			Clay (%)			Illite (%)[a]		
	X	S	N	X	S	N	X	S	N	X	S	N
Lake Border Moraines	8	3.6	36	43	5.4	36	49	7.0	36	71	2.2	30
Inner	8	3.7	25	45	4.8	25	47	6.8	25	71	2.2	22
Outer	7	3.3	11	39	5.0	11	54	4.8	11	71	2.1	8
Tinley Moraine	8	3.0	21	38	5.3	21	54	6.0	21	74	2.4	24
Valparaiso Moraine	15	4.2	41	45	3.8	41	40	5.2	41	76	1.9	55
Lake Chicago plain	--[b]	--	--	--	--	--	--	--	--	75	1.4	12
Lake Michigan	--	--	--	--	--	--	--	--	--	72	0.8	4

X = mean; S = standard deviation; N = number of samples

[a] Data from Ozaukee, Washington and part of Waukesha Counties, Wisconsin, not included

[b] No data

TABLE 2.--Characteristics of the Wadsworth Till Member in the Lake Border, Tinley, and Valparaiso Moraines, the Lake Chicago plain, and Lake Michigan.

LATERAL VARIATION

The character of the Wadsworth till of the study area varies along lines perpendicular to ice margin positions and along lines parallel to ice margin positions. Both types of variation show distinct patterns. Lateral variations in the characteristics of the Wadsworth till are reported in table 2.

Figure 5 shows lateral variation in percentage of illite in the clay-size fraction over the study area. The illite values are from unoxidized surface samples or the unoxidized portions of the top till unit from test-boring and water-well samples. In Illinois and the southern portion of the Wisconsin study area (Kenosha and Racine Counties), a fairly distinct change in illite content occurs between the Wadsworth till of the Valparaiso Morainic System and the Wadsworth till of the Lake Border Morainic System. The average illite content in the Valparaiso is 76 percent whereas the average in the Lake Border is 71 percent. The small standard deviations associated with the averages (around 2.0) (table 2) suggest that little overlap in percent illite occurs between the tills of the two morainic systems. The average percent illite in the Tinley Moraine is intermediate between the two--in some areas the clay-mineral content is similar to that of the Valparaiso, in other areas, to that of the Lake Border. The Lake Chicago plain is underlain by Wadsworth till similar in illite content (75 percent) to that in the Valparaiso Moraines (76 percent) while that in Lake Michigan is lower (72 percent) and more like that of the Lake Border (71 percent).

North of the border between Racine and Waukesha Counties in Wisconsin the percentage of illite in samples of Wadsworth till from the Valparaiso Morainic System is less than to the south. In Waukesha County the Wadsworth till appears to thin, and in some places the moraine truncates the Waukesha drumlin field (fig. 5). In these places the Wadsworth till is lower in illite and sandier, and thus--where oxidized--dificult to differentiate from the Haeger (New Berlin) till of the drumlin field.

The till of the Tinley and outer Lake Border Moraines becomes redder and progressively lower in illite northward from the vicinity of south Milwaukee. Illite in samples ranges from 72 percent in the south to 52 percent to the north in Washington County; such wide variation in illite is most uncommon within the Wadsworth Till Member and other till units in Illinois.

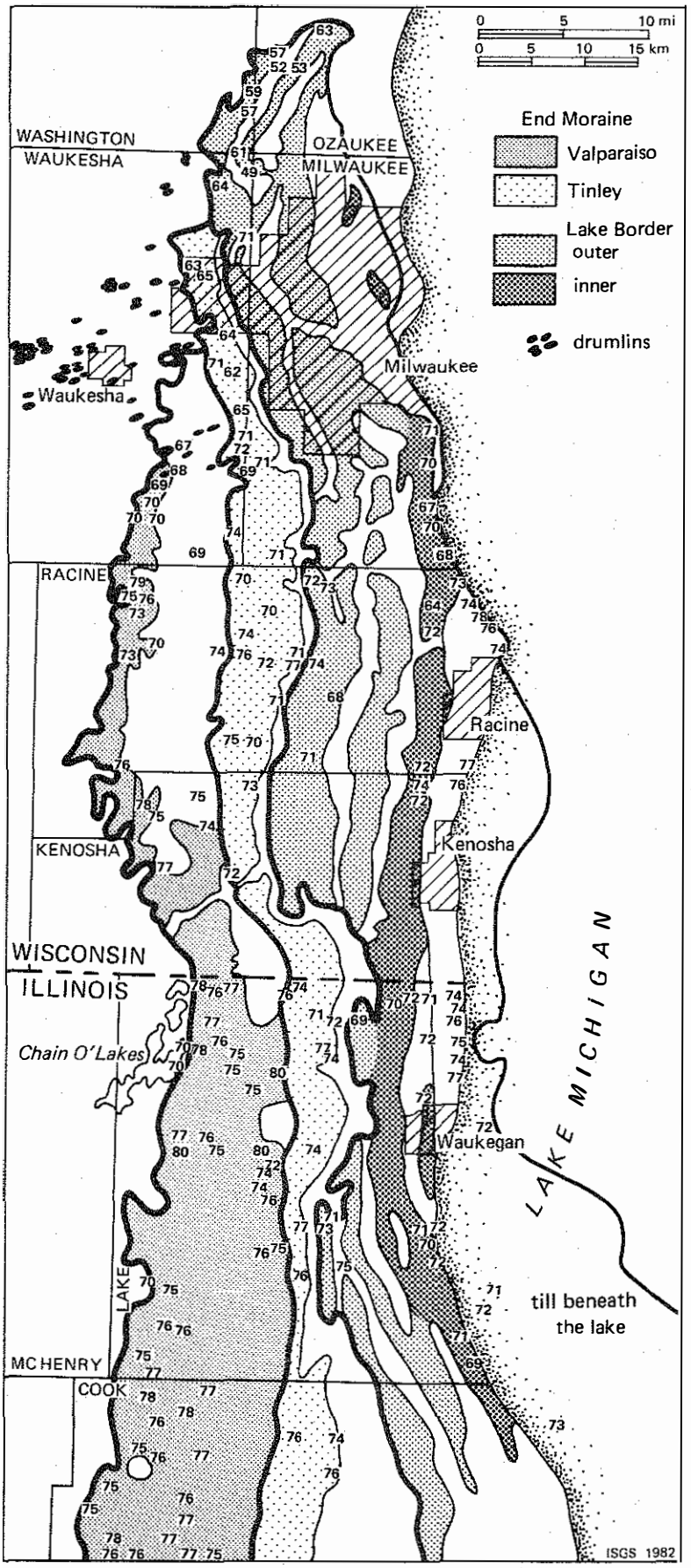

FIGURE 5.--Percentage of illite in the clay fraction of Wadsworth Till in the study area. Area of end moraine from Lineback (in press).

Lateral variation can also be noted in the texture of the Wadsworth till over the study area. Table 2 summarizes textural analyses of the till in the Valparaiso, Tinley, and Lake Border Moraines. The mean texture of the Wadsworth till in the Valparaiso Morainic System is sandier and less clayey than that of the Wadsworth till of the Tinley and Lake Border Moraines. The Tinley and outermost Lake Border Moraines are higher in clay content than the innermost Lake Border Moraines.

Variation in pebble lithologies has also been noted between the moraines composed of the Wadsworth Till Member (Willman and Frye, 1970). Black shale pebbles are more predominant in the till of the Tinley and Lake Border Moraines than in that of the Valparaiso.

VERTICAL VARIATION

Figure 4 illustrates typical stratigraphic variation in illite content within the Wadsworth till across the northern part of Illinois. In the Lake Border Moraines the less illitic (71 percent) Wadsworth till overlies the more illitic (76 percent) Wadsworth till, which is present at the surface in the Valparaiso Morainic System and beneath lacustrine sediment of the Lake Chicago plain. This relationship (a less illitic Wadsworth till over a more illitic Wadsworth till), commonly occurring with an intervening lacustrine or outwash sequence, is found in water-well and test-boring samples in Lake and Cook Counties of Illinois and can also be seen in the Illinois bluff exposures. Although some surface samples from the Tinley Moraine have less illite than do those at the surface in the Valparaiso, subsurface data indicate most of the moraine consists of till with more illite, similar to that of the Valparaiso Morainic System.

In the hummocky terrain of the Valparaiso Morainic System of Lake County another type of vertical variation occurs. Analyses of samples from water wells and test borings in this area show illite compositions of 75 to 76 percent interbedded with illite compositions of 70 to 71 percent. Some profiles have these randomly mixed compositions to depths of 35 m; most of the mixed profiles appear to contain non-homogeneous till interstratified with lacustrine deposits. The two compositions are similar to those of the lower part of the Wadsworth till (76 percent illite) and the reddish-gray, silty till (70 percent illite) underlying the Wadsworth.

Till samples collected along the bluffs south of Milwaukee show vertical variation in illite composition with depth within continuous till units that are homogeneous in texture. For example, a unit may range progressively from 70 percent illite at the top to 65 percent illite at the base. In some exposures in Illinois and Wisconsin, Wadsworth till units of the same composition are separated by lacustrine and outwash deposits.

DISCUSSION

The Wadsworth till is the youngest till in Illinois and Indiana. Its distribution in the moraines immediately bordering the lake indicates that it was deposited by the last pulse of ice to reach the southern part of the Lake Michigan basin.

The distinctive characteristics (color, clay-mineral composition, amount and lithology of pebbles, matrix texture) of the Wadsworth till reflect its Lake Michigan source. The Paleozoic limestone, dolomite, and gray shale units of the basin are highly illitic and Wisconsinan tills derived from the Lake Michigan basin are typically gray and illitic (Willman and Frye, 1970). Ordovician, Silurian, and Devonian strata that border Lake Michigan are predominantly dolomite and shale, and these are by far the most common pebble lithologies found in the Wadsworth till. The clayey texture and scarcity

of pebbles in the Wadsworth till are attributed to glacial reworking of Paleozoic clay and shale from the Lake Michigan basin and incorporation of proglacial lacustrine clay derived from disaggregated Paleozoic rocks of the basin. Dreimanis (1961) found that the tills of the Lake Erie basin derived principally from shale are coarser textured (less clayey) than those that also contain incorporated lacustrine clay and silt. The latter are similar in texture to the Wadsworth till.

One explanation for the variation in the clay-mineral composition within the Wadsworth till is that it is directly related to the relative amount of the glacial load entrained from the Lake Michigan basin. A decrease in illite from the time that the Wadsworth till was deposited at its outermost margin (Valparaiso Morainic System) to the time it was deposited on the lake floor may indicate a decreasing relative amount of entrainment of the highly illitic Lake Michigan basin material over time. This trend continued as the Woodfordian ice retreated northward and the Shorewood and Manitowoc tills were deposited. Changes in dominance of areas of erosion and entrainment have been explained by variation in the basal thermal conditions of the ice through time (Boulton, 1972b). Wickham and Johnson (1981) suggest that changes in the Lake Michigan portion of the Laurentide ice sheet occurred during Woodfordian time and can account for differences in the composition of some of the red and gray Woodfordian tills.

A second explanation for the changing composition and color of the clayey till that borders Lake Michigan is that the composition of glacial Lake Chicago sediment changed with time. Clayton (1983) suggests the possibility that influx of red sediment (less illitic) from the Lake Superior basin may have occurred between ice advances of latest Wisconsinan time although no connection between Lake Superior and glacial Lake Chicago has been confirmed. Change in the composition of glacial Lake Chicago sediment could also have resulted from a changing composition of the ice in the Lake Michigan basin (due either to change in the area of dominant entrainment or to change in the source rocks available for erosion). For this reason, the possibility of influx from Lake Superior is difficult to evaluate.

The fact that change in clay mineral composition is not entirely gradual, but instead is clearly associated with ice-margin positions (Valparaiso and Lake Border) suggests that in some cases fluctuation of the ice front accompanied change in source. This idea is supported by the fact that lacustrine and outwash sequences commonly occur stratigraphically between the less illitic "Lake Border" till and the more illitic "Valparaiso" till. The textural change between the till of the Valparaiso Moraines and the till of the Tinley and Lake Border fronts is consistent with a period of ice withdrawal and later readvance with incorporation of proglacial lake clay.

Change in illite with distance along north-south ice-margin positions may reflect differences in the length of flow path. The material deposited in the moraines at the southern margin of the lake might have been transported more than 100 km farther than the till in the same moraines west of Milwaukee. The smaller percentage of illite and the redder color of the till in the Tinley and Lake Border Moraines to the north indicate less incorporation of the gray Paleozoic sediment from the Lake Michigan basin than occurs in the till farther south. This is not surprising since flow paths of the ice which deposited the Wadsworth till west of Milwaukee would not have traversed the southern basin of Lake Michigan as would flow paths of the ice which deposited the Wadsworth till at the southern margin of the lake. Some differences in composition of the tills

would be likely to occur, considering the differences in length of flow path in the Lake Michigan basin and the resultant differences in opportunity for incorporation of gray illitic Paleozoic sediment.

Progressive vertical variation in illite in homogeneous till as occurs in the lake bluffs south of Milwaukee may be due to a gradual change in dominance of entrainment areas or source rock eroded. This phenomenon is not uncommon in till units that occur between red (greater influence of Lake Superior basin source) and gray (dominance of Lake Michigan basin source) end members in the Wedron Formation of Illinois (Wickham and Johnson, 1981). Rock-stratigraphic classification of these intermediate units poses problems.

The mixed compositon of thick sequences in the Valparaiso Morainic System of Lake County, Illinois, is not well understood. The heterogeneity of the till and lacustrine deposits is consistent with a supraglacial origin (Boulton, 1972a). The interbedding of Wadsworth till compositions with the reddish-gray silty till compositions in vertical profiles can be explained by the advance and stacking of Valparaiso ice over older stagnant ice (or the shearing of older till into the Valparaiso ice). Ablation and resedimentation could have resulted in the interbedding of the two compositions and the heterogeneity of the sequences. The hummocky topography with numerous kettles and lakes is further evidence for supraglacial sedimentation due to regional stagnation of the ice which deposited the Valparaiso Moraines. The thinning and compositional changes in the Wadsworth till of the Valparaiso Morainic System in Waukesha County, Wisconsin, may be due to local incorporation of the sandy Haeger till of the Waukesha drumlin field.

SUMMARY

On the basis of this research, I propose the following sequence of events for the deposition of the Wadsworth till.

1. Late Woodfordian ice from the Lake Michigan basin advanced to the Valparaiso morainic front, overriding older Woodfordian till and abutting stagnant ice in the Chain O'Lakes lowland. This ice deposited the gray illitic Wadsworth till of the Valparaiso Morainic System.

2. The ice downwasted and the active ice margin retreated an unknown distance, possibly back into the present area of the lake. Proglacial drainage was blocked by the Valparaiso end moraines.

3. Ice advanced to the position of the Tinley Moraine. During the advance, the ice incorporated proglacial lake sediment and deposited Wadsworth till similar in composition but more clayey than that in the Valparaiso Morainic System.

4. As the ice margin retreated (at least back to the present area of the lake), Wadsworth till of the same composition as that in the Tinley Moraine was deposited. Proglacial drainage was blocked between the Tinley Moraine and the ice margin forming glacial Lake Chicago.

5. Ice advanced out of the lake hasin, incorporating Lake Chicago sediment. Wadsworth till, similar in texture to that of the Tinley Moraine but with less illite, was deposited in the outer Lake Border Moraines over lacustrine sediment and more illitic Wadsworth till.

6. Wadsworth till was deposited behind several distinct ice-margin positions as the front fluctuated, generally retreating basinward. As the ice

front retreated northward in the Lake Michigan basin, Wadsworth till was deposited on the lake floor.

7. Change of dominance of areas of entrainment, source rocks eroded and/or influx of sediment from outside the Lake Michigan basin resulted in change in the composition and when the ice readvanced over the Wadsworth till to form an end moraine on the lake bottom, the redder, less illitic Shorewood till was deposited.

CONCLUSIONS

The gray, clayey Wadsworth till of Illinois and Wisconsin is a distinctive field unit that can usually be differentiated from other till units surficially and stratigraphically with the possible exception of the Yorkville till of Illinois. Although these two till units are very similar, the sandier Valparaiso Moraine forms a boundary between them where they are in contact at the surface. In the study area of Illinois the Wadsworth Till Member is a serviceable rock-stratigraphic unit suitable for formation rank and it is equivalent to what is being defined as the Oak Creek Formation in Wisconsin.

In Illinois a "Wadsworth Formation" can be subdivided, by means of analytical data, into two mappable rock-stratigraphic units: (1) a slightly sandy, relatively more illitic lower unit and (2) a clayey, relatively less illitic upper unit. The more illitic unit occurs in the Valparaiso and Tinley Moraines and beneath sediment of the Lake Chicago plain. The less illitic unit occurs in the Lake Border Moraines and beneath nontill sediment in southern Lake Michigan. These rock-stratigraphic units appear to lose their distinctive characteristics northward. The till in the northern part of the Tinley and Lake Border Moraines is considered to be a less illitic facies of the Wadsworth till.

If the Wadsworth till should be raised in rank from a member to a formation in the Illinois rock-stratigraphic hierarchy, the next logical step would be to reevaluate the rank and status of the younger two members of the Wedron Formation (the Shorewood Till Member and the Manitowoc Till Member).

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REFERENCES

Acomb, L. J., Mickelson, D. M., and Evenson, E. B., 1982, Till stratigraphy and late glacial events in the Lake Michigan Lobe of eastern Wisconsin: Geological Society of America Bulletin, v. 93, p. 289-296.

Alden, W. C., 1904, The Delavan lobe of the Lake Michigan glacier of the Wisconsin stage of glaciation and associated phenomena: U.S. Geological Survey Professional Paper 34, 106 p.

Alden, W. C., 1918, The Quaternary geology of southeastern Wisconsin: U.S. Geological Survey Professional Paper 106, 356 p.

Bogner, J., 1974, The Lemont drift of northeastern Illinois--a regional approach (abs.): Geological Society of America Abstracts with Programs, v. 5, no. 4, p. 301.

Boulton, G. S., 1972a, Modern Arctic glaciers as depositional models for former ice sheets: Journal Geological Society London, v. 128, p. 361-393.

Boulton, G. S., 1972b, The role of thermal regime in glacial sedimentation, in Price, R. J. and Sugden, D. E., eds.: Polar geomorphology: London, Institute of British Geology Special Publication 4, p. 1-19.

Bretz, J H., 1955, Geology of the Chicago region, Part II--The Pleistocene: Illinois State Geological Survey Bulletin 65, 132 p.

Chamberlin, T. C., 1878, On the extent and significance of the Wisconsin kettle moraine: Wisconsin Academy of Science, Arts, and Letter Transactions, v. 4, p. 201-234.

Chamberlin, T. C., 1882, The bearing of some recent determinations of the correlation of the eastern and western terminal moraines: American Journal of Science, v. 24, p. 93-97.

Clayton, Lee, 1983, Chronology of Lake Agassiz Drainage to Lake Superior in Teller, J. T., and Clayton, Lee, eds., Glacial Lake Agassiz: Geological Association of Canada Special Paper 26.

Dreimanis, A., 1961, National Research Council of Canada Associate Committee on Soil and Snow Mechanics: Ottawa, Fourteenth Canadian Soil Mechanics Conference Proceedings Technical Memmorandum 69, p. 23-24.

Evenson, E. B., 1973, Late Pleistocene shorelines and stratigraphic relations in the Lake Michigan basin: Geological Society of America Bulletin, v. 84, p. 2281-2298.

Kempton, J. P., and Gross, D. L., 1971, Rate of advance of the Woodfordian (Late Wisconsinan) glacial margin in Illinois: stratigraphic and radiocarbon evidence: Geological Society of America Bulletin, v. 82, p. 3245-3250.

Killey, M. M., 1982, The Dwight mineralogical zone of the Yorkville Till Member, northeastern Illinois: Illinois State Geological Survey Circular 526, 25 p.

Leverett, Frank, 1897, The Pleistocene features and deposits of the Chicago area; Chicago Academy of Science, Geological and Natural Histotory Survey Bulletin 2, 86 p.

Leverett, Frank, 1899, The Illinois glacial lobe: U.S. Geological Survey Monograph 38, 817 p.

Lineback, J. A., Chicago quadrangle Quaternary map: U.S. Geological Survey, scale 1:1,000,000 (in press).

Lineback, J. A., Gross, D. L., and Meyer, R. P., 1974, Glacial tills under Lake Michigan: Illinois State Geological Survey Environmental Geology Notes 69, 48 p.

Mickelson, D. M., Acomb, L. J., Brouwer, N., Edil, T., Fricke, C., Haas, B., Hadley, D., Hess, C., Klauk, R., Lasca, N., and Schneider, A. F., 1977, Shoreline erosion and bluff stability along Lake Michigan and Lake Superior shorelines of Wisconsin: Wisconsin Coastal Management, Shore Erosion Study, Technical Report, 199 p.

Mickelson, D. M., Clayton, Lee, Baker, R. W., Mode, W. N., and Schneider, A. F., in press, Pleistocene stratigraphic units of Wisconsin: Wisconsin Geological and Natural History Survey,

Powers, W. E., and Ekblaw, G. E., 1940, Glaciation of Grays Lake, Illinois, Quadrangle: Geological Society of America Bulletin, v. 51, p. 1329-1335.

Wickham, J. T., Gross, D. L., Lineback, J. A., and Thomas, R. L., 1978, Late Quaternary sediments of Lake Michigan: Illinois State Geological Survey Environmental Geology Notes 84, 26 p.

Wickham, S. S., 1975, The Tiskilwa Till Member, Wedron Formation; a regional study in northeastern Illinois: Champaign, University of Illinois, M.S. Thesis, 229 p.

Wickham, S. S. and Johnson, W. H., 1981, The Tiskilwa Till, a regional veiw of its origin and depositional processes: Annals of Glaciology, v. 2, p. 176-182.

Willman, H. B., 1971, Summary of the geology of the Chicago area: Illinois State Geological Survey Circular 460, 77 p.

Willman, H. B., and Frye, J. C., 1970, Pleistocene stratigraphy of Illinois: Illinois State Geological Survey Bulletin 94, 204 p.