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CLAY MINERALOGY OF WISCONSINAN TILLS OF THE CUYAHOGA VALLEY NATIONAL RECREATION AREA, NORTHEASTERN OHIO[1]

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ABSTRACT. Five Wisconsinan tills crop out in the Cuyahoga Valley National Recreation Area in southern Cuyahoga and northern Summit Counties. Middle Wisconsinan Mogadore Till is restricted to isolated outcrops in deep valleys whereas Middle Wisconsinan Northampton till crops out throughout the area. Kent Till overlies Northampton till in the northeastern corner of the area. Late Wisconsinan Lavery and Hiram Tills are less extensive and restricted to the uplands.

Illite is the dominant clay mineral of the tills. Fe-chlorite in unweathered tills alters to vermiculite or a vermiculite-montmorillonite intergrade in oxidized tills. Kaolinite is present in small amounts. The ratio of illite to kaolinite and chlorite increases in weathering profiles as chlorite alters to vermiculite. The diffraction intensity is 0.8 for Mogadore Till, 1.4 for Northampton and Kent tills, and greater than 4.0 for Lavery Till. These values are consistent throughout the area.

The use of clay mineralogy in differentiating among tills poses problems. Local bedrock influences the proportions of clay minerals in till. Tills containing the same relative amounts of clay minerals are not necessarily the same age. Alteration of clay minerals in tills by groundwater percolating through adjacent permeable deposits may be confused with that produced by subaerial weathering.

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INTRODUCTION

Clay mineralogy has been used as a means to differentiate among tills. Willman et al. (1963) used clay mineralogy to delineate two major provenances of tills in Illinois. Tills from the Michigan lobe are dominated by illite whereas tills deposited by glaciers originating to the northwest are dominated by expandable clay minerals such as montmorillonite. Furthermore, individual till sheets could be differentiated as to the relative amounts of expandables, illite, and kaolinite-chlorite. Hallberg (1980) demonstrated that clay mineralogy could be used to differentiate tills in eastern Iowa in a similar fashion. Ruhe and Olson (1978) used clay mineralogy to differentiate between loess deposits derived from outwash of two different provenances in Indiana.

Early work by Droste (1956a, 1956b) and Droste and Tharin (1958) in northeastern Ohio showed that clay mineralogy changed with depth in weathering profiles developed in tills. Willman et al. (1966) examined weathering profiles and attempted to quantify these changes with depth. They developed standards which have come into general use.

Since Droste's work during the mid-1950s, very little has been published on the clay mineralogy of tills in northeastern Ohio. Soil surveys report some data on clay mineralogy, but rarely do they contain data from completely unweathered material. Their data show a dominance of illite and chlorite. This study was undertaken because of the paucity of data on clay mineralogy of tills in northeastern Ohio. Numerous samples were available from sections sampled for M.S. theses at the University of Akron. These theses covered

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relatively large areas of the Cuyahoga Valley National Recreation Area (CVNRA), and substantial areal, vertical, and stratigraphic controls are available.

PURPOSE OF STUDY

The first purpose of this study is to determine the clay mineralogy of Wisconsinan tills found within the CVNRA. This includes analysis of differences in clay mineralogy among tills and of variations within a till over a large area. Secondly, some clay minerals weather rapidly when exposed to surficial processes. As a result alteration of clay minerals in weathering profiles also is investigated.

STUDY AREA

The Cuyahoga Valley National Recreation Area is situated in the glaciated Cuyahoga River Valley in Cuyahoga and Summit Counties (fig. 1). The park follows the Cuyahoga Valley from Bath Rd. in Northampton and Bath Twps. in Summit Co. north to Rockside Rd. in Independence and Valley View in Cuyahoga Co. Its eastern and western boundaries are irregular, reflecting zoning and land use rather than physiographic boundaries. This study extends beyond the eastern and western borders of the CVNRA.

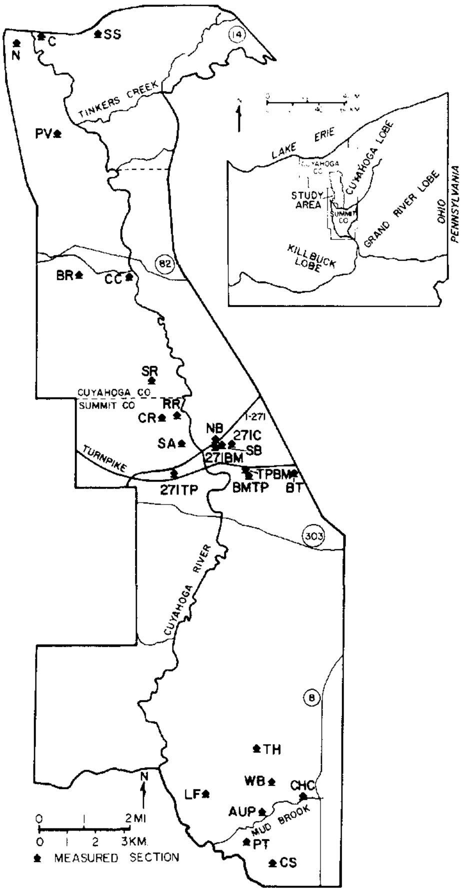

FIGURE 1. Study area showing location of measured sections in the CVNRA. Exact boundaries of the CVNRA lie within the limits of this figure.

PREVIOUS STUDIES

In his history of glacial lakes in Ohio, Claypole (1887) described in detail Lake Cuyahoga and its deposits in the Cuyahoga Valley now within the CVNRA. Leverett (1902) described the characteristics and thickness of glacial deposits in the area, as well as their morphology, distribution, and age.

The classical Pleistocene stratigraphy of northeastern Ohio has been developed by George White and his students who have studied Pleistocene deposits and applied rock-stratigraphic terms to them. These workers have also delineated the extent of glaciation, correlated deposits to the Wisconsinan Stage, and assigned radiocarbon ages to certain glacial deposits.

Others have contributed to work of this nature within the CVNRA. Rau (1969) discussed buried valleys, glacial lakes, and till deposits in his study of the Cuyahoga River Valley which covered its evolution from its pre-glacial ancestor, the Dover River, through glacial Lakes Cuyahoga and Independence to the present. Wittine (1970) discussed the lacustrine silts in the Cuyahoga Valley crediting them to several phases of Lake Cuyahoga. Bain (1975) examined terraces and deltaic deposits in the valley between Akron and Peninsula. Ryan (1980), Szabo and Ryan (1981), Angle (1982), Donovan (1983), Ospanik (1983), Fernandez (1983), and Szabo and Angle (1983) have studied Quaternary stratigraphy in various parts of the CVNRA. They correlated deposits to the classical stratigraphy of White and identified as well as described a previously unnamed till, informally referred to as the Northampton till (Szabo and Fernandez 1983). The spatial arrangement of Pleistocene deposits within the Cuyahoga Valley is illustrated in fig. 2.

Other studies have shown that the distinct lithologic character of the tills of the Allegheny Plateau region enable till samples to be identified and correlated with relative ease and certainty. Totten (1960) has demonstrated the presence of distinct differences in quartz and feldspar content in tills of northeastern Ohio. This has been verified by workers in the CVNRA. White et al. (1969) summarized lithologic data of tills which have been traced from northeastern Ohio into northwestern Pennsylvania.

METHODS AND MATERIALS

Samples used in this study came from many contributors. North of State Rt. 82 (fig. 1) samples were collected as part of a M.S. thesis by Fernandez (1983). These include samples taken from measured sections, hand borings, and outcrops along streams. Samples from 303N Section were collected by Szabo et al. (1981) from a large section exposed along Furnace Run approximately two km west of where Rt. 303 ends on fig. 1. Splits of samples from WBE (eastern section at WB) and CHC Section (fig. 1) originally used by Ryan (1980) were also X-rayed in this study. In all of the above cases about 200 g of sample were taken at 0.25, 0.50, or 1.00–m intervals.

Laboratory analyses included standard procedures for working with tills. Matrix texture of the less than two–mm fraction was determined using the methods of Folk (1974). Carbonate content of the less than 0.074–mm fraction was calculated using a Chittick apparatus (Dreimanis 1962). The ratio of quartz to feldspar in the fine sand fraction was determined by cathodoluminescence (Ryan and Szabo 1981).

Because of its significance to this paper, the procedure for X-ray diffraction analysis will be discussed

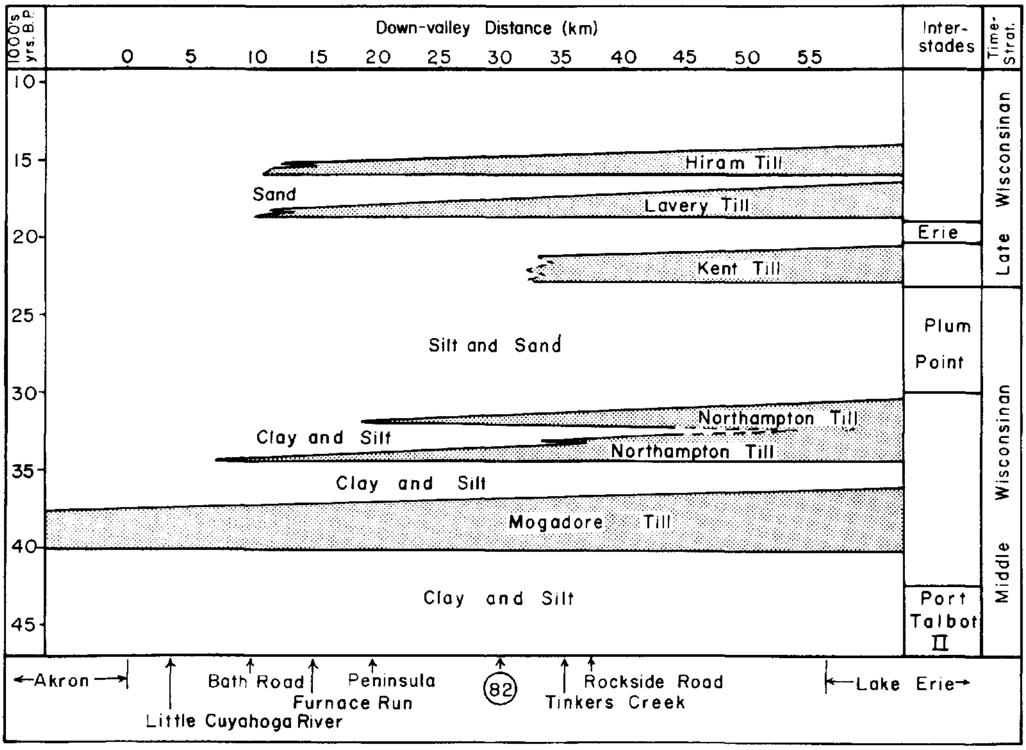

FIGURE 2. Diagrammatic stratigraphy of Wisconsinan deposits of the CVNRA (modified from Dreimanis and Goldthwait (1973) and White (1982)).

in detail. Approximately 50 g of sample were disaggregated in 250 ml of deionized water for 24 h. The samples were dispersed for 10 min and approximately the top 100 ml were poured into a beaker and allowed to settle overnight. If the clay minerals flocculated, a small amount of sodium hexametaphosphate was added to prevent further flocculation. A settling method was then employed to obtain the less than 0.002–mm fraction which was pipetted onto a pair of glass slides to form oriented mounts (Carroll 1970).

One of the duplicate slides was placed inside a dessicator in an atmosphere of ethylene glycol for 24 h before X-raying. The other slide was X-rayed after first being heated in a 450 °C oven for 30 min and X-rayed again after being heated in a 600 °C oven for another 30 min. A Phillips-Norelco XRG-2500 machine was used with Ni filtered CuKα radiation. Scanning was at a rate of 2° 2θ/min from 2° to 28°. Clay minerals were identified using guides by Jackson (1969), Carroll (1970), and Chen (1977). Of particular interest are: illite, chlorite, vermiculite, kaolinite, and montmorillonite.

Illite, in glycolated oriented mounts, exhibits characteristic basal d-spacing peaks at 10.0 Å (002) and at 5.0 Å (004). The 10 Å peak is sharp and symmetrical if the illite is well crystallized; slightly asymmetrical on the low angle side if the illite is hydrated; and very asymmetrical, possibly with a shoulder on the low angle side, if illite-montmorillonite mixed layering is present (Droste 1956b, Carroll 1970). Heating to 450 °C dehydrates illite and forms the sharp, symmetrical diffraction pattern characteristic of well-crystallized illite.

Chlorite has d-spacings of 14.0-14.4 Å (001), 7.0-7.2 Å (002), 4.7 Å (003), and 3.55 Å (004) in glycolated samples. Heating to 450 °C has no effect on the (001) diffraction pattern but slightly reduces higher orders. Heating to 600 °C causes the 14 Å peak to intensify as higher orders disappear. Fe-chlorites exhibit weak first and third basal reflections and strong second and fourth basal reflections. Mg-chlorites have more uniform reflections (Carroll 1970).

Chlorite alters to vermiculite through an intermediate phase of vermiculite-chlorite mixed layer clay. As chlorite alters the 14 Å peak becomes less intense and migrates towards 14.6 Å. If substantial vermiculite is present, the 14 Å peak will disappear on heating to 450 °C and may reappear after heating to 600 °C depending upon the amount of chlorite still present.

Vermiculite, in glycolated samples, is characterized by a broad diffraction peak at 14.6 Å which is more intense than its higher order peaks at 7.14 Å and 4.76 Å. Heating to 450 °C for 30 min causes a temporary collapse of the unit cell to 10.0 Å. Heating to 600 °C causes vermiculite to collapse to a 9.3 Å d-spacing from which it will not rehydrate (Walker 1975).

Kaolinite is the most troublesome mineral to identify because its basal spacings of 7.14 Å (001), 4.79 Å (002), and 3.58 Å (003) are all shared by chlorite. Upon heating to 600 °C, kaolinite becomes amorphous the 14 Å peak of chlorite intensifies. If both minerals are well crystallized, the (002) reflection for kaolinite may differentiate itself from the (004) reflection for chlorite. Droste (1956b) suggests that in weathering profiles early stage chlorite alteration not represented by an immediate and rapid intensity reduction of the 7 Å reflection indicates the presence of kaolinite. He also points out that the 7 Å/14 Å intensity ratio for chlorite can have a maximum value of 3/1. Any ratio greater than this indicates the presence of kaolinite.

Mixed layer illite-montmorillonite is indicated by asymmetry of the 10.0 Å illite peak in glycolated samples. Mixed layer montmorillonite-chlorite is characterized by a (001) reflection at 31.8 Å and a sharper, more intense (002) reflection of 15.9 Å. As with all mixed layer clays the actual d-spacing may vary anywhere between the appropriate basal reflections of the two components.

Semi-quantitive methods are used to identify the dominant clay mineral in tills and to rank the remaining constituent clays. The X-ray diffraction patterns from glycolated slides are used to determine the diffraction intensity ratio or D.I. (Willman et al. 1966). First, a horizontal line is drawn across the base of the 10 Å illite and 7 Å kaolinite-chlorite peak. The areas above these lines and under the peaks are calculated by counting squares on the diffractogram. The D.I. is the ratio of the area under the 10 Å illite peak to the area under the 7 Å kaolinite-chlorite peak. The D.I. is used to compare unweathered till samples to each other or to construct a weathering profile in a till.

WISCONSINAN STRATIGRAPHY

Each of the Wisconsinan tills in northeastern Ohio (fig. 2) is lithologically distinctive and can be identified in the field with reasonable certainty (White 1982). This consistency of character has been reiterated in numerous studies by White which describe the Mogadore, Kent, Lavery and Hiram Tills. Recently Ryan (1980), Angle (1982), Ospanik (1983) and Donovan (1983) verified the lithologic consistency of these tills within the CVNRA. Although laboratory analysis imparts greater certainty to till identification, field identification is both useful and necessary.

Mogadore Till (Smith and White 1953) is correlative with Millbrook Till of the Killbuck lobe to the west and Titusville Till of the Grand River Lobe to the east (fig. 1). The till is sandy (27.5% sand, 54.1% silt, 18.4% clay), contains many pebbles, cobbles, and boulders and oxidizes to olive brown. Dark gray unweathered Mogadore Till is very firm and platy and reacts weakly to hydrochloric acid.

Northampton till is clay rich (9.9% sand, 48.0% silt, 42.1% clay) and contains dark gray dolomite pebbles. Dark gray, firm, blocky till oxidizes olive brown to dark yellowish brown and reacts strongly with hydrochloric acid.

Kent Till (White 1960) is sandy (34.2% sand, 44.2% silt, 21.6% clay) and contains cobbles and a few large boulders. The oxidized till is characteristically "bright" yellow-brown. Blocky to platy Kent Till is less compact than the Mogadore and Northampton tills and reacts moderately with hydrochloric acid. This till is often interbedded with sand and silt.

Thin, discontinuous Lavery Till (White 1960) is a very calcareous clay till (10.5% sand, 48.3% silt, 41.2% clay) containing few pebbles. The till oxidizes brown to dark brown and often contains nodules of secondary calcite or calcite coatings along joints.

Hiram Till (White 1960) is also a clay till (17.9% sand, 47.4% silt, 34.7% clay) which oxidizes brown to dark brown. It is similar to the Lavery Till but the depth of leaching is less than that of the Lavery Till.

RESULTS

MOGADORE TILL. Illite is the dominant clay mineral of the Mogadore Till (fig. 3). Its 10 Å peak is asymmetric, often with a shoulder to the low angle side. Heating

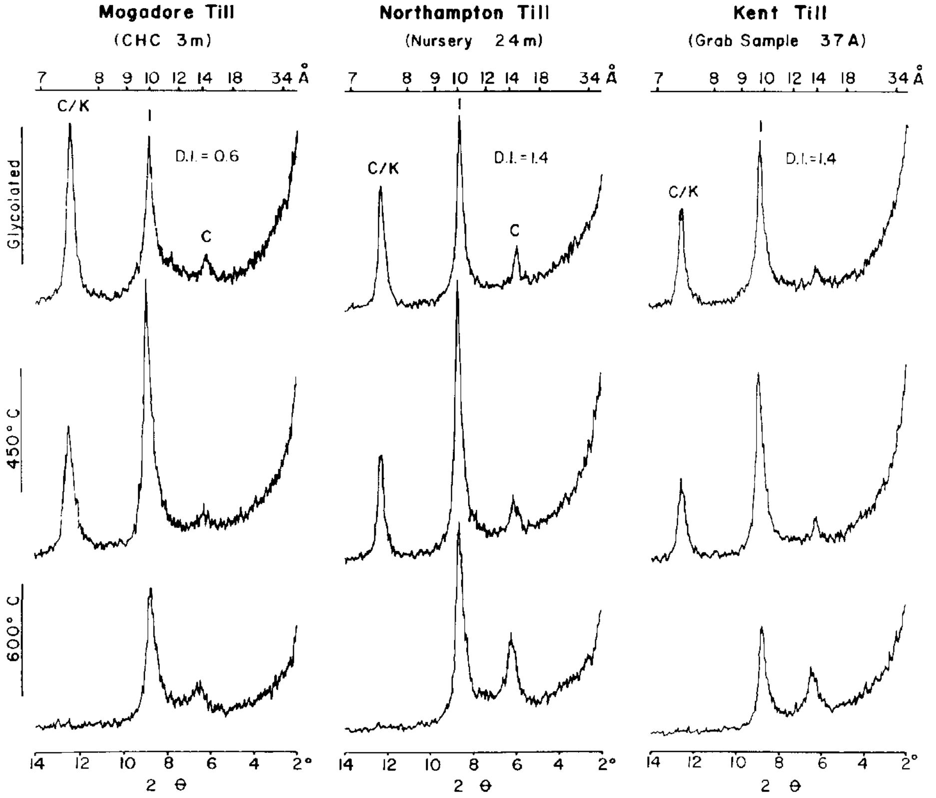

FIGURE 3. Comparison of diffractograms of representative samples of unoxidized Mogadore, Northampton, and Kent Tills. C-chlorite, I-illite and K-kaolinite.

increases the intensity of the peak, but the asymmetry remains indicating the mineral is hydrated and partially altered to a mixed layer illite-montmorillonite.

Chlorite is the 14 Å mineral in all but the most-weathered samples where it has been altered to vermiculite. Some samples exhibit a 14 Å peak which disappears on heating to 450 °C and reappears on heating to 600 °C, which indicates a vermiculite-chlorite mixed layering. Differentiation of kaolinite and chlorite is possible at the 3.5 Å reflection which indicates that kaolinite is less abundant than chlorite. The D.I. of unweathered Mogadore Till averaged 0.8 and 0.9 for the two sections analyzed (table 1).

A series of diffractograms representing partial weathering profiles developed in the uppermost two m of the CHC Section is illustrated in fig. 4. The upper two diffractograms are from an oxidized zone; chlorite is altered to vermiculite as shown by a weak 14 Å peak. The other three diffractograms of unoxidized till show a strong 14 Å chlorite peak and very strong 7 Å kaolinite-chlorite peak when compared to the upper diffractograms. This indicates that clay mineral alteration has not penetrated more than 1.4 m into the Mogadore Till at this location.

NORTHAMPTON TILL. Northampton till is dominated by illite, but the 7 Å kaolinite-chlorite peak is not as high as that of the Mogadore Till (fig. 3). Chlorite is well crystallized and most diffractograms of glycolated unweathered till samples show strong 14 Å peaks. The chlorite appears to be of the Fe-rich variety because the second and fourth order peaks are more intense than the first and third order peaks (Carroll 1970). The D.I.'s of unoxidized till in the sections averaged between 1.4 and 1.5.

The six sections of Northampton till examined in this study (table 1) exhibit weathering profiles similar to those described by Droste (1956b), Droste and Tharin (1958) and Willman et al. (1966). In these profiles the 10 Å illite peaks are strong and generally symmetrical in glycolated lower samples. Upward, it becomes increasingly asymmetrical on the low angle side indicating the illite is first beginning to hydrate, then to partially alter to illite-montmorillonite. Illite has not begun to alter to vermiculite except in the heavily weathered top 0.1 m of the Northampton till of the WBE Section (fig. 5). The 14 Å chlorite peak becomes less intense and has altered to vermiculite. The 7 Å kaolinite-chlorite peak is strong and gradually becomes less intense and symmetrical upward in these sections.

KENT TILL. Gray Kent Till, found in outcrops, has diffraction patterns and calculated D.I.'s indistinguishable from unoxidized Northampton till (table 1,

TABLE 1

Diffraction intensities of tills in the CVNRA. Cases include only unoxidized samples except for the Lavery Till (modified from Fernandez 1983).

	Summit County					Cuyahoga County					
	Mogadore Till		Northampton till		Lavery Till	Northampton till					Kent Till
Section	CHC	303N	303N	WBE	WBE	C	N	PV	SS	GRABS	GRABS
Cases	(23)	(6)	(18)	(8)	(14)	(19)	(11)	(9)	(9)	(23)	(6)
Mean	0.8	0.9	1.5	1.4	9.1	1.4	1.5	1.5	1.4	1.5	1.4
S. Dev.	0.1	0.1	0.2	0.0	3.7	0.2	0.2	0.1	0.1	0.2	0.1
Var.	0.0	0.0	0.0	0.0	12.8	0.0	0.0	0.0	0.0	0.0	0.0
Minimum	0.6	0.7	1.0	1.3	3.3	1.2	1.3	1.4	1.2	1.1	1.3
Maximum	1.1	0.9	1.8	1.4	15.7	1.8	1.8	1.6	1.5	2.0	1.6
Range	0.5	0.2	0.8	0.1	12.4	0.6	0.5	0.2	0.3	0.9	0.3

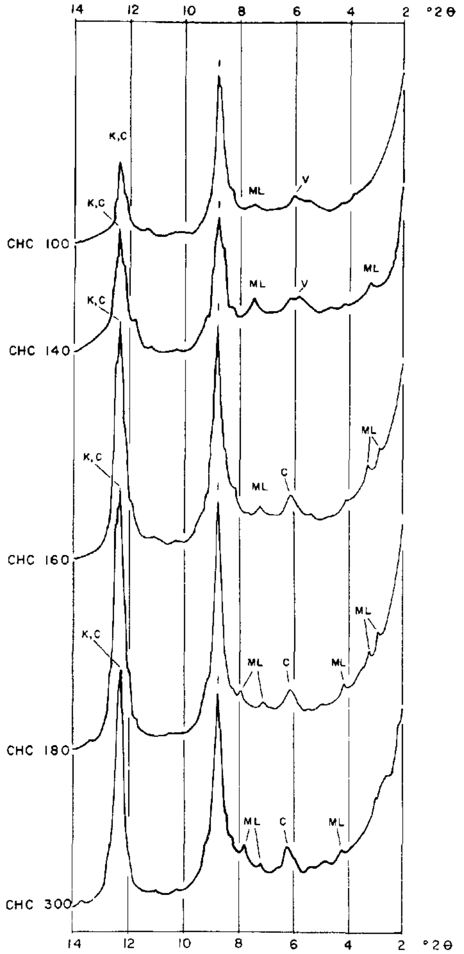

FIGURE 4. Weathering profile of Mogadore Till from the CHC Section (Ryan 1980). V-vermiculite, C-chlorite, I-illite, K-kaolinite, and ML-mixed layered clays. Numbers on left are sampling depths in centimeters.

fig. 3). The D.I.'s of both tills are near 1.4. The diffractograms show the same relative peak heights and areas. Kent Till and Northampton till exhibit the same clay mineral alteration in their weathering profiles.

LAVERY TILL. The Lavery Till of the WBE section (Ryan 1980) is oxidized throughout its entire thickness. Illite is the dominant clay mineral and has a somewhat asymmetrical 10 Å peak. This peak has several small steps (fig. 5) which may represent mixed layered clay minerals. The 14 Å peak is very broad suggesting vermiculite and/or a vermiculite–montmorillonite intergrade. The 7 Å koalinite-chlorite peak is very weak and diffuse implying that very little chlorite remains.

The D.I. has no significance here in comparison to the other tills, but it serves as an indicator of the degree of clay mineral alteration (fig. 6, table 1). At the bottom of the Lavery Till the D.I. increases as chlorite alters to vermiculite. Then as illite alters to vermiculite, the D.I. generally decreases. The trend in this entire unit resembles the "B-zone" of Willman et al. (1966) which is the deepest zone of illite to vermiculite transformation.

HIRAM TILL. No Hiram Till was analyzed in this study. This till is thin and often mixed into the modern soil. Because it is generally oxidized throughout, the clay mineralogy is similar to that of the Lavery Till and shows a similar trend also in its weathering profile (Donovan 1983).

AREAL VARIATION IN CLAY MINERALOGY. Each till unit exhibits a characteristic diffraction pattern and D.I. for unoxidized samples. T-test results show to a 5% level of significance that there are no differences in the D.I.'s within a till unit with respect to its location within the CVNRA. Also, statistical tests show the D.I.'s of unoxidized Northampton and Kent tills to be of the same population, and the unoxidized Mogadore Till to be of a distinctly different population. Table 1 illustrates the lack of variation within tills and the similarity of Kent and Northampton tills.

DISCUSSION

The results show that in addition to field characteristics, clay mineralogy is useful to differentiate between the Mogadore Till and the Northampton and Kent tills. However, the study of the tills in the CVNRA has brought out some problems in using clay mineralogy.

The first problem is related to the influence of local bedrock on the composition of tills. Actively eroding glaciers incorporate large amounts of local bedrock; clay miner-

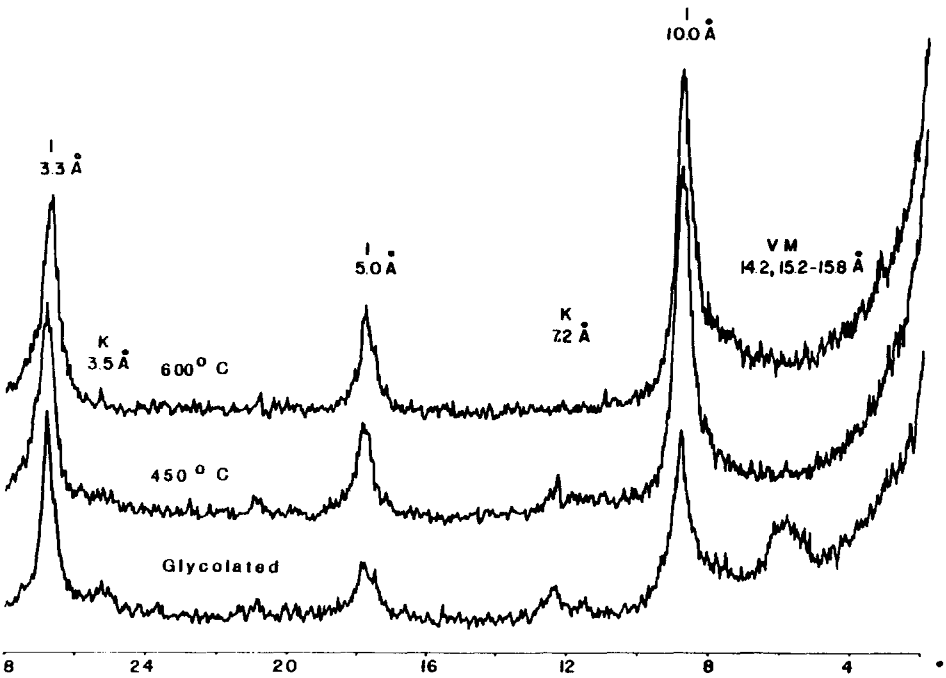

FIGURE 5. Representative diffractograms of the Lavery Till from the WBE Section (Ryan 1980). VM-vermiculite-montmorillonite intergrade, I-illite and K-kaolinite.

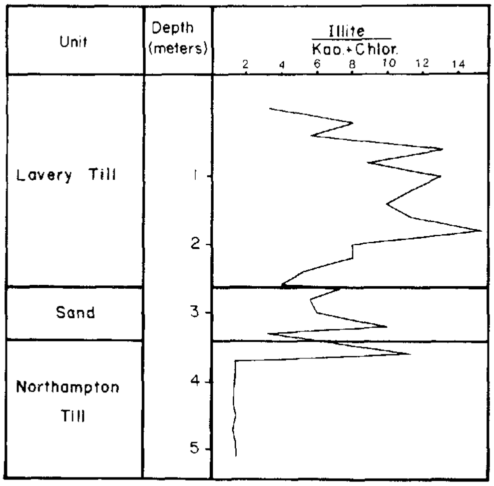

FIGURE 6. Vertical change in diffraction intensity ratio (D.I.) of tills in the WBE Section. Note increase in D.I. in the intervening sand.

alogy of the till should reflect that of the underlying bedrock. The Middle Wisconsinan Mogadore Till generally has the lowest D.I. Its 7 Å kaolinite-chlorite peaks are significantly greater than those of the younger tills. The local bedrock consists of Pennsylvanian, Mississippian, and Devonian clastics. The Devonian and Mississippian shales are illitic. The Pennsylvanian is represented by the Sharon Sandstone; no other Pennsylvanian rocks are reported in well logs near the CVNRA. Preliminary studies of tills from Stark Co., south of Summit Co., show that these tills are higher in kaolinite-chlorite and also overlie Pennsylvanian cyclothems. If rocks representative of Pennsylvanian cyclothems were once more extensive over northeastern Ohio, tills of earlier glaciations may contain more kaolinite-chlorite than younger tills. As successive glaciers eroded into the older illitic rocks, the composition of the tills would change.

Another problem that has been compounded by the study of clay mineralogy of the Wisconsinan tills is that of the origin of the Northampton till. Ryan (1980), Angle (1982), Ospanik (1983), and Donovan (1983) suggested that Northampton till may represent a readvance of Mogadore ice during the Middle Wisconsinan or that it may be the equivalent of the Kent Till. Fernandez (1983) found Kent Till overlying Northampton till in the Substation Section (SS, fig. 1) and also inferred this relationship from outcrops along streams in the same area. This implies that Northampton till is older than Kent Till (fig. 2). But the clay mineralogy suggests a similar provenance, specifically Mississippian and Devonian shales. This supports an alternative hypothesis that Kent Till and Northampton till may be stratigraphic equivalents. One possible explanation is that the Cuyahoga and Grand River lobes (fig. 1) were not synchronous during the early part of the Late Wisconsinan. The Cuyahoga lobe may have deposited Northampton till; slightly later the Grand River lobe deposited Kent Till over Northampton till in this area of the Cuyahoga Valley. This hypothesis needs more stratigraphic evidence.

A third problem which affects the use of a clay mineralogy as a tool in stratigraphic studies is the influence of sand and silt lenses between and within tills. Groundwater moving through more permeable materials oxidizes the materials and probably causes alteration of clay minerals. Fig. 6 illustrates this problem; a sand lens less than meter–thick separates Lavery and Northampton tills. The D.I. of the clays within the lens is greater than that of the overlying Lavery Till and higher than that of most of the Northampton till. Groundwater moving through the sand has altered chlorite to vermiculite. Movement of water in the lens may be responsible for the high D.I. in the upper part of the Northampton till, or this till may have weathered before deposition of sand and Lavery Till.

In a similar situation an apparent slight weathering profile is developed on Northampton till where it is overlain by the Kent Till at the Substation Section (fig. 1). Kent Till has a sandy texture and contains numerous sand and silt lenses. Because of its permeable nature, it often is oxidized throughout its entire thickness. Water percolating through the Kent Till may have been impeded by the less permeable Northampton till. Water flowing horizontally along the contact may have produced a thin oxidized zone in the Northampton till. Interpretation of the clay mineralogy of the weathered zone might suggest a period of subareal weathering between deposition of these two tills when in reality, the time between deposition of these tills may have been relatively short. When using changes in clay mineralogy as indicators of weathering, care should be taken in interpretation of the stratigraphic record, especially when more permeable deposits also are within the section.

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