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PEDOLOGIC EVIDENCE OF TWO MAJOR PRE-ILLINOIAN GLACIATIONS NEAR CLEVES, OHIO[1]

L. D. NORTON, National Soil Erosion Laboratory, Purdue University, West Lafayette, IN 47907
G. F. HALL, Department of Agronomy, The Ohio State University, Columbus, OH 43210
R. P. GOLDTHWAIT, Department of Geology and Mineralogy, The Ohio State University, Columbus, OH 43210

ABSTRACT. Glacial derived materials of a pre-Illinoian age rarely are observed in Ohio. In this study a multiple till/outwash exposure was sampled and analyzed pedologically in detail. Based on the weathering of the soils developed in the exposure and other geomorphic relationships, it was concluded that 2 episodes of soil formation had occurred in pre-Illinoian glacial materials. Physical, chemical, mineralogical and micromorphological investigations of the soils formed in these materials demonstrated they had formed under different drainage conditions. Apparently, much of the dissection in the area had occurred after formation of the older soil. The occurrence of 2 glacial sequences of pre-Illinoian age in the Cleves exposure fit the classic count-back sequence of continental glaciations and can be considered as Kansan and Nebraskan in age.

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INTRODUCTION

Several continental glaciers have invaded the southwestern Ohio, southeastern Indiana, and northern Kentucky area. In the past, glacial tills and/or glacio-fluvial materials in this region have been recognized as Wisconsinan, Illinoian, Kansan, and Nebraskan in age. This paper will use Kansan and Nebraskan to represent 2 episodes of Pleistocene deposition prior to the Illinoian. No time framework of these pre-Illinoian age deposits is suggested. Recently, workers have shown multiple pre-Illinoian glaciations to have occurred and that the time framework of the classic pre-Illinoian site near Afton, Iowa, is in question (Shackelton and Opdyke 1976, Boellstroff 1978).

Evidence for drift of pre-Kansan (Nebraskan) age includes the occurrence of erratics beyond the presumed boundary of Kansan till (Jillson 1925, Leverett 1929). A weathering profile in a glacially derived outwash unit near the greater Cincinnati airport was interpreted by Leighton and Ray (1965) and Ray (1974) as a truncated Aftonian soil and Teller (1970) gave the St. Maurice till in southeastern Indiana a Nebraskan age. He based this classification on an exposure that contained Illinoian till at the surface, a buried Yarmouth soil in Kansan till and a weathering profile in a lower (St. Maurice) till. He later rescinded the Nebraskan age (Teller 1972) and explained the lower weathering profile as oxidation due to exposure of the outcorp. Swadley (1979) placed the cutting of the present channel of the Ohio River downstream from Cincinnati as Nebraskan in age. His evidence included weathered glacial drift (presumed to be Nebraskan) which apparently filled the channel of the pre-glacial Kentucky River and caused the drainage to be reversed along a new ice margin channel: the present Ohio valley. He found a weathered till along the Silurian divide in north-central Kentucky and postulated it was deposited prior to the Ohio breaching the preglacial drainage divide at Madison, Ind., during Nebraskan time. Despite the frequency of these reports, the occurrence of Nebraskan age glacial material has not been well documented.

Kansan drift has been reported in the study area by Rich 1956, Durrell 1961,

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Goldthwait et al. 1965, 1981, Leighton and Ray 1965, Gooding 1966, Ray 1974, and Teller 1970, 1972, 1973. Evidence for Kansan material has been the lack of finding glacial deposits in "deep stage" valleys (Rich 1956, Durrell 1961), the extreme weathering and depth of carbonate leaching (Goldthwait et al. 1965, Leighton and Ray 1965, Ray 1974, and Swadley 1979), and the occurrence of soils buried by Illinoian deposits (Gooding 1966, Teller 1970, 1972, Ray 1974, and Goldthwait et al. 1981). These different authors had various interpretations of the occurrence and extent of the Kansan drift in the area. Gooding (1966) suggested the Garrison Creek interstadial within Kansan time in southeastern Indiana.

Illinoian till is the most extensive glacial deposit beyond the terminal Wisconsinan (Hartwell) moraine in the Miami Sublobe of the Erie lobe (Goldthwait et al. 1965). The distinction between Wisconsinan and Illinoian age materials is based on the depth of carbonate leaching and the extent of soil development. Late-Wisconsin tills are typically leached of carbonates to a depth of approximately one meter; whereas, Illinoian till is leached to as much as 3 m depending on the thickness of Wisconsinan loess capping the till (Ray 1974). End or recessional moraines of Illinoian age have not been identified in the region by Ray (1974) and the Illinoian ground moraine is characteristically a featureless, dissected ground moraine.

Associated with the glacial advances in the Cincinnati area are slackwater lacustrine materials deposited in tributary valleys of the pre-Illinoian Teays River (Teller 1973). Ettensohn (1974) described the characteristics and occurrence of lake clays in the area, and Ettensohn and Glass (1978) reconstructed a possible sedimentation record for these deposits using clay mineralogy.

The recent exposure of an extensive section of Pleistocene materials near Cleves, Ohio, afforded an opportunity to evaluate further study of the glacial history of the region. The objective of this study was to evaluate the amount of weathering and soil formation that has occurred within the materials and relate the genesis of the soils to the glacial history of the area.

METHODS AND MATERIALS

The exposure was formed by excavation of a nose-slope and is located at the northeastern edge of the village of Cleves, Ohio, in the E 1/2, NE 1/4, Section 21, Township 1N, Range 1E of the first principle meridian. Fig. 1 shows the location of the site and its relation to possible delineations of till sheets in the area. In the text of this paper the exposure will be designated as the Cleves cut.

While the exposure was fresh, it was described and sampled using standard Soil Survey techniques (Soil Survey Staff 1951). Field morphology was described, and samples were taken within major soil and geologic boundaries during the spring of 1978. Oriented clods samples for thin-sectioning and petrographic analysis were taken from various levels at a later date. Laboratory samples were analyzed using standard methods of the Ohio State University Soil Characterization Laboratory. The procedures utilized were as follows: Particle-size distribution was determined by the pipette method of Kilmer and Alexander (1949) using standard USDA particle-size groupings (Soil Survey Staff 1951). Calcite and dolomite determinations were made using the Chittick apparatus as described by Dreimanis (1962).

Extractable bases were determined using the extraction procedure of Peech et al. (1947) in combination with atomic absorption and emission spectrophotometry for elemental analyses. Extractable acidity was determined by the barium chloride-triethanolamine (pH 8.2) procedure of the Soil Survey Staff (1972). Organic carbon was measured using a dry combustion procedure (Soil Survey Staff 1972). Determinations of pH were made on one part soil to one part water mixtures, and on one part soil

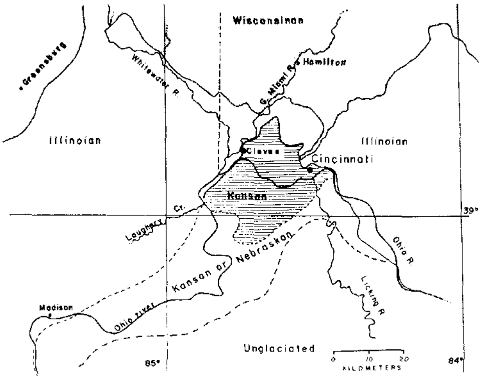

FIGURE 1. Glacial map of the Cincinnati area showing the location of the Cleves cut and the major drainage in the area (taken from Goldthwait et al. 1965, Wayne 1958 and Ray 1974).

TABLE 1

Morphological description of the Cleves cut.

Unit	Thick-ness m	Depth m	Soil Horizon	Boundary	Matrix Color	Field Texture	Soil Structure	Moist Consis-tency	% Coarse Fragments (by volume)	Cutans on Peds or in Pores
6. Loess	.7	0–.2	Ap	abrupt smooth	10YR 4/4	silt loam	weak fine granular	friable	0	
		.2–.3	Blt	clear wavy	7.5YR 4/6	light silty clay loam	weak fine subangular blocky	friable	0	
		.3–.7	B21t	abrupt smooth	7.5YR 4/6	light silty clay loam	moderate fine subangular blocky	firm	0	thin patchy 5YR 4/6 argillans; thin patchy 10YR 2/1 mangans; few 10YR 5/3 silans.
5. Stoneline	.2	.7–.9	IIB22tb	clear wavy	7.5YR 4/6	gravelly silty clay loam	moderate coarse subangular blocky	firm	7	thin continuous 5YR 4/6 argillans; common 10YR 2/1 mangans; few 10YR 6/3 silans.
4. Yarmouth Soil in Kansan Till	4.4	.9–1.4	IIB23tb	clear wavy	5YR 4/6	clay	strong medium subangular blocky	very firm	5	thick continuous 5YR 4/6 argillans; common 10YR 2/1 mangans.
		1.4–1.7	IIB24tb	clear wavy	5YR 5/6	clay	strong medium subangular blocky	very firm	4	thick continuous 5YR 4/6 argillans.
		1.7–1.9	IIB25tb	clear wavy	7.5YR 5/8	clay	moderate fine subangular	very firm	4	thick continuous 5YR 4/6 argillans.
		1.9–2.1	IIB26tb	clear wavy	7.5YR 5/8	clay	moderate fine subangular	very firm	3	thick patchy 5YR 4/6 argillans; common 10YR 2/1, mangans.
		2.1–2.4	IIB27tb	clear wavy	10YR 5/4	clay loam	moderate coarse subangular blocky	firm	3	thick patchy 7.5YR 5/6 argillans; common 10YR 2/1 mangans.
		2.4–2.9	IIB28tb	clear wavy	7.5YR 5/8	clay loam	moderate medium subangular blocky	firm	3	thin patchy 7.5YR 5/6 argillans; common 10YR 2/1 mangans.
		2.9–3.6	IIB29tb	clear smooth	10YR 5/6	clay loam	moderate medium subangular blocky	firm	2	thin continuous 10YR 5/6 argillans; many 10YR 2/1 mangans.
		3.6–5.3	IIB31tb	abrupt smooth	10YR 5/8	clay loam	weak coarse subangular blocky	firm	2	thin patchy 10YR 5/6 argillans; few 10YR 2/1 mangans.

3. Kansan Outwash	1.8	5.3–7.1	IIIB32tb	abrupt smooth	10YR 5/6	fine sandy loam	very weak coarse subangular blocky	very friable	0	few 10YR 2/1 mangans; common 10YR 5/6 clay bridging grains.
2. Aftonian Soil in Nebraskan Till	1.7	7.1–7.8	IVB21gtb	gradual wavy	10YR 6/1	silty clay	moderate coarse prismatic parting to moderate	very firm	3	thick patchy 5YR 5/6 argillans; common 10YR 2/1 mangans.
		7.8–8.8	IVB22gtb	gradual wavy	10YR 6/2	clay loam	medium angular blocky			
2. Nebraskan Till	6.2	8.8–9.8	IVB31gtb	gradual wavy	10YR 6/3	light clay loam	moderate coarse prismatic parting to subangular blocky	firm	7	thick patchy 10YR 5/6 and 10YR 6/2 argillans; common 10YR 2/1 mangans; few 10YR 7/2 calcans.
		9.8–15.0	IV C1	abrupt smooth	10YR 6/3	loam	weak thick platy; massive	firm	7	few 10YR 2/1 mangans.
1. Ordovician Shales		15.0+	V C2		2.5Y 5/4		weak thick platy; massive	firm	15	

to two parts 0.1M calcium chloride solution. Clay mineralogical analyses were performed on the total clay (<2 μm) fractions using CuK_α radiation and oriented aggregate samples; data interpretations followed the semi-quantitative X-ray diffraction procedures of Johns et al. (1954). Thin sections (30 μm) were prepared from samples vacuum impregnated with castolite resin (methyl methacrylate) and were subsequently analyzed on a petrographic microscope according to procedures established by Brewer (1976).

STUDY SITE

A detailed description of the exposure is given in table 1. In brief, the Cleves cut consists of thin loess (unit 6) over extremely weathered till containing a soil (unit 4), over outwash (unit 3), over a lower soil developed in till (unit 2). All these overlie Ordovician age shales of the Dillsboro formation (Cincinnati group). A well developed stone-line (unit 5) separates the loess (unit 6) from the upper, till derived soil (unit 4). A graphical representation of the Cleves cut is given in fig. 2 to show possible stratigraphic separations.

The upper-most till can be considered Kansan in age based on the glacial geology map of Ohio (Goldthwait et al. 1965) and the distribution of Kansan age materials reported by other work (Rich 1956, Durrell 1961). However, the state of weathering and depth of leaching of carbonates greatly exceeds that of Illinoian age till on similar geomorphic positions and makes a pre-Illinoian interpretation reasonable (Ray 1974). Also, the site is located south of the narrows of the Great Miami River, which represents the terminal drainage of Illinoian ice in the area (Fenneman 1916). The loess, although shallow at the cut, is nearly 3 m thick on the bluff 30 m upslope on a more stable position. Modern soil formation has taken place almost entirely within the loess at the site, and the soil formed in the Kansan material is truly a paleosol in this case (Yaalon 1971).

Pedologic evidence also supports the concept of a Kansan age for the upper till unit. Total clay (<2 μm) distribution with depth (fig. 3) exhibits a much greater maximum and depth of accumulation than

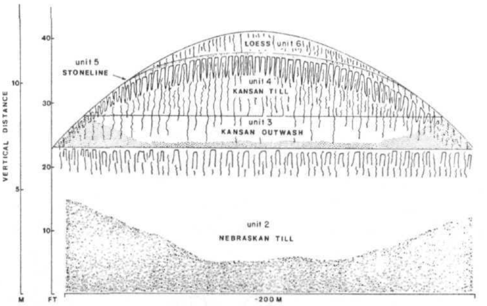

FIGURE 2. Graphical representation of the Cleves cut.

that observed for soils formed on similar geomorphic positions in Illinoian till in the area (Rutledge 1969). Fine clay (<0.2 μm), which is more indicative of translocation, also bears out this observation.

Micromorphological investigation indicates much of the clay contained in the soil was indeed illuvial in nature based on the occurrence of oriented cutans and glaebules (fig. 4a). The s-matrix, excluding the oriented clay, is a mixture of sand, silt, and clay particles which is a fabric very typical of all ages of glacial tills in the Cincinnati area. The plasmic fabric was omnisepic, inferring the soil was extremely weathered. Likewise, the interpretation of the outwash unit is substantiated by micromorphology.

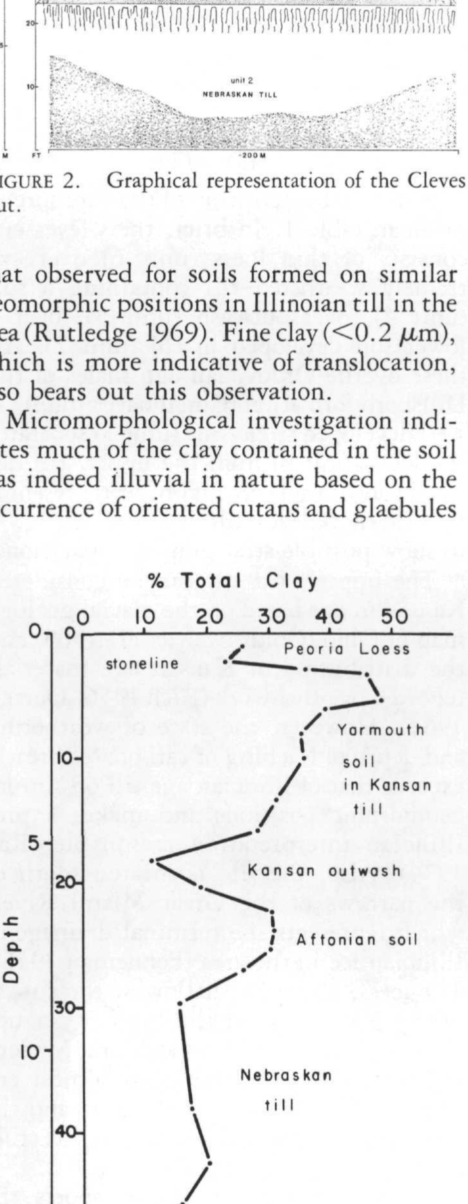

FIGURE 3. Total clay distribution with depth for the Cleves cut.

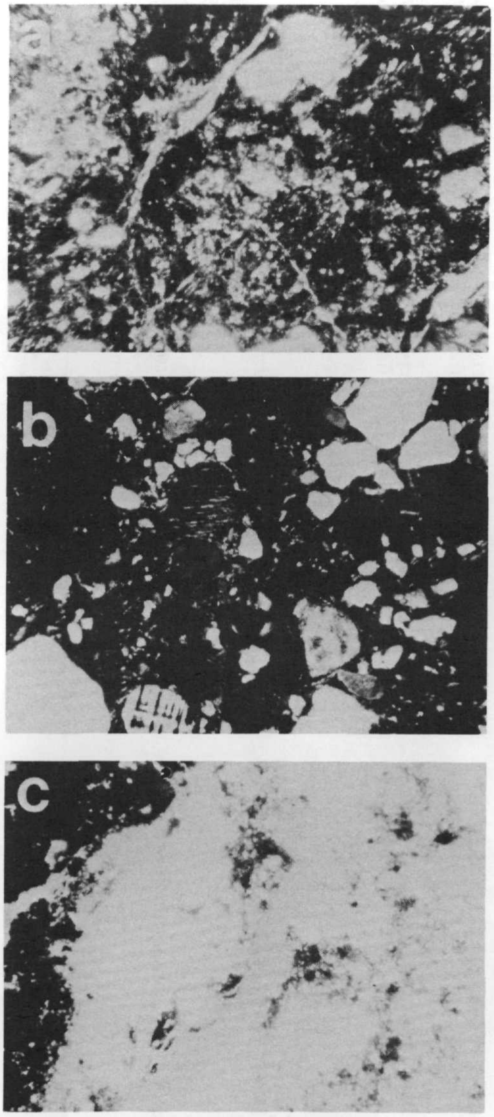

FIGURE 4. Photomicrographs of (A) Yarmouth soil argillic horizon, (B) Kansan outwash, (C) Aftonian soil argillic horizon. (Frame width 620 μm).

TABLE 2

Particle-size distribution data for the Cleves cut.

		Sand					Silt			Clay		
		Very Coarse	Coarse	Medium	Fine	Very Fine	Coarse	Fine	Very Fine	Fine	Total	
	Depth			mm					µm			Textural
Unit	m	2–1	1–.5	.5–.25	.25–.1	.1–.05	50–20	20–2	5–2	.2	2	Class
						%						
6. Peoria Loess	.4	0.4	1.4	2.3	5.8	4.8	26.3	33.5	5.4	13.7	25.4	silt loam
5. Stoneline	.8	1.5	3.6	5.8	12.1	6.2	17.8	30.1	6.4	8.6	22.8	loam
4. Yarmouth Soil in Kansan Till	.9	2.7	4.0	7.0	15.2	5.0	12.4	17.3	5.0	17.5	36.3	clay loam
	1.2	1.1	2.1	5.0	11.3	5.0	13.1	16.0	4.7	23.1	46.3	clay
	1.6	0.8	1.1	2.1	6.6	5.2	14.8	20.5	6.1	25.8	48.8	clay
	2.0	0.2	0.5	1.1	4.1	10.8	27.3	16.2	1.9	22.4	39.7	clay loam
	2.6	0.9	2.4	3.4	8.8	7.3	15.5	26.1	6.3	15.2	35.4	clay loam
	3.3	0.9	2.5	3.5	8.9	6.8	16.3	24.5	6.4	16.2	36.4	clay loam
	4.7	1.1	2.4	3.1	7.1	11.1	22.0	21.2	5.8	17.3	32.0	clay loam
	5.3	1.5	3.6	4.7	15.5	13.1	16.6	17.3	4.5	14.5	27.6	clay loam
3. Kansan Outwash	6.0	0.0	0.0	0.2	36.3	31.4	14.1	6.8	1.8	5.6	11.2	fine sandy loam
	6.7	0.0	0.1	4.1	54.3	12.3	6.0	4.0	1.3	11.4	19.1	fine sandy loam
2. Aftonian Soil	7.4	1.3	3.5	5.2	12.6	8.1	14.8	24.3	7.5	12.1	30.2	clay loam
	7.9	1.6	2.8	3.2	8.3	6.1	15.2	32.0	8.1	11.3	30.7	clay loam
	8.4	0.5	1.0	1.5	4.2	3.1	11.5	47.5	12.3	10.7	30.6	silty clay loam
	8.8	3.1	3.5	3.9	9.8	6.5	13.8	33.5	11.8	7.1	25.8	loam
2. Nebraskan Till	9.7	1.9	3.8	5.0	14.3	11.0	19.7	24.1	5.9	8.1	20.2	loam
	12.7	3.5	4.3	4.1	10.3	8.6	19.3	27.2	7.5	9.5	22.6	loam
	14.0	4.4	5.2	4.9	10.6	6.8	14.3	28.0	8.0	11.4	25.7	loam
	15.0	3.1	4.1	4.3	13.9	13.4	16.9	22.7	5.9	9.9	21.5	loam

The outwash consists of a uniformly sorted fine sand (table 2) with oriented clay bridging grains and filling many of the pores (fig. 4b).

Based on the field morphologic description (table 1) and the physical and chemical data (tables 2 and 3), the upper "Yarmouth" soil would classify as a member of the fine, mixed, mesic, Typic Paleudalfs (Soil Survey Staff 1975), whereas, Illinoian till soils in the area classify as fine-silty (loamy), mixed, mesic Typic Hapludalfs (or Fragiudalfs) (Rutledge 1969).

The identification of a paleosol ("Aftonian") in the lower till is also based on clay distribution, micromorphology, clay mineralogy and field morphology. Of these, the most indicative properties are its gray color relative to the upper "Yarmouthian" soil profile and its relationship to the present topography. The upper soil profile occurs across the slope and has a uniform topographic relationship with the present topography (fig. 2) and consists dominantly of reddish (7.5YR-5YR) hues. The lower soil profile is horizontally bedded (not related to the present topography) and is dominantly gray (10YR 6/1-6/2). The discontinuity in oxidation states intrepreted from the color and the topographic positioning cannot be accounted for by one episode of soil formation; the lower soil profile must have developed in a poorly drained (gumbotil) condition before it was overridden by

TABLE 3

Chemical data for the Cleves cut.

Unit	Depth m	pH (in water)	pH (in .1m $CaCl_2$)	Organic Carbon	Calcite	Dolomite	$CaCo_3$ Equivalent	Exchangeable Cations H	Ca	Mg	K
				%				meq/100g			
6. Loess	.4	4.6	4.1	0.23				9.0	5.2	2.9	0.14
*											
5. Stoneline	.8	4.7	4.0	0.13				7.0	3.6	2.7	0.13
4. Yarmouth Soil in Kansan Till	.9	5.0	4.4	0.22				9.3	7.2	5.1	0.13
	1.2	4.7	4.1	0.21				11.8	7.2	6.4	0.14
	1.6	4.9	4.2	0.20				10.4	9.3	8.2	0.16
	2.0	5.3	4.4	0.18				6.6	8.1	6.6	0.21
	2.6	5.9	5.5	0.11				4.4	10.4	6.4	0.18
	3.3	5.4	5.0	0.11				4.5	10.4	6.5	0.19
	4.7	5.7	5.2	0.10				4.7	10.4	6.4	0.18
	5.3	5.3	4.6	0.15				5.3	7.4	5.1	0.19
3. Kansan Outwash	6.0	5.1	4.4	0.08				3.6	3.2	1.9	0.10
	6.7	5.1	4.3	0.10				4.8	5.0	2.2	0.14
2. Aftonian Soil	7.4	6.3	6.0	0.10				2.5	13.7	3.3	0.29
	7.9	7.6	7.3		4.5	1.3	6.0				
	8.4	7.5	7.2		0.4	0.5	0.9				
	8.8	7.9	7.5		13.6	6.8	21.0				
2. Nebraskan Till	9.7	7.9	7.5		10.6	7.5	18.7				
	12.7	7.8	7.5		12.0	8.3	20.9				
	14.0	7.8	7.5		11.4	6.9	19.0				
	15.0	7.8	7.5		11.9	7.6	20.1				

*———— Suggested lithologic breaks

younger material which was subsequently weathered and dissected.

Micromorphological evidence also supports the contention that the lower soil profile developed under different conditions than the upper soil. Thin sections of the lower profile (fig. 4c) contained both diffuse and discrete sesquioxidic nodules and mangans which usually form in poorly drained soils (Brewer 1976). The argillans that were present were gray also inferring development under poor drainage. The lower soil profile contained carbonates within the illuvial pedologic B-horizon. However, these carbonates probably represent secondary enrichment from the leaching of previously calcareous overlying material as evidenced from the field morphology and the occurrence of calcans rather than primary carbonate grains in thin section. The lower till (unit 2) in which this soil is formed contains considerably more carbonates both in the coarse fragments (>2 mm) and fine earth fraction (<2 mm) than the lower soil profile. The percentage of carbonates in the fine earth fraction is comparable to that of calcareous Illinoian and Wisconsinan tills in the area (Ohio State University Soil Characterization Laboratory, unpubl. data). Evaluation of pebbles from the lower till indicated a local provenance; however, there was also a significant number of igneous and metamorphic cobbles ranging in size up to 20 cm in diameter.

The amounts of clay mica (100 nm) and smectite (170 nm) were greater in the lower soil profile than in the upper soil

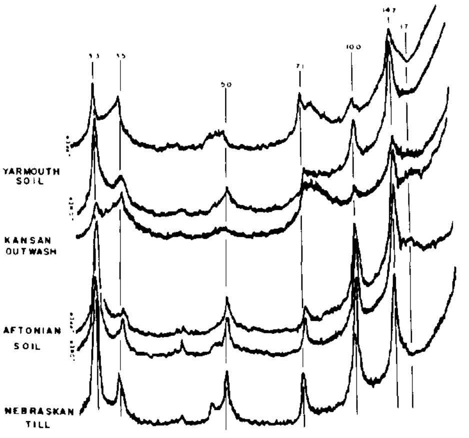

FIGURE 5. X-ray diffractograms for the ethylene-glycol treated (<2 μm) clay fraction for selected units in the Cleves cut. Peaks are labeled in Angstroms (1 Angstrom = 0.1 nm).

(fig. 5). There is also evidence of halloysite in the Yarmouth soil, as indicated by the broad peak from 71 to 89 nm, which dehydrates on heating to 400 C. This peak is not found in the lower soil profile patterns or in soil clays of Illinoian or Wisconsinan age till in the area. Halloysite is a common clay mineral in many highly weathered (Ultisols and Oxisols) soils and may be a significant stratigraphic marker for separating Kansan age soils from Illinoian profiles in the area. In general, clay mineralogy indicates the 2 soils in the Cleves exposure formed under different drainage environments and represent 2 different episodes of soil formation in pre-Illinoian glacial till.

The topography in the area when the lower paleosol was forming must have been subdued with very low relief for a poorly drained gleyed soil to develop. In contrast, the upper paleosol probably formed in a well drained environment created by extensive dissection of the post Kansan landscape. The relationship also suggests much of the dissection now observed in the area has occurred in post Kansan time. Swadley (1979) claims the present Ohio River downstream from Cleves was incised more than 100 m after the upland Nebraskan till was disserted and Kansan till was deposited in the lower lying valleys. Evidence from the Cleves cut does not support this contention. Likewise, reexamination of his sites reveals that a Kansan age for both his "high level" and "low level" tills south of the Ohio River is Illinoian. This would suggest the present Ohio River valley was cut as a result of the Kansan invasion into northern Kentucky.

An interesting observation on the dynamics of glacial ice movement is the occurrence of 4 glacial epochs, separated by nearly equal periods of soil formation whose termini coincide within a relatively short latitudinal distance in the Cincinnati area. Evidence of 4 major continental glaciations in this area may represent the maximum extent of only the major glaciations of several that may have occurred during the Quaternary. The classic sequence of Nebraskan, Kansan, Illinoian, and Wisconsinan glacial periods seems to be reasonable for evaluating glacial effects on the continental land mass and the subsequent intervals of soil formation, and probably does not correlate with data from sea cores (Shackelton and Opdyke 1976). A useful definition for these deposits in the Cincinnati area would be from the most extensive to the least extensive: Nebraskan greater than Kansan, greater than Illinoian, greater than Wisconsinan on a regional basis.

CONCLUSIONS

Pedologic evidence from the Cleves cut suggests there were 2 episodes of soil formation in glacial material of pre-Illinoian age in southwestern Ohio. The Upper "Yarmouth" soil must have been subjected to a long period of weathering which would account for its extremely weathered state and great depth of leaching. Topographic relationships suggest the present dissection in the area has occurred since Kansan ice left the area. The lower "Aftonian" soil developed in a poorly drained (gumbotil) position and appeared to have underwent soil formation prior to its burial by Kansan deposits and developed to an extent similar to that found in buried Sangamon soils in the area.

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