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AGE OF THE BURIED SOIL IN THE SIDNEY, OHIO, AREA

JANE L. FORSYTH

Ohio Geological Survey, Columbus, Ohio

ABSTRACT. The buried soil in the Sidney exposure, in a railroad cut two miles south of Sidney, Shelby County, Ohio, is unusual in having been developed in till and in having a datable buried log (22,480 ± 800; W-356) lying directly on it. Molluscs from an underlying silt, once believed to demonstrate a Wisconsin age for the entire section, are now recognized to have greater ranges and can no longer be used to identify age. Most helpful in the determination of the age of the buried soil is the nature of the soil itself, which is weakly developed with poor horizonation and a very thin oxidized calcareous zone, although the first two characteristics are partially obscured by the development of Taschenboden, or subsurface shifting and sorting of particles due to ground ice.

Along Brush Creek, two miles farther south, are two other exposures of the soil, both showing strong gleying. The upper Brush Creek section also has a peat (maximum date: >50,000 years), lying just above but associated with the soil and below an overlying till (22,000 ± 1000; W-414). A short pollen profile from the peat shows poplar, elm, alder, grass, and high percentages of oak pollen, but almost no spruce or pine.

The interval represented by the Sidney soil is clearly fairly long, as shown by the nature of the buried soil, by the species of plants recorded in the pollen profile, and by radiocarbon dates. The dates show also that the soil-forming interval ended about 22,000 years ago. Because the soil, though clearly a paleosol, is not strongly developed, with little clay mineralogy alteration or destruction of less-stable heavy minerals, it seems very unlikely that any of Sangamon time is represented. Rather, the Sidney soil is believed to be mid-Wisconsin in age, and the till in which the soil was developed is believed to be of "early" Wisconsin age, correlating with early Altonian tills in Illinois, the Whitewater and/or Fayette Drifts in Indiana, the Mogadore Till in eastern Ohio, and the Bradtville and Sunnybrook Tills of southern Ontario.

INTRODUCTION

Buried soils have been reported many times from a number of localities in Ohio (Goldthwait, 1952; 1955). Most of these have followed a consistent stratigraphic pattern of calcareous till over calcareous gravel, with a discontinuous zone at the top of the gravel composed of red, leached, sticky, clayey material containing pebble "ghosts", material identical in appearance with the B horizon of the modern Fox soil developed in gravel. There has been some question as to whether such buried soils may not have developed *after* deposition of the overlying till (Gooding, Thorp, and Gamble, 1959; Gooding and Gamble, 1960). Such an interpretation would negate the conclusion. reached by Goldthwait and Forsyth (Goldthwait, 1959; Forsyth and La Rocque, 1956; Forsyth, 1957), that there was a significant ice-free interval, long enough for the development of a soil comparable to those at the surface today, between the depositions of the underlying gravel and of the overlying till. Before discovery of the Sidney cut, no similar buried soils developed in till had been observed. In addition, despite the number of radiocarbon dates obtained from buried wood in western Ohio, no logs had been found in association with any of the buried soils.

The Sidney cut, first discovered in 1954, immediately became famous because it revealed a buried soil, indisputably a paleosol, developed in *till*, and also because it had a buried log lying directly on the soil. Subsequently, two other exposures of this soil were found a few miles south along Brush Creek, the more easterly (upper) of which provided a more complete stratigraphic

PLATE 1

General view of Sidney cut. South end of east side of railroad cut. Arrow points to level of buried soil horizon and, more specifically, to place from which buried log was collected.

section and also samples of wood and peat for dating. A typical buried soil in gravel, apparently lying at the same stratigraphic position as the soil in the Sidney cut, was exposed in the past in the old Sidney Sand and Gravel Company pit one mile northeast of Sidney.

Much information has been accumulated about this buried soil. Molluscs, from silt temporarily exposed in the Sidney cut below the till in which the soil was formed, have been studied (La Rocque and Forsyth, 1957). The soil morphology has been investigated, both in the field and in the laboratory (courtesy of N. Holowaychuk). Heavy mineral studies have been made by a number of R. P. Goldthwait's students. Clay-mineralogy analysis has been run on a suite of samples of the soil (courtesy of Dr. Herbert Glass). And six radiocarbon dates, provided by the U. S. Geological Survey (courtesy of Dr. Meyer Rubin) and the Natuurkindig Laboratorium of Rijks Universiteit in Groningen, the Netherlands (courtesy of Dr. J. C. Vogel) have been received.

This paper records the available data relating to the buried soil and to the Sidney and Brush Creek cuts, in which the soil is exposed, and applies the information to the problem of the age of the soil and associated stratigraphic units.

ACKNOWLEDGMENTS

This report would not have been possible without the continued encouragement and cooperation of Dr. R. P. Goldthwait, both in his guidance through the academic doctoral studies out of which it grew and throughout subsequent years. He has also made available the results of the heavy-mineral studies.

Thanks are due also to Dr. Aurèle La Rocque for information on the molluscs and for the drafting of figures 1 and 2; to Dr. William J. Wayne for additional mollusc data; to Dr. Nicholas Holowaychuk for help with the soil interpretation and for making available the facilities of The Ohio State University Soils Testing Laboratory; to Dr. Herbert D. Glass for performing and interpreting the clay mineralogy analysis; to Dr. J. Gordon Ogden, III, and L. G. Gellein for the pollen profile; and to Dr. Meyer Rubin and Dr. J. C. Vogel for the radiocarbon determinations.

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LOCATION

All three sites in which the buried soil is exposed lie south of and within four miles of the town of Sidney, Shelby County, western Ohio. The Sidney cut is a 50-foot bank along the east side of the Baltimore and Ohio Railroad two miles south of Sidney; it is the second such bank south of Sidney and exactly one mile south of the railroad bridge across the Miami River.

The two Brush Creek exposures are two miles farther south. The main, "upper", Brush Creek section (called "Kirkwood" by Rubin and Alexander, 1958, p. 1477) is about two miles upstream from the confluence of Brush Creek with the Miami River, half a mile east of the Piqua-Sidney Road, and just south of the Sidney-Plattsville Road. The lower, less informative section was a little less than a mile downstream (west) from the upper section, just west of the Piqua-Sidney Road.

All three sections are located in Orange Township, R13T1: the Sidney cut in the southeast corner of section 14, the upper Brush Creek cut in the northeast corner of section 12, and the lower Brush Creek cut in the northwest corner of section 12.

THE REGIONAL SETTING

The three cuts exposing the buried soil lie within a broad area of unusually flat ground moraine, deposited by the Miami Glacial Lobe .To the north is a sequence of Wisconsin recessional moraines, which begins with the Union City Moraine. Twenty miles or more to the south, are other, older moraines, the northernmost of which is the Farmersville Moraine.

Soils associated with this ground moraine and also with the Farmersville Moraine are thin (22 to 27 inches) and belong to the Miami 6A soils association. Farther south are thicker soils (30 to 55 inches), presumed to identify slightly older Wisconsin tills; these soils are mapped as Miami 60 where the silt (loess) cap is less than 18 inches and as Russell soils where the silt cap is thicker (Forsyth, 1961, p. 58; Forsyth, 1965).

To the north, in the area of the recessional-moraine sequence, tills are higher in clay, and Morley-Blount (Miami 6B) soils occur. This additional clay is interpreted (Forsyth, 1965) as an admixture of lake clay, accumulated in short-lived ice-dammed lakes during a temporary ice retreat to north of the Ohio divide and brought south by the glacial readvance which deposited the clay-rich till. Because the clay content of the till continues to increase northward across this belt, the sequence of retreat, accumulation of lake clays, and readvance is believed to have been repeated several times. This interpretation is

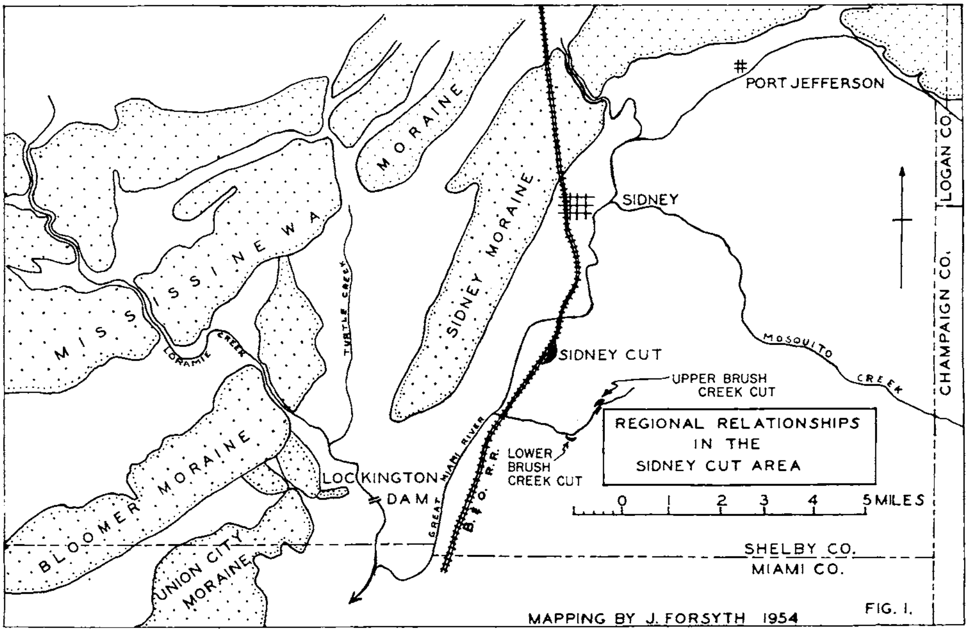


FIG. 1.

Fig. 1.

supported by higher calcium-magnesium ratio values for the high-clay tills to the north (lake clays tend to have higher ratios) (Wenner, ms; Wenner, Holowaychuk, and Schafer, 1961) and by a series of overlapping relationships between adjacent moraines. The major difficulty with this interpretation is the speed with which the shifts would have had to have taken place, for according to dependable radiocarbon information, there were only four to five thousand years available for the entire retreat of the last glacier from Ohio, and the several retreats and readvances discussed above represent only the last third of that brief history.

The overlapping of one end moraine across another, differently oriented moraine, is strikingly exhibited in several places in the sequence of recessional moraines north and west of the Sidney cut. Each of the overlapping situations is interpreted to represent a minor readvance of the retreating ice, with modifications in the configuration of the ice margin due to irregularities in the land surface of that time, resulting in a somewhat different orientation for each subsequent moraine (Forsyth, ms, p. 128-131). Figure 1 shows two such examples, the earlier of which involves the Union City Moraine. As mapped by Leverett (1902, p. 476), this moraine was traced eastward from the town of Union City on the Indiana-Ohio line to a broad mass of moraine in the area of the Bellefontaine outlier in Logan County. However, more detailed field information (Forsyth, ms, p. 124) suggests that, in southern Shelby County, this moraine bends north, disappearing beneath the Bloomer Moraine just west of Lockington Dam, southwest of Sidney. The Sidney Moraine (fig. 1), therefore, is not a segment of this moraine, but appears to be somewhat older, though it probably antedates the Union Moraine by very little. The Bloomer Moraine (Forsyth, ms, p. 129), which Leverett included as part of his Mississinewa Moraine, appears to be separate, representing a distinct ice position, because it, too, may be traced eastward and northward until it is lost beneath the overlapping Mississinewa Moraine. The latter, the youngest moraine shown on figure 1, is compound; its two major components are both overlapped, in different places beyond the limits of figure 1, by the next moraine to the north, the St. Johns Moraine (Goldthwait, White, and Forsyth, 1961). Despite the questions raised by the overlapping relationships, the Union City Moraine of the Miami Lobe is believed to correlate with the Powell Moraine of the Scioto Lobe (Forsyth, ms, p. 74).

Because the buried soil lies stratigraphically well below all these features, it must be older, but whether the soil-forming interval was mid-Wisconsin, as contended by Goldthwait (1959) and myself, or pre-Wisconsin, as argued by some others, cannot be determined from the regional setting alone.

STRATIGRAPHY OF THE SIDNEY CUT

In the Sidney cut, five tills are exposed, represented in figure 2 by units numbered 9, 8, 6, 4, and 1. Slight differences in mechanical composition distinguish these tills, but the differences are not sufficient for their identification elsewhere in the county. Indeed, single "grab" samples of the same tills taken from the opposite (west) side of the same railroad cut could not be correlated by mechanical analysis with those from the east side.

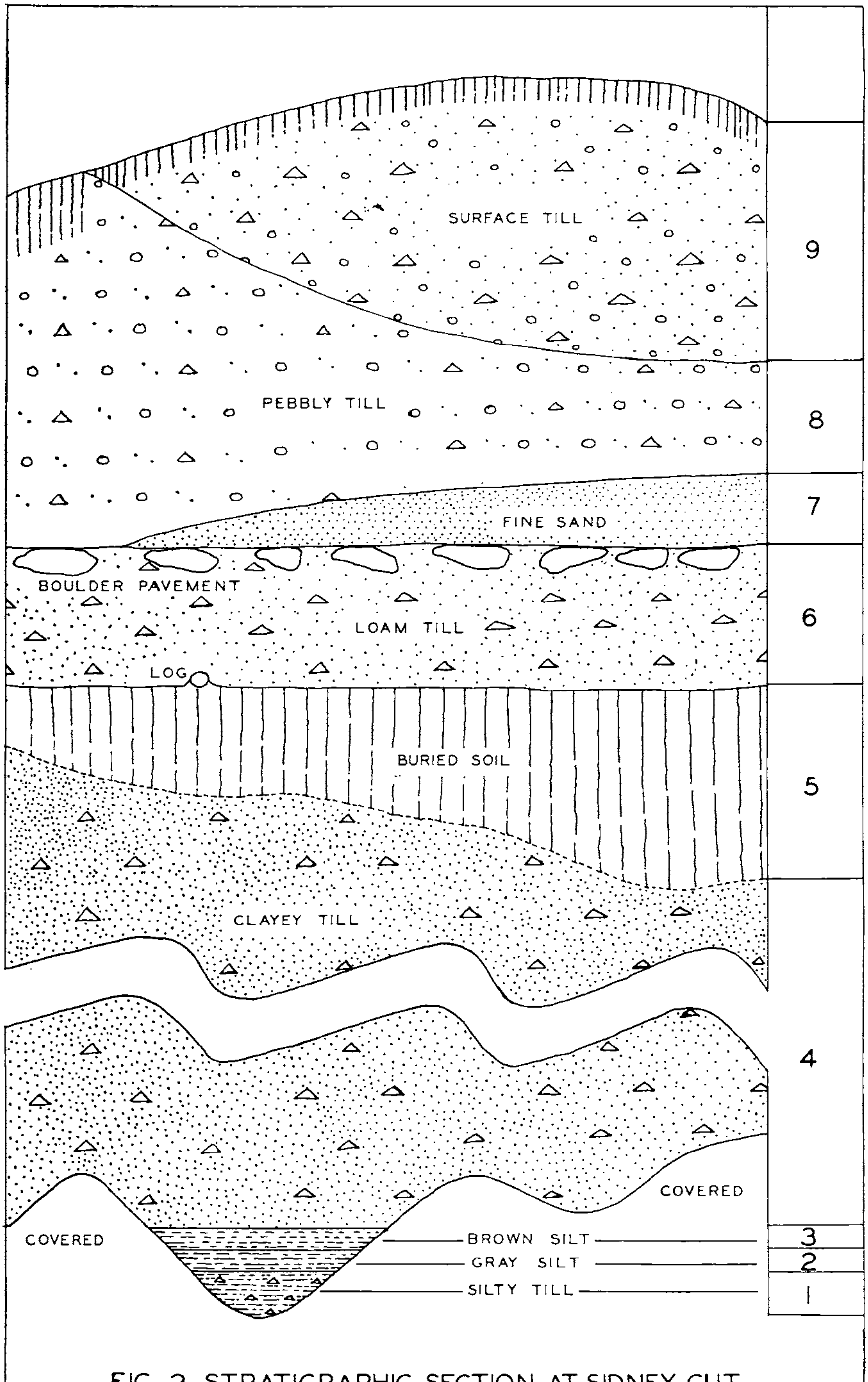


FIG. 2. STRATIGRAPHIC SECTION AT SIDNEY CUT

Fig. 2.

Stratigraphy of the Sidney Cut

Unit	Description	Thickness (feet)
9	Till, oxidized yellowish brown; clayey loam texture, with small silt and sand lenses; Miami 6A soil profile, leached 26± inches at surface; discontinuous surface distribution; pebble count shows source mainly from west or northwest.	0-8
8	Till, oxidized brown, loam texture, more pebbly than other tills.	5-15
7	Sand, fine, well sorted and bedded, locally gravelly, in one place containing an irregular oxidized, leached, clay-enriched zone at top (not believed to be a paleosol).	0-5
6	Till, oxidized reddish brown, lower part locally unoxidized blue gray; loam texture; entire unit calcareous (pH of 7.4), but oxidized, with strong iron stains above thickest exposure of buried soil; pebble count and pebble orientation both show source to be mainly from west or northwest. Embedded in top of till is a boulder pavement, represented by relatively few boulders, but which follows a remarkably straight, horizontal line; no striae have been observed on boulders. Remarkably uniform in thickness.	4
5	Buried paleosol, completely leached to 26± inches, partly calcareous to 40± inches; morphology described in separate section of paper. To north along same side of cut and also on opposite bank, soil is represented only by calcareous, strongly oxidized till and is thinner (0 to 2 ft). Log lying on this soil and incorporating soil material within spaces in wood was dated at 23,000 ± 800 (W-188) and 22,480 ± 800 (W-356) years B.P.	0-6
4	Till in which paleosol was developed, gray-blue, clayey loam texture; pebble count and pebble orientation studies both show source from north to northeast.	30±
Units no longer exposed		
3	Silt, brown, containing molluscs.	½
2	Silt, gray, containing molluscs, seeming to grade into underlying till.	½
1	Till, gray, silty loam texture, somewhat pebbly.	1+
Base covered		

Only units 4 through 9 have been continuously exposed since the discovery of this buried soil in 1954. Units 1 through 3 were revealed in one spot at the base of the bank by local erosion for only a short period a year or so later, at which time the molluscs reported from unit 2 were collected. Since that time, these three units have again been covered.

The fauna recovered from the one-foot silt beneath the till in which the buried soil was formed has been studied by La Rocque (La Rocque and Forsyth, 1957, p. 85). Fourteen molluscs were recognized, of which ten were identifiable to species (table 1). All but one of these were terrestrial pulmonate gastropods; the other was a freshwater pulmonate gastropod capable of inhabiting "small, even temporary bodies of water" (La Rocque and Forsyth, 1957, p. 85). Thus, the environment indicated by this fauna was probably that of a flat, poorly drained upland surface with a thick cover of vegetation. It is unlikely that this thin silt, lying beneath thick till and grading into till below, represents a long ice-free interval. Rather it suggests an area temporarily uncovered by the ice. This interpretation is supported by the small size of the mollusc shells (La Rocque, personal communication, March, 1965).

TABLE 1

Ecology and ranges of Mollusca from silt in Sidney cut

Species	Ecology[1]	Percentage overall Abundance[2]	Range of Species								
			P	N	A	K	Y	I	S	W	modern (Ohio)
Carychium exile canadense Clapp	M	8[3]				X	X	X	X	X	
Cionella lubrica (Müller)	M	0.4				X	X	X	X	X	X
Columella alticola (Ingersoll)	W	2[4]						X	X	X	
Deroceras? sp.	—	0.2									
Discus cronkhitei (Newcomb)	W	0.2				X	X	X	X	X	X
Euconulus? sp.	D	0.2									
Fossaria parva (Lea)[5]	P	2			X	X	X	X	X	X	X
Hawaiia minuscula (Binney)	W to D	1	X	X	X	X	X	X	X	X	X
Helicodiscus sp.	M	0.4									
Helicoid, undetermined fragments	—	1									
Stenotrema sp.	D	3									
Catinella cf. *avara* (Say)[6]	D	18				X	X	X	X	X	X
Succinea grosvenori Lea	P	20[3]			X	X	X	X	X	X	
Vallonia gracilicosta Reinhardt	D	15[4]			X	X	X	X	X	X	
Vertigo alpestris oughtoni Pilsbury	D	29				X	X	X	X	X	
Vertigo elatior Sterki[7]	D	?				X	X	X	X	X	

[1] All ecological data from La Rocque and Forsyth, 1957, p. 85; and from La Rocque, personal communications, 1958 and 1965.

All molluscs are pulmonate; symbols represent:
M—marginal to puddles
W—wet margins of puddles
P—in puddles of water
D—drier vegetated ground

[2] For actual figures for two separate units, see table on page 85 in La Rocque and Forsyth, 1957.

[3] Abundance decreases markedly going from lower to upper part of silt unit.

[4] Abundance increases markedly going from lower to upper part of silt unit.

[5] Only freshwater form.

[6] Called *Succinea avara* in La Rocque and Forsyth, 1957.

[7] Reported by Wayne (personal communication, 1965).

In the original study, La Rocque (La Rocque and Forsyth, 1957, p. 86-88) preferred a Wisconsin age for the assemblage because of the presence of two gastropods considered at that time to be limited to the Wisconsin, *Columella alticola* and *Vertigo alpestris oughtoni*. Later, Wayne (1958, p. 11) reported *Vertigo alpestris oughtoni* from pro-Kansan loess in Indiana, although he acknowledged that the percentage of this form in the pro-Kansan loess was only 0.3 (two out of 700 forms), while it constituted almost one-third (29 percent) of the total Sidney cut fauna. Subsequently, *Columella alticola* was also reported by Wayne (1963, p. 62) from Illinoian deposits, although he again admitted (personal communication, March, 1965) that, in these older deposits, "neither of these species constitutes more than about 10 percent of a sample" and "in most faunas, they seem to run about 2 percent to 5 percent". In the same letter, Wayne also reported an identification of *Vertigo elatior* Sterki from this silt.

Thus the Wisconsin age determined by La Rocque on the basis of the molluscs is no longer valid. Although the two species of snails originally interpreted as diagnostic appear to be more abundant in Wisconsin-age deposits than in older, factors such as ecology and climate are also in effect, so no age inference can be drawn. In view of the new evidence, La Rocque has stated (personal communication, March, 1965): "These later records by Wayne remove all arguments for considering this assemblage to be Wisconsin on the basis of molluscan distribution. From the revised ranges (Table 1) it appears that the assemblage could be anything from Kansan to 'late' Wisconsin, as far as distribution of Mollusca is concerned. It becomes advisable, therefore, to consider other lines of evidence for dating this deposit".

Pebble counts were made of three of the tills in the cut: units 4, 6, and 9. The results are shown in table 2. Analysis of extensive earlier pebble counts made farther south in west-central Ohio by R. P. Goldthwait and his students has shown that the ratio of dolomite to limestone pebbles (maximum diameters between one and three inches) may be used to determine the direction of ice movement, because the dominant bedrock of westernmost Ohio is dolomite, whereas a broad north-south band of limestone characterizes central Ohio. Thus, in table 2, the dolomite/limestone ratios of 14.7 and 31.3 for the upper two tills point strongly to a west or northwest source. Conversely, the ratio of only 3.6 for the till in which the buried soil was developed indicates a source more to the north or northeast. The older advance apparently involved such thick ice that the direction of movement was little affected by the underlying topography and so the ice went nearly due south, whereas later tills were probably deposited by thinner ice, whose direction of motion was more controlled by bedrock irregularities, including the massive Bellefontaine outlier to the northeast. Results of pebble-orientation measurements, shown in figure 3, substantiate this interpretation.

The buried log, which was embedded horizontally and at right angles to the bank, was sampled at several different times during the few years immediately following its discovery; the final sampling required such deep excavation that a large slump block subsequently buried deeply whatever remains of the log. The two radiocarbon dates, 23,000 ± 800 (W-188) (Rubin and Suess,

TABLE 2

Pebble counts from Sidney and upper Brush Creek cuts ("pebbles" are restricted to maximum diameters of between one and three inches)

	Percentages of Lithologies				Dolomite/ limestone ratio
	Crystallines	Sandstone and shale	Limestone	Dolomite	
Sidney cut					
Top till (unit 9)	2	1	3	94	31.3
Till above soil (unit 6)	2	4	6	88	14.7
Till below soil (unit 4)	12	6	17	61	3.6
Upper Brush Creek cut					
Till above soil	4	33*	6	57	9.5
Till below soil	3	3	12	82	6.8

* Till has unusually high percentage of pebbles of nonresistant black shale (Ohio Shale), which crops out 25 miles almost due east and 90 miles directly north of here.

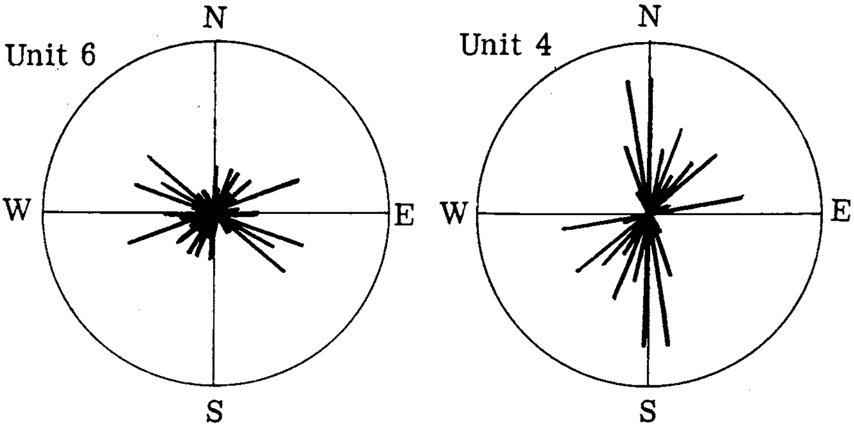


Fig. 3. Pebble orientation diagrams for the tills just above (left) and just below (right) the buried soil in the Sidney cut.

1955, p. 483) and 22,480 ± 800 (W-356) (Rubin and Alexander, 1958, p. 1477), represent samples collected at two different times. The log lay on the buried soil and incorporated soil material in its interstices; on the other three sides, the overlying calcareous till covered the log. The soil, therefore, must have been completed before, and then have been truncated by, the advance of the "late" Wisconsin glacier.

In one place along the Sidney exposure, the sand (unit 7) contains a thin, irregular zone that is oxidized red brown, leached, and clay enriched, with scattered white pebble ghosts. This zone looks exactly like the many similar "buried soils" developed in buried gravel elsewhere in Ohio and, like them, is very much like the B horizon of a modern Fox soil. If this were truly a paleosol, it would have to record a different, younger, soil-forming period from that of the stratigraphically lower Sidney soil; however, I do not believe it is a paleosol. As indicated earlier, geologists concerned with the interpretation of such zones acknowledge that some of them, especially those at rather shallow depths, probably represent the effects of surface soil-forming processes at depth, *after* deposition of the overlying till; leaching and oxidizing solutions carrying soil clay are believed to follow joints or cracks down through the overlying till. Although the location of this zone in the Sidney cut is about 18 feet diagonally below the top of the bank, the original land surface directly above it or diagonally above it to the west might have been considerably lower. Indeed, the bank on the west side of the railroad cut here is less than half as high as that on the east side, and well below the level of this zone. I believe, therefore, that the original land surface directly above this spot was so close above the sand that soil-forming processes were able to create this soil-like zone after deposition of the overlying till. In addition, the zone is weaker and more restricted than similar zones elsewhere believed to be true paleosols.

Thus it may be seen that stratigraphic information about the Sidney cut, although very interesting, does not provide useful evidence concerning the age of the soil-forming interval or of the till in which the soil was formed. One must turn, then, to data about the nature of the soil itself, as presented in a later section of this paper, for help in solving the problem of dating.

Stratigraphy of the Brush Creek Sections

The two sections along Brush Creek that expose the paleosol lie two miles south of the Sidney cut and about a mile apart. The upper Brush Creek section is the most informative of the two and has been the most studied; all the Brush Creek (Kirkwood) radiocarbon dates have come from this site. The lower Brush Creek section, though exposing the buried soil, lacked an underlying calcareous till; it has since become badly slumped.

Section in upper Brush Creek site.—

Unit	Description	Thickness (feet)
6	Alluvium, sandy silt with erratic pebbles and cobbles.	0-8
5	Till, silty with local thin discontinuous sand and silt lenses, oxidized to a depth of 12 feet below top of surface soil; log present near base in blue-gray compact till dated at 22,000 ± 1000 (W-414).	1-15
4	Peat, discontinuous, irregular lens-like, providing pollen profile and dates of >37,000 (W-415) 22,430 ± 140 (GrN-1761) >39,300 (GrN-4133) >50,000 (GrN-4415).	0-1
3	Silt with fine sand and some clay, leached, mottled.	0-2
2	Buried soil developed in till	
	upper zone of mottled light-blue and red-brown leached clay and silt, with slickensides in clay, and few white pebble ghosts.	0-3
	lower zone of red-brown leached clay loam, mottled, with white pebble ghosts; where 3 feet thick, lowest foot is less weathered, less brightly colored, and only partially leached.	0-3
1	Till, calcareous, clayey, silty, pebbly, compact, blue gray.	1+

Section in lower Brush Creek site.—

Unit	Description	Thickness (feet)
4	Alluvium, poorly sorted sandy gravel.	0-5
3	Till, clayey, silty, with local thin sand and silt lenses; along basal contact, small masses extend down into underlying unit (see fig. 4).	20±
2	Loam, clayey, yellow-brown, leached, compact.	1-2
1	Buried soil developed in till, characterized by striking light-blue clay with some silt, mottled with red-brown stains; leached, few pebble ghosts; slickensides in clay.	2+

Base of soil not exposed

The lower part of the buried soil exposed in the upper Brush Creek cut is much like the paleosol of the Sidney cut in color and development, though it is not as thick. In addition, this Brush Creek cut has an unusual weathered unit above the mottled red-brown Sidney-like soil, which is composed of clay with some silt, and which has a striking light-blue color with some red-brown mottl-

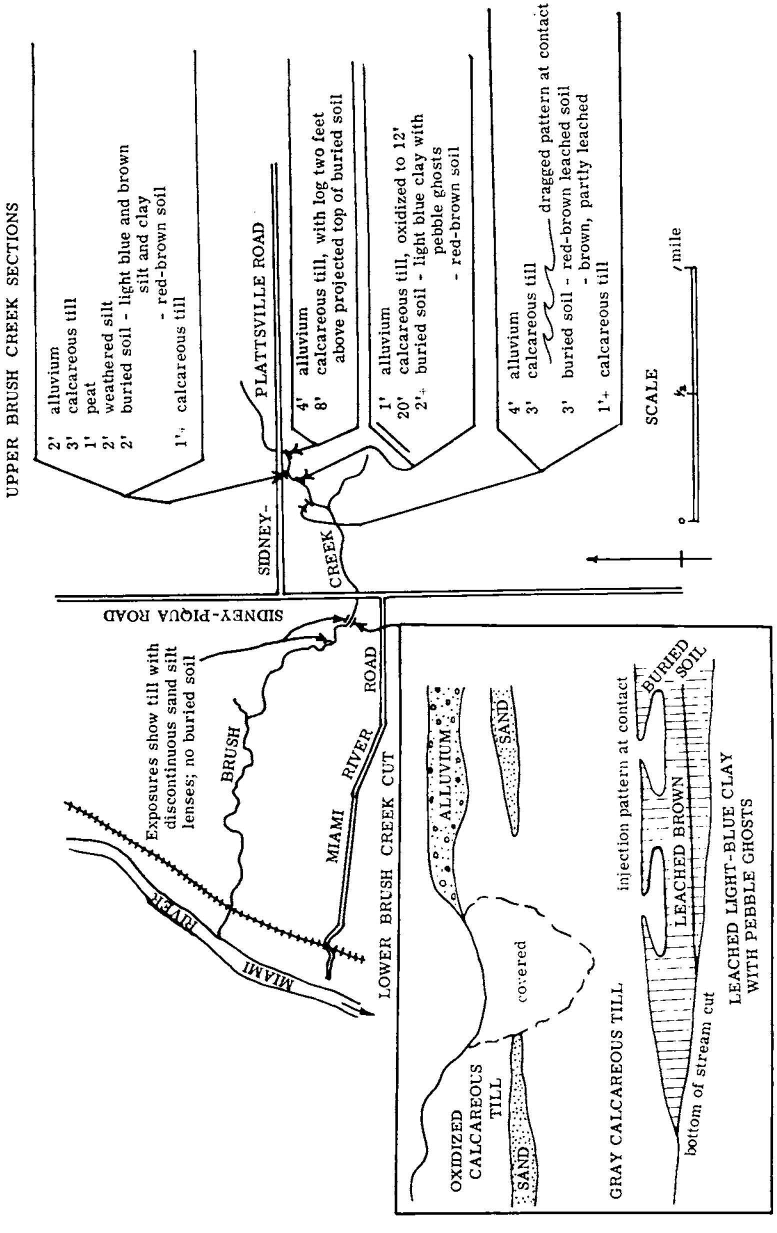


Fig. 4. Map of Brush Creek area, listing the stratigraphy found in several sections of the upper Brush Creek area and diagrammatically presenting the stratigraphic relationships once visible in the lower Brush Creek cut.

ing. The material is leached, the few pebbles in the unit appearing as white powdery ghosts. The clay has abundant slickensided surfaces.

The same type of light-blue clay composed the buried soil in the lower Brush Creek exposure before slumping obliterated the stratigraphy. Because it occurred only at the base of the section, it is not known whether any red-brown soil material was also present below; no calcareous till was ever observed below the soil in the lower Brush Creek section.

Originally this light-blue unit was not recognized as being part of a soil profile. However, subsequent discussions with a soils expert (N. Holowaychuk, personal communications, 1956 and 1965) revealed that the light-blue color was probably due to reduced iron, and the combination of the color and the strong clayey texture might well indicate a very poorly drained, gleyed type of soil profile developed in till. Certainly the mottling of the underlying red-brown soil material in the upper Brush Creek site and in the Sidney cut soil suggests poorly drained profiles. The gleying must have taken place in shallow depressions on a very flat, poorly drained till plain and, because of the presence of the underlying, better drained red-brown material, extended only through the upper part of the soil. The existence of a poorly drained flat surface at that time is supported by three other lines of evidence: (1) the occurrence of the three exposures of the paleosol (that is, three different occurrences of that ancient land surface) at elevations within 30 feet of each other: in the Sidney cut at 1010 feet, in upper Brush Creek at 1010 feet, and in lower Brush Creek at 980 feet; (2) the presence, in the pollen profile, of tree species indicative of poorly drained uplands; and (3) the ecological interpretation provided by the molluscs (see above and also in La Rocque and Forsyth, 1957, p. 85).

Above the light-blue clayey zone at the upper Brush Creek site is a thin, weathered, discontinuous, poorly sorted silt, interpreted as local colluvium. In places above the silt is a thin peat, never more than one foot thick, which has provided samples for radiocarbon dating and for a short pollen profile (figure 5).

Though incomplete, this pollen profile is very informative. Most of the plant species recorded, notably *Larix* (larch), *Populus* (poplar), *Ulmus* (elm), *Betula* (birch, some species), *Alnus* (alder), *Salix* (willow), and sedge, are characteristic of poorly drained uplands and upland depressions. The pollen profile is so short that most of the vertical changes recorded in it probably mean little. Most striking is the decrease in pine, accompanied by increase in larch, elm, and grass pollen. This may indicate a slight change to a somewhat cooler and more moist climate, a brief stage in some local natural ecological succession, or simply vagaries in some of the physical factors affecting pollen accumulation. The percentage of *Picea* (spruce) is remarkably low, despite the high percentage of this species composing the logs found in the base of the overlying till, both in the upper Brush Creek and Sidney cuts and elsewhere in western Ohio (Goldthwait, 1957; Burns, 1957). The pollen types present are generally representative of a cool but not cold climate, indicating an environment somewhat warmer than that implied by the spruce logs in the overlying till. This would indicate that the peat accumulated well within the ice-free interval; there is no suggestion of a shift back to cooler, more moist periglacial conditions, which would have been characterized by more spruce and less elm, poplar, and grass pollen. This interpretation is supported by the contrast in radiocarbon dates from the peat and from the overlying till. If a way should become possible to show that these cool-climate species represent the warmest

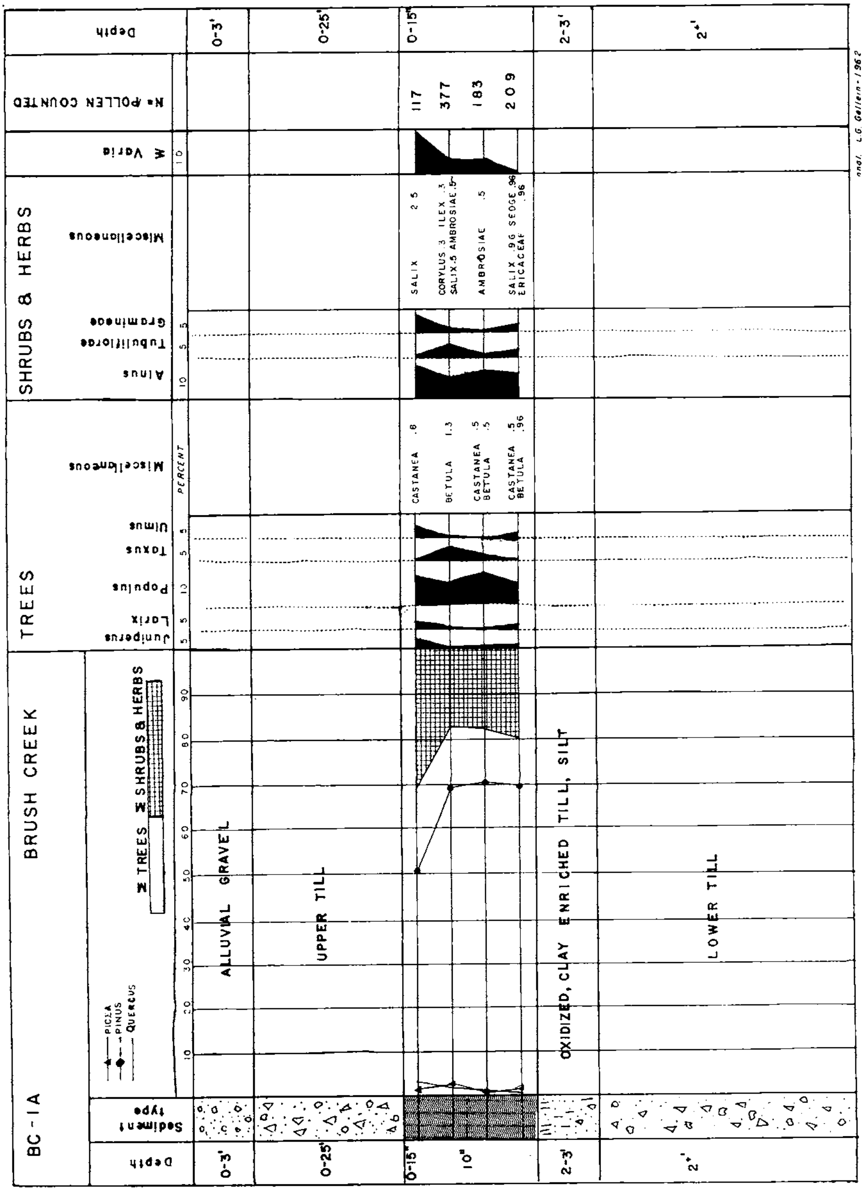


Fig. 5. Pollen profile of the peat in the upper Brush Creek site.

part of the ice-free interval, the problem of the age of the Sidney soil would be solved.

Radiocarbon dates on this peat have been determined in both the Washington and Groningen laboratories: >37,000 (W-415), 22,430 ± 140 (GrN-1761), >39,300 (GrN-4133), and >50,000 (GrN-4415). When the initial date (W-415) on the peat was received, it was interpreted, in conjunction with the 22,000-year date from the overlying till, as confirming the interpretation of a lengthy soil-forming interval within the Wisconsin Stage. Though the first Groningen date (GrN-1761) raised serious questions about this interpretation, the dilemma was solved by the more recent Groningen dates, which confirm the earlier Washington date.

It is apparent from the nature of the stratigraphy at the upper Brush Creek site that the suite of four units, the red-brown lower soil unit, the upper soil unit of light-blue clay, the leached silt, and the peat were all formed during the same long ice-free interval. The next, "late" Wisconsin, advance of the ice took place much later and is represented by the deposit of thick calcareous till lying above the buried soil everywhere along Brush Creek. The date of 22,000 ± 1000 (W-414) (Rubin and Alexander, 1958, p. 1477) came from a log found approximately two feet above the base of this till in the upper Brush Creek site. Because of subsequent stream erosion, the top of the till has been truncated in most places and covered with a veneer of alluvial gravel.

Stratigraphy, then, in the cases of both the Brush Creek exposures, taken in conjunction with the pollen profile and radiocarbon dates, again shows only that the buried soil was formed during an ice-free interval of significant duration; whether it dated from mid-Wisconsin or earlier age cannot be told. The nature of the buried soil profile, on the other hand, does provide critical evidence regarding this problem.

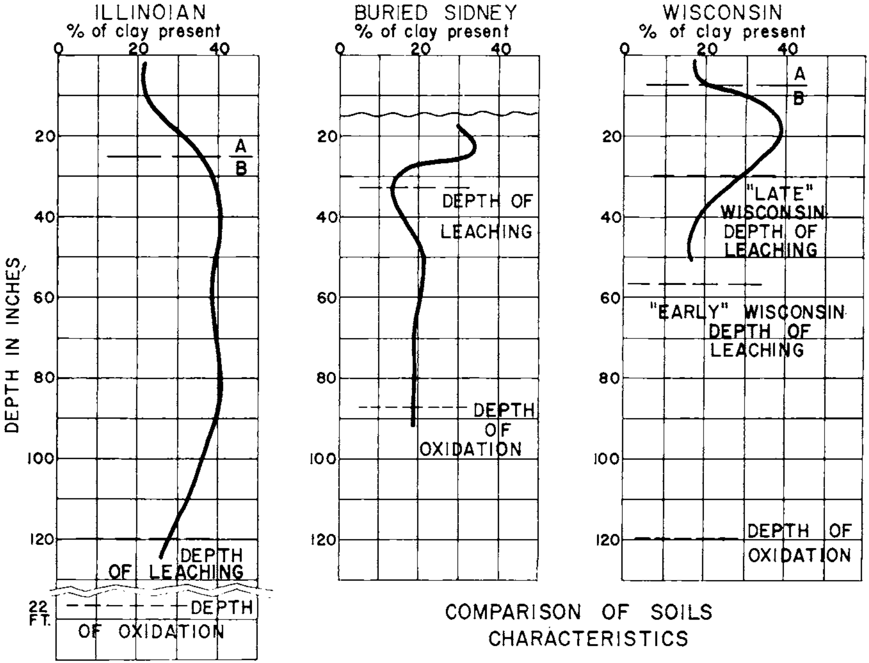
Morphology of the Buried Soil

From the beginning, the morphology of the buried soil has been one of the strongest factors in the evaluation of its age. When first observed, the soil's bright reddish-brown colors suggested strong weathering and considerable age. However, when samples of the soil were analyzed, only a slight amount of weathering was indicated, as measured by clay concentration in the B horizon. This information is summarized (table 3) and plotted against depth in a clay

TABLE 3

Summary of laboratory data on original samples of the Sidney buried soil (sampled August 10, 1955 by Holowaychuk and Forsyth)

Horizon	Depth (inches)	Carbonate (percent)	Percentage of particle sizes Sand	Silt	Clay	Fine clay
B_{21}	0-6	1.7	32.1	37.9	30.0	17.0
B_{21}	6-12	2.0	31.8	34.4	33.8	16.6
B_{22}	12-18	25.3	46.6	40.0	13.4	4.4
B_{22}	18-24	18.7	51.2	36.1	12.7	4.3
B_{23}	24-48	19.9	31.5	47.9	20.6	5.7
C_1	48-72	25.2	37.7	44.2	18.1	5.0
C_2	72-78	27.2	39.2	42.6	18.2	4.6



Data courtesy of N. Holowaychuk

Fig. 6. Graphs contrasting the clay profile of the Sidney soil in the Sidney cut (as sampled in 1955) with a composite Illinoian profile, drawn from data from three modern surface soils, and a composite Wisconsin profile, representing six modern surface soil profiles.

profile (fig. 6), which for comparison also shows similar curves for modern Wisconsin and Illinoian till soils at the surface, each based on an average of several profiles with drainage characteristics similar to those of the Sidney soil. The brief soil description made at the time of sampling (August 10, 1955) by Holowaychuk and Forsyth follows:

	Buried soil starts about 1/3 of way from top of cut. Unit just above soil, hard, calcareous till, rests on what appears to be the truncated B horizon of a buried soil.
0-12″ B_{21}	Clay. Distinctly mottled with intermingling of grayish brown, yellowish brown, and yellowish red. Weak subangular structure. Noncalcareous. This horizon is covered by 1- to 2-inch layer of yellowish-red platy material, which occurs at contact between B_{21} and overlying till. Two samples taken.
12-24″ B_{22}	Yellowish-red loam with prominent black and red coatings. Massive, breaking up into coarse angular units. Extremely hard. Lower boundary wavy with tongues extending to 48″. Calcaerous in lower part. Appears to be fragipan-like. Two samples taken.
24-48″ B_{23}	Yellowish-brown clay loam; massive, breaking up into coarse angular units; partly calcareous. One sample taken.

48-72" C_1	Dark grayish-brown till. Calcareous. Coarse skeleton of dolomite, quartzite, and igneous pebbles represents 10-20% of volume. One sample taken.
72+"	Gray-blue calcareous till. One sample taken.

Soil appears to be strongly developed because of extremely hard consistence, black coatings in B_{22}, and bright colors. On the other hand, the gray-blue till is very close to the B_{22} horizon, which suggests a short time of oxidation; present soils show about 10 feet of oxidized till. Clay profile is also very poorly developed.

It was not until Dr. J. de Heinzelin of Belgium (Institut Royal des Sciences Naturelles de Belgique) visited the site in 1957 that evidence for *Taschenboden*[1], or a form of cryoturbation, was recognized. By this term is meant the moving and sorting of subsurface materials, thus separating them into finer and coarser components, by the action of ground frost or permafrost. What processes take place to create such structures or sorting are not well understood, but when they are observed in temperate climates, such as that of Ohio, they are believed to record a period of seasonally or perennially frozen ground produced. in this area, presumably by the subsequent "late" Wisconsin ice advance.

In the Sidney cut, the Taschenboden appears as large wave-like outlines (fig. 7) within the main section of the soil profile, separating a finer-grained bluish-gray, clayey soil material from a coarser-grained, sandy, bright reddish component. In general, the finer-grained materials overlie the coarser, but the boundary between the two is very irregular and wavy, thus creating the appearance of pockets, or *Taschen*. As a result, the upper and lower units vary greatly in thickness along the exposure, and from time to time; variations of from 3 to 24 inches in thickness have been observed for each unit. Elliptical masses, 5 to 12 inches across, of the finer bluish-gray materials may also be present within the reddish sandy zone. The strongest variations in color and texture throughout the buried soil appear to be related to the development of the Taschenboden; ordinary soil horizons, modified by the Taschenboden, are present, but not strongly developed; soil structure is also present, but it is distorted by the Taschenboden. Despite the weakness and deformation of the normal soil horizons, profile development can be seen and the description of the buried soil, below, is organized on this basis.

Above the Taschenboden is a rather uniform soil zone, fine grained and more yellow brown in color, identified as the B_1 horizon of the buried soil. No unquestioned A-horizon material has been recognized in the Sidney cut, although R. P. Goldthwait (personal communication, 1957) has reported seeing, on an early visit to the cut, one spot that had a small amount of material like basal A-horizon soil. With this exception, the soil begins, beneath a sharp, generally horizontal contact, within but apparently close to the top of the B horizon. Below the strongest development of the Taschenboden, the contrast between the two units decreases, and ultimately the soil becomes weaker and partly calcareous. Below this partly calcareous zone is a zone of oxidized, calcareous till, one to two feet thick; this is in strong contrast to thicknesses of nine to twelve feet for the same zone in modern surface soils in western Ohio.

[1] European term used by de Heinzelin, meaning "pocket-like ground structure".

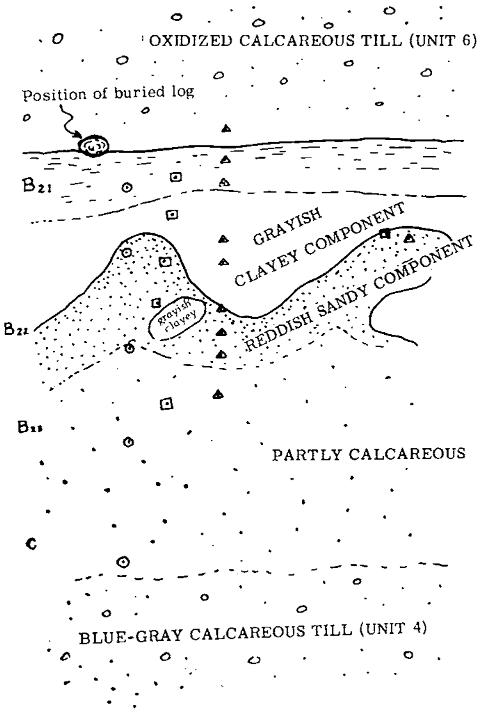


Fig. 7. Diagram showing relationship of Taschenboden and soil horizons in Sidney soil at south end of Sidney cut. Dots in circles represent probable original 1955 sampling spots. Dots in squares mark later sampling spots. Dots in triangles identify locations of clay mineralogy samples.

The morphological data is summarized below; these characteristics are best observed and have been measured at the south end of the Sidney cut:

Soil Horizon	Thickness	Description
B_1	8-12 inches	Top soil zone: clay loam (sand 34 percent; clay 32 percent), dominantly yellow brown (10YR5/6), with minor mottles of pale olive (5Y6/3); leached; with platy structure, especially near top; pH of 6.4.
B_2	3-14 inches	Upper cryoturbate zone: light gray (5Y6/2) clay loam (sand 27 percent; clay 37 percent), locally mottled with yellow-brown (10YR5/6); leached; platy structure locally near top, otherwise moderately well developed subangular blocky structure.
	10-24 inches	Lower cryturbate zone: strong brown (7.5YR5/8) gritty, sandy loam (sand 51 percent; clay 14 percent); massive, hard; leached; enclosing some elliptical masses of gray leached clayey material; pH of 6.8.
B_3	8-12 inches	Bottom soil zone: loam to clay loam (sand 30 percent; clay 34 percent) of strong-brown (7.5YR5/8) to yellow-brown (10YR5/6) colors, more pebbly; partly calcareous.

C	10-24 inches	Calcareous loam (sand 38 percent; clay 18 percent) till, oxidized to yellow-brown or olive colors (10YR5/6); average depth to top of zone about three feet.
—	30 inches	Calcareous blue-gray unoxidized loam (sand 39 percent; clay 18 percent) till; pH of 7.9; average depth to top of zone about five feet.

When the clay contents of these two strongly contrasting zones in the Taschenboden are plotted against depth (fig. 8), the samples from the reddish sandy zone lie far to the left and samples from the grayish clayey areas plot far to the right of the original clay profile (fig. 6), also reproduced in figure 8. This latter graph shows that the initial sampling was made indiscriminately down across the gritty and clayey zones, without knowledge of their presence; the strong bend to the right in the initial curve apparently represents a sample taken from a gray clayey area, whereas the sample that draws the curve far to the left must have come from a reddish sandy area. These suspicions are confirmed by information about the early samples in the original soil description. A single sample from what appeared in the field to be material intermediate in nature between the two extremes plots on this graph, as might be expected, in an intermediate position, the dot with the circle around it in figure 8.

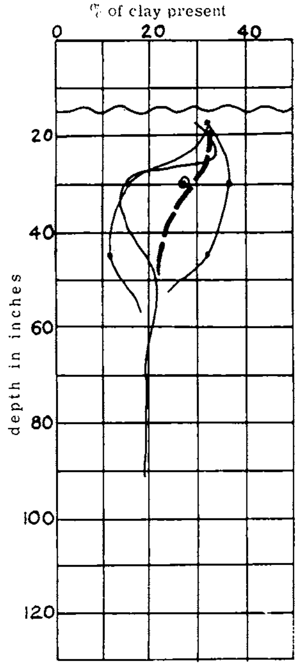


Fig. 8. Revised clay profile curves of the Sidney soil, superimposed over older curve (taken from fig. 6), showing results of sampling from the sandy and the clayey components created by the development of the Taschenboden. Dashed line represents an estimate of the possible shape of the original clay profile before modification by cryoturbation. collected.

Because of the sorting created by the Taschenboden, it is impossible from this data to draw a curve representing the initial clay distribution in the soil, which is the curve that should be compared with the other, modern clay profiles (fig. 6) if this data is to have any meaning in an evaluation of the age of the buried soil. However, the widely divergent curves of the clayey and sandy components (fig. 8) probably represent the outer limits of that original clay profile, so, as an estimate of it, a dashed line has been drawn, a rough average of these limiting curves, but drawn with due respect for the various proportions and distributions of the two Taschenboden components observed in the field. However this estimated clay profile is drawn, it can not show a clay accumulation commensurate with that in the Illinoian profile (fig. 6); indeed, the lack of sufficient clay buildup in the profile, the lack of strongly developed soil structure, the lack of a strong horizonation in the soil, and the restricted thickness of the oxidized calcareous zone all lead to the interpretation that the buried Sidney soil is only weakly developed and lacks the characteristics to be expected if development had taken place during the long, warm Sangamon Interglacial, although it could well have formed during the shorter mid-Wisconsin ice-free interval.

The interpretation of the Sidney paleosol as weakly developed is supported by the results of heavy-mineral analysis. Such work has been done on the buried soil in both the Sidney and upper Brush Creek cuts, under the direction of R. P. Goldthwait, by D. R. Sparling, J. B. Epstein, and P. J. Barrett. From a study of all the data, of which the results of the most detailed sampling are presented in tables 4 and 5, Goldthwait makes the following statement concerning the nature of the buried soil (personal communication, March, 1965):

> This is a very poorly developed, or juvenile paleosol. The reduction in grain size by weathering lowers sand content only in the top few inches of either profile (less than 10 to 14 inches). The increase of silt and clay fractions is small (about 10 percent) affects only middle-depth analyses (to less than 44″ or 58″). The only heavy mineral exhibiting consistent graded effects of chemical weathering is pyroxene. The pyroxene-amphibole ratio is a quarter as great at 16 to 22″ depth as it is in the parent till below or the covering till. The ratio of pyroxene to stable minerals (like garnet) is a third as great at 16″ to 22″ or 4″ to 14″ (Brush Creek). In spite of strong yellow-brown-red-brown colors, the limonite-hematite occurs as fine divided powder and does not show up in fine sand counts.

The clay mineralogy of the buried soil in the Sidney cut has been run and analyzed by Dr. Herbert D. Glass of the Illinois Geological Survey. For comparison, a buried Sangamon soil, near Martinsville, Clinton County, Ohio, was also sampled and analyzed. This section, located one mile west-northwest of Martinsville on the west side of the Cuba-Martinsville Road and on the northwest bluff of Little East Fork, exposes oxidized calcareous Wisconsin till (with Miami 60 soil) over a bright colored (7.5YR 5/8) Sangamon profile in Illinoian till, with an intervening three-foot dark blue-black (5Y 4/1) clayey silt, believed to represent weathered accretion gley, probably of "early" Wisconsin (Altonian) age.

The clay mineralogy data in tables 6 and 7 and the following discussion of these data have been provided by Dr. Glass (personal communications, 1963 and 1965):

Using oriented-aggregate techniques, the amounts of montmorillonite, illite, chlorite, and kaolinite were calculated from X-ray diffraction data of the less than 2-micron fraction. Montmorillonite includes all clay materials that expand to about 17A with ethylene glycol. Mixed-layer clay minerals and expandable chlorite or vermiculite are included, therefore, with the montmorillonite. Chlorite includes all 14A material that does not expand with ethylene glycol, and it includes any nonexpandable vermiculite. Illite and kaolinite are used as generally accepted. The values for kaolinite and chlorite are combined in the tables; the values for montmorillonite and illite are given for each.

Unaltered tills of this area generally have an illite-chlorite-kaolinite composition and undoubtedly reflect the composition of the bedrock from

TABLE 4

Mechanical analyses of sand in samples of Sidney soil
(prepared by P. J. Barrett)

Samples	Cumulative percentages of weight of grain sizes (millimeters)						
	4.00 granules	2.00 very coarse sand	1.00 coarse sand	0.50 medium sand	0.25 fine sand	0.125 very fine sand	0.062 silt and clay
Sidney cut							
overlying till	7.4	9.6	12.4	15.9	23.8	33.4	45.6
buried soil							
4 inches below top	2.8	5.8	9.3	14.1	22.4	32.0	41.6
10 ”	7.3	12.5	18.6	24.8	33.0	42.0	52.3
16 ”	7.5	11.7	17.5	23.5	31.7	40.5	49.4
22 ”	5.8	9.8	15.6	21.6	30.0	38.4	47.6
28 ”	9.5	13.9	19.9	25.6	33.1	42.2	53.3
34 ” *	10.3	14.4	20.2	26.2	33.7	41.6	49.2
40 ” *	6.9	12.2	18.8	25.3	33.8	42.5	51.7
46 ”	6.7	11.7	18.1	24.6	33.4	42.6	51.0
52 ”	7.2	12.0	18.9	25.4	34.2	43.6	52.2
58 ”	5.4	10.8	17.5	24.4	34.6	46.9	59.8
64 ”	6.5	12.5	19.1	26.1	34.6	44.0	52.4
70 ”	5.0	9.0	13.9	19.2	25.9	33.0	42.5
80 ”	5.5	8.9	13.4	18.1	24.9	30.3	41.0
90 ”	7.0	10.7	14.4	19.3	26.4	35.4	51.0
100 ”	6.4	9.3	14.0	19.7	27.8	37.4	46.0
120 ”	4.2	8.2	13.0	18.1	25.4	34.0	42.5
140 ”	5.3	8.8	13.5	18.3	25.2	33.2	41.1
Upper Brush Creek cut							
overlying till**	0.4	1.9	4.8	8.5	14.4	22.8	30.3
buried soil							
4 inches below top	0.5	1.5	4.7	10.5	22.2	36.3	46.8
14 ”	2.9	7.0	10.6	13.8	22.2	30.9	37.5
24 ”	2.7	3.8	5.3	8.2	15.4	24.2	32.2
44 ” ‡	5.9	10.1	14.7	19.2	25.2	32.5	18.4
54 ”	4.0	5.1	6.2	7.9	12.3	18.4	25.0

* The moderately strong contrast between these two samples suggests that the upper one was in one of the reddish, sandy components of the Taschenboden level and the lower one was in material intermediate in nature.

** The similarity of this series of values with those below suggests that the sampling may have been confused by the upper Brush Creek stratigraphy and that the top of the buried soil used in making these collections may not have been the same as that described elsewhere in this paper.

‡ No sand analyses available for 34-inch depth.

which they were derived. Montmorillonite, vermiculite, and mixed-layer clay minerals are formed from the alteration of chlorite and illite in the soil profile due to weathering. Kaolinite is probably neither formed nor destroyed in these profiles. Chlorite is much more sensitive to alteration than illite, initial depletion occurring before the leaching of calcite. Only with increased duration and intensity factors do alteration and depletion of illite occur. Climatic condition, clay-mineral composition, and physical properties of the tills were probably similar, any differences in weathering being principally a function of time.

In the Sidney Cut, essentially unaltered gray calcareous till (illite-chlorite-kaolinite) is shown by sample 10 in table 6. The 3:1 ratio of illite to chlorite and kaolinite is common for both till and shale in this area. Samples 9, 8, 7, and 6 are oxidized, contain goethite, and show a progressive decrease in amount of chlorite upward in the profile. Sample 3 shows a composition similar to that of sample 6. None of these oxidized samples show any decrease in amount of illite, the intensity of weathering having reached only to the stage of chlorite depletion.

TABLE 5

Percentages of heavy minerals in samples of Sidney soil
(prepared by P. J. Barrett)

Sample	Carbonate	Magnetite-ilmenite	Limonite-hematite	Amphibole	Pyroxene (ortho)	Pyroxene (clino)	Garnet (pink)	Garnet (cless)	Monazite	Rutile	Tourmaline	Zircon	Apatite	Epidote	Sphene	Zoisite
Sidney cut																
overlying till	4	17	19	22	4	6	3	8	x	–	1	1	4	x	2	x
buried soil																
4 inches below top	2	8	35	30	1	2	4	5	–	–	–	x	2	3	1	1
10 ”	4	7	39	26	2	2	4	6	x	–	x	x	2	3	2	1
16 ”	6	20	12	30	1	2	6	11	x	x	x	1	2	2	1	1
22 ”	5	20	18	28	3	4	5	9	x	–	–	x	2	1	2	1
28 ”	x	5	69	13	1	1	1	4	x	x	x	x	2	x	x	x
34 ”	4	14	13	31	2	7	3	14	x	x	1	–	2	2	1	1
40 ”	4	17	13	31	3	3	3	16	1	x	x	1	1	2	1	x
46 ”	5	22	11	27	2	3	4	13	x	1	–	x	3	2	2	1
52 ”	7	16	13	32	1	2	4	13	1	–	x	x	4	1	1	1
58 ”	9	18	20	25	4	3	4	10	x	x	x	x	1	1	x	1
64 ”	6	17	18	29	3	2	4	9	x	x	2	1	3	2	x	–
70 ”	10	20	16	25	3	3	4	8	x	x	1	1	1	2	1	1
80 ”	6	16	17	33	3	3	4	9	x	x	–	x	2	x	x	2
90 ”	12	10	16	29	4	6	3	10	x	x	x	1	2	2	2	x
100 ”	6	17	24	25	4	3	3	7	1	1	–	2	1	2	x	x
120 ”	3	18	23	25	2	3	3	9	1	1	x	1	2	2	2	x
140 ”	5	19	16	29	7	3	3	10	1	x	x	x	1	1	x	–
Upper Brush Creek cut																
overlying till	7	17	9	30	3	5	5	12	1	x	1	x	3	1	1	1
buried soil																
4 inches below top	1	21	5	36	x	2	12	15	1	–	x	x	x	1	1	–
14 ”	5	25	10	30	2	3	6	9	1	x	x	–	2	2	1	1
24 ”	1	15	30	25	2	2	5	11	x	x	x	1	1	x	–	2
34 ”	16	16	10	35	1	2	2	8	x	–	1	1	2	1	2	x
44 ”	8	13	10	39	2	4	6	8	1	–	x	1	3	x	1	x
54 ”	4	16	3	38	2	3	4	15	1	x	1	1	2	2	1	1

TABLE 6

Clay minerals in $<2\mu$ fraction in Sidney cut

Sample Number	Nature of sample	Montmorillonite	Illite	Kaolinite and Chlorite	
A	Surface till (unit 9) in cut	2	84	14	goethite
B	Till (unit 6) directly above buried soil	7	83	10	goethite
Buried Soil (unit 5) sample depths in inches below top of soil:					
1	3; yellow-brown clayey soil (B_1)	19	71	10	
2	11; olive-colored clayey soil (B_1)	24	67	9	
3	17; reddish sandy component (B_2); sampled 16″ to right in order to penetrate one of cryoturbate "rises"	3	89	8	goethite
4	17; bluish-gray clayey component (B_2)	13	77	10	
5	24; bluish-gray component (B_2)	8	81	11	
6	30; reddish sandy component (B_2)	3	89	8	goethite
7	40; reddish sandy component (B_2)	4	90	6	goethite
8	47; less reddish sandy component (B_3)	3	88	9	goethite
9	56; partly calcareous, olive-colored soil (B_3)	2	84	14	goetihte
10	108; gray-blue calcareous till (unit 4)	1	76	23	

TABLE 7

Clay minerals in $<2\mu$ fraction in Martinsville section

Sample Number	Nature of sample	Montmorillonite	Illite	Kaolinite and Chlorite	
1	Overlying calcareous, oxidized Wisconsin till	25	62	13	
Soil developed in dark blue-black clayey silt; sample depths in inches below top of silt:					
2	1; tan 2-inch silt at top (ancient A horizon?)	76	10	14	
3	7; blue-black silt	78	8	14	
4	14; blue-black silt	78	8	14	
5	29; sampled 4 inches above top of weathered till	76	10	14	
Soil (Sangamon) developed in Illinoian till; sample depths continue in inches below top of silt					
6	33; bright red sandy soil, sampled 4 inches below top of Sangamon Soil	74	13	13	goethite
7	38; bright red soil mottled with green clay	64	18	18	goethite
8	46; bright red clayey soil	65	18	17	goethite
9	56; greenish-yellow clay soil mottled with red	55	26	19	goethite
10	67; greenish-yellow clay soil mottled with red	15	76	9	
11	partly calcareous Illinoian till sampled 30 feet away, actual sample not calcareous	32	53	15	

Samples 5, 4, 2, and 1 show a progressive change in color upward from blue-gray to yellow-brown, goethite is absent, and all samples are characterized by conspicuous vermiculite. This is in sharp contrast with the oxidized samples in which weathering would be expected to deplete markedly the chlorite and vermiculite content. The increase of montmorillonite in the unoxidized samples results from the expansion of the fine-grained vermiculite.

The unoxidized samples are not necessarily part of the in-situ weathering profile on the oxidized materials. The composition and color suggest an accretion-gley environment in which upgrading of vermiculite has taken place. The change in color may indicate a slight weathering profile imposed on the gley. The irregular field relations of the two types of materials are probably related to distortions during the subsequent glacial advance.

The overlying till samples A and B are again good examples of oxidized, high-illite types very similar to samples 8 and 9 below. The clay mineral composition again shows alteration of chlorite, but not of illite.

Samples from the Martinsville section included no unaltered till. Sample 10, the least altered till in the soil profile, has been essentially depleted of chlorite. The illite content is normal, and the slight increase in montmorillonite derives from the alteration of chlorite. There is no evidence that any illite has been lost by weathering. However, samples 9, 8, 7, and 6 are oxidized, contain goethite, and show a marked decrease in illite and an increase in montmorillonite as the illite alters to montmorillonite. The overlying blue-black clay has a composition similar to the oxidized till below. It seems possible that an accretion-gley relationship occurs here as well, although the clay-mineral evidence is not clear.

In summary, the outstanding difference between the weathering of clay minerals in the two sections is that only chlorite is altered in the Sidney Cut whereas alteration of illite occurs at Martinsville. Alteration of Woodfordian (Wisconsinan) tills in Illinois characteristically shows alteration of chlorite, but not of illite. On the other hand, well-developed profiles on Illinoian or older tills invariably show the intensive alteration of illite.

Studies on the weathering of tills of known age in Illinois indicate that the degree of clay-mineral depletion is primarily a function of time. The alteration of illite at the Martinsville section (Illinoian) agrees with alteration of tills of similar age in Illinois, and the lack of alteration of illite in the Sidney Cut profile compares with alteration of Wisconsinan tills in Illinois. From the degree of clay-mineral alteration, it is most probable that the Sidney Cut profile is Wisconsinan in age.

Summary: Age and correlation of the Sidney soil and underlying till

Ever since the discovery of the buried soil in the Sidney cut, there has been a great deal of discussion about its age. Accepted as a true paleosol, the soil profile unquestionably represents a fairly long ice-free interval, an interpretation supported by the nonglacial aspect of the short pollen profile and by the radiocarbon dates. According to the latter, the soil-forming interval ended 22,000 to 23,000 years ago and began at least 30,000 years earlier. Whether this interval was only a little longer than 30,000 years, dating the soil as mid-Wisconsin and the till in which the soil was formed as a true "early" Wisconsin deposit, or whether it was a great deal longer, dating from the beginning of the Sangamon Interglacial, has been the controversy.

Neither the regional relationships nor the molluscs from the underlying silt provide an answer to this question. It is the buried soil itself which provides the critical data. Morphologically the soil is weak, with little good horizonation or soil structure and poorly developed clay profile (subsequently modified by the formation of Taschenboden). Heavy mineral and clay mineralogy data

TABLE 8

Chart showing correlation of Sidney soil and underlying "early" Wisconsin till with other midwest Wisconsin units

Illinois		**Indiana**	Sidney	Eastern Ohio and Pennsylvania	Southern Ontario
Frye and Willman, 1960; Frye, Glass, and Willman, 1963		Gooding, 1963	this report	White, 1963; Shepps and others, 1959	Dreimanis, 1964
Woodfordian 15,000-20,000		Late Wisconsin 14,000-20,000	overlying "late" Wisconsin till 14,000-23,000	Ashtabula, Hiram, Hayesville-Lavery, and Navarre-Kent Tills	"Main" glaciation 12,000-24,000
Farmdalian 22,000-26,000			Sidney soil-forming interval >50,000 (peat)	Mogadore Till	Plum Point Interstadial 24,000-28,000
Altonian	Winnebago Till 31,000	Early Wisconsin Fayette Drift >40,000			Southwold Till
	Danville Till >40,000	Whitewater Drift >43,000	"early" Wisconsin till		Port Talbot Interstadial and Dunwich Till 44,000-47,000
	"glaciation in northern Illinois?"			?Millbrook Till	Bradtville and Sunnybrook Tills
Sangamonian		Sangamon	(Sangamon)	(Sangamon)	(Sangamon)

strongly support this interpretation. Such a weak soil must certainly have developed through a relatively short interval; therefore, I believe that there can be little doubt that the buried soil in the Sidney cut is mid-Wisconsin and the underlying till is "early" Wisconsin in age, supporting the interpretation by Goldthwait and Forsyth of an "early" Wisconsin glacial episode in Ohio.

On the basis of this interpretation and the radiocarbon date of >50,000, the underlying till, in which the Sidney soil was formed, appears to correlate with the Whitewater and/or Fayette drifts of Indiana (Gooding, 1963) and the earliest Altonian glaciation (unnamed) and/or the "Danville" till of Illinois (Frye and Willman, 1960; Frye, Glass, and Willman, 1963) to the west, and, to the east, with the Bradtville and Sunnybrook tills of southern Ontario (Dreimanis, 1963) and possibly with the Mogadore till of eastern Ohio and western Pennsylvania (White, 1963; Shepps, White, Droste, and Sitler, 1959). These relationships are shown diagrammatically in table 8. It is likely that some of these correlated units were not exactly synchronous, but all appear to date from the same interval, the earliest part (50,000 to 70,000? years ago) of the Wisconsin Stage (early Altonian). Most other areas had deposits of subsequent pre-"late"-Wisconsin (later Altonian) glacial advances; it was the lack of such deposition that allowed the Sidney soil to develop without interruption into a significant paleosol.

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