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DEPARTMENT OF NATURAL RESOURCES
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DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

Report of Investigations No. 127

GLACIAL GEOLOGY
OF
ROSS COUNTY, OHIO

by

Michael J. Quinn

and

Richard P. Goldthwait

Columbus
1985

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ABSTRACT

Glacial drift from the Illinoian and Wisconsinan Stages covers the northwestern three-quarters of Ross County. During these two glaciations the ice sheets deposited at least four till units in the county: Rainsboro (Illinoian); Boston, Caesar, and Darby (Wisconsinan). Two end moraines, Lattaville and Reesville, were constructed at the maximum advance or readvance positions associated with the Caesar and Darby Tills, respectively.

A significant difference (99 percent confidence level) exists between the Darby, Caesar, Boston, and Rainsboro Tills for mean values of loess-cover thickness and depth of carbonate leaching. These criteria can be used to differentiate between the major till-soil associations and, therefore, the identity of the till parent material in a given area.

Results of laboratory analyses indicate that the Rainsboro, Caesar, and Darby Tills are compositionally and texturally indistinguishable from each other. These three tills are characterized by (1) clay-mineral composition that is high in illite (80 percent) and low in vermiculite and chlorite (15 percent), (2) high carbonate-pebble content (80 percent) and a low limestone/dolomite ratio (0.4), (3) high total calcium carbonate equivalent in the less-than-2-millimeter fraction (28 percent), and (4) similar percentages of sand (25 percent), silt (51 percent), and clay (23 percent). The compositionally and texturally distinct Boston Till is characterized by (1) clay-mineral composition that is low in illite (65 percent), (2) low carbonate-pebble content (64 percent), (3) low total calcium carbonate content in the less-than-2-millimeter fraction (19 percent), and (4) about one-third as much sand (8 percent) and twice as much clay (43 percent) as in the Darby, Caesar, and Rainsboro Tills.

Three levels of Late Wisconsinan outwash—Worthington, Circleville, and Kingston—were deposited in association with ice-margin positions at the Powell, Marcy-Yellowbud, and Lattaville Moraines, respectively. Two levels of Illinoian Higby Outwash form high terraces in southeastern and southwestern Ross County. All outwash units in the county except the Paint Creek valley portion of the Kingston Outwash are compositionally similar and are characterized by low carbonate-pebble content (77 percent), high crystalline-pebble content (13 percent), and a limestone/dolomite ratio of about 0.5. Outwash units in Ross County can be identified on the basis of terrace elevations, gradients on projected profiles, and soil profiles.

Glacial drainage modifications in the county include northward shifting of drainage divides resulting from impoundment of proglacial lakes and drift deposition along the Appalachian Plateau escarpment and major drainage diversions caused by downcutting at outlets of proglacial ice-dammed lakes (Glacial Lakes Bourneville, Massieville, Humboldt, and Bainbridge).

INTRODUCTION

REGIONAL SETTING

Ross County, located in south-central Ohio, lies in two distinct topographic provinces. The northwestern third of the county consists of rolling plains and low hills of the glaciated portion of the Central Lowlands Province. Streams in the lowlands flow in broad shallow valleys. The central and southern portions of the county rise 200 to 300 feet above the lowlands and are included in the Appalachian Plateaus Province. This region is hilly, with small streams flowing in deep narrow valleys. The north-facing bedrock escarpment which separates these two physiographic provinces trends northeast-southwest across central Ross County.

Two broad valley systems dominate the glacial map (pl. 1) and provide access routes (*e.g.*, U.S. Routes 23 and 50) through the hills. One is the Scioto River in a broad "S" pattern north to south in the eastern half of the county. The Scioto River occupies the route of a pre-Illinoian valley system, the Deep-Stage Newark River, which cut into bedrock nearly 100 feet beneath the Scioto River floodplain. The second valley system is the still-earlier, preglacial (Tertiary) Teays River (Teays Stage), which once flowed in just the opposite direction, southeast to northwest! This system enters southeastern Ross County from an abandoned course through West Virginia. Its shallow broad valley passes under Higby, crosses the Scioto River valley, and continues in a "D" curve under Richmond Dale, Vigo, Londonderry, and northwest to Chillicothe (Stout and others, 1943). From Chillicothe northward the Teays valley gets lost beneath the glacial drift, but has been traced by very deep wells and geophysical methods under London in Madison County and northwestward. The main Teays tributary in Ross County was the Paint Creek valley, swinging in a broad "U" from southwestern Ross County to a buried junction near Andersonville in north-central Ross County.

PREVIOUS INVESTIGATIONS

The earliest geological descriptions of Ross County were subsidiary reconnaissance investigations produced during land surveys or during travel by visiting scientists. On the basis of observations taken during a canal trip through southern Ohio, Hildreth (1834) published the first geological report on the Ross County region. He noted water quality, deposits of iron ore ("globular pyrites"), "high banks

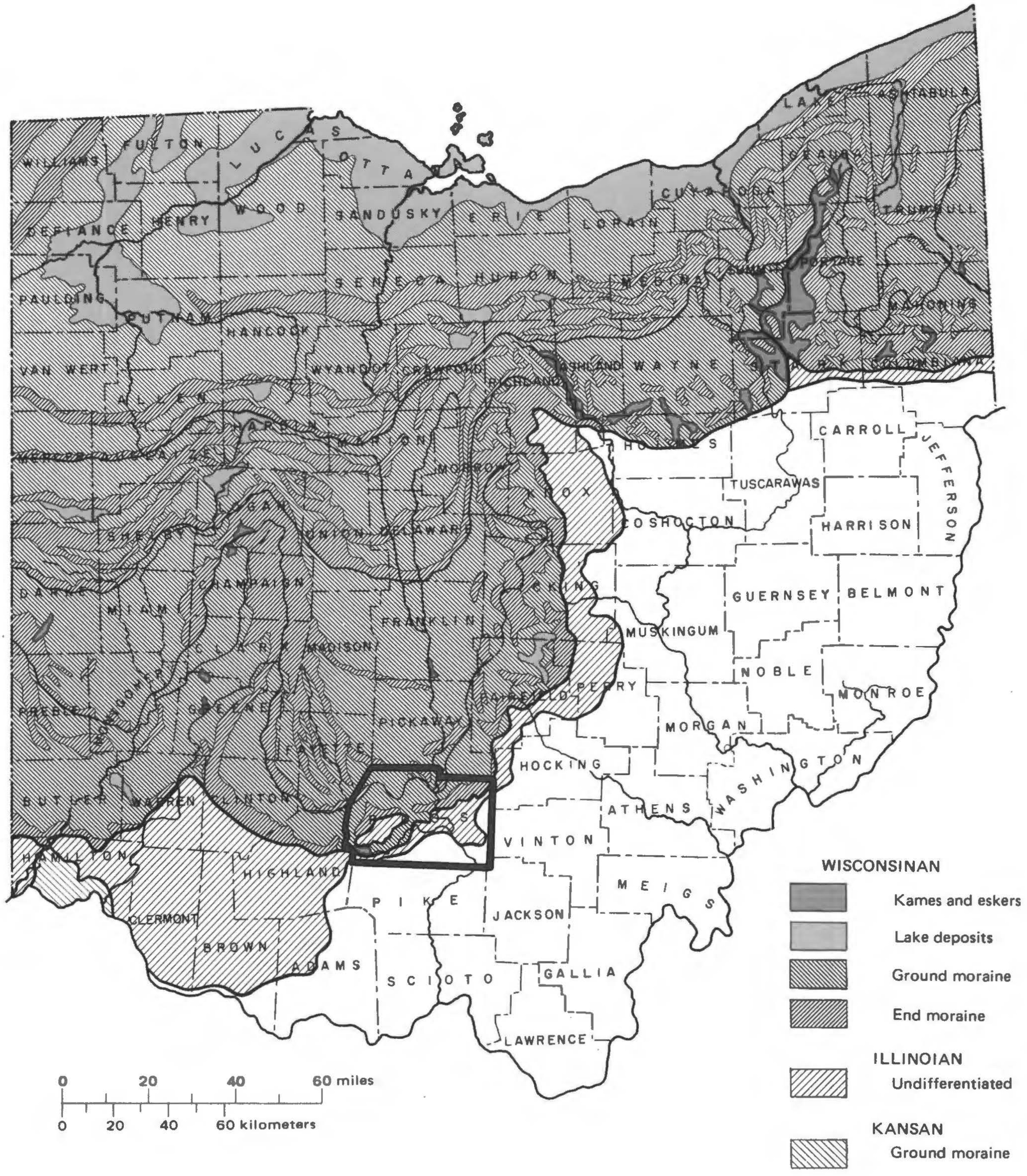


FIGURE 1.—Glacial geology of Ohio and location of Ross County.

of gravel" (terraces) bordering the major valleys, and the general regional topography. The first report on the general geomorphology of south-central Ohio was made by Whittlesey (1838), the Topographer of the Geological Survey of Ohio. He produced a cross section of central Ohio and indicated that the surface material was "Tertiary with primitive bowlders."

Orton (1874) published the first geological report on Ross County. His comprehensive publication included thorough discussions of the bedrock geology, economic geology, and glacial history of the entire county. Also in 1874, Newberry published a lengthy description of glacial materials, glacial theory, the glaciated portion of Ohio, and glacial morphology. In Ross County he noted the presence of a "forest bed" beneath 30 feet of glacial material, boulders ("erratic blocks"), and loess.

In his classic report on the glacial deposits of the midwestern and eastern United States, Chamberlin (1883) observed and mapped the moraines of the "Scioto Glacier." He noted relative ages, topographic relationships, and composition of the moraine segments in Ross County. The morphology of the glacial limit was described in detail by Wright (1890) in his report on the glacial boundary from Pennsylvania to Illinois.

Glacially induced drainage modifications in south-central Ohio were discussed by Fowke (1895) and Tight (1895, 1903). Davis (1884) briefly described the Alum Cliffs diversion of Paint Creek in his summary of the major gorges and waterfalls in the United States. In his classic monograph, Leverett (1902) described the Scioto River drainage system and its modification by repeated continental glaciation. He described the structure, thickness, and composition of "Early" and "Late" Wisconsinan drift and associated glacial features in Ross County.

Campbell (1918) and Hyde (1921) reported on the bedrock geology and general glacial geology of that portion of Ross County surrounding the now long-defunct Camp Sherman. Stauffer (1909), Melvin (1933), Stout (1941), Carman (1947, 1955), and Hyde (1953) thoroughly studied various aspects of the bedrock geology of Ross County.

The general geomorphology of south-central Ohio and the influence of glaciations on the topography and drainage history were discussed by Stout and Lamb (1938). Goldthwait (1947), Foster (1950), and Reynolds (1959) each studied a small portion of Ross County and determined age relationships between various glacial deposits and erosional features. Hubbard (1954) discussed the sand and gravel terraces along the present Scioto River valley. He described terrace morphology, composition of the terrace materials, and general correlation of the terrace levels with episodes of continental glaciation. Kempton and Goldthwait (1959) described the outwash terraces of the Scioto River and Paint Creek valleys and indicated time correlations with various end moraines of the Scioto Sublobe.

The relationships between glacial deposits, buried-valley systems, and ground-water resources have been described in various publications (Stout and others, 1943; Van Tuyl and Bernhagen, 1947; Schmidt, 1954, 1961-62, 1980; and Walker and others, 1965). Selected exposures of glacial deposits were described and discussed in a series of guidebooks for the Friends of the Pleistocene and the Geological Society of America (Goldthwait, 1955, 1962; Goldthwait and Rosengreen, 1969). The glacial history of the Scioto Sublobe is summarized in Goldthwait and others (1965) and Dreimanis and Goldthwait (1973).

METHODS OF INVESTIGATION

Field procedures

Field investigations were carried out during the summers of 1972 and 1973. Nearly every roadcut and stream cut in Ross County was examined and sampled. Areas not readily accessible by car were visited on foot. The field area was revisited in late fall and early spring to plot boulder occurrences and map moraine topography. Crops and foliage present during summer and early fall hinder a detailed survey of these features at those times.

Numerous pits were dug in areas of limited natural exposures to examine and sample the glacial materials. Several hundred auger borings were made to delineate thickness of loess cover, depth of leaching, soil parent material, and the soil profile. Samples for laboratory analyses were obtained from pits, augerings, and natural exposures.

Pebble counts were made at 70 exposures in till and gravel. One-hundred 1- to 3-inch pebbles were randomly collected at each exposure. In the lab each pebble was washed, broken, and identified as to rock type. This procedure allows consistent lithologic identification, especially in separating limestone from dolomite.

Till fabric was determined at 30 locations by measurement of the preferred long-axis orientation of 30 to 50 pebbles greater than 1 inch long. Only pebbles with a length-to-breadth ratio greater than 3.0 were measured.

Field mapping was done on U.S. Geological Survey 7½-minute (1:24,000) topographic quadrangle maps. Final mapping (pl. 1) is at a scale of 1:62,500. The Ross County soil survey (Petro and others, 1967) was very useful in determining parent materials associated with specific soil groups.

Office and laboratory procedures

Over 750 water-well logs and several bedrock test-hole records on file with the Ohio Division of Water were analyzed for information concerning the thickness and nature of the glacial deposits in Ross County. Air photos of Ross County were examined to aid in delineation of outwash terraces, channels, moraine topography, and ice-contact features.

Particle-size distribution was determined for 92 till and loess samples. The total sand fraction was removed by wet sieving, dried, and then separated into the various sand fractions by dry sieving. Hydrometer analysis was used to determine quantitatively the silt (0.062-0.002 mm) and clay (<0.002 mm) fractions according to procedures described by the American Society for Testing and Materials (1964, p. 95-106).

The calcite, dolomite, and total carbonate content of 92 till and loess samples was determined by Chittick gasometric analysis (Dreimanis, 1962). Samples were ground to <0.074 mm prior to analysis to diminish the effect of grain size on the gasometric reaction and thus promote internal analytical consistency. Clay mineralogy of 42 till, loess, and lacustrine samples was determined semiquantitatively by an x-ray diffraction method modified from Johns and others (1954, p. 242-251) by L. P. Wilding and L. R. Drees of the Department of Agronomy, Ohio State University (see Quinn, 1974, for procedure).

PREGLACIAL ENVIRONMENT

BEDROCK GEOLOGY

Exposed bedrock in Ross County ranges from Silurian to Pennsylvanian in age (fig. 2; table 1). Exposures are common in the southern, unglaciated portion of the county, although some stream cuts, roadcuts, and uplands in the glaciated area display the bedrock stratigraphy. The upper Paleozoic strata generally dip east-southeast at approximately 30 feet per mile, forming part of the eastern limb of the Cincinnati Arch.

The oldest exposed bedrock is Silurian limestone and dolomite in the Paint Creek and Buckskin Creek valleys in western Ross County. Most of the county west of the Scioto River valley is underlain by Devonian shales and Mississippian shales and sandstones. The Berea Sandstone (Mississippian) caps the outliers and uplands in the central and southern portions of western Ross County. East of the Scioto River valley, Mississippian shales and thin sandstones form the uplands. In small areas of northeastern and southeastern Ross County the Sharon conglomerate (Pennsylvanian) caps the higher uplands.

PREGLACIAL SURFACE AND TOPOGRAPHY

The preglacial topography of Ross County (fig. 3), as reconstructed from well logs and exposures, displays two distinctive topographic situations. The variations in bedrock topography closely conform to the distribution of bedrock lithologies.

Prior to glacial modification, the southeastern two-thirds of the county was a prominent, deeply incised upland forming a portion of the western margin of the Appalachian Plateau. Deep entrenchment in the Mississippian bedrock by the preglacial drainage (Deep Stage) created a maximum local relief of approximately 800 feet in southwestern Ross County. The nearly accordant elevation (1,000 to 1,100 feet) of the plateau was interrupted by small hills which rose 200 to 300 feet above the general upland surface.

The northwestern third of Ross County had a much more subdued bedrock surface, in contrast to the bordering

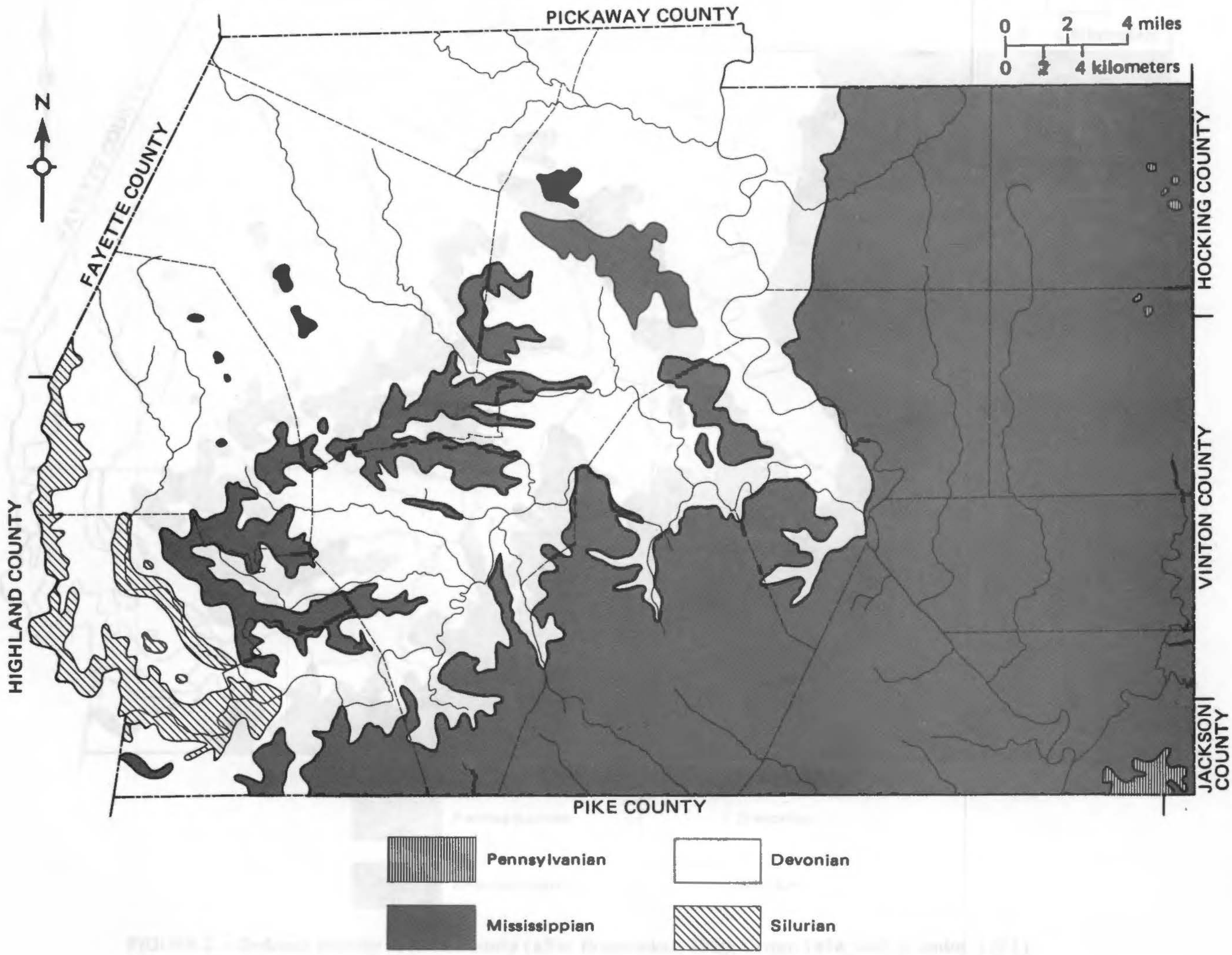


FIGURE 2.—Bedrock geology of Ross County (after Bownocker, 1920; Orton, 1874; and Schmidt, 1954).

TABLE 1.—*Generalized section*[1] *of bedrock in Ross County*

System	Group/ formation	Approximate thickness (ft)	Character
Pennsylvanian	Pottsville Group	40	coarse, pebbly sandstone
Mississippian	Cuyahoga Formation and Sunbury Shale	670	alternating sandstone, shale, and siltstone
	Berea Sandstone	24-40	thin-bedded sandstone and siltstone
	Bedford Shale	90	clay shale
Devonian	Ohio Shale Olentangy Shale	270-300	black carbonaceous shale brown shale
Silurian	Greenfield Dolomite	100	fine-grained dolomite
	Peebles Dolomite	20-90	porous dolomite

[1] Modified from Schmidt, 1954.

dissected upland. This bedrock surface was developed primarily in Devonian shale and lay 300 to 400 feet below the neighboring upland. Prominent outliers of Mississippian strata dominated the southeastern margin of this region. Additionally, small rounded hills and minor tributary stream valleys interrupted the generally planar nature of the bedrock topography.

GLACIAL STRATIGRAPHY

Glacial stratigraphy is characterized by repetitive sequences of varied drift units (*e.g.*, till-outwash-till). In the absence of a distinctive marker bed or an abundance of datable material, correlation based on stratigraphic sequence from section to section or between water-well logs is

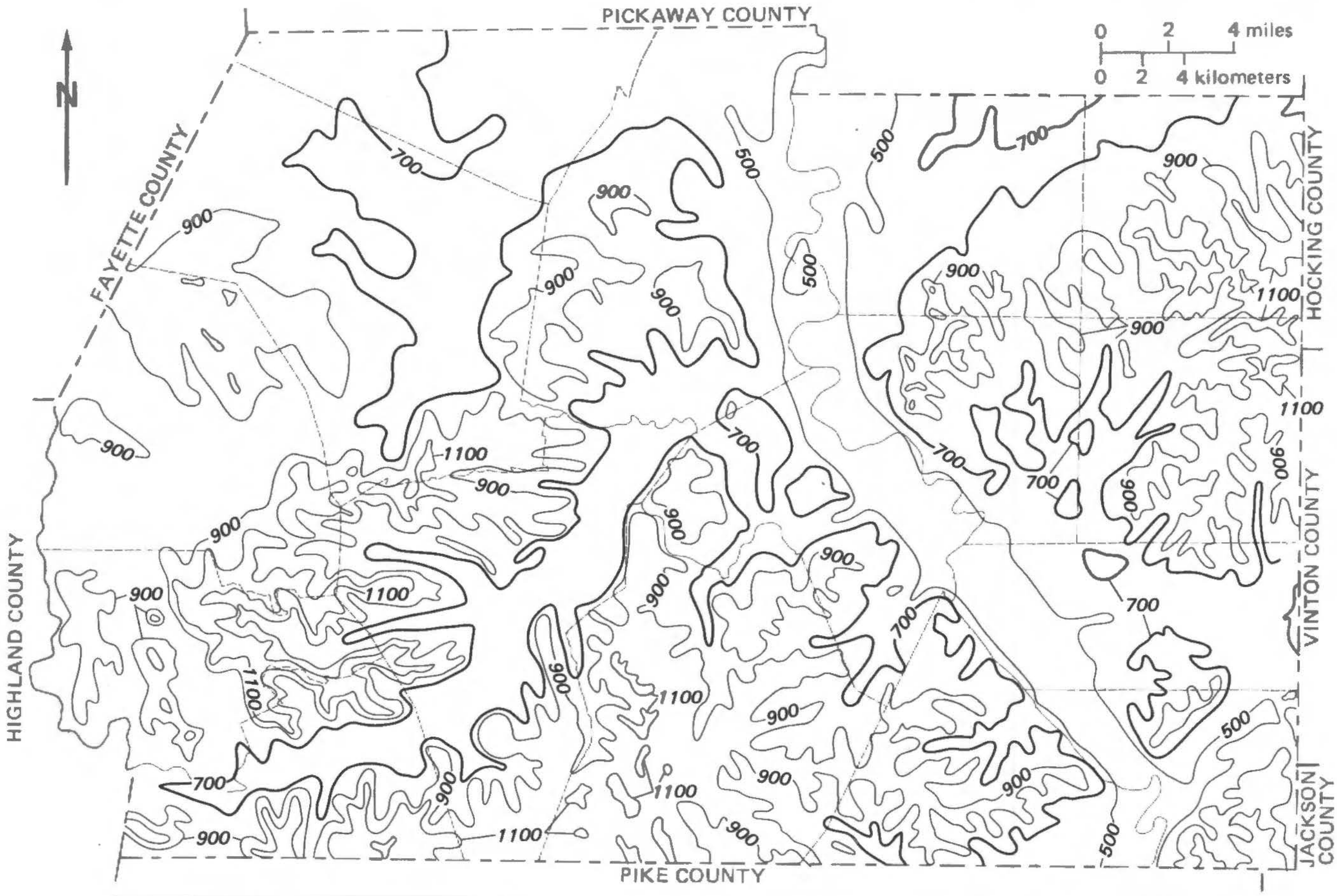


FIGURE 3.—Elevation of bedrock surface in Ross County. Contours in feet above sea level; contour interval 200 feet.

tentative at best. No multiple-till exposures were identified in Ross County. The glacial stratigraphy in Ross County is established on the basis of areal extent of physically and compositionally distinct till units and regional pedologic variations. Stratigraphic correlation is hindered by physical similarities between nonsynchronous glacial strata, lack of datable organic materials in tills, variations in quality of water-well logs, and paucity of stratigraphic exposures in key areas.

RAINSBORO TILL

Fifteen feet of oxidized, brown (7.5 YR 5/2) Illinoian till is exposed on the south side of a Baltimore and Ohio railroad cut on the boundary between secs. 16 and 17 of Liberty Township in southeastern Ross County. The pebble-poor till is calcareous below an 85-inch-thick leached zone. This till is areally and texturally correlative with the Rainsboro Till (Danville Till of Goldthwait, 1955) of Highland County (Rosengreen, 1970).

The Rainsboro Till overlies flaggy Mississippian shale. Directly overlying the finely striated bedrock surface is a 6- to 9-inch-thick brownish-yellow (10 YR 6/6) sand unit containing many well-rounded quartz pebbles. This exposure is within 1 mile of the Illinoian glacial boundary in the area where the erosive power of the ice sheet would have been greatly diminished. The sand may represent a remnant of a Yarmouthian weathering profile that was not incorporated into the till of the advancing Illinoian ice sheet.

Exposures of Rainsboro Till in Ross County are limited to areas outside the Wisconsinan glacial boundary in the southern portion of the county. Generally a thick loess (mean thickness 29.8 inches) covers the till. Rainsboro Till forms thin, patchy ground moraine or till plain on the bedrock uplands of the Appalachian Low Plateau.

BOSTON TILL

Till probably associated with the maximum advance of the Late Wisconsinan ice sheet is exposed only in valleys tributary to the Paint Creek valley in southwestern Ross County. This till is areally, texturally, and compositionally distinct from all other till units in the county.

The reference section of this distinctive till in Ross County is in the main scarp of a rotational slump 1 mile south-southwest of Storms in southwestern Twin Township. Approximately 7 feet of friable, pebble-rich, yellowish-brown (10 YR 5/4) till is exposed here. The till is leached of carbonates to a depth of 32 inches and is overlain by about 15 inches of loess. Just north of the reference section, this till clearly overlies rhythmically laminated lacustrine deposits of Illinoian Glacial Lake Bourneville.

Areal extent in conjunction with compositional and textural distinctiveness suggests that this till in Ross County is probably correlative with the Boston Till of Highland County (Rosengreen, 1970). Lack of exposures and datable materials north of the Paint Creek valley hinders a definite correlation. The question of validity of age of this till by

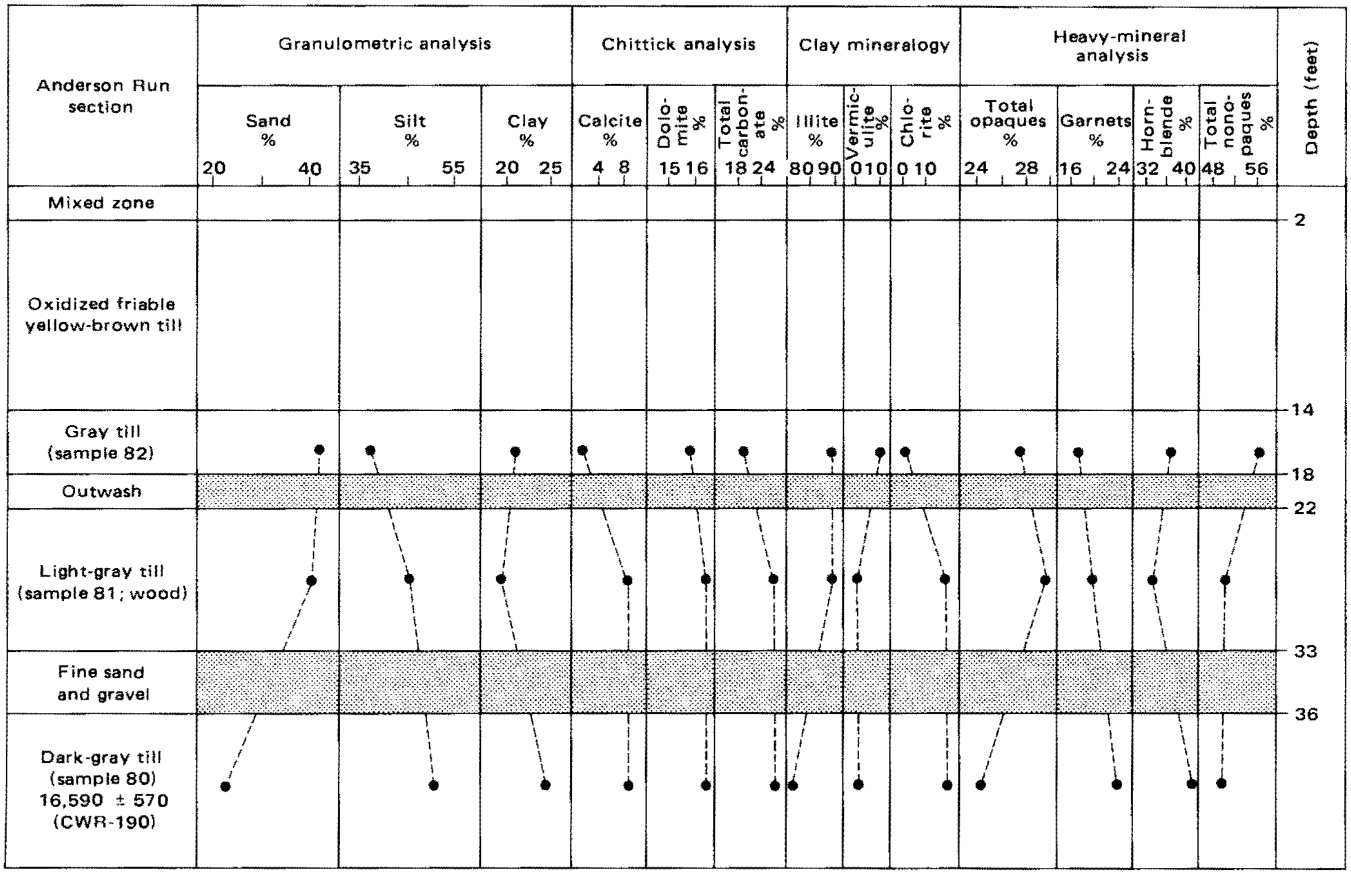


FIGURE 4.—Results of laboratory analyses of the tills at the Anderson Run section, 1 mile northwest of Anderson, in southwestern Union Township.

correlation to Highland County does remain because the exposed sections might be just eroded soil profiles on Illinoian Rainsboro Till. The postulated Boston Till forms patchy ground moraine in the tributary valleys south of the Paint Creek and North Fork Paint Creek valleys (pl. 1). Isolated patches of Boston Till also are exposed in tributary valleys along the north side of the Paint Creek valley north of Bourneville.

CAESAR TILL

Three till units separated by two thin outwash zones are exposed in the west bank of Anderson Run 1 mile northwest of Anderson, in southwestern Union Township. This exposure is 0.3 mile upstream from the "Anderson buried forest" field-conference stop (Stop 13A) of Goldthwait (1955). This section displayed 18 feet of pebbly, blue-gray (10 YR 5/1) to yellow-brown (10 YR 5/4) Late Wisconsinan till with a "buried forest" near its base. The till overlay a sandy gravel, but the exposure is now badly slumped and overgrown.

Spruce logs from the lowest till at the Anderson Run cut have been dated at 17,980±400 years before present (B.P.) (W-331) and 16,590±570 years B.P. (CWR-190). This lowest till is unoxidized, calcareous, dark gray (7.5 YR 4/1), and very compact. The till is texturally and stratigraphically correlative with the Caesar Till of the southwestern portion of the Scioto Sublobe (Rosengreen, 1970). Caesar Till is the surface till south of the Darby Till limit at the Reesville Moraine position as far as the distal margin of the Lattaville Moraine (pl. 1).

Differences in analytical results from the three till units at Anderson are so minor (fig. 4) that, coupled with the thinness of the intercalated outwash units, they suggest that all three till units are associated with minor oscillations of the same Late Wisconsinan ice sheet. All variations in particle-size distribution, calcite-dolomite content, clay mineralogy, and heavy-mineral content can be explained by progressive pedologic development.

DARBY TILL

In north-central Ross County, 22 feet of homogeneous, pebbly, dark-gray (10 YR 4/1) till is exposed in the north bank of Dry Run 1.1 miles southeast of Dry Run Chapel in Union Township. The well-jointed till is leached of carbonates to a depth of 24 inches and lacks a loess cover of measurable thickness. Secondary clay accumulations along the joint margins are common. A similar exposure is found in the village of Austin in Concord Township, in northwestern Ross County. This till is texturally and areally correlative with the Darby Till (Goldthwait and others, 1965; Rosengreen, 1970) of the southwestern portion of the Scioto Sublobe.

Darby Till is the surface till north of the distal edge of the Reesville Moraine throughout north-central and northwestern Ross County. The recessional Yellowbud Moraine is capped with Late Wisconsinan Darby Till.

Totten (1969) suggested that the constructional topography associated with the end moraines and till plains of central Ohio was formed during the Altonian. The present subdued nature of this topography resulted from deposition of thin Woodfordian tills on the Altonian moraines and till plains. If such postulated thin tills occur as far south as Ross County, they should be detectable in thick till sections such as the Dry Run stream cut in west-central Union Township. The Dry Run section was sampled at 2-foot intervals and the samples were subsequently analyzed for particle-size distribution, calcite-dolomite content, heavy-mineral composition, and clay mineralogy (fig. 5). Except for an anomalous silt-clay content at a depth of 20 feet, all variability is expectable as the result of normal pedologic development. If thin Woodfordian tills are present in Ross County, they are texturally and compositionally indistinguishable from other tills of the southern Scioto Sublobe.

PEDOLOGY

Till-soil associations

Five Late Wisconsinan till-soil associations are recognized in western Ohio (Forsyth, 1965). These associations are distinguished on the basis of variations in (1) loess cover, (2) amount of clay in the B horizon, (3) amount of clay in the C horizon, and (4) depth of the soil profile. These till-soil groups occur in irregular bands generally parallel to end moraines. Boundaries between most till-soil associations reflect major variations in parent material, which are attributed to significant readvances of the ice sheet. However, the boundary separating the Miami 6A and Miami 6O soils appears to be the result of the proximity of an end moraine representing a major glacial readvance. This boundary separating the two slightly different Miami soil groups is placed at the distal margins of the Farmersville (Miami Sublobe) and Reesville (Scioto Sublobe) Moraines (Quinn, 1972; Quinn and Goldthwait, 1979).

Soil mapping (Wilding and others, 1965; Petro and others, 1967) indicates little significant difference between Miami 6A and 6O soil associations in western Ohio. Laboratory analyses completed for the above studies and for this study confirm that there is no consistent difference in the composition of the parent material of 6A (Darby Till) and 6O (Caesar Till) soils. Under current terminology, areas formerly mapped as Miami 6A and 6O are called "Miamian" (for well-drained sites). Although the Miami 6A and 6O areas are not easily differentiated throughout western Ohio, the two soil groups are readily distinguished in Ross County on the basis of differences in loess thickness. Loess thickness is similarly distinctive in Highland County (Rosengreen, 1970).

One Illinoian and four Late Wisconsinan till-soil associations occur in Ross County (fig. 6). The characteristics of these associations are listed in table 2. The "deep" Russell till-soil association was used to support "early" Wisconsinan glaciation in the southern Scioto Sublobe. Russell soils have a degree of development intermediate between known Illinoian and Late Wisconsinan profiles. The "deep" Russell soils are areally limited to a narrow belt along the Wisconsinan glacial boundary in Ross and Highland Counties. Rosengreen (1970) has shown that the "deep" Russell soil profile is attributable to a unique parent material and that the soil occurs in drift of early Late Wisconsinan (Woodfordian) age.

The Russell soils are characterized by a loess cap greater than 18 inches thick. "Deep" Russell soils are differentiated from "shallow" Russell soils by a greater depth of carbonate leaching (table 2). Russell soils have a colored, more weathered appearance than typical Late Wisconsinan "Miamian" profiles. The "deep" Russell soils in Ross County are limited areally to patchy till (Boston Till) and lacustrine deposits in the Paint Creek valley.

The "shallow" Russell and Miami 6O soils commonly occur together in a complex distribution; differentiation at

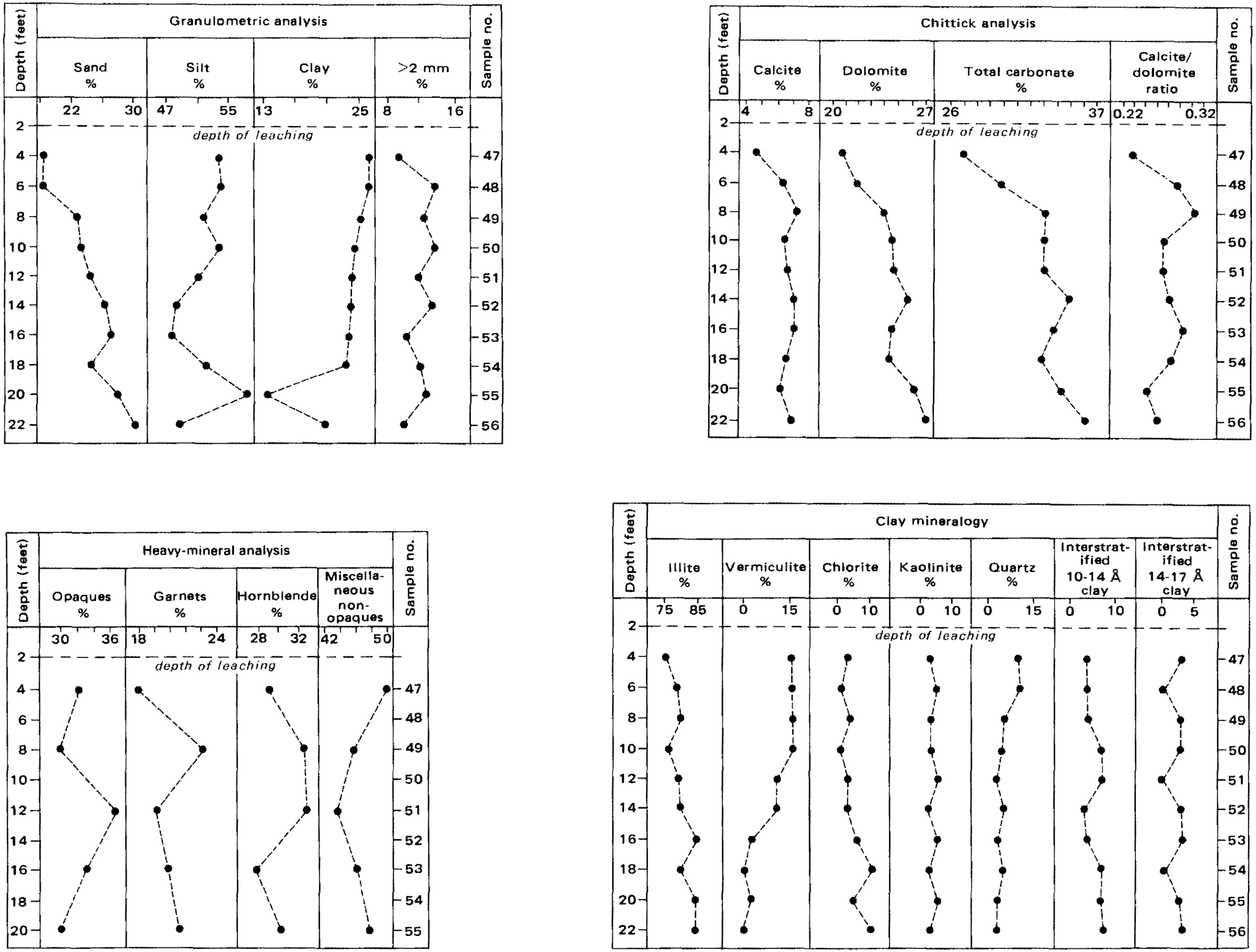


FIGURE 5.—Results of laboratory analyses of the tills at the Dry Run section, 1.1 miles southeast of Dry Run Chapel, in west-central Union Township.

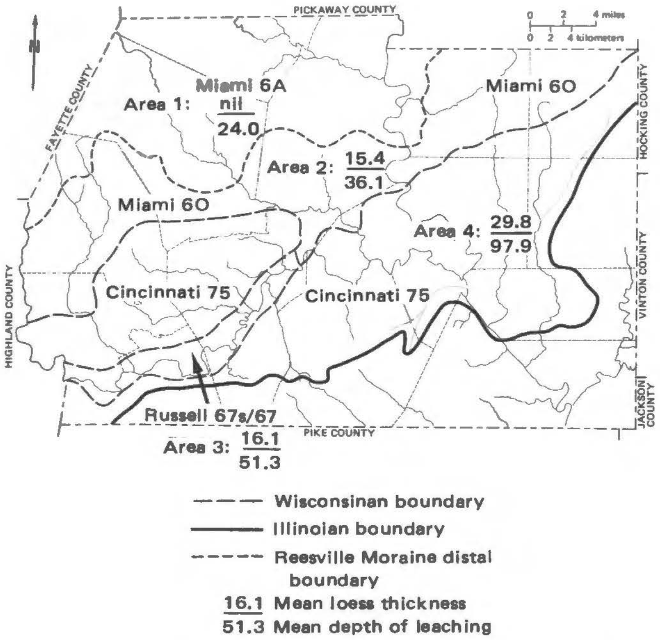


FIGURE 6.—Distribution of till-soil associations in Ross County and differentiation of mean loess thickness and mean depth of carbonate leaching. Area 1, Darby Till; Area 2, Caesar Till; Area 3, Boston Till; Area 4, Rainsboro Till.

a specific locality is based on the thickness of the loess cover (Forsyth, 1965). Clearly no great age difference exists between parent materials of "shallow" Russell and Miami 60 soils. In portions of the Miami Sublobe of western Ohio, a "silt line" separates areas dominated by "shallow" Russell soils to the south from areas characterized by higher concentrations of Miami 60 soils to the north. A similar silt line is nearly coincident with the southern margin of the Lattaville Moraine in Ross County, suggesting that the major episodes of loessial deposition occurred before construction of the end moraine. Although "shallow" Russell and Miami 60 soils occur on both sides of the silt line, "shallow" Russell soils are more common south of the boundary, where they occur in complex association with "deep" Russell soils. In this complex association, variability between the two Russell soil groups is related to local differences in composition of parent material and variable loess thickness.

Another silt line separates areas dominated by the loess-free Miami 6A soils to the north from the region characterized by Miami 60 soils. Based on loess distribution in the Miami Sublobe and the southwestern part of the Scioto Sublobe, this silt line is correlated with the Farmersville-Reesville Moraine position.

Depth of carbonate leaching

Glacial geologists commonly use surface soils as a tool in delineating relative ages of glacial deposits. The characteristics of a soil profile in any area depend on the interrelationships of (1) physical and mineralogical composition of the parent material, (2) duration of subaerial exposure, (3) climate, (4) topography, and (5) organic activity. If climate, topography, and organic activity are averaged over a given area by careful site selection, then any differences in soil development can be attributed to variations in parent material and/or time. The relative importance of these two factors must be ascertained to allow utilization of pedologic information in interpretation of the glacial history.

Four areas of Ross County were differentiated on the basis of variation in mean depth of carbonate leaching (fig. 6). These areas are coincident with the areas delineated by the major till-soil associations because in each case time and parent materials are the primary controlling factors.

Histograms for each till (fig. 7) show the distribution of depths of leaching in relation to the observational frequency for Ross County sites. Soil characteristics associated with the tills in the county are listed in table 3. The rates of carbonate leaching in Ross and Highland Counties are compared in table 4. The statistical validity of the mean depths of carbonate leaching in the Ross County tills ranges from 97 to 99 percent.

Radiocarbon age determinations in the southern Scioto Sublobe indicate that Caesar Till (Area 2) was deposited approximately 800 years before Darby Till (Area 1). However, the mean depth of carbonate leaching for Area 2 is 50 percent greater than in Area 1. Percent calcium carbonate equivalent is similar for both tills. This apparent anomaly is easily explained by consideration of the loess component of the soil profile. Because Area 1 lacks a consistently measurable loess cap, the entire leached zone is developed in Late Wisconsinan till. Area 2 has a loess cover with a mean thickness of 15.4 inches. Although the loess fraction must have been leached very rapidly compared to the till, the appreciable loess cover in Area 2 served to diminish the depth of carbonate leaching in the underlying till as compared to loess-free Area 1.

Area 3 (Boston Till) is leached to a mean depth of 51.3

TABLE 2.—*Significant characteristics of major till-soil associations in Ross County*

Till-soil association	Soil characteristics[1]						
	Thickness of silt cap (inches)	Depth of leaching (inches)	% Clay in B horizon	% Clay in C horizon	% Clay B / % Clay C	Boundary to south	Boundary to north
Miami 6A	*generally absent or very thin*	6-45	33-40	11-27	1.8	Reesville Moraine	Powell Moraine
Miami 60	*<18*	11-65	33-40	10-27	1.8	Lattaville Moraine	Reesville Moraine
"shallow" Russell 67s	*>18*	35-60	33-40	15-27	1.7	Mt. Olive Moraine	Reesville Moraine
"deep" Russell 67	*18*	*60-85*	33-40	15-27	1.7	Boston Till	Lattaville Moraine
Cincinnati 75	*10-80*	*66-145*	33-40	15-27	1.7	Illinoian boundary	Wisconsinan boundary

[1] Diagnostic characteristics in italics. Modified from Forsyth (1965, p. 223).

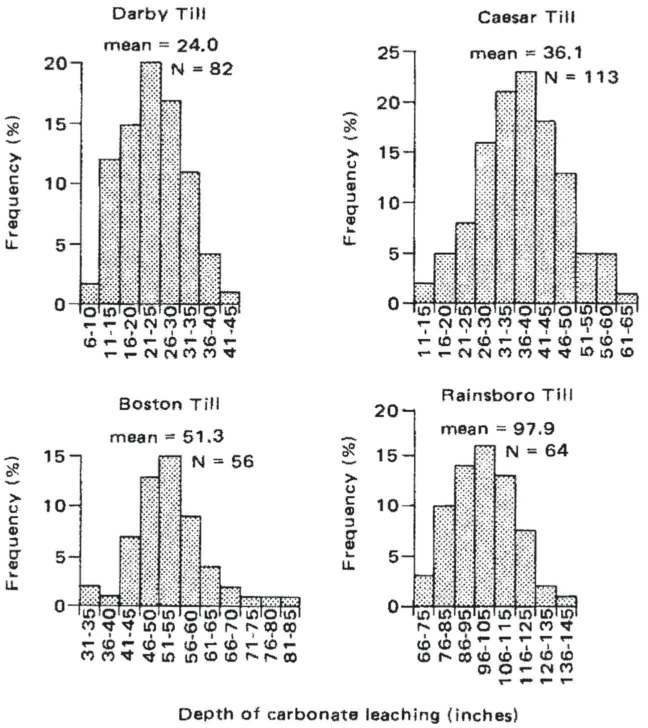


FIGURE 7.—Distribution of depth of carbonate leaching in relation to frequency for Ross County tills. N = number of observations.

inches, which includes a mean loess cover of 16.1 inches. Thus the mean depth of carbonate removal in the till is 35.2 inches, which is 32 and 42 percent greater than in Areas 1 and 2, respectively. This greater depth of leaching in Area 3 (Boston Till, Russell soils) was attributed to an "early" Wisconsinan age of the glacial drift (Rogers, 1936; Forsyth, 1961, 1965; Petro and others, 1967). Two radiocarbon age determinations date the correlative Boston Till in Highland County (Rosengreen, 1970) at 21,000 years B.P., clearly early Late Wisconsinan (Woodfordian), not Early Wisconsinan (Altonian).

TABLE 3.—*Soil characteristics associated with tills in Ross County*

Till	Depth of leaching (inches)	Loess thickness (inches)	Percent total carbonate[1]
Darby			
arithmetic mean	24.0	generally	31.8
standard deviation	7.3	absent	6.4
number of observations	82	82	27
range of values	9-44		10.8-41.6
Caesar			
arithmetic mean	36.1	15.4	27.3
standard deviation	9.8	4.8	7.7
number of observations	113	102	25
range of values	14-63	5-32	9.3-40.0
Boston			
arithmetic mean	51.3	16.1	19.1
standard deviation	9.3	5.4	7.8
number of observations	56	58	9
range of values	31-82	5-31	6.7-29.1
Rainsboro			
arithmetic mean	97.9	29.8	27.0
standard deviation	14.8	10.4	9.3
number of observations	64	46	8
range of values	67-143	10-79	6.9-37.2

[1] Percent total carbonate = (% dolomite x 1.083) + % calcite.

TABLE 4.—*Comparison of rates of mean carbonate leaching of tills in Ross and Highland Counties*

Till	Approximate age (years B.P.)	Rate of carbonate leaching[1] (inches/thousand years)	
		Ross County	Highland County
Darby	17,200[2]	1.40	1.25
Caesar	18,000[3]	1.15	
Boston	21,000[4]	1.68	1.88
Rainsboro	128,000[5]	0.53	0.59

[1] Loess fraction has been subtracted from depth of leaching. Highland County data from Rosengreen (1970).
[2] Radiocarbon date OWU-256 (Moos, 1970).
[3] Radiocarbon dates W-331, W-91, OWU-331.
[4] Radiocarbon dates D-46, D-47.
[5] Fairbridge (1968, p. 923).

Soils associated with the Illinoian Rainsboro Till (Area 4) are characterized by deeper weathering zones than in any Wisconsinan soils. Compositionally, the parent material of the Illinoian till is very similar to that of the Darby and Caesar Tills. Soils in Area 4 have a mean depth of leaching of 97.9 inches and a mean loess thickness of 29.8 inches. Subtracting the loess component gives a mean depth of leaching in the Rainsboro Till of 68.1 inches, which is 44.1 and 47.4 inches thicker than the leached zones of the Darby and Caesar Tills, respectively.

Figure 8 shows the mean depth of leaching plotted against the mean values of the compositionally similar Darby, Caesar, and Rainsboro Tills. Note that the rate of leaching decreases with time, the rate being the slope of a line tangent to the curve at any given time. Certainly the difference in weathering profiles between the two Late Wisconsinan tills and the Illinoian till is related primarily to age of the drift and not to variations in parent material.

Percent total carbonate for the Boston Till (Area 3) averages 40 percent less than the Darby Till (Area 1) and 30 percent less than the Caesar Till (Area 2). Thus the anomalously greater depth of leaching in Area 3 appears to

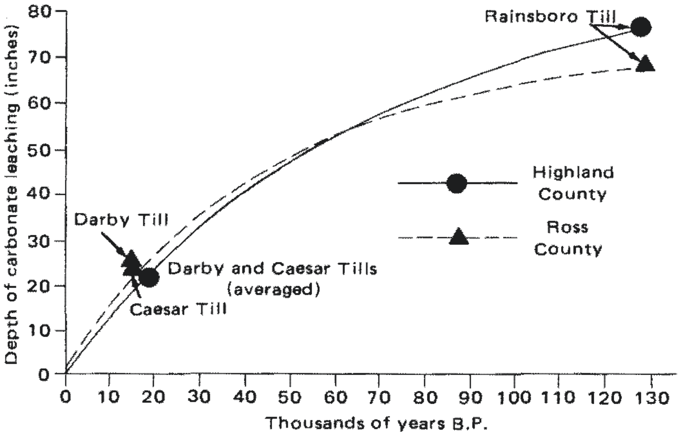


FIGURE 8.—Change of rate of leaching with time. The slope of a line tangent to the curve represents the rate of leaching in inches per thousand years at that time. The loessial component of the depth of leaching has been subtracted. Highland County data from Rosengreen (1970).

be caused by anomalously low calcium carbonate content in the original parent material and is not related to a significant difference in time of subaerial exposure. Rosengreen (1970, p. 44, fig. 10) suggested that variability of depth-of-leaching values within a single parent material results from local variations in the calcium carbonate content of the parent material.

Loess

Boundaries between areas of significant change in loess thickness (fig. 6) coincide with the distal edges of major end moraines or correlative positions (Reesville and Lattaville). Petrographic and x-ray analyses of the loess of southwestern Ohio indicate two episodes of loess deposition—Early (Altonian) and Late (Woodfordian) Wisconsinan (Goldthwait, 1968). Mineralogic and minor textural variations allow areal and stratigraphic separation of distinct loess types. A stratigraphic mid-loess break has been recognized at several localities in the southern part of the Scioto Sublobe. This break is defined by textural and mineralogic anomalies and in places by a weak paleosol with organic accumulations.

The series of histograms in figure 9 show the thickness of loess cover in relation to frequency of observation for Ross County tills. (See table 3 for a statistical summary of the data on the Ross County loess cover.) Thickest loess (mean thickness 29.8 inches) overlies Illinoian till and outwash and the unglaciated region of southern Ross County. The loess cover generally thins eastward from western Ross County to the Scioto River valley. East of the valley the loess cap abruptly thickens, indicating that the Late Wisconsinan outwashes in the Scioto River valley were a significant source of loess material. Subdued loess dunes occur in areas of thick loess on Illinoian outwash terraces (*e.g.*, NW¼ sec. 31, Springfield Township). Agricultural modification hinders use of these dunes to establish paleowind directions. Thickest loess accumulations commonly overlie a Sangamonian paleosol. Clay mineralogy of the buried soil clearly indicates a weathering period longer than postglacial time (Goldthwait and others, 1965).

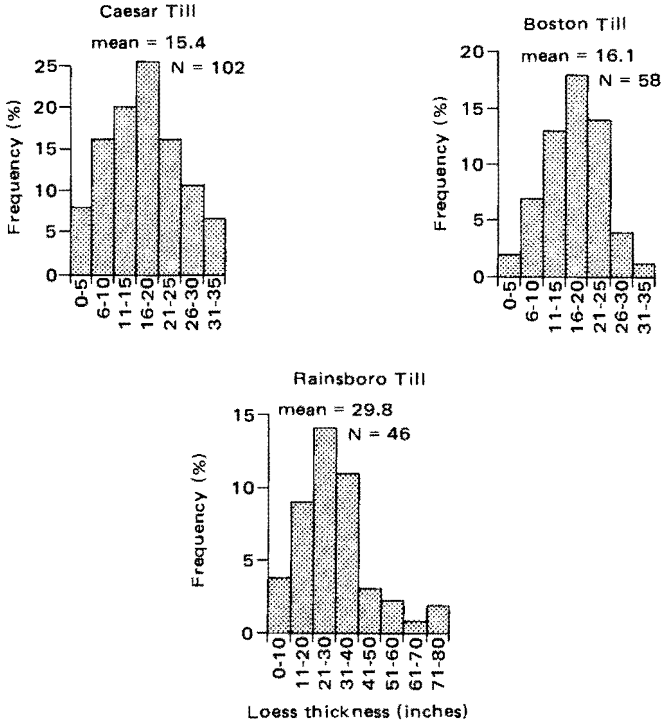


FIGURE 9.—Thickness of loess cover in relation to frequency for Ross County tills. N = number of observations.

Measurements at 58 localities in the area of early Late Wisconsinan (Boston Till) deposits in the Paint Creek valley gave a mean loess thickness of 16.1 inches. Thus approximately the lower 13.7 inches of loess in the Illinoian area was deposited prior to early Late Wisconsinan time, probably in the Early Wisconsinan (Altonian). Deposition of the second, upper loess (upper Melvin loess) probably began at least 20,000 and perhaps as much as 28,000 years B.P. (Goldthwait, 1968).

Loess cover on the Caesar Till averages 15.4 inches thick. Thus only a small amount of loess (less than 2 inches) was deposited between retreat from the distal boundary of the Boston Till and initiation of retreat from the Lattaville Moraine, about 18,000 years B.P. Loess deposition in the area of the Caesar Till continued until the ice sheet readvanced to the Farmersville-Reesville Moraine position (*circa* 17,200 years B.P.). Ice-sheet readvance is indicated by the presence of loess, which is stratigraphically correlative with the surface loess on the Caesar Till, beneath the Reesville Moraine in Fayette County (Moos, 1970). Most water-well logs north of the Reesville boundary in Ross County penetrate a "silt zone" or a "buried forest," which is probably this buried loess zone and associated organic deposits. North of the distal boundary of the Reesville Moraine, surficial loess is generally absent.

Except for the loess cap on the Caesar and Boston Tills, there is a significant difference (99 percent confidence) between the mean values of loess thickness associated with Ross County tills. Thus loess thickness is a useful criterion for differentiating till parent materials in the county. Means for the Caesar and Boston Tills are significantly different only to a confidence level of 60 percent. Thus use of mean loess thickness to distinguish between these two tills must be done cautiously and in conjunction with other diagnostic criteria.

The lower loess, the lower Melvin loess, which directly overlies the Sangamonian paleosol, lies stratigraphically beneath Caesar Till of the Cuba Moraine (Goldthwait and Forsyth, 1965). Thus the loess must have been deposited before 18,000 years B.P. Suggested correlations of the lower Melvin loess with the Gahanna Till-Lockbourne Outwash of central Ohio and the Roxana loess of Illinois indicate loess deposition in the Early Wisconsinan (Altonian, 46,000-52,000 years B.P.).

The loess above the mid-loess break, the upper Melvin loess, is clearly Late Wisconsinan (Peoria equivalent). A small component of this loess overlies the Boston Till in Ross and Highland Counties; thus deposition of the upper loess may have begun as early as 21,000 years B.P. Loess deposition probably ceased after 17,000 years B.P. because of an abrupt decrease in the availability of fine outwash source material due to changing meltwater-stream regimens and vegetational stabilization of some loess source materials.

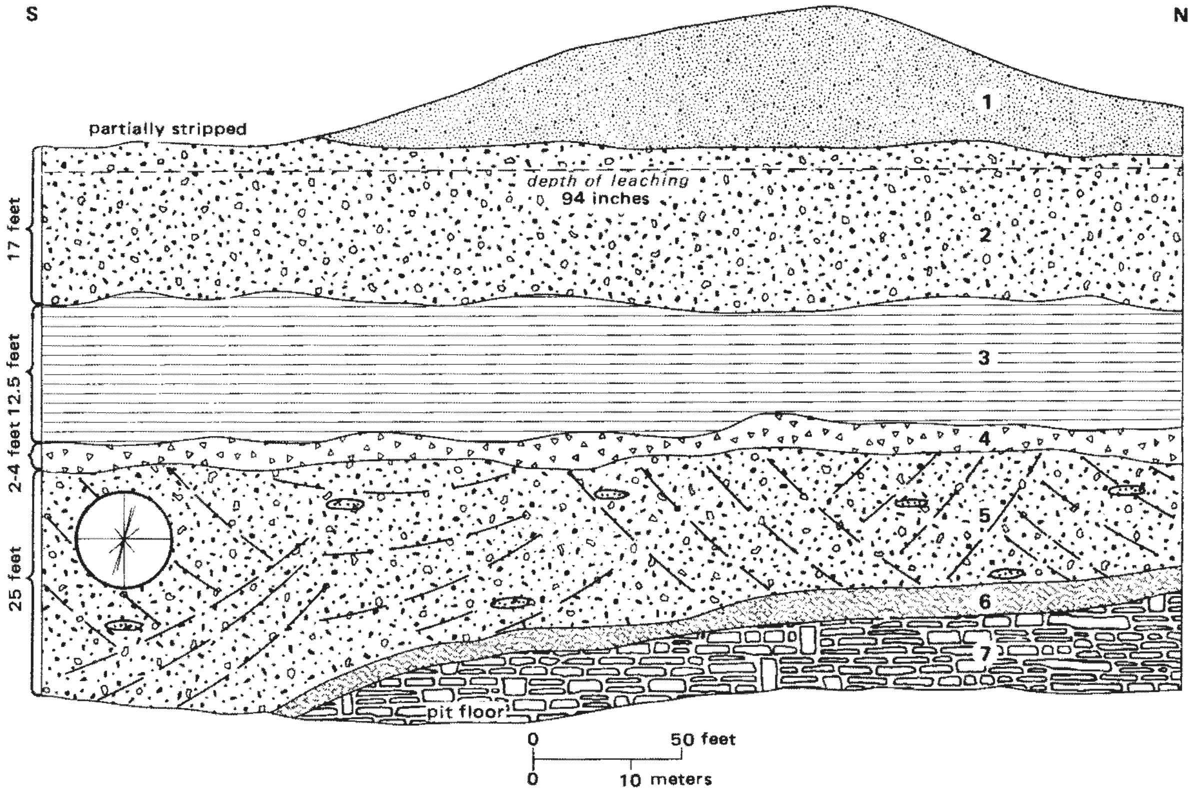
Two sites of thick loess bordering the Scioto River valley were sampled and analyzed in an attempt to delineate the mid-loess break and determine the thickness of the Early and Late Wisconsinan loess components. In an excavation 2.0 miles northwest of Massieville, 73 inches of noncalcareous loess overlies 17 feet of coarse Illinoian Higby Outwash. Variations in percent silt, percent clay, and the distribution

TABLE 5.—*Heavy-mineral data for the Massieville and Seymoreville loess sections*

Sample number	Sample depth (inches)	Percent heavy minerals							
		Magnetite/ ilmenite	Hematite/ limonite	Total opaques	Augite/ diopside	Hornblende	Garnet	Zircon/ monazite	Total nonopaques
Massieville									
40	6	20.8	40.1	78.9	5.2	2.4	0.9	3.0	21.1
41	24	31.6	42.3	80.4	6.1	0.1	1.8	2.9	19.6
42	40	49.4	36.5	88.3	3.9	3.7	2.1	5.1	11.7
43	60	38.2	21.9	64.6	2.8	14.1	2.6	5.3	35.4
44	72	32.6	18.0	59.7	1.1	17.3	3.8	7.1	40.3
Seymoreville									
83	15	19.6	39.5	72.3	6.9	2.6	0.3	2.7	27.7
84	42	28.2	36.1	81.9	8.4	1.4	0.9	3.8	18.1
85	64	32.6	40.1	79.4	7.9	3.1	1.4	4.9	20.6
86	75	34.1	29.8	74.2	5.2	2.8	2.1	5.0	25.8

of heavy minerals (table 5) in the loess indicate the Massieville section contains two parent materials. The data suggest a mid-loess break at a depth of about 50 inches. No recognizable color change or organic accumulation marks the boundary which separates the Late Wisconsinan loess from a thicker and older (Early Wisconsinan or Illinoian) loessial component.

In a gravel pit in the highest Higby Outwash terrace in SE¼NE¼ sec. 20, Springfield Township, on the east side of the Scioto River valley opposite Chillicothe, a thick (84 inches) partially calcareous and fossiliferous loess section is exposed. The loess at this site, which is in the vicinity of



1. Loess, 10 YR 6/6, noncalcareous, maximum thickness 73 inches. Late and Early Wisconsinan (samples 40-44)
2. Sand and gravel, coarse, calcareous. Illinoian
3. Lacustrine sediments, rhythmically banded. Illinoian
4. Till, 7.5 YR 4/1, calcareous, silt loam. RAINSBORO
5. Sand and gravel, fine, cross-bedded, calcareous, with fine-sand lenses. Illinoian
6. Organic zone; wood fragments, manganese oxide crust; 10-17 inches thick
7. Sandstone fragments, fractured, angular

FIGURE 10.—Diagram of the Massieville section, 0.1 mile west-northwest of the junction of U.S. Route 23 and Three Locks Road, in south-central Scioto Township, as exposed during the summer of 1972. The stratigraphy at present is poorly exposed due to slumping and human modification. Rose diagram shows cross-bedding directions.

the former village of Seymoreville, is leached of carbonates to a depth of 54 inches. The sparsely fossiliferous zone lies between 66 and 72 inches below the top of the exposure. Three species of terrestrial Pleistocene Mollusca were identified from this zone: *Anguispira alternata* (Say), *Stenotrema fraternum* (Say), and *Succinea grosvenori* (Lea). According to La Rocque (1968), all three species are adaptable to wide ecological ranges, but the assemblage is indicative of a scrub woodland to open-field environment. On the basis of these fossils, the mid-loess break at the Seymoreville section is placed at a depth of 66 inches.

Paleosols

The occurrence of a buried soil, developed in outwash gravel or till, beneath 2 to 10 feet of till has been reported at several localities in western and southern Ohio (Goldthwait, 1952, 1955, 1959). These paleosols typically exhibit (1) distinctive red-brown color, (2) clay enrichment, and (3) ghosts of former calcareous material. In some cases, leached reddish pods of paleosol are incorporated into the overlying till. The origin and age of these paleosols have been questioned (Gooding and others, 1959), but some do appear to be valid. There are two such paleosol occurrences in Ross County.

Newberry (1874) was the first to note the occurrence of a buried "forest bed" and related paleosol about 30 feet beneath the surface in north-central and northwestern Ross County. Most water-well logs in this area indicate the presence of this zone. This organic deposit is probably correlative with the paleosol beneath the Reesville Moraine in Fayette County described by Moos (1970). If the correlation is correct, then the paleosol and "forest bed" must have developed during the short interval between the retreat from the Cuba and Lattaville Moraines and subsequent readvance to the Reesville Moraine.

A well-developed Sangamonian paleosol is exposed in a gravel pit 0.3 mile south of Humboldt in central Paint Township, in western Ross County. The paleosol is developed in Illinoian gravel that is overlain by till ("early" Wisconsinan till of Petro and others, 1967). Depth of leaching, stratigraphy, and particle-size distribution indicate that this is Boston Till (early Woodfordian). Determination of the age of the buried soil is critical in establishing the age of Glacial Lake Humboldt deposits, which overlie the Boston Till (Reynolds, 1959).

Sangamonian paleosols developed in Illinoian till or outwash beneath thick loess accumulations are common in Ross County. Although exposures are limited, a more highly weathered profile, upon which the present soil has been superimposed, can be seen by augering in thick loess areas (*e.g.*, Plyley and Poplar Ridges, in Concord and Twin Townships, respectively).

Two exposures in Ross County show evidence of pre-Sangamonian weathering intervals. A brownish-yellow sand unit underlies Rainsboro Till at a Baltimore and Ohio railroad cut 1.8 miles east of Schooley, in Liberty Township. Coloration and the local stratigraphy suggest the sand is a remnant of a Yarmouthian weathering profile.

Near the base of the Massieville section (fig. 10), a 10- to 17-inch-thick noncalcareous black (7.5 YR 2/1) organic-rich zone was exposed. The organic zone directly overlies a fractured sandstone surface, which rises to the north in the section. The upper surface of the organic zone is a ⅛- to ¼-inch-thick crust of manganese oxide containing small, decomposed wood fragments. The crust is overlain in turn by fine, cross-bedded sand and gravel which contains many lenses of very fine sand. The sand and gravel is capped by a slightly calcareous dark-gray (7.5 YR 4/1) till. Local stratigraphy and laboratory analyses indicate the till is Rainsboro Till (Illinoian). Thus the organic zone must be related to a period of subaerial or subaqueous exposure in pre-Illinoian, possibly Yarmouthian, time. Two episodes of Illinoian glaciation are indicated by two levels of Higby Outwash in Ross County, so it is likely that the outwash below the till represents the earlier maximum and that the till was deposited during the second Illinoian interval.

GRANULOMETRIC ANALYSES

Particle-size distribution is a standard tool for correlation of tills in Ohio. Although some studies have yielded inconclusive results (*e.g.*, Forsyth, 1956), in most cases the data have been internally consistent and useful (*e.g.*, Shepps, 1953; Steiger, 1967; Steiger and Holowaychuk, 1971).

Particle-size distribution was determined for 70 Ross County till samples to determine the usefulness of this criterion in stratigraphic correlation. Grain-size distribution for the Darby, Caesar, and Rainsboro Tills is remarkably similar (table 6; fig. 11); the variance between the arithmetic means for the sand, silt, clay, and pebble fractions of the three tills is only 3 percent or less. Compositionally the three tills are nearly indistinguishable. The particle-size distributions of the Ross County tills are similar to distributions in tills from other southern Scioto Sublobe localities (fig. 11).

Except for the silt fraction, the Boston Till is very different from the Darby, Caesar, and Rainsboro Tills. Boston Till has about two-thirds less sand, twice as much clay, and about one-fourth as many pebbles as the other three tills. Confidence levels for differentiation of the Boston Till from other Ross County tills are 99 percent. The high clay content in the Boston Till is probably the result of incorporation of lacustrine sediments of Illinoian Glacial Lake Bourneville by the initial Late Wisconsinan ice advance.

TABLE 6.—*Particle-size distribution of tills in Ross County*

Till	Weight percent[1]			
	>2 mm	Sand	Silt	Clay
Darby				
no. of samples = 28				
arithmetic mean	11.7	24.8	52.1	23.1
standard deviation	7.8	4.3	4.7	6.8
range of values	0.6-29.7	15.9-30.4	48.4-61.1	14.0-38.6
Caesar				
no. of samples = 25				
arithmetic mean	13.1	26.9	50.7	22.4
standard deviation	7.6	5.5	4.2	4.0
range of values	3.2-36.4	19.5-40.5	46.6-62.5	16.7-30.1
Boston				
no. of samples = 8				
arithmetic mean	2.8	7.7	48.8	43.4
standard deviation	2.2	5.7	4.2	9.1
range of values	0.0-5.5	0.5-16.8	43.5-55.9	33.4-56.1
Rainsboro				
no. of samples = 9				
arithmetic mean	10.9	24.7	50.9	24.5
standard deviation	5.6	8.3	5.9	6.2
range of values	1.7-17.1	14.1-41.0	38.5-60.5	17.4-35.2

[1] >2 mm determinations on whole sample; sand-silt-clay determinations on <2 mm fraction.

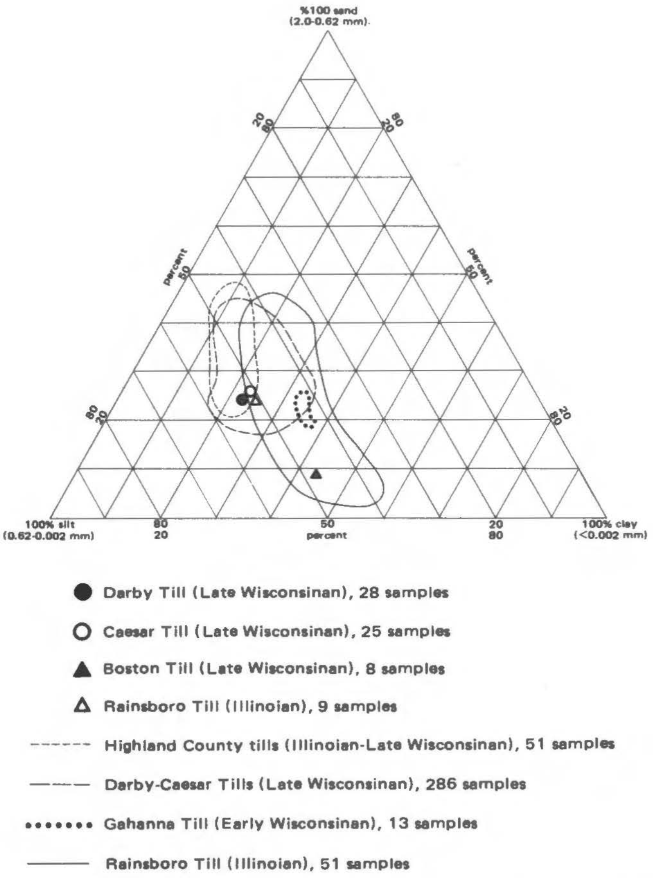


FIGURE 11.—Relationship of mean particle-size distribution of Ross County tills to other Scioto Sublobe tills (data from Goldthwait and Rosengreen, 1969, and Rosengreen, 1970).

Correlation between areas mapped as Boston Till in Ross County and in Highland County is supported by the granulometric data. Although the variations between Boston Till and other Highland County tills (Rosengreen, 1970, p. 58) are not as pronounced as between correlative Ross County tills, all differences are consistent in character; that is, Boston Till has less sand, fewer pebbles, and more clay than other Highland County tills.

CALCITE-DOLOMITE ANALYSES

Variation in calcite-dolomite content in tills reflects differences in the composition and quantity of bedrock and soil material incorporated into drift by an advancing ice sheet. Weight percentages for the calcite, dolomite, and total carbonate ($CaCO_3$ equivalent) content of 69 Ross County till samples were determined by the Chittick gasometric procedure (Dreimanis, 1962). Statistical results of these analyses are listed in table 7.

The calcite content of the four tills is nearly identical within the accuracy limits of the procedure. However, the dolomite content, and consequently the total carbonate content, of Boston Till is distinctly lower than that of the Darby, Caesar, and Rainsboro Tills. Variations in the calcite/dolomite ratio also clearly separate the Boston Till from the other tills. These differences are consistent with compositional data determined by pebble counts.

Carbonate content of the Boston Till in Highland County (Rosengreen, 1970, p. 65) has similar variations with respect to other Highland County tills, except for an anomalous calcite/dolomite ratio. Confidence levels of 95 to 99 percent indicate that percent dolomite and total carbonate are diagnostic criteria for distinguishing the Boston Till from the Darby, Caesar, and Rainsboro Tills. For this reason the remote Boston Till localities in Ross County are not considered just "eroded Sangamonian soil profiles."

CLAY MINERAL ANALYSES

The clay mineralogy of a till matrix reflects the composition and quantity of material incorporated during ice advance. Although studies of clay mineralogy of Ohio tills have been primarily by soil scientists (Bidwell, 1949; Holowaychuk, 1950; Andrew, 1960; Wilding and others, 1965), geologists (*e.g.*, Droste, 1956; Rosengreen, 1970; Teller, 1970) have made contributions. Studies in Illinois (Willman and others, 1963; Johnson, 1964; Frye and others, 1969) have provided detail of the clay mineralogy of glacial deposits elsewhere in the Midwest. Some workers (*e.g.*, Bhattacharya, 1962) have used clay mineralogy as a tool in determining degree of weathering in tills. Others suggest clay mineralogy is indicative of the intensity of interglacial erosion and inclusion of previously weathered regolith.

Thirty-one Ross County till samples were analyzed by x-ray diffraction for eight clay-size mineral components (table 8) (for procedural details see Quinn, 1974, p. 240). Data determined by this semiquantitative method should be reported only to the nearest 5 percent (L. P. Wilding, personal commun., 1973).

Clay mineralogy of the Darby and Caesar Tills is nearly identical (table 8; fig. 12). These tills are characterized by high illite and low vermiculite content. Clay mineralogy of the Rainsboro Till is intermediate between those of the Darby and Caesar Tills and that of the anomalous Boston Till. Rainsboro Till has 5 percent less illite and 5 percent more quartz than the Darby and Caesar Tills. This variation may be the result of sampling of slightly weathered till

TABLE 7.—*Calcite and dolomite content in the <2 mm size fraction of tills in Ross County*

Till	Weight percent			
	Calcite	Dolomite	Total carbonate[1]	Calcite / Dolomite
Darby				
no. of samples = 27				
arithmetic mean	7.3	22.3	31.8	0.3
standard deviation	1.9	4.4	7.0	0.1
range of values	2.4-10.6	6.0-29.4	10.8-41.6	0.2-0.7
Caesar				
no. of samples = 25				
arithmetic mean	7.2	18.6	27.3	0.4
standard deviation	2.8	4.6	7.1	0.1
range of values	3.1-13.6	5.7-27.9	9.3-40.0	0.1-0.7
Boston				
no. of samples = 9				
arithmetic mean	7.4	10.8	19.1	0.7
standard deviation	4.3	3.4	6.9	0.2
range of values	1.3-13.7	6.0-14.7	6.7-29.1	0.3-1.1
Rainsboro				
no. of samples = 8				
arithmetic mean	8.0	17.5	27.0	0.5
standard deviation	3.4	5.8	8.6	0.2
range of values	3.3-13.0	3.3-28.0	6.9-37.2	0.2-1.0

[1] Percent total carbonate = (% dolomite x 1.083) + % calcite.

TABLE 8.—*Clay mineralogy of the $<2\mu$ size fraction of Ross County till and loess units*

Unit	Percent[1]							
	Illite	Montmorillonite	Vermiculite	Chlorite	Kaolinite	Quartz	Interstratified clays (13.8Å)	Interstratified clays (16.7Å)
Darby Till								
no. of samples = 13								
arithmetic mean	80	0	10	5	0	5	0	0
standard deviation	5		5	5		5		
range of values	75-85	0-tr	0-15	0-10	0-tr	0-10	0-tr	0-tr
confidence level[2]	99		99			99		99
Caesar Till								
no. of samples = 9								
arithmetic mean	80	0	10	5	0	5	tr	tr
standard deviation	10		5	5		5		
range of values	55-85	0-tr	0-30	0-10	tr-5	0-15	0-tr	0-5
confidence level[2]	99		99			99		99
Boston Till								
no. of samples = 5								
arithmetic mean	65	0	20	0	tr	10	0	5
standard deviation	5		5			5		
range of values	60-75		10-25	0-tr	tr-5	5-10	0-tr	0-5
Rainsboro Till								
no. of samples = 4								
arithmetic mean	75	0	10	0	5	10	0	0
standard deviation	5		5			5		
range of values	75-80	0-tr	5-15	0-5	0-5	5-10	0-tr	0-tr
confidence level[2]	99		99			99		99
Loess								
no. of samples = 10								
arithmetic mean	35	0	35	0	tr	15	tr	15
standard deviation	10		10			5		5
range of values	20-60	0-tr	15-45	0-tr	0-5	10-20	0-5	0-30

[1] Rounded to nearest 5 percent (except confidence level). tr, trace—less than 2.5%.
[2] Confidence level of mean differences compared to Boston Till value.

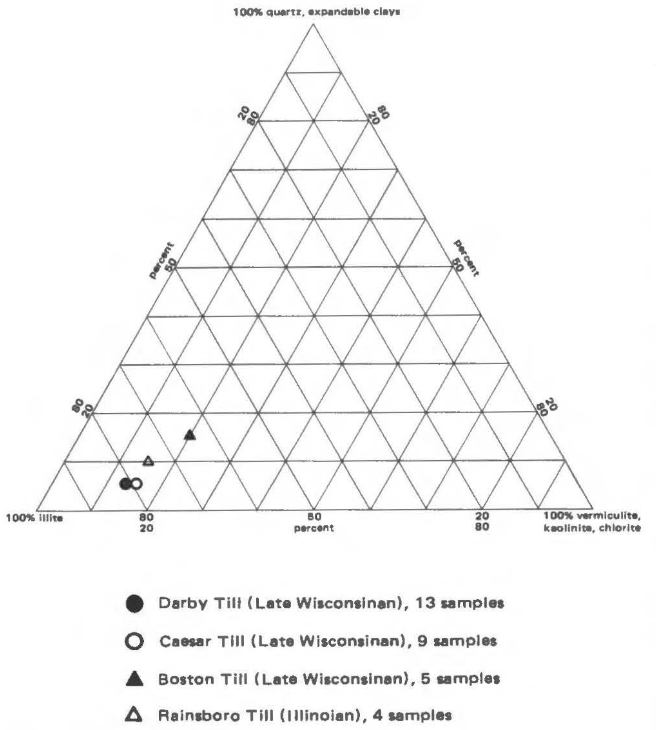


FIGURE 12.—Mean clay mineral composition of Ross County tills.

instead of fresh, unweathered material. Proportionate decrease in illite and increase in resistant quartz can be attributed to weathering phenomena. If the differences are related to sampling error, the clay mineralogy of unweathered Rainsboro Till is very similar to that of the Darby and Caesar Tills. Such similarity can be expected because the ice sheets which deposited all three tills advanced over the same middle to upper Paleozoic bedrock in Ohio.

Boston Till is characterized by lower illite content and higher content of vermiculite and interstratified clay minerals compared to the Darby, Caesar, and Rainsboro Tills. This difference may be related to incorporation of material weathered during the Sangamonian Interglacial by the initial Late Wisconsinan ice advance which deposited the Boston Till. Confidence levels (99 percent) for distinguishing the Boston Till from the other Ross County tills (table 8) indicate such differentiation can be readily made on the basis of clay mineralogy of the till matrix.

Ross County tills are similar in clay mineral composition to correlative units in Highland County and in Illinois (fig. 13). Pre-Illinoian and Illinoian tills, as expected, have a higher content of weathering products with a consequent decrease in the percent of easily weathered constituents. Variations in percent montmorillonite between tills in adjacent Ross and Highland Counties may be more the result of differences in data presentation than in actual variation in montmorillonite content.

Analyses of 10 loess samples from the Massieville and Seymoreville sites indicate that the loess is characterized by half as much illite, twice as much vermiculite, half to two-thirds as much quartz, and three times as much interstratified clay minerals than Ross County tills. Because all

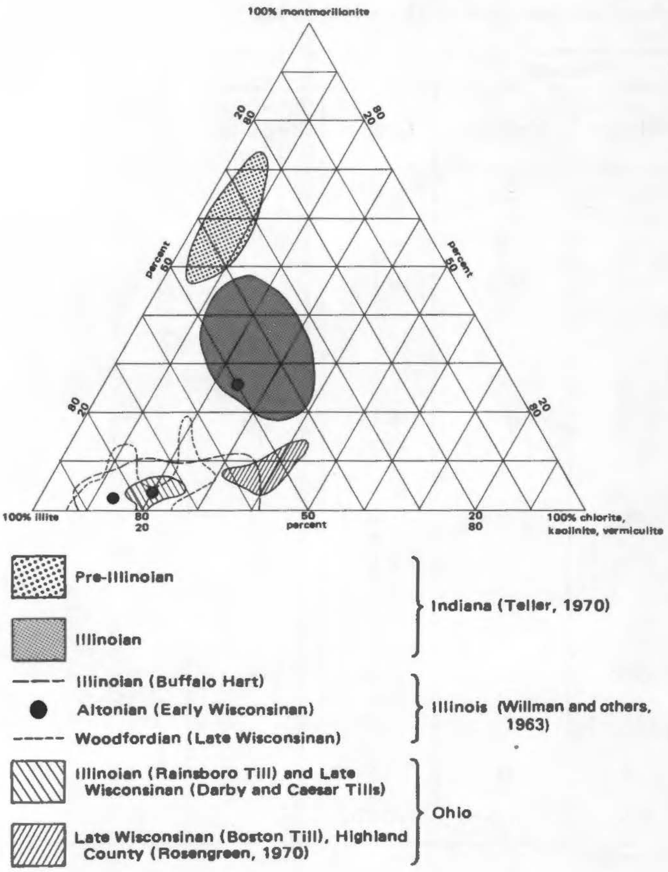


FIGURE 13.—Clay mineral compositions of selected tills from Ohio, Illinois, and Indiana (after Rosengreen, 1970, fig. 13, p. 56).

of the loess samples are from the upper portion of deeply weathered profiles, the variations are probably as much the result of weathering as of differences in clay content of the unweathered parent materials.

PEBBLE COUNTS

Till

Lithology of pebble-size material in till has been used to differentiate till units that were deposited by ice sheets that traversed areas of slightly different bedrock lithologies. Pebble counts have proven useful in stratigraphic correlation in many studies (Norris and others, 1950; Anderson, 1957; Drake, 1968; Rosengreen, 1970).

Results of 28 pebble counts of Ross County tills are listed in table 9. Darby, Caesar, and Rainsboro Tills have very similar pebble lithologies (fig. 14). These tills are characterized by 75 to 81 percent carbonate pebbles with approximately twice as many dolomite as limestone pebbles. The pebble lithologies reflect the provenance of the tills, which were derived from the north to northwest up the central and western parts of the Scioto Sublobe.

Boston Till is significantly different from the Darby, Caesar, and Rainsboro Tills to at least a 95 percent confidence level for all lithology groups (table 9) except limestone, chert, and metamorphics. This earliest Late Wisconsinan till averages fewer carbonate, more clastic, and more crystalline pebbles than the other Ross County tills. Boston Till also has a much higher limestone/dolomite ratio than the other tills. The low dolomite-pebble content of this till can only be related to differences in bedrock traversed. The provenance indicates that the ice gathered bedrock east of the center line of the Scioto Sublobe, where the bedrock is clastic. The distribution of limestone and dolomite pebbles in the Boston Till is consistent with the calcite/dolomite ratio in the <2 mm fraction (table 7).

Although Boston Till averages only 3 percent chert pebbles, several samples had a much higher (up to 11 percent) chert content. The chert must be derived from weathering of the Paleozoic limestones of Ohio, and it is consistent that the first till deposited after the Sangamonian weathering interval would contain locally high concentrations of this residual weathering product.

Outwash

Kempton and Goldthwait (1959) found significant differences in the pebble lithologies between Illinoian and Wisconsinan outwashes down some valleys such as the Hocking River valley. Thirty-three pebble counts were made of the four Ross County outwashes (table 10). Percentages of pebble lithologies for the Worthington, Circleville, Kingston (Scioto River), and Higby Outwashes are all very similar. These outwashes are characterized by 76 to 78 percent carbonate pebbles (with about twice as many dolomite as limestone pebbles), 8 to 10 percent clastic pebbles, and 12

TABLE 9.—*Pebble lithologies of tills in Ross County*

Till	Percent											
	Dolomite	Limestone	Chert	Total carbonate	Limestone + chert / Dolomite	Sandstone	Shale	Siltstone	Total clastics	Igneous	Meta-morphic	Total crystallines
Darby												
no. of samples = 9												
arithmetic mean	51	26	2	79	0.54	6	3	4	13	5	3	8
standard deviation	6	5		6	0.19				5			2
range of values	42-64	19-35	0-6	68-87	0.32-0.79	2-12	0-8	1-11	4-21	4-8	2-6	4-10
Caesar												
no. of samples = 9												
arithmetic mean	52	20	3	75	0.44	7	4	5	16	7	2	9
standard deviation	13	5		7	0.18				10			4
range of values	23-69	15-31	0-6	55-87	0.26-0.61	2-14	0-9	0-20	5-40	4-18	0-5	5-20
Boston												
no. of samples = 6												
arithmetic mean	34	27	3	64	0.88	10	5	7	22	11	3	14
standard deviation	6	8		19	0.27				4			14
range of values	16-42	5-41	0-11	26-80	0.62-1.20	5-15	0-10	1-15	13-29	4-37	0-8	5-45
Rainsboro												
no. of samples = 4												
arithmetic mean	58	22	1	81	0.39	6	3	2	11	6	2	8
standard deviation	3	3		2	0.11				2			2
range of values	54-63	17-26	0-2	78-84	0.27-0.47	5-8	2-4	1-2	9-13	5-7	0-4	6-9

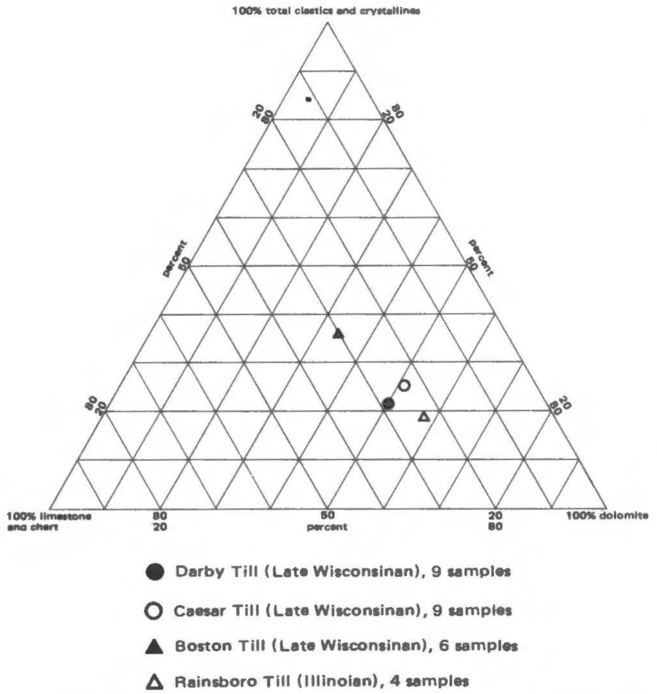


FIGURE 14.—Mean pebble lithology of Ross County tills.

to 16 percent crystalline pebbles.

Although the number of pebble counts is minimal (five), that portion of the Kingston Outwash in the Paint Creek valley can be readily distinguished from the other outwash units on the basis of pebble lithologies. The Paint Creek Kingston Outwash has a higher dolomite and carbonate content, a lower limestone/dolomite ratio, and a lower crystalline-pebble content in comparison to the other Ross County outwash units.

HEAVY-MINERAL ANALYSES

Heavy-mineral analyses generally provide an effective means of differentiating tills from different source areas. The usefulness of heavy-mineral data in glacial stratigraphic correlation has been demonstrated in Ontario (Dreimanis and others, 1957) and in Illinois (Willman and others, 1963). The primary source of the heavy minerals in the Ross County tills must be the Precambrian igneous-metamorphic complex of the Canadian Shield in Ontario.

Heavy-mineral analyses of the very fine sand fraction (0.062-0.125 mm) of 25 Ross County till samples indicate all four tills have a similar distribution of heavy minerals (table 11). These tills average about 30 percent opaques, 20 percent garnets, and 50 percent other nonopaque heavy minerals. This similarity in data is consistent with other heavy-mineral studies of Ohio tills (Rosengreen, 1970; Teller, 1970). Because all four tills were deposited by the same sublobe of the Erie Lobe and the source area of the heavy minerals is far distant from Ross County, any local variations in heavy minerals in the source area would be normalized during the hundreds of miles of glacial transport prior to deposition.

On the basis of weight percent of heavy minerals in the very fine sand fraction (table 11), Illinoian-Stage Rainsboro Till can be distinguished from all three Late Wisconsinan tills. Rainsboro Till contains 28 to 37 percent more heavy minerals in the same size fraction than the younger tills. This difference may reflect source-area variations or concentration of resistant heavy minerals after removal of more mobile constituents by preglacial weathering.

TILL-FABRIC ANALYSES

Many studies (Evenson, 1971; Lineback, 1971; Ramsden and Westgate, 1971) have shown the utility of till fabrics in determining direction of glacier motion. Thirty fabrics were measured in the four Ross County tills. Results of these analyses are plotted as rose diagrams in figures 15, 16, and

TABLE 10.—*Pebble lithologies of outwash in Ross County*

Outwash	Percent											
	Dolomite	Limestone	Chert	Total carbonate	Limestone + chert / Dolomite	Sandstone	Shale	Siltstone	Total clastics	Igneous	Meta-morphic	Total crystallines
Worthington												
no. of samples = 7												
arithmetic mean	46	26	4	76	0.65	6	1	2	9	9	6	15
standard deviation	5	3		3	0.19				2			3
range of values	37-54	20-31	2-6	70-81	0.48-0.89	2-7	0-3	1-5	5-13	6-13	2-9	11-20
Circleville												
no. of samples = 7												
arithmetic mean	53	23	2	78	0.47	5	1	4	10	8	4	12
standard deviation	3	4		3	0.15				2			3
range of values	49-60	16-30	0-4	73-84	0.28-0.64	3-7	0-2	2-6	6-12	5-10	1-8	9-18
Kingston (Scioto River)												
no. of samples = 8												
arithmetic mean	50	24	3	77	0.54	6	0	3	9	9	5	14
standard deviation	4	3		3	0.16				2			4
range of values	43-59	19-28	1-4	71-83	0.35-0.74	4-9	0-1	0-5	5-12	5-14	2-7	10-21
Kingston (Paint Creek)												
no. of samples = 5												
arithmetic mean	73	13	1	87	0.19	4	3	1	7	5	1	6
standard deviation	2	2		3	0.02				2			3
range of values	69-76	11-16	0-3	82-91	0.17-0.24	2-6	2-4	0-2	6-10	1-7	0-3	1-10
Higby												
no. of samples = 6												
arithmetic mean	54	20	2	76	0.40	5	1	2	8	10	6	16
standard deviation	3	3		4	0.10				2			4
range of values	51-60	17-26	0-4	69-84	0.25-0.51	3-6	0-2	0-3	6-10	7-15	3-9	11-24

TABLE 11.—*Heavy-mineral percentages in the very fine sand*[1] *fraction of tills in Ross County*

Till	Percent heavy minerals														
	Opaques		Nonopaques												
	Dark	Total	Garnets			Rutile	Monazite	Hornblende	Hypersthene	Enstatite	Sphene	Actinolite	Augite	Epidote	Total other than garnets
			Pink	Clear	Total										
Darby															
no. of samples = 8; mean weight percent of heavy minerals in size fraction = 2.73															
arithmetic mean	26.1	31.9	6.7	14.3	21.0	2.7	2.4	32.1	2.0	1.6	0.2	1.6	2.0	1.8	47.1
standard deviation	4.5	3.5	1.9	2.3	3.3			3.9							3.4
range of values	19.7-32.3	27.3-36.9	3.9-10.4	11.3-16.9	14.9-25.3	1.4-4.1	1.2-4.0	26.2-38.6	0.9-3.5	0.6-3.6	0.0-0.8	0.9-3.9	1.0-3.0	0.6-3.3	43.3-53.8
Caesar															
no. of samples = 7; mean weight percent of heavy minerals in size fraction = 2.74															
arithmetic mean	21.1	25.5	6.4	13.8	20.2	2.4	2.8	35.9	2.6	2.0	0.4	2.8	2.4	2.2	54.3
standard deviation	4.0	2.8	2.7	1.4	2.6			3.4							3.3
range of values	15.3-27.2	21.9-30.3	2.7-10.6	11.6-17.1	16.4-25.8	1.0-4.7	2.1-4.3	30.1-41.8	0.8-4.6	0.9-3.8	0.0-1.1	0.8-4.0	1.0-3.1	1.0-2.9	46.8-61.0
Boston															
no. of samples = 5; mean weight percent of heavy minerals in size fraction = 2.54															
arithmetic mean	26.3	30.3	4.9	15.7	20.6	2.8	2.2	34.1	2.2	1.5	0.2	1.9	1.6	1.6	49.1
standard deviation	2.1	2.8	1.1	2.3	2.2			4.3							4.1
range of values	24.0-30.4	26.7-35.2	2.6-7.3	12.0-19.4	18.6-24.1	1.8-3.7	1.1-3.1	25.4-39.2	1.0-4.2	0.5-3.0	0.0-1.0	0.8-3.9	0.8-2.6	0.9-2.7	45.5-54.7
Rainsboro															
no. of samples = 5; mean weight percent of heavy minerals in size fraction = 3.49															
arithmetic mean	27.9	30.2	8.4	14.8	23.2	3.2	2.8	29.1	2.5	2.1	0.5	2.0	2.3	1.1	46.6
standard deviation	2.8	3.0	1.2	1.1	1.4			1.5							4.3
range of values	20.9-32.1	24.8-36.1	6.7-10.2	12.9-16.3	19.8-26.2	2.1-4.8	2.2-3.4	26.1-31.6	2.1-3.1	1.4-2.4	0.0-1.1	0.8-3.1	1.1-3.7	0.9-1.3	40.6-55.4

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[1] 0.062-0.125 mm.

17. The well-developed nature of the till fabrics and the number of striated pebbles indicate that all Ross County tills, with the possible exception of ablation material in the soil zones, are basal (lodgment) till. Although criteria have been established to differentiate between basal and ablation till (Drake, 1968), no ablation till has been identified with certainty in Ohio.

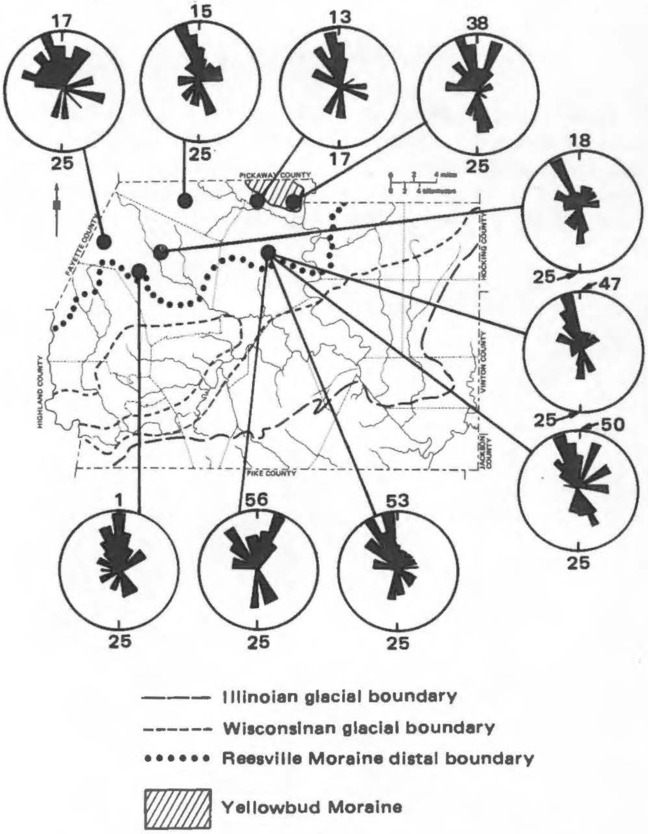


FIGURE 15.—Till fabric of Darby Till in Ross County. Sample number at top of each diagram, number of pebbles measured at bottom of each diagram.

Till fabrics in the youngest till, the Darby Till (fig. 15), give a consistent direction of ice movement from the north-northwest. Till fabrics were measured at four 6-foot intervals in the Dry Run section (samples 47, 50, 53, and 56 of fig. 15). Similar till fabrics in the upper portion of the section (samples 47, 50, and 53) indicate that only one till is present in this part of the section and that the Darby Till has a homogeneous pebble orientation both areally and vertically. Till fabrics at the base of the Dry Run section (sample 56) and at sample locations 17 and 38 have a secondary north-northeast-trending axis, which indicates a slight variation in ice-flow direction and possibly a different till. The fabrics at sample locations 17, 38, and 56 were measured in the basal portions of exposed sections. Their orientation is more closely related to Caesar Till fabrics (fig. 16) and therefore may represent exposures of Caesar Till or an older Darby Till unit. However, no other evidence suggests the presence of a separate till.

Twelve Caesar Till fabrics (fig. 16) show a general north-to-south direction of ice movement, with an increase in an easterly directional component in the western portion of the county. This slight variation may be due to the influence of the changing orientation of the escarpment of Mississippian bedrock that borders the southern margin of the Caesar Till. Because the escarpment trends generally northeast-southwest across Ross County, the ice sheet was able to penetrate to a more southerly position in western Ross County, thus facilitating some westward expansion of the Scioto Sublobe in this region.

Till fabric in the Boston Till (fig. 17) illustrates strong topographic control of ice motion. This control hinders delineation of bedrock source materials which could account for anomalous carbonate content, distribution of heavy minerals, and pebble-count lithologies in this till. Boston Till is distributed primarily in low-relief deposits in north-south-trending tributary valleys on the southern margin of the Paint Creek valley. Till fabrics of all five samples are aligned with the trend of the tributary valley in which the Boston Till is exposed. The two fabrics (samples 31 and 39) that were measured nearest the mouth of tributary valleys show a more southwesterly ice motion than the other fabrics. A southwestward motion means that the ice which deposited the Boston Till came primarily from the northeast, entering the Paint Creek valley in the

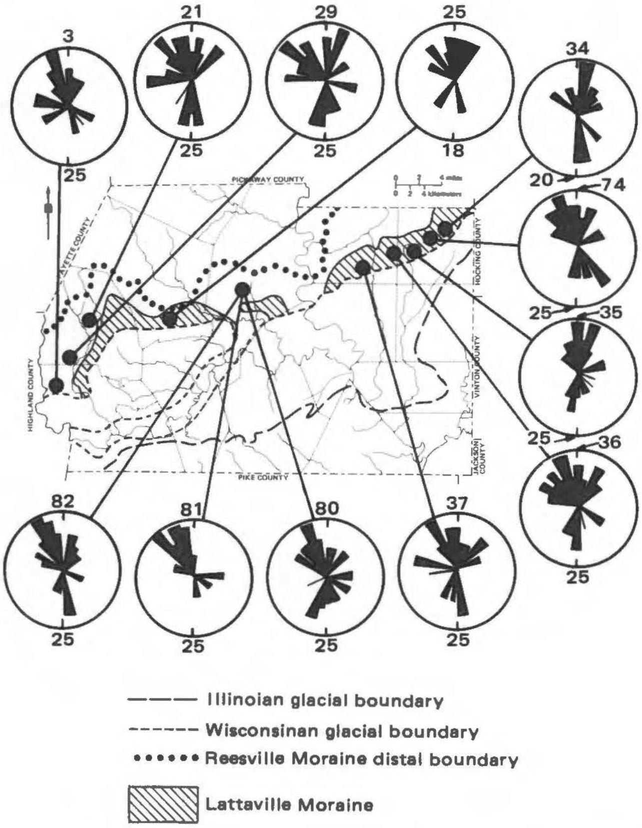


FIGURE 16.—Till fabric of Caesar Till in Ross County. Sample number at top of each diagram, number of pebbles measured at bottom of each diagram.

vicinity of Slate Mills. It confirms the northeasterly provenance of pebbles in that till.

RADIOCARBON DATING

Late Wisconsinan ice invaded Ohio at Cleveland about 24,600 years B.P. (White, 1968). Maximal positions of the ice sheet were nonsynchronous between the Miami Sublobe (20,500 years B.P., W-304) and the Scioto Sublobe (18,500 years B.P., Y-448). Many radiocarbon dates from the overlapping end moraines (fig. 18) in eastern Warren and western Clinton Counties indicate the Miami Sublobe reached its farthest position about 1,400 years prior to the Scioto Sublobe (Dreimanis and Goldthwait, 1973).

Dates on buried wood from pre-Cuba Moraine till in the Todd Fork valley in Clinton County (Teller, 1964) indicate occupation of the Scioto Sublobe maximum position about 21,350 years ago (average of OWU-159, OWU-160, D-46, D-47), roughly 850 years before the Miami Sublobe maximum.

Teller (1964) indicated that the radiocarbon dates from the Todd Fork valley (21,140±1,435 years B.P., OWU-159; and 22,255±1,652 years B.P., OWU-160) probably date the advance to the stand at the Vandervort Moraine in Clinton County. In Highland County, the Boston Till of the overridden Mt. Olive Moraine, once considered to be "early" Wisconsinan in reconnaissance investigations from 1956 to 1969, has been proven to be early Late Wisconsinan (Woodfordian) by radiocarbon dating (Rosengreen, 1970). A date of 21,080±200 years B.P. (D-46) was obtained from wood fragments near the base of the Boston Till; the base of the overlying till was dated at 20,910±240 years B.P. (D-47). These age determinations clearly indicate the Boston Till in Highland County was deposited during the initial Late Wisconsinan ice advance. There are no radiocarbon dates from Ross County for this earliest Late Wisconsinan glaciation.

Grouping of radiocarbon dates from Caesar Till of the Cuba Moraine (Highland and Clinton Counties) and the correlative Lattaville Moraine (Ross County) presents an enigmatic distribution of age determinations (table 12). Two explanations can account for this anomalous distribution. The group of four older dates may indicate the time at which the trees were overridden in central Ohio and incorporated into the till of the advancing ice sheet. The younger group of dates would then indicate the incorporation of wood into till in the southern part of the Scioto Sublobe, shortly before formation of the Lattaville Moraine. This explanation is supported by the fact that many of the logs which date in the 18,000 years B.P. range retained their bark, suggesting a short distance of transport between the points of incorporation and deposition. Alternately, the timing of the maximum position may have differed between Highland County and part of Clinton County and the rest of the southern Scioto Sublobe (Rosengreen, 1970).

The early Late Wisconsinan date (25,300±600 years B.P., I-4797) from a log in the lower till along Blinco Branch in Highland County is probably inaccurate. This conclusion is drawn because the dated log was found in a till unit that correlates best to the Illinoian Rainsboro Till by stratigraphy, clay mineralogy, pebble lithology, texture, and carbonate content. The till is overlain by 10 feet of weathered

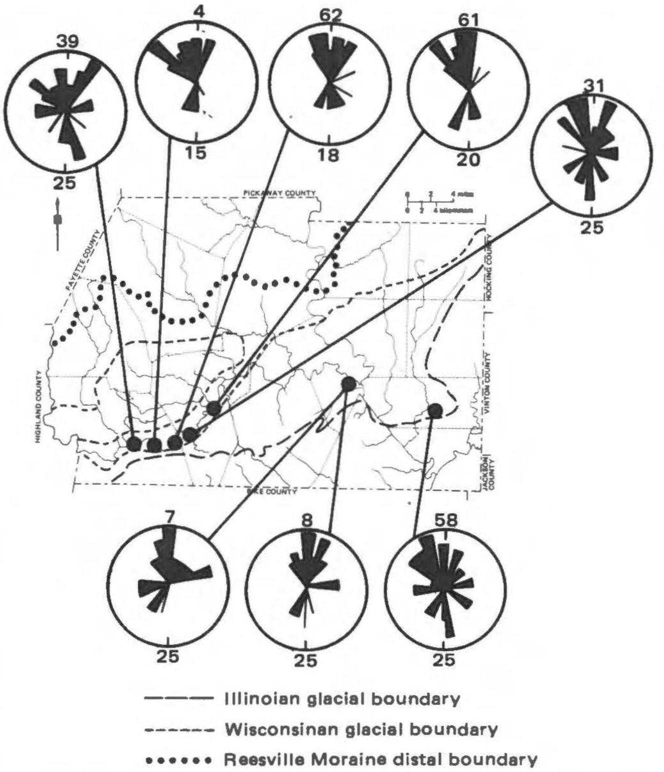


FIGURE 17.—Till fabric of Boston Till (samples 4, 31, 39, 61, 62) and Rainsboro Till (samples 7, 8, 58) in Ross County. Sample number at top of each diagram, number of pebbles measured at bottom of each diagram.

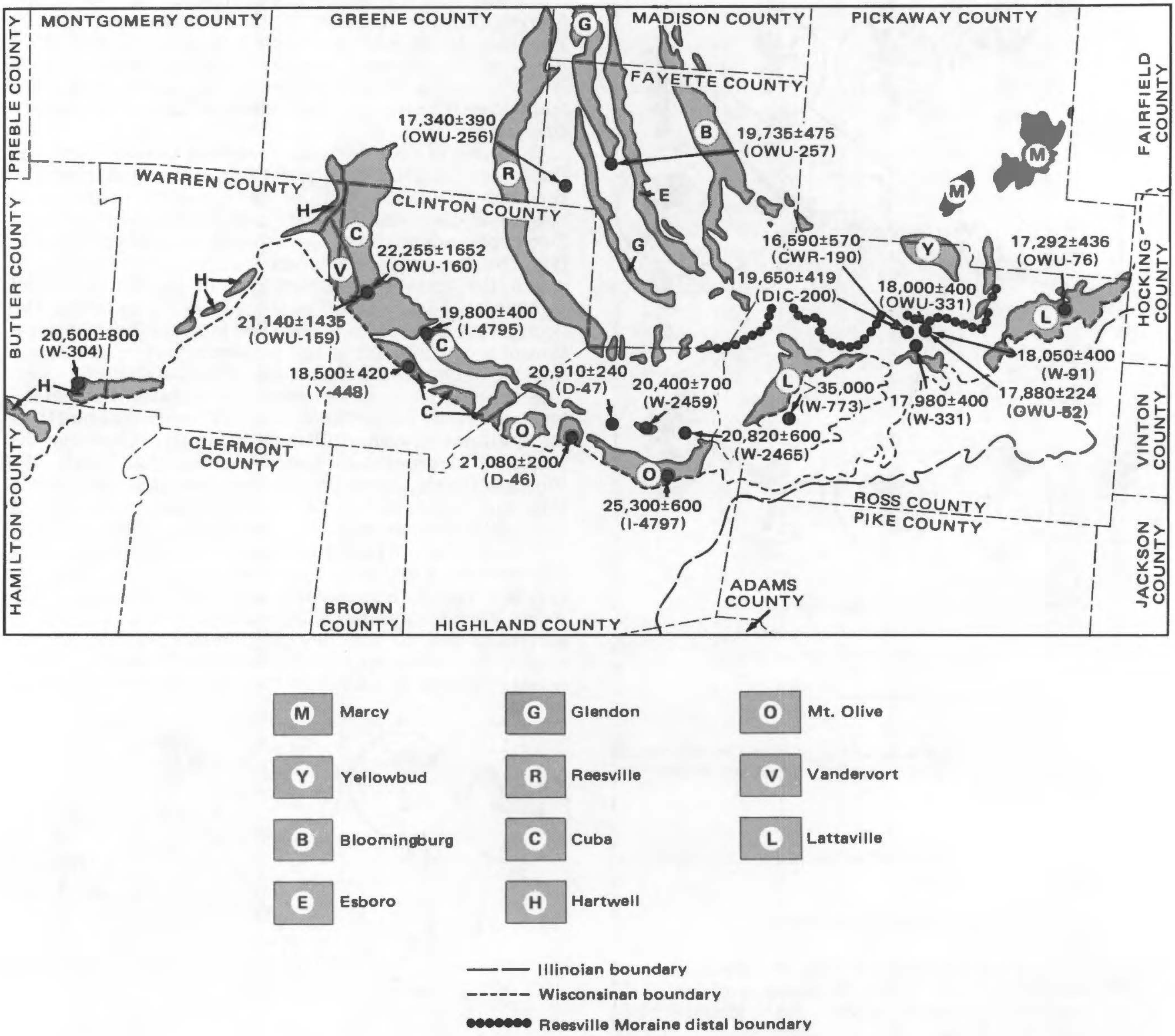


FIGURE 18.—Location of end moraines and radiocarbon dates (years B.P.) in the southern part of the Scioto Sublobe. Moraine boundaries modified from Goldthwait and others (1961), Teller (1967), and Rosengreen (1974).

TABLE 12.—*Radiocarbon dates from the Caesar Till of the Cuba-Lattaville Moraine of the southern Scioto Sublobe*

County	Age (years B.P.)	Lab designation[1]	Average age of grouping
Ross	19,650 ± 419	DIC-200	20,167 ± 530
Highland	20,400 ± 700	W-2459	
	20,820 ± 600	W-2465	
Clinton	19,800 ± 400	I-4795	
Ross	18,050 ± 400	W-91	18,082 ± 369
	17,980 ± 400	W-331	
	18,000 ± 400	OWU-331	
	17,880 ± 224	OWU-52	
Clinton	18,500 ± 420	Y-448	

[1] DIC, Dicar Corp.;I, Isotopes; OWU, Ohio Wesleyan University; W, U.S. Geological Survey; Y, Yale University.

gravel which contains a Sangamonian-like paleosol in its upper portion. Boston Till of the Mt. Olive Moraine (dated at about 21,000 years B.P.) overlies the buried soil.

Two radiocarbon dates from Caesar Till at the Anderson Run site were obtained during this study (table 13, CWR-190, DIC-200). Unfortunately, these dates do little to clarify dating of the Lattaville-Cuba Moraine position. The accuracy of at least the younger date is questionable because the older radiocarbon date, 19,650±419 years B.P. (DIC-200), is stratigraphically above the younger date of 16,590± 570 years B.P. (CWR-190). The older date was determined from a group of small wood fragments. If this date is valid, it is evidence that incorporation of the material into the till corresponds to the incorporation of the material of the earlier Cuba Moraine dates (W-2459, W-2465, I-4795) from Highland and Clinton Counties. Thus the idea of nonsynchroneity in establishment of the maximum positions of

TABLE 13.—*Radiocarbon age determinations from Ross County*

Stratigraphic unit	Location	Material dated	Age (years B.P.)	Lab designation[1]
interglacial peat	Humboldt, Paint Twp.	peat	>35,000	W-773
Caesar Till	Bier's Run, Union Twp.	*Picea* *Picea* *Picea*	18,050 ± 400 18,000 ± 400 17,880 ± 224	W-91 OWU-331 OWU-52
Caesar Till	Anderson Run (Stop 13A, Goldthwait, 1955)	*Picea*	17,980 ± 400	W-331
Caesar Till(?)	NW¼ Sec. 11, Colerain Twp.	*Picea*	17,292 ± 436	OWU-76
Caesar Till	Anderson Run, Union Twp.	*Picea* *Picea*	16,590 ± 570 19,650 ± 419	CWR-190 DIC-200
extensive marl (late-glacial ponding)	Hallsville, Secs. 7, 8, Colerain Twp.	*Picea* in marl *Picea* in marl *Picea* in marl *Picea* in marl	12,835 ± 275 12,685 ± 244 13,695 ± 520 13,180 ± 520	OWU-260A OWU-260B OWU-260C OWU-220

[1] CWR, Case Western Reserve University; DIC, Dicar Corp., OWU, Ohio Wesleyan University; W, U.S. Geological Survey.

the Cuba-Lattaville Moraine (Dreimanis and Goldthwait, 1973) would be refuted.

The younger date was from a large spruce log near stream level in the lower of the three till units at the Anderson Run section. The horizon containing the log was saturated by ground-water seepage. The date indicates a post-Reesville Moraine age (*i.e.*, less than 17,200 years B.P.) for the till. All stratigraphic, textural, and compositional evidence indicates that the till is Caesar Till, which definitely predates the Reesville Moraine. Additionally, the dated till can be physically traced downstream to the location (Stop 13A, Goldthwait, 1955) where a log in the same till was dated at 17,980±400 years B.P. (W-331). Therefore, this new date appears to have been derived from a sample which was contaminated, most likely by addition of recent carbon.

Peat from two buried organic-silt zones in northwestern Fayette County were dated at 17,340±390 years B.P. (OWU-256) and 19,735±475 years B.P. (OWU-257) (Moos, 1970). Presence of these two buried silt zones indicates two periods of significant, yet short-duration, retreat of the ice sheet during active loess deposition: (1) after deposition of the Boston Till and prior to formation of the Lattaville Moraine, and (2) after deposition of the Lattaville Moraine but preceding the readvance to the Reesville Moraine position.

The date of 17,292±436 years B.P. (OWU-76) from near-surface till in the Lattaville Moraine near Hallsville (Colerain Township) is thought to be associated with the readvance to the Farmersville-Reesville position (Dreimanis and Goldthwait, 1973). However, the local stratigraphy, loess distribution, and compositional and textural parameters of the till suggest the unit dated is Caesar Till, not Darby Till as the radiocarbon date indicates. Because other radiocarbon dates (fig. 18) indicate the Caesar and Darby Tills were deposited only about 800 years apart, it appears likely that the near-surface spruce fragments that yielded the Reesville-age date (OWU-76) were contaminated by rootlets or humic wastes from nearby pastures.

MORPHOLOGY OF THE GLACIAL DEPOSITS

ILLINOIAN MARGIN AND GLACIAL BOUNDARY

The limit of Illinoian glaciation transects Ross County from northeast to southwest, generally paralleling the bedrock escarpment of the Appalachian Plateau. Throughout the county there is no marginal, constructional drift accumulation which delineates the maximum position of Illinoian ice. Complete post-Illinoian removal of an Illinoian end moraine is unlikely. Illinoian ice which advanced onto the Appalachian Plateau south of the Paint Creek valley was thin because relatively low relief (less than 100 feet) protuberances on the upland had a pronounced deflecting effect on the ice sheet. A thin ice mass on an upland surface would be susceptible to relatively rapid removal during early stages of deglaciation and construction of any significant end moraine would be inhibited.

The boundary between the unglaciated area and the area of well-defined drift is a transition zone up to ½ mile in width. Because most of the upland south of the Paint Creek valley is capped by dark shale, binocular examination of topsoil samples for quartz content has proven to be an effective tool in delineating the glacial boundary (Foster, 1950). In the Illinoian-glaciated area, all samples contain greater than 10 percent quartz grains, but the quartz content decreases to near zero in the unglaciated terrain. However, care must be taken in using this method because several small knobs on the upland are capped with Berea Sandstone (Mississippian), which locally yields high concentrations of quartz grains in the unglaciated area.

Problems arise in defining the Illinoian boundary in areas where the terminal position is near divides of south-flowing streams. Pebble-size granitic erratics were found near the divide separating Black Run and Pee Pee Creek drainage near Summithill. Similar erratics were noted in the upper portion of the Crooked Creek basin in south-central and southeastern Huntington Township. Foster (1950) reported cobble-size erratics in the upper reaches of the Sunfish Creek system in Scioto and Paxton Townships. These erratic pebbles and cobbles were probably carried beyond the area of actual glaciation by turbulent streamflow during periods of meltwater discharge.

The width of the area of Appalachian Plateau glaciated during the Illinoian Stage is much greater west of the Scioto River valley than it is east of the valley between Chillicothe and Adelphi. This difference is probably due to more moderate relief at the escarpment margin and a more head-on approach of the main ice flow in western Ross County. The area of glaciated plateau significantly increases near the Deep-Stage Bourneville Creek (present-day Paint Creek) valley, showing how it bore the direct flux of Illinoian glaciation. The Illinoian boundary along the eastern margin of the Walnut Creek valley in east-central Ross County is established on the basis of sparsely distributed granitic erratics on the valley side above the level of Illinoian outwash. In southeastern Colerain Township, the Illinoian limit is defined by deposits of thin, patchy till and cobble-size erratics in cols between bedrock knobs and on the north-facing slopes. There is a marked reduction in valley-and-col relief between the drift-covered area and the unglaciated terrain.

ILLINOIAN GROUND MORAINE

Illinoian ground moraine covers a northeast-to-southwest wedge-shaped area of approximately 50 square miles in central Ross County. The moraine is restricted to the Appalachian Plateau upland except for the drift accumulations in the northern portion of the old Teays valley in the southeast corner of Ross County. Illinoian drift is absent in the bottoms of the numerous valleys which transect the area of Illinoian glaciation, and ground moraine is patchy to absent on most valley slopes.

The Illinoian ground moraine is typically thin, patchy, and loess covered to a mean depth of about 30 inches. In the valleys the drift averages 34 feet thick (average of data from 47 water-well logs), with a range from effectively zero to 71 feet. Thinness of the ground moraine is attributed to a short-duration stand by the Illinoian ice near its maximum position. Leighton and Brophy (1961) suggested a short duration for the entire Illinoian glaciation on the basis of thin drift accumulations in central and southern Illinois.

Exposures of Illinoian till are rare in Ross County. In seven deep exposures, the depth of oxidation averaged 12 feet with a range of 9 to 14 feet. Illinoian till in the oxidized zone is typically yellowish brown (10 YR 5/4); the unoxidized till is dark gray (7.5 YR 4/1). The till is commonly highly jointed, with secondary clay accumulations along the joint margins in the lower part of the oxidized zone. Augerings in thin-drift areas show that residual highly weathered zones (Yarmouthian?) in till, alluvium, or colluvium overlie the bedrock beneath the ground moraine. Thus subglacial erosion must have been minimal during deposition of the ground moraine in Ross County.

The Illinoian ground moraine west of the Scioto River valley is typically planar. Portions of the moraine on the upland are small, poorly drained till plains. The drift accumulations are typically thickest on north-facing slopes and in cols between bedrock knobs.

Because of the erosional nature of the Appalachian Plateau margin in Ross County, several inliers of Illinoian drift occur on topographically high remnants within the area of Wisconsinan glaciation. The largest of these areas is the plateau segment north of the Paint Creek valley and south of the Lattaville Moraine. Water-well logs, augerings, and rare erratics indicate all of this upland was glaciated by Illinoian ice, including the highest summits (about 1,300 to 1,360 feet) along Benner and Farrell Hills in southeastern Paint Township. Thin Illinoian ground moraine also occurs on several bedrock highs just north of the Lattaville Moraine. These areas were glaciated during the Illinoian Stage but were nunataks during the Wisconsinan glaciation. On most of these drift inliers the boundary between Illinoian and Wisconsinan drift is distinct owing to variations in (1) loess thickness, (2) depth of leaching, and (3) weathering profiles.

Cobble- and pebble-size erratics were found on the summits of Sugarloaf Mountain, Bunker Hill, Mount Logan, Rattlesnake Knob (Harrison Township), and several unnamed summits in Colerain and Springfield Townships in eastern Ross County. These erratics demonstrate that even the highest areas of the plateau margin were ice covered during the Illinoian Stage.

LATE WISCONSINAN MORAINES

Late Wisconsinan (Woodfordian) drift covers the northwestern 40 percent of Ross County and small areas of valleys tributary to Paint Creek. This drift was deposited in association with three end-moraine positions. Each end moraine represents a significant advance, readvance, or recessional stand of the ice sheet and, except for the Yellowbud Moraine, is associated with a separate till.

Lattaville Moraine

Hummocky Late Wisconsinan drift forms a nearly continuous 0.5- to 3.5-mile-wide end moraine for 20 miles from Adelphi (Colerain Township) to Humboldt (Paint Township). The end moraine generally parallels the northeast-southwest-trending Appalachian Plateau escarpment. Major discontinuities in this end moraine result from Wisconsinan outwash deposition through the moraine topography at the Scioto River valley west of Hopetown and at North Fork valley near Slate Mills.

Till characteristics and areal position indicate that this moraine is correlative with the Cuba and Wilmington Moraines of Highland and Clinton Counties. At one place south of Roxabell the Darby Till of the Reesville Moraine forms part of the end moraine. The Cuba, Wilmington, and Reesville Moraines converge by topographic tracing in eastern Highland and western Ross Counties. This composite end moraine bordering the escarpment margin in Ross County is named the Lattaville Moraine after the small village on the moraine in south-central Concord Township.

Laboratory analyses indicate that most of the Lattaville Moraine drift is Caesar Till. This till is compositionally and texturally indistinguishable from the Rainsboro Till (Illinoian), which caps the plateau upland south of the end moraine, and the Darby Till, which forms Wisconsinan ground moraine north of the moraine. Radiocarbon dates (Goldthwait, 1958) on wood in Caesar Till at Bier's Run and Anderson Run (Union Township) indicate that much of the Lattaville Moraine was constructed about 18,000 years B.P. Pedologic criteria indicate that thin Darby Till forms the surface material in a narrow east-west zone along the proximal margin of the end moraine 1.3 miles south and southeast of Roxabell (Concord Township). This is one of the few areas in Ross County where drift associated with the readvance to the Reesville Moraine (*circa* 17,200 years B.P.) forms hummocky moraine topography.

The segment of the Lattaville Moraine west of the Scioto River valley consists of a 0.5- to 3.0-mile-wide, 18-mile-long crescentic area along the Appalachian Plateau escarpment from Humboldt to North Fork village. This hummocky end moraine is continuous except in the area west of Slate Mills, where Wisconsinan outwash and ice-contact deposits transect the moraine topography. These till-covered ice-contact deposits probably formed contemporaneously with the Lattaville Moraine.

From Humboldt to just south of Lattaville, the clearly defined distal boundary of the end moraine closely parallels the high-relief escarpment margin. Moderation in the slope of the plateau edge east of Lattaville allowed the Late Wisconsinan ice sheet to advance onto the northern margin of the plateau along Plyley Ridge. The distal boundary of the Wisconsinan drift on the upland is a narrow diffuse zone rather than a sharply defined limit. The distal margin on the ridge is delineated on the basis of (1) variations in loess thickness and depth of carbonate leaching, (2) augerings which penetrate through Wisconsinan till into Sangamonian paleosols in the thin-drift edge of the moraine, and (3) small, subdued ridge segments of Late Wisconsinan till near the Wisconsinan-Illinoian boundary. This boundary is most clearly defined by these criteria 0.2 mile south of the junction of Ohio Route 28 and Poplar Ridge Road.

Mean drift thickness for the Lattaville Moraine west of the Scioto River valley is 69 feet (based on data from 37 water-well logs), with a range of 26 to 210 feet. Drift is thickest in the area between Lattaville and Musselman, where several wells penetrate more than 150 feet of till, sand, and gravel. Wood fragments were recorded in seven wells near Lattaville at depths ranging from 13 to 46 feet. Except for zones of sand and gravel near the ice-contact deposits, most of the end-moraine drift is till.

East of the Scioto River valley, the Lattaville Moraine is 14 miles long and up to 3.5 miles wide, with well-developed hummocky topography rising halfway up the north-facing escarpment of the plateau. The end moraine is continuous except for two transecting stream valleys: South Fork of Kinnikinnick Creek-Dry Run (Green Township) and Bull Creek (Colerain Township). The end moraine in this region lies 100 to 300 feet below the Illinoian-glaciated summits of the upland south of the Wisconsinan boundary and 50 to 200+ feet above the lacustrine plain and ground moraine which border the end moraine to the north.

Large areas of ice-contact deposits are included in the end moraine from 1.5 miles west of Hallsville east to Adelphi and in the region north of Sugarloaf Mountain. Water-well logs indicate a much greater portion of the drift is sand and gravel compared to the moraine west of the Scioto River valley.

In this eastern portion of the Lattaville Moraine the drift averages 79 feet thick (from 48 water-well logs) with a range of 25 to 119 feet. Many sand and gravel zones 1 to 25 feet thick are included in the drift mapped as till. Only wells within 1 mile of the southern margin of the end moraine penetrate to bedrock (at depths of 25 to 80 feet), indicating that the escarpment slopes steeply northward beneath the Lattaville Moraine.

Evidence of penecontemporaneous deformation in association with construction of the end moraine is common in numerous small borrow pits along the northern margin of the Lattaville Moraine. The deformational features include small-scale folds, faults, and various slump and flow features.

Reesville Moraine

The distal boundary of drift associated with the readvance of the Scioto Sublobe to the Reesville Moraine is defined on pedologic criteria in Ross County because, except for a small area of the Lattaville Moraine south of Roxabell and the kame-moraine deposits east of the Scioto River valley, there is no topographic expression of the drift margin.

The Reesville Moraine is a well-defined arcuate accumulation of drift throughout Greene, Clinton, and Highland Counties. The distal boundary of the end moraine in these counties is established on the basis of topography and abrupt changes in thickness of loess as well as depth of carbonate leaching. Although the end moraine is absent throughout most of Ross County, the variations in loess cover and depth of leaching provide tools for defining the extent of the drift sheet. Even though the break between the Miami 6A and Miami 60 soils is well defined areally, the boundary separating these two soil groups in Ross County is not a precise line but a transitional zone. The area north of the boundary generally lacks a loess cover and has shallower depths of carbonate leaching compared to the loess-covered soils south of the boundary.

Four areas of ice-contact deposits on the east side of the Scioto River valley from just north of Hopetown north to the Ross-Pickaway County line are at least partially covered with loess-free Darby Till. These areas are mapped as Reesville kame moraine. However, a topographically high ridge must have existed in this region before deposition of the Darby Till. The thin till cover has been removed in some areas by postglacial erosion, exposing ice-contact sand and gravel. Kingston Outwash and ice-contact deposits, which border the eastern margin of these kame-moraine areas, lack a till cover but do have a surface loess unit. This areal relationship of the Darby Till supports the idea that the Reesville-age date (17,292±436, OWU-76) from the Lattaville Moraine east of Hallsville is a contaminated sample.

The location of drift associated with the Reesville Moraine position in Ross County indicates strong topographic control on the readvancing ice sheet. The southernmost penetration of the ice was in those areas of lowest relief—the Frankfort-Roxabell area and along the western margin of Ross County near Greenfield (Highland County).

The lack of hummocky-drift accumulation along most of the Darby Till margin in Ross County is anomalous because of the significant Reesville Moraine drift accumulations elsewhere in the southern part of the Scioto Sublobe (Rosengreen, 1970; Teller, 1964; Quinn, 1972). This anomaly may be related to large-scale deflection of the ice motion in the Scioto Sublobe by the bedrock escarpment of the Appalachian Plateau. The glacial map of Ohio (Goldthwait and others, 1961) shows that maximum development of end moraines in the Scioto Sublobe occurred in the southwestern portion of the sublobe. Each end moraine becomes less pronounced and more poorly defined toward the southeast. The north-northeast/south-southwest orientation of the confining bedrock high may have caused the southwesterly deflection of ice movement in the southern portion of the sublobe. Primary ice-flow direction would also coincide with the main trend of drift transport, accounting for the much larger morainic accumulations in the southwestern portion of the Scioto Sublobe.

Yellowbud Moraine

Bordering Pickaway County in north-central Ross County is a 6.2-square-mile area of hummocky end moraine. It is bounded on the southwest and east by Late Wisconsinan outwash in the Deer Creek and Scioto River valleys. The end moraine extends northward into Pickaway County, where it grades into ground moraine. This drift accumulation is here named the Yellowbud Moraine after a small village along the eastern margin of the moraine.

Although topography is similar throughout the Yellowbud Moraine, the end moraine is composed of two distinct moraine types. The southeastern third is kame moraine with rolling topography developed on ice-contact sand and gravel. Thicknesses of sand and gravel in this area range from 53 to 106 feet (data from four water-well logs). The northwestern two-thirds of the end moraine is typical till (Darby Till) moraine. The boundary separating these two end-moraine types in the vicinity of Swaney Road is clearly defined on the basis of (1) a topographic rise of 5 to 15 feet, and (2) augerings, which easily delineate the till/sand and gravel boundary. Average till thickness in the northwestern portion of the Yellowbud Moraine is 28 feet (data from 15 water-well logs) with a range of 10 to 41 feet of "clay" (till). This till overlies thick sand and gravel accumulations which seem to be continuous with the surface deposits in the kame-moraine area. Lack of any drainage channels or other indications of surface erosion coupled with the similarity in topography between the end-moraine types indicates that no till was ever deposited on the kame-moraine surface.

The relationship of the Yellowbud Moraine to the Glendon, Esboro, and Bloomingburg Moraines (fig. 19) is problematic. Correlation of the end moraine is hindered by (1) lack of morainic topography in northwestern Ross and southwestern Pickaway Counties, (2) no radiocarbon dates on the post-Reesville moraines, and (3) the similarity in drift (Darby Till) composing each of the end moraines. Areal position clearly indicates that the Yellowbud Moraine was constructed in conjunction with a significant short halt of the ice margin during recession from the Reesville Moraine.

A key to possible correlation of the Yellowbud Moraine is the location of Circleville Outwash valley-train remnants in the Scioto River and Deer Creek valleys (fig. 19). Circleville

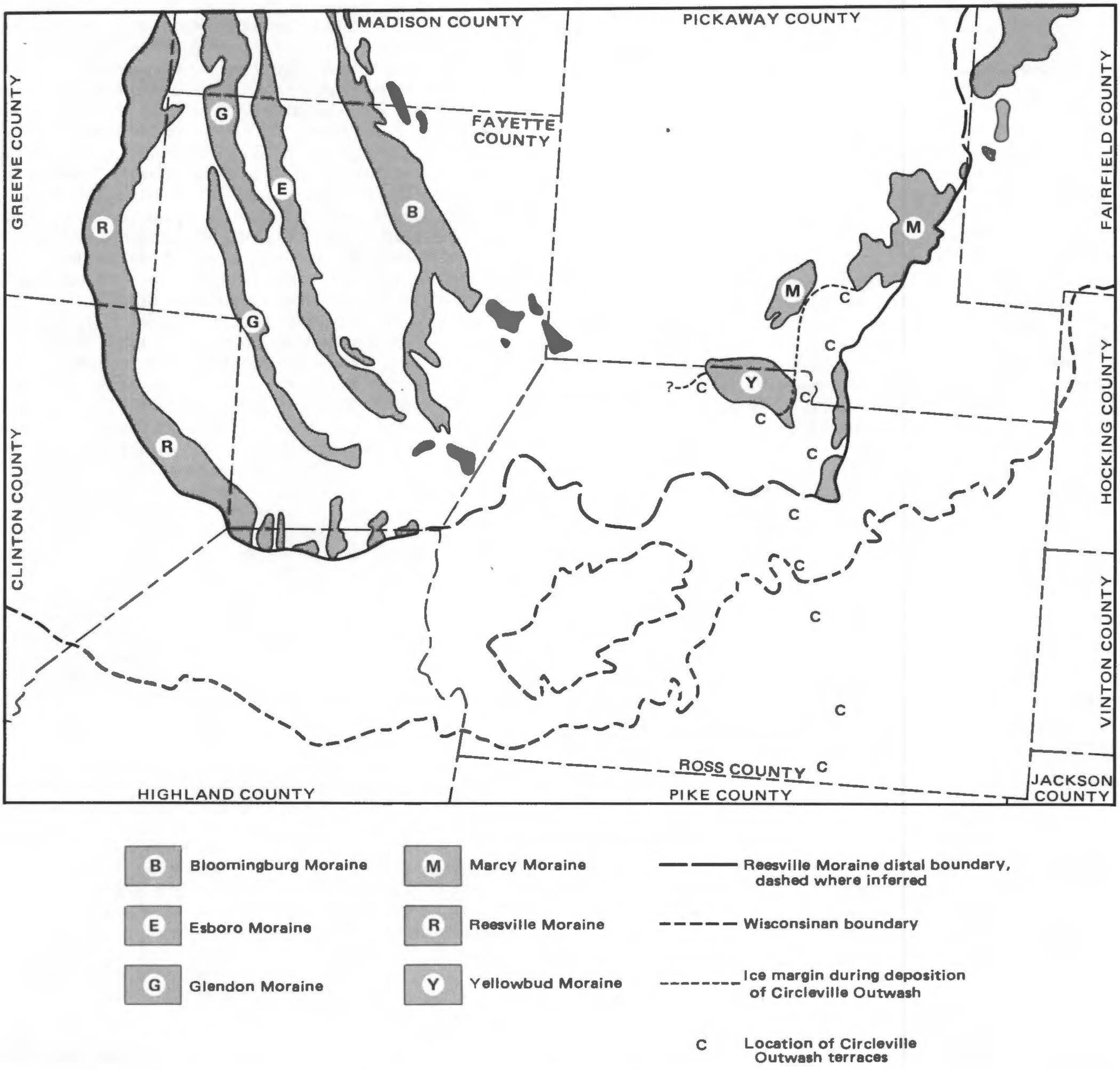


FIGURE 19.—Relationship between the Yellowbud Moraine, Circleville Outwash, and Reesville and later end moraines (earlier moraines not shown) in the southern part of the Scioto Sublobe.

Outwash is traced definitely to the distal margin of the Marcy Moraine at Circleville, Pickaway County (Kempton and Goldthwait, 1959) and defines one ice margin in that area. Other terraces accordant with Circleville Outwash are limited to the Ross County portion of the lower Deer Creek valley, indicating that the Scioto Sublobe margin was near the Ross-Pickaway County line west of the Yellowbud Moraine during deposition of this outwash.

A silt line and related variations in parent material define the distal boundary of the Reesville Moraine position along the eastern edge of the Marcy Moraine east of Circleville. Therefore, the Circleville Outwash has been correlated to Reesville Moraine time (*circa* 17,200 years B.P.) (Kempton and Goldthwait, 1959). This same loess relationship indicates that the Circleville Outwash was deposited synchronously with the Mad River Outwash of the Miami River basin (Quinn, 1972) and the Carroll Outwash of the Hocking River valley (Kempton and Goldthwait, 1959).

Although the distal margin of the Marcy Moraine is Reesville Moraine equivalent, the ice-margin position at the Marcy Moraine during deposition of the Circleville Outwash is post-Reesville and probably correlates with the retreatal Glendon, Esboro, and Bloomingburg Moraines. In the area of most extensive ice movement, in the southwestern part of the Scioto Sublobe, end moraines formed during halts in relatively rapid recession, while in the area nearer the bedrock escarpment general stagnation occurred, as evidenced by deposition of outwash, absence of large end moraines, and abundance of ice-contact deposits.

Although small areas of outwash associated with the Glendon Moraine have been mapped in the Paint and Walnut Creek valleys of Highland County (Rosengreen, 1970), there is no post-Reesville Moraine outwash in the North Fork Paint Creek or Paint Creek valleys in Ross County. As these valleys head near the Glendon, Esboro, and Bloomingburg Moraines, it appears that little outwash deposition occurred in conjunction with construction of these moraines.

Ground moraine

Late Wisconsinan ground moraine covers most of the northwestern 30 percent of Ross County. The ground moraine is generally of low relief, except in those areas where thin drift overlies topographic/bedrock highs and postglacial stream erosion has created up to 150 feet of local relief.

Boston Till ground moraine associated with the initial Late Wisconsinan ice advance is exposed in scattered, small areas only in valleys tributary to the Paint Creek valley in southwestern Ross County. The exposed ground-moraine segments are generally elongated north-south, paralleling the trends of the enclosing valleys. The total area of the ground-moraine patches is only 1.5 square miles. Boston Till ground moraine commonly borders higher Illinoian ice-contact deposits, which range up to 950 feet in elevation. The boundary between the ground moraine and the kames is very distinct because of (1) a topographic break to steeper, rougher gravel slopes, (2) variation in loess thickness and depth of carbonate leaching, and (3) differences in soil profiles associated with changes in parent materials.

Data from 17 water-well logs indicate a mean thickness of 31 feet for the Boston Till, with thicknesses ranging from 15 to 78 feet. These logs indicate that several drift segments are underlain by weathered sand and gravel, presumably Illinoian ice-contact deposits. For this reason it has been suggested, long after field mapping was completed, that these areas might be eroded remnants of older, Illinoian material which have had time to gain only Wisconsinan soil profiles and a thinner coating of Late Wisconsinan loess. Nevertheless, this Boston Till in Ross County has other unique properties described earlier which do not match either Rainsboro or Caesar Till and correlates well with the Boston Till of Highland County (approximately 21,000 years B.P.) (Rosengreen, 1970).

Caesar Till ground moraine extends in a 1- to 3-mile-wide zone from the proximal margin of the Lattaville Moraine to the edge of the Darby Till drift (Reesville distal boundary). Caesar Till ground moraine is divided into three separate areas by penetration of the Reesville boundary to the Lattaville Moraine south of Roxabell and by erosion and outwash deposition in the Scioto River valley. The loess-covered Caesar Till ground moraine surrounds several Illinoian-drift inliers west of Fruitdale and Roxabell.

Mean drift thickness of Caesar Till ground moraine is 36 feet (data from 51 water-well logs) with a range from effectively zero (bedrock with rare erratics on outcrop) to 64 feet. Thinness of the Caesar Till ground moraine is related to its areal position on a high bedrock surface near the escarpment margin. Except in those areas where the northern margin of the Caesar Till drift sheet coincides with a change in bedrock topography (*e.g.*, east of Frankfort), this ground moraine is topographically continuous with the loess-free Darby Till ground moraine to the north.

The northwestern fifth of Ross County is covered with Darby Till ground moraine, which takes the form of a till plain over large areas. Data from 73 water-well logs indicate that this moraine is composed of an average of 22 feet of till covering several tens of feet of sand, sand and gravel, and "hardpan." Depth to bedrock ranges from 15 to 125 feet. Drift is thinnest in areas of high bedrock topography such as in eastern Union and southwestern Concord Townships.

ICE-CONTACT DEPOSITS

Illinoian

The only Illinoian constructional topography in Ross County is a series of ice-contact deposits bordering bedrock slopes in valleys tributary to the Paint Creek valley. Typical kame topography is developed along the southern valley margin north of Jones Hill (southwestern Paxton Township), in the Massie Run valley, in Jimtown Hollow, and in the valleys of Sulfur Lick and Black Run (pl. 1). Illinoian kames are also at the surface in the Upper Twin Creek valley 0.4 mile west of the junction of Tong Hollow and Upper Twin Creek Roads.

The Illinoian kames are generally symmetrical and conical. Lack of erosional modification of these ice-contact deposits appears to be due to (1) the highly permeable material forming the kames, and (2) the isolation of the deposits from the main drainage lines. The unmodified nature also attests to the lack of an extensive Wisconsinan glacial lake in the Paint Creek valley.

The elevation of the ice-contact deposits ranges from less than 700 feet to more than 1,070 feet. Relief above the Paint Creek valley floor averages about 200 feet, with a maximum local relief of 330 feet north of Jones Hill in extreme southwestern Ross County.

Exposures of Illinoian ice-contact stratified drift are limited to several small gravel pits southeast and southwest of Bainbridge. The ice-contact drift has a wide particle-size distribution and locally may contain erratics up to 3 feet in diameter. Almost all of the ice-contact material has a surficial yellowish-brown or reddish-brown secondary iron oxide staining.

Pebble counts in the various groups of Ross County ice-contact features (table 14) indicate that the Illinoian kames are characterized by lower content of total carbonates and crystallines and higher clastic-pebble percentages in comparison to the other areas of ice-contact features. The pebble composition of the Illinoian kames may reflect post-Illinoian weathering in part, as all samples were taken from deep in the oxidized zone. The depletion of the more mobile, more easily weathered constituents such as the carbonates would cause a relative increase in the more resistant materials. The pebble composition of the Illinoian kames is very different from the pebble composition of the Higby and Kingston (Paint Creek) Outwashes (table 10) and of the Rainsboro Till (table 9).

The Illinoian kames formed on dead ice stagnating against the bedrock margins of valleys tributary to Paint Creek. The lack of till accumulation along the Illinoian boundary contrasts the styles of Illinoian and Wisconsinan deglaciation in western Ross County. During deglaciation, that portion of the Illinoian ice sheet which moved over the plateau segment north of the Paint Creek valley and onto the upland south of the valley probably became a separate stagnant ice remnant. Because the ice surface sloped naturally to the south and the ice on the upland was relatively thin compared to the ice mass in the valley, most debris-laden meltwater naturally flowed to the southern bedrock margin of the present Paint Creek valley; thus the preponderance of Illinoian ice-contact features in this region.

Late Wisconsinan

Deposits west of the Scioto River valley.—Kames were formed in Late Wisconsinan time along the Wisconsinan glacial boundary south and west of Lattaville in west-central Ross County. These asymmetrical accumulations of ice-contact stratified drift along the bedrock escarpment formed in conjunction with construction of the Lattaville Moraine (*circa* 18,000 years B.P.). Maximum elevation of these kames is 1,045 feet, which is about 70 feet lower than the bordering plateau upland. The kames are topographically indistinguishable from the surrounding Lattaville Moraine.

A group of ice-contact features formed in conjunction with deposition of a drift "plug" west of Slate Mills about 18,000 years B.P. These deposits permanently altered the northeasterly drainage trend of the Paint Creek valley to the present Alum Cliffs drainageway. Most of these deposits were covered by thin Caesar Till during construction of the Lattaville Moraine.

The remainder of the ice-contact features in the Roxabell-Lattaville area formed about 17,000 years B.P. in association with the ice readvance to the Reesville Moraine position. Three separate kame groups were constructed near the Reesville boundary 1 mile southwest of Roxabell. These symmetrical, coincal kames rise 40 to 70 feet above the surrounding till deposits. Between the southern margin of the easternmost kame area and the bordering Lattaville Moraine is an easterly sloping drainage channel, which indicates the direction of meltwater discharge associated with the formation of these features. A gravel pit on the northern margin of the same kame area, near the junction of Montgomery Lane and Davis Hill Road, exposes 50 feet of chaotically cross-bedded drift.

Two eskers are located in the vicinity of Roxabell. They formed in the outermost zone of the ice mass more or less parallel to the ice edge during Reesville time. The larger, more northerly esker trends northwest-southeast along the northern edge of Roxabell. This broad feature is continuous throughout its 1.8-mile length and consists of a series of higher conical areas connected by a broad ridge of low relief. Local relief between the esker and bordering Wisconsinan outwash ranges up to 90 feet. An exposure in a gravel pit on the western edge of Roxabell displays the pseudo-anticlinal structure that is typical of the axial zone of an esker.

The second esker is south of Roxabell and consists of four discontinuous, narrow segments which trend east-west over a 2.7-mile-long area. Small borrow pits in each of the segments expose the ice-contact drift.

Both eskers probably formed in association with the readvance to the Reesville Moraine and subsequent stagnation in the topographic basin near Roxabell. The local bedrock surface in this area had an easterly slope, which controlled the direction of meltwater drainage and thus the orientation of the eskers in the easterly sloping, ice-walled meltwater channels.

TABLE 14.—*Pebble lithologies of Ross County ice-contact deposits*

Ice-contact features	Percent										
	Dolomite	Limestone	Chert	Total carbonate	Sandstone	Shale	Siltstone	Total clastics	Igneous	Meta-morphic	Total crystallines
Illinoian											
no. of samples = 3											
arithmetic mean	29	19	5	53	27	1	15	43	2	2	4
standard deviation	1	3		4	4		1	5			1
range of values	28-30	12-26	4-5	45-60	19-36	0-1	13-16	46-52	1-3	2-3	3-6
Roxabell-Lattaville											
no. of samples = 4											
arithmetic mean	50	28	1	79	5	1	4	10	4	7	11
standard deviation	2	3		3	1			2			2
range of values	47-52	19-33	0-3	73-84	4-6	1-2	3-4	8-12	3-5	4-7	7-15
Kinnikinnick-Kingston											
no. of samples = 2											
arithmetic mean	54	25	4	83	8	0	2	10	5	3	8
standard deviation	1	1		1				1			1
range of values	52-56	24-26	3-4	81-84	7-8		1-4	9-11	5-5	2-3	7-8
Hallsville-Adelphi											
no. of samples = 3											
arithmetic mean	36	34	3	73	12	1	5	18	5	4	9
standard deviation	2	4		3	2		1	4			3
range of values	31-40	29-43	1-6	68-80	10-16	0-2	3-8	13-26	4-8	1-7	7-15

Pebble lithologies for the Roxabell-Lattaville area (table 14) show that these ice-contact features are compositionally similar to the pebble fractions of the Darby, Caesar, and Rainsboro Tills (table 9) and all outwash units (table 10) in Ross County except the Kingston Outwash in the Paint Creek valley.

Deposits east of the Scioto River valley.—Many discontinuous Late Wisconsinan ice-contact features occur in a 3- by 6-mile area extending north from Hopetown (western Green Township) to the Pickaway County line along the eastern margin of the Scioto River valley. This valley was the primary meltwater drainageway in the Scioto Sublobe during deglaciation.

Most of these ice-contact deposits are asymmetrical kames with local relief ranging from 50 to 190 feet. The largest kame in this area is ½ mile south of Kinnikinnick in the western portion of sec. 29, Green Township. This deposit has been modified by extensive extraction of sand and gravel. The original kame-summit elevation of 860 feet has been reduced by over 100 feet after three decades of quarrying. The Kinnikinnick-Kingston group of ice-contact features is the southernmost deposit in an esker/kame system that extends northward for 32 miles along the eastern side of the Scioto River to Spangler Hill near the I-270 Outerbelt south of Columbus (Franklin County).

A small kame terrace 1.5 miles southwest of Kingston (center of sec. 8, Green Township) heads the Kingston Outwash deposits, delineating the ice margin during outwash deposition. Although kames are predominant in this area, several esker segments are included in these stagnation deposits.

Darby Till covers most of the western third of these ice-contact deposits, probably marking the easternmost expansion of the Reesville-age ice sheet. These deposits accumulated in association with the Lattaville Moraine at a time when large areas of the Late Wisconsinan ice sheet east of the Scioto River valley were decaying near the bedrock escarpment.

The ice-contact features bordering the Kingston Outwash clearly predate the outwash. This time relationship is based on (1) the sharp boundary between the outwash and the kames, indicating erosion on the margins of the kames prior to outwash deposition; and (2) the tracing of the Kingston Outwash to a kame terrace that is clearly in a recessional position, *i.e.*, the kame terrace formed after the Lattaville Moraine, to which the ice-contact features bordering the Kingston Outwash are correlative.

A group of discontinuous ice-contact deposits extends from 1.5 miles west of Hallsville to near Adelphi in northeastern Ross County. These deposits are concentrated along the proximal margin of the Lattaville Moraine and were produced during stagnation following or accompanying end-moraine construction about 18,000 years B.P.

Most of the ice-contact drift in this area takes the form of large kames, which rise up to 140 feet above the bordering lacustrine plain (The Prairie) and ground moraine. The kames are topographically continuous with the end moraine. Many small gravel pits (not shown on plate 1) in these features expose slumped, faulted, and folded ice-contact drift.

A large esker 1.8 miles long, up to 0.3 mile wide, and averaging 70 feet high extends from the west-central portion of sec. 9, Colerain Township, to the SE¼ sec. 16, Colerain Township. This esker is confined to a northwest-southeast-trending valley, and its southeastern margin is nearly coincident with the drainage divide of south-flowing Walnut Creek. The esker construction is probably related to southerly meltwater drainage, glacial-lake formation, and consequent northward extension of the Walnut Creek drainage basin.

OUTWASH

Glaciofluvial deposition adjacent to and beyond the Illinoian and Wisconsinan ice-margin positions created extensive outwash deposits in the Ross County meltwater drainageways. The characteristics of all Ross County outwash units are listed in table 15.

Illinoian Stage—Higby Outwash

Illinoian-age outwash in Ross County is named Higby Outwash after the hamlet of Higby, which borders Illinoian outwash along the western margin of the Scioto River valley in south-central Ross County. In the eastern portion of the county Higby Outwash occurs as (1) large, flat-topped terrace remnants east and southeast of Chillicothe, (2) small terraces along the Lick Run, Dry Run, and Walnut Creek valleys, (3) a pitted outwash plain and terrace remnants throughout the abandoned Teays River valley in southeastern Ross County, (4) large terraces on the northwest margin of the Scioto River valley from Higby southwest to the Ross-Pike County line, and (5) small terrace remnants near the mouth of Paint Creek, in the Brewer Heights area

TABLE 15.—*Characteristics of Ross County outwash deposits*

Outwash	Ice-margin position during outwash deposition	Loess thickness (inches)	Range of terrace elevations (ft)	Outwash gradient (ft/mile)	Mean depth of leaching (inches)	No. of samples	Soil group
ILLINOIAN							
Higby	near Illinoian boundary in eastern Ross County, recessional position in western Ross County	25-71	higher: 860-670 lower: 825-660	higher: 13 lower: 10	145	9	Rainsboro-Parke-Negley-Pike
WISCONSINAN							
Bainbridge	Boston Till; ice dam at Bainbridge (*c.* 21,000 years B.P.)	entire terrace silty	800-770	12	96	6	Bartle-Pekin-Markland
Kingston	Lattaville Moraine and later recessional positions (*c.* 18,000-17,800 years B.P.)	5-32	725-650	6	46	14	Ockley
Circleville	Yellowbud/Marcy Moraine; Roxabell ice-contact group (Reesville Moraine) (*c.* 17,000-16,800 years B.P.)	generally absent	670-615	3.2-1.5	30	21	Fox
Worthington	Powell Moraine (Delaware County) (*c.* 15,000 years B.P.)	none	660-600	3.4-1.5	21	16	shallow Fox

just west of Chillicothe, and in the vicinity of Renick, Three Locks, and Pride along the western margin of the Scioto River valley. The areal distribution of the terrace deposits indicates that the main Illinoian meltwater discharge passed through the Teays-Stage valley rather than occupying the Deep-Stage Newark River valley. Evidently, interglacial (Yarmouthian) erosion of the lacustrine valley fill (Minford Silt) in the Teays River valley and deposition in the Newark River valley created a lower outlet for the Illinoian meltwater through the Teays valley. The Newark River valley may have been a very narrow bedrock gorge. This bedrock constriction would have inhibited passage of the huge volumes of Illinoian meltwater, thus deflecting the main flow eastward through the older Teays outlet. Final post-Illinoian breaching of the Deep-Stage cutoff and the final establishment of the present course of the Scioto River may have occurred as late as during deposition of the Kingston Outwash (*circa* 18,000 years B.P.).

Two levels of loess-covered Higby Outwash have been recognized in eastern Ross County (Hyde, 1921; Leverett, 1942; Kempton and Goldthwait, 1959). The higher level heads on the southern flank of Mount Logan, just east of Chillicothe. This Higby Outwash level extends as terrace remnants for about 5 miles southeastward to Walnut Creek. The two Higby Outwash levels, which are not mapped separately on plate 1, are well displayed just north of Sandy Bottom Run west of Higby in southeastern Franklin Township. Elevations on the higher Illinoian level range from 670 to 860 feet in Ross County with a southerly gradient of about 13 feet per mile.

The lower Higby Outwash level heads as far north as sec. 34, Colerain Township, in northeastern Ross County. Terrace remnants of this level are found along the Walnut Creek and Little Walnut Creek valleys southward to the easterly sloping pitted outwash plain in the northern portion of the Teays valley. The lower Higby Outwash level has a southerly gradient of about 10 feet per mile.

Leverett (1942) attributed the two levels of Higby Outwash to formation and later destruction of an ice dam on the Ohio River at Cincinnati. The higher terraces were thought to have formed during the period of ice-dam ponding, and the lower level terraces to have been deposited after the dam was destroyed. However, Kempton and Goldthwait (1959) showed that the two Illinoian-age levels may merge before reaching the Ohio River. This possibility suggests that the two levels may be related to variations in ice and hydraulic characteristics within a single period of Illinoian glaciation or during two successive substages of glaciation. Several workers (Durrell, 1961; Gooding, 1963; Goldthwait and Rosengreen, 1969; White, 1969) in Indiana and Ohio have indicated the existence of two distinct episodes of Illinoian glaciation in other valleys. Therefore, the two levels of Higby Outwash in Ross County are most likely attributable to deposition in two substages of Illinoian glaciation. Kempton and Goldthwait (1959) reported that Illinoian till overlies the higher level of Higby Outwash in Springfield Township east of Chillicothe. Although patches of till are present on this outwash surface, they do not represent a complete till cover. However, the restricted till cover does indicate an Illinoian ice readvance following deposition of the higher outwash level.

The Higby Outwash has a pebble composition similar to that of the Worthington, Circleville, and Kingston (Scioto River) Outwashes and all of the Ross County tills except the Boston Till (tables 9, 10). All outwash units, except the Kingston Outwash in the Paint Creek valley, contain 76 to 78 percent carbonate pebbles with a limestone/dolomite ratio between 0.40 and 0.65. Mean clastic- and crystalline-pebble content is 9 and 14 percent, respectively. Data from 9 water-well logs which penetrated through the Illinoian outwash to bedrock indicate an average outwash thickness of 79 feet, with a range of 42 to 144 feet.

Reconstructed profiles (fig. 20) show a pronounced steepening of outwash gradient toward the ice-margin position (south to north). The more pronounced gradient increase in the higher Higby Outwash indicates a thicker ice mass and closer ice-sheet control on outwash deposition compared to the lower Higby Outwash. The two profiles converge to the south within Ross County and may be inseparable in the lower Scioto River valley (Kempton and Goldthwait, 1959). Local relief between the two terrace levels decreases from about 40 feet at the latitude of Chillicothe to about 15 feet at the Ross-Pike County line.

Higby Outwash also occurs in western Ross County in the Paint Creek valley and tributary valleys as (1) highly dissected terrace remnants west and northwest of Bainbridge, (2) high terraces in the Lower Twin, Upper Twin, and Plug Run valleys, and (3) a narrow remnant (identified on the basis of soil profile) on the southeast wall of the Paint Creek valley opposite Shotts Bridge. The distribution of Higby Outwash in western Ross County indicates primary outwash deposition occurred in association with meltwater discharge south through the Beech Flats area of southwestern Ross, northwestern Pike, and eastern Highland Counties.

During the Sangamonian Interglacial, extensive valley cutting occurred in the Higby Outwash deposits. Some of the valleys which formed during this interval in eastern Ross County served as meltwater drainageways in Late Wisconsinan time. The Dry Run, Walnut Creek, Little Walnut Creek, Salt Creek, and Sandy Bottom Run valleys all contain Wisconsinan outwash or inwash terraces several tens of feet below the Higby Outwash.

Early Wisconsinan Substage

Early Wisconsinan (Altonian) outwash deposits have not been identified in Ross County. Only in the Hocking River valley, east of Ross County, have terraces of Early Wisconsinan age been identified on the basis of a markedly distinct soil profile and pebble lithology. The absence of similar terraces in the Scioto River valley is probably related to several factors. The Early Wisconsinan ice mass may have terminated in widespread downwastage, forming extensive ice-contact deposits (Dreimanis and Goldthwait, 1973). Outwash deposition may have taken the form of a fan rather than a valley fill, so that most of the Altonian outwash (Lockbourne Outwash) may have been deposited north of Ross County nearer the glacial limit.

Erosion during the Sidney Interstadial and erosion and deposition in association with the Wisconsinan glaciation may have removed or buried all of the Early Wisconsinan outwash. Buried sand and gravel surfaces, such as the one beneath the Yellowbud Moraine and Darby Till ground moraine south of the end moraine in north-central Ross County, may represent Early Wisconsinan (Lockbourne Outwash) deposits.

Late Wisconsinan Substage

Following further erosion and valley cutting in the Illinoian valley fill during the Sidney Interstadial, four episodes

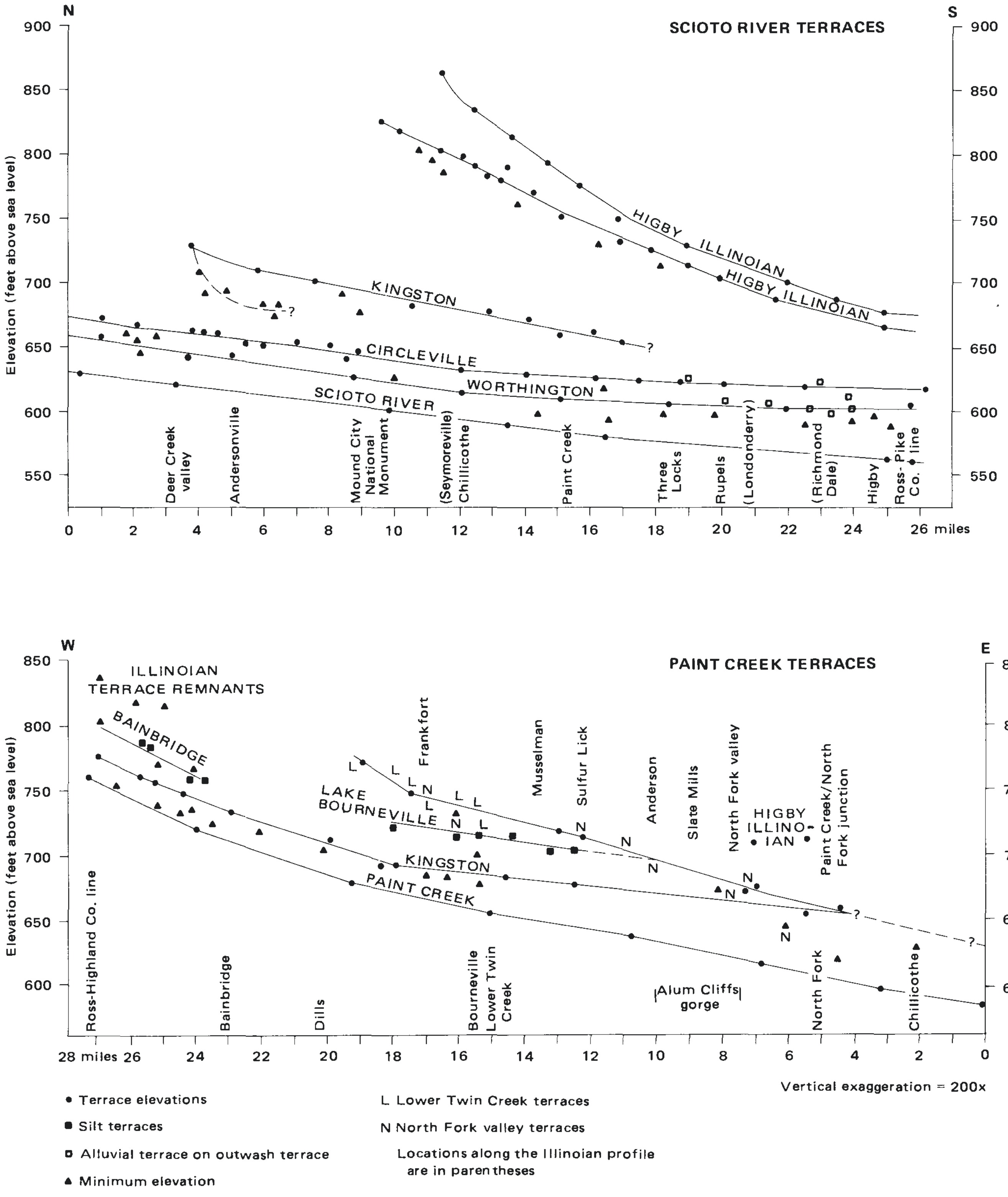


FIGURE 20.—Reconstructed profiles of Ross County outwash terraces.

of Late Wisconsinan outwash deposition created extensive accumulations of glaciofluvial drift.

Bainbridge Outwash.—Bainbridge Outwash (Kempton and Goldthwait, 1959) in Ross County consists of a series of intermediate-level (elevation 770 to 800 feet) silt terraces confined to the Paint Creek valley west of Bainbridge. Augerings indicate that these silt deposits are at least 10 feet thick. Bainbridge Outwash terraces lie about 150 feet lower than the nearby Higby Outwash terraces and about 20 to 40 feet above the bordering Kingston Outwash remnants. The intermediate elevation of these terraces, coupled with the transitional nature of the soil profile developed on the silt terraces, led many workers (*e.g.*, Petro and others, 1967) to conclude that the Bainbridge Outwash deposits are "early" Wisconsinan (Altonian). However, radiocarbon chronology from Highland County (Rosengreen, 1970) indicates this outwash formed in conjunction with the Boston Till (Mt. Olive Moraine in Highland County) about 21,000 years B.P., *i.e.*, early Late Wisconsinan (Woodfordian).

On the basis of the limited areal extent of the terraces and the silt-size grains composing the Bainbridge Outwash, Kempton and Goldthwait (1959, p. 145) proposed that these terraces represent "... slackwater deposits accumulated in 'early' Wisconsin time along decaying ice which squeezed into both ends of Paint Creek valley." However, mapping in Highland County (Rosengreen, 1970) and now in Ross County indicates that the earliest Late Wisconsinan ice sheet did not advance into the western end of the Paint Creek valley.

The Bainbridge Outwash silt terraces in Ross County project on a profile to sand and gravel terraces associated with the Mt. Olive Moraine in eastern Highland County. Thus the Bainbridge Outwash consists of normal sand and gravel in Highland County but grades to slackwater lacustrine silt in western Ross County. Therefore, the thin Late Wisconsinan ice that advanced southwestward up the Paint Creek valley and deposited the Boston Till must have dammed the Paint Creek valley drainage near Bainbridge. Slackwater deposition in this glacial lake (Glacial Lake Bainbridge) west of Bainbridge may have been synchronous with deposition of the molluscan fauna and lake sediments in Glacial Lake Humboldt, 3 miles to the north in the Buckskin Creek valley.

Reconstructed profiles (fig. 20) indicate that the Bainbridge Outwash had an easterly gradient of about 12 feet per mile, slightly steeper than the later Kingston Outwash. The effect of a Bainbridge ice dam in creating a temporary local base level is clearly seen on the profiles because the outwash terraces do not project to any similar outwash level downstream in the Scioto River valley.

Kingston Outwash.—The highest level Late Wisconsinan outwash in the Scioto River valley is the Kingston Outwash (Kempton and Goldthwait, 1959). At the latitude of Chillicothe the Kingston Outwash is about 115 feet below the higher Higby Outwash and about 45 feet above the next highest Wisconsinan outwash terrace, the Circleville Outwash.

Kingston Outwash heads in a kame terrace in the center of sec. 8, Green Township. There are a few shallow kettles in the terrace segment bordering the ice-contact deposit. Kingston Outwash terraces in eastern Ross County extend about 5 miles southeast of Chillicothe down the Scioto River valley. Terraces are also present in the Walnut Creek and Dry Run valleys east of Chillicothe, and in the Salt Creek valley near the Ross-Vinton County line.

The absence of Kingston Outwash terraces in the Scioto River valley south of the Walnut Creek valley (Rupels) may be related to the steeper gradient of this outwash level as compared to the younger Circleville and Worthington levels. Linear projection of the Kingston-level profile in figure 20 suggests that this level may become buried beneath the Circleville Outwash between Rupels and Higby. Alternatively, the Kingston Outwash may have been deposited while the cutoff of the Teays River valley by the Newark River was taking place. Thus the higher level of the Kingston Outwash and the absence of terraces south of Rupels may have been controlled by a bedrock constriction in the cutoff area. As the Scioto River valley between Rupels and Higby continued to be widened, the bedrock control on outwash deposition was diminished.

The portion of the Kingston Outwash east of the Scioto River valley is readily identifiable on the basis of (1) terrace elevation, (2) outwash gradient, (3) loess cover, and (4) the Ockley soil profile (table 15). Compositionally this outwash is indistinguishable from all of the bordering Late Wisconsinan and Illinoian outwash.

Kingston Outwash is also present in western Ross County in the Paint Creek and Lower Twin Creek valleys. The Paint Creek Kingston Outwash is compositionally distinct from all other Ross County outwashes (table 10), containing about 50 percent fewer crystalline pebbles and 11 percent more carbonates, with a much lower limestone/dolomite ratio. Kingston Outwash in the Paint Creek valley also lacks the loess cover which typifies the Scioto River valley portion of this level. The lack of loess cover here suggests that the loess was derived from the main Scioto River valley and spread eastward.

The projected profiles (fig. 20) of the outwash deposits show an anomalous situation in which two nonsynchronous outwash levels in separate valleys lie along the same profile. The high silt terraces (Glacial Lake Bourneville) near Bourneville project to the valley fill west of Slate Mills (Anderson, fig. 20). Higher sand and gravel terraces in the Lower Twin Creek valley tie to sand and gravel terraces in the North Fork valley. Kempton and Goldthwait (1959) suggested that, following construction of the Lattaville Moraine, meltwater that discharged down the Lower Twin Creek valley was able to enter the North Fork valley across the valley fill west of Slate Mills and form the higher level Kingston Outwash terraces in the Lower Twin Creek valley. Following further retreat of the ice sheet from the Lattaville Moraine, meltwater from the wasting ice mass discharged down the Paint Creek and Buckskin Creek valleys and then through the Alum Cliffs gorge, depositing the Kingston Outwash in the Paint Creek valley (*circa* 18,000 years B.P.). Presumably Kingston Outwash deposition was occurring simultaneously in the North Fork valley. Because only a short time (600 to 800 years) elapsed between deposition of the Kingston Outwash and readvance of the ice sheet to the Reesville Moraine maximum position, only minor entrenchment of the outwash terraces occurred.

Circleville Outwash.—Circleville Outwash (Kempton and Goldthwait, 1959) heads at the southern margin of the Marcy Moraine near Circleville in Pickaway County and in the Roxabell group of ice-contact features in west-central Ross County. These intermediate-level Late Wisconsinan terraces are areally the most extensive Wisconsinan outwash deposits in Ross County. Circleville Outwash terraces extend up the Deer Creek valley to near the Ross-Pickaway County line, thereby marking the position of the ice margin during outwash deposition.

Circleville Outwash deposition occurred at two distinctly different ice-margin positions—initially from the Reesville Moraine maximum position near Roxabell (*circa* 17,000 years B.P.) down the North Fork valley, and later in the Scioto River valley while the ice sheet stood at the Reesville recessional position at the Yellowbud and Marcy Moraines (*circa* 16,800 years B.P.). Under some moisture and crop conditions, old braided channels show faintly in fields below the Veterans Hospital just west of Ohio Route 104.

The gradient of the Circleville Outwash was locally controlled by the only slightly eroded Kingston Outwash valley fill. Because of this gradient control and the minor duration of this episode of outwash deposition in the North Fork valley, the North Fork Circleville terraces project to the profile gradient established by the Kingston Outwash terraces associated with the Lower Twin Creek valley.

Meltwater drainage during retreat from the Darby Till limit at the patchy Reesville Moraine eroded a lower level in the Kingston Outwash which extends from Hopetown north to near Kinnikinnick along the eastern margin of the Scioto River valley. Darby Till is present on the ice-contact features along the eastern valley margin but is lacking on the intervening lower, dissected Kingston Outwash level.

Although compositionally indistinguishable from the other Wisconsinan and Illinoian outwashes in the Scioto River valley (table 10), the Circleville terraces can be identified on the basis of terrace elevation and depth of leaching (soil profile) (table 15).

Worthington Outwash.—The lowest Late Wisconsinan outwash level in the Scioto River valley, the Worthington Outwash (Kempton and Goldthwait, 1959), heads near the Powell Moraine in southern Delaware County. Worthington Outwash terraces are identified in Ross County, 50 miles south of the source, on the basis of terrace elevation and depth of leaching (table 15). Worthington sand and gravel has a slightly higher limestone/dolomite ratio than the other Wisconsinan and Illinoian outwashes (table 10), but is not distinguishable solely on this criterion.

Large areas of outwash plain in the Scioto River valley have been mapped as alluvial terraces and alluvium (pl. 1) because they are covered with surficial alluvium. The sand and gravel underlying most of these low-lying alluvial segments is Worthington Outwash.

The projected profiles (fig. 20) show that the Worthington and Circleville levels are nearly parallel in gradient throughout Ross County. Both profiles have an anomalous inflection point near Chillicothe, where the gradient decreases from about 3.2 to 1.5 feet per mile. Note that no similar gradient variation occurs in the higher Kingston and Higby Outwash levels. North of Chillicothe the two profiles nearly parallel the present gradient of the Scioto River. South of the city the outwash levels remain parallel but decrease in gradient relative to the Scioto River. The divergent gradients continue down the Scioto River valley (Kempton and Goldthwait, 1959, fig. 3), although the magnitude of divergency is not as pronounced south of Ross County.

This gradient anomaly appears to be related to the narrowing of the Scioto River valley by the constrictive nature of the bedrock uplands and higher outwash terraces. The point of inflection on the outwash profiles is nearly coincident with the Appalachian Plateau escarpment and the northern limit of the Higby Outwash terraces. Both of these features served to confine Late Wisconsinan meltwater to a narrower channel compared to the valley north of Chillicothe.

LACUSTRINE DEPOSITS

Minford Silt

Pre-Illinoian (Kansan?) lacustrine sediments are exposed in southeastern Ross County. These accumulations of Minford Silt (Stout and Schaaf, 1931) formed in an extensive finger lake created by Kansan or pre-Kansan ice damming the Teays-Stage drainage.

The best exposure of Minford Silt in Ross County is on the north side of a Baltimore and Ohio railroad cut 0.7 mile northwest of Lickskillet, where 42 feet of varved silt and clay is exposed (fig. 21). Augering at the base of the exposure indicates the lacustrine sediments continue at least 8 feet below the railroad level.

The varved sediment is slightly calcareous (table 16) and has been oxidized to a depth of 17 feet. Individual laminations range in thickness from 1 mm to 1 cm and in grain size from clay to very fine sand. The laboratory data (table 16) show that the term "Minford Silt" is actually a misnomer when applied to this clay-rich sediment.

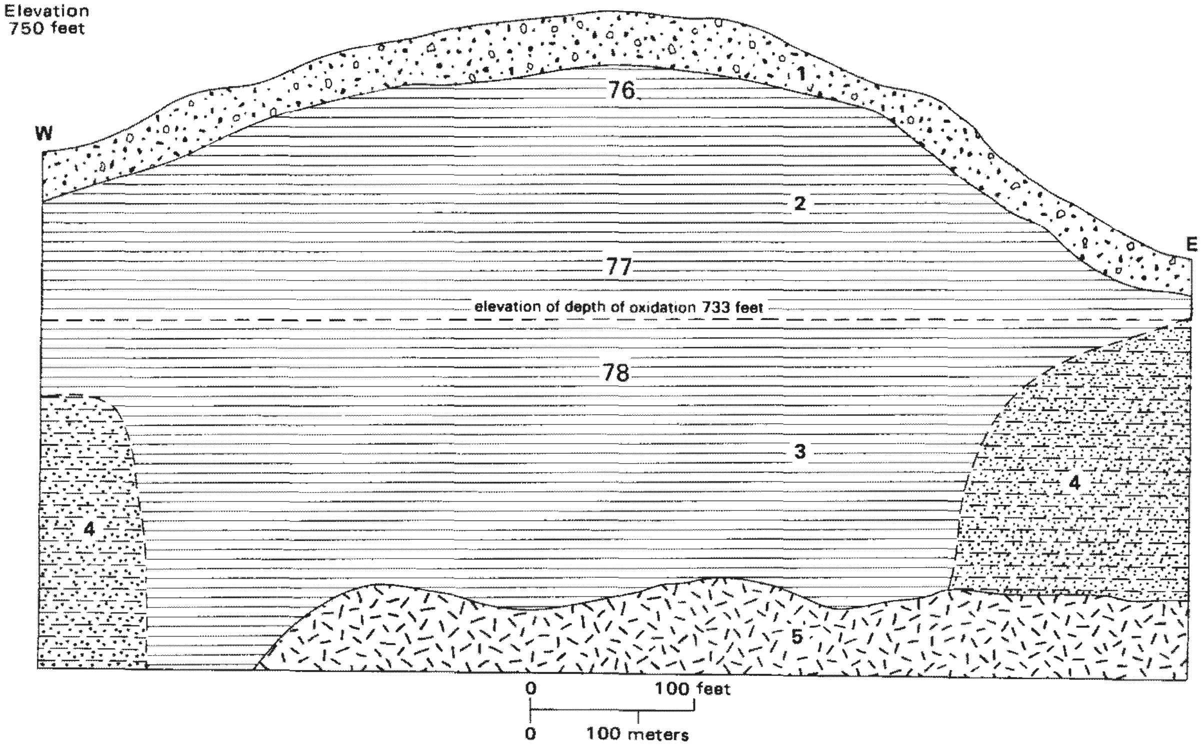
Minford Silt was preserved up to an elevation of 750 feet at the Lickskillet section because of the protective influence of higher bedrock topography which borders both the eastern and western margins of the section. Evidently the varves were deposited in a small tributary valley or bedrock alcove on the south side of the Teays River valley. Water-well logs in Illinoian outwash 1 mile northeast of the Lickskillet section indicate the presence of Minford Silt ("blue muck") beneath the outwash at elevations ranging from 600 to 660 feet. The differences in elevation of these Minford Silt deposits indicate that locally up to 150 feet of the lacustrine valley fill was removed prior to deposition of the Higby Outwash. Loess-covered Minford Silt is exposed in a large area of the southern portion of the old Teays valley north of Richmond Dale (secs. 27, 33, and 34, Jefferson Township). Small remnants (not mapped on plate 1) are also present in the small tributary valleys southeast of Richmond Dale.

Glacial Lake Massieville

The northeasterly drainage trend in the Indian Creek valley in southeastern Scioto Township was blocked near the mouth of the valley by both the Illinoian and early Late Wisconsinan ice sheets. Drainage impoundment resulted in the formation of Glacial Lake Massieville in the Indian Creek valley. Lacustrine sediments from both the Illinoian and Wisconsinan Stages of this glacial lake are exposed from Massieville northeast to the Scioto River valley.

Illinoian lacustrine sediments are exposed in the Massieville section (fig. 10) near the mouth of the valley. About 12.5 feet of rhythmically banded, reddish-yellow (7.5 YR 6/6) lacustrine clay and silt overlies Rainsboro Till. The lacustrine sediment is unconformably overlain by 17 feet of coarse Higby Outwash.

Dark-gray (5 YR 4/1) varved clay is present in several localities in the Indian Creek valley. The clay is well exposed in drainage ditches and shallow roadcuts along U.S. Route 23. Hyde (1921) noted these deposits and considered them to be Illinoian because he did not think that Late Wisconsinan ice had advanced south of Chillicothe. However, striae on shale, formerly exposed 1 mile north of the Indian Creek valley, were considered fresh enough to be of Wisconsinan age by Kempton and Goldthwait (1959). These striae,



1. Mixed zone
2. Lacustrine sediments, varved, oxidized; many secondary $CaCO_3$ accumulations along joints. Sample 76, 10 YR 5/4; sample 77, 10 YR 5/3. MINFORD SILT
3. Lacustrine sediments, varved, unoxidized. Sample 78, 5 YR 4/1. MINFORD SILT
4. Sandstone and shale
5. Slumped debris

FIGURE 21.—Diagram of the lacustrine sediments in the Baltimore & Ohio railroad cut 0.7 mile northwest of Lickskillet, SE¼ sec. 16, Liberty Township. Laminations are 1 mm-1 cm thick.

coupled with the low elevation (590 to 610 feet) of the varved deposits compared to the nearby Illinoian terraces, indicate a Late Wisconsinan age for the deposits. Because the initial Late Wisconsinan ice advance was the most extensive in the Paint Creek valley, it appears likely that lacustrine sedimentation in the Wisconsinan stage of Glacial Lake Massieville occurred during this period (*circa* 21,000 years B.P.). Thus these lake deposits are correlative with the Boston Till and Bainbridge Outwash (Glacial Lake Bainbridge) of the Paint Creek valley.

TABLE 16.—*Results of laboratory analyses[1] from the Lickskillet Run lacustrine section*

Particle-size distribution (percent)		Calcite-dolomite analysis (percent)		Clay mineral analysis (percent)	
>2 mm	0.0	Calcite	2.5	Illite	80
Sand	0.4	Dolomite	3.6	Montmorillonite	0
Silt	33.6	Total carbonate	6.4	Vermiculite	15
Clay	66.0	Calcite / Dolomite	0.69	Chlorite	trace
				Kaolinite	trace
				Quartz	5
				Interstratified clays	trace

[1] Mean values from four samples.

Glacial Lake Humboldt and Glacial Lake Bainbridge

Lacustrine sediments at the Humboldt deposit, 0.4 mile north of the community on the east side of Ohio Route 41, in central Paint Township, were described by Reynolds (1959). He considered the lake beds to be of "early" Wisconsinan age on the basis of interpretation of the local stratigraphy (table 17) and comparison of the molluscan assemblages from this deposit to assemblages from deposits of known age.

Unit 1 of the Humboldt deposit is stratigraphically and compositionally correlative to a gravel unit containing a well-developed Sangamonian paleosol in an exposure 0.3 mile south of the Humboldt section. Thus the basal gravel is probably Illinoian outwash. The till overlying the gravel was mapped as "early" Wisconsinan by Petro and others (1967) because of pedologic variations which differentiate this unit from known Illinoian or Wisconsinan drift. Reynolds (1959) indicated that the unit 2 till of the Humboldt deposit was continuous with the uppermost till (unit 9) in the composite section. He thus concluded that the interbedded lake deposits were also "early" Wisconsinan.

TABLE 17.—*Composite stratigraphic section[1] of the lacustrine and related sediments in the Buckskin Creek valley*

Unit	Description	Thickness (ft)
9	Till, silty and clayey, oxidized brown, calcareous	15
8	Till, silty and clayey, unoxidized blue-gray, calcareous	17
7	Clay, smooth and somewhat plastic, blue-gray, noncalcareous	24
6	Peat, contains many crushed molluscs	⅓-2
5	Marl, clayey, very fossiliferous	3-5
4	Marl and clay, laminated in places, some fossils in upper portion	1-6
3	Sand and gravel, reddish-brown, calcareous	0-5
2	Till, oxidized brown, calcareous, silty	5-8
1	Gravel, coarse, stratified	10+

[1] After Reynolds (1959, p. 165).

Till similar to unit 2, once mapped as "early" Wisconsinan in Highland County, has been shown to be of early Late Wisconsinan age (Rosengreen, 1970). Because unit 2 appears to correlate with the Boston Till and Bainbridge Outwash of Ross and Highland Counties, the age of the Humboldt lake sediments must be about 21,000 years B.P. (Woodfordian).

The lacustrine sediments are primarily clay and marl and are highly fossiliferous in restricted zones. These sediments range from 4 to 10 feet thick within the valley.

Early Late Wisconsinan ice advanced southwestward up the Paint Creek valley, and Glacial Lake Bainbridge was formed west of an ice dam in the vicinity of Bainbridge. Simultaneously, the ice sheet blocked a north-flowing stream, which headed in a col 2.5 miles southeast of Humboldt, in the Buckskin Creek valley north of Humboldt. In the resultant proglacial lake, Glacial Lake Humboldt, the lacustrine sediments of the Humboldt deposit accumulated. Eventually the col at the southeastern end of the lake was breached and Glacial Lake Humboldt drained into the Paint Creek valley, possibly into Glacial Lake Bainbridge. Relatively rapid downcutting through the Ohio Shale at the outlet caused permanent reversal of the drainage direction of Buckskin Creek following deglaciation.

Glacial Lake Bourneville

Illinoian lacustrine sediments associated with Glacial Lake Bourneville are present in the Paint Creek valley from Dills northeast to Schotts Bridge and in the Owl Creek valley north of Schotts Bridge. Although the lacustrine terrace remnants predominate along the northwestern margin of the Paint Creek valley, highly eroded lake deposits are present in the Sulfur Lick valley and in the valley between Copperas and Little Copperas Mountains along the southeastern valley margin.

These lacustrine terraces, which range in elevation from 700 to 720 feet, project (fig. 20) to the level of the valley fill west of Slate Mills, where the Illinoian ice dam which created Glacial Lake Bourneville was located. The terraces typically consist of silt but also contain zones of laminated clay and lenses of fine sand and gravel. Shallow roadcuts along U.S. Route 50 and small borrow pits afford the best exposures of the terrace stratigraphy.

The Prairie

Dark (7.5 YR 2/1) lacustrine silt and intercalated marls are present in a large area of northeastern Ross and southeastern Pickaway Counties known locally as The Prairie. These sediments have an average thickness of 25 feet (data from four water-well logs) and generally overlie coarse sand and gravel. The lake-sediment surface slopes gently to the northeast, indicating the glacial lake drained through the Salt Creek valley.

Spruce fragments from a thick marl unit in these lake sediments 0.8 mile northeast of Hallsville range in age from 12,685 to 13,695 years B.P. These dates indicate that the lacustrine sediment of The Prairie was deposited in a post-Late Wisconsinan glacial lake which developed along the proximal edge of the Lattaville Moraine and associated ice-contact features following ice-margin recession. Deposition could have begun as early as 17,000 years B.P. if the mapping of the Darby Till (Reesville Moraine) position is correct.

BOULDER CONCENTRATIONS

The distribution of Ross County boulders (fig. 22) larger than 1 foot in diameter indicates a slightly greater concentration of boulders along the Lattaville Moraine and in an east-west zone of northwestern Ross County which lies in the areal trend of the boulder-rich Bloomingburg Moraine. Goldthwait and Rosengreen (1969) suggested that the greater concentrations of boulders on end moraines as compared to the surrounding ground moraine indicate the boulders accumulated as ice-marginal, probably supraglacial, drift.

Boulders on the Illinoian-glaciated uplands are generally smaller and less numerous compared to the erratics in the Wisconsinan-glaciated terrain. Illinoian erratics occur mostly along the margin of the plateau escarpment. The distribution and size of boulders in areas of Illinoian drift support the idea of a thin ice cover on the uplands south of the bedrock escarpment during the Illinoian glaciation.

Boulder counts at four localities indicate that an average of 78 percent of the boulders are Canadian crystalline lithologies, and the remaining 22 percent are composed of local bedrock types (14 percent dolomite, 8 percent limestone). Very few of these boulders are striated.

The majority of the boulders are on the surface or in near-surface drift, although several erratics were observed beneath thick drift accumulations in large exposures. Because glaciers have a very poor capacity for sorting, selective concentration of the boulders must have occurred before the material became incorporated into an advancing ice sheet. Goldthwait and Rosengreen (1969) suggested that periglacial concentration by water or chemical weathering in northern crystalline-rock areas could have supplied the advancing ice sheet with the supraglacial load. They noted that ". . . surface concentration of scattered boulders without equivalent till matrix is similar to the debris pattern left by recently surging glaciers and might represent just such lobate activity."

DIRECTIONAL INDICATORS

During this study no striations were observed on any rock surface in Ross County. Two striae localities, no longer exposed, have been described in the county (fig. 22). Leverett (1902, p. 424) reported striae that trended north-south near Buckskin Station (between Lyndon and Greenfield) in western Ross County. In 1954, R. P. Goldthwait measured striae that trended S 30° E (149° to 155°) on a massive shale surface ½ mile north-northwest of Renick on the western margin of the Scioto River valley. The striae were on a surface which was partially covered with recent mudflow and slump debris. These striae are nearly coincident with the directions of ice motion derived from till-fabric analyses (figs. 15, 16, 17).

The lack of striae on the numerous bedrock surfaces in the county is attributed to (1) postglacial weathering of exposed surfaces, (2) minimal glacial erosion along the Illinoian and Wisconsinan glacial margins, and (3) large areas in which shale, with its typical poor retention of striations, forms the bedrock surface.

GLACIAL HISTORY

PRE-ILLINOIAN TIME

In Ohio, surficial pre-Illinoian glacial drift is restricted to the southwestern portion of the state near Cincinnati (Durrell, 1961; Teller, 1970; Norton and others, 1983). Although pre-Illinoian ice-contact material may be present in Highland County (Rosengreen, 1970), it has not been identified in either subsurface or surficial deposits in Ross County. However, there are exposures of early Pleistocene lacustrine deposits (Minford Silt) in southeastern Ross County. The Minford Silt accumulated in the Teays River valley when drainage was dammed by early Pleistocene ice.

ILLINOIAN GLACIAL STAGE

Deep-Stage erosion was truncated as Illinoian ice advanced into Ross County from the north-northwest. At its maximum extent the Illinoian ice sheet covered the northwestern three-quarters of the county (pl. 1). The Illinoian glacial boundary has a northeast-southwest trend across Ross County except in the region southeast of Chillicothe, where a sublobe advanced up the Teays River valley as far as Londonderry.

Because of the general absence of Illinoian morainic accumulations, recessional ice-margin positions are delineated on the basis of erosional and depositional features such as ice-contact deposits, heads of outwash units, and ice-dammed lacustrine deposits.

While at or near its southernmost position, the ice sheet

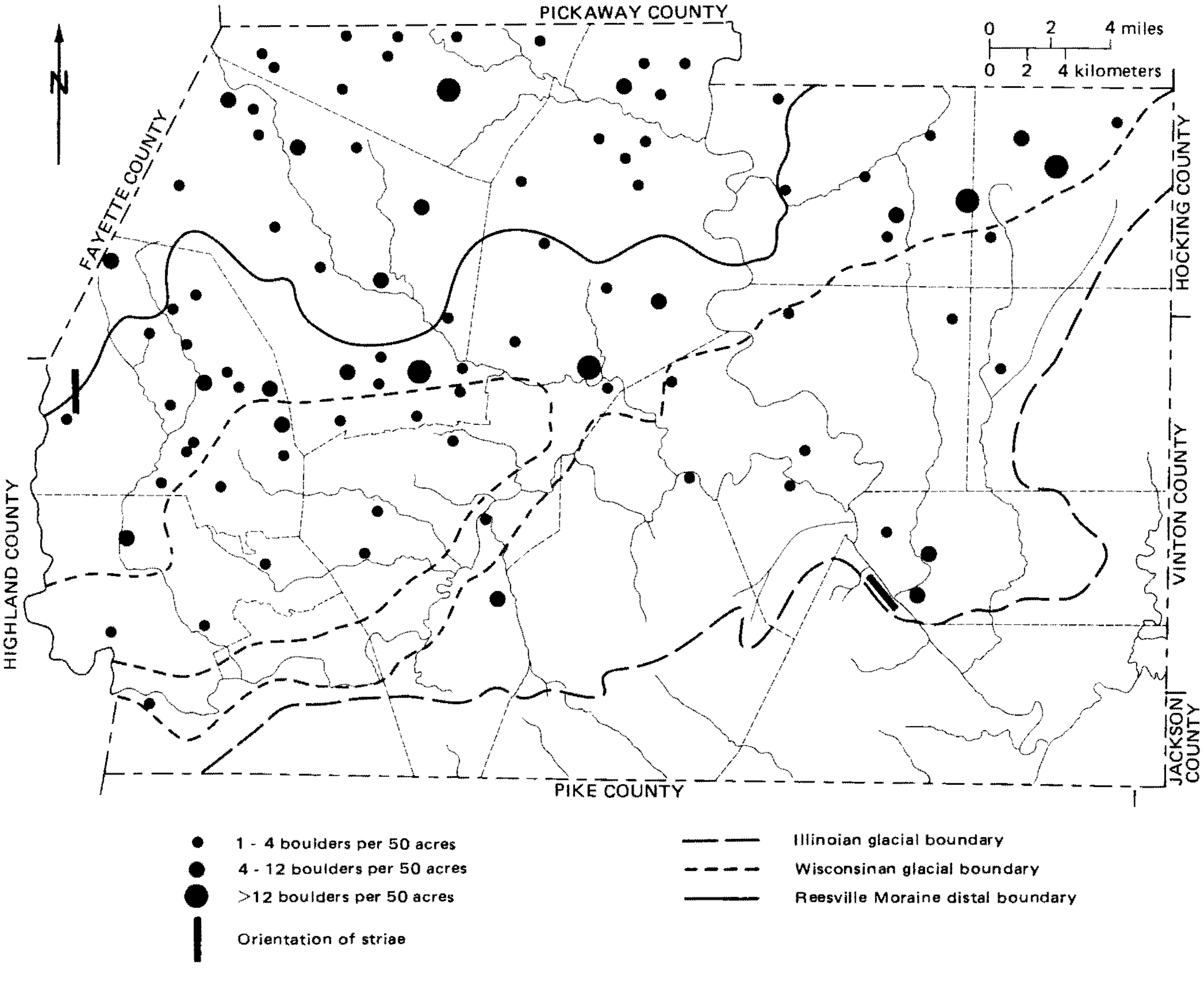


FIGURE 22.—Distribution of boulders larger than 1 foot in diameter and orientation of striae in Ross County.

deposited till on the northern margin of the bedrock "island" between the old Teays valley and the younger Deep-Stage valley (modern Scioto River valley) in southeastern Ross County. A thin till was deposited at the same time on the plateau upland along the Illinoian limit in eastern and southwestern Ross County. The absence of morainic accumulations along the crenulated glacial boundary indicates the Illinoian ice sheet was probably thin and stood near the glacial limit for only a short time. Crystalline erratics in the upper portions of the drainage basins of south-flowing streams suggest minor periods of southerly meltwater discharge all along the glacial limit.

During occupation of near-maximum positions, the Illinoian ice caused a permanent reversal in the northeasterly Deep-Stage drainage trend in the Beech Flats area in southwestern Ross County and adjacent Pike and Highland Counties. While the ice margin stood along the southern margin of Jones Hill (fig. 23), aggradation in the ice-dammed proglacial lake created an extensive lacustrine plain at an elevation of about 960 to 1,000 feet. Lacustrine sedimentation in the Beech Flats area was sufficient to cause permanent drainage reversal following subsequent recession of the ice margin. Synchronously, Glacial Lake Massieville formed in the recently deglaciated Indian Creek valley owing to the ice dam across the valley mouth (fig. 23). Lacustrine sedimentation formed the rhythmites which are now exposed in the Massieville section (fig. 10). During various stages of retreat from the Illinoian boundary, the ice sheet deposited thin drift on segments of the plateau upland.

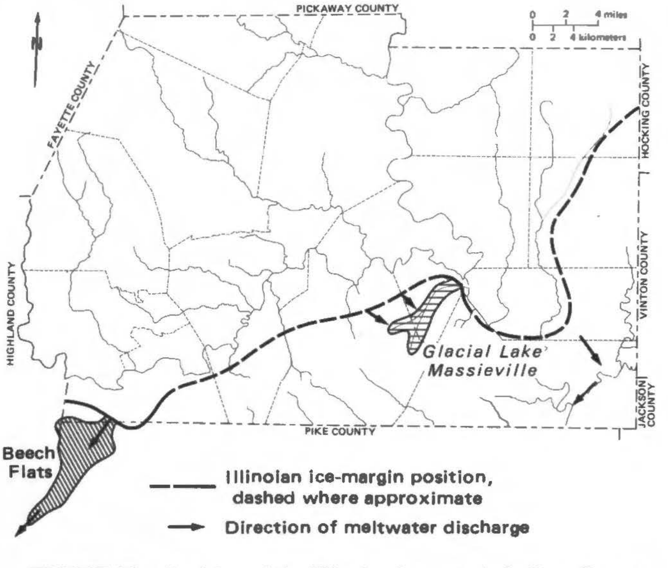


FIGURE 23.—Position of the Illinoian ice margin in Ross County during formation of the Beech Flats lacustrine plain and Glacial Lake Massieville.

Another Illinoian ice-margin position is defined by ice-contact features in the Paint Creek valley and the northern limit of higher level Higby Outwash east of Chillicothe (fig. 24). Ice stagnation occurred along the southern bedrock margin of the Paint Creek valley. The southerly regional slope caused the concentration of meltwater discharge and deposition of stratified drift along the southern edge of the valley. The stagnant ice mass may have been isolated from the main portion of the Illinoian ice sheet by an ice-free, thin-till-covered upland north of the Paint Creek valley.

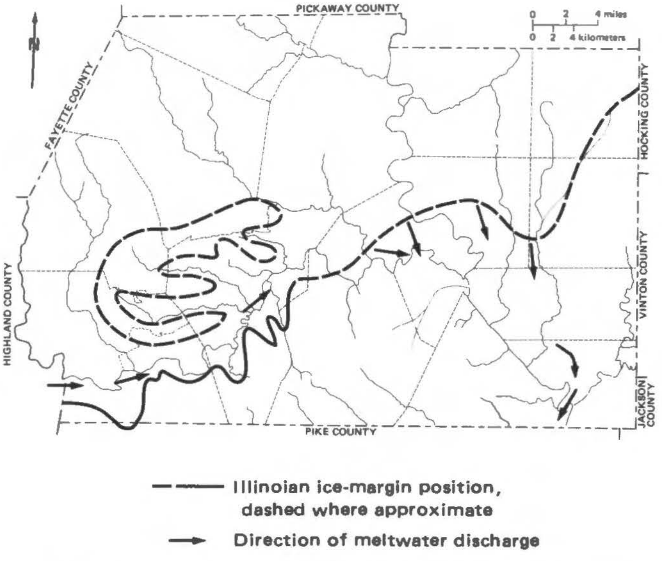


FIGURE 24.—Location of the Illinoian ice margin in Ross County during formation of ice-contact features in the Paint Creek valley and the higher Higby Outwash level in eastern Ross County.

The lack of Illinoian ice-contact deposits in eastern Ross County indicates a more active mass-balance regimen during ice-margin recession and less topographic control over deglaciation in comparison to the transverse Paint Creek valley. The recessional position in eastern Ross County may be correlative with deposition of kames in the Paint Creek valley (fig. 24) and is delimited by the northern edge of the higher Higby Outwash level and a possible kame terrace east of Chillicothe. This Illinoian ice-margin position during outwash deposition may be the equivalent of the Centerville Stade (Gooding, 1963). A minor Illinoian ice advance after deposition of the higher level Higby Outwash is indicated by the patchy cover of thin till on the outwash in portions of

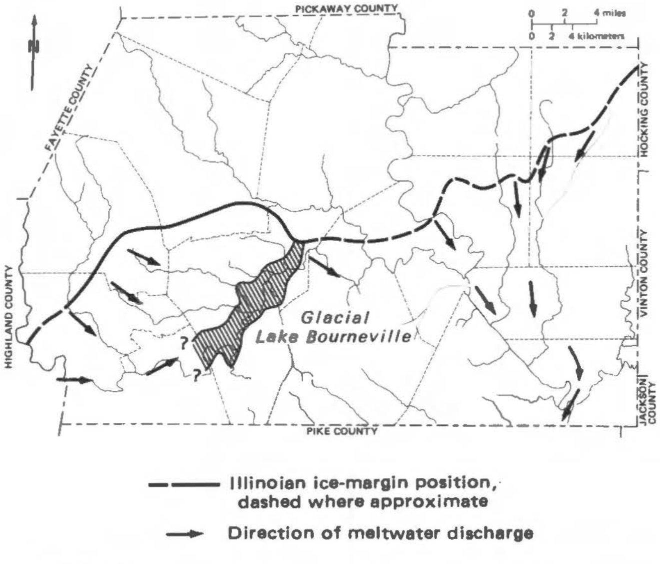


FIGURE 25.—Location of the Illinoian ice margin in Ross County during formation of Glacial Lake Bourneville, the Alum Cliffs diversion, and the lower level Higby Outwash in eastern Ross County.

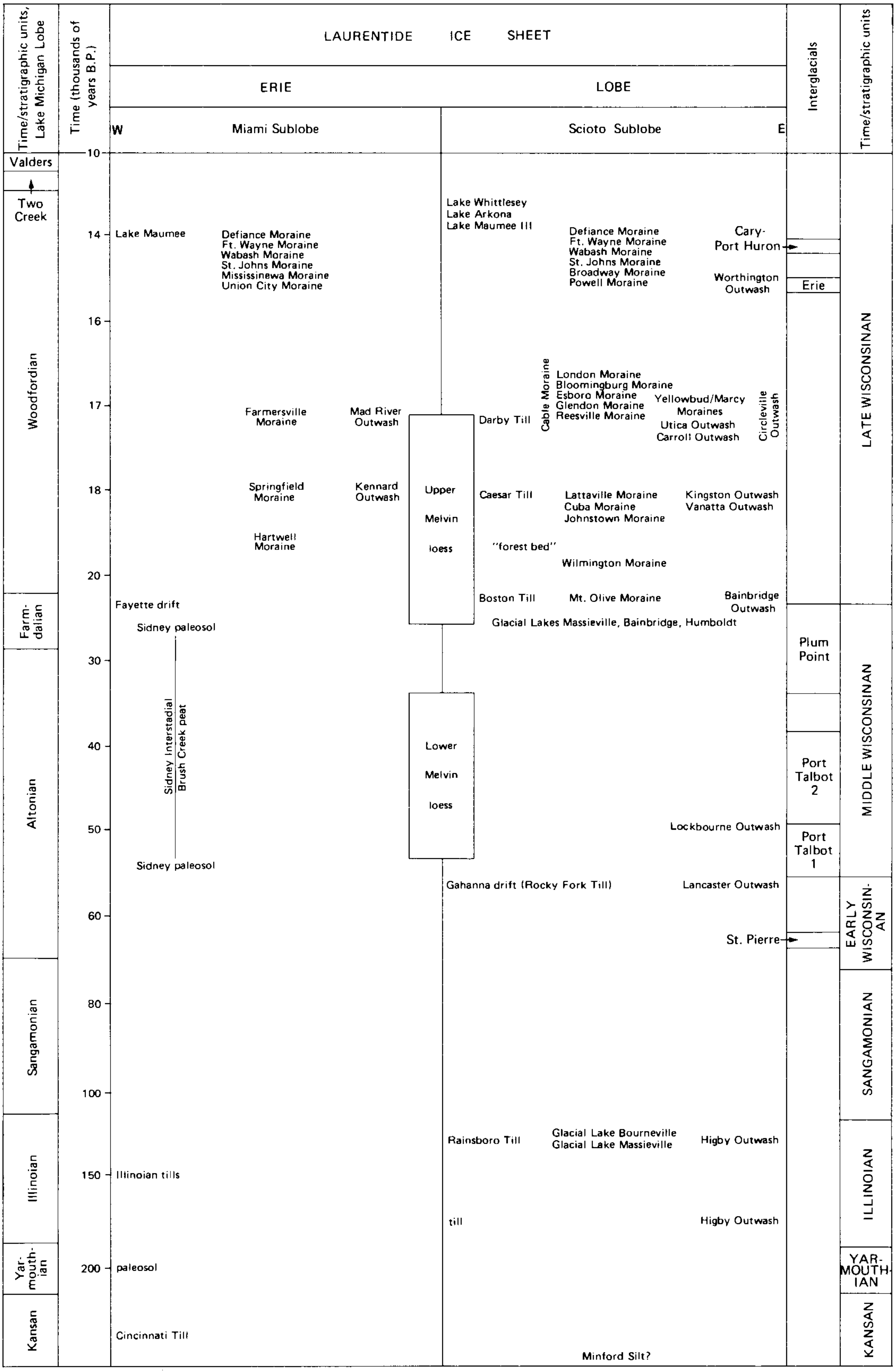


FIGURE 26.—Correlation chart of the glacial deposits of the Miami and Scioto Sublobes of the Laurentide ice sheet in Ohio (modified from Dreimanis and Goldthwait, 1973, figs. 3 and 4).

Springfield Township. Areas of higher topography in eastern Ross County probably emerged as thin-drift-covered nunataks during early stages of deglaciation. Throughout Illinoian recession, Teays- and Deep-Stage drainage lines were used as major spillways for meltwater discharge and outwash accumulation.

As disintegration continued in the isolated ice mass in the Paint Creek valley, the main Illinoian ice sheet retreated to a new position along the plateau escarpment in western Ross County and near the head of the lower Higby Outwash northeast of Chillicothe (fig. 25). Outwash deposition in the Buckskin Creek, Upper Twin Creek, and Plug Run valleys of western Ross County was initiated during retreat to this ice-margin position. Illinoian ice in the Schotts Bridge-Slate Mills area probably blocked northeasterly meltwater drainage in the Paint Creek valley to form Glacial Lake Bourneville at this time. The impounded meltwater eventually rose to the elevation of the lowest col in the southern bedrock margin of the valley. Downcutting at the lake outlet through easily eroded shale created the Alum Cliffs gorge. Following retreat from the ice-dam position, the northeasterly drainage trend through the Slate Mills region may have been reestablished, with abandonment of the newly formed Alum Cliffs gorge drainageway.

The lower Higby Outwash (Richmond Stade equivalent?, Gooding, 1963) was deposited in the Walnut Creek, Little Walnut Creek, and Dry Run valleys of eastern Ross County simultaneously with the formation of Glacial Lake Bourneville (fig. 25). The presence of shallow kettles in the pitted plain in the old Teays valley west of Londonderry attests to the proximity of the ice sheet and rapid sedimentation during outwash deposition. No surficial Illinoian deposits have been identified north of the plateau escarpment to delineate subsequent Illinoian ice-margin recessional positions.

WISCONSINAN GLACIAL STAGE

The Wisconsinan Stage began following the Sangamonian Interglacial (*circa* 120,000-73,000 years B.P., Suggate, 1974), a period of erosion and deep soil development (fig. 26).

Early Wisconsinan Substage

Early Wisconsinan (Altonian, *circa* 73,000-55,000 years B.P.) ice did not advance into the southern part of the Scioto Sublobe, as was proposed by Goldthwait and others (1965) and Petro and others (1967) on the basis of pedologic and stratigraphic relationships in Highland, Clinton, and Ross Counties. The main Early Wisconsinan glacial advance of the Erie Lobe occurred after the well-documented St. Pierre Interstade (*circa* 67,000-63,000 years B.P. in the St. Lawrence River valley). This ice advanced into central Ohio (Goldthwait and Forsyth, 1965; Goldthwait and Rosengreen, 1969), depositing the Gahanna drift (Rocky Fork Till) near Columbus (Franklin County), the tills below the paleosol at the Sidney cut (Shelby County) (La Rocque and Forsyth, 1957; Forsyth, 1965) in west-central Ohio, and perhaps the intermediate-level Lancaster Outwash in the Hocking River valley (Kempton and Goldthwait, 1959). Probable correlatives (Dreimanis and Goldthwait, 1973) of the Gahanna drift include: (1) Olean drift south of Lake Ontario (Dreimanis, 1960; Denny and Lyford, 1963; Connally, 1964; Muller, 1965); (2) Sunnybrook, Canning, and Upper Bradtville Tills of southern Ontario; and (3) Whitewater Till (Gooding, 1963) of southeastern Indiana.

Relict truncated profiles (Sidney Interstadial soils) developed in gravel (*e.g.*, Lockbourne Outwash) indicate the Early Wisconsinan Substage was terminated by rapid downwastage and disintegration of the ice mass without construction of typical morainic forms (Dreimanis and Goldthwait, 1973). The palimpsest end moraines of north-central Ohio (Totten, 1969) may be an exception.

Middle Wisconsinan Substage

There are no Middle Wisconsinan (middle or late Altonian, *circa* 55,000-23,000 years B.P.) glacial deposits in Ohio. Middle Wisconsinan features in Ohio include (1) a paleosol (Sidney Interstadial soil) at the Sidney cut (La Rocque and Forsyth, 1957), (2) the Brush Creek peat (22,000-50,000 years B.P.; Forsyth, 1965) near the Sidney cut, (3) paleosol remnants at several localities in central and western Ohio (Goldthwait, 1958; Goldthwait and others, 1965), and (4) lower Melvin loess (Goldthwait, 1968).

Dreimanis and Goldthwait (1973) indicated that the portion of the Melvin loess stratigraphically beneath the Caesar Till (Lattaville/Cuba Moraine, *circa* 18,000 years B.P.) was deposited about 35,000 years B.P. This loessial episode may relate to the Middle Wisconsinan glacial interval between the Plum Point and Port Talbot 2 Interstadials (fig. 26). However, as no Middle Wisconsinan source material is present in Ohio, the lower Melvin loess may relate to silt deposition in association with the late Early Wisconsinan Gahanna drift and Lockbourne Outwash (*circa* 55,000 years B.P.).

Late Wisconsinan Substage

Evidence of the initial ice-sheet advance (*circa* 21,500 years B.P.) following the Middle Wisconsinan (Sidney) interstadial is found primarily in the Paint Creek and tributary valleys. This earliest Late Wisconsinan advance represents the maximum extent of Wisconsinan ice in the Scioto Sublobe (fig. 27).

A small sublobe advanced down the Scioto River valley, forming the striae on shale near Renick and damming the Indian Creek valley to form the Wisconsinan phase of

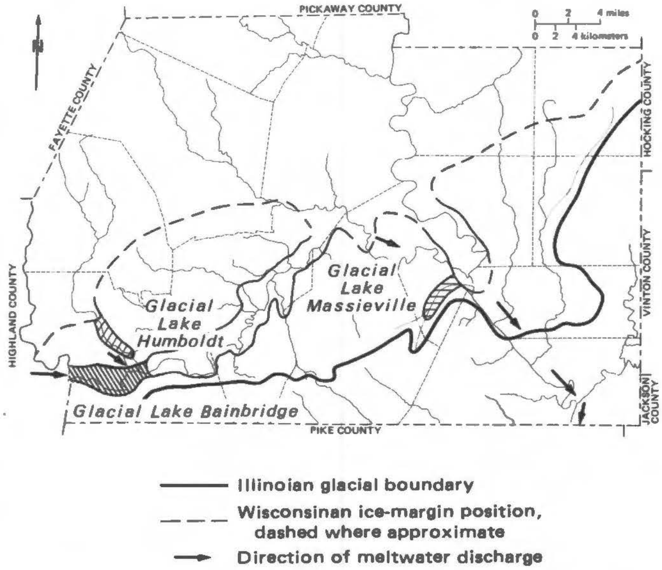


FIGURE 27.—Location of the Late Wisconsinan ice margin in Ross County at its maximum position during deposition of Boston Till and formation of Glacial Lakes Humboldt, Bainbridge, and Massieville (*c.* 21,500 years B.P.).

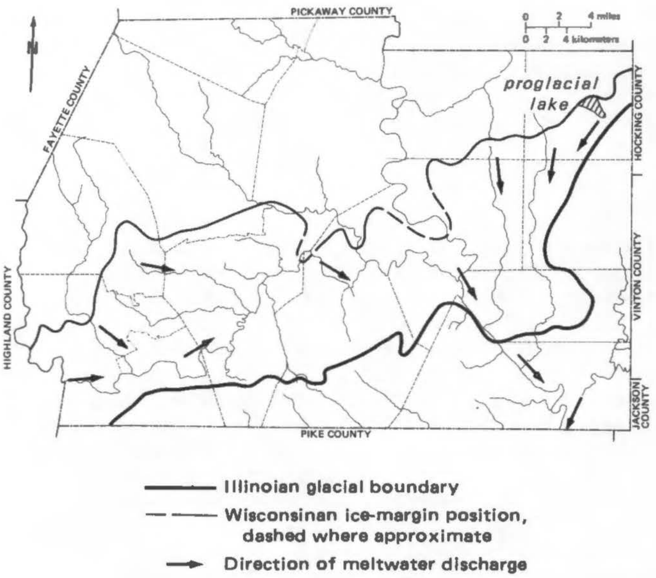


FIGURE 28.—Location of the Late Wisconsinan ice margin in Ross County during formation of the Lattaville Moraine (*c.* 18,000 years B.P.).

Glacial Lake Massieville. The areal distribution of varved silt and clay in the valley indicates that this proglacial lake was much more extensive during the Illinoian than in the Late Wisconsinan. No till deposits of this minor sublobe are known. During recession from this position, meltwater discharged down the Scioto River valley, completing the cutoff of the Teays River valley which had been initiated by the Deep-Stage Newark River.

At the same time, an ice tongue from the main ice mass in the Slate Mills area advanced up the Paint Creek valley. This minor sublobe deposited the compositionally and texturally distinctive Boston Till in valleys tributary to the Paint Creek valley. At its maximum point of advancement near Bainbridge, the ice mass dammed the easterly drainage to form Glacial Lake Bainbridge. Meltwater from this ice mass coupled with discharge from the main ice sheet in Highland County deposited the intermediate-level Bainbridge Outwash. This outwash was probably a local source of upper Melvin loess. Correlative deposits and features include the Mt. Olive Moraine of Highland County and the northeast-southwest striae on the Brassfield Limestone surface in northwestern Greene County, which are transected by younger northwest-southeast striae (Dreimanis and Goldthwait, 1973).

This earliest Late Wisconsinan advance also blocked northward drainage in the Buckskin Creek valley near Humboldt to form Glacial Lake Humboldt. The unique molluscan assemblage (Reynolds, 1959) of the Humboldt deposit accumulated in the sediments of this proglacial lake.

In the Scioto River tributary valleys whose drainage basins did not extend to the area of actual glaciation, alluvial and colluvial silt and clay accumulated as inwash and backwater deposits. Remnants of these deposits typically are found on the lower flanks of Higby Outwash terraces. Such deposits occur in the valleys of Indian Creek, Toad Hollow, Coon Hollow, Snake Hollow, Stony Creek, Sandy Bottom, Wilson Run, Lick Run, Dry Run, Walnut Creek, Salt Creek, and Little Salt Creek.

Following a retreat of unknown extent, the Scioto Sublobe readvanced (*circa* 18,000 years B.P.) (fig. 28) to a position generally coincident with the northern margin of the Appalachian Low Plateau. A readvance is indicated by the presence of a "forest bed" (dated at 19,800-20,910 years B.P. in Highland and Clinton Counties) beneath Caesar Till. Logs up to 8 inches in diameter were incorporated by the readvancing ice sheet and are presently exposed in basal Caesar Till in the valleys of Anderson Run and Bier's Run.

The extensive, composite Lattaville Moraine was constructed along the plateau-escarpment margin during this interval. The ice mass extended onto the upland surface only in the area between Lattaville and Musselman. At this time in the western portion of the Scioto Sublobe the Cuba, Xenia, and Springfield Moraines were constructed. The numerous ice-contact deposits associated with the Lattaville Moraine indicate large areas of ice-mass stagnation along the escarpment, probably during early stages of deglaciation.

The readvance at 18,000 years B.P. penetrated up the Paint Creek valley only to the area of Schotts Bridge. Local ice-sheet stagnation occurred, with resultant deposition of the large kame complex west of Slate Mills. These deposits permanently deflected the general northeasterly drainage of Paint Creek through the Alum Cliffs gorge, which had formed as an outlet spillway of Illinoian Glacial Lake Bourneville. A minor oscillation or readvance of the ice mass deposited the thin cover of Caesar Till over much of this group of ice-contact deposits.

During retreat from the Lattaville Moraine position, the highest level of Late Wisconsinan outwash, the Kingston Outwash, was deposited. Outwash accumulated in the valleys of Paint Creek, Lower Twin Creek, North Fork, the Scioto River, Walnut Creek, Little Walnut Creek, and Dry Run. The loess-covered Kingston Outwash is probably correlative with the silt-capped Kennard Outwash of the Little Miami River valley (Quinn, 1972; Quinn and Goldthwait, 1979) and the Vanatta Outwash of the Licking River valley (Jones, 1959). The silt cover on these outwash units indicates deposition of the upper Melvin loess continued during this period. During ice-margin recession from the Lattaville

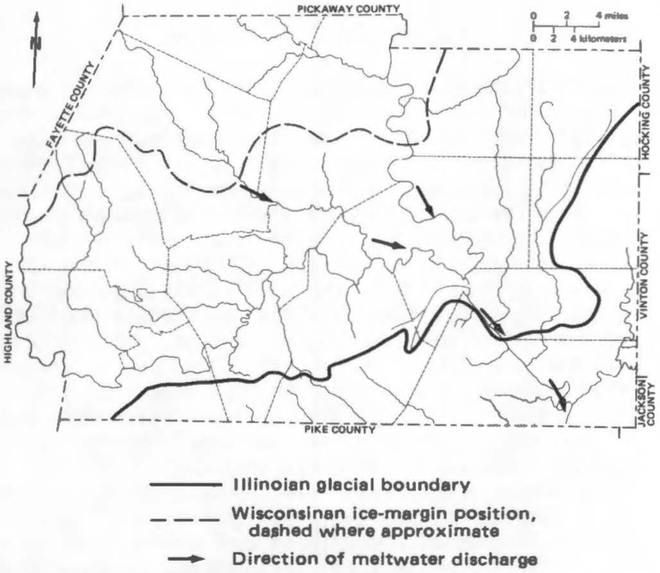


FIGURE 29.—Location of the Late Wisconsinan ice margin in Ross County following readvance to the Reesville Moraine position (*c.* 17,200 years B.P.).

Moraine, the Caesar Till ground moraine of northwestern and western Ross County was deposited.

Following an ice-margin retreat of at least 15 miles from the Cuba-Xenia Moraine in Greene, Clinton, and Highland Counties (Goldthwait, 1974), the Scioto Sublobe readvanced to the Reesville Moraine position (fig. 29) about 17,200 years B.P. Several lines of evidence suggest that this readvance may have taken the form of a sublobe surge: (1) lack of drift accumulations along portions of the ice-margin position, (2) anomalous concentration of boulders (correlative to the Farmersville Moraine and boulder belt in the Miami Sublobe) similar to the tenuous drift deposits of recently surging glaciers (Goldthwait and Rosengreen, 1969), and (3) the short time interval (about 800 years) between the construction of the Lattaville Moraine (*circa* 18,000 years B.P.) and readvance to the Reesville Moraine (*circa* 17,200 years B.P.).

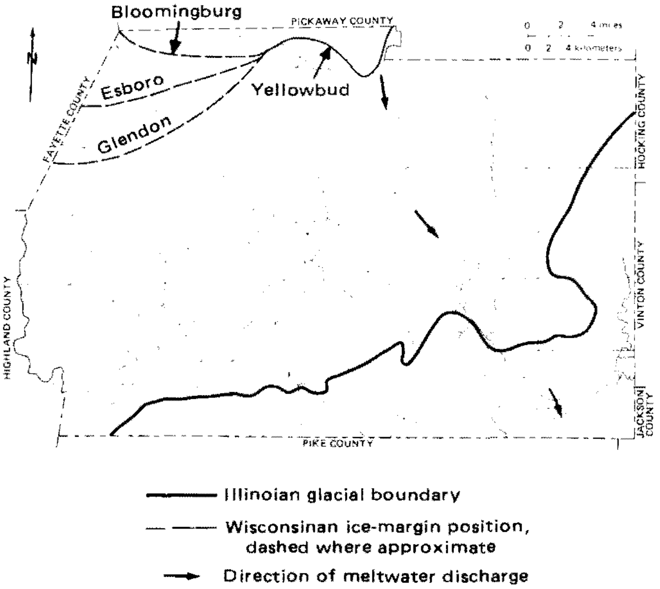


FIGURE 30.—Location of the Late Wisconsinan ice margin in Ross County during deposition of the Circleville Outwash and formation of the Yellowbud Moraine.

Darby Till was deposited over the northwestern quarter of Ross County in association with the Reesville position. This till overlies Wisconsinan ice-contact deposits in a narrow zone along the eastern margin of the Scioto River valley north of Hopetown, delineating the eastern limit of the readvance. Only in the area south of Roxabell did this readvance penetrate as far south as the Lattaville Moraine. Local stagnation in the Roxabell area during deglaciation produced a complex of ice-contact features. Southeasterly meltwater drainage down the North Fork valley from the Roxabell region deposited the initial phase of Circleville Outwash. Meltwater discharge during the early stages of recession from the Reesville Moraine cut the loess-free lower level Kingston Outwash near Kinnikinnick. The lack of silt cover on the Darby Till and Circleville Outwash indicates deposition of upper Melvin loess ceased by 17,000 years B.P.

The main episode of Circleville Outwash deposition occurred about 17,000 years B.P. while the Late Wisconsinan ice margin stood in a recessional position at the Marcy Moraine near Circleville and the Yellowbud Moraine in north-central Ross County (fig. 30). Correlative position in

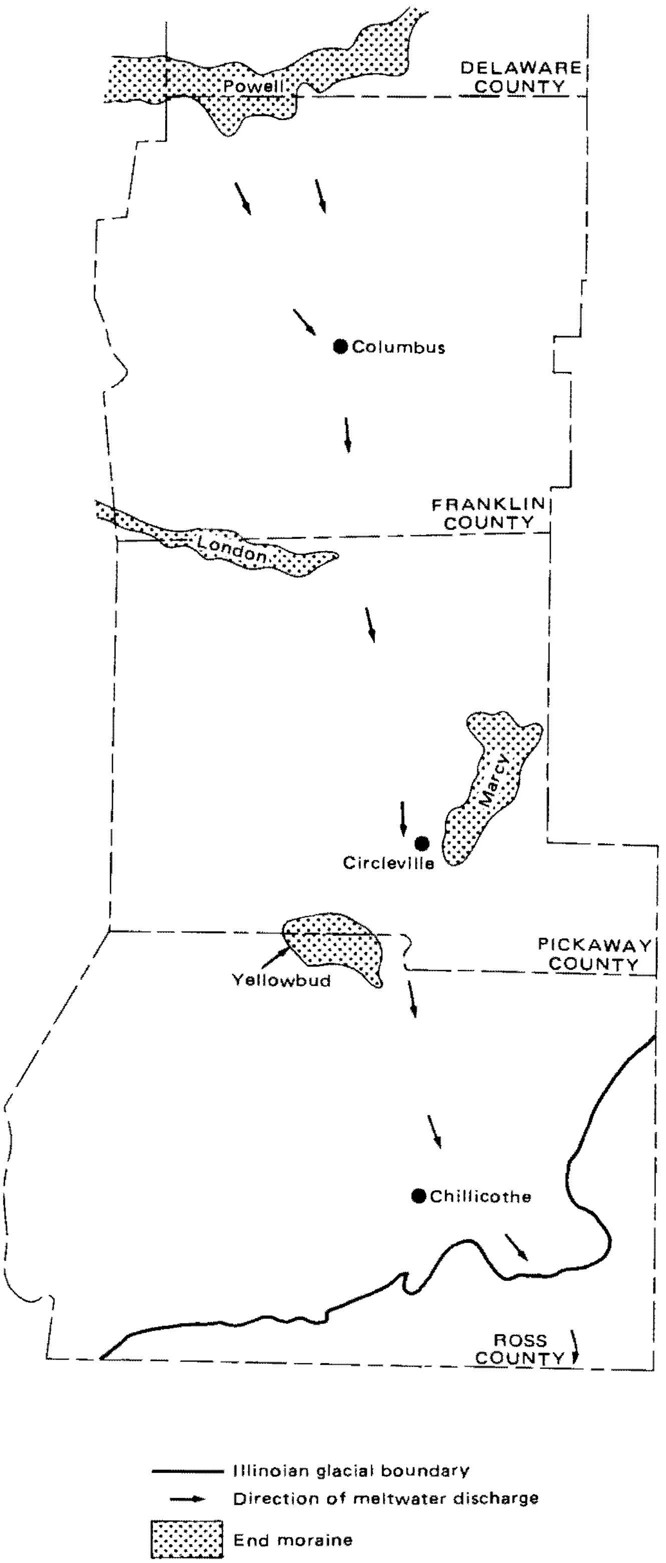


FIGURE 31.—Map of the Scioto Sublobe in central Ohio showing the areal relationships of the Wisconsinan ice-margin position at the Powell Moraine during deposition of the Worthington Outwash (*c.* 15,000 years B.P.).

the western Scioto Sublobe may be the Glendon, Esboro, or Bloomingburg Moraines (composite Cable Moraine in Champaign County, Quinn, 1972; Quinn and Goldthwait, 1979). The lower Deer Creek and Scioto River valleys served as spillways for meltwater discharge and outwash deposition. Similar loess-free outwashes were deposited synchronously in the Great Miami River valley (Mad River Outwash), Hocking River valley (Carroll Outwash), and Licking River valley (Utica Outwash).

Subsequent ice-margin retreat produced the Darby Till plain (The Prairie) of Ross and Pickaway Counties. A short halt during general recession (*circa* 16,500 years B.P.) allowed construction of the London Moraine of northwestern Pickaway County and southwestern Franklin County.

The Erie Lobe then retreated into the Erie basin, where an extensive proglacial lake developed during the Erie Interstade (Mörner and Dreimanis, 1973). About 15,000 years B.P. the lobe readvanced, incorporating the lacustrine sediments which had accumulated in the proglacial lake. The resultant unique fine-textured tills were deposited as far south as the Powell and Union City Moraines. While the Scioto Sublobe stood at the Powell Moraine (fig. 31), the lowest level Late Wisconsinan outwash, the Worthington Outwash, was deposited down the Scioto River valley. This loess-free outwash is the youngest glacial deposit in Ross County.

Postglacial modifications of the Ross County drift deposits include (1) extensive gullying on higher outwash terraces and end moraines; (2) deposition of low-lying, thin, silty, alluvial terraces overlying gravel outwash terraces, and (3) erosion of outwash terraces and associated formation and abandonment of a series of stream channels on the valley-fill surface.

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STATE OF OHIO
Richard F. Celeste, Governor
DEPARTMENT OF NATURAL RESOURCES
Lt. Gov. Myrl H. Shoemaker, Director
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

GLACIAL GEOLOGY OF ROSS COUNTY, OHIO

by Michael J. Quinn
and Richard P. Goldthwait

1985

EXPLANATION

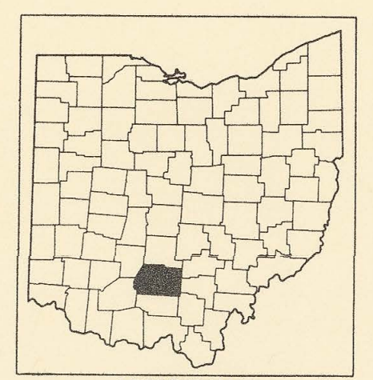
QUATERNARY	Recent	al, alt	Alluvium, alluvial terrace
	Pleistocene, Wisconsinan	Wl	Lacustrine deposit
		Wob, Wok, Woc, Wow, Wot	Outwash. Wob, Bainbridge; Wok, Kingston (may be at more than one level); Woc, Circleville; Wow, Worthington; Wot, erosional terrace
		Wi, Wit (2, 3)	Ice-contact features—kames, kame terraces, eskers. Wit, ice-contact feature overlain by till
		Wg (1, 2, 3, 4)	Ground moraine
		We (2, 3, 4)	End moraine. *Areas of kame moraine shown by overprint*
	Pleistocene, Illinoian	Il	Lacustrine deposit
		Ii	Ice contact features—kames
		Io	Outwash (Higby Outwash)
		Ig	Ground moraine (Rainsboro Till)
	Pleistocene, Pre-Illinoian	pI	Lacustrine deposit (Minford Silt) (Kansan?)

Drift and related end moraines (where applicable)

- 1 Boston Till
- 2 Caesar Till (Lattaville Moraine)
- 3 Darby Till (Reesville Moraine)
- 4 Darby Till (Yellowbud Moraine)

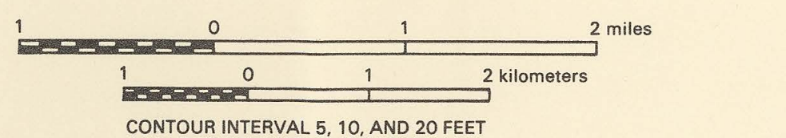
——	Boundary of deposit, *dashed where approximate*
— — ——	Distal boundary of Reesville Moraine, *dashed where approximate*
—— ——	Boundary of a major glacial advance (stage), *dashed where approximate*
—700—	Contour on bedrock surface. *Contour interval 100 feet. Contours shown only within mapped glacial drift and alluvial deposits. Drift may be very thin on the uplands so that bedrock is at or very near the surface*
⚒	Gravel pit

NOTE: Steep valley walls and upland areas may be bedrock in part, but are mapped with contiguous glacial materials


LOCATION MAP

BASE COMPILED FROM THE FOLLOWING 1:24,000 U.S.
GEOLOGICAL SURVEY TOPOGRAPHIC QUADRANGLE MAPS

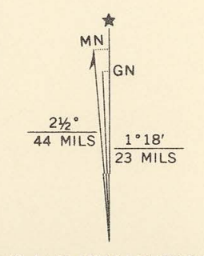
Andersonville (1961)
Bainbridge (1961)
Bourneville (1961)
Chillicothe East (1961)
Chillicothe West (1971)
Circleville (1971)
Clarksburg (1974)
Frankfort (1974)
Good Hope (1960)
Greenfield (1960)
Hallsville (1961)
Kingston (1961)
Laurelville (1975)
Londonderry (1961)
Morgantown (1961)
New Holland (1961)
Rainsboro (1961)
Ratcliffsburg (1975)
Richmond Dale (1961)
South Salem (1961)
Summithill (1974)
Waverly North (1975)
Williamsport (1961)



CONTOUR INTERVAL 5, 10, AND 20 FEET
DATUM IS MEAN SEA LEVEL

10,000-foot grid based on Ohio coordinate system, south zone
Areas outlined by light-blue dashes are subject to controlled inundation

CONTOURS ON BEDROCK SURFACE BY JOEL D. VORMELKER
JAMES A. BROWN, CARTOGRAPHER



UTM GRID AND 1971 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET