Glacial Geology of Crawford County, Ohio

by
Stanley M. Totten

Open-File Report 87-1
Columbus 2018

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Graphic design & layout: David S. Orr

Cover image: Hand-drafted map of the glacial geology of Crawford County, Ohio, by Stan Totten.

Recommended bibliographic citation: Totten, S.M., 1987 [2018], Glacial geology of Crawford County, Ohio: Columbus, Ohio Department of Natural Resources, Division of Geological Survey Open-File Report 87-1, 89 p., 21 figs., 3 tables, 1 pl., 2 appendices.

FOREWORD

Stan Totten worked on both his M.S. and Ph.D. with Dr. George White who was at the University of Illinois in Champaign-Urbana. Together, they spent every summer in the 1960s and early- to mid-1970s field mapping glacial geology in Ohio, one county at a time. As White's health declined during the late 1970s, Totten's role increased.

After graduation from the University of Illinois, Totten taught at Hanover College in southern Indiana. While teaching at Hanover College, he continued working summers for the Ohio Geological Survey mapping about one county each year. He conducted fieldwork each summer and then wrote the report and manuscript during the school year. Totten was dedicated, often working 12-hour days all summer to complete the fieldwork.

Lab analysis on samples collected in the field were conducted by either the Survey's sedimentology lab in Columbus, by John Szabo at the University of Akron, or by Totten's students at Hanover College.

Four mapping staff members joined the Survey during 1983–1984, along with a lab technician for the sedimentology lab, to form a Quaternary mapping subsection within the Regional Geology Section. Three of the new staff members, Rene Fernandez, Rick Pavey, and I, were assigned Seneca, Erie, and Sandusky Counties, respectively, in western north-central Ohio.

During the early 1980s, Totten was assigned to map several counties in eastern north-central Ohio, essentially an area between that previously mapped by White and Totten in northeastern Ohio and that being mapped by the newer staff members. Totten was tasked with extending westward the stratigraphic nomenclature used for the eastern Killbuck Lobe in Ashland, Medina, and Richland Counties, linking with mapping being done by the Quaternary mapping subsection. He mapped Crawford, Hardin, Huron, Lorain, Marion, and Morrow Counties during this period. Additional impetus for mapping in Morrow County was the result of research done for the field trip guidebook for the 1987 Midwest Friends of the Pleistocene Field Conference, which centered on Knox, Morrow, and Richland Counties.

Totten produced manuscript reports and draft maps (at a scale of 1:62,500) for each of these counties. The original goal was to publish a report of investigations for each county map and report that Totten produced, as well as the county maps and reports being produced by the Quaternary mapping subsection.

The maps and manuscripts were left unpublished for a number of reasons:

- The Survey encountered funding problems during the late 1980s, and the printing process was very expensive for both the maps and bound reports.
- The cartographic work for producing the maps was totally manual and involved an elaborate process of creating photographic negatives for base maps, peel-coats, scribing, type-setting and other steps that took a team almost a year to produce one map. And since there was inadequate cartographic staff to produce the maps and reports, this level of detail and completion was not provided for all the counties.
- Totten's ability to create tables, captions, and figures was very limited by the technology of that time, thus all this work fell on the editorial and graphics section.
- USGS funding supported reconnaissance-level mapping at a regional scale, and the concept of county-based maps and reports was abandoned by the Survey in favor of 30 x 60-minute quadrangle-based mapping initiatives. This was done to meet USGS standards being introduced nationally at that time.

It should be noted that these maps and reports are scanned as-is and may include typos, errors, editorial notes, and other marks. Maps are largely hand-colored and may represent the "final" of several versions. Legends accompanying the maps also may be hand-colored.

The Survey feels that these manuscripts may be of value to the public, academia, and perhaps consulting/geotechnical geologists. The reports contain a tremendous amount of particle size and mineralogical data and in-depth discussions of the materials and stratigraphy. The maps depict only the uppermost surficial materials and geomorphology, and they are very detailed. The maps and reports are of value to those who might need info on the background geology of a specific county, are doing detailed work in the county, or have a keen interest in the glacial geology of north-central Ohio.

Mike Angle
May 24, 2017

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by

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1987

Original

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INTRODUCTION

Crawford County is located in north-central Ohio about 45 miles north of Columbus and 33 miles south of Lake Erie (fig. 1). The county is bounded on the north by Seneca and Huron counties, on the east by Richland County, on the south by Morrow and Marion counties, and on the west by Wyandot County. The county lies between 82°43'30" and 83°07' west longitude, and 40°42' and 40°59'30" north latitude. It is a medium-sized county, with nearly square dimensions of about 21 miles east to west and about 20 miles north to south, for a total area of 404 square miles and 258,560 acres. It is largely rural with a population (1980 Census) of 50,075 which represents a slight decrease of 289 since the 1970 Census. The county seat is Bucyrus (pop. 13,433). Other major cities or towns are Galion (pop. 12,391) and Crestline (pop. 5392). The larger villages include New Washington (pop. 1213), Chatfield (pop. 228), Tiro (pop. 279), and North Robinson (pop. 302). Agriculture accounts for about 90 percent of the land use in the county; however the manufacturing, retailing, and transportation industries employ larger number of people than does farming (Bartrop, 1974).

Topographic map coverage is included on the following 7½ minute maps: Blooming Grove, Bucyrus, Caledonia, Chatfield, Crestline, Galion, Lykens, Monnett, New Washington, North Robinson, Oceola, and Shelby.

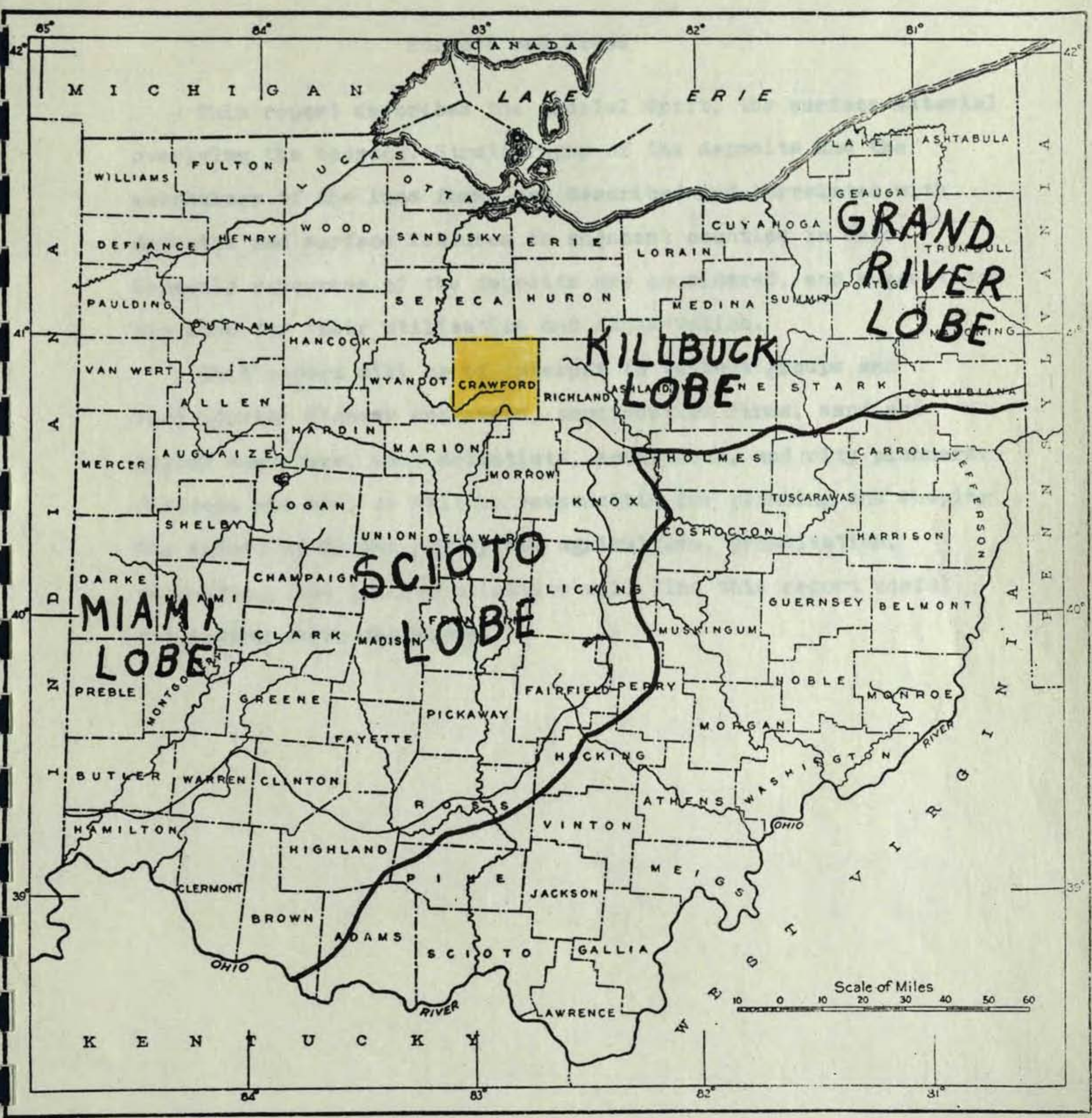


Figure 1. Map showing location of Crawford County, glacial boundary (heavy line), Woodfordian drift boundary (light line), and glacial lobes.

Purpose and Scope

This report describes the glacial drift, the surface material overlying the bedrock. Stratigraphy of the deposits and the morphology of the land forms are described and correlated with deposits and surface features in adjacent counties in Ohio. Economic resources of the deposits are considered, and suggestions are made for their utilization and conservation.

This report will be of interest to various groups and individuals: Highway engineers, construction firms, sand and gravel operators, soil scientists, architects, and city planners. Citizens who are, or will be responsible for planning and shaping the future of Marion County for agriculture, urbanization, recreation, and industrialization will find this report useful for making their decisions.

Acknowledgments

This report is based on a detailed field study conducted in 1983. Supplementary materials useful in preparing this report included air photos, water well records, and soil maps. Till samples were analyzed at the University of Akron under the supervision of John Szabo. Drift thickness and top-of-rock maps were prepared by Mac Swinford primarily from water well records. Dennis Hull of the Geological Survey provided valuable support and encouragement in the development of this report.

Previous Investigations

The earliest report on the geology of Crawford County was by Winchell in 1874 (p. 235-252) who described the surface features, drift, bedrock, and economic deposits. Winchell stressed the bedrock in his report and he included valuable data regarding the rocks exposed in several quarries in the county.

Leverett (1902) in his monograph on the Erie Glacial Lobe mentioned Crawford County glacial features in brief terms. Leverett's (1902, Plate 13) glacial map of the Scioto Lobe showed a distribution of moraines in Crawford County that bears a close resemblance to the map (Plate 1) included with this report. Leverett's (1902) moraine mapping was revised by White (1935, 1939) and incorporated in the Glacial Map of Ohio (Goldthwait and others, 1961). The drainage history of Crawford County was included in reports by Ver Steeg (1934), White (1934), Coffey (1958), and Stout and others (1943). The principal sources of information regarding water supply are the report by Stout and others (1943) and the map by Schmidt (1981). Peat deposits in Crawford County have been described by Dachnowski (1912, p. 45-47), areas of shallow bedrock pertaining to quarrying of limestone and dolostone have been described by Stith (1973), and the economic resources have been described by Hall and Alkire (1956). The detailed soils report by Steiger and others (1979) is a useful reference in the study of the surficial materials. A study of the Pleistocene geology of Crawford County was made by Gregory (1956) who mapped the geomorphic features and described the drift exposed in quarries, road cuts, and stream cuts.

Reports on adjacent counties provide information on glacial deposits at or near the margin of Crawford County. There are reports on Seneca County (Echelbarger, 1978; Fernandez, in preparation) and Huron County (Campbell, 1955; Totten, in manuscript) to the north, Richland County, (Totten, 1973) to the east, Morrow County (Totten, in manuscript) and Marion County (Totten, in manuscript) to the south, and Wyandot County (Fernandez, in preparation) to the west.

PHYSIOGRAPHY

Topography

Crawford County has a varied topography that ranges from flat to gently rolling to moderately steep in a few places. The flat surfaces are the former lake bottoms of Lake Willard, Lake Cranberry, and Lake Shelby in the eastern and northeastern portions of the county. Most of the county is characterized by gently rolling topography with 10 to 20 feet of relief in the distance of one mile. The steepest topography is along valley walls where steep cliffs as much as 30 to 40 feet high may occur.

The topography of Crawford County is controlled mainly by the nature of the glacial deposits, particularly the end moraines. Seven end moraines which criss-cross the county are characterized by hummocky topography having local relief of 20 to 30 feet. The greatest local relief is near Sulphur Springs in the center of the county where knolls of the Wabash moraine rise about 78 feet above the nearby till plain. Knolls of the Mississinewa moraine rise about 70 feet above the floodplain of the Sandusky River south of Leesville in Jefferson Township. The modern valleys of Sandusky and Olentangy rivers have been entrenched 30 to 40 feet into the glacial drift.

The highest elevation in Crawford County, approximately 1234 feet, is located in the Powell moraine at the southeastern corner of the county. In Jackson and Polk Townships in south-eastern Crawford County the Allegheny escarpment attains elevations in excess of 1200 feet. Both the Powell and Broadway moraines are situated on the westward facing escarpment (fig.3), which

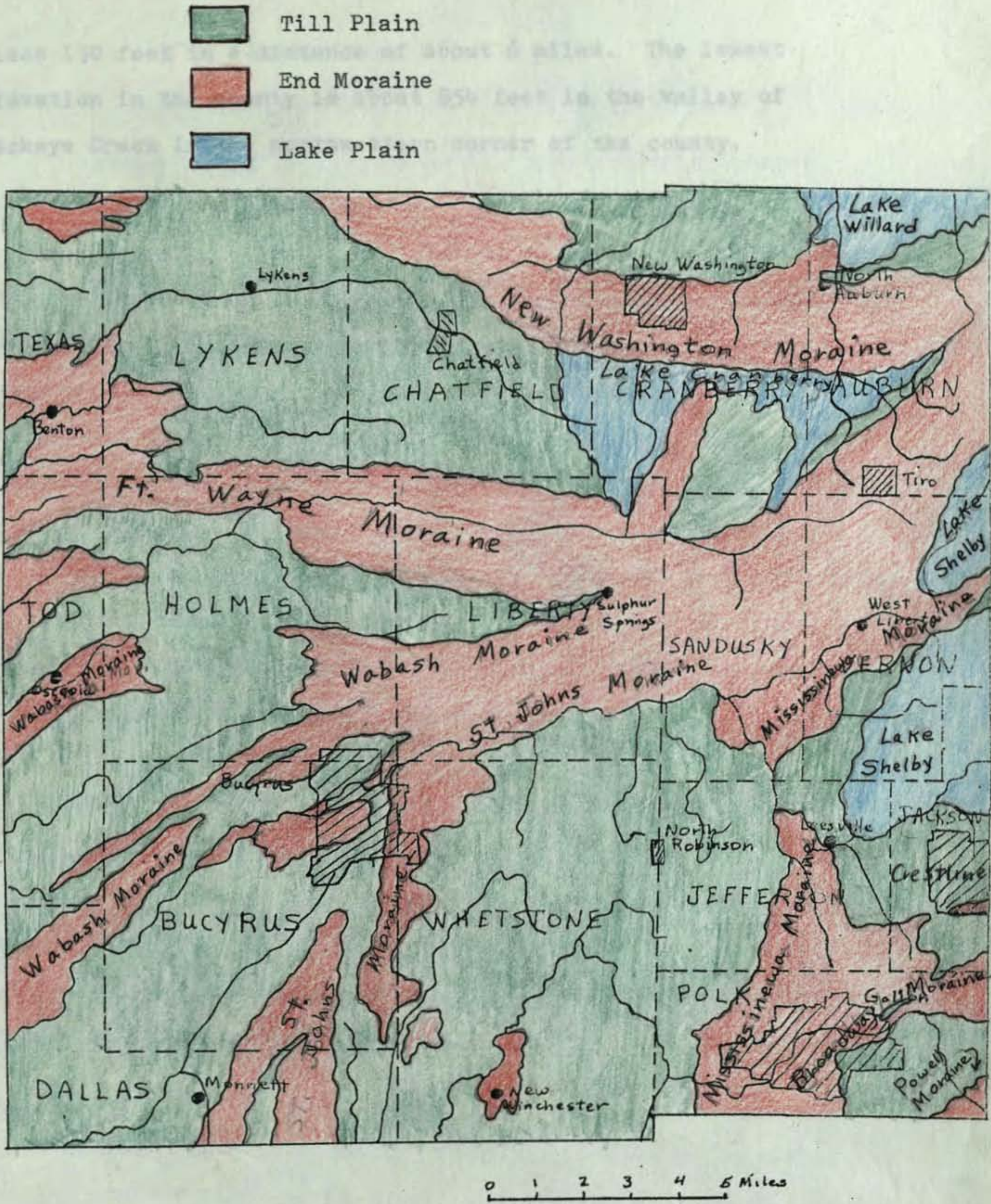


Figure 2. Physiographic divisions of Crawford County, Ohio

rises 150 feet in a distance of about 6 miles. The lowest elevation in the county is about 854 feet in the valley of Buckeye Creek in the northwestern corner of the county.

Physiographic Provinces

General Statement

Crawford County is located at the junction of two major physiographic sections as defined by Fenneman (1928, 1938) and modified by White (1934). The two are the Till Plains Section of the Central Lowland Province in the western and central parts of the county, and the Low Plateau Section of the Allegheny Plateau Section in the eastern part of the county (fig. 3). The Low Plateau, first recognized by White (1934), is a transitional zone between the Till Plains and the Allegheny Plateau; it marks the position of the Allegheny escarpment developed in the relatively resistant sandy rocks of the Cuyahoga Formation and the Berea Sandstone, both of Mississippian age (fig. 6). The boundary between the Till Plains and the Low Plateau follows the contact between the Bedford Shale to the west and the Berea Sandstone to the east.

For this report, local physiographic divisions have been recognized (fig. 2) based on the major glacial features in Crawford County. The main distinction in the classification used in this report is between the hummocky end moraine and gently rolling till plain. In addition the three lake beds are grouped into a third category.

Till Plain

The Till Plain is a smooth, slightly undulating to gently rolling surface that covers about half of Crawford County (fig. 2). Every township contains a portion of Till Plain, and two townships, Lykens and Whetstone, are almost entirely covered by

Till Plain. Relief on the Till Plain varies from 5 to 10 feet in a mile in most places except there streams have entrenched their valleys 20 to 40 feet into the Till Plain surface. The smooth Till Plain surface resulted from several glacial advances during which the bedrock surface was scoured and most preglacial or interglacial valleys were filled with drift. The Till Plain surface is underlain by till typically 10 to 50 feet thick.

End Moraines

Seven end moraines which criss-cross the county in nearly every direction (fig. 2) make up a distinct section of hummocky topography. From north to southeast, the moraines are the New Washington, Ft. Wayne, Wabash, St. Johns, Mississinewa, Broadway, and Powell. These moraines tend to be bunched closely together in the eastern part of the county, and they tend to diverge in the west toward the center of the Scioto lobe. Every township contains a portion of an end moraine, and several townships including Liberty, Sandusky, Vernon, Auburn, and Polk are composed predominantly of end moraine. Topographically, the moraines exhibit great diversity, ranging from broad smooth ridges to sharp knolls and hummocks. In most places the end moraine surface is moderately rolling with hummocks 10 to 30 feet high arranged in a linear or ridge-like manner.

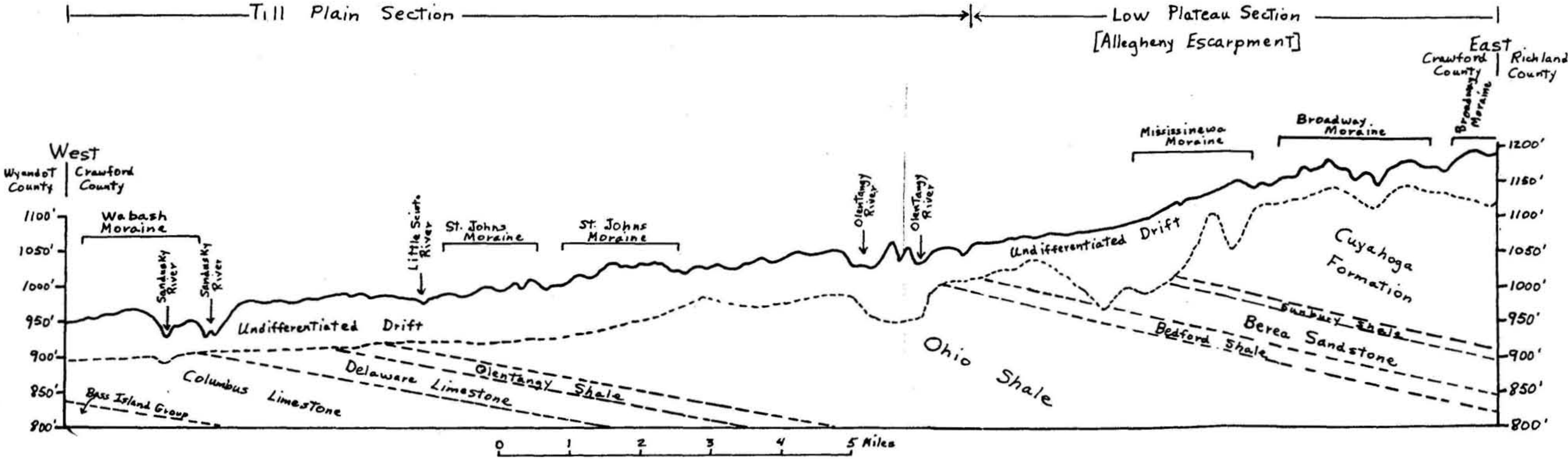


Figure 3. Cross-section of Crawford County at 40°45'30" North Latitude. Dashed line beneath "Undifferentiated Drift" represents the bedrock surface.

Lake Plain

Three major tracts of Lake Plain occur in eastern and northeastern Crawford County. These tracts are the lake beds of Lake Willard in northern Auburn Township, Lake Cranberry in southern Cranberry Township and surrounding areas, and Lake Shelby located primarily in eastern Vernon and northern Jackson Townships (fig. 2). The lake plain surface varies from nearly featureless to gently undulating. In many places, the lake plain surface resembles the till plain surface and the distinction between the two must be made on the basis of material.

Drainage

Modern Drainage

General Statement

Six drainage basins containing small to moderately sized streams occur in Crawford County. These basins are the Honey Creek and Sycamore Creek basins in the northern part of the county, Broken Sword Creek and Sandusky River basins in the central part of the county, and the Olentangy River and Little Scioto River basins in the southern part of the county (fig. 4). All of these major streams except the Olentangy River have their headwaters in Crawford County. A major drainage divide extends in a general east-west direction across the southern tier of townships, separating Lake Erie drainage to the north from Ohio River drainage to the south. The Olentangy and Little Scioto rivers flow south as part of the Ohio River basin whereas the Sandusky River, the major stream in Crawford County, flows northward toward Lake Erie in Wyandot County and collects the drainage of Broken Sword Creek, Sycamore Creek, and Honey Creek.

Although Crawford County streams are small with low discharges, valley development has progressed, especially in the southern part of the county, so that portions of the valley bottoms attain widths of 0.3 to 0.4 mile. In the wider portions of these valleys the streams have extensive meanders, are changing their courses as evidenced by significant oxbow lake development, and are widening their valleys. The maximum entrenchment of any stream in the county, about 40 feet, occurs in the Sandusky River valley near Bucyrus and Leesville.

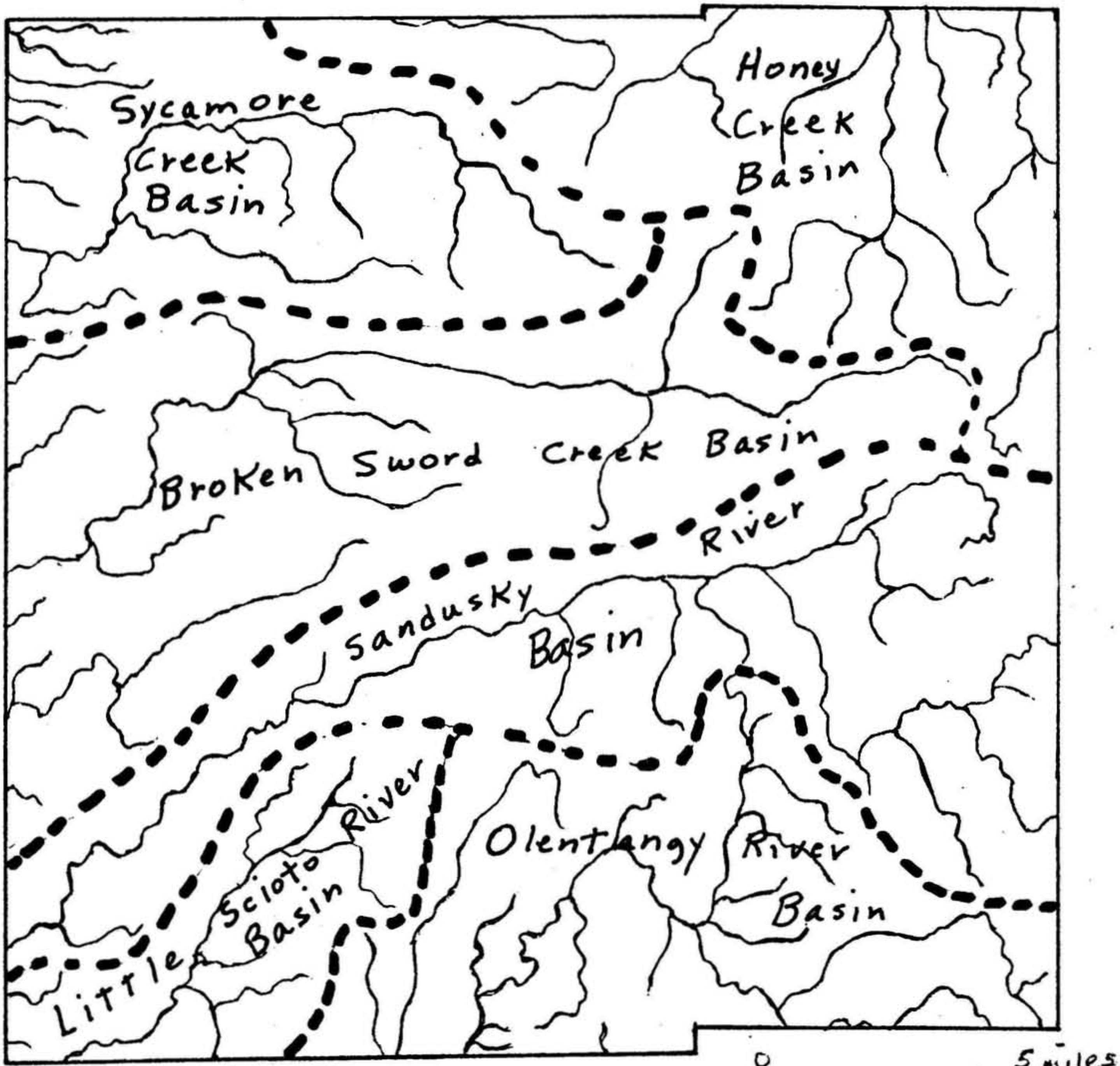


Figure 4. Modern drainage of Crawford County. Drainage divides shown by dashed lines.

Sandusky River Basin

The headwaters of the Sandusky River originate in the hummocky topography of the Broadway moraine about 1 mile north of Galion in the southeastern corner of the county. Paramour Creek and Allen Run join the Sandusky River near Leesville in Jefferson Township to form the largest river in Crawford County. The Sandusky River meanders within a narrow valley as it flows north-northwestward a distance of 6 miles to the southern (distal) margin of the combined St. Johns-Wabash morainic system. At the distal moraine margin, the Sandusky River bends sharply westward and it maintains a west-southwestward course for a distance of about 17 miles to the Crawford-Wyandot County line. Lost Creek, a sizable tributary which follows the narrow depression between the Mississinewa and St. Johns moraines, joins the Sandusky River at the sharp westward bend. Near Bucyrus the river cuts diagonally across the St. Johns moraine as it meanders within a valley as much as 0.3 to 0.4 mile wide. From Bucyrus southwestward to the county line, the Sandusky River valley follows the distal margin of the Wabash moraine. In Wyandot County the river bends sharply northward and follows a northerly course to Lake Erie. All of the drainage in northern Crawford County, including Broken Sword Creek, Sycamore Creek, and Honey Creek drain into the Sandusky River west and northwest of Crawford County.

Although the drainage basin of the Sandusky River (fig. 4) extends from east to west across all of Crawford County, the basin is very narrow from north to south. Tributaries on the north side of the Sandusky River are very small and short as they drain the backslope of the moraine. Tributaries on the south side of the river also are small, but several attain lengths of 3 or 4 miles. The low divide south of the Sandusky River Basin (fig. 4) separates the drainage of Lake Erie and the St. Lawrence River from the Ohio River drainage.

Broken Sword Creek

Broken Sword Creek originates in the high knolls of the Ft. Wayne moraine near Tiro in eastern Crawford County along the Crawford-Richland County line. The stream flows 16 miles westward in a broad depression between two elments of the Ft. Wayne moraine. In western Holmes Township south of Broken Sword Creek, the stream flows southward 2½ miles, and then flows 3 miles southwestward between two elements of the Wabash moraine into Wyandot County. Tributaries of Broken Sword Creek include Red Run, a short stream which enters from the north, and Brandywine Creek which drains part of Holmes Township. All other tributaries are very short. The drainage basin is relatively small for a stream which transects the entire length of the county. Major tributaries are lacking because the elements of the Ft. Wayne moraine which confine the valley of Broken Sword Creek also serve as drainage divides. Consequently it has a low discharge and a relatively narrow floodplain. Most of the valley width, which ranges from 0.3 to 0.5 mile, is represented by a relatively flat terrace surface which is elevated slightly above the floodplain surface.

Honey Creek

The headwaters of Honey Creek originate in the hummocky topography of the northern (proximal) part of the Ft. Wayne moraine near Tiro in eastern Crawford County. Honey Creek follows a twisting northward course across three elements of the New Washington moraine and across two elements of the Ft. Wayne moraine. It traverses the western part of the flat bed of glacial Lake Willard in the northeastern corner of Crawford County and flows northward into Huron County. Honey Creek and its tributaries drain much of Auburn and Cranberry townships. Its largest tributary is Broken Knife Creek which originates in the New Washington moraine in eastern Chatfield Township. Broken Knife Creek flows 5 miles northeastward into Seneca County, and it joins Honey Creek in southwestern Huron County. Honey Creek bends sharply westward in Huron County and joins the Sandusky River in central Seneca County.

Sycamore Creek

Sycamore Creek originates in the lake plain of northern Crawford County along the border of Cranberry and Chatfield townships. It flows northwestward to Chatfield from which it bends westward and flows toward Lykens. In western Lykens Township, Sycamore Creek flows southward for a distance of 2 miles and then flows westward between 2 elements of the Ft. Wayne moraine. It flows past Benton in Texas Township into Wyandot County where it is tributary to the Sandusky River.

Olentangy River Basin

Headwaters of the Olentangy River are in the Powell moraine near Blooming Grove, Morrow County, a very short distance from the southeastern corner of Crawford County. The Olentangy River flows northward into Crawford County a distance of 2.5 miles to the southern border of the Broadway moraine. The flow of the river is diverted westward by the moraine to Galion where it cuts into and across the weakly developed elements of the moraine. West of Galion the Olentangy River cuts across the weakly developed Mississinewa moraine and flows northwestward 4.5 miles toward Bucyrus. In central Whetstone Township the river makes a sharp bend and reverses its flow toward the south-southwest. In its southward course toward Marion County the Olentangy River meanders within a valley that is 0.3 to 0.4 mile wide. The largest tributary to the Olentangy River is Mud Run which flows southward in western Whetstone Township.

Little Scioto River Basin

The Little Scioto River drains the southwestern corner of Crawford County. Headwaters of the river are in the St. Johns moraine at the southeastern edge of Bucyrus. From Bucyrus, the Little Scioto River flows southwestward in a small, narrow valley 9 miles to the Marion-Crawford County line. Near the county line the valley becomes wider and a few small terrace remnants are preserved along the valley sides. Very few short tributary streams join Little Scioto River in Crawford County.

Pleistocene drainage systems

Several relatively small buried valley systems (fig. 5) have been recognized in Crawford County based on bedrock contours. It is probable that the preglacial valley systems were both deeper and more numerous than the buried valley systems preserved beneath the modern topographic surface. An unknown amount of the bedrock surface of Crawford County was removed by glacial erosion, and it is possible that the preglacial valleys were partially or wholly removed by glacial scour. White (1934) presented evidence for a major preglacial divide that extended east-west across northern Morrow County just south of the Crawford-Morrow County line, but he was of the opinion that the preglacial valleys were at higher elevations than at present. White's (1934) interpretation suggests that the system of buried valleys present in north-central Ohio originated in the Pleistocene, and is not a preglacial system. Stout, Ver Steeg, and Lamb (1943) agreed with White and indicated that preglacial drainage in Crawford County was northward by small tributaries which drained into the preglacial Tiffin River.

The buried drainage systems (fig. 5) of Crawford County were influenced by two regional slopes—a major westward slope down the backslope of the Allegheny escarpment (fig. 3) and a major northward slope toward the Erie basin. Most of the buried valleys trend westward down the escarpment front. Whether or not these valleys were tributary to the northward flowing Tiffin River is not clear from evidence available in Crawford County.

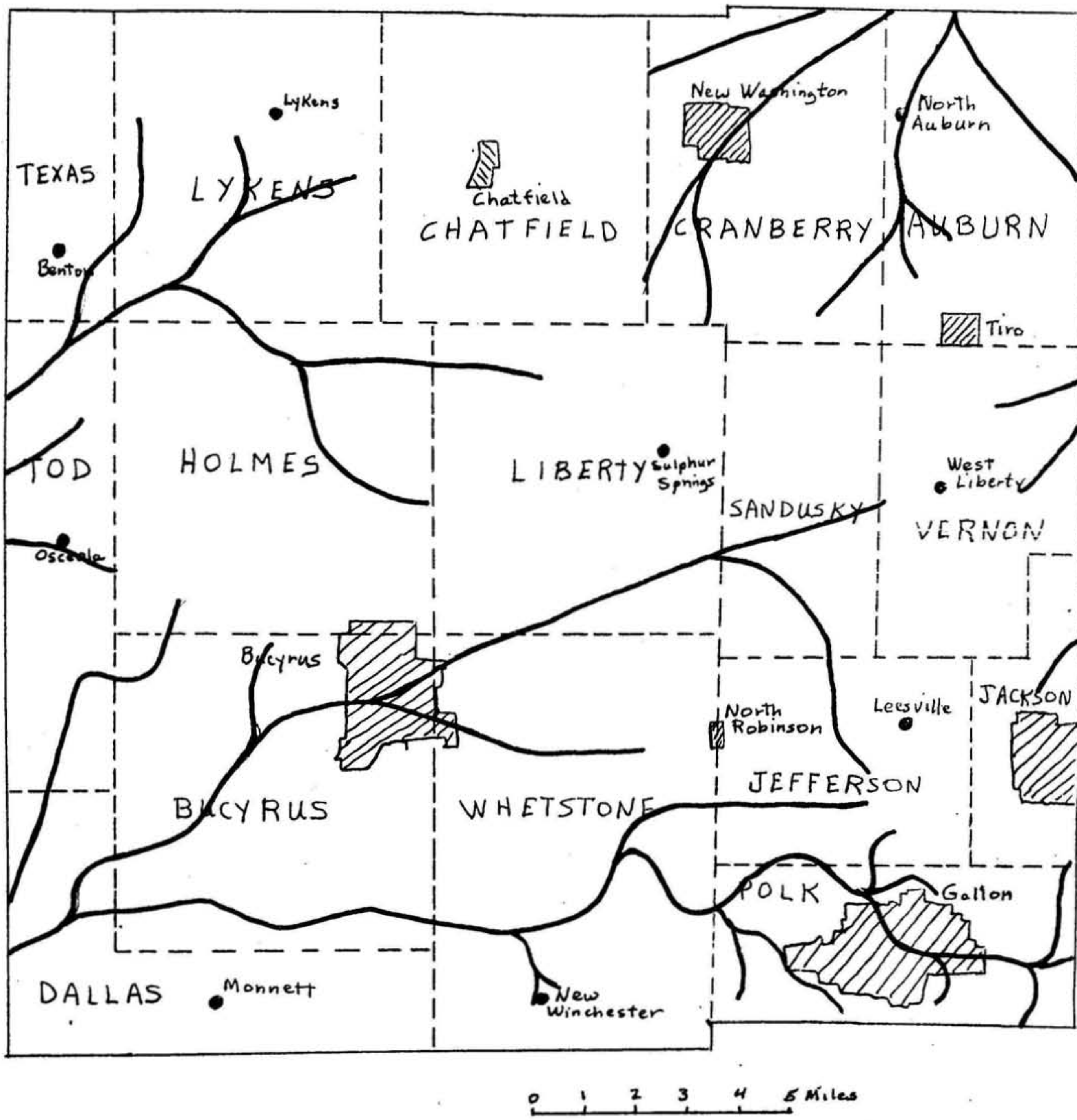


Figure 5. Buried valley systems of Crawford County.
(based on bedrock contour map by Mac Swinford).

Much of the buried drainage of northeastern Crawford County drained northward (fig. 5) similar to the pattern of modern Honey Creek and its tributaries in the county. Most of the buried valleys of Crawford County apparently were filled with drift during one or more of the Millbrook ice advances. Moraines of Millbrook age completely fill many of the pre-Millbrook valleys and serve as divides where valleys once were located. Thus the courses of the modern valleys in Crawford County bear little resemblance to the earlier valley systems.

BEDROCK

The bedrock underlying the drift of Crawford County is composed of limestone, shale, siltstone, and sandstone of Devonian and Mississippian age (fig. 6). Older rocks of Cambrian, Ordovician, and Silurian age have been encountered in the subsurface during exploratory drilling for oil and gas (fig. 7). The rocks at the surface dip gently toward the east at approximately 20 feet per mile. Older rocks in the subsurface dip more steeply toward the east at approximately 40 feet per mile. The nature of many of the rock units which "crop out" beneath drift in Crawford County is poorly known because of the scarcity of bedrock exposures.

The oldest rock unit exposed in Crawford County is the Columbus Limestone of Devonian age (fig. 6) which occurs in the western part of the county. Columbus Limestone is a massive gray fossiliferous stone which was sufficiently resistant to glacial scour in Marion County to the south (Totten, Marion County manuscript) to form a prominent 100 foot high excarpment. Columbus Limestone is quarried and crushed for aggregate and agricultural lime near Oceola (fig. 20) at the large Bucyrus Quarry of the National Lime and Stone Company. The Columbus Limestone "crops out" beneath a moderately thick covering of drift in a north-south trending belt in the western part of the county where it is an important source of groundwater.

Above the Columbus Limestone is the Delaware Limestone which crops out beneath drift in a narrow 2 to 5 mile wide belt which trends north-south through the central and west-central part of the county (Hall and Alkire, 1956). Hall and Alkire (1956) describe the Delaware Limestone as a dark blue impure limestone about 40 feet thick which is cherty, hard, and fine grained.

Overlying the Delaware Limestone is the Olentangy Shale which occurs beneath drift cover in a narrow north-south trending belt near the center of the county. The Olentangy Shale typically is bluish-gray, silicious, and about 30 feet thick as interpreted from well records (Hall and Alkire, 1956).

Above the Olentangy Shale is the black fissile Ohio Shale which crops out beneath drift in a north-south trending belt in the east-central part of the county. Hall and Alkire (1956) assigned a tentative thickness of 250 to 280 feet to the Ohio Shale in the Crawford County area.

Light bluish gray soft Bedford Shale overlies the Ohio Shale. Bedford Shale, estimated to be about 50 feet thick (Hall and Alkire, 1956) crops out beneath drift in a narrow north-south trending belt in east-central Crawford County.

Overlying the Bedford Shale is the Berea Formation which typically is a fine to medium grained buff to blue-gray sandstone 30 to 60 feet thick (Hall and Alkire, 1956). Much of the Berea Sandstone is massive and resistant to weathering, and it forms the basal part of the Allegheny escarpment (fig. 3). Hall and

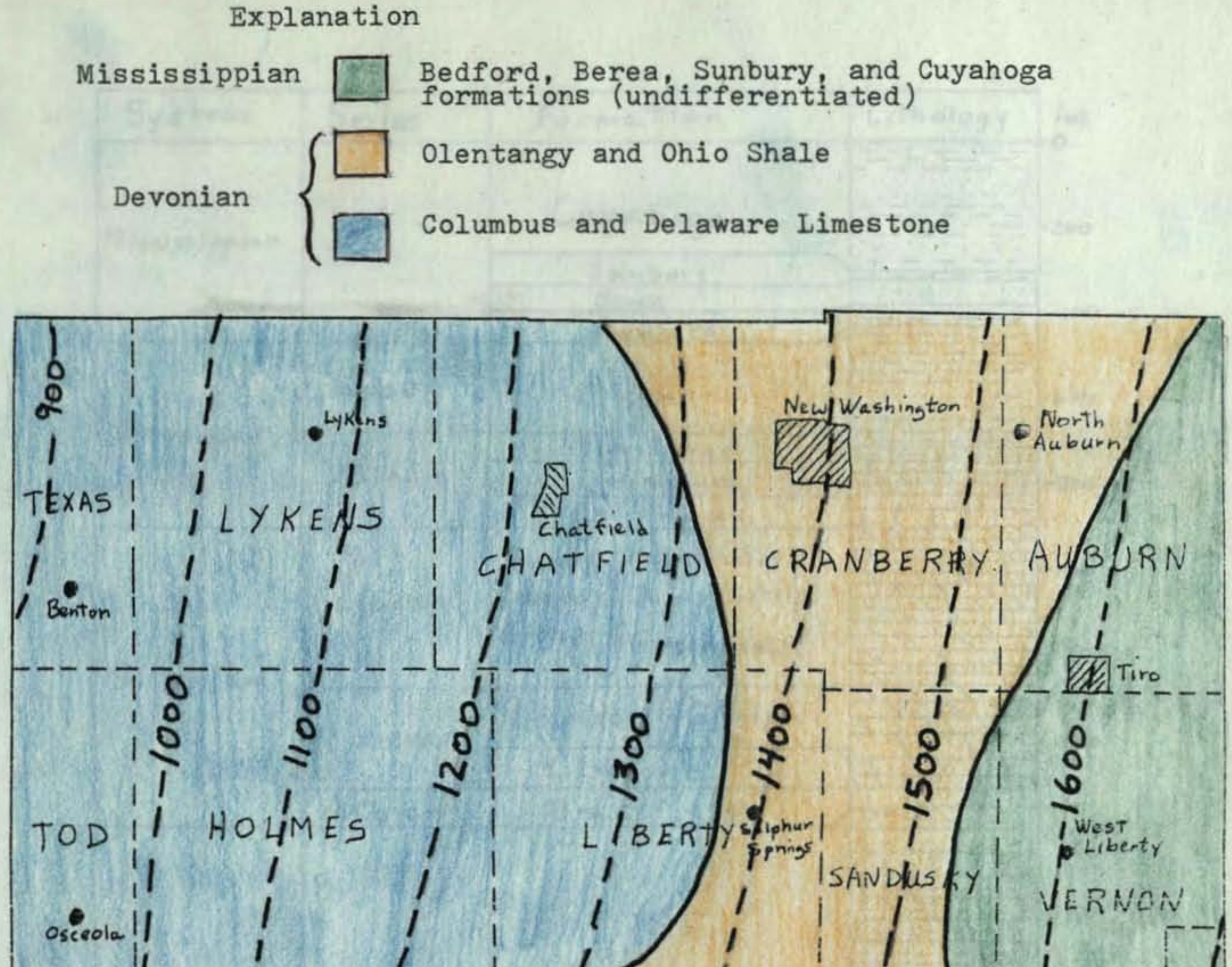


Figure 6. Geologic map of Crawford County. Structure contours on top of Trenton Limestone. Contours show elevation (in feet) below sealevel. (after Hall and Alkire, 1956).

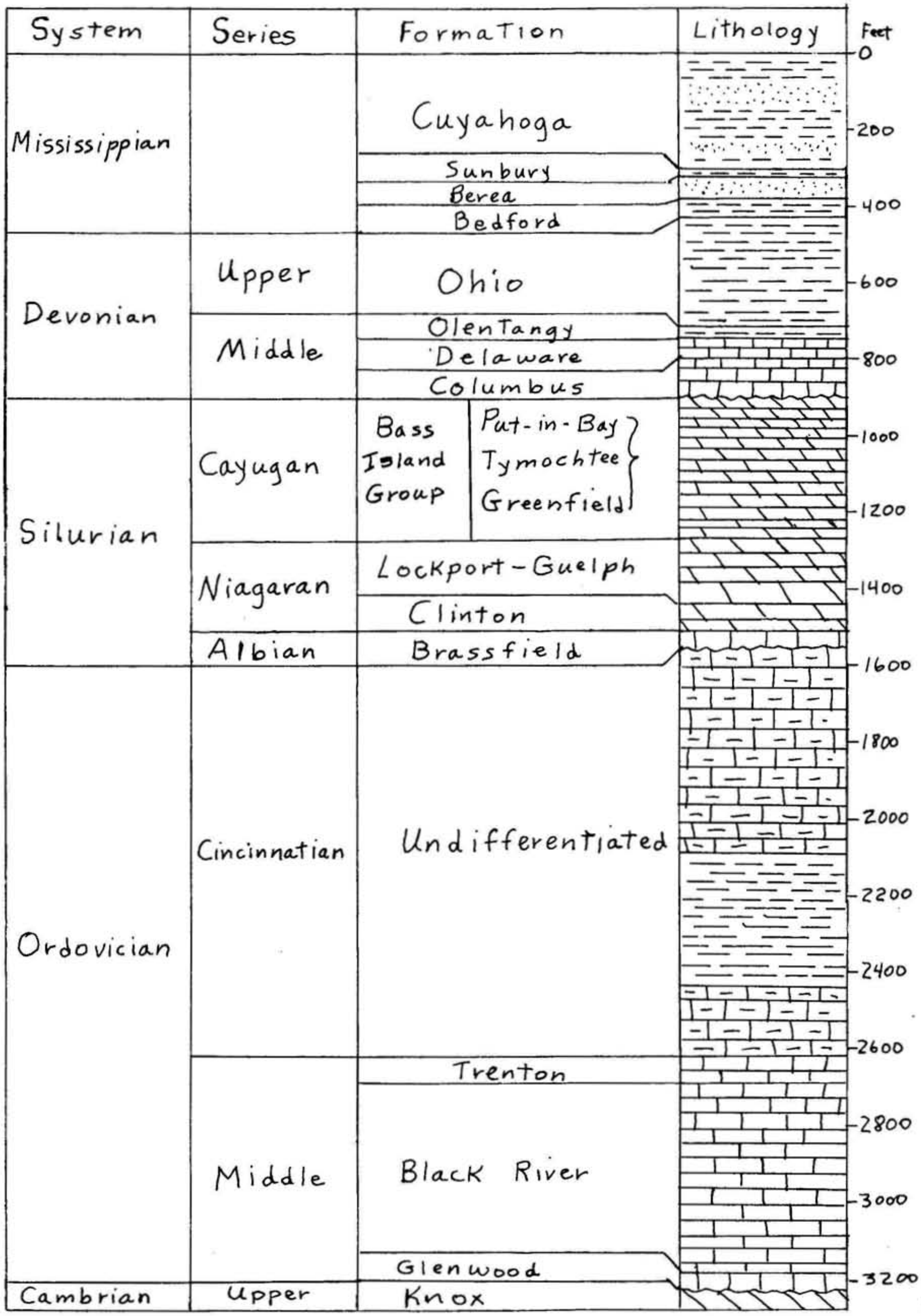


Figure 7. Stratigraphic column of Crawford County.
(after Hall and Alkire, 1956)

Alkire (1956) mentioned an old flagstone and building stone quarry in the Berea Sandstone in Jefferson Township near Leesville. They also reported that the Berea Sandstone crops out in Polk, Vernon, Jefferson, and Auburn Townships.

Above the Berea Sandstone is the Sunbury Shale, a thin brown to black shale about 20 feet thick which is buried beneath drift everywhere in Crawford County (Hall and Alkire, 1956). The Sunbury Shale occurs in the lower part of the Allegheny escarpment where it is confined between more resistant sandy units.

Overlying the Sunbury Shale is the Cuyahoga Formation which is the youngest rock unit in Crawford County. The Cuyahoga Formation crops out beneath drift in Vernon, Jackson, and Polk Townships in the eastern part of the county (Hall and Alkire, 1956) where it comprises the upper part of the Allegheny escarpment (fig. 3). Hall and Alkire (1956) have described the Cuyahoga Formation as consisting of alternating thin bedded, fine grained sandstone and gray-blue shales.

DRIFT THICKNESS

The thickness of glacial materials (drift) overlying the bedrock in Crawford County ranges from a few feet to over 150 feet (fig. 8), and the average drift thickness is 62 feet. In general, the thinnest drift in Crawford County (less than 20 feet thick) occurs in portions of the valleys of Broken Sword Creek, Sycamore Creek, and the Sandusky River, and near the crest of the Allegheny escarpment in Jefferson and Vernon Townships. Small areas of thin drift also occur in Polk and Auburn Townships. Thin drift covers only about 2½ percent of the county.

Relatively thin drift 20 to 50 feet thick occurs in all regions of the county (fig. 8) though in some townships the thin drift is restricted to narrow river valleys. Besides its occurrence in most river valleys, relatively thin drift occurs in two general areas—near the crest of the Allegheny escarpment in the eastern part of the county and on the divides of major buried valley systems (fig. 5) in the western part of the county. Moderately thin drift covers about 31 percent of the county.

Drift of moderate thickness, 50 to 100 feet thick, occurs in all townships and covers 65 percent of the county. Townships dominated by moderately thick drift include Bucyrus, Dallas, Whetstone, Liberty, Lykens, Holmes, Chatfield, and Cranberry.

Drift Thickness

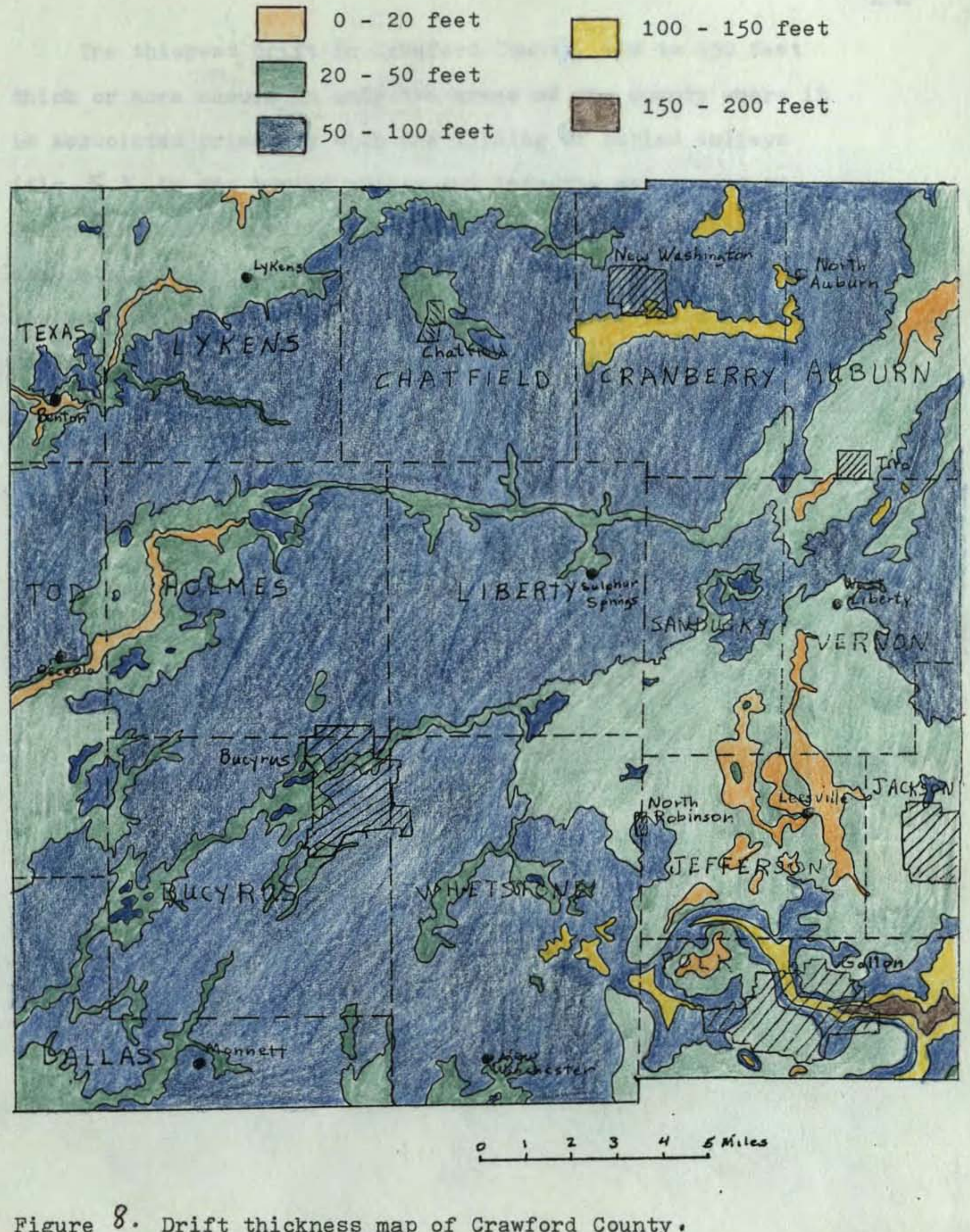


Figure 8. Drift thickness map of Crawford County. (based on map prepared by Mac Swinford)

The thickest drift in Crawford County, 100 to 150 feet thick or more occurs in only two areas of the county where it is associated primarily with the filling of buried valleys (fig. 5). In the buried valley cut into the escarpment at Galion in Polk Township, drift more than 150 feet thick completely fills the valley. In Cranberry Township near New Washington, drift more than 100 feet thick fills a broad basin that may have been partially excavated by glacial ice as well as by streams. Thick drift covers only about 1½ percent of the county.

GLACIAL EROSION

Glaciers moving southward and southeastward across Crawford County most likely scowed the bedrock surface several times, removing an undetermined thickness of regolith and rock. The amount of bedrock removed by glacial erosion in Crawford County is unknown, but it may be on the order of 10 feet to several tens of feet based on several lines of evidence. First, the preglacial regolith (soil) which may have been quite thick, has been stripped in its entirety, presumably by glacial scour. Another line of evidence for erosion is the complete lack of karst and other solutional features in the Columbus Limestone. At no place in the very extensive quarry of the National Lime and Stone Company near Oceola was any evidence of solution seen in the limestone which has most of the characteristics required for optimum development of karst. A third line of evidence favoring glacial erosion is the lack of glacial deposits older than Millbrook in the county. Evidently any pre-Millbrook drift deposited in the county was removed during subsequent glacial advances.

TILL DEPOSITS

All of the glacial deposits at the surface and in shallow to deep cuts in Crawford County are of the Wisconsinan Stage, the latest stage in glacial history (table 1). It is possible that pre-Wisconsin deposits occur buried beneath Wisconsinan deposits, primarily in buried valleys.

Deposits of several advances of Wisconsinan ice are sufficiently distinctive to be separated in the exposures where they may be seen. It is to be expected that, in any large exposure showing considerable thickness of glacial material, the glacial material will have been deposited by more than one ice advance and will differ more or less in character. The till deposited by each ice advance often is very thin. The last ice advance into Crawford County, ice that deposited the Hiram Till, covered all of the county. Yet the Hiram Till is thin or non-existent at many places so that the uppermost recognizable till is not Hiram, but the earlier Hayesville Till. At places where the Hayesville Till is very thin, even earlier till may be evident at or very close to the surface. The thickest till is found in the belts of end moraine and the thinnest till occurs in the ground moraine areas of the Till Plain (Plate 1).

Table 1. Classification of glacial deposits in Crawford County

	Stage	Substage	Unit or Interval		Material	Approximate dates (Years BP)
Pleistocene	Wisconsinan	Woodfordian	Postglacial		Alluvium, loess, peat, lacustrine silt and clay	
			Late glacial			15,000
			Hiram Till		Dark brown silty clayey till	17,000
			Hayesville Till		Dark brown silty clayey till	19,000
			Navarre Till		Yellow brown silty till	23,000
		Farmdalian	Ice retreat		Stones, silt, sand, gravel	33,000(?)
		Altonian	Millbrook Till	Unit U	Yellow brown, olive brown, and dark gray brown compact, firm stony till; sand and gravel lenses	
				Unit A		40,000(?)
	Sangamon(?)		Interglacial Ice retreat		Stones, silt, sand, gravel	75,000(?) – 120,000(?)
	Illinoian (?)		Millbrook Till	Unit BI	Yellow brown, olive brown, and dark gray brown compact, firm stony till; sand and gravel lenses	
				Unit BII		
				Unit BIV		(?)
	Pre-Illinoian		Lower units unknown		No Pre-Millbrook material known. Possible till, outwash, and alluvium in buried valleys	

Character and Composition of the Till

General Statement

The various tills in north-central Ohio may be distinguished from one another by using several criteria including texture, composition, color, and weathering horizons. These characters are dealt with in more or less detail in several publications describing the glacial geology of Richland County (Totten, 1973), Wayne County (White, 1967), and Ashland County (White, 1977) to name just a few.

Texture

Tills in north-central Ohio range from silty sandy tills with relatively low clay content to clayey, silty tills with a low sand content. The texture (grain size) of each till is reasonable constant. The tills at the surface in Marion County are clayey or silty, but some relatively sandy till occurs in places in the subsurface below the fine grained tills.

Mineral Composition

Tills differ in content of quartz, feldspar, carbonate, and clay minerals. The carbonate content, including the calcite/dolomite ratios, has proven useful in identifying certain till units, particularly the Millbrook units. Mineral content of tills are included in Appendix B.

Color

The color of till is a subtle but useful physical characteristic in till identification. At every thick till section two dominant colors may be seen: brown where oxidized at the surface and gray where unaltered at depth, the boundary between the colors commonly being 6 to 10 feet below the surface. The original gray color is due primarily to ferrous iron; oxidation to ferric iron gives the till a brown color, the shade of which is characteristic and relatively consistent. The oxidized tills at the surface of Crawford County are generally dark brown, tending toward chocolate brown, whereas the older subsurface tills have weathered yellow brown or olive brown. In the till descriptions, colors are recorded according to hue, value, and chroma as shown on a standard Munsell color chart.

Weathering Horizons

Where the upper part of a till has not been removed by erosion or the work of man, tills can be divided vertically into five distinct horizons based on degree of weathering. In the weathering of till the first minerals to be attacked are the iron-bearing minerals, especially pyrite. These are oxidized, furnishing the brown color to the weathered till. Carbonates are leached, and the most resistant minerals, the silicates, are degraded.

Horizon 5 is the unaltered till in which the iron minerals have not been altered. On drillers' and engineers' records this horizon is sometimes called "blue clay with stones", but the color is some shade of gray rather than blue. Its top is usually 6 to 10 feet below the surface. In Crawford County gray till may be seen in the lower parts of deep highway cuts, in quarry and gravel pit excavations, and in the cliff sections along major streams.

Horizon 4 is calcareous till similar to that of Horizon 5 except it has been oxidized to a brown color. The top of horizon 4 is also the depth of leaching, which ranges from about 18 to 52 inches and averages 31 inches in Crawford County (fig. 11). In places carbonates leached from horizon 3 are reprecipitated along joints and partings in this horizon to form gray zones of secondary carbonate.

Horizon 3 is similar to horizon 4, except that in horizon 3 the carbonates have been leached. Iron oxide and manganese stains may be present along joints.

Horizon 2 (essentially the B3 horizon of soil scientists) is the zone of decomposed till underlying the main part of the true soil. The horizon is not only oxidized and leached, but some of the pebbles and granules may have been decomposed. Some clay material has accumulated in the joints, and soil-forming processes are advanced. The material is not so completely weathered, however, that it cannot be identified as once having been till. The color of the upper part generally is a mixture of buff, gray, and brown. The lower part may have dark stains along the joints.

Horizon 1 is the soil, divided into the A and upper B soil horizons of pedologists. The characteristics of the soil differ with drainage and slope, as well as with parent material. The soils of Crawford County (fig. 9) are dealt with in great detail in a report containing detailed soils maps (Steiger and others, 1979).

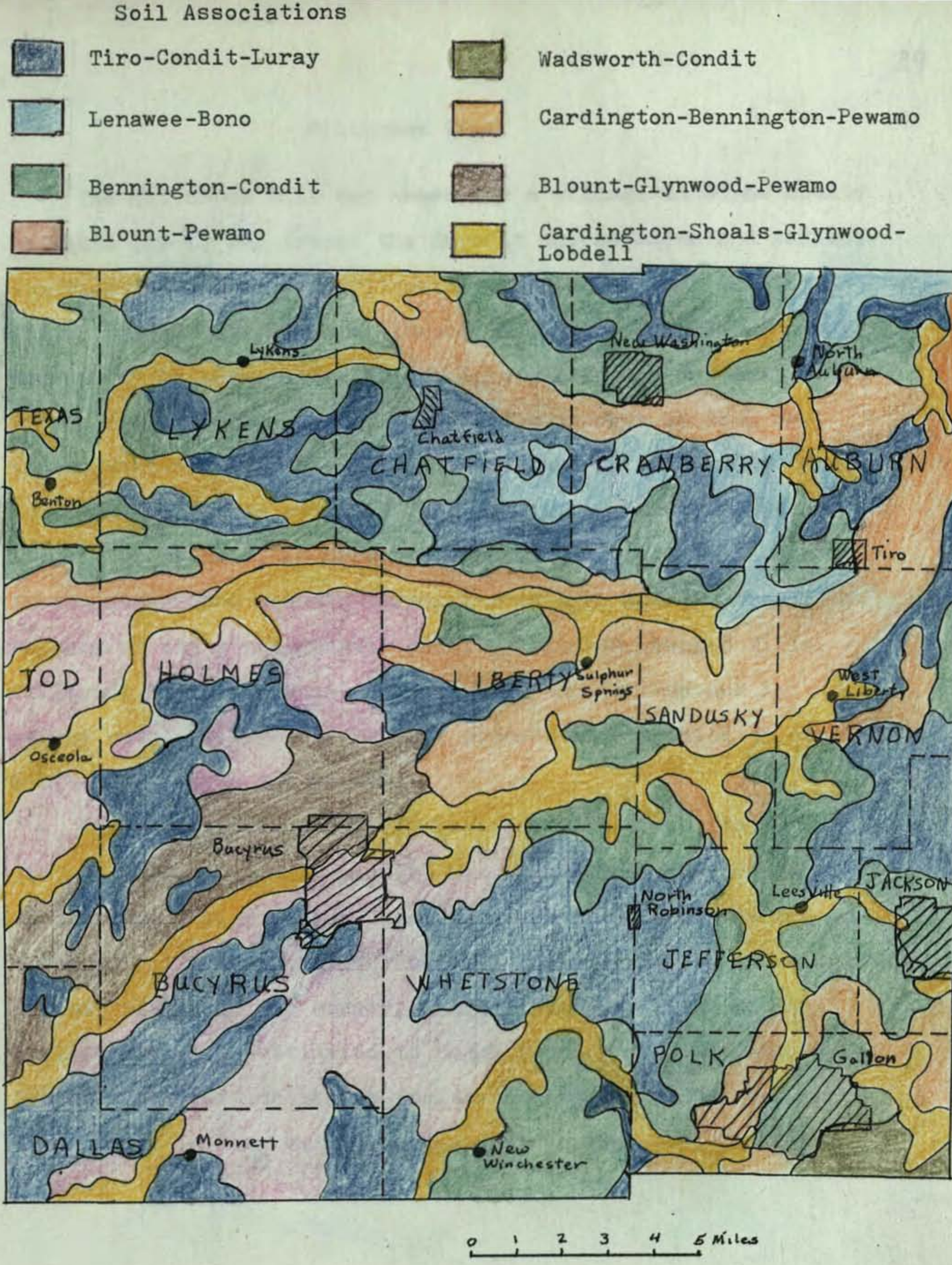


Figure 9. Generalized soil map of Crawford County, Ohio. (Steiger and others, 1979).

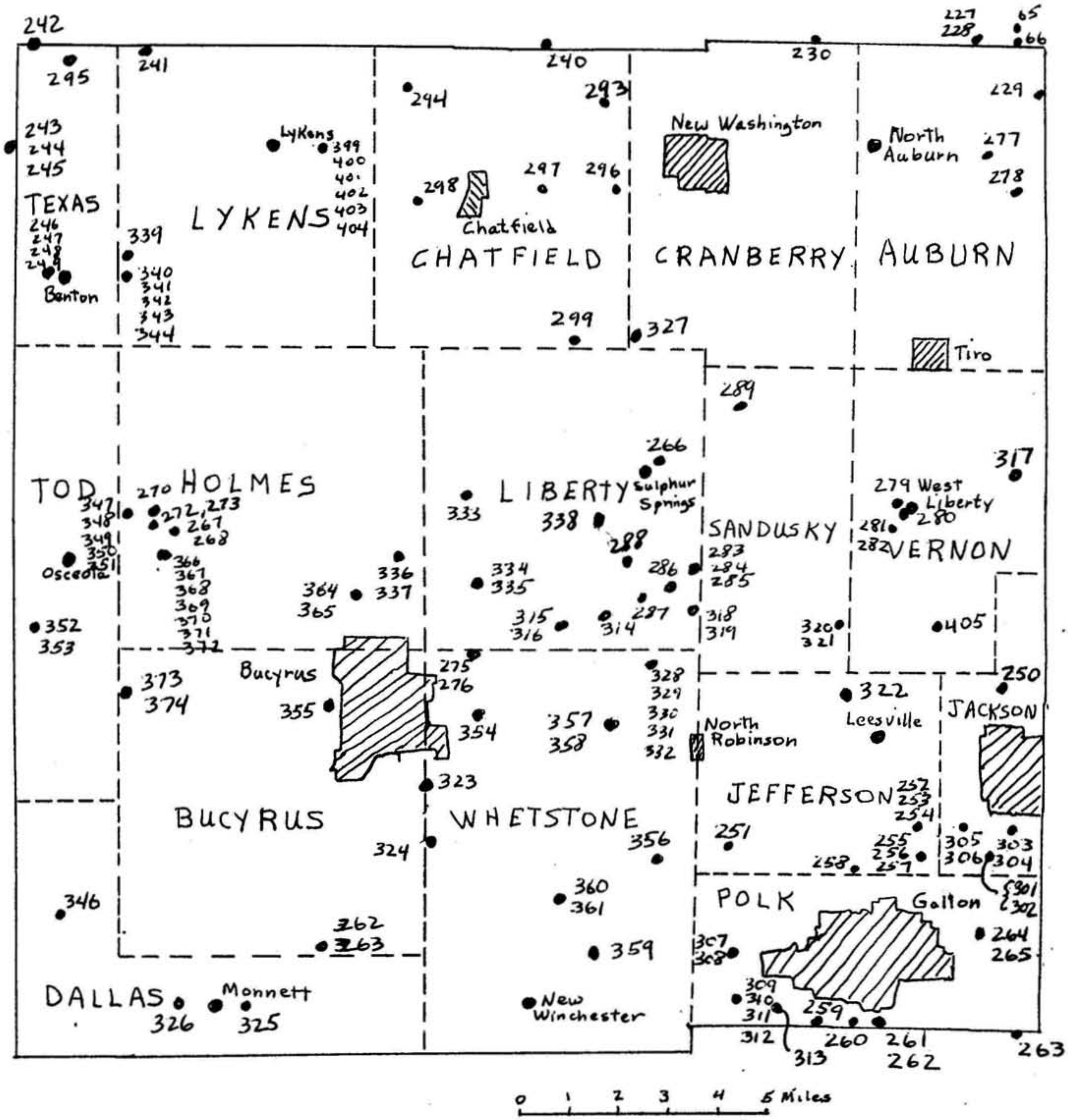


Figure 10. Crawford County sample localities.

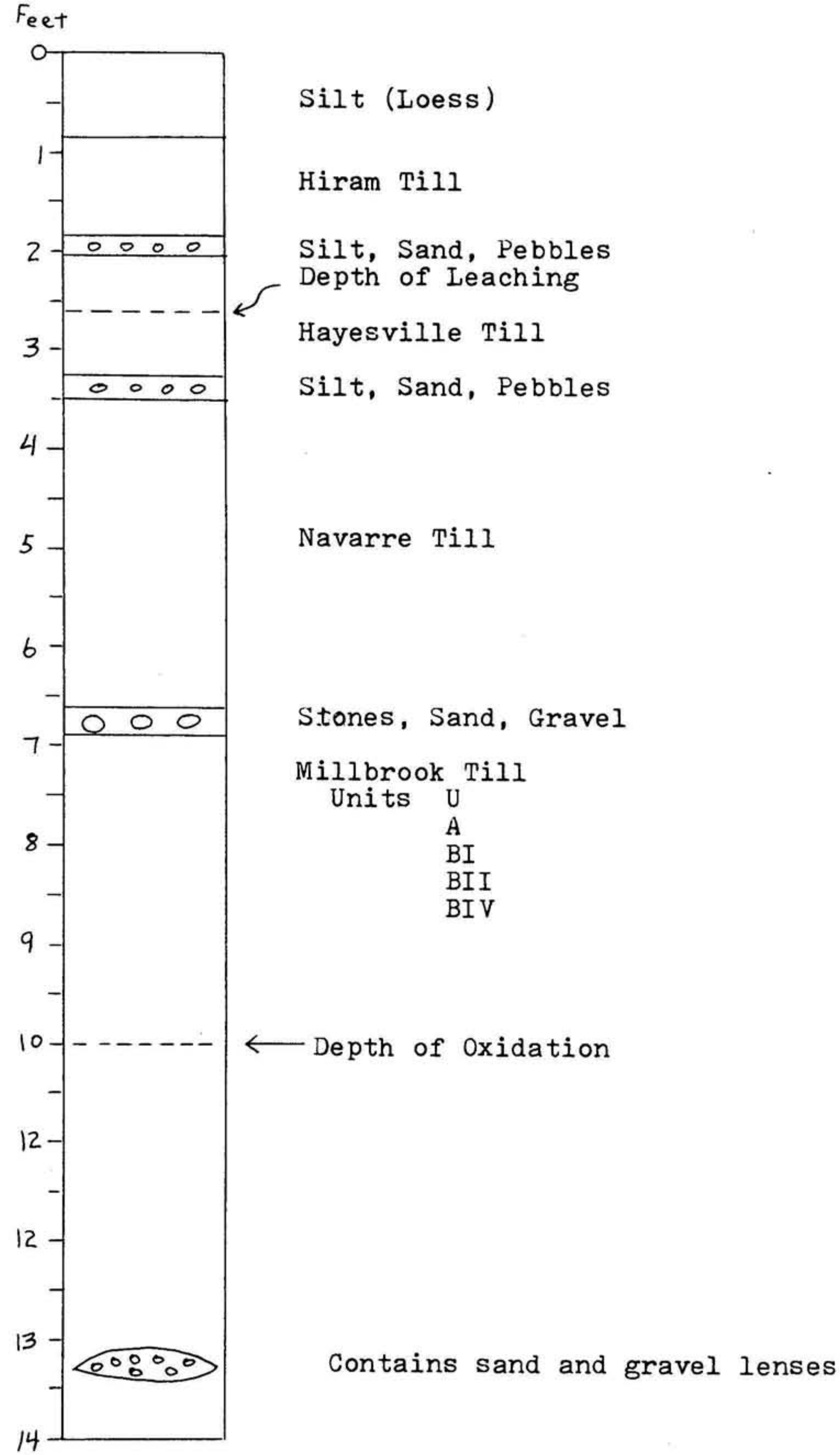


Figure 11. Profile showing average thickness of drift units in Crawford County

Millbrook Till

The Millbrook Till was named for a village in Wayne County by White (1961) who traced the deposit across Wayne and Ashland Counties (White, 1967, 1977) mainly as a subsurface unit. Totten (1973) traced the Millbrook Till across Richland County and named its correlative in the Scioto Lobe the Jelloway Till. Killbuck Lobe tills exhibit only subtle changes as they are traced westward into the Scioto Lobe; thus in this study, Killbuck Lobe terminology is retained for the tills of Crawford County in the Scioto Lobe. In Crawford County, Millbrook Till occurs in the subsurface beneath Hiram, Hayesville, and Navarre Tills. Because of its stratigraphic position beneath younger tills, Millbrook Till is exposed only in deep excavations and in stream cuts. Still rarer are the places where a thick or complete Millbrook section can be seen.

The thickest sections of Millbrook Till approximately 30 feet, are along drainage ditches of the National Line and Stone Company Quarry near Oceola and along the Route 30 Bypass northeast of Bucyrus. Millbrook Till probably rests on bedrock in most places in the county, and the average thickness of Millbrook Till is estimated to be 55 feet, or 7 feet less than the average drift thickness for the county. Where Millbrook Till occurs in deep cuts, it occurs at an average depth of 81 inches.

Millbrook Till may be recognized by its dense, firm, compact habit and its pebbly, stony texture. Typical Millbrook Till is considerably more dense and compact than the overlying Woodfordian tills. Millbrook Till commonly exhibits gray, reddish brown, or black stains along prominent joints and in pebble molds. These rusty joints commonly extend downward a short distance below the zone of oxidation into the gray unoxidized till. The firm Millbrook Till may be broken with difficulty, and the till breaks around pebbles and stones in such a way to preserve perfectly the pebble shapes as molds.

Millbrook Till oxidizes to various shades of brown, generally olive brown (2.5 Y 4/4) or yellow brown (10YR 4/4). Unoxidized Millbrook Till exhibits a gray brown color, most frequently dark gray brown (10YR 3/1-4/1).

In Crawford County, Millbrook Till is divided into five units based on carbonate composition, stratigraphic position, and the occurrence of stones, sand, and gravel between units. These five units, designated from top to bottom, U, A, BI, BII, and BIV have similar physical characteristics and are not reliably distinguished from each other in the field. They are best subdivided by carbonate composition. The sand, silt, clay percentages of all Millbrook units are remarkably similar (Table 2).

Table 2

Statistical data of till sample analyses for Crawford County

Till Unit		No. of Samples	Sand		Silt		Clay		Calcite		Dolomite		Total Carbonate		Calcite/Dolomite
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Hiram		2	20.0	1.0	44.0	5.0	36.0	4.0	0.0	0.0	3.0	0.0	3.0	0.0	0.00
Hayesville		31	20.0	4.0	46.0	6.0	34.0	7.0	1.9	2.5	4.7	1.6	6.6	3.0	0.40
Navarre		51	24.0	4.0	48.0	6.0	28.0	6.0	3.2	2.5	6.6	3.2	9.8	4.4	0.48
Millbrook	U	9	24.0	3.0	47.0	4.0	29.0	5.0	5.3	2.3	5.3	1.4	10.5	3.4	1.00
Millbrook	A	16	26.0	6.0	48.0	5.0	27.0	8.0	4.7	2.2	7.5	2.8	12.2	4.8	0.63
Millbrook	B I	14	25.0	2.0	48.0	5.0	27.0	4.0	0.4	0.7	6.3	2.3	6.7	1.6	0.06
Millbrook	B II	3	28.0	9.0	42.0	8.0	30.0	12.0	2.3	0.9	6.8	2.1	9.1	2.9	0.34
Millbrook	L	1	25.0		44.0		31.0		6.3		5.2		11.5		1.20

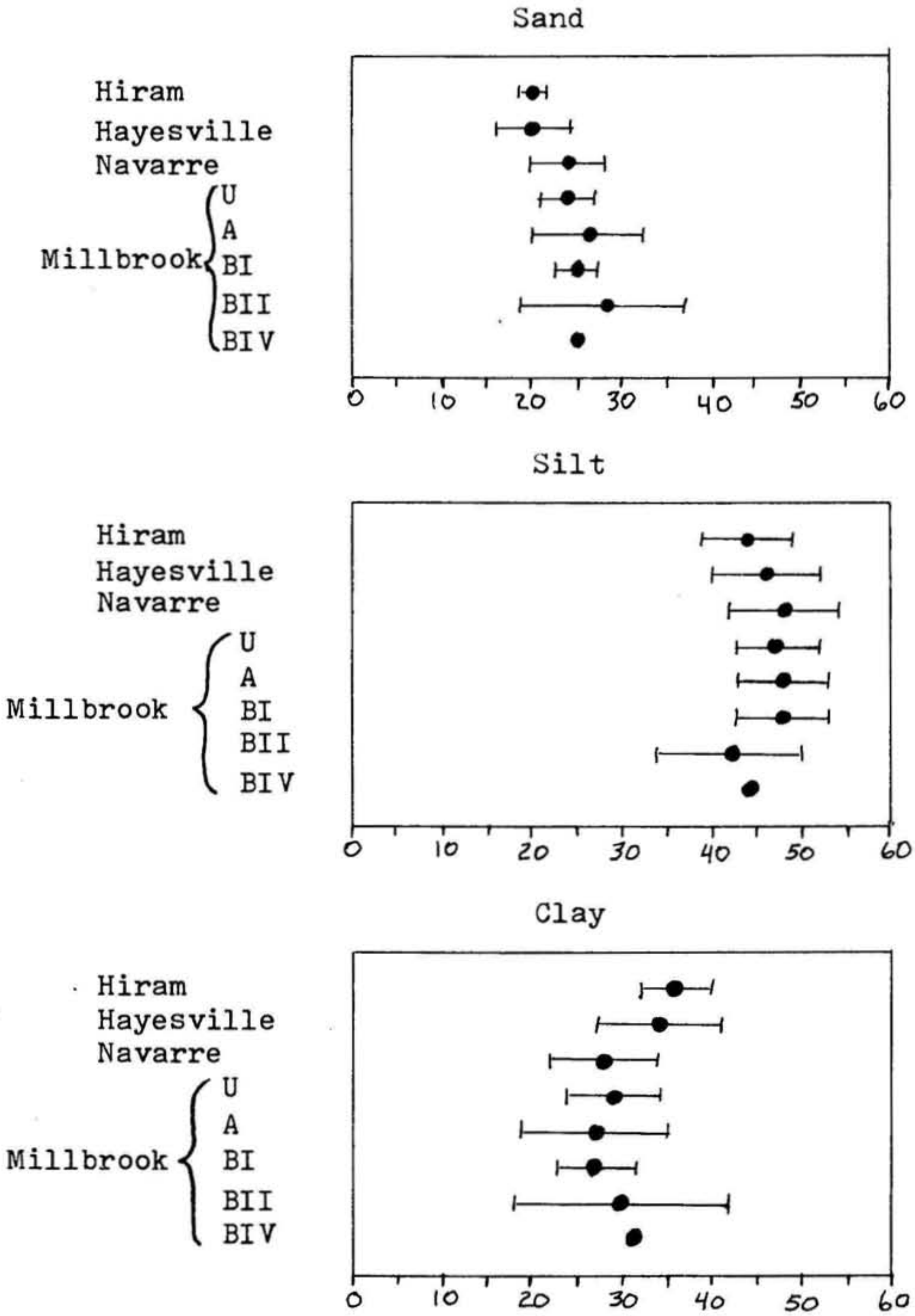


Figure 12. Plot of means (solid circles) and standard deviations (solid lines) of sand, silt, and clay percentages of Crawford County till units.

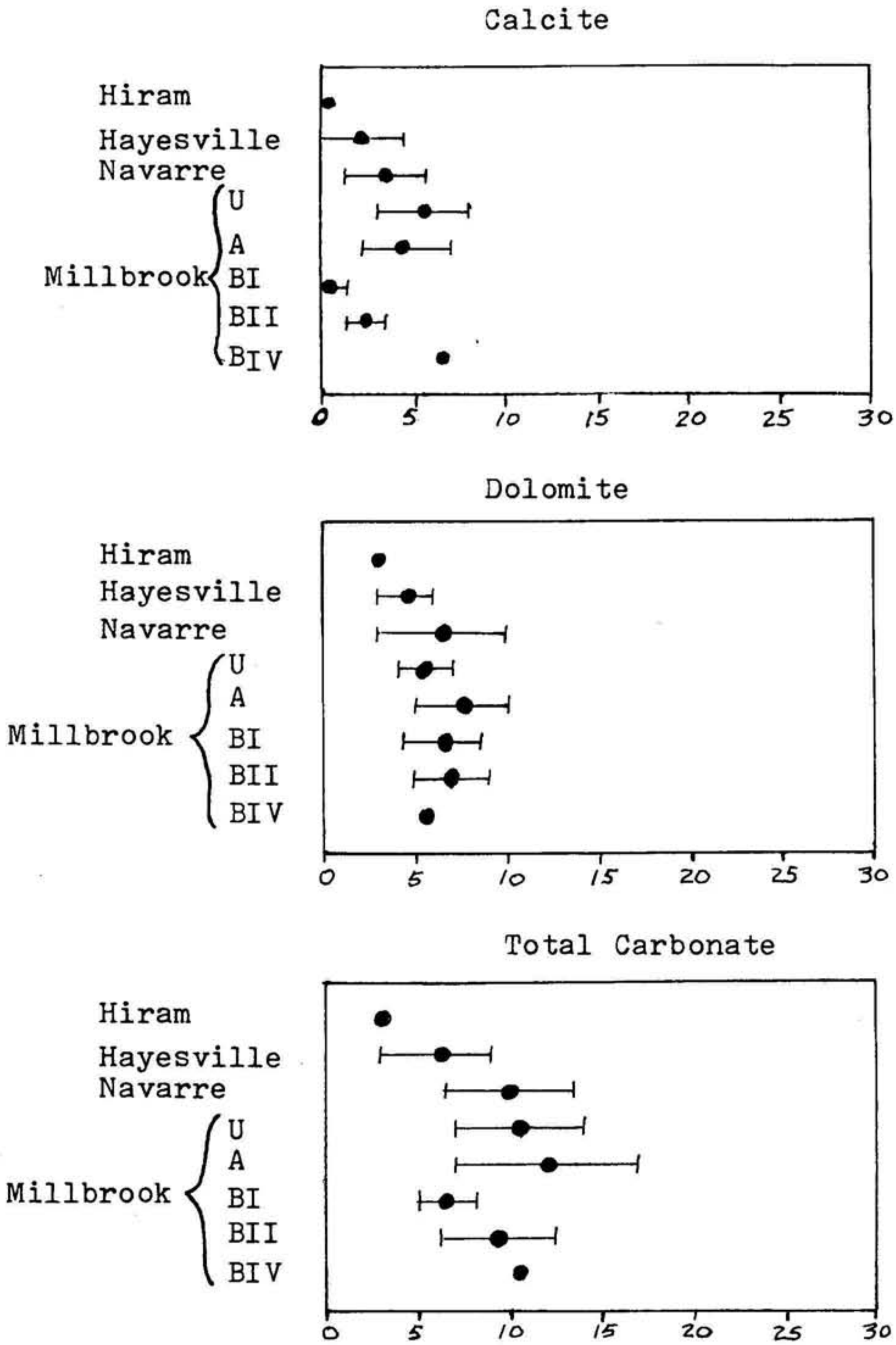
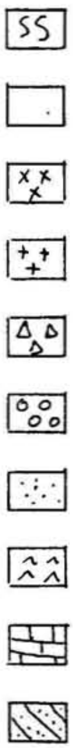


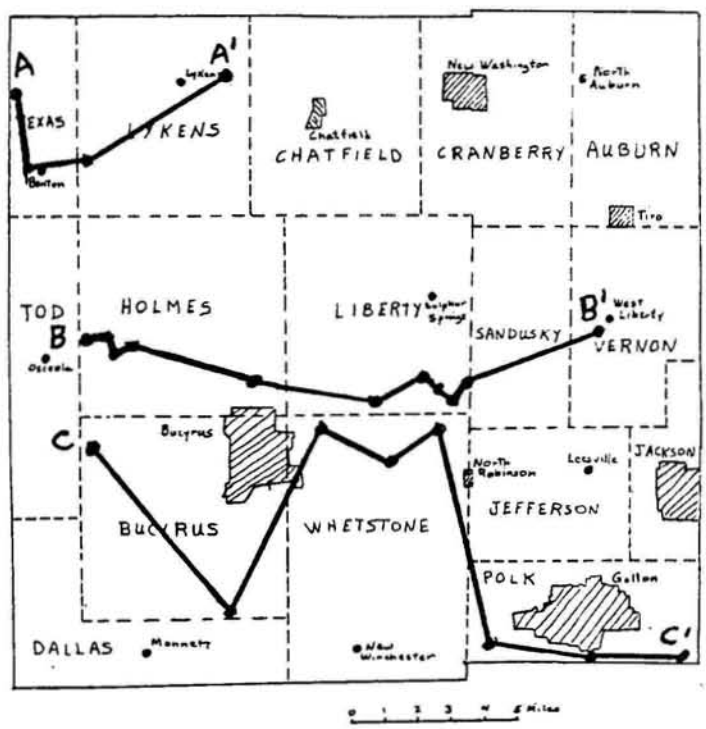
Figure 13. Plot of means (solid circles) and standard deviations (solid lines) of carbonate percentages of Crawford County till units.

Explanation

H - Hiram Till
V - Hayesville Till
N - Navarre Till
U - Millbrook Till Unit U
A - Millbrook Till Unit A
BI - Millbrook Till Unit BI
BII - Millbrook Till Unit BII
BIV - Millbrook Till Unit BIV

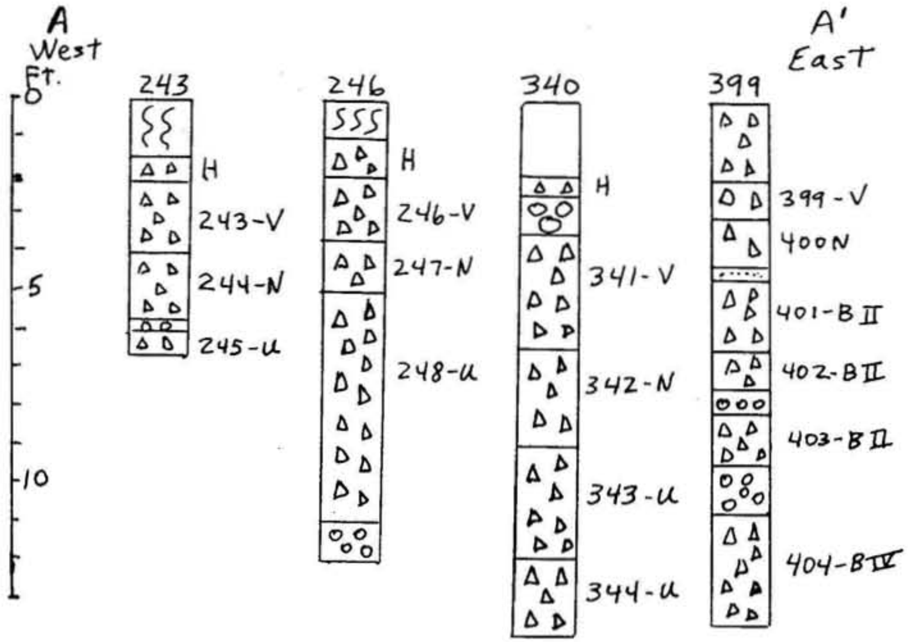


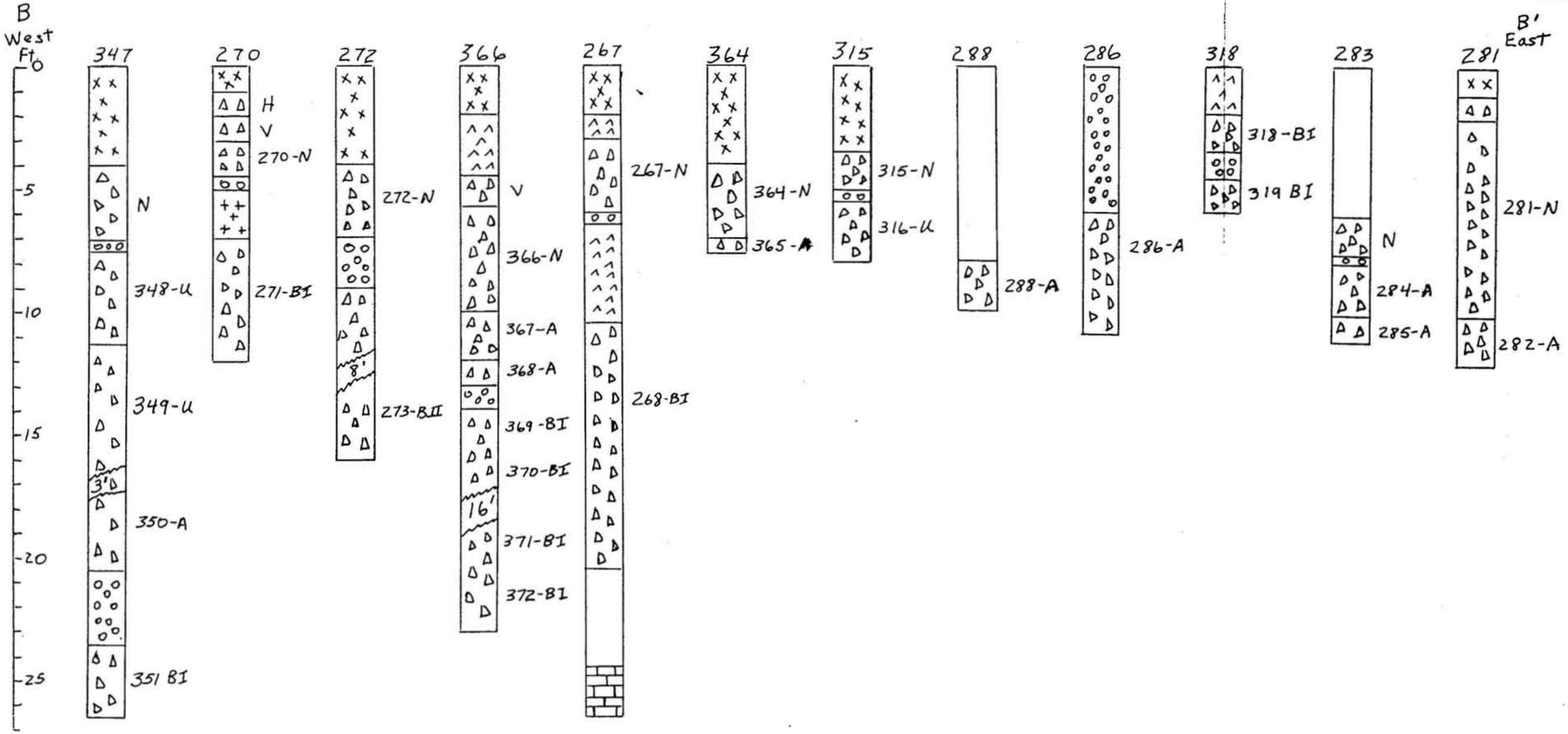
SS Soil undifferentiated
Covered
Disturbed
Colluvium
Till
Gravel
Sand
Silt
Limestone
Sandstone



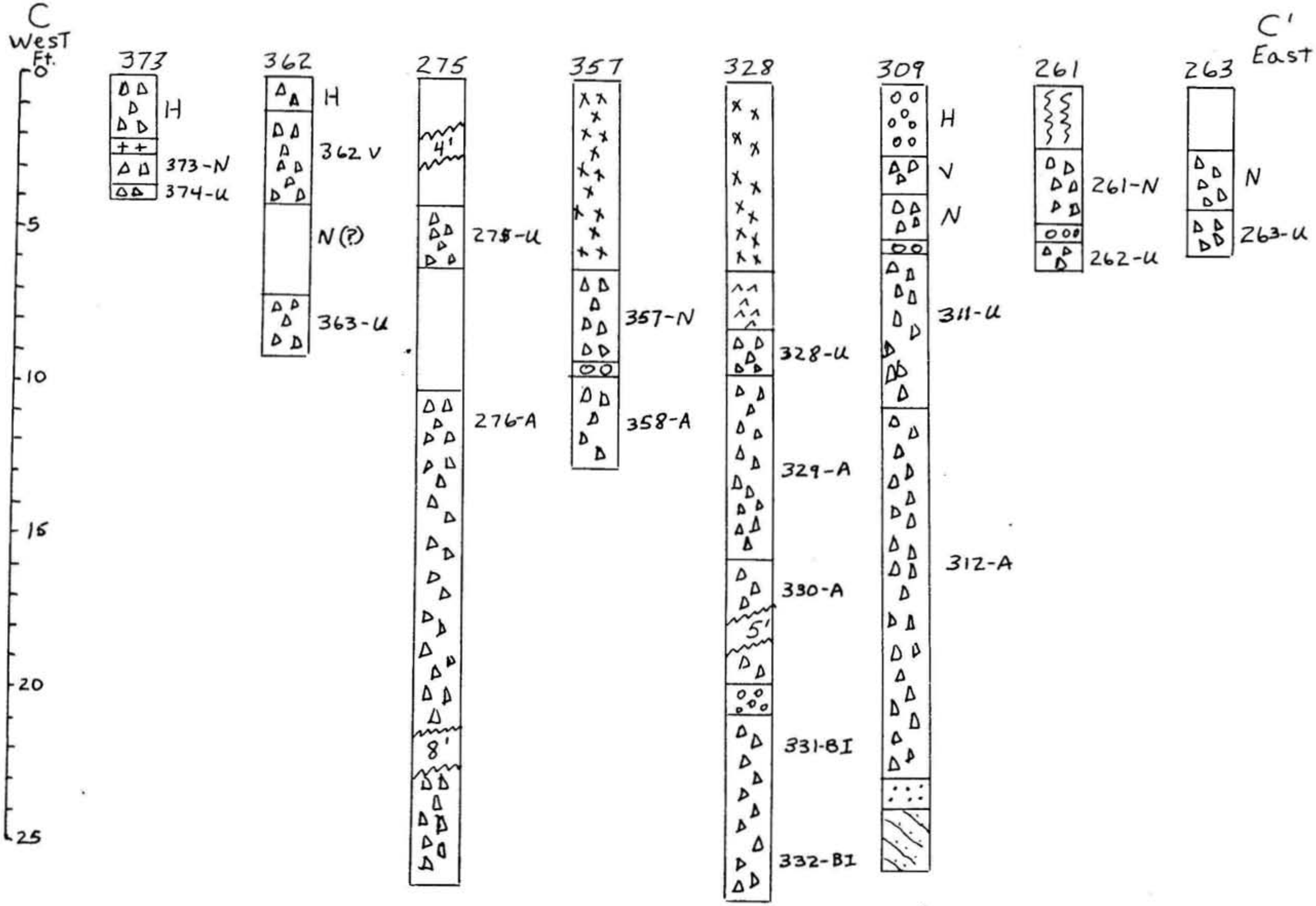
Location of cross-sections

Figure 14. Stratigraphic cross-sections of Crawford County


A
West
Ft.
0
5
10
243
246
340
399
A'
East
H
243-V
244-N
245-u
246-V
247-N
248-u
341-V
342-N
343-u
344-u
399-V
400N
401-B II
402-B II
403-B II
404-B IV



B
West
Ft
0
5
10
15
20
25
347
N
348-U
349-U
3'
350-A
351 BI
270
H
V
270-N
271-BI
272
272-N
8'
273-BII
366
V
366-N
367-A
368-A
369-BI
370-BI
16'
371-BI
372-BI
267
267-N
268-BI
364
364-N
365-A
315
315-N
316-U
288
288-A
286
286-A
318
318-BI
319 BI
283
N
284-A
285-A
281
281-N
282-A
B'
East



C
West
Ft.
0
5
10
15
20
25
373
H
373-N
374-U
362
H
362 V
N (?)
363-U
275
4'
275-U
276-A
8'
357
357-N
358-A
328
328-U
329-A
330-A
5'
331-BI
332-BI
309
H
V
N
311-U
312-A
261
261-N
262-U
263
N
263-U
C'
East

The lowermost Millbrook unit, probably BIV, is exposed at only one locality-along Sycamore Creek in Lykens Township. At this exposure, Unit BIV is a silty stony till, and its calcite content of 6.3 percent and its calcite/dolomite ratio of 1.2 are the highest of any till in the county (Table 2).

Unit BII is a silty till that contains nearly equal amounts of sand and clay. It has a relatively high dolomite content of 6.8 percent and a relatively low calcite content of 2.3 percent for a low calcite/dolomite ratio of 0.34 (Table 2). Unit BII is exposed in only two localities, along Sycamore Creek in Lykens Township and at the National Lime and Stone Company quarry near Oceola. At Oceola, unit BII occurs in a buried 15 foot knoll and is overlain by Navarre Till. Along Sycamore Creek, Unit BII consists of three till layers each 10 to 16 inches thick interbedded with thin layers of water-bearing sand and gravel.

Unit BI is a silty till characterized by a virtual absence of calcite (0.4 percent) and a relatively low dolomite content of 6.3 percent. Unit BI till is dark gray (5Y 4/1) where unoxidized, and it oxidizes to a mottled yellow brown (10YR 4/4) and olive brown (2.5Y 4/4) color. This till unit is widespread and it probably occurs in all parts of the county although most exposures are not deep enough to expose BI till. The thickest exposures of Unit BI till, about 25 feet, in a drainage ditch and quarry near Oceola (fig. 15, 16, 17) where a partially buried knoll of BI till overlies bedrock, and is overlain by Millbrook A, Navarre, and

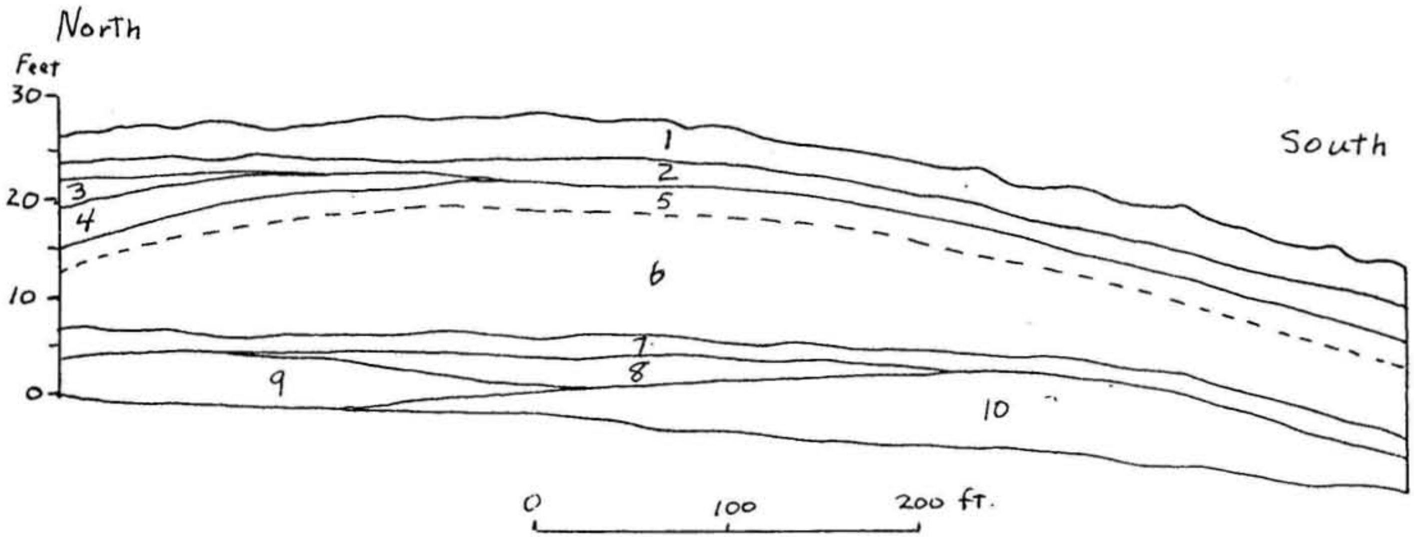


Figure 15. Sketch of the glacial deposits exposed in a drainage ditch of the Bucyrus Quarry, National Lime and Stone Company, NW$\frac{1}{4}$, Section 19, Holmes Township.

(Unit descriptions for Figure 15)

Drainage Ditch Section, Bucyrus Quarry, National Lime and Stone Company

Unit

1. Disturbed land
2. Till, dark yellow brown 10YR4/4, calcareous sample H—347, Navarre Till.
3. Gravel, brown
4. Sand, brown
5. Till, olive brown, 2.5Y4/4, calcareous, pebbly, moderately stony, samples H—348 and H—349, Millbrook Till, unit U.
6. Till, dark gray, calcareous, firm, stony, massive, jointed, sample H—350, Millbrook Till, unit A
7. Gravel, gray, calcareous, water-bearing
8. Silt, gray, laminated, calcareous
9. Gravel, gray, calcareous, well-sorted, water-bearing.
10. Till, dark gray, 5Y4/1, calcareous, firm, stony, massive, jointed, sample H—351, Millbrook Till, unit BI.

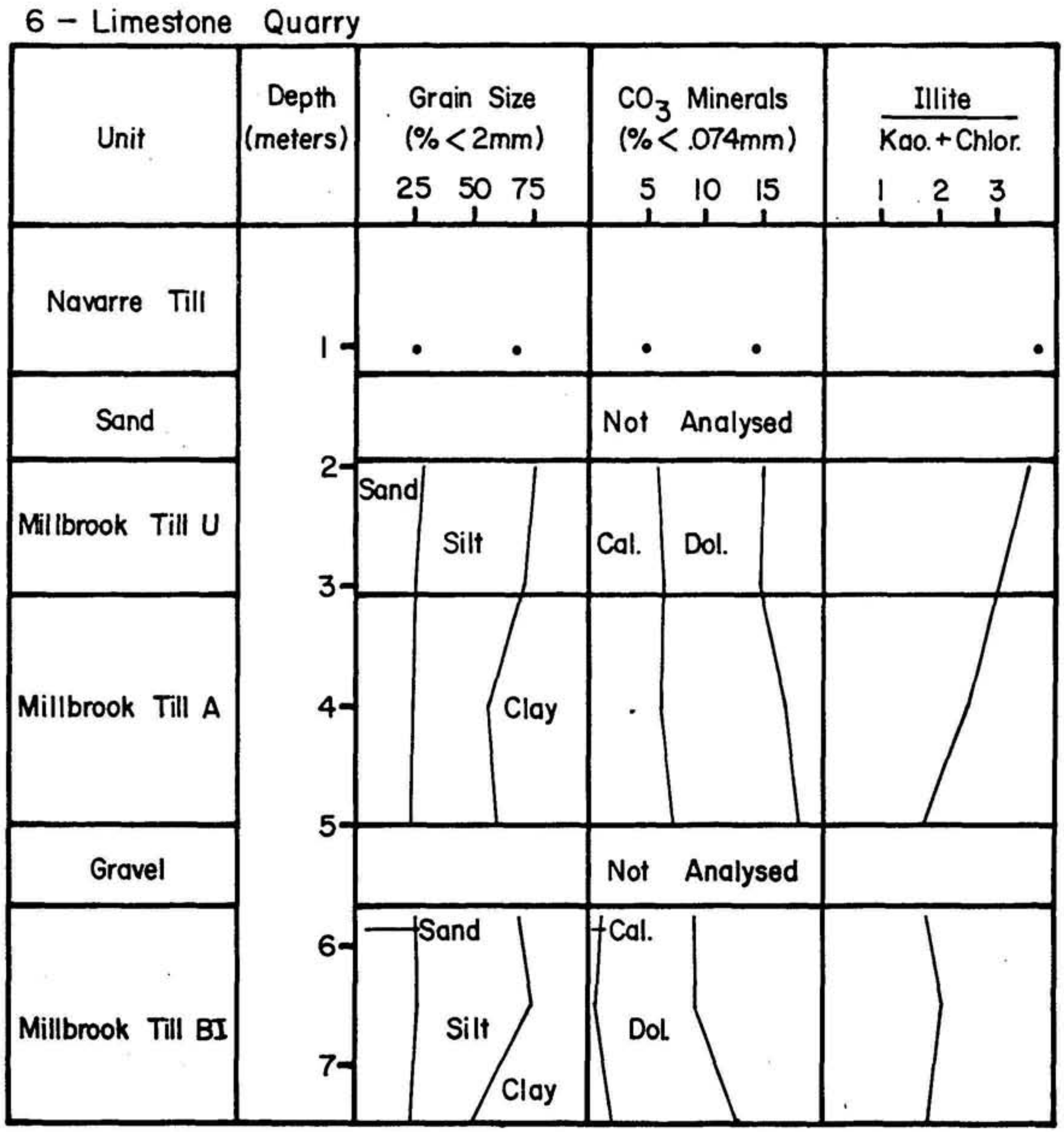


Figure 16. Graph showing variation in texture and mineralogy of tills exposed in a drainage ditch of the Bucyrus Quarry, National Lime and Stone Company 1 mile northeast of Oceola.

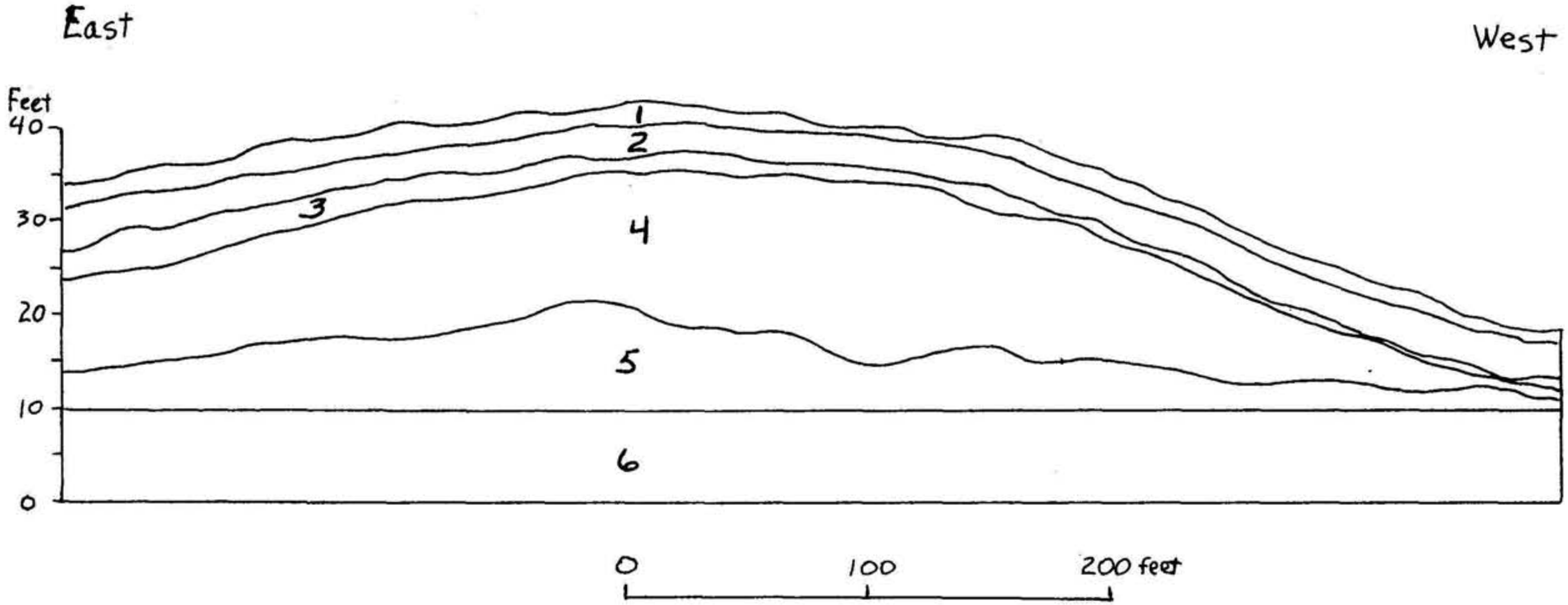


Figure 17. Sketch of the glacial deposits exposed in the south face of the Bucyrus Quarry, National Lime and Stone Company, center of Section 19, Holmes Township.

(Unit descriptions for Figure 17)

Unit

1. Disturbed; includes sand, silt, and till.
2. Till, dark yellow brown 10YR4/4, lower part calcareous, sample H-267, Navarre Till
3. Silt and fine sand, brown, water-bearing
4. Till, dark gray, calcareous, firm, pebbly, massive, jointed, stony, sample H-268, Millbrook Till, unit BI
5. Covered
6. Columbus Limestone

Hayesville Tills. According to Totten (Morrow County manuscript) Unit BI makes up the cores of the Powell and Broadway end moraines in Morrow County, and this same stratigraphic relationship is believed to continue northward into Crawford County.

Millbrook Unit A Till is characterized by a relatively high calcite content averaging 5.3 percent (Table 2) and the highest carbonate content, 12.2 percent, of any till unit in Crawford County. It is a silty till and it contains nearly equal amounts of sand and clay. Its original color where unoxidized is very dark gray brown (2.5Y 3/2) and it oxidizes to an olive brown (2.5Y 4/4) at depths ranging from 9 to 12 feet below the ground surface. Unit A is widely distributed across Crawford County and it occurs beneath Millbrook Unit U Till or Navarre Till in most of the deeper exposures (fig. 14). The thickest exposure of Unit A Till, about 20 feet, is located 1 mile northeast of Bucyrus where Highway 30 Bypass has been cut through the St. Johns end moraine (fig. 18). Another thick exposure occurs in southern Polk Township southwest of Galion where the Olentangy River has cut through an element of the Mississinewa end moraine, exposing 17 feet of Unit A Till. Other prominent exposures of Unit A Till include the Crawford County landfill (fig. 19) and the National Lime and Stone Company quarry and drainage ditches (fig. 15, 20). Millbrook Unit A Till probably makes up the cores of the Mississinewa, St. Johns, Wabash, Ft. Wayne, and New Washington end moraines based on exposures in Crawford County and in Morrow County (Totten, Morrow County manuscript) to the south. The interface between Unit A and the underlying Unit BI is marked in a few places by the presence of water-bearing silt, sand, and gravel as much as 6 feet thick.

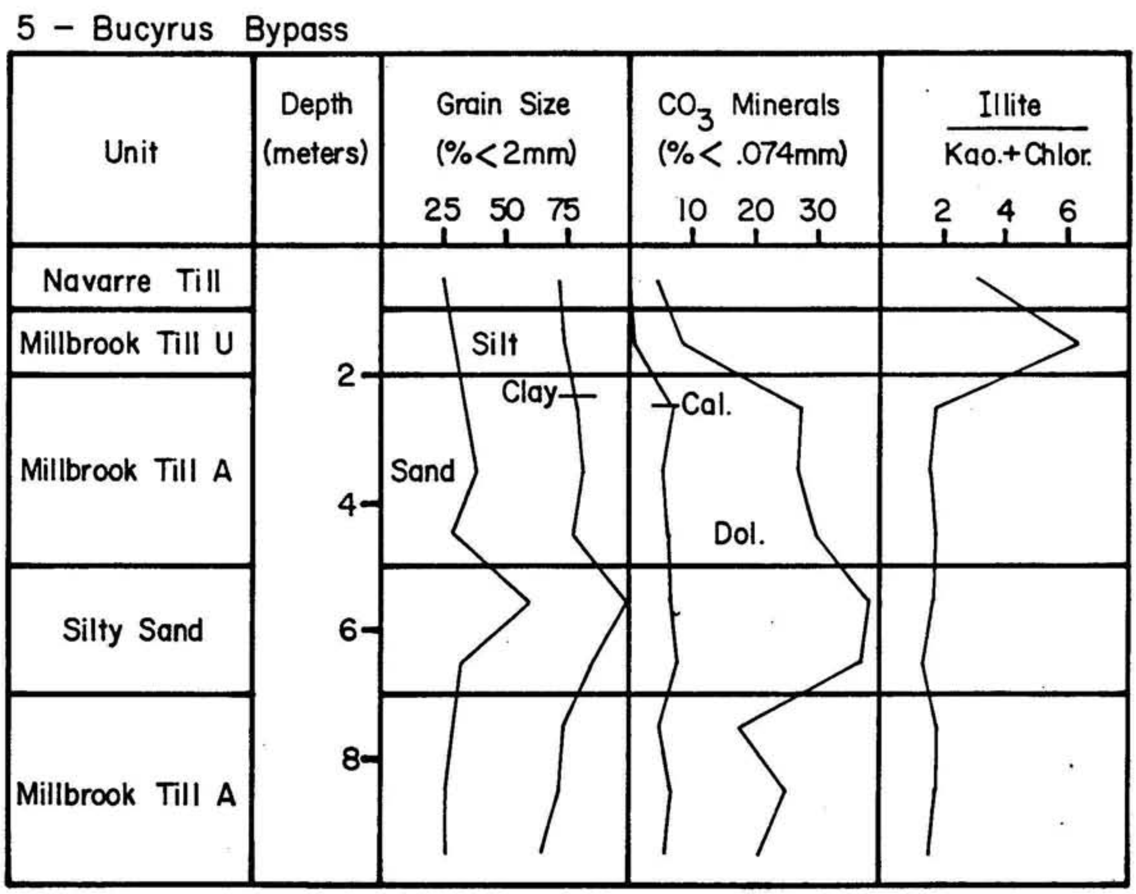


Figure 18. Graph showing variation in texture and mineralogy of tills exposed in the Bucyrus Bypass section 1 mile northeast of Bucyrus. Section is in the St. Johns moraine.

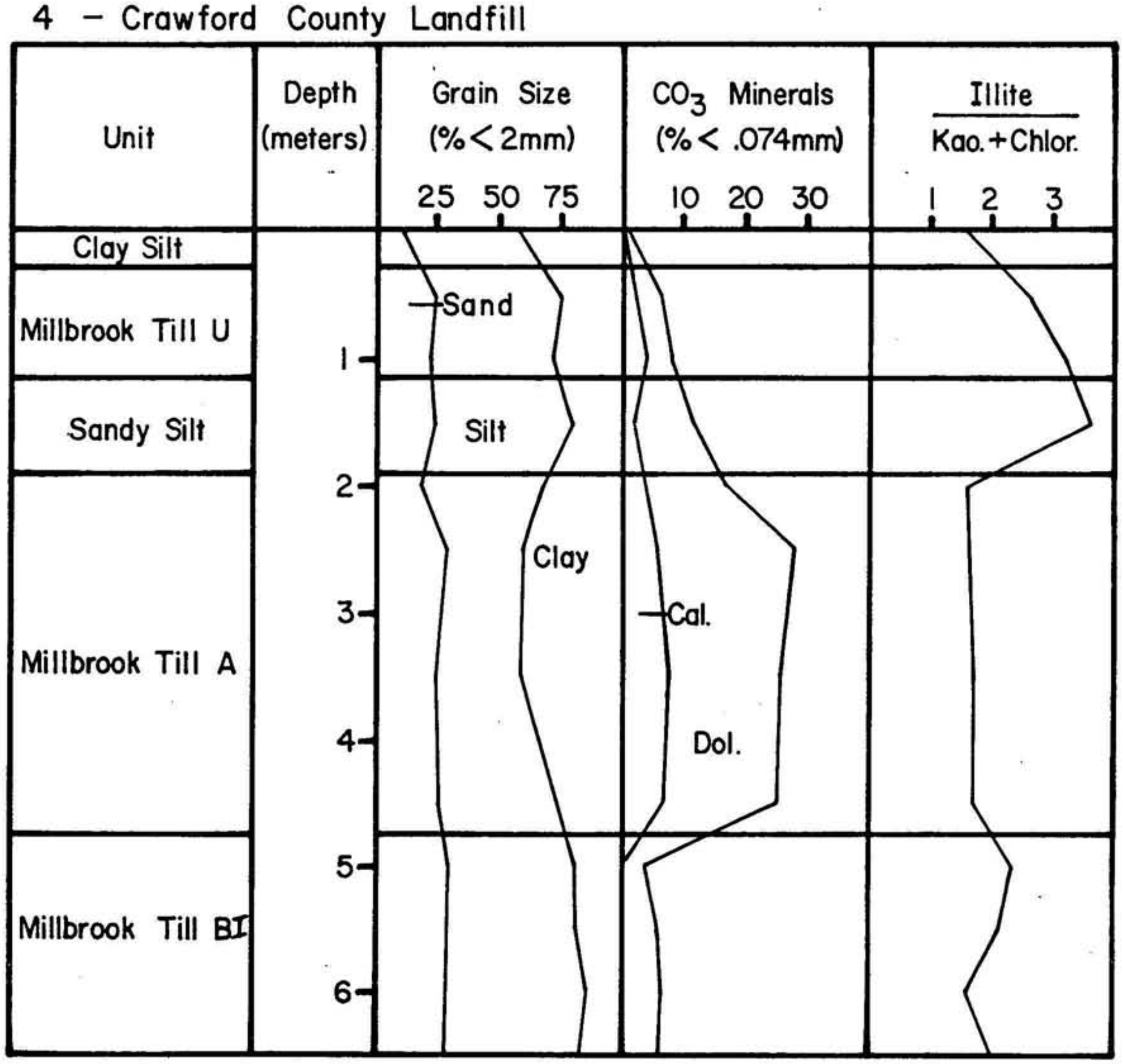


Figure 19. Graph showing variation in texture and mineralogy of tills exposed in the Crawford County landfill about 5½ miles east of Bucyrus, NE¼, Sec. 2, Whetstone Township.

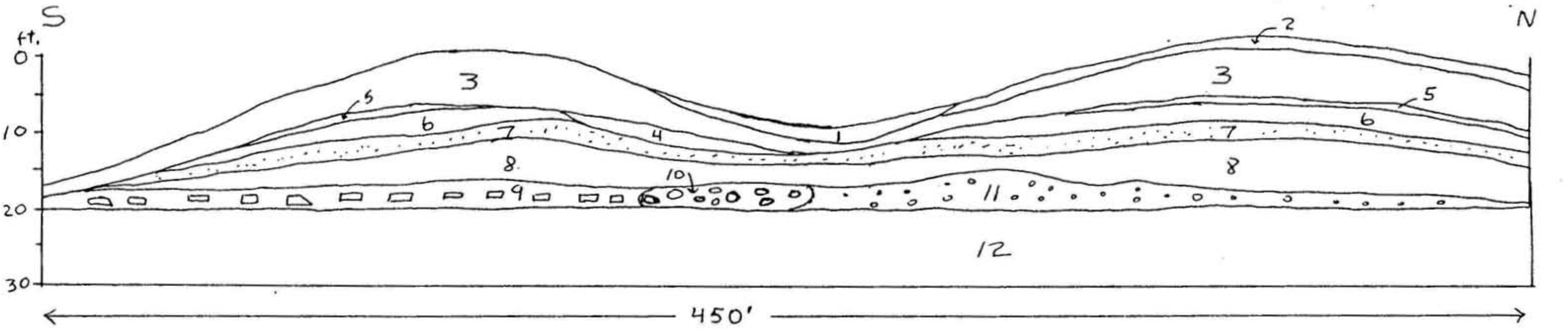


Figure 20. Sketch of the glacial deposits exposed along the west wall of the Bucyrus Quarry, National Lime and Stone Company, NW¼, Section 19, Holmes Township.

(Unit descriptions for Figure 20)

Bucyrus Quarry, National Lime and Stone Company

1. Silt ALLUVIUM

2. Till, dark brown, not calcareous, weathered, blocky, silty, clayey, northern part of section. Consists of thin Hiram Till containing very sparse pebbles overlying thin Hayesville Till containing a few pebbles.

3. Till, dark yellow brown, lower part calcareous, silty, moderately pebbly, few stones, NAVARRE.

4. Till, as above, dark gray, NAVARRE.

5. Gravel, dark reddish brown, sandy, firm, clayey matrix .

6. Till, yellow brown to olive brown where oxidized, very dark gray brown where unoxidized, calcareous, massive, firm, pebbly, MILLBROOK, Unit U

7. Sand and laminated silt, loose, water bearing.

8. Till, very dark gray, calcareous, firm, pebbly, massive, MILLBROOK, Unit A

9. Till (diamicton), dark gray and olive brown, rubbly, contains large slabs of dolostone, MILLBROOK, unit A

10. Gravel, consists mainly of boulders, lenticular (paleochannel).

11. Gravel

12. Columbus Limestone (Devonian) Glacial pavement developed on surface. Prominent, small, most recent striae on polished surface trend due south. Older striae trend S 50° W, and oldest stria and deep gouges trend S 70° E.

The uppermost Millbrook Till unit, Unit U, is characterized by a high calcite content averaging 5.3 percent (Table 2) and a high calcite/dolomite ratio of 1.0. Its texture is very similar to the overlying Navarre Till and also is similar to the underlying Unit A Till. Unit U Till oxidizes to a yellow brown (10YR 4/4) color similar to the Navarre Till. However Unit U is much more pebbly and stony than Navarre Till, and also is much more firm. Unit U in many places also is separated from the overlying Navarre Till by a prominent stone line.

Most exposures of Unit U Till in Crawford County occur in the northwestern part of the county where the till is thin and discontinuous.

The interface between Millbrook Till and the overlying Navarre Till is marked by the occurrence of a variety of materials including silt, sand, gravel, and stones in layers as much as 4 feet thick. In places this zone resembles colluvium but no paleosol or other evidence of soil formation was observed at this horizon in the county.

Millbrook Till (B units) is the oldest till observed in Crawford County. It occurs on unweathered bedrock in several places in the county. However, the base of the Millbrook Till is exposed at so few places that it is possible that older till or tills may be present at depth.

The Millbrook Till and its correlatives form the bulk of the till in the moraines of north-central Ohio (Totten, 1969; White, 1982). The multiple units of Millbrook Till indicate a complex depositional history which probably includes both minor readvances during ice retreat, and thrusting of the ice near its outer margin. The Millbrook Till and its correlatives are closely associated with thick, high quality gravel deposits in many places in north-central and northeastern Ohio (Totten, 1973; White, 1982). Much of the gravel in Crawford County apparently was deposited by meltwater from melting Millbrook ice.

Millbrook Till is correlative with Mogodore Till of the Cuyahoga Lobe and with Titusville Till of the Grand River Lobe (White, 1982). It is also correlative with the Jelloway Till (Totten, 1973) of the eastern margin of the Scioto Lobe. In this report, Jelloway and the younger Woodfordian till unit names formerly assigned to the Scioto lobe have been dropped in favor of retaining the names assigned tills in the Killbuck lobe. White, Totten, and Gross (1969) have assigned an Altonian (Middle Wisconsinan) age for Titusville 40,000 years. Totten and Szabo (1987) have identified a loess unit dated by thermoluminescence as approximately 125,000 years old which occurs between Millbrook Unit BI Till and Navarre Till at MT. Gilead in Morrow County. This new date raises serious doubts about the age assignment of Millbrook Till. If the loess date is correct, then all Millbrook Till units could be of Illinoian age, or preferably, the Millbrook B Till units could be of Illinoian age and the Millbrook A and U Till units could be Early or Middle Wisconsinan.

Navarre Till

The Navarre Till, the oldest of three Wisconsinan (Woodfordian) tills deposited in Crawford County, was named by White (1961) for the village of Navarre in southwestern Stark County. This till has been traced by White (1967, 1977) at the surface and in the subsurface across Wayne and Ashland Counties, and by Totten (1973) who traced the till across Richland County into Crawford County. The Navarre Till in Crawford County occurs as a subsurface unit covered by Hayesville and Hiram Till.

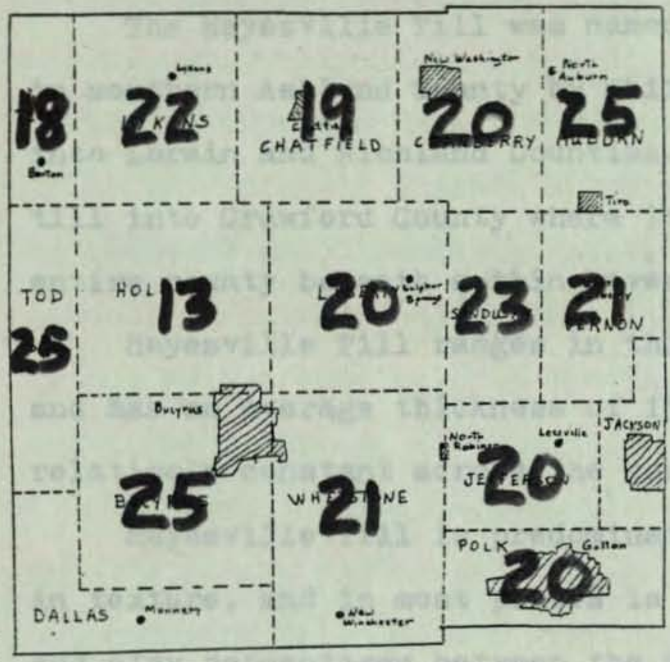
Navarre Till ranges in thickness from 1 to 11 feet and has an average thickness, where it could be measured, of 37 inches. The base of the Navarre is not seen in most roadcuts and thus the till thickness was measured in relatively few places.

Navarre Till is silty, relatively pebbly, contains moderate amounts of sand and clay, and has a loose crumbly or priable structure. The oxidized color of the till typically is dark yellow brown (10YR4/4). In a few places where the till is thick, unoxidized gray (10YR4/1) Navarre Till occurs about 10 feet below the surface. Weathering of the till produces distinct, closely spaced horizontal partings and a platy appearance.

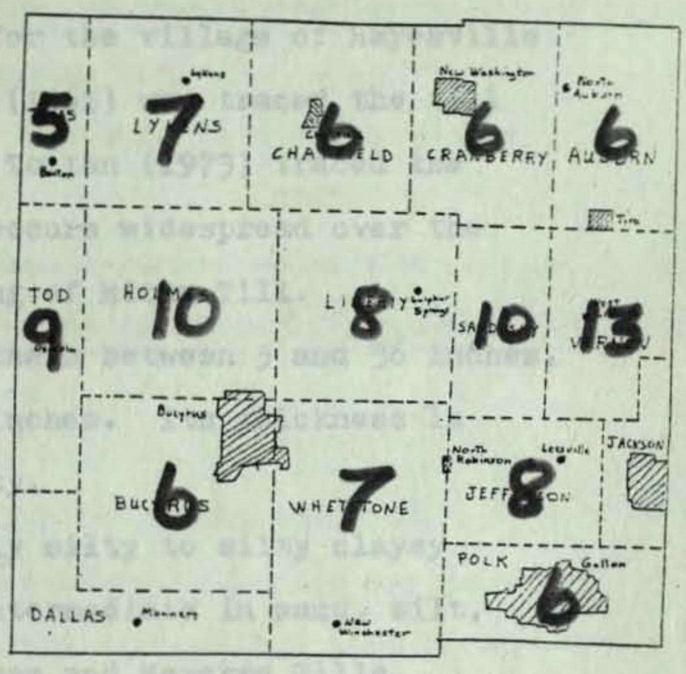
Analyses of Navarre Till samples (Table 2, Appendix B) average 24 percent sand, 48 percent silt, and 28 percent clay. The sand content is lowest in Auburn Township in the northeastern part of the county, and is lowest in Texas Township in the northwestern part of the county (fig. 21). The carbonate content of Navarre Till samples averages 3.2 percent calcite, 6.6 percent dolomite, and 9.8 percent total carbonate, for a calcite/dolomite ratio of 0.48. The carbonate content ranges from a low of 6 percent in Auburn and Texas Townships to a high of 15 percent in Vernon Township (fig. 21). The Navarre Till is similar to the Millbrook Till (U unit) in composition and color. However, the Navarre Till is much softer than the compact, firm Millbrook Till.

Navarre Till contains abundant pebbles, and a freshly broken till surface often displays small orange "spots" which are the exposed cross-sections of broken iron-cemented sandstone pebbles. The interface between the Navarre and the overlying Hayesvill Till often is marked by a line of stones or pebbles. Thin silt and sand lenses may also occur at places along the interface.

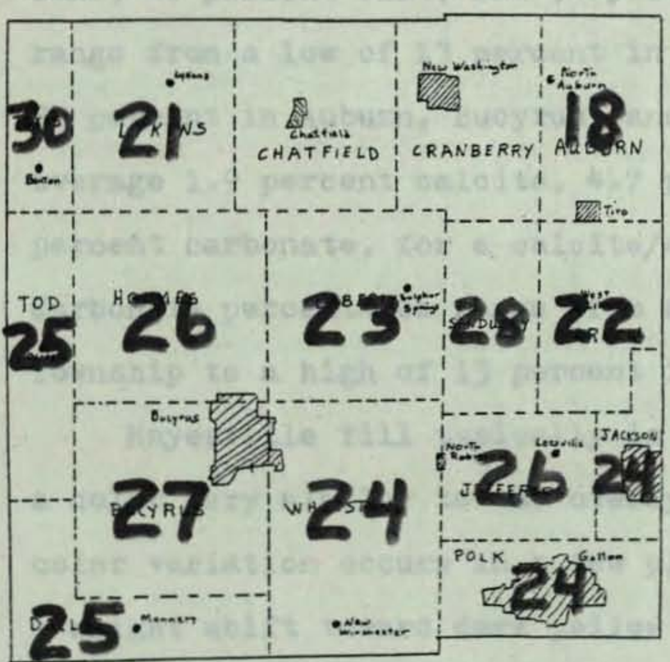
The Navarre Till is correlated with the Kent Till of the Grand River Lobe of northeastern Ohio which has a radiocarbon age of 23,000 YBP (White, 1968). Thus the Navarre Till is earliest Woodfordian in age.



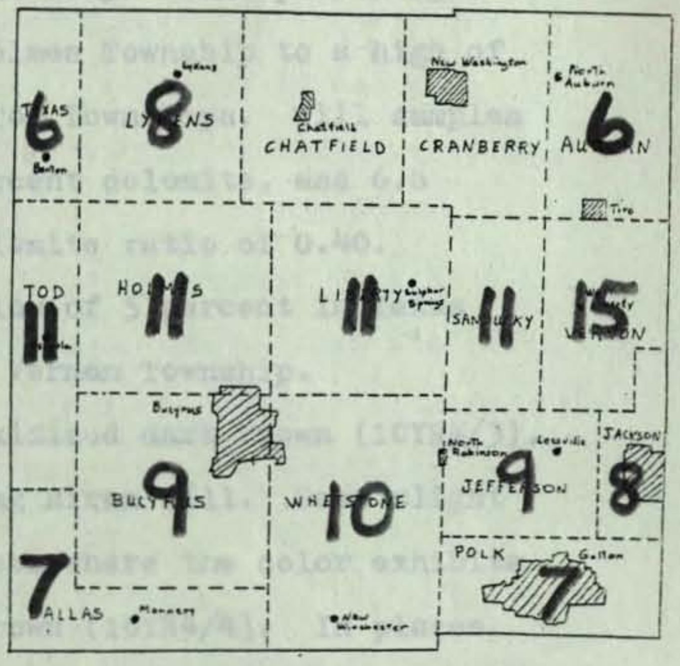
A. Hayesville Till Sand Percentages



B. Hayesville Till Carbonate Percentages



C. Navarre Till Sand Percentages



D. Navarre Till Carbonate Percentages

Figure 21. Distribution of sand and carbonate percentages of Hayesville Till and Navarre Till (by township)

Hayesville Till

The Hayesville Till was named for the village of Hayesville in southern Ashland County by White (1961) who traced the till into Lorain and Richland Counties. Totten (1973) traced the till into Crawford County where it occurs widespread over the entire county beneath a thin covering of Hiram Till.

Hayesville Till ranges in thickness between 5 and 36 inches, and has an average thickness of 15 inches. Its thickness is relatively constant across the county.

Hayesville Till is predominately silty to silty clayey in texture, and in most places is intermediate in sand, silt, and clay percentages between the Hiram and Navarre Tills. Hayesville Till samples (table 2, Appendix B) average 20 percent sand, 46 percent silt, and 34 percent clay. Sand percentages range from a low of 13 percent in Holmes Township to a high of 25 percent in Auburn, Bucyrus, and Tod Townships. Till samples average 1.9 percent calcite, 4.7 percent dolomite, and 6.6 percent carbonate, for a calcite/dolomite ratio of 0.40. Carbonate percentages range from a low of 5 percent in Texas Township to a high of 13 percent in Vernon Township.

Hayesville Till typically is oxidized dark brown (10YR4/3), a color very similar to the overlying Hiram Till. Some slight color variation occurs in a few places where the color exhibits a slight shift toward dark yellow brown (10YR4/4). In places the till also has a dull appearance which is described as "drab" or "punky" in field notes. Unoxidized Hayesville Till at depths of 10 feet or more below the surface is dark gray (10YR4/1).

Hayesville Till breaks into large, smooth, irregular to nearly square blocks on a freshly exposed surface. A short period of exposure causes horizontal partings to develop in the till, resulting in a platy structure. The till contains a moderate to small amount of pebbles and granules which are predominately sedimentary in origin. The presence of granules is one of the best ways to distinguish between the Hayesville and Hiram Tills.

Hayesville Till in most places has been leached of carbonates in its uppermost part, and secondary carbonate may be concentrated in an area directly beneath the leached zone. The average depth of leaching in Crawford County, 31 inches, falls midway within the column of Hayesville Till (fig. 11). Leaching of carbonates from the till is influenced by the thickness and composition of the overlying material. The depth of leaching may reach 40 inches or more if material overlying the Hayesville Till is thin or absent.

The contact or interface between the Hayesville Till and the overlying Hiram Till is difficult to detect because the two tills are so similar, and because little foreign material occurs between the tills. At many sections exposing the two tills in Crawford County the interface is marked by a line of pebbles or small stones. The most reliable method of detecting the Hiram-Hayesville Till contact is by noting the pebble-granule increase in the Hayesville Till.

Hayesville Till is sufficiently near the surface in many places to influence the development of the soil profile.

In Richland County (Totten, 1973) to the east, the Bennington-Cardington soil has been mapped in areas covered by thin Hiram Till where the somewhat permeable Hayesville Till allows better drainage and deeper root penetration beneath thin Hiram Till. In Crawford County, the Bennington-Condit soil association, as well as the closely related Cardington and Glynwood soils, have been mapped in areas where Hayesville Till is the dominant parent material (Steiger and others, 1979).

The Hayesville Till was deposited during the Woodfordian glacial state, and is intermediate in age between the older Navarre Till and the younger Hiram Till. Its exact age in radiocarbon years has not been determined because of the lack of datable organic material associated with the till; its estimated age is about 18,500 YBP based on its relationship to deposits of known age.

Hiram Till

The Hiram Till, the youngest till in Crawford County, was named for the village of Hiram in northeastern Portage County by White (1960). A thin covering of Hiram Till extends over all of Crawford County excepting along stream courses where it has been eroded away. Hiram Till may be considered to be the surface material over most of the county, the main exceptions being the lake plains in the northeastern part of the county.

The thickness of Hiram Till ranges from 0 to 24 inches and averages 12 inches. The till thickness is relatively consistent over the county as over half of the recorded thickness measurements are between 10 and 20 inches.

The Hiram Till is oxidized to a dark brown (10YR4/3) color often with a slightly different shade of dark brown from the underlying brown Hayesville Till. The difference in color between the Hiram and Hayesville Tills is so slight as to not be a reliable criterion for distinguishing between them. Hiram Till is rich in silt and clay, and has a blocky or prismatic structure. Hiram Till is very sparsely pebbly, contains almost no granules, and may be mistaken for lacustrine clay which it closely resembles.

The depth of leaching of carbonates in Crawford County is dependent primarily upon the thickness of Hiram Till. The Hiram Till and the thin covering of loess overlying the till average a total 22 inches in thickness, which is 9 inches less than the average depth of leaching in the county. Thus unleached Hiram Till rarely occurs in the county. In the subsoil, weathering of Hiram Till develops horizontal partings and a fine prismatic structure.

Analyses of Hiram Till samples (Table 2, Appendix B) indicate the till averages 20 percent sand, 44 percent silt, and 36 percent clay. Thus the Hiram Till has the lowest sand and silt percentages, and highest clay percentage, of any till in Crawford County. Insufficient calcareous Hiram Till samples were available to obtain accurate determination of carbonate content. It is probable that all Hiram Till samples were at least partially leached.

The major soil association developed in Hiram Till is the Blount-Pewamo association (Table 3) (Steiger and others, 1979). Blount soils are somewhat poorly drained and occur on level to gently sloping areas. Pewamo soils are very poorly drained and occur on nearly level areas.

Although the Hiram Till is the youngest till in the county, late glacial and post-glacial events were responsible for deposition of a wide variety of materials on top of the till in many places. Numerous undrained shallow depressions existed on the till surface, and these are wholly or partially filled with lacustrine sediments such as clay, silt, marl, and peat. The widespread lake sediments in the northeastern part of the county are described in another section.

Wind-blown silt called loess forms a thin silt capping at the surface over most of Crawford County. Silt ranging in thickness from 5 to 16 inches was recorded at 22 localities.

Table 3

Relationship of Soil Associations to Geology

Soil Association	General Characteristics	Dominant parent materials
Tiro-Condit-Luray	Nearly level, Poorly drained	Lake silt, Hiram Till
Luray-Tiro	Nearly level, Poorly drained	Lake silt
Lenawee-Bono	Nearly level Very poorly drained	Lake silt and clay
Bennington-Condit	Nearly level Somewhat poorly drained	Thin Hiram Till Hayesville Till
Blount-Pewamo	Nearly level, Poorly drained	Hiram Till, Hayesville Till
Wadsworth-Condit	Nearly level Somewhat poorly drained	Hiram Till thin or absent Hayesville Till, Navarre Till
Cardington-Bennington-Pewamo	Gently sloping Somewhat poorly drained	Thin Hiram Till Hayesville Till
Blount-Glynwood-Pewamo	Very gently sloping Somewhat poorly drained	Thin Hiram Till Hayesville Till
Cardington-Shoals	Level to moderately steep Moderately well-drained	Recent alluvium (level) Glacial Till (steep)
Glynwood-Lobdell	Level to moderately steep Moderately well-drained	Recent alluvium (level) Glacial Till (steep)

The loess is characterized by a loose, friable, nearly pure silt texture and an almost total lack of pebbles and granules. Loess differs from lacustrine silt in that the lake deposits usually show some stratification and usually contain some clay which causes the material to be more dense and compact. Generally where loess is thinner than about 8 or 9 inches, it becomes mixed with the underlying till or other material by organic activity and agricultural practices, thus rendering the loess unidentifiable.

GEOMORPHOLOGY OF THE GLACIAL DRIFT

General Statement

The surface expression of the glacial drift in Crawford County has been produced by several ice advances, and, during ice retreat, by outwash deposits laid down upon, within, or beyond the melting ice. In addition to ice-related deposits, three large lakes and numerous small lakes existed for varying lengths of time after disappearance of the ice, and these ancient lake beds form distinctive features.

End Moraines

General Statement

Seven end moraines, each consisting of two or more elements, criss-cross all parts of Crawford County (fig. 2). From the southeast corner to the north in the county, these moraines are the Powell, Broadway, Mississinewa, St. Johns, Wabash, Ft. Wayne, and New Washington end moraines. In Crawford County these moraines trend mainly east-west in the northern part of the county, and mainly northeast-southwest in the southern part of the county (Plate 1).

End moraines were distinguished primarily on field recognition of hummocky topography. Moraine mapping was complicated by the gradation of end moraine topography to till plain topography in many places. Stratigraphic evidence indicates the end moraines predate the Woodfordian glaciation, and the moraines are believed to have been overridden two or three times, smoothed, and in places nearly "wiped out" by later ice advances. The end moraines in Crawford County were formed during the advance and retreat of one or more ice advances that deposited the Millbrook Till. White (1982) assigned an age of about 40,000-35,000 RYBP to the Millbrook Till. Thermoluminescence dating of loess within the Millbrook sequence (Totten and Szabo, 1987) suggests at least some Millbrook Till (and some of the moraines) is pre-Wisconsinan in age.

Powell Moraine

The Powell moraine in the Scioto lobe was first mapped by Leverett (1902) who described it as a minor moraine probably equivalent to the Mississinewa moraine of the Miami lobe. The Powell moraine has been traced eastward and northward from its locality in Delaware County into Crawford County by White (1935) who traced it as far northeast as Richland County. Only a very small part of the northeast trending Powell moraine occurs in the extreme southeastern corner of Crawford County (fig. 2). The Powell moraine was deposited near the crest of the Allegheny escarpment (fig. 3) and the morainic knolls represent the highest elevation in the county. Totten (1973) recognized two elements of the Powell moraine in Richland County, and three ridge crests which in places are joined comprise the Powell moraine in Morrow County to the south.

Broadway moraine

The Broadway moraine was named by Leverett (1902) who mapped the moraine across the northern part of the Scioto lobe. White (1935) traced the moraine from its type locality in Union County eastward into Delaware County and northward into Morrow and Crawford Counties. In Crawford County the Broadway moraine consists of two discontinuous elements which trend northeast across Polk, Jefferson, and Jackson Townships in the southeastern corner of the county (fig. 2). Both elements consist of low, broad knolls that rise 15 to 25 feet above their surroundings. The elements occur along the upper part of the Allegheny escarpment in the Low Plateau section (fig. 3) in a position intermediate between the Powell and Mississinewa moraines. The wider, outer element of the Broadway moraine bends eastward at Galion whereas the narrow inner element continues northeastward to near Crestline where it also bends eastward toward Richland County. Both elements of the moraine are dissected by the Olentangy River at Galion.

<u>Mississinewa moraine</u>

The Mississinewa moraine which is well-developed in the Miami lobe of western Ohio (Goldthwait, White, and Forsyth, 1961) was first traced into western Morrow County by Totten, (1969) who traced it northward into Crawford County. In Polk Township west of Galion, the Mississinewa moraine consists of a northward-trending belt of low knolls having a total width of nearly 2 miles. North of Galion three ridge-like elements of the moraine are evident. These elements join to make a single element west of Leesville. Between Galion and Leesville the outer (distal) margin is bordered by hummocky kames and an esker containing deposits of sand and gravel. About 1 mile northwest of Leesville the Mississinewa moraine becomes very narrow and is virtually absent for an interval of about 1 mile. Two miles north of Leesville in southeastern Sandusky Township the moraine is well-developed and can be traced northeastward across Vernon Township into Richland County. In Vernon Township the Mississinewa moraine attains a width of 1½ miles and near the Crawford-Richland County line the moraine splits into three separate elements bordered by the bed of Lake Shelby. The morainic knolls rise 10 to 30 feet above their surroundings, and near the county line the knolls resemble kames though their composition is till, at least in the explored portions. At Leesville the Sandusky River cuts across a narrow segment of the moraine, and farther north a tributary, Loss Creek, flows southwestward in the narrow depression between the Mississinewa and St. Johns moraine.

St. Johns moraine

The St. Johns moraine was named by Winchell (1872,1874) for the village of St. Johns located on the ridge in Anglaize County. Winchell's mapping of the moraine was primarily in the Miami lobe where the St. Johns moraine is situated between the Mississinewa moraine to the south and the Wabash moraine to the north. Leverett (1902) mapped the Scioto lobe and named the ridge south of the Wabash moraine the MT. Victory moraine for the village in Hardin County. White (1939) determined that the MT. Victory moraine was a continuation of the St. Johns moraine and assigned the name St. Johns to both on the basis of priority. The St. Johns moraine extends in a general west to east direction across west-central and north-central Ohio and it makes gentle southward loops in both the Miami and Scioto lobes (Goldthwait, White, and Forsyth, 1961).

The St. Johns moraine consists of three elements in southern Crawford County where it trends north-northeastward between the Marion-Crawford County line and Bucyrus. The outer (eastern) element is discontinuous and very weakly developed at the Marion - Crawford County line, but it strengthens southeast of Bucyrus where it is a low, broad ridge ½ to 1 mile wide and 15 to 25 feet high. The middle and inner (western) elements which are continuous though weakly developed belts of knolls in Dallas Township merge in Bucyrus Township and apparently disappear about 1 mile south of Bucyrus. A large tract of hummocky topography east of Bucyrus and south of the Sandusky River is attributed to the St. Johns moraine. Near Bucyrus the St. Johns moraine bends northeastward across the southern part of Liberty Township. In eastern Crawford County the St. Johns moraine is represented by a single narrow element $\frac{1}{4}$ to $\frac{1}{2}$ mile wide which is in contact with the Wabash moraine to the northwest. A part of this narrow ridge stands 30 to 40 feet above its surroundings. About 2 miles northeast of Bucyrus the Sandusky River has carved a valley through a low part of the moraine. In the eastern part of the county the distal (southern) margin of the moraine is followed by the Sandusky River and by a major tributary, Loss Creek. A deep roadcut through the moraine northeast of Bucyrus revealed the moraine is composed of Millbrook A Till with a thin veneer of Millbrook U Till and Navarre Till on top (fig. 18).

Wabash moraine

The Wabash moraine was named by Winchell (1872) for the Wabash River in Indiana which flows along the southern margin of the moraine for a considerable distance. Winchell traced the Wabash moraine into the Miami lobe of western Ohio where it trends generally eastward across Mercer, Auglaize, southeastern Allen, and Hardin Counties. Leverett (1902) traced the moraine eastward into the Scioto lobe across Hardin County, Marion County, and a corner of Wyandot County to Crawford County. In Crawford County (Plate 1) the Wabash moraine extends northwestward diagonally from near the southwest corner to near the northeast corner. In the western part of the county the Wabash moraine consists of two weakly developed belts of hummocky topography separated by a two-mile wide tract of ground moraine. The distal (southern) hummocky belt consists of as many as four low, narrow ridge segments each 1000 to 2000 feet wide and about 10 feet high. This belt is bounded on the south by the Sandusky River. The proximal (northern) belt near Oceola in Todd Township is about ½ mile wide and consists of broad knolls 10 to 20 feet high. A gap 3 miles long occurs in the northern belt across Holmes Township, but the moraine has sufficient though weak development in the eastern part of the township to permit its tracing eastward where it merges with the southern morainic belt north of Bucyrus. Northeast of Bucyrus in Liberty Township the Wabash moraine narrows to a single belt 1 to 1¼ miles wide.

As many as 3 separate ridge crests may be recognized in this portion of the moraine. The Wabash moraine can be traced as a single continuous element from north of Bucyrus northeastward a distance of 12 miles to the Crawford-Richland County line. Across northeastern Crawford County the Wabash moraine is closely bordered by the St. Johns moraine to the south and the FT. Wayne moraine to the north. The mapping of crestlines within the complex morainic belt in Sandusky, Vernon, and Auburn Townships is useful in tracing individual moraines. However, crestlines and ridge segments cannot be traced with certainty for more than 1 or 2 miles. Contributing to the difficult tracing of morainic elements is the presence of younger ice-contact features (kames, kettles, eskers) which are superposed on the older morainic hummocks across several square miles in central Sandusky Township. In general, the ridges and knolls that comprise the Wabash moraine are more prominent in the northeast part of the county where hummocks rise to 20 to 30 feet above their surroundings. Quarry and drainage ditch exposures through several morainic knolls most closely associated with the Wabash moraine near Oceola northwest of Bucyrus (fig. 15, 20) reveal that Millbrook A Till makes up the bulk of several surface knolls. A buried knoll of Millbrook B I till occurs in a large drainage ditch and in a quarry (fig. 15, 17). Younger Millbrook U Till and the Navarre, Hayesville, and Hiram Tills occur as thin blanket-like deposits on top of the knolls.

Ft. Wayne moraine

The Ft. Wayne moraine was named by Gilbert (1871) for the city in northeastern Indiana situated on the moraine. Leverett (1902) traced the Ft. Wayne moraine eastward from Indiana across the Miami and Scioto lobes of Ohio. Like the Wabash moraine several miles to the south, the Ft. Wayne moraine bends southward a short distance near the center of each lobe. In Crawford County the Ft. Wayne moraine is represented by two complex belts of east-west trending hummocky topography. The depression between the two belts is followed for 15 miles by Broken Sword Creek. Along the western margin of the county in Tod and Texas Townships, hummocky topography that appears to be part of the Ft. Wayne stretches over a width of 6½ miles. However, 4 miles east of the Wyandot-Crawford County line, the moraine is reduced in width to less than 1 mile. The southern-most element of the Ft. Wayne moraine extends eastward for 3 miles in western Crawford-County (fig. 2). A gap 3 miles long occurs in the southern element in Holmes Township. In northeastern Holmes County the portion of the moraine south of Broken Sword Creek consists of weakly developed ridge segments each 10 to 15 feet high and ½ to 2 miles long. In northern Liberty Township the distal (southern) moraine margin is accentuated by the presence of a prominent narrow arcuate ridge 25 to 30 feet high and 4 miles long. This prominent ridge merges with hummocky topography of the Wabash moraine at Sulphur Springs. East and northeast of Sulphur Springs the Ft. Wayne moraine overlaps the proximal (northern) margin of the Wabash moraine.

The northern belt of the Ft. Wayne moraine which is located north of Broken Sword Creek is nearly continuous from west to east across the entire county. In most places the northern morainic belt is between ½ and 1 mile wide and it consists of two distinct ridges. The crest lines of the ridges rise about 40 to 50 feet above the adjacent Broken Sword Creek Valley. The continuity of the northern morainic belt is broken by several southward flowing tributaries of Broken Sword Creek including Red Run. At Tiro in Auburn Township this belt bifurcates to form two elements which trend northeastward into Richland County.

A small morainic ridge in southern Cranberry Township extends northward from the Ft. Wayne moraine at nearly a right angle (fig. 2). This low broad ridge, about 3 miles long and 3/4 mile wide, probably is not related to the Ft. Wayne moraine or to other named moraines which trend east-west in the samd general area. Its northward trend is similar to the trend of the Delphi moraine in Huron County (Totten, Huron County manuscript).

New Washington moraine

The New Washington moraine was named by White (1939) for the village of New Washington in northeastern Crawford which is located on the moraine. The New Washington moraine is shown as a small "loop" of the Fort Wayne moraine in northern Crawford County by Goldthwait, White, and Forsyth (1961). However regional mapping (Totten, 1969) has confirmed the presence of a distinct and continuous morainic belt north of and separate from the Ft. Wayne moraine in the Scioto and Killbuck lobes. The New Washington moraine is represented by a small irregular, eastward trending hummocky belt about 2½ miles long and ½ to 3/4 mile long in the northwestern corner of the county. Buckeye Creek cuts scross the moraine near the Crawford-Seneca County line. The New Washington moraine extends northeastward into Seneca County for several miles, and then extends southeastward into Crawford County at the northeastern corner of Lykens Township. In northern Chatfield Township, four elements of the moraine having a combined width of 2½ miles are present. These elements make a small southward loop into central Cranberry Township and are joined together into single belt 1¼ miles wide at New Washington. At least two ridge crests, and in places, three crests are present in the New Washington moraine in Chatfield, Cranberry, and Auburn Townships. The crest of the southern-most element is especially prominent and it attains heights of 30 to 40 feet above the bordering bed of Lake Cranberry to the south.

North of Auburn Center in the northeastern corner of the county the moraine narrows to a width of 1 mile along the eastern edge of the Scioto lobe.

Ground moraine

Almost half of the surface of Crawford County consists of ground moraine (Plate 1, fig. 2). The ground moraine surface in most parts of the county is a very gently undulating plain which has undergone slight dissection by small streams. In many places, such as in Lykens Township, the surface may appear to be flat with only a few low knolls and shallow swampy depressions to provide topographic relief. Most parts of the ground moraine surface contain at least 5 feet of relief in the distance of a mile, and a few areas of ground moraine have 10 to 15 feet of relief in a mile. The surface till of the ground moraine is mainly Hiram Till overlain in many places by a thin veneer of lacustrine silty clay and/or loess as much as 1 or 2 feet thick. Soils developed on ground moraine include the poorly drained Tiro, Condit, Luray, and Bennington silty clay loams. In places where the Hiram Till is thin, the soils are developed in older tills which usually provide better drainage characteristics.

Lake Willard

Lake Willard is the name applied to a large lake bed about 10 miles long and 5 miles wide located in southwestern Huron County, northwestern Richland County and northeastern Crawford County (Plate 1). Lake Willard, which has previously been called Willard Lake, Willard Marsh, Huron Marsh, New Haven Marsh, Celeryville Muck Area, and The Muck, occupied the lowland between the New Washington moraine to the south and the Defiance moraine to the south. During its greatest extent, Lake Willard apparently reached a level of about 948 feet along its southern margin in Auburn Township although a level of 940 feet appears to mark the upper limit of the lake in Huron County (Totten, Huron County manuscript). The maximum extent of the lake is based both on topography and the distribution of lacustrine sediment. No distinct shoreline or shore deposits such as beaches occur and thus the lake margins (Plate 1) must be regarded as approximate. Hubbard and Rockwood (1942) mapped the margin of the lake bed on the basis of silt deposits they recorded at elevations considerably higher than the levels recognized in this study. The lake levels postulated by Hubbard and Rockwood (1942) of 980 to 985 feet on the south side of the lake may have been based on a misidentification of Hiram Till as lacustrine sediment, a problem common to glacial studies in northern Ohio. The northward regional slope north of Ft. Wayne moraine probably caused considerable ponding of water in northern Crawford County during ice retreat. For a very short time, the water level in Lake Willard probably exceeded 1000 feet, and the lake may have overflowed southward into Lake Cranberry through a pass in the New Washington moraine, As soon as the ice had retreated far enough to the north to open the westward drainage by way of Honey Creek, the level of early ponding fell to about 948 feet and remained relatively constant until a lower northward outlet was opened. Although silt of probable lake origin can be found at elevations exceeding 948 feet north of the New Washington moraine, the 948 foot level marks the boundary between soils derived from lake silty clay and soils derived from till (Steiger and others, 1979). A very small area of organic-rich silt or muck (Carlisle soil) is present in a broad shallow depression at an elevation of about 935 feet near the northeastern corner of the county. A much larger muck area associated with Lake Willard occurs in Huron County (Totten, Huron County manuscript).

Lake Shelby

Lake Shelby is the name given a large lake bed located primarily in Richland County (Totten, 1973). Hubbard and Rockwood (1942) originally named and described the lake bed as a small feature located in Plymouth Township, Richland County. Totten (1973) remapped and expanded the margin of the lake bed to include parts of 5 townships in Richland County and a considerable area in eastern Crawford County. The bed of Lake Shelby in Crawford County includes parts of Auburn, Vernon, Jefferson, and Jackson Townships. The extent of Lake Shelby in Crawford County was controlled primarily by the position of the stagnating ice front rather than topography. Soils maps (Steiger and others, 1979) were used to locate the western margin of the lake bed (Plate 1) in Vernon and Jefferson Townships at an elevation of about 1120 feet, which is too low to have been the shoreline elevation. Elevations of the lake bed range from 1120 feet to about 1140 feet in the county, which is higher than the till plain west of the Sandusky River. Topographically, the lake bed basically is very gently rolling to nearly featureless till plain veneered with about 2 to 7 feet of lake silt and clay. The lake bed as mapped (Plate 1) remained intact for only as long as Hiram ice remained in the Sandusky River Valley near Leesville. Northward retreat of Hiram ice allowed Lake Shelby to expand westward over the till plain for a brief time and then to ultimately drain westward via the Sandusky River. Much of the Richland

County portion of the bed of Lake Shelby slopes northeastward toward Shelby, and Totten (1973) proposed that a low stage for Lake Shelby of about 1085 feet may have existed in Richland County for a considerably longer period. It was this smaller and longer lasting lake that was mapped by Hubbard and Rockwood (1942).

Lake sediment of Lake Shelby consists primarily of silty clay. In an exposure of thick lake sediment north of Crestline, silty clay 6½ feet thick occurs over thin gravel and Hiram Till. Poorly drained Luray, Lenawee, and Tiro silty clay loam soils (Steiger and others, 1979) are developed from the lake sediment.

Lake Cranberry

Lake Cranberry is the name applied to a narrow two-pronged lake bed located in Cranberry Township and adjourning areas south of the New Washington moraine (Plate 1). This lake bed was first mapped by Hubbard and Rockwood (1942) who characterized it as little more than a large irregular kettle, and who called it the Tabor School lake bed. More recently this area has become known to local residents as Cranberry Marsh, and the adoption of Lake Cranberry recognizes common usage. The bed of Lake Cranberry has a highly irregular shoreline resembling a horseshoe about 7½ miles wide and about 3 miles long. It is bordered on the north by the distal margin of the New Washington moraine, on the east and south by the 1010 foot contour line, and on the west by the front of an ice sheet probably stagnating at a ground elevation of about 1000 feet. The western margin of the lake (Plate 1) is based on the presence of soils derived from lake silt and silty clay (Steiger and others, 1979). Poorly drained Bono and Lenawee silty clay loam soils are developed in the lake sediment. The till plain west of Lake Cranberry has a lower elevation than the lake plain, a situation similar to Lake Shelby. Even so, Lake Cranberry apparently had a stable water level of 1010 feet, a level which may have represented the overflow drainage southward from the valley of Broken Sword Creek. The topography of the lake bed varies from nearly flat to very gently rolling, and is not visibly different from the nearly flat till plain surface west of the bed near Chatfield. The thickest exposure in the lake bed revealed 5 feet of silty clay overlying sand and gravel.

ALLUVIAL (OUTWASH) DEPOSITS

Introduction

Water from the melting ice sheets carried gravel, sand, silt, and clay away from the ice to greater or lesser distances. The deposits are sorted as to grain size, and generally the finer silt and clay are washed farthest downstream leaving sand and gravel nearest the source.

The outwash which was carried down the valleys that were free of ice was deposited as valley trains, which filled the valleys to a certain level. Later when sediment was no longer supplied by the melting ice, the streams began to erode and lower their channels below the valley train surface, leaving more or less extensive remnants as terraces along the valley sides.

In some places, water flowing from the ice deposited cones of material against the ice edge, or in holes or low places in or on the ice itself. When the ice disappeared, these became mounds called kames. As some of this material was deposited right at the ice edge, it incorporated masses of unsorted debris (till) in the sand and gravel, which in kames tend to be more poorly sorted and irregularly bedded than valley train deposits.

Some of the meltwater carved sinuous channels on top of the ice sheet. Sand and gravel representing the bedload of the stream were deposited in the channel. When the ice finally melted, the sand and gravel formed a sinuous ridge known as an esker.

During deglaciation, ice remained in some valleys after the uplands were free of ice, and meltwaters flowed on, around, or beneath the valley ice. Most commonly, meltwater streams deposited sand and gravel between the tongue of ice in the valley and the valley sides. When the ice in the valley melted, the outwash remained along the valley sides as kame terraces. Smaller ice masses which were buried in the outwash eventually melted and the sand and gravel over them collapsed to form kettle holes, some of which were deep enough to extend below the water table, and thus were the sites of lakes or swamps.

During the latter part of the Pleistocene, the major drainage mainly was to the west and south in Crawford County, and small amounts of sand and gravel were deposited in the larger valleys. The Wabash, Ft. Wayne, and New Washington end moraines deposited by Millbrook ice blocked drainage, thereby creating three temporary lakes. Consequently, much outwash from melting Wisconsinan ice was ponded, and finer grained silts and clays were deposited in the lakes and in the ponded valleys.

Kames

A relatively small number of kames occur in Crawford County. One of the largest concentration of kames in Crawford County occurs in the lowland between Galion and Leesville (Plate 1). Hummocky topography of the Mississinewa moraine is so closely associated with the kames that the presence of gravel is the only way of identifying which knolls are kames. The kame and moraine complex in Polk and Jefferson Townships covers an area 3½ miles long and about 2 miles wide and contains at least 6 gravel pits, most of which are old and overgrown. Most kames have the appearance of low broad knolls that rise only about 10 to 20 feet above their surroundings. Several low, broad ridges which bear a slight resemblance to eskers also occur in the complex. Some of the sharpest kame-like knolls occur near Middletown between Galion and Leesville and are mapped as gravelly moraine based on the presence of thick till at the surface. Gravel pit exposures in knolls southeast of Middletown reveal 15 feet of gravel overlain by as much as 13 feet of Navarre Till and 3 feet of Hayesville Till. The till-gravel interface has 10 feet of relief and the gravel layers dip in many directions typical of ice-contact kame deposits. Well-drained Chili, Wilmer, and Bogart soils are developed in the kame complex (Steiger and others, 1979). These kames probably were deposited during the retreat of Millbrook ice though it is possible some or all could be of Navarre age.

Less than a mile southwest of Galion and north of the Olentangy River within the Mississinewa moraine is a small area of low knolls about ½ mile wide and 1 mile long. The kame origin of these knolls is indicated by the presence of sandy Wilmer and Bogart soils (Steiger and others, 1979). No pits have been opened in these knolls to reveal the thickness or nature of the deposit.

Two well-developed kames occur in the Ft. Wayne moraine in eastern Auburn Township within 0.6 mile of the Crawford-Richland County line (Plate 1). The larger kame, 0.7 mile east of Auburn Center, is about 30 feet high and 1000 feet in diameter. A pit in the kame revealed 20 feet of well-sorted crossbedded coarse to fine sand and some sandy gravel. The kame deposits exhibit considerable variation in the dip of the bedding and in the grain size.

The Mississinewa, St. Johns, Wabash, and Ft. Wayne end moraines in the eastern part of the coundy in places contain sharp knolls that resemble kames. Some sand and gravel is known to occur within these moraines; however most exposures reveal only till. Exposures are not adequate to determine the composition of these knolls at depth. The well-drained Alexandria soils which are developed on these knolls (Steiger and others, 1979) indicates that at least small amounts of sand and gravel may occur in the moraines at depth.

Kame Terraces

Kame terraces are not extensively developed in Crawford County, primarily because of the lack of major drainage lines leading southward from the melting ice sheet. The two north-south trending sandy ridges about 3/4 mile long, 400 to 600 feet wide, and 20 to 25 feet high in Sandusky Township south of Broken Sword Creek resemble a kame terrace in that the ridges are paired on either side of a small valley. Gregory (1956), who referred to the ridges as eskers, reported stratified sand to be the major component of these features.

Other ridges which resemble kame terraces are located on both sides of a shallow valley which extends northward from the Olentangy River in Galion a distance of about 4 miles to Leesville. This shallow valley is notable in that its middle section serves as a drainage divide between the Olentangy River and the Sandusky River. The gravelly, terrace-like ridge segments consist of low knolls having linear arrangement, and they are closely associated with the kame complex described in another section.

Eskers

Leesville esker

The Leesville esker, first reported by Winchell (1874) who referred to it as a "hogs-back", is a narrow north-south trending ridge about ½ mile long and as much as 40 feet high located ½ mile southwest of Leesville. Winchell (1874) also reported that another ridge or "spur" had been completely excavated for construction purposes. The esker is situated within the hummocky topography and the kame complex in the headwaters of the Sandusky River between Leesville and Galion.

Outwash Plain

A small outwash plain about 0.4 mile wide and 1.5 mile long is located in the southeast corner of Auburn Township between the St. Johns moraine and the bed of Lake Shelby. This eastward sloping plain ranges in elevation from 1110 feet next to the moraine to about 1085 feet at the margin of the bed of Lake Shelby. Several soil series are developed in the outwash deposits; included are the gravelly Chili soil near the moraine and the silty sandy Kibbie, Wilmer, Bogart, and Jimtown soils near the lake bed.

Alluvial Terraces (and valley trains)

One of the most extensive alluvial terraces in Crawford County occurs along both sides of the valley of Broken Sword Creek which extends from east to west across nearly the entire county. The valley and the terrace originate in the depression between two elements of the Ft. Wayne moraine at Tiro in southern Auburn Township. The valley bottom is nearly 2000 feet wide in many places in Vernon and Sandusky Townships where the floodplain of Broken Sword Creek is narrow and the terrace is wide. Farther downstream toward the west in Liberty and Holmes Townships, the valley floor narrows in places to about 1200 feet, half of which is occupied by the floodplain. Narrow terrace segments, each about 400 to 600 feet wide and fairly continuous occur along both sides of the valley in Liberty Township. In north-central Holmes Township the valley and its contained terrace widens and bifurcates into two separate channels 2000 feet apart for a distance of about 4/5 mile. In northwestern Holmes Township and extending southwestward to the Crawford-Wyandot County line, the alluvial terrace has been dissected and only small remnants remain. The elevation of the terrace is 1050 feet at its head at Tiro and is 910 feet at the west edge of the county, for a gradient of about 7 feet per mile. Very few good exposures occur in the terrace, and a sandy composition is inferred from the presence of Jimtown and Bogart soils. An exposure south of Broken Sword revealed 3 feet of silty clay overlying 2 feet of gravel. During deglaciation the westward flow of Broken Sword

Creek probably was ponded by ice in Wyandot County, and unrestricted flow did not occur until drainage into Lake Erie was initiated.

Relatively wide though much dissected terrace segments occur along the valley sides and valley bottom of the Sandusky River and its chief tributary Paramour Creek. The alluvial terrace along Paramour Creek at the west edge of Crestline is represented by short segments about 800 feet wide and having a cumulative length of about 2 miles. Near Leesville in northeastern Jefferson Township, the Paramour Creek terrace bends sharply northward and merges with the Sandusky River terrace. The terrace segments preserved along the sides of the valley occupied by the meandering Sandusky River are short and few in number. The widest and most extensive terrace segments occur in Sandusky and Liberty Townships where the valley follows the southern (distal) margin of the St. Johns moraine (Plate 1). The Paramour Creek terrace drops from an elevation of 1130 feet at Crestline to about 1080 feet west of Leesville for a relatively steep gradient of 16 feet per mile. The Sandusky River terrace begins at an elevation of 1060 feet west of Leesville, drops to 995 feet at Bucyrus and to about 925 feet at the Wyandot-Crawford County line for a gradient of 6 feet per mile. Good exposures of terrace materials are lacking. Soils developed in terrace materials indicate a variable sand and gravel composition.

Several small terrace segments and several broad sandy gravelly plains are associated with the course of the Olentangy River near Galion. Two sandy plains, each about a mile in length, occur beside the Olentangy River in northwest and southwest Galion. A larger sandy plain 2 miles long and ½ mile wide occurs next to the Olentangy River 2½ miles west of Galion, and a small gravelly plain occurs along the Crawford-Morrow County line 1 mile southwest of Galion. Good exposures are lacking in these broad plains; however the presence of sand and poorly sorted gravel indicate an outwash origin. Jimtown, Bogart, and Chili soils (Steiger and others, 1979) are developed in these broad sandy plains which appear to be closely related to the Olentangy River. In most other places the Olentangy River valley contains only a few small terrace segments.

Small terrace segments occur in the valley of Sycamore Creek near Benton in Texas Township, and along the south side of the valley of Silver Creek in Chatfield Township. The sandy terrace along Silver Creek is about 2 miles long, and its elevation of about 945 to 955 feet is only a few feet higher than the floodplain.

Floodplains

Modern floodplains are developed along all major streams and along many smaller streams (Plate 1) in Crawford County. These floodplains are quite variable in width, and generally the larger the stream, the wider the floodplain. Floodplain surfaces range from flat to undulating, and vary from swampy to well-drained. Floodplain materials include variable amounts of clay, silt, sand, and gravel, usually interbedded. The sandy, moderately well-drained floodplain surfaces are characterized by the development of Lobdell soils. Shoals and Sloan soils are developed in the silty clayey floodplain materials.

MINERAL RESOURCES

General Statement

The mineral resources of the glacial drift in Crawford County consist of sand, gravel, and groundwater. These are discussed in detail below.

The resources of the bedrock do not form a part of this report, and only a brief summary is possible. The only active quarry in Crawford County is operated in the Columbus and Delaware Limestones of Devonian age by the National Lime and Stone Company. At this quarry located about 2 miles northeast of Oceola, limestone ranging from about 40 to 60 feet thick is being quarried and crushed for use as agricultural lime and as aggregate.

Petroleum production in Crawford County has been negligible. Hall and Alkire (1956) recorded small discoveries of oil and gas in the Ohio Shale and the underlying Devonian limestone in Jackson and Vernon Townships north of Crestline. According to their report and from the maps of Calvert (1964) and Debrosse and Vohwinkle (1974), the Crestline North gas pool was discovered in 1916 when a well was drilled 710 feet through the Ohio Shale and into the uppermost Devonian limestone. Although initial production of the gas well was promising, additional wells failed to yield much new production and producing wells soon were drowned out by excess water associated with the gas.

Sand and Gravel

Sand and gravel have been excavated from several pits in eastern Crawford County for over 100 years. As of 1983, no pits in the county were being operated commercially although one or more pits received occasional use for bank run aggregate. Winchell (1874) mentioned that such large amounts of gravel had been excavated from an esker south of Leesville that one entire ridge segment had been removed. At least 8 pits can be identified that have been operated in the county for sand and gravel. Three of the largest pits are located in Section 20 in the southeastern corner of Jefferson Township 2 miles south of Leesville. Sand and gravel about 15 feet thick were exposed in one of the pits which was operated for occasional bank run use. The sand and gravel in these kame deposits are poorly sorted and the bedding dips at steep angles in all directions typical of kames. Hiram, Hayesville, and Navarre Tills 5 to 15 feet thick overlie the gravel kames and tend to conceal their identity. Moderate amounts of sand and gravel still remain in the kames and esker in Jefferson Township south of Leesville, and an unknown amount of sand and gravel may be concealed beneath till in this area. The relatively thick till cover, the variability of the deposits, and the availability of crushed limestone for aggregate suggest that these sand and gravel deposits will have only limited and local use in the forseeable future.

Gravel pits occur in two small kames near Auburn Center close to the Richland-Crawford County line (Plate 1). At the larger pit about 3/4 mile east of Auburn Center, 10 feet of well-sorted, cross-bedded coarse sand and fine gravel are exposed. According to local reports 20 feet of good quality sand and gravel was exposed when the deposit was being excavated for road aggregate. The amount of gravel known to occur in the Auburn Center kames is relatively small. However, larger amounts of sand and gravel may occur beneath thick till cover in nearby hummocky areas. The well drained Alexandria soils (Steiger and others, 1979) are mapped on till-covered knolls which contain at least small amounts of sand and gravel. Moraines that may contain significant amounts of sand and gravel are the St. Johns and Mississinewa end moraines in Auburn and Vernon Townships.

The alluvial terraces and outwash plains (Plate 1) have not been exploited for sand and gravel in Crawford County. In nearly all places where exposed, the materials of these terraces are too thin, too fine grained, and too close to the water table to have commercial importance.

Most floodplains in Crawford County (Plate 1) also contain at least small amounts of sandy material. These deposits are highly variable and are not considered to have economic potential.

Water Supply

This report does not deal with water supply in any great detail but some generalizations can be made. An earlier report by Stout, Ver Steeg, and Lamb (1943, p. 251—256) gives some information about water supplies of the towns and villages in the county, and a map by Schmidt (1981) summarizes more recent information. A great deal of more recent information is in the files of the Division of Water and the Division of the Geological Survey in Columbus.

Historically, the water used in Crawford County has been from a variety of sources including surface water diverted to reservoirs, cisterns, springs, and wells drilled into both bedrock and glacial drift.

According to Schmidt (1981), water supply from wells drilled into bedrock falls into three categories which are directly related to the major bedrock units (fig. 6): fair to moderately good water possibilities (3 to 20 gallons per minute) from Berea Sandstone and Cuyahoga Formation along the eastern border of the county, very poor water possibilities from the Ohio Shale in the central part of the county, and good water possibilities (10 to 500 gallons per minute) from Delaware and Columbus Limestones in the western part of the county. Steiger and others (1979) report that most wells in limestone produce water at depths of 50 to 125 feet. The amount of water produced from limestone depends on the number and nature of cracks and solution cavities encountered in drilling. Wells drilled into large solution features have provided yields greater than 1500 gallons per minute (Schmidt, 1981). Many wells drilled into limestone and shale contain an odor of hydrogen sulfide, and Schmidt (1981) mentions that wells drilled into the Ohio Shale yield black sulfurous water.

Water supply from the glacial drift is highly variable. In general yields suitable for at least minimal household needs can be obtained from wells completed in drift in buried valleys (fig. 5) and in end moraines (fig. 2), whereas drift in areas of till plain and lake plain (fig. 2) may provide insufficient yields for household needs. Water from the drift occurs in sand and gravel lenses which also occur between till units in some places. Water-bearing sand and gravel lenses most frequently occur between units of Millbrook Till (figs. 14, 15). Steiger and others (1979) report that wells drilled into sand and gravel in Holmes, Liberty, and Sandusky Townships yield 10 to 20 gallons per minute at depths of 30 to 90 feet. They also report that extensive sand and gravel layers a short distance east of Bucyrus yield 25 to 50 gallons per minute at depths of 30 to 60 feet. In most places in Crawford County the buried valleys are too small, too shallow, and have the wrong orientation for the development of significant sand and gravel layers needed for aquifers.

ENVIRONMENTAL AND ENGINEERING GEOLOGY

General Statement

The environment is influenced in general by the major physiographic divisions (fig. 2) and in detail by the glacial and post-glacial forms and materials that comprise or mantle them. The glacial drift is an improtant factor in performance of engineering structures built upon or in the drift. The thickness, composition, and surface configuration of the drift must be considered. Of great importance for large structures or those involving deep excavation is the vertical variation in the drift, because at most places the till or tills below are of different composition, texture, and engineering properties. Gravel and sand may underlie the upper tills at depths ranging from a few feet to 40 feet or more, and be water bearing.

Engineering interpretations of the surface soils of Crawford County have been treated in the soil report by Steiger and others (1979). That report should be consulted for specific engineering test data and classification both in the Unified and in the AASHTO systems. The test data recorded in the soil survey pertain primarily to the upper 60 inches of the soil. The present geological report deals not only with the surface material, but is also concerned with the whole column of glacial deposits. These reports therefore are complimentary to each other. This geological report cannot provide sufficient detail for planning at a specific site, but it can point out features of the glacial stratigraphy that should be anticipated in detailed engineering investigations for a specific site.

The subsurface material becomes of increasingly greater importance as larger and larger structures and deeper and deeper excavations become more common. The parent materials of soils over 95 percent of Crawford County are the relatively clay-rich lake deposits and Hiram and Hayesville tills. The material beneath the Hayesville till is slightly less clayey and therefore may have more desirable engineering properties. In some projects, it may be desirable to strip off and discard the clayey material to take advantage of the more permeable material below. Also, the "interfaces" between till units often are water-bearing and this must be taken into account in excavations because water seeping may cause piping and slumping.

Till Plain

The Till Plain represents a very gently rolling to nearly featureless surface in Crawford County (fig. 2). This surface is dissected by a few small stream channels which provide fair to moderate drainage for the relatively clayey surface. The drainage of the area has been improved considerably since pioneer days by dredging and tiling so that the soil has high productivity. Homesites and other construction projects should be carefully planned to provide adequate drainage. Potential problems are wet basements and inoperative septic systems, particularly where homesites are closely spaced.

End Moraine

The steepest slopes and the most diverse topography occurs in the several end moraine belts that extend across much of Crawford County (fig. 2). Many small streams and rivulets head in the moraines and numerous valleys offer opportunities for the construction of small lakes or ponds. The moraines tend to be somewhat better drained than the surrounding areas, and in many places offer favorable conditions for homesites in scenic surroundings. Caution should be used in the installation of septic waste disposal systems as the relatively clayey till at the surface over most of this area is very slowly permeable and will accept effluent with difficulty.

Lake Plain

The three large areas of lake plain in eastern and northeastern Crawford County are characterized by nearly featureless topography and poor drainage. Surface materials are mainly silty clay extending to depths of 5 feet or more in many places. The impermeable clay subsoil and the lack of slope have resulted in poor natural drainage and temporary ponding after heavy rainfall over parts of the lake plain. Drainage in the area has been improved considerably by tiling and the construction projects should be carefully planned to provide adequate drainage. Potential problems are wet basements and inoperative septic systems.

WASTE DISPOSAL

Solid Waste

The safe and prudent disposal of solid waste is becoming more important as the population increases, as the amount of waste multiplies, and as environmental regulations become more detailed. Open burning and dumping have been illegal in Ohio since 1969 and the sanitary landfill method has become the standard method of disposing of solid waste. Landfills should be located in areas of Crawford County that have a thick till cover, have a low water table, have slight to gentle slope, and are not closely adjacent to urban centers. Areas where bedrock is closer than 25 feet of the surface should be avioded as should sand and gravel areas, valley bottoms, and steep hillsides. A comprehensive review of geologic considerations for selecting landfill sites is given by Groenewold (1974). The drift thickness map (fig.) is a most useful tool for preliminary selection of possible landfill sites in the county. Nearly 2/3 of Crawford County is underlain by drift at least 50 feet thick, and most of the drift is till, especially beyond the confines of the valleys. The till, actually a stratigraphic sequence composed of several till sheets, is suitable for most types of landfill operation. Two problems that may be encountered are the possibility of a high water table and the presence of water-bearing gravel between till sheets.

Groenewald (1974) states that the minimum amount of till or similar material between the solid waste and the water table should be 5 to 30 feet depending on the circumstances, and he advises 25 feet for Ohio. If other conditions are suitable, the water table may be lowered and kept low by pumping ground water from wells or by constructing deep drainage ditches to a nearby valley. The drainage operation should be monitored carefully to ensure that effluent does not contaminate the water being drained from the area.

In 1986 the Crawford County landfill was located on the north side of Highway 30 about 5 and 1/2 miles east of Bucyrus in an area of till plain. A trench section in the landfill exposed 3 units of Millbrook Till (fig. 19) having an aggregate thickness of about 20 feet. Although silt layers occur in the upper 6 feet, no water-bearing sand and gravel layers were exposed in the landfill.

Crawford County has several areas that may be suitable for landfill sites pending detailed studies and the consideration of many factors. Areas where the drift thickness is more than 50 feet should be given careful consideration as potential sites. The most promising areas appear to be in the central part of the county where moderately thick drift overlies impermeable Ohio Shale which is unsuited as an aquifer.

Any future landfill in the county located in thick drift, as is the present one, can be expected to have its lower part excavated in one or more units of Millbrook

Till. The Millbrook Till is more compact than the overlying tills and is excavated with difficulty. Besides the compact nature of the till, other potential problems include sand and gravel lenses and joints in the till. Both the sand and gravel lenses and the joints could permit effluent to percolate toward aquifers if they are not properly sealed with an impermeable barrier. A careful engineering study should be made before a proposed landfill site is selected.

Septic Tanks And Tile Fields

The disposal of sewage effluent from septic tanks is a significant problem in many parts of the county that are not served by municipal sewers and sewage treatment plants. The geologic factors which affect the operation of septic tanks include permeability of the soil, depth to bedrock, depth to the water table, slope, and drainage. Limitations affecting proper disposal are listed by Steiger and others (1979) for each of the soil series for the county. In general, the soils over most of the county have severe limitations for septic tanks, mostly due to the low permeability of the Hiram and Hayesville Tills and the lacustrine silty clays which form the surface materials. Many localities are characterized by a seasonably high water table, and tile fields may be flooded by rising water levels in wet seasons.

Areas best suited for disposal of effluent are the sandy terraces, kames, and outwash plain (Plate 1). Drainage of effluent from septic tanks and tile fields may percolate downward along joints in till until it reaches a shallow gravel aquifer in the Millbrook Till sequence. Shallow wells deveooped in the gravel lenses within the Millbrook sequence may be subject to bacterial pollution, particularly in areas where several septic tanks occur in a limited area.

Recreation

Recreational opportunities provided by the natural landscape are limited in Crawford County. However the natural and man-made features in nearby counties provide abundant and diverse opportunities for recreational fishing, boating, swimming, hiking, and camping. Within Crawford County, canoeing, boating, and fishing are possible on portions of the major drainage lines including the Sandusky River and the Olentangy River.

Recreation areas near to Marion County include Clear Fork Reservoir 7 miles east of Galion and the Sandusky area along the southern Lake Erie shore about 30 miles north of the county.

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APPENDIX A

Crawford County Till Samples

Crawford County Samples

Sample No.	Township	Age Assignment		Depth Collected Inches	Grain-size percentages			Carbonate Percentages		
					Sand	Silt	Clay	Calcite	Dolomite	Total
229	Auburn	ML	V	38	25	54	21	1.7	4.6	6.3
230	Cranberry	ML	V	30	21	56	23	0.7	5.3	6.0
241	Lykens	KL	N	38	21	50	29	3.6	3.5	7.1
246	Texas	ML	V	40	18	49	33	0	5.2	5.2
247	Texas	KL	N	56	25	61	14	0	5.7	5.7
248	Texas	JU	Mu	100	26	46	28	4.5	5.3	9.8
250	Jackson	KL	N	48	26	38	36	0	5.9	5.9
251	Jefferson	KL	N	60	26	38	36	1.9	10.6	12.5
252	Jefferson	ML	V	96	21	41	38	4.7	4.3	9.0
253	Jefferson	ML	V	120	20	53	27	2.6	5.3	7.9
255	Jefferson	ML	V	30	18	42	40	2.6	5.2	7.8
256	Jefferson	KL	N	80	32	38	30	1.5	8.4	9.9
257	Jefferson	KL	N	144	19	61	20	3.5	5.3	8.8
258	Jefferson	KL	N	64	25	42	33	2.2	2.8	5.0
259	Polk	KL	N	48	29	45	26	0	4.4	4.4
260	Polk	KL	N	63	23	57	20	0	4.8	4.8
261	Polk	KL	N	54	24	50	26	0	2.8	2.8
262	Polk	JU	Mu	64	24	50	26	0	3.9	3.9
264	Polk	ML	V	36	14	32	54	0	3.4	3.4
265	Polk	KL	N	44	21	42	37	0	3.3	3.3
266	Liberty	ML	V	36	19	44	37	5.0	5.7	10.7
267	Holmes	KL	N	48	27	44	29	4.5	6.4	10.9
268	Holmes	JBI	MBI	190	26	49	25	0	7.6	7.6
270	Holmes	KL	N	48	26	51	23	1.5	8.3	9.8
271	Holmes	JBI	MBI	96	24	36	40	0	6.7	6.7
272	Holmes	KL	N	84	26	53	21	1.6	7.6	9.2
273	Holmes	JBII	MBII	244	26	51	23	1.3	4.4	5.7
274	Holmes	KL	N	24	22	44	34	6.0	5.8	11.8
275	Whetstone	JU	Mu	108	28	50	22	7.8	6.5	14.3
276	Whetstone	JA	MA	244	33	56	11	6.3	9.7	16.0
277	Auburn	KL	N	60	18	54	28	0.7	5.7	6.4
279	Vernon	KL	N	60	16	49	35	6.7	10.3	17.0
280	Vernon	ML	V	–	17	46	37	5.9	5.7	11.6
281	Vernon	KL	N	30	31	49	20	2.7	14.8	17.5

Sample No.	Township	Age Assignment		Depth Collected Inches	Grain-size percentages			Carbonate Percentages		
					Sand	Silt	Clay	Calcite	Dolomite	Total
282	Vernon	JA	MA	120	31	36	33	5.5	9.1	14.6
283	Liberty	KL	N	84	24	46	30	1.1	6.1	7.2
284	Liberty	JA	MA	100	26	45	29	2.7	4.4	7.1
285	Liberty	JA	MA	120	33	40	27	2.4	3.7	6.1
286	Liberty	JA	MA	120	16	41	43	3.5	6.6	10.1
287	Liberty	ML	V	34	21	42	37	0	5.0	5.0
288	Liberty	JA	MA	108	20	48	32	2.6	5.3	7.9
289	Sandusky	ML	V	--	16	52	32	0	4.6	4.6
293	Chatfield	ML	V	27	19	46	35	3.1	4.1	7.2
294	Chatfield	ML	V	28	20	42	38	2.1	5.0	7.1
295	Texas	KL	N	--	35	40	25	5.7	20.7	26.4
296	Chatfield	ML	V	30	22	54	24	0	8.0	8.0
297	Chatfield	ML	V	29	19	47	34	0	2.9	2.9
298	Chatfield	ML	V	36	18	39	43	0	5.0	5.0
299	Chatfield	ML	V	28	16	40	44	0	2.5	2.5
301	Jackson	ML	V	27	20	46	34	0	8.1	8.1
302	Jackson	KL	N	35	21	49	30	5.8	11.3	17.1
303	Jackson	KL	N	78	26	57	17	0	5.1	5.1
304	Jackson	JBI	MBI	85	26	47	27	0	3.7	3.7
305	Jackson	KL	N	39	19	51	30	2.9	8.8	11.7
306	Jackson	JA	MA	87	20	53	27	5.6	6.6	12.2
307	Polk	ML	V	48	20	47	33	5.0	3.0	8.0
308	Polk	KL	N	54	20	51	30	4.3	8.6	12.9
309	Polk	ML	V	39	25	44	31	0	5.0	5.0
310	Polk	KL	N	53	26	46	28	0.7	6.7	7.4
311	Polk	JA	MA	91	28	50	22	0.7	5.7	6.4
312	Polk	JA	MA	200	28	47	25	2.8	5.9	8.7
313	Polk	KL	N	66	24	51	25	0	4.4	4.4
314	Liberty	KL	N	42	21	46	33	4.6	6.8	11.4
315	Liberty	KL	N	54	21	53	26	4.1	4.3	8.4
316	Liberty	JU	MU	84	21	50	29	5.2	4.8	10.0
317	Vernon	KL	N	38	20	56	24	4.5	5.3	9.8
318	Liberty	JBI	MBI	—	29	45	26	0	10.6	10.6
319	Liberty	JBI	MBI	—	23	51	26	0	5.7	5.7

Sample No.	Township	Age Assignment		Depth Collected Inches	Grain-size percentages			Carbonate Percentages		
					Sand	Silt	Clay	Calcite	Dolomite	Total
320	Sandusky	ML	V	33	30	44	26	6.7	6.8	13.5
321	Sandusky	KL	N	36	32	45	23	5.9	9.5	15.4
322	Jefferson	ML	V	36	21	42	37	0	0	0
323	Whetstone	ML	V	34	24	55	21	0	6.7	6.7
324	Whetstone	KL	N	42	25	48	27	0	7.8	7.8
325	Dallas	KL	N	37	19	43	38	0	4.3	4.3
326	Dallas	KL	N	32	22	50	28	0	3.4	3.4
327	Cranberry	ML	V	50	18	53	29	2.2	3.2	5.4
328	Whetstone	JA	MA	96	32	46	22	0	3.4	3.4
329	Whetstone	JA	MA	178	30	52	18	5.2	9.7	14.9
330	Whetstone	JA	MA	274	26	49	25	6.9	13.5	20.4
331	Whetstone	JBI	MBI	298	29	46	25	0	3.0	3.0
332	Whetstone	JBI	MBI	370	29	46	25	0	3.9	3.9
333	Liberty	KL	N	27	21	51	28	6.7	7.0	13.7
334	Liberty	KL	N	84	24	47	29	7.3	4.8	12.1
335	Liberty	KL	N	120	25	36	39	6.8	3.2	10.0
336	Holmes	ML	V	28	13	48	39	5.6	4.5	10.1
337	Holmes	KL	N	55	29	40	31	4.9	4.5	9.4
338	Liberty	KL	N	48	28	44	28	3.5	5.7	9.2
339	Lykens	KL	N	60	21	47	32	2.6	5.2	7.8
340	Lykens	C	H	27	21	41	38	0	3.0	3.0
341	Lykens	ML	V	60	23	49	28	1.0	4.6	5.6
342	Lykens	KL	N	102	19	46	35	3.7	6.8	10.5
343	Lykens	JU	MU	130	20	50	30	5.8	6.3	12.1
344	Lykens	JU	MU	154	23	40	37	5.7	2.8	8.5
346	Dallas	KL	N	60	33	49	18	6.2	7.9	14.1
347	Holmes	KL	N	72	25	54	21	4.9	5.0	9.9
348	Holmes	JU	MU	102	24	48	28	6.2	7.0	13.2
349	Holmes	JU	MU	132	27	49	24	4.5	4.1	8.6
350	Holmes	JA	MA	264	20	52	28	5.6	7.0	12.6
351	Holmes	JBI	MBI	348	23	47	30	1.6	6.1	7.7
352	Tod	ML	V	30	25	32	43	5.2	3.6	8.8
353	Tod	KL	N	42	25	47	28	7.3	3.9	11.2
354	Whetstone	ML	V	48	22	48	30	2.2	3.7	5.9

Sample No.	Township	Age Assignment		Depth Collected Inches	Grain-size percentages			Carbonate Percentages		
					Sand	Silt	Clay	Calcite	Dolomite	Total
355	Bucyrus	KL	N	60	24	51	25	0	5.7	5.7
356	Whetstone	KL	N	60	24	51	25	4.5	5.2	9.7
357	Whetstone	KL	N	84	22	43	35	3.9	7.7	11.6
358	Whetstone	JA	MA	132	13	45	42	4.8	9.2	14.0
359	Whetstone	ML	V	31	18	46	36	0.8	3.0	3.8
360	Whetstone	C	H	18	19	48	33	0	2.9	2.9
361	Whetstone	ML	V	30	21	51	28	6.8	4.8	11.6
362	Bucyrus	ML	V	34	25	49	26	0	6.2	6.2
363	Bucyrus	JBI	MBI	96	24	50	26	0	5.1	5.1
364	Holmes	KL	N	36	32	39	29	6.2	6.3	12.5
365	Holmes	JA	MA	42	26	48	26	8.3	10.2	18.5
366	Holmes	KL	N	72	23	53	24	7.2	8.0	15.2
367	Holmes	JA	MA	110	27	51	22	7.0	9.2	16.2
368	Holmes	JA	MA	132	28	54	21	6.0	7.1	13.1
369	Holmes	JBI	MBI	146	22	58	20	1.0	8.9	9.9
370	Holmes	JBI	MBI	218	24	50	26	0	7.8	7.8
371	Holmes	JBI	MBI	290	24	49	27	1.9	9.5	11.4
372	Holmes	JBI	MBI	362	24	50	26	0.7	5.2	5.9
373	Bucyrus	KL	N	35	30	42	28	5.3	6.0	11.3
374	Bucyrus	JU	MU	43	22	42	36	7.9	6.6	14.5
399	Lykens	ML	V	34	21	54	25	0	7.5	7.5
400	Lykens	KL	N	46	22	48	30	2.6	4.5	7.1
401	Lykens	JBII	MBII	68	26	45	29	1.5	8.3	9.8
402	Lykens	JBII	MBII	81	20	36	44	2.7	8.1	10.8
403	Lykens	JBII	MBII	106	38	39	23	2.9	7.9	10.8
404	Lykens	JL	ML	150	25	44	31	6.3	5.2	11.5
405	Vernon	ML	V	23	24	41	35	2.2	11.3	13.5

APPENDIX B

Crawford County Till Analyses

Till Sample H series	Depth Collected Inches	Age	Brown B or Gray G	Depth of Leaching Inches	Section	County	Township	Quadrangle Map
229	38	V	B	—	NE, SE, 3	Crawford	Auburn	Shelby
230	30	V	B	20	NE, NE, 2	Crawford	Cranberry	New Washington
241	38	N	B	32	NW, NW, 6	Crawford	Lykens	Lykens
246	40	V	B	26	SW, NE, 26	Crawford	Texas	Lykens
247	56	N	B	26	SW, NE, 26	Crawford	Texas	Lykens
248	100	MU	B	26	SW, NE, 26	Crawford	Texas	Lykens
250	48	N	B	—	SE, NE, 4	Crawford	Jackson	Crestline
251	60	N	B	—	NE, NE, 22	Crawford	Jefferson	No. Robinson
252	96	V	B	29	SW, NE, 20	Crawford	Jefferson	No. Robinson
253	120	V	G	29	SW, NE, 20	Crawford	Jefferson	No. Robinson
255	30	V	B	—	SW, SE, 20	Crawford	Jefferson	No. Robinson
256	80	N	B	—	SW, SE, 20	Crawford	Jefferson	No. Robinson
257	144	N	G	—	SW, SE, 20	Crawford	Jefferson	No. Robinson
258	64	N	B	52	SW, SE, 19	Crawford	Jefferson	No. Robinson
259	48	N	B	—	SE, SW, 1	Crawford	Polk	Galion
260	63	N	B	51	SW, SW, 6	Crawford	Polk	Galion
261	54	N	B	52	SE, SW, 6	Crawford	Polk	Galion
262	64	MU	B	52	SE, SW, 6	Crawford	Polk	Galion
264	36	V	B	34	NW, NW, 34	Crawford	Polk	Bloom. Grove
265	44	N	B	34	NW, NW, 34	Crawford	Polk	Bloom Grove
266	36	V	B	33	SW, NE, 14	Crawford	Liberty	No. Robinson
267	48	N	B	—	SE, NW, 19	Crawford	Holmes	Oceola
268	190	MBI	G	—	SE, NW, 19	Crawford	Holmes	Oceola
270	48	N	B	—	NE, NW, 19	Crawford	Holmes	Oceola
271	96	MBI	G	—	NE, NW, 19	Crawford	Holmes	Oceola
272	84	N	B	—	SE, NW, 19	Crawford	Holmes	Oceola
273	244	MBII	G	—	SE, NW, 19	Crawford	Holmes	Oceola
274	24	N	B	—	SE, SW, 30	Crawford	Holmes	Oceola
275	108	MU	B	—	NE, NE, 6	Crawford	Whetstone	Bucyrus

Till Sample H series	Depth Collected Inches	Age	Brown B or Gray G	Depth of Leaching Inches	Section	County	Township	Quadrangle Map
276	244	MA	G	—	NE, NE, 6	Crawford	Whetstone	Bucyrus
277	60	N	B	—	SW, SW, 10	Crawford	Auburn	Shelby
279	60	N	B	22	SW, SW, 17	Crawford	Vernon	No. Robinson
280	—	V	B	—	SW, SW, 17	Crawford	Vernon	No. Robinson
281	30	N	B	—	SE, SE, 18	Crawford	Vernon	No. Robinson
282	120	MA	G	—	SE, SE, 18	Crawford	Vernon	No. Robinson
283	84	N	B	—	NE, SE, 25	Crawford	Liberty	No. Robinson
284	100	MA	B	—	NE, SE, 25	Crawford	Liberty	No. Robinson
285	120	MA	G	—	NE, SE, 25	Crawford	Liberty	No. Robinson
286	120	MA	G		SW, SW, 25	Crawford	Liberty	No. Robinson
287	34	V	B	33	NE, NE, 35	Crawford	Liberty	No. Robinson
288	108	MA	B	—	NE, SW 26	Crawford	Liberty	No. Robinson
289	—	V	B	—	NW, SW, 2	Crawford	Sandusky	New Washington
293	27	V	B	25	SE, SW, 3	Crawford	Chatfield	Chatfield
294	28	V	B	24	NE, NW 12	Crawford	Chatfield	Chatfield
295	—	N	B	—	SE, NE, 2	Crawford	Texas	Lykens
296	30	V	B	24	SE, SE, 15	Crawford	Chatfield	Chatfield
297	29	V	B	28	SW, SW, 16	Crawford	Chatfield	Chatfield
298	36	V	B	32	SW, SE, 13	Crawford	Chatfield	Chatfield
299	28	V	B	26	SE, SE, 33	Crawford	Chatfield	Chatfield
301	27	V	B	23	NW, SW, 22	Crawford	Jackson	Crestline
302	35	N	B	23	NW, SW, 22	Crawford	Jackson	Crestline
303	78	N	B	—	NE, NW, 22	Crawford	Jackson	Crestline
304	85	MBI	B	—	NE, NW, 22	Crawford	Jackson	Crestline
305	39	N	B	—	SE, SW, 16	Crawford	Jackson	No. Robinson
306	87	MA	B	—	SE, SW, 16	Crawford	Jackson	No. Robinson
307	48	V	B	—	NW, SW, 35	Crawford	Polk	Galion
308	54	N	B	—	NW, SW, 35	Crawford	Polk	Galion
309	39	V	B	27	NE, NW, 2	Crawford	Polk	Galion

Till Sample H series	Depth Collected Inches	Age	Brown B or Gray G	Depth of Leaching Inches	Section	County	Township	Quadrangle Map
310	53	N	B	27	NE, NW, 2	Crawford	Polk	Galion
311	91	MA	B	27	NE, NW, 2	Crawford	Polk	Galion
312	200	MA	G	27	NE, NW, 2	Crawford	Polk	Galion
313	66	N	B	—	SW, NE, 2	Crawford	Polk	Galion
314	42	N	B	—	SE, NE, 34	Crawford	Liberty	Bucyrus
315	54	N	B	—	NE, SE, 33	Crawford	Liberty	Bucyrus
316	84	MU	B	—	NE, SE, 33	Crawford	Liberty	Bucyrus
317	38	N	B	26	SW, NE, 15	Crawford	Vernon	Crestline
318	—	MBI	G	—	SE, NE, 36	Crawford	Liberty	No. Robinson
319	—	MBI	G	—	SE, NE, 36	Crawford	Liberty	No. Robinson
320	33	V	B	21	NE, NE, 36	Crawford	Sandusky	No. Robinson
321	36	N	B	21	NE, NE, 36	Crawford	Sandusky	No. Robinson
322	36	V	B	34	SW, NW, 6	Crawford	Jefferson	No. Robinson
323	34	V	B	28	NW, NW, 18	Crawford	Whetstone	Bucyrus
324	42	N	B	36	NW, SW, 18	Crawford	Whetstone	Bucyrus
325	37	N	B	35	NE, NW, 9	Crawford	Dallas	Monnett
326	32	N	B	26	SW, SW, 5	Crawford	Dallas	Monnett
327	50	V	B	44	SW, SW, 35	Crawford	Cranberry	Chatfield
328	96	MA	B	—	NE, NE, 2	Crawford	Whetstone	No. Robinson
329	178	MA	G	—	NE, NE, 2	Crawford	Whetstone	No. Robinson
330	274	MA	G	—	NE, NE, 2	Crawford	Whetstone	No. Robinson
331	298	MBI	G	—	NE, NE, 2	Crawford	Whetstone	No. Robinson
332	370	MBI	G	—	NE, NE, 2	Crawford	Whetstone	No. Robinson
333	27	N	B	25	SE, SE, 18	Crawford	Liberty	Bucyrus
334	84	N	B	—	SW, SW, 29	Crawford	Liberty	Bucyrus
335	120	N	G		SW, SW 29	Crawford	Liberty	Bucyrus
336	28	V	B	25	NE, NW, 25	Crawford	Holmes	Bucyrus
337	55	N	B	25	NE, NW, 25	Crawford	Holmes	Bucyrus
338	48	N	B	46	SE, 22	Crawford	Liberty	Bucyrus

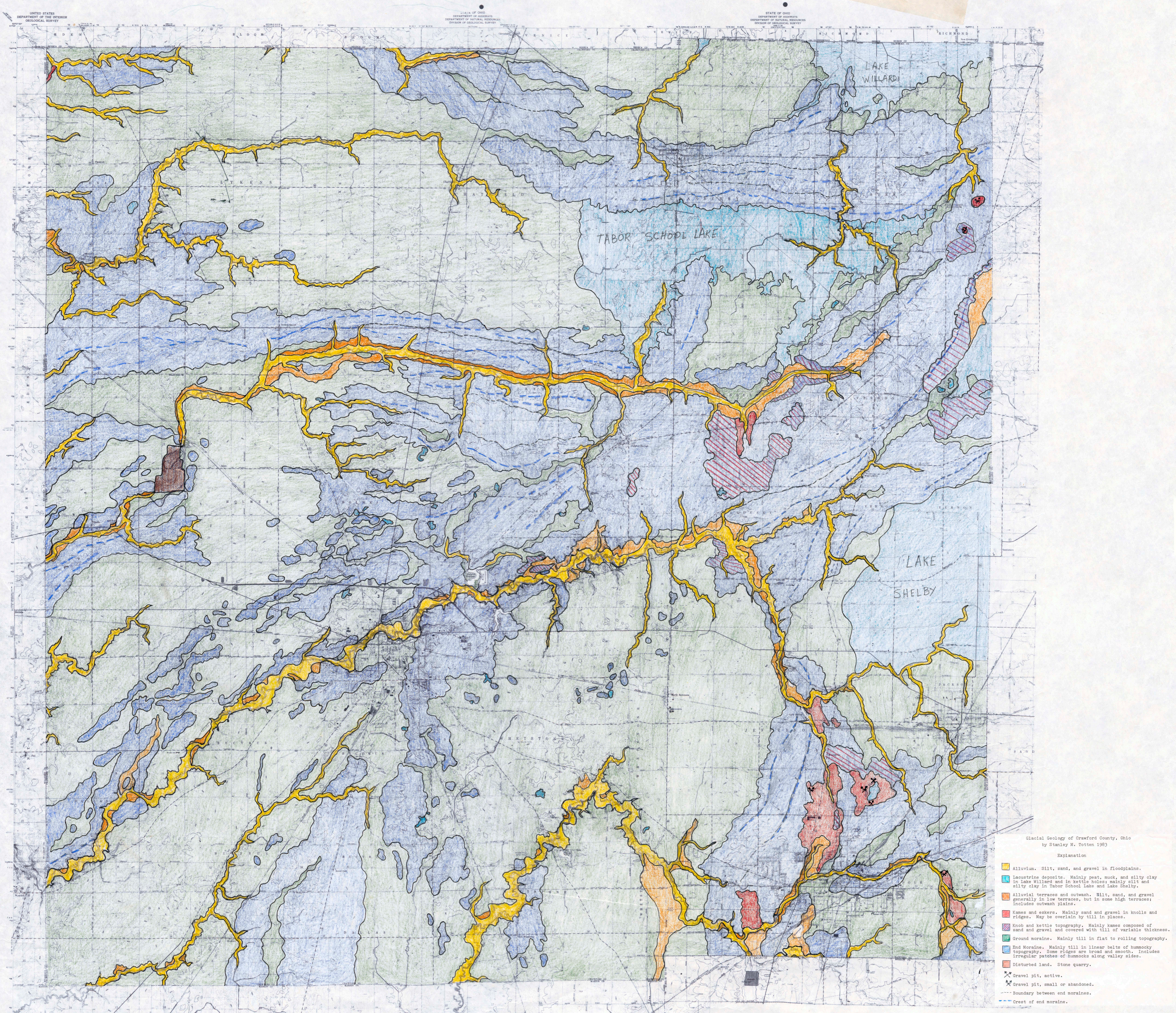
Till Sample H series	Depth Collected Inches	Age	Brown B or Gray G	Depth of Leaching Inches	Section	County	Township	Quadrangle Map
339	60	N	B	—	NW, NW, 30	Crawford	Lykens	Lykens
340	27	H	B	24	SW, NW, 30	Crawford	Lykens	Lykens
341	60	V	B	24	SW, NW, 30	Crawford	Lykens	Lykens
342	102	N	B	24	SW, NW, 30	Crawford	Lykens	Lykens
343	130	Mu	B	24	SW, NW, 30	Crawford	Lykens	Lykens
344	154	Mu	G	24	SW, NW, 30	Crawford	Lykens	Lykens
346	60	N	B	—	SE, SE, 26	Crawford	Dallas	Monnett
347	72	N	B	—	SW, NW, 19	Crawford	Holmes	Oceola
348	102	Mu	B	—	SW, NW, 19	Crawford	Holmes	Oceola
349	132	Mu	B	—	SW, NW, 19	Crawford	Holmes	Oceola
350	264	MA	G	—	SW, NW, 19	Crawford	Holmes	Oceola
351	348	MBI	G	—	SW, NW, 19	Crawford	Holmes	Oceola
352	30	V	B	28	SE, NW, 35	Crawford	Tod	Oceola
353	42	N	B	28	SE, NW, 35	Crawford	Tod	Oceola
354	48	V	B	—	NE, NW, 8	Crawford	Whetstone	Bucyrus
355	60	N	B	—	SE, NE, 10	Crawford	Bucyrus	Oceola
356	60	N	B	42	NW, NE, 26	Crawford	Whetstone	No. Robinson
357	84	N	B	—	SW, NW, 11	Crawford	Whetstone	Bucyrus
358	132	MA	G	—	SW, NW, 11	Crawford	Whetstone	Bucyrus
359	31	V	B	25	SW, SW, 34	Crawford	Whetstone	Caledonia
360	18	H	B	18	NW, SE, 28	Crawford	Whetstone	Bucyrus
361	30	V	B	18	NW, SE, 28	Crawford	Whetstone	Bucyrus
362	34	V	B	22	SE, SW, 34	Crawford	Bucyrus	Monnett
363	96	MBI	G	22	SE, SW, 34	Crawford	Bucyrus	Monnett
364	36	N	B	—	SW, SE, 26	Crawford	Holmes	Bucyrus
365	42	MA	B	—	SW, SE, 26	Crawford	Holmes	Bucyrus
366	72	N	B	46	SE, SW, 19	Crawford	Holmes	Oceola
367	110	MA	B	46	SE, SW, 19	Crawford	Holmes	Oceola
368	132	MA	G	46	SE, SW, 19	Crawford	Holmes	Oceola

Till Sample H series	Depth Collected Inches	Age	Brown B or Gray G	Depth of Leaching Inches	Section	County	Township	Quadrangle Map
369	146	MBI	G	46	SE, SW, 19	Crawford	Holmes	Oceola
370	218	MBI	G	46	SE, SW, 19	Crawford	Holmes	Oceola
371	290	MBI	G	46	SE, SW, 19	Crawford	Holmes	Oceola
372	362	MBI	G	46	SE, SW 19	Crawford	Holmes	Oceola
373	35	N	B	29	SW, NW, 7	Crawford	Bucyrus	Oceola
374	43	MU	B	29	SW, NW 7	Crawford	Bucyrus	Oceola
399	34	V	B	31	NW, NE, 15	Crawford	Lykens	Chatfield
400	46	N	B	31	NW, NE, 15	Crawford	Lykens	Chatfield
401	68	MBII	B	31	NW, NE, 15	Crawford	Lykens	Chatfield
402	81	MBII	G	31	NW, NE, 15	Crawford	Lykens	Chatfield
403	106	MBII	G	31	NW, NE, 15	Crawford	Lykens	Chatfield
404	150	ML	G	31	NW, NE, 15	Crawford	Lykens	Chatfield
405	23	V	B	—	NE, NE, 32	Crawford	Vernon	No. Robinson

Glacial Geology of Crawford County, Ohio

Stanley M. Totten

1983



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