STATE OF OHIO
Richard F. Celeste, Governor
DEPARTMENT OF NATURAL RESOURCES
Joseph J. Sommer, Director
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

Report of Investigations No. 134

GLACIAL AND SURFICIAL GEOLOGY OF CUYAHOGA COUNTY, OHIO

by

John P. Ford

Columbus
1987

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John P. Ford

ABSTRACT

Cuyahoga County extends from the dissected northwestern margin of the Appalachian Plateaus physiographic province across the Portage Escarpment to the Lake Plain in the Central Lowland province. Deeply incised north-flowing streams provide locally steep slopes and scenic erosional topography, with relief up to 400 feet between valley floors and adjacent uplands. The varied preglacial physiography strongly influences the character and distribution of the glacial surface features. Ground moraine is widespread. A sinuous hummocky ridge of end moraine crosses the Plateau and the deep valleys that have dissected it. Subdued linear moraines are emplaced at the base of the Escarpment. Thin drift over resistant bedrock masks the erosional topography on the Escarpment and on the uppermost parts of the Plateau. Beach ridges on the Lake Plain mark the positions of former higher water levels in the Erie Basin. Prominent terraces in the valleys of deeply incised streams are erosional remnants of lacustrine and fluviatile deposits that accumulated in the valleys at times of glacial ponding.

Bedrock outcrops are numerous and widespread. Bedrock consists of shales and sandstones ranging in age from Late Devonian to Early Pennsylvanian. The aggregate stratigraphic thickness of exposed bedrock is over 500 feet.

Thickness of the glacial cover is mostly less than 40 feet. The glacial deposits are correlated to the glacial rock-stratigraphic classification in use in northeastern Ohio. Detailed field descriptions of tills are supported by laboratory analyses of texture, clay mineral composition, and carbonate content. Pre-Woodfordian Mogadore Till and Woodfordian-age Kent, Lavery, and Hiram Tills are identified and mapped. Two units of Kent Till and three units of Lavery Till are distinguished. Kent Tills and Lavery Tills that are texturally similar are differentiated lithologically by their carbonate content and their color characteristics. The clay mineral composition of each of the Kent and the Lavery Tills as well as of the Hiram Till closely resembles the clay mineral composition of the adjacent shale bedrock. The clay mineral composition of the older Mogadore Till is notably different. The geographic distribution of the till units is related to the physiography of the county. The Mogadore Till is limited to a very few upland outcrops. Kent Tills are distributed mostly in topographically subdued localities on the Plateau. Kent Till outcrops are up to 32 feet thick. Two of the Lavery Tills are widely distributed across the county; one unit of Lavery Till is restricted to the Lake Plain. The Lavery Tills overlap geographically, and do not exceed 32 feet in combined thickness. Hiram Till is restricted to the east and southeast upland on the Plateau, where it overlies the uppermost Lavery Till. The Hiram Till is commonly thinner than the modern soil profile, which passes through it and obliterates the distinctive till lithology.

Surficial deposits of lacustrine or fluviatile origin are segregated into materials that are predominantly sand and gravel or materials that are predominantly silt and clay. The clay mineral composition of the silt and clay deposits is practically identical to that of the Woodfordian tills. The deposits remain unnamed stratigraphically and are mapped as surficial sand and gravel or as surficial silt and clay. Made land is widely distributed in urban areas.

The bedrock and the glacial cover have been extensively exploited for rock and mineral resources. The types and amounts of materials produced have varied over the years with changing demand and with accessibility. Current rock and mineral production consists of clay and sandstone from bedrock quarries, salt from an underground mine, and sand and gravel. Water resources from drift or bedrock aquifers are limited. The bulk of the water used in the county is obtained from Lake Erie. Scenic valleys form an important local and national recreational resource.

INTRODUCTION

Cuyahoga County occupies 456 square miles of glaciated terrain in northeastern Ohio (fig. 1). It ranks among the most highly urbanized and densely populated counties in Ohio. Housing developments, shopping centers, factories, and highways have steadily encroached on areas that were formerly used for farming. Cuyahoga County includes all the communities and industry in the Greater Cleveland metropolitan area and adjacent communities to the south in Olmsted Falls, Berea, Strongsville, North Royalton, Broadview Heights, Brecksville, Solon, and Chagrin Falls. The county still has an agricultural industry, and is an important center for greenhouse vegetables in northeastern Ohio. The population of the county in July 1985 was estimated at 1,455,100 (Ohio Data Users Center, oral commun.). Cuyahoga County is bounded by Lake Erie to the north, by Lake and Geauga Counties to the east, by Summit and Medina Counties to the south, and by Lorain County to the west.

PURPOSE AND SCOPE

The major purpose of the present study is to differentiate and map the glacial deposits and surficial materials in Cuyahoga County. Tills and associated lacustrine and fluviatile deposits are treated as rock-stratigraphic units. The textural and compositional characteristics of the tills are defined quantitatively. Glacial advances and retreats are interpreted from the character, distribution, and stratigraphic relations of the tills. Stratigraphically unnamed lacustrine and fluviatile deposits and bedrock exposures are discriminated with respect to the dominant surficial lithology and are mapped accordingly. This report should serve as a guide to geologists, planners, developers, engineers, conservationists, and others with an interest in the character and distribution of surficial materials in Cuyahoga County. The vertical interval between the present surface and the elevation of the bedrock surface shown on the accompanying map (pl. 1) provides a general indication of the drift thickness. It does not provide sufficient detail for intensive site-specific studies.

SURFICIAL MAPPING

The mapping of the surficial materials in Cuyahoga County was completed in 1974 on the basis of 1,231 field localities in the county. The report was extensively reviewed and updated in 1986. Much of the county is built over, but excavations in the urban areas yielded numerous temporary sections. Excavations that exposed a continuous

FIGURE 1.—Location of Cuyahoga County, Ohio.

weathering profile above fresh drift were extensively sampled and described. Such excavations provided a significant increase in the number of mapping control points in the county. The surficial geology was mapped on 14 U.S. Geological Survey 7½-minute series topographic quadrangles (see index map on pl. 1). The field maps for this study are on file at the Division of Geological Survey. The county map (pl. 1) is a composite at a scale of 1:62,500 and represents the materials at or within 5 feet of the surface.

Bedrock outcrops are numerous and widespread throughout Cuyahoga County. Bedrock consists of shales and sandstones that range in age from Late Devonian to Early Pennsylvanian. The aggregate stratigraphic thickness of exposed bedrock is over 500 feet. Glacial and postglacial surficial materials in the county include tills, lacustrine and fluviatile deposits, alluvium, muck, and made land. The glacial deposits are predominantly Woodfordian in age and mostly less than 40 feet thick.

PREVIOUS INVESTIGATIONS

Previous mapping studies that relate partially or totally to glacial geology and to bedrock outcrop in the area have been made by Newberry (1873), Leverett (1902), Carney (1911), Cushing and others (1931), Winslow and others (1953), Pepper and others (1954), and Goldthwait and others (1961). In these studies, glacial deposits were not defined or mapped as rock-stratigraphic units. In addition, the deposits were referred to by names that carried both time and rock connotations. In 1960 and later the tills in northeastern Ohio were defined as rock-stratigraphic units (White, 1960) and were related to a revised time terminology (White, 1969). This definition provided the necessary framework for studies that have resulted in a series of county glacial maps and reports of most counties in northeastern Ohio (Totten, 1973; White, 1963, 1967, 1973, 1977, 1980, 1984; White and Totten, 1979, 1985) and an overall review of the glacial geology and Pleistocene history of the region (White, 1982). More recent investigations by Szabo and others (1986, and references therein) offer continuing refinements to the glacial rock-stratigraphic classification in northeastern Ohio.

ACKNOWLEDGMENTS

The author gratefully acknowledges the enthusiastic support and encouragement of the late Professor George W. White. Dr. White provided stimulating discussions on numerous occasions and much valuable reference material which was used in the compilation of this report. Horace R. Collins, State Geologist of Ohio, has taken a continued interest in the progress of the study and has provided valuable direction during its implementation. Stratigraphic correlation with the glacial deposits in adjacent counties was discussed with Stanley M. Totten and John P. Szabo. Valuable insight into the interpretation of weathering profiles from clay mineral and carbonate analyses was provided by H. D. Glass. Geologic problems associated with lakeshore erosion were discussed with C. H. Carter. D. K. Musgrave and D. M. Holloran discussed and compared their soils-mapping field data. Merrianne Hackathorn provided valuable editorial assistance.

PHYSIOGRAPHY

Cuyahoga County covers the northern end of the Appalachian Plateaus Province and the Eastern Lake Section of the Central Lowland Province in Ohio. Consequently, the county shows strong contrasts in topography. Cuyahoga County is subdivided here into four physiographic units (fig. 2). To the north and west is the Lake Plain. To the south and east is the dissected northwest margin of the Appalachian Plateaus, hereafter also referred to as the Plateau. The Lake Plain and the Plateau are joined by the prominent Portage Escarpment, hereafter also referred to as the Escarpment. The Escarpment is interrupted by the deep reentrants of valleys that drain the county northward to Lake Erie. These valleys are treated as a separate physiographic unit.

LAKE PLAIN

The Lake Plain forms a wedge-shaped area that extends across the northern portion of Cuyahoga County from the Lake Erie shoreline southward to the base of the Escarpment. It is over 10 miles wide in the west and narrows to about 2 miles wide in the east. The Lake Plain abruptly rises 30 to 50 feet from the shoreline in most places to form a steep wave-cut cliff. The cliff is fairly continuous but has been breached by stream valleys that drain northward to Lake Erie. The cliff is subject to rapid and violent wave erosion, which is facilitated by the preferential passage of ground water through porous, permeable sand and gravel layers that are interbedded with till above the shale bedrock. In Cleveland between Edgewater Park and Gordon Park the wave-cut cliff is separated from the shoreline and protected from wave erosion by a strip of made land (pl. 1). The surface of the Lake Plain slopes smoothly toward Lake Erie and is largely built over.

ESCARPMENT

The Escarpment crosses Cuyahoga County in a broad arc from northeast to southwest. The slope of the Escarpment

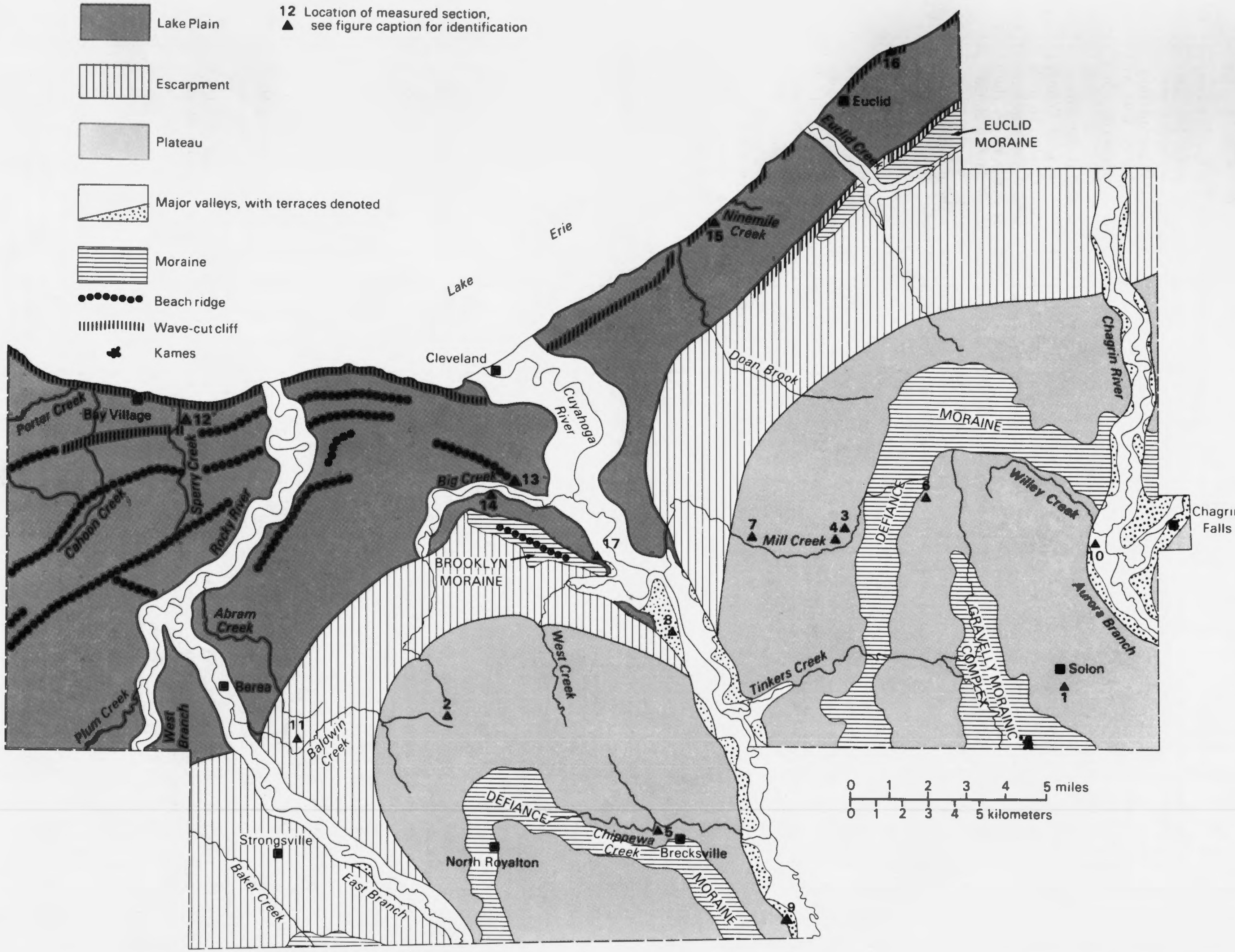

FIGURE 2.—Distribution of physiographic units and major glacial features in Cuyahoga County. Measured sections: 1, Roxbury School; 2, Sprague Road; 3, Miles Road; 4, South Miles Road; 5, Brecksville Interchange; 6, Sunny Acres Sanatorium; 7, Calvary Cemetery Lake; 8, Old Rockside; 9, Sterner gravel pit; 10, South Chagrin Reservation; 11, Baldwin Creek; 12, Bay Village; 13, Fulton Parkway bridge; 14, Brookside Park; 15, Lake Shore Boulevard; 16, Moss Point; 17, Brooklyn Heights. Measured sections are described in Appendix A.

is predominantly long and gentle where it is underlain by shales in excess of 100 feet thick, and locally short and steep where the bedrock consists of sandstone or conglomerate 20 to 50 feet thick. The Escarpment is notably broken by reentrants formed by the valleys of major north-flowing streams.

East of the Cuyahoga River valley the Escarpment rises abruptly from the Lake Plain at an elevation of about 700 feet and reaches over 1,100 feet in elevation at the dissected margin of the Plateau. The Escarpment has a patchy mantle of thin till or silty clay that is generally less than 5 feet thick. Owing to nondeposition or to subsequent erosion, the glacial deposits on the Escarpment east of the Cuyahoga River valley are too thin to obscure the erosional form of the underlying bedrock surface. Bedrock is exposed in stream valleys along the Escarpment slopes (pl. 1).

West of the Cuyahoga River valley the base of the Escarpment is less obvious. The base may be placed at an elevation of about 800 feet, which coincides with the base of the Berea Sandstone (Mississippian) in the area. The Escarpment rises steeply to about 1,150 feet in elevation. It is underlain predominantly by shale that is partly mantled with till and associated silty clay deposits. The glacial deposits generally exceed 30 feet in thickness, but bedrock is exposed on the slopes of the Escarpment from Independence westward to Middleburg Heights (pl. 1).

PLATEAU

The topography in south-central and southeastern Cuyahoga County consists of rolling upland that has a prong-shaped outline on the map (fig. 2). The upland ranges from about 1,000 feet to over 1,250 feet in elevation and represents the northwest margin of the Appalachian Plateaus (also referred to as the Allegheny Plateau) in Ohio. The prong shape results from deep dissection of the upland by the valleys of the Cuyahoga, Chagrin, and East Branch Rocky Rivers.

The highest hills on the Plateau are underlain by erosional outliers of Sharon conglomerate (Pennsylvanian). Elsewhere the Plateau is underlain by shale of the Cuyahoga Formation (Mississippian). Bedrock outcrops on the upland are few and local in extent. The bedrock is mantled with Lavery Till. Thin patches of Hiram Till on the Plateau to the east and southeast are largely obscured by the modern weathering profile, which passes through the till into underlying deposits.

VALLEYS AND DRAINAGE

Stream valleys with relief ranging from 100 feet to over 400 feet form a distinctive element of the physiography in Cuyahoga County. The major valleys are outlined in figure 2. The Cuyahoga and Chagrin River valleys are deeply cut into the bedrock that underlies the Lake Plain, the Escarpment, and the Plateau. The Cuyahoga River valley is 2½ to 4 miles wide across the top and has a relief of over 400 feet. The Chagrin River valley is about 1 mile wide across the top with a relief slightly over 250 feet. These valleys contain till and associated lacustrine and fluviatile terraces through which the present rivers have cut their respective channels. In its lower reaches the Cuyahoga River has partially cut through a prism of sediment that was deposited in a deeper, wider bedrock valley. Surface and subsurface studies by Bagley (1953) and Peck (1954) show that in Cleveland this deep bedrock valley is situated a mile or more east of the present valley. At its lowest point it is 500 feet or more below the surface, at about sea level (pl. 1). Both the Cuyahoga and the Chagrin River valleys are preglacial in origin.

The valleys of East Branch and West Branch Rocky River are deeply incised into the upper part of the Lake Plain. The valley of East Branch Rocky River also is deeply cut into bedrock under the Escarpment and is cutting into the Plateau. This valley is about 1 mile wide at the top with a relief of 100 feet and contains till and a lacustrine terrace of laminated silty clay.

The valleys of Euclid Creek, Big Creek, and Rocky River are deeply cut into bedrock that underlies the Lake Plain. Euclid Creek has cut back through the Escarpment to the Plateau. Its valley is just over ¼ mile wide with a maximum relief of about 120 feet. Big Creek has cut back to the Escarpment and forms a major tributary of the Cuyahoga River. The Big Creek valley is ¼ to ½ mile wide with relief up to about 80 feet. The Rocky River valley is about ½ mile wide with relief up to 140 feet. None of these valleys contain glacial deposits. They are bedrock valleys that are postglacial in origin.

The regional drainage is generally north to the lake. However, there are abrupt diversions from this direction. Some tributary streams flow parallel to the lakeshore for considerable distances. Big Creek and West Creek flow north from the Escarpment. In their middle reaches both streams turn abruptly east toward the Cuyahoga River. Mill Creek flows northwest to the Escarpment, where it is diverted west and then south to the Cuyahoga River. East Branch Euclid Creek flows north from its source on the Escarpment and turns abruptly west to southwest along the south face of the Euclid Moraine. It is likely that each of these pronounced stream diversions is a response to blockage that occurred at a stagnant ice margin. When the ice retreated the diverted segments of the streams remained entrenched in the channels that they now occupy.

The upper reaches of the Chagrin River (in Geauga County) run southwest parallel to the present lakeshore, but about 16 to 18 miles south of it, as far west as Bentleyville. In that vicinity the Chagrin River is joined by Aurora Branch and turns abruptly north to the lake. The north-flowing portion of the river valley is preglacial in origin. When this segment of the valley was blocked by glacial ice, it is probable that the southwest-flowing upper reaches of the river were established. Deglaciation enabled the waters to drain northward.

Streams that rise on the Plateau flow in all directions, but those that do not flow northward become tributary to others that do. East Branch Rocky River rises on the Plateau south of the area between Broadview Heights and North Royalton and flows southeast into Medina County. East Branch turns abruptly west and then north to reenter Cuyahoga County downstream at a lower elevation. The southeastward drainage on the Plateau was probably initiated at a time when glacial ice had overridden the Escarpment and blocked all the north-flowing drainage channels. Modification of the local slope conditions due to deglaciation and isostatic uplift would account for the northward diversion of the waters that drained to the southeast.

SURFICIAL BEDROCK

The surficial bedrock in Cuyahoga County consists predominantly of thick Paleozoic shales and sandstones that range in age from Late Devonian to Early Pennsylvanian. Stratigraphically the rock section includes the Devonian-age Chagrin and Cleveland Shale Members of the Ohio

Shale; the Mississippian-age Bedford Shale, including its Euclid Sandstone Member, and the Cuyahoga Formation; and the Pennsylvanian-age Sharon conglomerate of the Pottsville Group. Most of these units were originally described and named for localities in Cuyahoga County. However, there is no locality in the county that exposes the entire section.

Outcrops of flat-lying bedrock 90 feet or more thick are found extensively in the major valleys and on the Escarpment. Outcrops 30 feet thick or less are distributed across the Lake Plain and on the Plateau. Additional bedrock outcrops have been exposed in quarries and other types of excavations. The thickest stratigraphic interval exposed at a single outcrop is along Granger Road (Ohio Route 17) on the west side of Garfield Heights. At this locality, on the Escarpment, the rocks extend from the Chagrin Shale Member to the Cuyahoga Formation across a horizontal distance of about 1 mile and through a vertical interval of about 300 feet.

The stratigraphic relations and lithologic characteristics of the rock section in Cuyahoga County have been described and mapped by Cushing and others (1931). The lithology and the depositional environments of the Bedford Shale and the Berea Sandstone and their more extensive stratigraphic relations in the Appalachian Basin were reported by Pepper and others (1954).

For purposes of this study the exposed bedrock formations are combined into four bedrock mapping units. Table 1 shows the stratigraphic relations and age of these units. Map units that consist predominantly of shale alternate with map units that are mostly sandstone (pl. 1). Samples of fresh and weathered shale from bedrock units I and III were analyzed in the laboratory to determine their clay mineral content. Typical values for fresh samples are: expandable clays, 1 percent; illite, 74 percent; chlorite plus kaolinite, 25 percent. These values compare very closely to the clay mineral composition of most of the fresh tills (see table 3, Appendix B, and section on Pleistocene and Recent deposits). Bedrock unit II (Berea Sandstone) provides a prominent stratigraphic and lithologic marker; it separates underlying shale formations (unit I) from overlying ones (unit III). Bedrock unit IV (Sharon conglomerate) consists of erosional bedrock outliers.

BEDROCK UNIT I

Bedrock unit I comprises the Chagrin and Cleveland Members of the Ohio Shale and the Bedford Shale and its Euclid Sandstone Member. In outcrop the Chagrin Member is medium to greenish gray where fresh, or yellowish gray where weathered, very soft, and clayey. It is medium to thick bedded and contains thin irregular interbeds of siltstone or sandstone that weather to a dark brown. The Cleveland Member is dark gray to black, thin bedded, and weathers to thin slaty fragments that are stained brown. The Bedford Shale is a soft clay shale that ranges in color from blue gray at its type section on Tinkers Creek to maroon or black in localities to the north and west. It has thin interbeds of fine-grained blue-gray sandstone and contains hard dark-gray concretions. Locally the sandstone interbeds thicken from 9 to about 30 feet and form the Euclid Sandstone Member.

The shales in bedrock unit I are exposed at numerous localities on the Lake Plain (pl. 1). The proximity of this bedrock unit to the surface is emphasized by the wide spread of measured sections and field localities where it forms the basal unit. The largest area of outcrop is west of the Rocky River, from Bay Village and Westlake to Avon Lake. Large areas of former outcrop in Euclid and in the eastern part of Cleveland have been covered by urban land. The shales are exposed in cliffs along the lakeshore in thicknesses that range from about 40 feet at Avon Lake to 4 feet at Moss Point. The present cliff and its bench have been likened to a model for similar sets of much earlier features south of Lake Erie (Totten, 1985, and *in* White, 1982, p. 52-60). Along North Ridge south of Bay Village and about 1 mile south of the present cliff the shale is exposed in a 20-foot bluff for about 3 miles. This bluff is a wave-cut cliff that has been designated as the Lower I Cliff (Totten, 1985, and *in* White, 1982, p. 52-60). Its base (660 feet elevation) marks the strandline (Lower) of an earlier higher lake level (Warren). The bluff is overlain westward by a sandy beach ridge known as the Warren beach.

Shales of bedrock unit I 60 feet and more thick are exposed in steep-sided cliffs along the Rocky River, Big Creek, Cuyahoga River, Tinkers Creek, Ninemile Creek, Euclid Creek, and Chagrin River valleys, and along the lower part of the Escarpment from Middleburg Heights to Parma and Independence and from Garfield Heights to Euclid. The maroon Bedford Shale crops out in the Cuyahoga River valley at Independence, north along the Escarpment at Bedford Heights, and in the Rapid Transit cut at Shaker Heights. In Parma to the west, and farther north in the Big Creek valley, the maroon shale is up to 30 feet thick. The Euclid Sandstone Member is present in a few stream sections and disused quarries on the Escarpment north and west of Doan Brook, and on the west side of the Cuyahoga River valley at Independence, where it was formerly quarried. It was also noted at the base of the Bedford Shale as far west as Big Creek.

TABLE 1.—*Stratigraphic relations and age of surficial bedrock units mapped in Cuyahoga County*

Bedrock unit	Dominant lithology	Stratigraphy	Age
IV	sandstone	Pottsville Group Sharon conglomerate	Pennsylvanian
III	shale	Cuyahoga Formation	Mississippian
II	sandstone	Berea Sandstone	Mississippian
I	shale	Bedford Shale Euclid Sandstone Member Ohio Shale Cleveland Shale Member Chagrin Shale Member	Mississippian and Devonian

BEDROCK UNIT II

Bedrock unit II consists of the Berea Sandstone. In Cuyahoga County the Berea is the lowest persistently outcropping bedrock formation that strongly resists erosion. Lithologically it consists of medium- to fine-grained clay-bonded quartz sandstone that is commonly light gray to yellowish brown in outcrop. The lower portion of the unit consists of massive thick-bedded to crossbedded sandstone. Many beds are ripple marked. In the upper part of the unit the sandstone is more thinly bedded.

The Berea Sandstone varies considerably in thickness, largely owing to the extreme irregularity of its base and to its filling of numerous channels cut in the underlying Bedford Shale. Because it strongly resists erosion, the Berea Sandstone forms prominent outcrops. Deep gorges are cut through it on West Branch Rocky River at Olmsted Falls and on East Branch Rocky River at Berea, where it is reported to reach 150 feet in thickness. To the east, deep gorges expose 30 feet of Berea Sandstone on Tinkers Creek at Bedford and 20 feet of Berea on Aurora Branch at Bentleyville. The most areally extensive exposures of the Berea Sandstone are on the Escarpment from Middleburg Heights to Independence, and from South Euclid to Highland Heights, where the average thickness is about 50 feet.

In addition to natural outcrops on the Escarpment and in many tributary valleys along the upper slopes of the Cuyahoga and Chagrin River valleys, the Berea Sandstone is widely exposed in artificial cuts for railroads and highways, in abandoned quarries, and in excavations for construction. Because of its strong differential resistance to erosion relative to the underlying soft shale, there is a tendency for the Berea Sandstone to be undercut and thus form prominent ledges in stream channels. This phenomenon is most marked on Chippewa Creek in Brecksville Reservation, where very large blocks of Berea Sandstone have collapsed because of undercutting and clog the channel downstream.

BEDROCK UNIT III

Bedrock unit III includes the predominantly shaly beds and the interbedded sandstones that are assigned to the Cuyahoga Formation. The shales are mostly dark gray where fresh, or dark brown where weathered, soft, and clayey. Bedding is medium to thick. Sandstone interbeds are medium gray, weathering to pale yellowish gray, flaggy, and fine grained.

Thick shales and thin interbedded sandstones assigned to bedrock unit III crop out on the Escarpment in many of the deep, narrow headwater areas of streams south and southwest of Strongsville, and from North Royalton north to Parma. The most extensive area of outcrop is on the Escarpment between Parma and Seven Hills. Other areas of thick outcrops are in the upper valleys of East Branch Rocky River, Chippewa Creek, Tinkers Creek, and Willey Creek.

BEDROCK UNIT IV

Bedrock unit IV is made up of rocks assigned to the Sharon conglomerate of the Pottsville Group. Lithologically these rocks in Cuyahoga County are predominantly medium- to coarse-grained yellowish-brown to pinkish-brown quartz sandstone. Locally this sandstone contains thin interbedded layers of pebbles in a sandy matrix. The pebbles are well rounded and consist mostly of frosted white quartz. Very little conglomerate is present.

The Sharon forms the summit bedrock unit in Cuyahoga County. Outcrop thicknesses from 20 to over 30 feet are common. The sandstone forms resistant erosional outliers that underlie the highest hills on the Plateau. The outliers are located in the hills from 1 to 2 miles north of Solon, in the hilly area around Brecksville and North Royalton, and in the Brunswick Hills area about 3 miles south of Strongsville. Till is banked against and over the tops of the bedrock outliers; the hills outline portions of the Defiance Moraine in Cuyahoga County.

SURFICIAL ANOMALIES

Several massive, bedded sandstone blocks about 5 to 6 feet thick and about as wide were observed embedded in shale on the Lake Plain at two separate localities about 8½ miles apart. In the vicinity of Brook Park Road and West 130th Street, at the common municipal boundaries of Cleveland, Brook Park, and Parma, the blocks of bedded sandstone are embedded in maroon-colored Bedford Shale of bedrock unit I. They are randomly lodged in the shale and covered by 4 to 6 feet of clay. The maroon-colored shale is strongly sheared and contorted, though stratigraphically in place. About ½ mile west of Dover Center Road, between Center Ridge and Butternut Ridge in North Olmsted near Westlake, two small rises are underlain by massive sandstone blocks that are embedded in shale of bedrock unit I, across a distance of about 300 feet.

Lithologically the sandstone blocks resemble the massive Berea Sandstone. The relation of these blocks to the shale in which they are embedded probably results from glacial plucking and transport, followed by subglacial crushing and lodgment in the shale. The presence of large buried sandstone blocks in areas of known shale outcrop and subcrop poses significant and unexpected problems with respect to excavating foundations for major construction. The existence of such problems cannot be anticipated without detailed exploratory drilling prior to construction.

PLEISTOCENE AND RECENT DEPOSITS

LITHOLOGIC CHARACTERISTICS OF TILLS

Till is unsorted, unstratified glacial drift that has been deposited directly from ice without reworking by meltwater. Color, weathering, texture, clay mineral composition, and carbonate content are diagnostic field characteristics of till deposits that tend on average to remain remarkably constant for individual tills over a limited area. Field characteristics supported by laboratory analyses have previously been used to identify and map tills in northeastern Ohio (for examples see White, 1982, and references therein) and elsewhere in Illinois and Pennsylvania (for examples see Shepps and others, 1959; Frye and others, 1969; White and others, 1969; Ford, 1973).

METHODS OF ANALYSIS

A combination of field records and laboratory analyses were used to identify and correlate the tills described in this report. Field records include descriptions of color, weathering, texture, composition, parting characteristics, thickness, and geographic and stratigraphic distribution. Seventeen measured sections are described in Appendix A. Stratigraphic relations of deposits at the measured sections are summarized in table 2. A total of 115 till samples from 43 different outcrops were analyzed in the laboratory. Textural and compositional characteristics of the samples, grouped in accordance with their physiographic distribution, are summarized in Appendix B.

Color

The color of a till varies according to the extent that it has been altered from the fresh condition. Color is commonly a diagnostic feature of individual tills. Most fresh tills are some shade of gray. A few are red or green. All weathered tills are predominantly some shade of brown. The change from the fresh color to brown reflects the oxidation of iron from the ferrous to the ferric state.

Weathering

Much attention has been given to the weathering

TABLE 2.—*Stratigraphic relations of mapped units at measured sections*
Units listed at each location are directly superposed

Stratigraphic units	Measured sections[1]																
	Plateau							Valleys			Escarpment	Lake Plain					
	Roxbury School	Sprague Road	Miles Road	South Miles Road	Brecksville Interchange	Sunny Acres Sanatorium	Calvary Cemetery Lake	Old Rockside	Sterner gravel pit	South Chagrin Reservation	Baldwin Creek	Bay Village	Fulton Parkway bridge	Brookside Park	Lake Shore Boulevard	Moss Point	Brooklyn Heights
Surficial silt and clay	*	*						*	*				*				
Surficial sand and gravel												*		*	*	*	*
Hiram Till	*								*								
Lavery Till III		*	*	*				*	*		*	*		*			
Lavery Till II					*	*	*	*					*		*	*	
Lavery Till I																*	
Unnamed gravel, sand, silt, and/or clay (**—includes boulders)		*	*	*	**	**		*	*	**	*						
Boulder pavement								*									
Kent Till II			*			*					*						
Kent Till I			*	*													
Pro-Kent? silt							*										
Mogadore Till					*					*							
Illinoian? sand and gravel							*										
Covered		*			*												
Bedrock unit III			*		*	*											
Bedrock unit I								*				*	*	*		*	

[1]Measured sections described in Appendix A; location shown on figure 2; Brooklyn Heights section partly in Valley.

characteristics of tills because they provide essential information from which to reconstruct glacial and climatic history. In addition, weathering characteristics are distinctively different among tills of different ages. Weathering results from a combination of chemical, mechanical, and biological alterations that, under favorable topographic and climatic conditions, result in the formation of soil. Weathering alters the texture and the clay mineral composition of tills. Distinctive layers of alteration form a weathering profile. The profile is divided into horizons (White, 1963, 1967) that range upward from fresh till, through till that is altered by oxidation and leaching of carbonates, to totally decomposed till that contains the soil. The change of color from fresh to oxidized in the weathering profile is a diagnostic characteristic of individual tills and marks the depth of weathering. Erosion and beveling of a weathering profile is common when a till has been overridden by a younger ice sheet.

Texture

The percent distribution of sand, silt, and clay that form the matrix of any given till is referred to here as the texture of the till. Texture is distinctive for fresh samples of individual tills and reflects the nature of the source material. Textural changes that result from deep weathering generally produce an increase in clay relative to silt and sand. Textural analyses for this study were done by the staff of the geochemistry laboratory of the Ohio Division of Geological Survey under the supervision of David A. Stith.

Clay mineral composition

The distribution of clay minerals in fresh tills reflects the clay mineral composition of the source materials. Clay mineral composition is distinctive for tills of different provenance. The weathering characteristics of individual tills are emphasized by grouping the clay minerals into percent distribution of expandable clays (montmorillonite, vermiculite, etc.), illite, and combined chlorite and kaolinite. The degradation of chlorite that accompanies weathering may or may not produce a significant quantity of vermiculite, depending on the proportions of iron and magnesium present in the chlorite. Iron-bearing varieties of chlorite in tills appear to alter rapidly to vermiculite during weathering. Consequently, weathered tills show a higher proportion of expandable clays with respect to illite and to combined chlorite plus kaolinite. Magnesium-bearing varieties of chlorite do not produce much vermiculite on weathering. Consequently, tills that contain much magnesium chlorite when fresh contain an apparently higher illite content and show no significant increase in expandable clays when weathered. For a detailed discussion of the clay mineralogy of tills and their weathering profiles as observed in Illinois see Willman and others (1966). Analyses of clay mineral and carbonate content for this study were done in the X-ray laboratories of the Illinois State Geological Survey under the supervision of H. D. Glass. More recent studies of the clay mineralogy of tills in the Cuyahoga Valley National Recreation Area have been reported by Szabo and Fernandez (1984).

Carbonate content

Carbonate content and calcite/dolomite ratios in the less-than-sand-size fraction of tills are diagnostic of their provenance. Low to zero values of carbonate content commonly signify leaching of the till. The extent to which carbonate is removed from weathered till by downward leaching marks the depth of leaching. Carbonate calculations for this study were made from X-ray diffraction and from Chittick-apparatus data. X-ray diffraction analyses provide counts per second of calcite and dolomite in the <2-micron fraction of the sample. Analyses using Chittick apparatus, described by Dreimanis (1962), provide percent of calcite and dolomite in the <74-micron fraction of the sample. Results from the two different methods are not directly comparable, though each method provides scientifically valid data for contrasting the tills.

STRATIGRAPHIC FRAMEWORK

Till units in northeastern Ohio were initially classified by White (1960) in accordance with rigid specifications of the U.S. Code of Stratigraphic Nomenclature. White (1961) made further elaborations on the rock-stratigraphic classification, and presented a revised time-rock classification (White, 1969). The till units that have been recognized in northeastern Ohio are listed below (from White, 1960, p. A-2).

Unit	*Character of material*
Ashtabula Till	Silty to silty-clay till
Hiram Till	Silty clay to clay till
Lavery Till	Silty till
Kent Till	Silty, sandy till
Mogadore Till	Sandy till

A time-space diagram that relates the stratigraphy of these Wisconsinan tills to their distribution in northeastern Ohio is given in figure 3. The Mogadore Till, Kent Till, Lavery Till, and Hiram Till have been identified in this study of Cuyahoga County. More recent lithologic and stratigraphic studies by Szabo and others (Szabo and Miller, 1986, and references therein) have distinguished a previously unrecognized older till, the Northampton Till, in the lower Cuyahoga River valley. Other deposits that have been mapped include erratic boulders and cobbles, surficial sand and gravel, and surficial silt and clay. No deposits of Ashtabula Till were encountered. All the glacial units except the Mogadore Till and the newly described Northampton Till (Szabo and Miller, 1986) are Woodfordian or younger in age. Woodfordian ice advanced into northeastern Ohio from the Erie Basin in three separate lobes—the Grand River, the Cuyahoga, and the Killbuck. Woodfordian tills in Cuyahoga County were deposited mostly in the Cuyahoga lobe (White, 1982). Sections referred to in the following discussion are found in Appendix A.

MOGADORE TILL

Age and stratigraphic position

The Mogadore Till was named for a locality near the village of Mogadore, in Summit County, Ohio (White, 1960). The till had previously been described as sandy and pebbly, chunky, with cobbles and boulders (Shepps, 1953). The age of the Mogadore Till is estimated at about 40,000 years B.P., based on its correlation with Titusville Till in Pennsylvania (White, Totten, and Gross, 1969). It is therefore pre-Woodfordian and the oldest till exposed in Cuyahoga County. The Mogadore Till is also correlative with the Millbrook Till

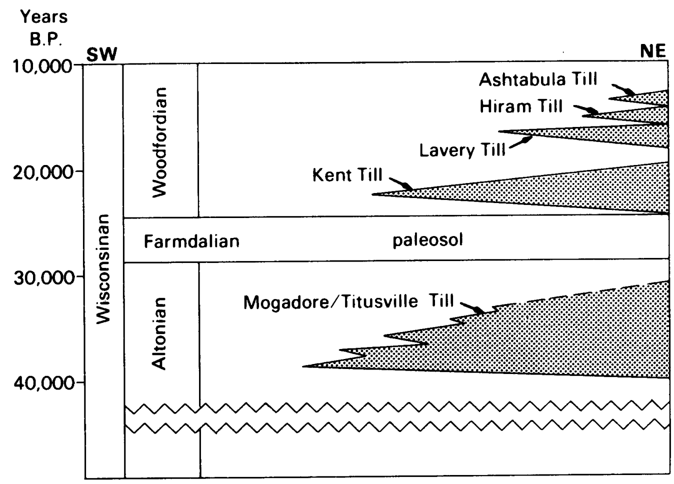

FIGURE 3.—Time-space diagram relating stratigraphy of Wisconsinan tills to generalized distribution in northeastern Ohio (simplified from White, 1969, p. 151).

in the Killbuck lobe to the west and southwest (White, 1967; Totten, 1973). At sections where the Mogadore Till is identified in this study its base is not exposed. The till is overlain by sand, gravel, and boulders which separate it from overlying Lavery Till.

Lithologic character

The Mogadore Till is gray to dark gray (5Y 4/1 to 10YR 4/1), very slightly calcareous, sandy to stony, tough, and blocky. The till is oxidized to yellowish brown adjacent to nearly vertical joint surfaces. Oxidized portions stand out owing to greater resistance to erosion. The till locally contains small lenses of deeply oxidized sand. Analyses of

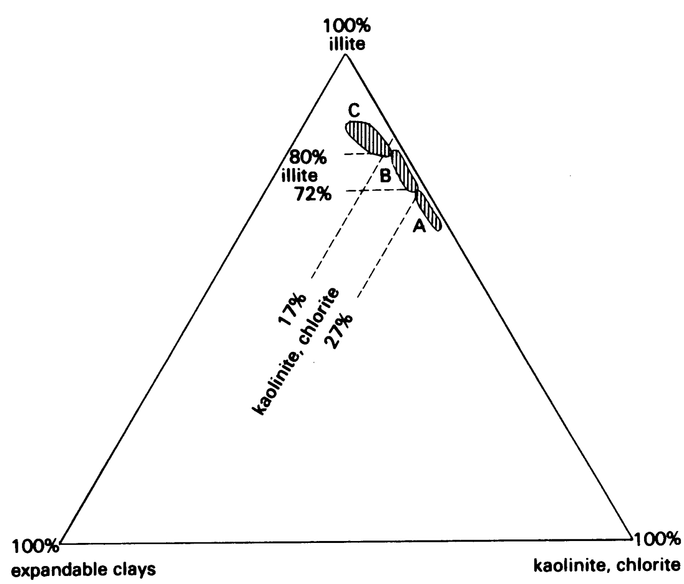

FIGURE 4.—Triangle diagram showing clay mineral composition of tills and shale in Cuyahoga County. **A**, Mogadore Till (6 samples, 2 localities); **B**, Kent Tills (15 samples, 8 localities), Lavery Tills (55 samples, 26 localities), Hiram Till (4 samples, 3 localities), shale (bedrock unit I, 6 samples, 3 localities); **C**, weathered tills, mostly Lavery Tills (24 samples, 13 localities).

TABLE 3.—*Average textures and compositions of tills in Cuyahoga County*

Till/Physiographic section	No. of field localities	Total no. of samples	Average grain-size distribution in the <2 mm fraction (%)			Average clay mineral composition in the <2μ fraction (%)			Average no. of carbonate counts/sec in the <2μ fraction		Average carbonate % in the <74μ fraction	
			Sand (<2> 0.074 mm)	Silt (<0.074> 0.0039 mm)	Clay (<0.0039 mm)	Expandable clay minerals	Illite	Chlorite and kaolinite	Calcite	Dolomite	Calcite	Dolomite
Hiram/Plateau	4	4	11	53	36	2	75	23	28	12	3	4
Hiram/Valleys	1	2	4	48	48	2	80	18	31	14	4	6
Lavery III/Plateau	3	11	13	42	45	3	79	18	60	19	7	7
Lavery III/Escarpment	1	3	12	41	47	3	73	24	66	20	7	17
Lavery III/Valleys	2	7	9	46	45	2	76	22	37	16	6	6
Lavery III/Lake Plain	5	12	12	40	48	2	78	20	47	17	5	9
Lavery II/Plateau	6	13	16	49	35	2	74	24	43	19	6	7
Lavery II/Valleys	1	4	9	53	38	1	77	22	16	11	3	5
Lavery II/Lake Plain	4	15	9	55	36	2	78	20	18	12	3	7
Lavery I/Lake Plain	3	6	24	50	26	1	78	21	14	13	3	6
Kent II/Plateau	3	6	18	49	33	2	77	21	9	13	1	3
Kent II/Escarpment	1	3	17	53	30	2	78	20			1	3
Kent I/Plateau	3	6	25	49	26	2	77	21	15	14	2	4
Kent I/Valleys	1	1	23	51	26	2	73	25	15		0	2
Mogadore/Plateau	1	3	38	44	18	2	69	29	21	16	2	4
Mogadore/Valleys	1	3	39	44	17	2	70	28	16	12	2	5

six Mogadore Till samples show a silty to sandy texture that averages 44 percent silt and about 39 percent sand. The clay mineral composition averages 70 percent illite and 28 percent kaolinite plus chlorite (fig. 4 and table 3). The till is low in carbonate content with an average 2 percent calcite and 5 percent dolomite in the <74-micron fraction.

Mogadore Till resembles Kent Till in the field, though it tends to be tougher and more thoroughly indurated. Both tills are characteristically overlain by sand, gravel, and boulders. Textural and clay mineral analyses show, however, that Mogadore Till is more silty to sandy, and that it is higher in kaolinite and correspondingly lower in illite than Kent Till. Positive identification of the Mogadore Till is therefore limited here to outcrops that were sampled and analyzed. No paleosol was observed on the Mogadore Till.

Location and extent

Exposures of Mogadore Till are rare in Cuyahoga County. Positive correlation based on stratigraphic relations and confirmed by laboratory analyses is limited to outcrops at topographically subdued locations (fig. 5). Mogadore Till is present at the Brecksville Interchange section in the Chippewa Creek valley west of Brecksville, where it is about 8 feet thick, and at the South Chagrin Reservation section in a valley tributary to the Chagrin River west of Bentleyville, where it is about 15 feet thick. A limited exposure of tough, stony, dark-gray till on the upper Lake Plain at Berea resembles the Mogadore in outcrop. The exposure is located in a small drainage channel off Sheldon Road, ½ mile east of the East Branch Rocky River valley and ¼ mile south of Abram Creek. Because of its degraded condition this outcrop was not sampled.

KENT TILL

Age and stratigraphic position

The Kent Till was named for a locality near Kent, in Portage County, Ohio (White, 1960). It has been traced from its type locality throughout the Grand River and Cuyahoga lobes. Radiocarbon dates and stratigraphic relations at Garfield Heights have been interpreted to show that Kent ice advanced over Cuyahoga County about 23,250 years ago (White, 1968). The Kent Till is the oldest known Late Wisconsinan (Woodfordian) till in northeastern Ohio. It has been correlated with the Navarre Till in the Killbuck lobe. In Cuyahoga County, Kent Till lies directly on bedrock and is overlain by sand and silt, which separate it from overlying Lavery Till. At a few localities the sand above the Kent Till contains cobbles and boulders of igneous and metamorphic rocks. At Garfield Heights, in a very small restricted area, Kent Till overlies laminated silt and clay, which in turn rest on gravels that were assigned an Illinoian age by White; it is reportedly overlain by Hiram Till (White, 1968).

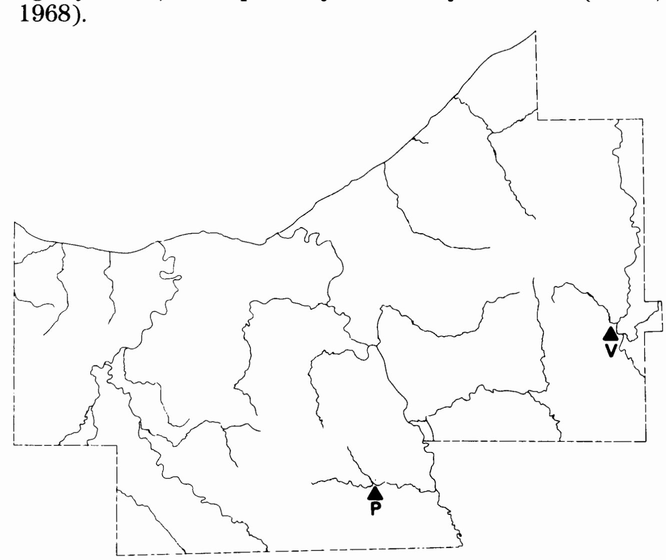

FIGURE 5.—Outcrop locations of Mogadore Till. P, Plateau locality; V, valley locality.

Lithologic character

Descriptions of Kent Till from 19 field localities in Cuyahoga County show that it ranges from dark gray (5Y 4/1) through gray brown (2.5Y 4/2) to olive gray (5Y 4/2). Kent Till is very slightly calcareous, with a silty to clayey or silty to sandy texture. The till is stony, with many black shale pebbles, and parts in plates and blocks. Locally it contains small lenses of sand.

Analyses of 16 samples of Kent Till from eight localities show two textural units (table 3 and Appendix B). One unit has a silty to sandy matrix with an average clay content of 26 percent and is designated Kent Till I. A second unit has a matrix averaging 50 percent silt with an average clay content of 32 percent and is designated Kent Till II. There is no overlap between the two units in their respective ranges of sand or clay content (fig. 6).

The clay mineral composition of Kent Tills I and II is uniformly low (1 to 2 percent) in expandable clays, and illite content commonly averages 75 percent. The clay mineral composition of the Kent Tills I and II does not differ significantly from that of the underlying shale bedrock from which presumably they were derived (see fig. 4). All samples of Kent Tills are very low in carbonate content, with an average of 1 percent calcite and 3 to 4 percent dolomite in the <74-micron fraction. The Kent Tills are typically leached and very slightly calcareous. They are not exceptionally degraded by weathering. No paleosol was noted on the Kent Tills.

Location and extent

The Kent Tills are exposed at topographically subdued localities, mostly on the Plateau (fig. 7). The Kent Tills crop out at intervals along the Mill Creek valley and along the north branch of Tinkers Creek in the Garfield Heights-Maple Heights-Warrensville Heights area. Isolated exposures are present along the upper reaches of tributaries that drain eastward to the Chagrin River valley, and along the headwaters of Chippewa Creek in the Broadview Heights area. At the Miles Road section in Warrensville Heights, silty to sandy Kent Till I is overlain by silty Kent Till II. This is the only known locality where the two units of Kent Till occur together. It is also the thickest (32 feet) recorded section of the Kent Tills. A typical outcrop of Kent Till II overlain by coarse sand, gravel, and boulders at Warrensville Heights is shown in figure 8. The Baldwin Creek section at the base of the Escarpment in Middleburg Heights exposes a block of Kent Till II about 4 feet thick and 14 feet long that is surrounded by Lavery Till III. The base of the exposure is covered, and the sand unit that separates the Kent Till from the Lavery Till wedges out across the outcrop. Sandy to stony Kent Till I is exposed on the upper Lake Plain in a tributary valley east of the Rocky River west of Grayton Road about 1 mile north of Brook Park Road. Kent Till I ranges in thickness from 0.7 foot between Bentleyville and Solon to 22 feet at the South Miles Road section. Kent Till II ranges in thickness from 3.7 feet at the Sunny Acres Sanatorium section to 17 feet at the Miles Road section.

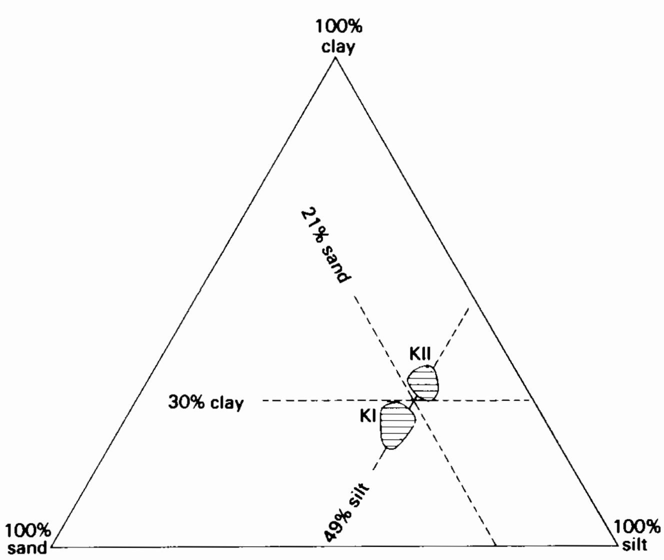

FIGURE 6.—Triangle diagram showing texture of Kent Tills in Cuyahoga County. Areas of Kent I and Kent II based on plots of 16 till samples from 8 localities.

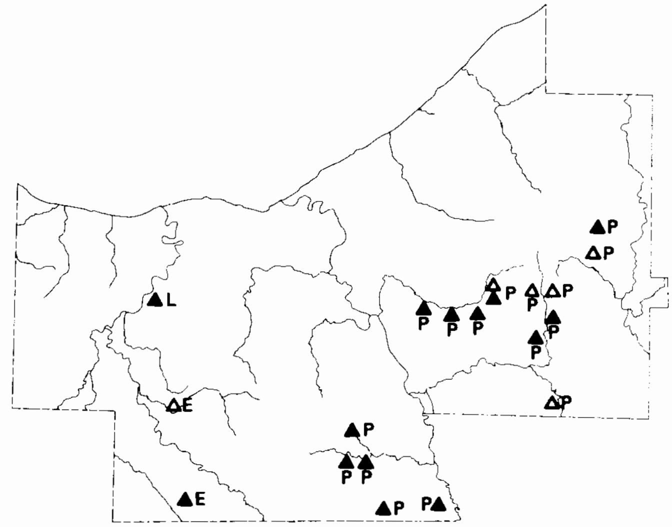

FIGURE 7.—Outcrop locations of Kent Tills. Solid symbol, Kent I; open symbol, Kent II; **E**, Escarpment locality; **L**, Lake Plain locality; **P**, Plateau locality.

LAVERY TILL

Age and stratigraphic position

Lavery Till was named for a locality near the hamlet of Lavery in northwestern Pennsylvania (Shepps and others, 1959). The till has been traced from its type locality throughout the Grand River and Cuyahoga lobes. The exact age of the Lavery Till is not known, but it is thought to be about 19,000 years (White, 1982). It is correlated with the Hayesville Till of the Killbuck lobe (White, 1961). Lavery Till is the most areally extensive and continuously exposed till in Cuyahoga County and forms the uppermost glacial unit over much of the area (pl. 1).

Lavery Till overlies bedrock or unnamed deposits of sand and silt that range in thickness from about 1 foot to 11 feet. At some sections the sand and silt deposits contain boulders in the basal portion. At the Brecksville Interchange section the base of these deposits also contains erosional fragments of the underlying till. Because unnamed sand and silt overlie both the Mogadore Till and the Kent Till at different sections (table 2), these deposits cannot be reliably correlated and their age remains uncertain.

Lavery Till contains the modern soil where it forms the

FIGURE 8.—Kent Till II in stream bed and bank at Dalebridge Road, Warrensville Heights. Exposure shows 3-4 feet of till overlain by an equivalent thickness of clay, coarse sand, gravel, and boulders. Photo taken in April 1974.

surface till. Typically the Lavery Till is oxidized to a depth of about 5 feet and leached to a depth of 2 to 3 feet. Locally the Lavery Till is overlain by surficial sand and gravel or surficial silt and clay. In the southeastern part of the county the Lavery Till is overlain by Hiram Till.

Lithologic character

Descriptions of Lavery Till from 264 field localities in Cuyahoga County show that it is dark gray to gray brown (10YR 4/1 to 10YR 5/3) with a texture that is silty to sandy, or silty, or silty to clayey. Lavery Till is strongly calcareous and cohesive, with platy to blocky parting. Pebble content ranges from a few to many, with diameters up to 1 inch. At the Old Rockside section, silty to clayey Lavery Till III was noted to be more strongly calcareous than underlying silty Lavery Till II. Commonly the till is transected by closely spaced, steeply inclined to near-vertical joints and is deeply oxidized from ½ inch to 1 inch on each side of the joint surfaces.

Analyses of 71 samples of Lavery Till from 25 field localities reveal three distinct textural units (table 3 and Appendix B). The contrast in percent of sand and percent of clay in the matrix of the Lavery Till units is remarkable. One unit has a sand content that exceeds 21 percent and an average clay content of about 26 percent; this unit is designated Lavery Till I. A second unit has no sample that contains over 20 percent sand and the average clay content is about 36 percent; this unit is designated Lavery Till II. A third unit has no sample with less than 40 percent clay and the average clay content is about 46 percent; this unit is designated Lavery Till III. All samples of Lavery Till are predominantly silty. Percent of clay content therefore differs more or less inversely with percent of sand content. Textural units of Lavery Tills are based on laboratory analyses, which confirm the descriptive field observations (fig. 9). Stratigraphic relations among the textural units are revealed at the Moss Point section in Euclid (fig. 10), where Lavery Till II overlies Lavery Till I, and at the Old Rockside section in the Cuyahoga River valley, where Lavery Till III overlies Lavery Till II. The stratigraphic relations are shown diagrammatically on the cross sections (pl. 1).

Lavery Tills have a uniformly low (1 to 3 percent) content of expandable clay minerals; illite averages 75 percent for fresh samples. Degradation of chlorite in weathered samples does not produce a significant increase in expandable clays, but does result in an apparent increase in illite, up to 85 percent, and a corresponding decrease in combined chlorite and kaolinite. The average clay mineral content of Lavery Tills is not significantly different from that of the shale bedrock or of the Kent Tills (see fig. 4). All Lavery Tills are strongly calcareous, although the highest X-ray counts and relative percent of carbonates were measured in the clay-rich Lavery Till III.

The textural similarity between Lavery Till I (fig. 9) and Kent Till I (fig. 6) may result in confusion where the stratigraphic relations of these tills are not evident in the field. Lavery Till I is distinguished from Kent Till I by its greater carbonate content and by its darker gray color. The field distinctions are substantiated by laboratory analyses. Lavery Till II is texturally similar to Kent Till II. These tills are distinguished in the field and in the laboratory by the same lithologic contrasts that distinguish Lavery Till I from Kent Till I.

Location and extent

The general distribution of Lavery Tills I, II, and III is shown in figure 11. Lavery Till I is widespread on the Lake Plain. Measured thicknesses range from 2 feet at the Moss

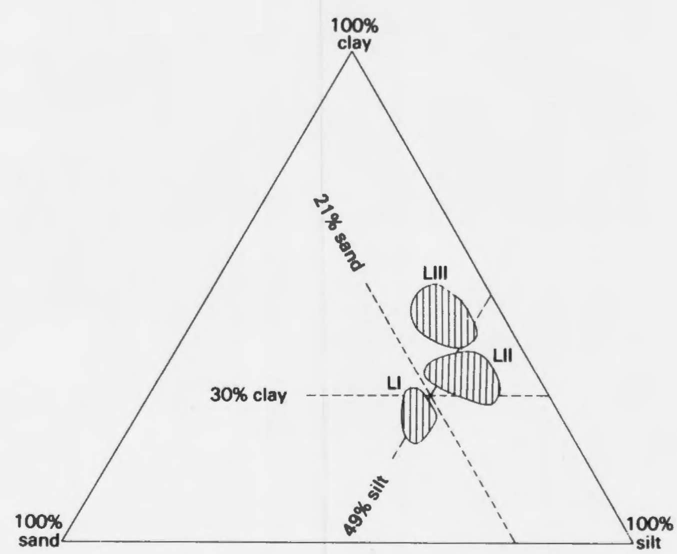

FIGURE 9.—Triangle diagram showing texture of Lavery Tills in Cuyahoga County. Areas of Lavery I, Lavery II, and Lavery III based on plots of 71 till samples from 25 localities.

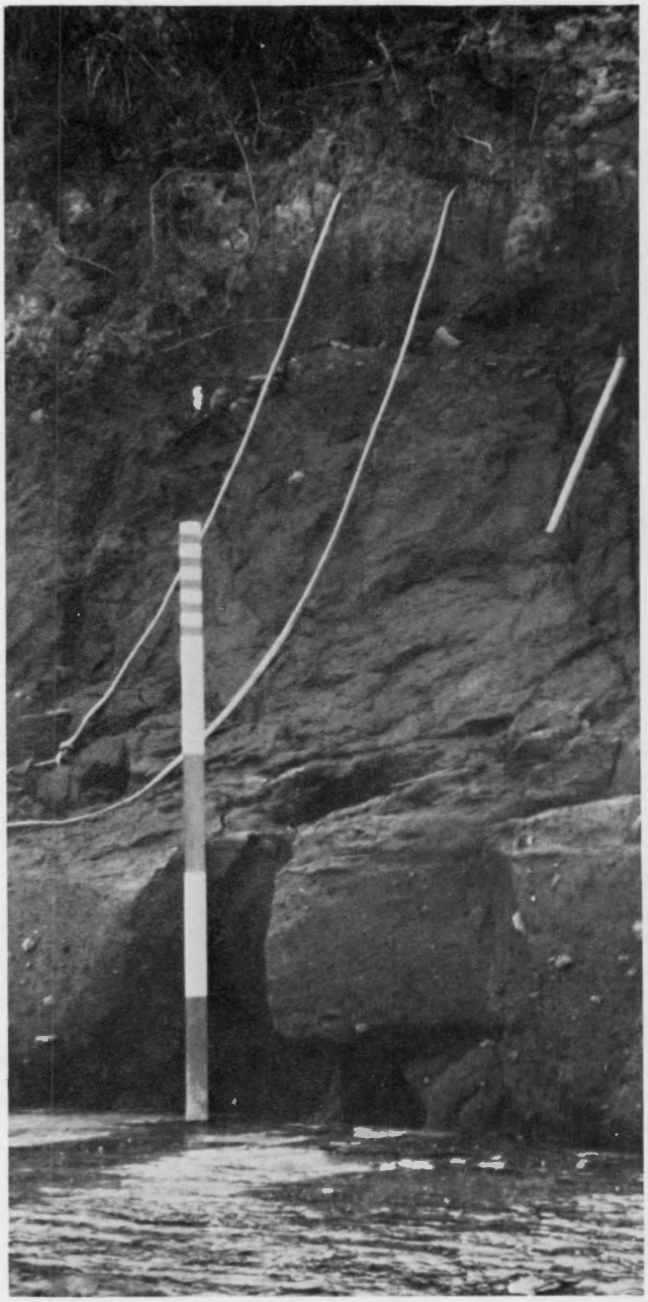

FIGURE 10.—Lake bluff at Moss Point section, Euclid. Lavery Till I is exposed above shale of bedrock unit I and overlain by Lavery Till II. Pickaxe handle is embedded at contact of till and overlying slumped sand and gravel. Photo taken in April 1974.

Point section in Euclid to over 5 feet in an excavation at the Great Northern Shopping Mall in North Olmsted. Lavery Till I was not found outside the Lake Plain.

Lavery Till II is the most extensive of the Lavery Tills. It is widely distributed on the Plateau and on the Defiance Moraine. An outcrop of typical Lavery Till II with a local pocket of overlying sand in the Defiance Moraine at Bedford Heights is shown in figure 12. Lake Plain exposures of Lavery Till II are widespread but localized. Lavery Till II was noted at one locality in the Cuyahoga River valley. Measured thicknesses on the Plateau range from 8 feet at Pettibone Road near Twinsburg to 31 feet in an excavation at the former Old Randall Racetrack (now Randall Park Mall) in North Randall. On the Lake Plain, Lavery Till II ranges from 10 feet thick along the lake bluff west of Rocky River to 16 feet thick at the Moss Point section in Euclid. In the Cuyahoga River valley at the Old Rockside section Lavery Till II is 5.2 feet thick.

Lavery Till III has its greatest extent on the Lake Plain west of the Cuyahoga River. Lavery Till III was identified at localities along the Cuyahoga River valley and at the margin of the Plateau. Lavery Till III is thin, commonly weathered, and totally leached. An outcrop of typical Lavery Till III at the base of the Escarpment adjacent to the Lake Plain in Parma Heights is shown in figure 13. Measured thicknesses on the Lake Plain range from about 5 feet in an excavation at Ridge Road and Woodhaven Avenue near Brookside Park to 10 feet at the Bay Village section. Muck on Lavery Till III occurs locally in a poorly drained area on the Lake Plain west of Middleburg Heights (pl. 1). In the Cuyahoga River valley, Lavery Till III is about 24 feet thick at the Old Rockside section. Thicknesses at the north margin of the Plateau range from 7 feet at the Miles Road section to about 21 feet at the Sprague Road section.

HIRAM TILL

Age and stratigraphic position

Hiram Till was named for exposures near Hiram, Portage County, Ohio (White, 1960), and has been traced in surface outcrop across the Grand River, the Cuyahoga, and the Killbuck lobes. The Hiram Till is late Woodfordian in age and was deposited about 17,000 years ago (White, 1982). A minimum age for the disappearance of the Hiram ice is 14,050 years B.P. (Totten, 1976, p. 514). Hiram Till is typically thin and discontinuous in Cuyahoga County, so that few reliable field identifications were made. Where present it is the uppermost till. It is commonly thinner than the modern soil profile, which passes through it into underlying Lavery Till and thus obliterates the Hiram Till's distinctive lithology.

Lithologic character

Field descriptions show that Hiram Till is brown (10YR 4/3), silty to clayey with sparse pebbles, calcareous, and has small prismatic partings. Thin clay layers are included within the till. Analyses of samples of Hiram Till from the Sterner gravel pit section and from several field localities in Cuyahoga County show a texture that consists of almost equal proportions of silt and clay, with less than 10 percent sand. Clay mineral composition is very low in expandable clays, with an average illite content of 75 percent for fresh samples and up to 84 percent for weathered samples. Carbonate content is moderate to high (table 3 and Appendix B).

Location and extent

Hiram Till in Cuyahoga County is present at localities on the eastern and southeastern portions of the Plateau and the Escarpment and in the Cuyahoga River valley (fig. 14). The textural and compositional characteristics of some samples from Plateau localities (see Roxbury School section) more closely resemble Lavery Till II than Hiram Till, so that field identification is open to question. At the Sterner gravel pit section in the Cuyahoga River valley, Hiram Till is 10 feet thick. It overlies Lavery Till III and is overlain by surficial silty clay.

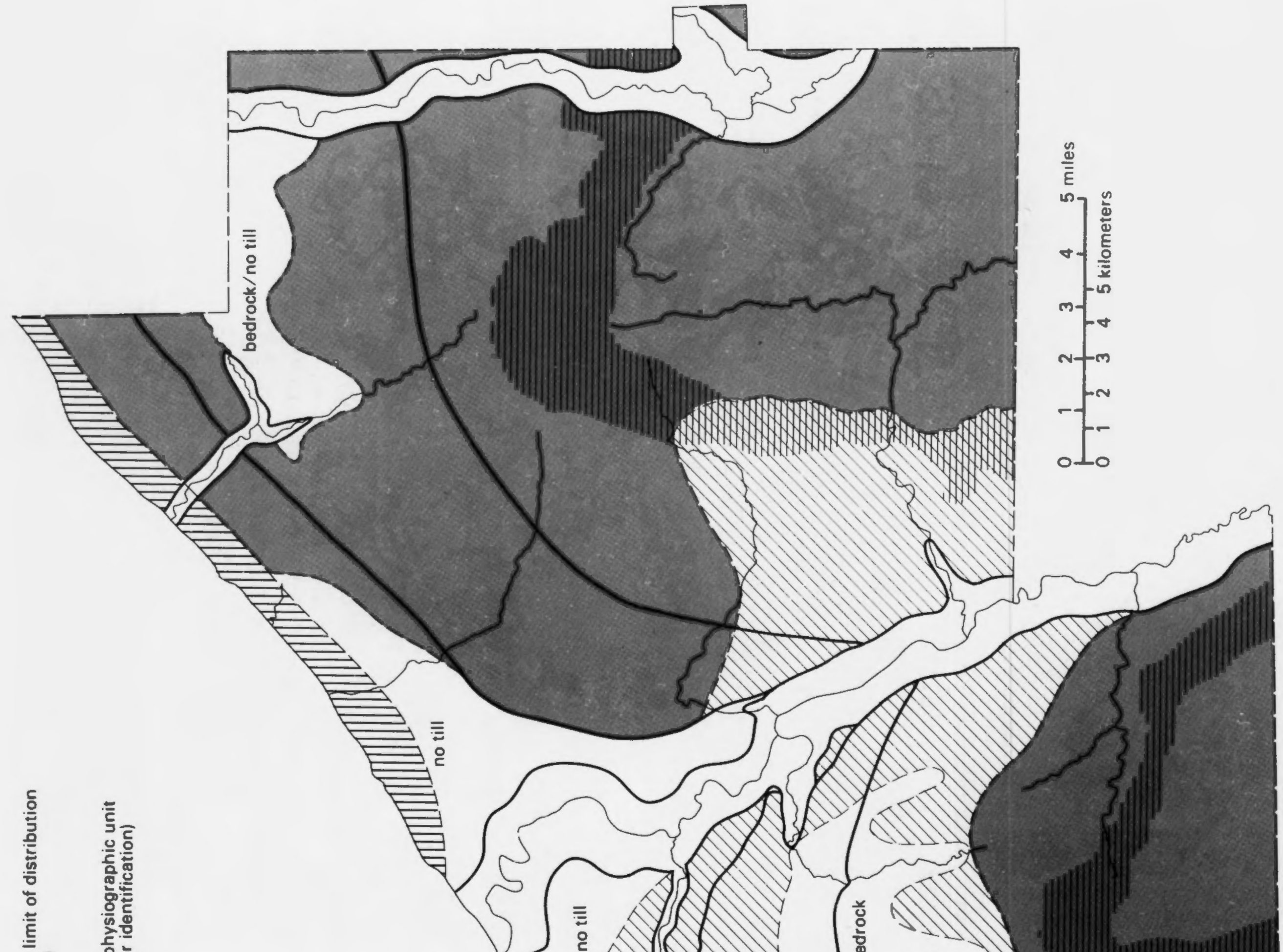

FIGURE 11.—General distribution of Lavery I, Lavery II, and Lavery III Tills relative to physiographic units in Cuyahoga County.

FIGURE 12.—Lavery Till II exposed in Defiance Moraine east of Naiman Parkway, Bedford Heights. Till is locally overlain by sand, up to 16 feet thick, concentrated in pocketlike form that has no topographic expression on the upland surface. Sand/till boundary shown by dotted line. Photo taken in April 1974.

SURFICIAL LACUSTRINE AND FLUVIATILE DEPOSITS

Layered deposits of sand and gravel or silt and clay of lacustrine and fluviatile origin are distributed at the surface in a variety of topographic forms; some are subdued, others are quite prominent. Most of the deposits were laid down following the Woodfordian glaciation. These deposits may overlie any of the Lavery Tills or, in the absence of till, may lie directly on bedrock. The deposits are not correlated to each other and remain stratigraphically unnamed. They are mapped on plate 1 as undifferentiated sand and gravel or as undifferentiated silt and clay. The surficial sand and gravel deposits in some localities are interbedded with or grade laterally into areally more extensive silt and clay.

Sand and gravel

Surficial deposits of sand and gravel range considerably in thickness, degree of sorting, and areal extent, depending on their origin. Poorly sorted deposits that include shale fragments are distributed in beach ridges on the Lake Plain. Poorly sorted deposits also are found in kames on the Plateau south of the Defiance Moraine. Pockets of coarse sand up to 16 feet thick locally overlie Lavery Till on the Plateau without any noticeable effect on the topography (see fig. 12).

The Lake Plain in the Cleveland area is underlain by sand that was deposited in the wide valley of an earlier course of the Cuyahoga River. In downtown Cleveland the surficial sand is over 90 feet thick and is extensively covered by urban land. Beneath the sand deposits lies a considerable thickness of interbedded silt, clay, and till deposits in the buried bedrock valley. The sand thins to a featheredge about 5 to 6 miles southward (up valley).

Well-sorted medium- to fine-grained sand with little or no gravel is found in stream-valley terraces. Surficial sand deposits are conspicuous in the upper valley of Chippewa Creek and in Griswold Creek. Sand deposits in the Mill Creek valley include significant volumes of gravel and boulders. Lithologically these deposits are distinct from the other surficial sands.

FIGURE 13.—Outcrop of Lavery Till III at base of Escarpment in Parma Heights. The till is 7-10 feet thick, brown, deeply weathered, and totally leached. It overlies Berea Sandstone (bedrock unit II). Photo taken in April 1974.

Silt and clay

Surficial silt and clay of presumed lacustrine origin are thinly spread along the Lake Plain and at a number of scattered localities along the Escarpment. Thin silt deposits at higher elevations on the Plateau are possibly eolian in origin. On the Lake Plain the silt and clay range in thickness from 4 feet in an excavation at the Ridge Road-Woodhaven Avenue intersection to 14 feet at the lake bluff by Euclid General Hospital. Deposits on the Escarpment range in thickness from 3 feet at Independence (fig. 15) and in the area northeast of Richmond Heights to 5 feet at the Sprague Road section. Silty clay interbedded with sand and gravel forms a thin outwash cover on the Plateau south of Solon, in the southeastern part of the county. Such deposits at the Roxbury Road section are 5 to 6 feet thick and overlie Hiram Till.

Silt and laminated clay also are found in valley terrace deposits. Samples from terraces at the Brooklyn Heights and Old Rockside sections are yellowish gray to yellowish brown. The silt content ranges from 56 to 81 percent, with the remainder consisting of clay. At the Sterner gravel pit section the deposits are mostly clay (54 to 63 percent). The clay mineral composition of the deposits is the same as that of the Lavery Tills. Fresh samples have an average 2 percent expandable clay minerals and 76 percent illite; weathered samples show an increase in illite up to 86 percent. The silt and clay are interbedded with sand in units 20 feet or more thick, so the terraces may reach an aggregate total of 140 feet or more. The terrace deposits overlie till or bedrock. Although the terrace surfaces are level to gently inclined, the underlying bedrock surface may show considerable relief (fig. 16). Because of differential porosity and permeability the interbedded silts, laminated silty clays, and sands are highly susceptible to slumping; therefore, the valley terraces undergo relatively rapid landscape degradation (fig. 17).

Alluvium and muck

Recent alluvium consists mostly of silt and sand and associated organic debris. Deposits are scattered along the bottoms of the Cuyahoga and the Chagrin River valleys and in some tributary valleys (pl. 1). The alluvial deposits are generally less than 10 feet thick. No significant thickness of alluvium was found in the Rocky River valley or in its East or West Branches downstream from Berea and Olmsted Falls, respectively.

Muck is finely divided, highly decomposed, dark-colored soil material that forms in undrained swampy depressions. Several small deposits located on the sites of former lagoons on the Lake Plain and in swales on the Plateau were reported by Cushing and others (1931) to contain peat. Most of these deposits have been drained, cleared, and built over. The only remaining muck and associated peat are located in small disconnected patches that extend for a little over a mile along a north-south stretch of Abram Creek in Middleburg Heights (pl. 1). The patches of muck and peat coincide with the areas of Carlisle soil mapped by Musgrave and Halloran (1980).

GLACIAL ERRATICS

Erratic cobbles and boulders that range from several inches to over 6 feet in diameter are widely scattered at the

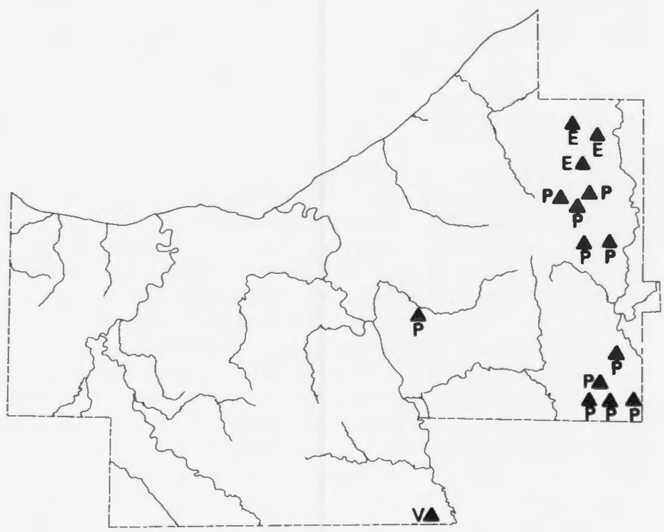

FIGURE 14.—Outcrop locations of Hiram Till. **E**, Escarpment locality; **P**, Plateau locality; **V**, Valley locality.

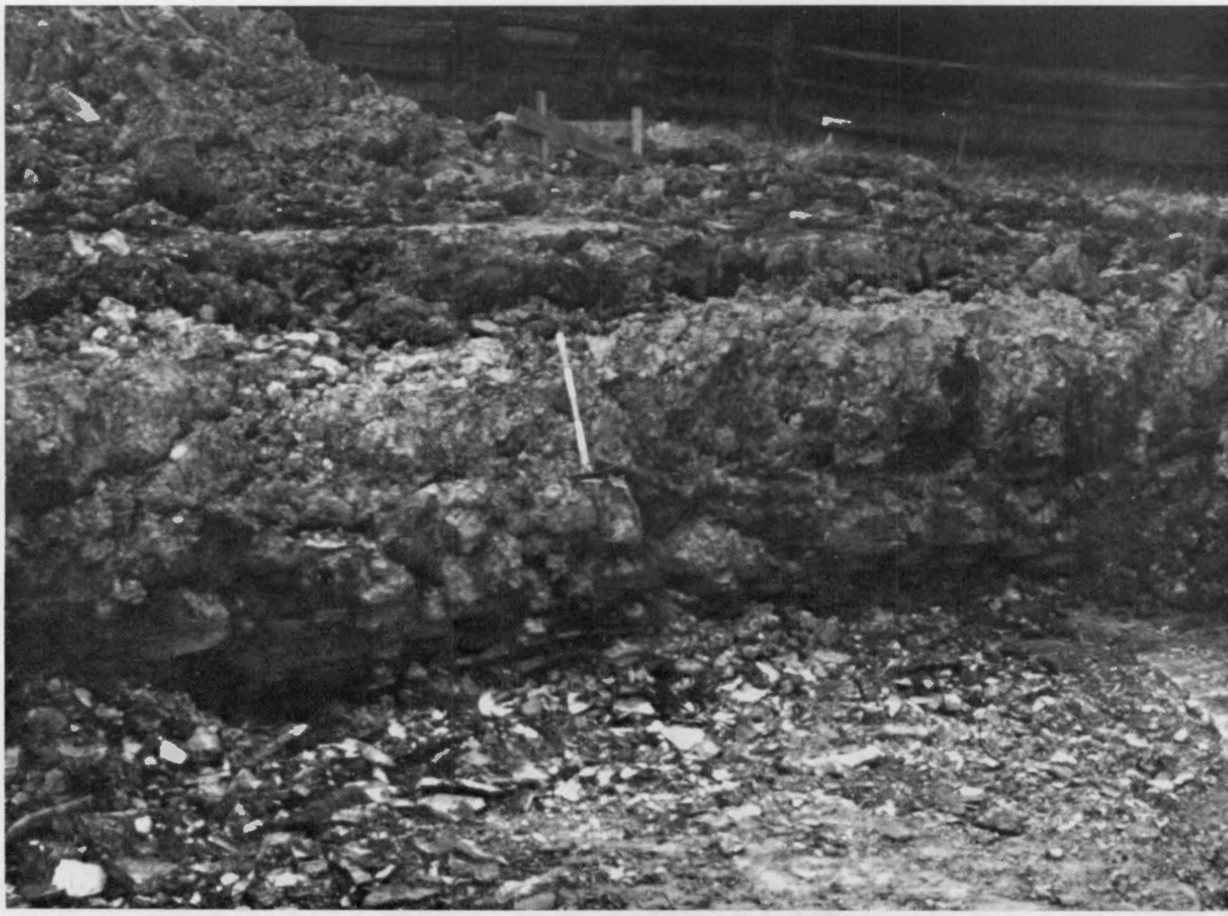

FIGURE 15.—Lacustrine clay approximately 3 feet thick on Berea Sandstone (bedrock unit II) overlain by modern soil in clay at construction site on Escarpment at Independence. Photo taken in April 1974.

surface in Cuyahoga County (pl. 1). The erratics include granite, gneiss, quartzite, greenstone, and dolomite of distant derivation, in addition to some sandstone possibly of local origin. The erratics are found mostly in the area of North Olmsted, Westlake, Bay Village, and adjacent parts of Avon Lake in Lorain County, and at widely scattered localities in the central and eastern parts of the county. In the North Olmsted-Westlake area some of the boulders are used for landscaping.

The stratigraphic relations of the erratics are not clear. On the Lake Plain in western Cuyahoga County they appear to be correlatives of a subsurface boulder belt in Lorain and Medina Counties which is commonly found along an interface of the Navarre Till—at either the Millbrook-Navarre contact or the Navarre-Hayesville contact (S. M. Totten, personal commun.). Cobbles and smaller boulders of igneous and metamorphic origin were observed above the Mogadore Till at the Brecksville Interchange section, and above the Kent Till at the Sunny Acres Sanatorium section. A boulder pavement composed largely of igneous and metamorphic rocks up to 3 feet in diameter was observed on bedrock and below Lavery Till at the Old Rockside section.

MADE LAND

Made land consists of areas of reclaimed land, fill, and manmade alteration, including urban land. Approximately 30 percent of the land surface in Cuyahoga County falls within this category. The made land shown on plate 1 includes large continuous areas of urban land where more than 90 percent of the surface is covered with fill or manmade materials. It is not practical, however, to show the urban land over large areas where it is intricately associated with other types of cover.

Urban land consists of areas where most of the surface is continuously covered with concrete, asphalt, buildings, structures, or other manmade surfaces. Widespread examples include industrial parks, storage facilities, factories, parking lots, business complexes, and shopping centers. Numerous small streams have been filled in and built over, most notably on the Lake Plain in East Cleveland and on the adjacent Escarpment in communities to the south. Construction on unstabilized fill sites has in some cases led to serious foundation problems.

Made land reclaimed from Lake Erie exists mostly in Cleveland along the lakeshore from Edgewater Park to Gordon Park. The fill has an average thickness of about 20 feet and is composed of diverse materials that include silty and sandy clay, gravel, cinders, concrete, brick fragments, slag, wood, rubber, and pebbles. The made land is used for industrial storage, docking and Coast Guard facilities, wastewater treatment, and for the Burke Lakefront Airport. Areas along the Cuyahoga River in downtown Cleveland

FIGURE 16.—Lacustrine terrace east of Brecksville on west side of Cuyahoga River valley. Exposure shows laminated silt and clay deposits overlying steeply sloping irregular bedrock surface on Chagrin Shale Member (bedrock unit I). Elevation of terrace surface is about 760 feet. Photo taken in March 1974.

have been channelized and filled with waste materials from steel mills.

Large dumps for the accumulation of solid waste are scattered throughout Cleveland and adjacent communities. In several localities disused sand and gravel pits now serve as dumps. The depth of the fill in the dumps ranges from 10 to about 100 feet. It should be noted that abandoned sand and gravel pits generally do not make appropriate sites for sanitary landfills because of serious hydrogeologic concerns.

Glacial deposits on the Lake Plain and the Escarpment have been extensively disturbed by construction. In places the deposits have been completely removed. Much of the fill used for the roadbed along stretches of the interstate highways consists of glacial deposits and bedrock that were scraped from the surface of adjacent land or hauled from road cuts.

SUMMARY OF GLACIAL DEPOSITS

The oldest glacial deposit that has been described (White, 1968) from an exposure in Cuyahoga County consists of gray sandy gravel on the southwest side of the Mill Creek valley. On the basis of its lithologic characteristics and the presence of a thick overlying paleosol, White assigned this deposit an Illinoian age. A probable correlative of the sandy gravel was measured in the present study about 2/3 mile across the valley on the northeast side at the Calvary Cemetery Lake section. No other deposit of this type was found.

The tills are identified and correlated here on the basis of their lithologic characteristics and their stratigraphic relations. The oldest till exposed is correlated with the pre-Woodfordian Mogadore Till. Successively younger tills include the Kent, the Lavery, and the Hiram Tills of Woodfordian age.

The deposits of Mogadore Till are sparse relics of the material brought in by pre-Woodfordian ice. The exposures provide no physical evidence of a paleosol that may have formed during the Farmdalian (Plum Point) interstadial, between the melting of Altonian ice and the advance of Woodfordian ice. The contrast in clay mineral composition between pre-Woodfordian Mogadore Till and the three Woodfordian tills suggests that the tills came from different bedrock sources. The clay mineral compositions of the Woodfordian tills and the adjacent shale bedrock are indistinguishable from each other, suggesting that these tills had a common source in the Erie Basin.

FIGURE 17.—Upper third of 60-foot-thick lacustrine terrace at Valley View, on south side of Tinkers Creek about 1 mile east of Cuyahoga River. Exposure shows sand and laminated silt overlain by about 5 feet of Lavery Till III and 1 foot of gravel and boulders beneath modern soil. Differential porosity and permeability of terrace deposits results in continued slumping and degradation of the land surface. Photo taken in March 1974.

Radiocarbon dates indicate an advance of the earliest Woodfordian Kent ice at about 23,250 years B.P. Textural contrasts and stratigraphic relations reveal that two units of Kent Till were deposited. Exposures of Kent Till are fairly widespread, though localized in extent. Although deeply leached, the Kent Tills show no paleosol, probably owing to erosion. Sand, silt, and boulders that were deposited on the beveled surfaces of the Kent Tills and the Mogadore Till were later buried by advancing Lavery ice. Three units of Lavery Till were deposited. The geographic distribution and stratigraphic relations of these units indicate that they were deposited from successive ice sheets.

Deposits of younger Hiram ice are missing from all but the eastern and southeastern areas of the county. The youngest Woodfordian till in northeastern Ohio, the Ashtabula Till, was not found in Cuyahoga County. Late-glacial and postglacial deposits of sand, silt, and clay are widely distributed, though gravel is sparse at the surface.

GEOMORPHOLOGY OF THE GLACIAL DRIFT

Many topographic features owe their formation directly or indirectly to glaciation. The surface landforms are largely controlled by the character and thickness of the drift, by the form of the substrate on which the drift was deposited, and by the environment of deposition. In Cuyahoga County the drift is relatively thin; most of it was deposited directly by the ice. Drift that was deposited from glacial meltwaters is locally prominent. Each type of deposit shows a characteristic topographic form. Salient topographic features (see fig. 2) that are associated with the drift are outlined below.

GROUND MORAINE

Thin sheets of till were deposited on the Lake Plain and the Plateau in the form of ground moraine. Where the underlying bedrock surface is reasonably level, the topography on the ground moraine is smooth to gently rolling. Where the underlying bedrock surface has greater relief, as on the Escarpment and in the vicinity of resistant bedrock outliers on the Plateau, the till cover produces a masked erosional topography.

END MORAINE

End moraine forms at the stagnant margin of an ice sheet. The morphologic and stratigraphic characteristics of end moraines have been used in Ohio to determine their glacial history (Totten, 1969). The Defiance Moraine is a prominent end moraine that has been traced completely across Ohio (Cushing and others, 1931). In Cuyahoga County the Defiance Moraine forms a sinuous ridge of hummocky topography, mostly 1 to 2 miles wide, which extends from the vicinity of Chagrin Falls in the southeast across the Plateau to Brunswick Hills in the south. The moraine extends southeastward from the Plateau in pronounced loops as it descends into, crosses, and rises out of the valleys of the Chagrin, the Cuyahoga, and the East Branch Rocky Rivers (pl. 1). The Defiance Moraine rises to 1,200 feet or more in elevation on the Plateau but descends to 950 feet or less in the valleys. The drift in the end moraine is generally thicker than in the ground moraine. A gravelly morainic complex extends north from Summit County and is about 3 miles wide in the vicinity of Glenwillow. This complex tapers out over a distance of about 5 miles, north toward Warrensville Heights.

LAKE ESCARPMENT MORAINES

Linear ridges of hummocky topography mantled with till along the base of the Escarpment are referred to as lake escarpment moraines (White, 1982). The deposition of the escarpment moraines was controlled by this pronounced bedrock feature. In Cuyahoga County there are two such moraines. The Euclid Moraine extends into the county from the northeast for about 3 miles along the Escarpment south of Euclid. In this area it is about ½ mile wide. It terminates to the southwest, beyond Euclid Creek. The Brooklyn Moraine is a subdued feature about 4 miles long and up to ¾ mile wide that extends west-northwest along the base of the Escarpment in Brooklyn Heights. Both moraines are bounded on the north side by the 760-foot contour. The surface characteristics of each are now obscured by urban cover.

BEACH RIDGES

Following the Woodfordian glaciation, beach and dune ridges were deposited on the Lake Plain in northeastern Ohio when lake levels were considerably higher than at present. Former lake levels have been described by Leverett (*in* Cushing and others, 1931). More recent detailed studies of the chronology and nature of beach ridges, wave-cut terraces, and cliffs in northeastern Ohio reported by Totten (1985, and *in* White, 1982, p. 52-60) indicate that the cliffs are older than the beaches, which are ridges built on top of older terraces in front of the cliffs.

Prominent beach ridges rise above the Lake Plain west of the Cuyahoga River and extend westward into Lorain County. In ascending order of elevation they form parts of the Warren, Whittlesey, Maumee III, and Maumee I beach ridges (Totten, 1985). The Cuyahoga County segments of the beach ridges southward from the present lakeshore are: North Ridge-Warren beach; Center Ridge-Whittlesey beach; Chestnut Ridge-Maumee III beach; and Butternut Ridge-Maumee I beach. Totten's studies (1985) show that the beach ridges in Ohio south of Lake Erie are progressively older toward the south in the same direction that they increase in elevation.

In Lakewood the ridges are nearly parallel to the present shoreline, and set back from it ½ mile up to 3 miles. Toward the west the ridges diverge progressively southward. The ridges range from about 500 to 1,500 feet in width. Eastward on the Lake Plain in Cleveland and Euclid the beach ridges mapped by Leverett (*in* Cushing and others, 1931) are indistinguishable because of dense urban cover. Prominent cliffs cut in bedrock by the waters of former higher glacial lakes are well preserved for about 3 miles along North Ridge from Sperry Creek to Cahoon Creek (elevation about 660 to 680 feet), and along the base of the Escarpment for about 6 miles from East Cleveland to Euclid (elevation about 720 to 740 feet). Because the beach ridges are composed of sand, gravel, and rock fragments they are well drained. They have been used extensively for homesites, and roads follow their crests. The southern portion of the beach ridge whose crest is followed by Schaaf Road in Brooklyn Heights provides a sandy soil that is cultivated commercially. Swamps that were common in local areas on the south sides of the ridges are now mostly drained.

VALLEY TERRACES

Terraces are prominent on both sides of the Cuyahoga and the Chagrin River valleys. They are the erosional remnants of lacustrine and floodplain deposits that accumulated in the valleys during intervals of glacial ponding. The valley terraces are distinct from the wave-cut terraces and cliffs that mark former strandlines on the Lake Plain.

The terrace surfaces are level to gently sloping; the margins are steep and deeply dissected. Terrace surfaces in the Cuyahoga River valley are found at elevations of 680, 720, 760, and 800 feet. Many of the terrace surfaces exist only as narrow erosional remnants along the sides of the valley. The largest and best preserved areas are east of Brecksville (about 760 to 780 feet elevation) and at Valley View (about 720 feet elevation), where the terraces are over a mile in width. The terraces in the Chagrin River valley are mostly smaller. Surface levels are at elevations of about 800, 850, 910, and 950 feet (pl. 1). A small lacustrine terrace of silt and laminated silty clay about 20 feet thick with a surface elevation of about 850 feet is located in the valley of East Branch Rocky River, about 1 mile west of North

Royalton. Terraces are conspicuously absent from the valleys of the Rocky River and from its East and West Branches downstream from Berea and Olmsted Falls, respectively, and from the valleys of Euclid and Big Creeks.

KAMES

Kames are conical hills or mounds of poorly sorted sand and gravel. Kames form when meltwater deposits accumulate at the edges of or in crevasses in and along the melting ice. A few large kames rise 50 to 60 feet above the level of the surrounding upland east of Glenwillow, in the southeastern part of Cuyahoga County (pl. 1), where they give rise to a hummocky surface that forms part of a gravelly morainic complex. Depressions between the kames are poorly drained and swampy. The kames provide an economic source of sand and gravel.

NATURAL RESOURCES

ROCK AND MINERAL RESOURCES

The bedrock and the glacial drift in Cuyahoga County provide a variety of rock and mineral resources. Paleozoic shales and sandstones are a valuable source of building material which has been exploited economically for many years. Salt deposits are mined from Silurian rocks beneath Lake Erie. Small volumes of oil and gas are obtained from diverse producing horizons. Surficial deposits of glacial sand and gravel have been extensively worked. Relatively small volumes of peat and glacial clay have been produced in Cuyahoga County.

Exploitation of the different resources has fluctuated with their accessibility and with changing demand over the years. In recent years, shale and salt have accounted for the overwhelming majority of the rock and mineral production both by volume and by dollar value. Production statistics for Cuyahoga County are published annually by the Division of Geological Survey in the *Report on Ohio mineral industries*.

Shale

The Chagrin Shale Member, the Cleveland Shale Member, and the Bedford Shale provide the bulk of the raw material that is used by the clay industry in Cuyahoga County. The shale is obtained from quarries in the Cuyahoga River valley and along the base of the Escarpment in the Greater Cleveland area. The shale has been used for many years in the manufacture of various types of brick and tile ware. In recent years shale from the Chagrin Member has served almost exclusively for the production of lightweight aggregate. Bloated aggregate is produced by the Hydraulic Press Brick Co. at Independence. The production accounts for 10 to 15 percent of the output of clay products in Ohio.

Sandstone

Sandstone was formerly an important resource in Cuyahoga County. It was quarried in great abundance near the cities of Euclid and Berea. Production was from the Euclid Sandstone Member of the Bedford Shale, known locally as the Euclid bluestone, and from the Berea Sandstone.

Because it is thinly and evenly bedded, the Euclid bluestone was used chiefly for flagstones. It was also sawed for caps, sills, and steps. Considerable quantities were crushed for concrete. The Euclid Sandstone Member is currently mined for aggregate.

The Berea Sandstone is the great quarry rock of northern Ohio. Owing to considerable variability in its lithologic character, it has had a wide range of uses as dimension stone, in construction, and notably for the manufacture of grindstones. More grindstones have been produced from Berea than from any other place in the United States.

Most of the sandstone quarries have been depleted and abandoned, and the output of sandstone has dropped to negligible proportions in recent years. Many disused quarries contain water and are used for fishing and swimming.

Salt

Salt was discovered in Cleveland in 1886 in the course of drilling for natural gas. The salt deposits are interbedded with dolostone, anhydrite, and shale of the Salina Group (Upper Silurian). Production by solution mining was initiated in 1889. In 1962 the International Salt Co. opened the Cleveland Mine at Whiskey Island. The salt is mined by the room-and-pillar method from strata 18 to 22 feet thick at a depth around 1,760 feet (Heimlich and others, 1974). Much of the production is used for snow and ice control; lesser quantities serve for industrial and agricultural uses.

Oil and gas

Relatively small volumes of oil and gas have been produced over the years by independent operators. Historically there has been production from the "Newburg" zone (Silurian) in the Cleveland area, and from the Devonian shales. The Devonian shale-gas wells were relatively widespread but produced only domestic supplies. Numerous gas wells in the "Clinton" sand (Silurian) have been productive in the area from Lakewood southward to Brook Park and Berea. Current production is primarily from the "Clinton."

Sand and gravel

Water-sorted deposits of Pleistocene sand and gravel are found in stream terraces along the Cuyahoga and the Chagrin River valleys, in beach ridges along the Lake Plain, and in kames on the Plateau. Favorable deposits in these areas have been commercially exploited for many years. Thicker and more extensive deposits in Cleveland and elsewhere on the Lake Plain, however, are inaccessible owing to their location beneath industrial or residential property.

Sand and gravel of good quality have been obtained from pits in the Mill Creek valley near Garfield Heights. Pits in the stream terraces have produced an abundance of fine sand suitable for mortar work and for fill, but no gravel. Many of the pits are exhausted and have been abandoned. Disused gravel pits can be developed as a habitat for wildlife or as recreational areas. Some pits have been used for sanitary landfills, although this is not a recommended practice.

Deposits of sand and gravel in the beach ridges have been worked locally, as at the junction of Schaaf Road and Ohio Route 21, but the quality of the material in the beach ridges is generally so poor that it has little economic value. Current production of sand and gravel is less than one-tenth of the output in former years. Most comes from a kame deposit in the Glenwillow subdivision south of Solon.

Peat

Undrained depressions on the Lake Plain and at the foot of the Escarpment locally contain peat in association with organic-rich muck. The peat has been worked commercially for use as potting soil and mulch. Production has declined with the depletion of this resource.

WATER RESOURCES

Lake Erie forms the major source of water for public, domestic, and industrial use. Supplies have also been obtained from the Cuyahoga and Rocky Rivers, and from wells in the drift and in the bedrock. The city of Berea has developed a water-reservoir system in the former Berea Sandstone quarries (Winslow and others, 1953). The availability of ground water varies considerably.

The most promising area for ground water is along the Mill Creek valley between Garfield Heights and Maple Heights. Test wells show that permeable sand and gravel at shallow depths in this area may yield up to 1,500 gallons of water per minute (Crowell, 1979). Other good areas for ground water lie along segments of the buried Cuyahoga River valley, and on the Plateau from Bedford Heights southeast for about 3 miles. Permeable sand and gravel interbedded with silt and clay in the buried Cuyahoga River valley between Newburgh Heights and Cleveland may yield as much as 250 gallons per minute from depths up to 180 feet. Exploratory drilling may be required to outline the limits of such deposits.

Yields from 10 to about 25 gallons per minute are obtainable from shallow bedrock wells in the Berea Sandstone in Olmsted Township and the area between Middleburg Heights and Parma, and from the Sharon conglomerate in areas south and east of Strongsville and North Royalton and between Warrensville Heights and Solon.

Large portions of the Lake Plain and the Escarpment and some areas of the Plateau are covered with impermeable clays overlying shale or shaly sandstone. Such areas are very poor for developing even minimal domestic supplies of ground water. Brackish to salty ground water is encountered in wells south of Berea.

RECREATIONAL RESOURCES

The scenic attraction of the major valleys combined with their unsuitability for urban, industrial, or agricultural uses provides large areas that are well suited for recreational purposes. Over the years the Cleveland Metropolitan Park District has obtained over 17,500 acres of parks along the slopes and floodplains of the Rocky, Cuyahoga, and Chagrin River valleys, in the Euclid Creek valley, and on the Lake Plain in the Bradley Woods and at Bay Village. These areas have been developed for recreational purposes and have been described as an "emerald necklace" that surrounds the Cleveland metropolitan area. The parks provide hiking trails, bridle paths, stables, playfields, picnic areas, and shelters for year-round public use and are within easy access of the densely populated urban areas.

In 1974 the U.S. Congress created the Cuyahoga Valley National Recreation Area as an urban park in the National Park System. The area extends south from Rockside Road along the Cuyahoga River valley into Summit County as far as Akron. In Cuyahoga County it includes the great forests and deep ravines of Cleveland's Bedford and Brecksville Reservations and the deep gorge of Tinkers Creek, which was designated several years ago by the National Park Service as a National Natural Landmark. The overall concept in the management and development of the Cuyahoga Valley National Recreation Area is one of resource preservation. The area is intended for recreational uses that will be compatible with the natural environment.

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APPENDIX A.—MEASURED SECTIONS, CUYAHOGA COUNTY

All sections were measured and sampled in 1974. Color descriptions were made from wet samples. Standard Munsell Color Code designations of hue and chroma are included. Numbers assigned to measured sections correspond to locations on figure 2.

Appalachian Plateau localities:
1. Roxbury School
2. Sprague Road
3. Miles Road
4. South Miles Road
5. Brecksville Interchange
6. Sunny Acres Sanatorium
7. Calvary Cemetery Lake

Valley localities:
8. Old Rockside
9. Sterner gravel pit
10. South Chagrin Reservation

Escarpment locality:
11. Baldwin Creek

Lake Plain localities:
12. Bay Village
13. Fulton Parkway bridge
14. Brookside Park
15. Lake Shore Boulevard
16. Moss Point
17. Brooklyn Heights (partly a Valley locality)

1. ROXBURY SCHOOL SECTION (Twinsburg 7½-minute quadrangle):

Measured and sampled up excavated drainage ditch east of Roxbury School in Solon. Base of section east of SOM Center Road (Ohio Rte. 91), about 0.15 mile north of junction of SOM Center Road and Arthur Road. Base elevation estimated at 1022 feet ± 3 feet.

Quaternary System Pleistocene Series Wisconsinan Stage Woodfordian Substage or younger	Thickness (feet)
Unnamed silt, sand, and gravel	
Silt, medium-gray, clayey, orange mottles; contains solum	2.2
Sand and gravel	0.8
Silt, yellowish-gray, orange, and medium-gray; streaks near top	2.1
Sand, yellowish-gray, coarse	0.6
Woodfordian Substage Hiram? Till	
Till, medium- to dark-gray (10YR 5/1), oxidized brown, calcareous; breaks into small prisms; scarce pebbles. Sample 1 from base	2.4
Total Pleistocene and total section	8.1

2. SPRAGUE ROAD SECTION (Broadview Heights 7½-minute quadrangle):

Measured and sampled up highway cut on north side of westward extension to Sprague Road. Base of section at curbside, about 425 feet west of State Road (Ohio Rte. 94). Base elevation estimated at 1070 feet ± 10 feet.

Quaternary System Pleistocene Series Wisconsinan Stage Woodfordian Substage	Thickness (feet)
Unnamed clay	
Clay, yellowish-gray	1.2
Clay, yellowish-gray, with orange mottles	1.4
Lavery Till III	
Till, brown (10YR 5/3), silty to clayey, noncalcareous, crumbly; a few pebbles and stones up to ½ inch diameter	1.6
Till, brown to gray-brown (10YR 5/3 to 10YR 5/2), silty, oxidized, strongly calcareous, crumbly. Sample 4 from base, sample 5 from mid-unit, sample 6 from top	9.5
Till, dark-gray (10YR 4/1), fresh, silty and sticky, calcareous; joints highly inclined, oxidized about ½ inch on each side of joint surfaces. Sample 1 from base, sample 2 from mid-unit, sample 3 from top	9.4
Unnamed sand	
Sand, yellowish-gray; some pebbles and clay; numerous ½-inch gypsum crystals	2.1
Covered interval	3.1
Total Pleistocene and total section	28.3

3. MILES ROAD SECTION (Shaker Heights 7½-minute quadrangle):

Measured and sampled from stream level up northwest-facing bluff on Mill Creek, about midway between the Erie-Lackawanna RR track and Miles Road. Base elevation estimated at 970 feet ± 5 feet.

Quaternary System Pleistocene Series Wisconsinan Stage Woodfordian Substage	Thickness (feet)
Lavery Till III	
Till, brown (10YR 5/3), silty, calcareous; orange mottles and medium-gray streaks in leached upper 4 feet, small prismatic partings in lower 3 feet. Sample 5 from 2 feet above base, sample 6 from 5 feet above base	7.0
Unnamed sand	
Sand, olive-brown, passing laterally to gravel; coarse texture	0.9
Kent Till II	
Till, dark-gray (5Y 4/1), silty to clayey; olive gray and noncalcareous in upper 1 foot; contains black shale pebbles; blocky parting. Sample 3 from 3 feet above base, sample 4 from 11 feet above base	17.0
Kent Till I	
Till, dark-gray (5Y 4/1), sandy, very slightly calcareous; contains black shale pebbles; parts in vertical plates and blocks. Sample 1 from 10 feet above base, sample 2 from top	15.0
Total Pleistocene section	39.9
Mississippian System Cuyahoga Formation (bedrock unit III)	
Shale, dark-gray; oxidized dark brown; rotten and yellowish gray in upper 3 feet, with ½-inch orange-brown clay zone at top	5.0
Total section	44.9

4. SOUTH MILES ROAD SECTION (Shaker Heights 7½-minute quadrangle):

Measured and sampled from stream level up west-facing bluff on Mill Creek, about $^2/_3$ of the way toward Erie-Lackawanna RR track from South Miles Road. Base elevation estimated at 965 feet ± 5 feet.

Quaternary System Pleistocene Series Wisconsinan Stage Woodfordian Substage	Thickness (feet)
Lavery Till III	
Till, gray-brown (10YR 5/2), silty, sticky; platy parting; very calcareous except in upper 4 feet, where it is oxidized to a brown color; contains solum. Sample 4 from base, sample 5 from 4 feet above base, sample 6 from 7 feet above base	12.0
Unnamed sand and gravel	
Sand and gravel, brown; percolation of ground water results in many slumps along this exposure	2.2
Kent Till I	
Till, dark-gray-brown (2.5Y 4/2) in upper 2 feet, becoming medium to dark gray below, chunky, sandy, very slightly calcareous; contains numerous large stones; oxidation stains extend about ½ inch on each side of nearly vertical joint surfaces. Sample 1 from 3 feet above base, sample 2 from 8 feet above base, sample 3 from 18 feet above base	22.0
Total Pleistocene and total section	36.2

5. BRECKSVILLE INTERCHANGE SECTION (Broadview Heights 7½-minute quadrangle):

Measured and sampled up the side of a stripped hill about 350 feet south of the junction of Ohio Rte. 82 with the terminus of Old Royalton Road, and about 1,600 feet due east of I-77. Base elevation estimated at 950 feet ± 10 feet.

Quaternary System Pleistocene Series Wisconsinan Stage Woodfordian Substage	Thickness (feet)
Lavery Till II	
Till, grayish-brown (10YR 5/2), silty and sticky, entirely oxidized, slightly calcareous; platy to prismatic parting; contains small stones and pebbles; contains solum at top, where there are light-gray vertical streaks and orange-brown mottles in upper 2 feet. Sample 4 from base, sample 5 from mid-unit, sample 6 from near top, within solum	17.0
Unnamed clay and sand	
Clay, brown (10YR 5/3), silty; fine sand toward top	4.2
Sand, light-olive-brown, gravel, and boulders; some layers of silt and sand and exotic blocks of underlying till	6.8
Altonian Substage	
Mogadore Till	
Till, light-olive-brown (2.5Y 5/4), sandy, crumbly, tough, very slightly calcareous, oxidized. Sample 3 from mid-unit	0.5
Till, dark-gray (5Y 4/1 to 10YR 4/1), sandy, blocky, tough, crumbly, slightly calcareous; oxidized yellowish brown adjacent to nearly vertical joint surfaces; oxidized portions stand out owing to greater resistance to erosion. Sample 1 from base, sample 2 from 4 feet above base	7.8
Total Pleistocene section	36.3
Covered interval	2.5
Mississippian System	
Cuyahoga Formation (bedrock unit III)	
Shale, light-gray, yellowish-gray mottles, decomposed	2.0
Sandstone, medium-gray, stained brown, fossiliferous	1.0
Shale, dark-gray, stained brown, platy	10.0
Total section	51.8

6. SUNNY ACRES SANATORIUM SECTION (Shaker Heights 7½-minute quadrangle):

Measured and sampled up stripped slope between Sunny Acres Sanatorium and I-271. Base of section about 1,000 feet south of Sunny Acres Sanatorium. Base elevation estimated 1175 feet ± 10 feet.

Quaternary System Pleistocene Series Wisconsinan Stage Woodfordian Substage	Thickness (feet)
Lavery Till II	
Till, gray-brown (10YR 5/2), silty, sticky, calcareous; oxidation staining adjacent to joint surfaces; contains solum; leached 2 feet. Sample 3 from base, sample 4 from 5 feet above base, sample 5 from 12 feet above base	15.0
Unnamed sand and gravel	
Sand, brownish, gravel, and boulders; many sandstone boulders, some greenstone and plutonic boulders	1.1
Kent Till II	
Till, gray (5Y 4/1), sandy, very slightly calcareous, blocky, tough. Sample 1 from base, sample 2 from top	3.7
Total Pleistocene section	19.8
Mississippian System	
Cuyahoga Formation (bedrock unit III)	
Sandstone, pale-yellowish-gray	0.5
Total section	20.3

7. CALVARY CEMETERY LAKE SECTION (Shaker Heights 7½-minute quadrangle):

Measured and sampled up north-facing cliff at extreme southeast corner of Calvary Cemetery Lake. Base of section about 0.1 mile west of East 131st Street and 0.15 mile north of Broadway. Base elevation estimated at 815 feet ± 5 feet.

Quaternary System Pleistocene Series Wisconsinan Stage Woodfordian Substage	Thickness (feet)
Lavery Till II	
Till, dark-gray to gray-brown (10YR 4/1 to 10YR 5/2), silty to sandy, cohesive, calcareous; blocky parting; fresh only in lower 0.5 to 1.0 foot above base, oxidized brown upward to top. Sample 4 from base, sample 5 from 4 feet above base, sample 6 from 8 feet above base	8.4
Pro-Kent? silt	
Silt, gray (5Y 5/1), clayey, laminated, cohesive, sticky, calcareous; gray brown in lower 0.5 foot, sand in lowermost 0.1 foot, oxidized olive gray in upper 3 feet where it is more fine silty. Sample 1 from base, sample 2 from 15 feet above base, sample 3 from top. Possible correlative of pro-Kent varved silt and clay of White (1968) in pit ⅔ mile southwest	29.6
Illinoian? Stage	
Unnamed sand and gravel	
Gravel and boulders, coarse; upper contact rises eastward toward valley side	6.6
Sand, gravel, and boulders; contact rises eastward toward valley side; descends westward toward valley center. Possible correlative of Illinoian gravel of White (1968) in pit ⅔ mile southwest	19.2
Total Pleistocene and total section	63.8

8. OLD ROCKSIDE SECTION (Cleveland South 7½-minute quadrangle):

Measured and sampled up stripped slope of Cuyahoga River valley. Base of section about 2,000 feet east of Brecksville Road

(Ohio Rte. 21), 900 feet south of Rockside Road, 300 feet west of a pylon that carries a north-south high-voltage line. Base elevation estimated at 628 feet ± 5 feet.

	Thickness (feet)
Quaternary System	
Pleistocene Series	
Wisconsinan Stage	
Woodfordian Substage or younger	
Unnamed clay, silt, and sand	
Clay, yellowish-gray, silty; small chunky parting; contains solum at top. Sample 12 from base	8.0
Sand, coarse; pebbles abundant; dark-gray shale fragments; layers of silty orange-brown clay irregularly interbedded with sand	16.0
Clay, medium-gray, silty, oxidized yellowish gray in upper 0.5 foot, very calcareous; platy parting. Sample 11 from mid-unit	2.4
Sand, yellowish-brown, silty, calcareous; broken into thin plates on top resembling desiccated mud peels	0.4
Sand, orange-brown, coarse	0.2
Sand, medium- to dark-gray, silty to clayey, cohesive, calcareous; yellowish gray to yellowish brown in upper 1 foot; forms steep slope. Sample 9 from base, sample 10 from top	21.5
Clay, dark-gray-brown, silty, cohesive, calcareous; contains fine sand; finely laminated in upper third. Sample 7 from base, sample 8 from top	20.0
Woodfordian Substage	
Lavery Till III	
Till, dark-gray (5Y 4/1), with slightly brownish hue, silty to clayey, sticky; more plastic and more calcareous than till below; abundant shale pebbles; numerous near-vertical joints penetrate till, which is oxidized about ½ inch on each side of joint surfaces; traces of joint surfaces from 0.5 to 1.5 foot apart evident at top. Sample 4 from base, sample 5 from mid-unit, sample 6 from top	24.3
Lavery Till II	
Till, dark-gray (5Y 4/1), silty, slightly calcareous, cohesive; chunky parting; many black stones and pebbles. Sample 1 from base, sample 2 from mid-unit, sample 3 from top	5.2
Unnamed clay	
Clay, brown-gray, silty, calcareous, cohesive, finely laminated; slabby to chunky parting	4.4
Unnamed boulder pavement	
Boulders, up to 3 feet in diameter, surrounded by clay; rock types include dolomite, striated sandstone, gneiss, conglomeratic quartzite, and greenstone	3.0
Total Pleistocene section	105.4
Devonian and Mississippian Systems	
Shale, undifferentiated (bedrock unit I)	
Shale, medium-gray to green-gray, platy, thick-bedded, massive; sandy toward top; stained yellowish gray; irregular interbeds up to 1 inch thick of siltstone stained dark brown; probably Chagrin Shale Member of Ohio Shale	12.0
Total section	117.4

9. STERNER GRAVEL PIT SECTION (Northfield 7½-minute quadrangle):

Measured and sampled up north-facing cut in pit, about 400 feet south of Snowville Road and about 1,000 feet southwest of junction of Snowville Road and Riverview Road. Base elevation estimated at 700 feet ± 15 feet.

	Thickness (feet)
Quaternary System	
Pleistocene Series	
Wisconsinan Stage	
Woodfordian Substage or younger	
Unnamed clay	
Clay, brown (10YR 4/3), silty, calcareous except in upper 1 foot. Sample 10 from base, sample 11 from mid-unit, sample 12 from top	6.4
Woodfordian Substage	
Hiram Till	
Till, brown (10YR 4/3), clayey, calcareous; few stones and small pebbles; sporadic thin clay layers. Sample 8 from base, sample 9 from top	10.0
Lavery Till III	
Till, dark-gray (10YR 4/1), oxidized gray brown (10YR 5/3) in upper 5 feet, silty to clayey, calcareous; chunky parting; cut by numerous near-vertical joints and oxidized up to 1 inch on each side of joint surfaces. Sample 3 from base, sample 4 from 6 feet above base, sample 5 from 12 feet above base, sample 6 from 18 feet above base, sample 7 from 24 feet above base	25.8
Unnamed clay and sand	
Clay, dark-gray (10YR 4/1), silty; local light-gray silt laminations about 6 feet above base, laminations about ¼ inch thick; locally contorted bedding microstructure; local gray-brown sand pod at top. Sample 1 from 5 feet above base, sample 2 from 15 feet above base	18.0
Clay, olive-brown (2.5Y 4/4), silty, locally laminated	4.0
Sand, yellowish-gray, coarse, crossbedded in lower 12 feet; irregular contact with overlying fine, powdery yellowish-brown sand	44.0
Total Pleistocene and total section	108.2

10. SOUTH CHAGRIN RESERVATION SECTION (Chagrin Falls 7½-minute quadrangle):

Measured and sampled up west-facing valley slope of tributary to Chagrin River, north of and below level of Bedford-Chagrin Parkway, about 600 feet west of Arbor Lane, and about 0.6 mile due west of Aurora Branch. Base of section at stream level. Base elevation estimated at 955 feet ± 10 feet.

	Thickness (feet)
Quaternary System	
Pleistocene Series	
Wisconsinan Stage	
Woodfordian Substage or older	
Unnamed clay, sand, and gravel	
Clay, olive-brown, sticky, cohesive to top, where section is covered by slump	2.0
Boulders, gravel, and sand; stratigraphic correlation uncertain	3.0
Altonian Substage	
Mogadore Till	
Till, gray (5Y 4/1), sandy, crumbly, calcareous; contains irregular localized lenses of oxidized sand and gravel. Sample 3 from mid-unit	2.9
Sand and silt, oxidized yellowish gray, boulders, gravel	1.8
Till, gray (5Y 4/1), sandy, crumbly, calcareous, very stony; contains localized lenses of oxidized sand. Sample 1 from 2 feet above base, sample 2 from 8 feet above base	11.0
Total Pleistocene and total section	20.7

11. BALDWIN CREEK SECTION (Berea 7½-minute quadrangle):

Measured and sampled up northeast-facing stream bank of Baldwin Creek. Base of section in creek southwest of Big Creek Parkway bridge, between bridge abutment and pipeline crossing, at bend of stream. Base elevation estimated at 790 feet.

	Thickness (feet)
Quaternary System	
Pleistocene Series	
Wisconsinan Stage	
Woodfordian Substage	

Lavery Till III	
Till, dark-gray (10YR 4/1), oxidized brown (10YR 5/3) in upper 3 feet, silty, stony, very calcareous; platy parting; jointed, joints highly inclined; oxidation on each side of some joint surfaces; blocky parting where oxidized. Sample 4 from base, sample 5 from 2 feet above base, sample 6 from 4 feet above base	6.0-5.0
Unnamed sand	
Sand and gravel, up to 1 foot thick at northwest end of outcrop, missing at southeast end	0.0-1.0
Kent Till II	
Till, olive-gray (5Y 4/2), silty to clayey, stony; platy parting; several prominent black shale pieces; joints pass into this unit from till above; some joint margins oxidized yellowish brown, others not; unit is a massive till block about 14 feet long, bounded by water level at base, surrounded by upper till unit; sharp contact noted from color difference. Sample 1 from base, sample 2 from 2 feet above base, sample 3 from top	4.0
Total Pleistocene and total section	10.0

12. BAY VILLAGE SECTION (Lakewood 7½-minute quadrangle):

Measured and sampled up north side of I-90 road cut, from drainage ditch to top of cut slope, on east side of stream and about 500 feet east of Bates Road. Base elevation estimated at 615 feet ± 5 feet.

Quaternary System Pleistocene Series Wisconsinan Stage Woodfordian Substage or younger	Thickness (feet)
Unnamed sand	
Sand, yellowish-brown; fine to medium texture; soil developed in upper 3-5 feet	8.0
Woodfordian Substage	
Lavery Till III	
Till, gray-brown (10YR 5/2), silty to clayey, compact, stony, very calcareous; till/bedrock contact exposed along highway cut is a very irregular surface with up to 10 feet of relief. Sample 1 from base, sample 2 from 2.5 feet above base, sample 3 from 5 feet above base, sample 4 from 7.5 feet above base, sample 5 from top	10.0
Total Pleistocene section	18.0
Devonian-Mississippian Systems	
Shale, undifferentiated (bedrock unit I)	
Shale, medium- to dark-gray, crumbly; some very thin sandstone near top; shale grades upward to olive gray in upper 2 feet; locally overlain by thin-bedded black shale that probably marks contact between Chagrin and Cleveland Members of Ohio Shale	7.0
Total section	25.0

13. FULTON PARKWAY BRIDGE SECTION (Cleveland South 7½-minute quadrangle):

Measured and sampled up steep slope beneath north end of Fulton Parkway bridge across Big Creek. Base of section by park road beneath bridge. Base elevation estimated at 665 feet ± 10 feet.

Quaternary System Pleistocene Series Wisconsinan Stage Woodfordian Substage or younger	Thickness (feet)
Unnamed clay, silt, sand, and gravel	
Clay, yellowish-gray, slightly silty, with laminated orange-brown layers; overlain by manmade rubbish beneath bridge. Sample 5 from base, sample 6 from top	4.5
Silt, brownish-gray, compact, organic; humus residue concentrated toward top. Sample 2 from top	1.0
Sand and gravel, dark-brown, coarse, with many shingled shale fragments	1.3
Woodfordian Substage	
Lavery Till II	
Till, pale gray when dry, dark gray (10YR 4/1) when wet, silty to sandy, calcareous; blocky parting; numerous vertical partings. Sample 3 from base, sample 1 from mid-unit, sample 4 from top	7.4
Total Pleistocene section	14.2
Devonian-Mississippian Systems	
Shale, undifferentiated (bedrock unit I)	
Shale, medium-gray; 0.6-foot-thick soft, crumbly sandstone ledge at top; probably Chagrin Member of Ohio Shale	21.4
Total section	35.6

14. BROOKSIDE PARK SECTION (Cleveland South 7½-minute quadrangle):

Measured and sampled up east end of north-facing slope in Brookside Park. Base of section at foot of slope, south of park road and east of baseball diamonds. Base elevation estimated at 645 feet ± 10 feet.

Quaternary System Pleistocene Series Wisconsinan Stage Woodfordian Substage or younger	Thickness (feet)
Unnamed sand	
Sand, dark-brown, clayey	5.0
Woodfordian Substage	
Lavery Till III	
Till, dark-gray (10YR 4/1), grading upward to dark gray brown (10YR 5/3), silty, calcareous except in upper 1.0 foot; chunky parting; large boulders near base. Sample 2 from base, sample 3 from 1 foot below top	7.8
Total Pleistocene section	12.8
Devonian-Mississippian Systems	
Shale, undifferentiated (bedrock unit I)	
Shale, black, thin-bedded, platy; probably Cleveland Member of Ohio Shale	8.7
Shale, medium-gray; interbedded with ledge-forming sandstone beds up to 4 inches thick; brown-stained surfaces; probably Chagrin Member of Ohio Shale	14.0
Shale, medium-gray, soft; brown-stained surfaces. Sample 1 from top	44.7
Total section	80.2

15. LAKE SHORE BOULEVARD SECTION (East Cleveland 7½-minute quadrangle):

Measured and sampled up south-facing slope of creek bank on south side of Lake Shore Boulevard, 0.18 mile southwest of Ninemile Creek. Base elevation estimated at 585 feet ± 5 feet.

Quaternary System Pleistocene Series Wisconsinan Stage Woodfordian Substage or younger	Thickness (feet)
Unnamed sand	
Sand, yellowish-brown, coarse-grained	5.0
Sand, with coarse gravel at base	0.6
Woodfordian Substage	
Lavery Till II	
Till, dark-gray (10YR 4/1), silty to clayey, calcareous; blocky parting; stones coarser than till layers below. Sample 5 from base, sample 6 from top	2.8

Sand, yellowish-gray, fine	0.1
Till, gray-brown (10YR 4/2), clayey to silty, sticky, calcareous, cohesive; blocky parting; small stones. Sample 4 from mid-unit	1.4
Sand, yellowish-gray, fine	0.1
Till, medium- to dark-gray (10YR 4/1), silty, calcareous; chunky parting; small pebbles and few stones. Sample 3 from mid-unit	1.2
Silt, dark-gray to gray-brown, calcareous; gray-brown oxidation stains along widely spaced parting surfaces and in upper 0.2 foot	1.4
Till, medium- to dark-gray (10YR 4/1), silty to clayey, very calcareous, cohesive; very few small pebbles. Sample 1 from 2 feet above base, sample 2 from top	4.0
Total Pleistocene and total section	16.6

16. MOSS POINT SECTION (East Cleveland 7½-minute quadrangle):

Measured and sampled up north-facing bluff along Lake Erie shore at Moss Point. Base of section at lake level on lakeshore at Kenneth J. Sims Park, Euclid, east of Cultural Gardens Apartments. Base elevation is mean lake level, 571 feet.

Quaternary System Pleistocene Series Wisconsinan Stage Woodfordian Substage or younger	Thickness (feet)
Unnamed sand	
Sand, yellowish-gray, very fine; orange and gray mottles in upper 3 feet, which contains solum	6.0
Woodfordian Substage	
Lavery Till II	
Till, medium- to dark-gray with brownish tinge (10YR 4/2), very clayey, calcareous, cohesive; many fewer stones than till below; numerous lenses with abundant pebbles, others with few pebbles; local sand and gravel pods 1.5 feet thick and 6 feet across; strongly jointed, oxidized staining in till up to ½ inch on each side of joints; blocky parting in upper 5 feet. Sample 3 from base, sample 4 from 4 feet above base, sample 5 from 8 feet above base, sample 6 from 12 feet above base	16.0
Lavery Till I	
Till, medium- to dark-gray (10YR 4/1), silty, very calcareous; very abundant stones; many flaggy sandstone and shale fragments; cut by near-vertical joints that pass upward through overlying drift. Sample 1 from base, sample 2 from just below top	2.0
Total Pleistocene section	24.0
Devonian and Mississippian Systems	
Shale, undifferentiated (bedrock unit 1)	
Shale, dark-gray, platy; vertical joints; probably Chagrin Member of Ohio Shale	4.0
Total section	28.0

17. BROOKLYN HEIGHTS SECTION (Cleveland South 7½-minute quadrangle):

Measured and sampled up east-northeast-facing stripped terrace slope in Cuyahoga River valley. Base of section in cut terrace slope 5 feet above level of road pavement at 1000 Valley Belt Road, about 0.2 mile north of Granger Road at Schaaf Road. Base elevation estimated at 610 feet ± 5 feet.

Quaternary System Pleistocene Series Probably Wisconsinan Stage	Thickness (feet)
Unnamed sand, clay, and gravel in terrace	
Sand, brown, fine; covered by slump, verified by excavation	25.0
Clay, gray-brown, silty, very calcareous; yellowish gray in basal 0.3 foot, oxidized yellowish gray in upper 12 feet. Sample 6 from base, sample 7 from mid-unit, sample 8 from top	26.0
Sand, pale-gray, coarse, crossbedded, oxidized yellowish brown; locally orange brown in upper 16 feet; contains gravel	24.8
Sand, medium-gray, fine; coarser than in unit below; laminated in upper 15 feet. Sample 4 from base, sample 5 from top	24.0
Clay, dark-gray, slightly silty, calcareous; laminated with fine dark-olive-gray sand; clay and sand laminae of variable thickness, commonly less than 1 inch; localized 10-foot-thick lens of orange-brown sand and gravel along the clay slope for about ¼ mile. Sample 1 from base of clay, sample 2 from 15 feet above base, sample 3 from 30 feet above base	40.0
Total Pleistocene and total section	139.8

APPENDIX B.—TEXTURE AND COMPOSITION OF TILL SAMPLES FROM CUYAHOGA COUNTY

Measured section or field locality	Thickness (ft)	No. of samples	Average grain-size distribution in the <2 mm fraction (%)			Average clay mineral composition in the $<2\mu$ fraction (%)			Average no. of carbonate counts/sec in the $<2\mu$ fraction		Average carbonate % in the $<74\mu$ fraction	
			Sand (<2> 0.074 mm)	Silt (<0.074> 0.0039 mm)	Clay (<0.0039 mm)	Expandable clay minerals	Illite	Chlorite and kaolinite	Calcite	Dolomite	Calcite	Dolomite
HIRAM TILL—Plateau localities												
Between Bentleyville & Solon in subdivision east of Liberty Rd.	1.0	1	9	45	46	1	78	21	17	8	3	4
Between Bentleyville & Solon in subdivision east of Liberty Rd.	4.0	1	9	51	40						3	3
Ursuline Academy, Pepper Pike	1.0	1	13	56	31	3	73	24	44	14	5	6
Roxbury School section	2.4	1	12	58	30	2	75	23	19	16	3	4
HIRAM TILL—Valley locality												
Sterner gravel pit section	10.0	2	4	48	48	2	80	18	31	14	4	6
LAVERY TILL III—Plateau localities												
Sprague Rd. section	20.5	6	13	43	44	3	77	20	50	23	6	7
Miles Rd. section	7.0	2	15	45	40	6	85	9	57	11	5	6
South Miles Rd. section	12.0	3	11	38	51	3	78	19	80	16	12	8
LAVERY TILL III—Valley localities												
Old Rockside section	24.3	2	10	43	47	3	73	24	38	15	6	7
Sterner gravel pit section	25.8	5	9	47	44	2	77	21	37	18	6	6
LAVERY TILL III—Lake Plain localities												
Bay Village section	10.0	5	10	40	50	3	81	16	27	14	5	7
Eastland Rd. south of Sheldon Rd.	8.0	3	17	38	45	3	75	22	102	25	7	8
Excavation of I-90 west of Wagar Rd.	5.0	1	12	40	48	2	75	23	40	25	5	10
Brookside Park section	7.8	2	12	40	48	1	79	20	19	19	2	6
Ridge Rd.-Woodhaven Ave. intersection	5.0	1	14	41	45	2	76	22	69	16	8	7
LAVERY TILL III—Escarpment locality												
Baldwin Creek section	6.0	3	12	41	47	3	73	24	66	20	7	17
LAVERY TILL II—Plateau localities												
Brecksville Interchange section	17.0	3	10	59	31	2	78	20	13	14	6	3
Sunny Acres Sanatorium section	15.0	2	24	44	32	3	73	24	75	25	8	13
Calvary Cemetery Lake section	8.4	3	17	48	35	1	72	27	30	20	5	5
Northfield Rd. at Mill Creek	15.0	3	17	49	34	3	73	24	44	15	5	6
Former Randall Racetrack	31.0	1	18	45	37	3	73	24	65	12	6	6
Pettibone Rd. at Broadway Ave.	8.0	1	16	51	33	2	76	22	50	29	12	10
LAVERY TILL II—Valley locality												
Old Rockside section	5.2	4	9	53	38	1	77	22	16	11	3	5
LAVERY TILL II—Lake Plain localities												
Fulton Parkway bridge section	7.4	3	12	50	38	2	80	18	22	9	3	6
Lakeshore 1.6 miles west of mouth of Rocky River	10.0	2	12	52	36	1	80	19	33	17	4	6
Lake Shore Blvd. section	11.0	6	9	56	35	2	77	21	14	10	3	7
Moss Point section	16.0	4	6	58	36	3	75	22	17	14	4	7

APPENDIX B.—TEXTURE AND COMPOSITION OF TILL SAMPLES FROM CUYAHOGA COUNTY (continued)

Measured section or field locality	Thickness (ft)	No. of samples	Average grain-size distribution in the <2 mm fraction (%)			Average clay mineral composition in the $<2\mu$ fraction (%)			Average no. of carbonate counts/sec in the $<2\mu$ fraction		Average carbonate % in the $<74\mu$ fraction	
			Sand (<2> 0.074 mm)	Silt (<0.074> 0.0039 mm)	Clay (<0.0039 mm)	Expandable clay minerals	Illite	Chlorite and kaolinite	Calcite	Dolomite	Calcite	Dolomite
LAVERY TILL I—Lake Plain localities												
Moss Point section	2.0	2	25	48	27	1	76	23	15	10	3	8
Lake bluff west of Euclid Hospital	4.0	1	20	51	29	1	80	19	16	20	4	7
East of Great Northern Mall	5.0	2	18	54	28	1	79	20	14	14	2	5
		1	27	49	24	1	80	19	12	12	2	5
KENT TILL II—Plateau localities												
Sunny Acres Sanatorium section	3.7	2	17	49	34	2	76	22	12	13	1	2
Dalebridge Rd. south of Emery Rd.	4.0	2	17	49	34	2	77	21			1	2
Miles Rd. section	17.0	2	19	50	31	2	77	21	7	13	2	5
KENT TILL II—Escarpment locality												
Baldwin Creek section	4.0	3	17	53	30	2	78	20			1	3
KENT TILL I—Plateau localities												
Miles Rd. section	15.0	2	27	47	26	2	76	22	20	15	3	5
South Miles Rd. section	22.0	3	26	47	27	2	77	21			1	3
North of Drake Rd. between Pearl & Howe Rds.	6.0	1	16	62	22	1	79	20		40	1	3
KENT TILL I—Valley locality												
Between Bentleyville & Solon in subdivision east of Liberty Rd.	0.7	1	23	51	26	2	73	25	15	?	0	2
MOGADORE TILL—Plateau locality												
Brecksville Interchange section	8.3	3	38	44	18	2	69	29	21	16	2	4
MOGADORE TILL—Valley locality												
South Chagrin Reservation section	15.7	3	39	44	17	2	70	28	16	12	2	5

STATE OF OHIO
Richard F. Celeste, Governor
DEPARTMENT OF NATURAL RESOURCES
Joseph J. Sommer, Director
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

GLACIAL AND SURFICIAL GEOLOGY OF CUYAHOGA COUNTY, OHIO

by John P. Ford

1987

DIVISION OF GEOLOGICAL SURVEY
REPORT OF INVESTIGATIONS NO. 134
GLACIAL AND SURFICIAL GEOLOGY OF CUYAHOGA COUNTY, OHIO

EXPLANATION

QUATERNARY

Recent

cf — *Made land.* Areas of reclaimed land, cut and fill, dumps, and continuous urban cover where 90 percent or more of the surface is covered with concrete, asphalt, building complexes, structures, or other manmade surfaces; does not include urbanized areas where manmade surfaces are intricately associated with other types of cover

al — *Alluvium.* Clastic deposits and associated organic debris, notably on floodplains of the Cuyahoga, Chagrin, and East Branch Rocky Rivers

Pleistocene and Recent

st/cl — *Silt and clay, undifferentiated.* Lacustrine deposits, thin on the Lake Plain and Escarpment, thick and interbedded with sand and gravel in terraces along the Cuyahoga and Chagrin River valleys. Includes thin outwash deposits with interbedded sand and gravel on the Plateau south of Solon

sd/gr — *Sand and gravel, undifferentiated.* Beach-ridge and valley-fill deposits on the Lake Plain, kames on the Plateau south of Solon, and local deposits in the valleys of Mill Creek, Chippewa Creek, and Griswold Creek. Terrace deposits along the Cuyahoga and Chagrin River valleys include sand and gravel interbedded with silt and clay

m — *Muck.* Finely divided, highly decomposed, dark-colored organic deposit in poorly drained depressions; overlies Lavery Till; includes peat; limited mostly to areas adjacent to Abram Creek, between Middleburg Heights and Berea

Pleistocene (Wisconsinan)

Wt — *Till, primarily Lavery Till.* Lavery Till is dark gray to dark brown, silty to clayey, strongly calcareous, and cohesive. Younger Hiram Till identifiable in local outcrops, but in most places is thinner than the modern soil; older tills present in more extensive outcrops and in the subsurface

PENNSYLVANIAN

IPp — *Pottsville Group, Sharon conglomerate (bedrock unit IV).* Medium- to coarse-grained yellowish-brown to pinkish-brown quartz sandstone; locally contains interbedded pebble layers. Forms resistant bedrock outliers beneath highest hills on the Plateau

MISSISSIPPIAN

Mc — *Cuyahoga Formation, undifferentiated (bedrock unit III)* Clayey, soft, medium- to thick-bedded, dark-gray shale, which weathers dark brown; interbedded with flaggy, fine-grained, medium-gray sandstone, which weathers pale yellowish gray; crops out along numerous deep headwater gullies southwest of Strongsville to Parma, across the Escarpment, and in the upper valleys of major tributary streams

Mb — *Berea Sandstone (bedrock unit II).* Massive, medium- to fine-grained, clay-bonded, light-gray to yellowish-brown quartz sandstone; thick bedded to cross bedded in lower portion, thin bedded in upper portion, many beds ripple marked; forms prominent outcrops along the Escarpment, in deep gorges on tributary streams, and in numerous highway and railroad cuts

DEVONIAN/MISSISSIPPIAN

M-D — *Shale, undifferentiated (bedrock unit I).* Includes the Cleveland and Chagrin Members of the Ohio Shale, the Bedford Shale, and the Euclid Sandstone Member of the Bedford Shale. Chagrin shale is medium to greenish gray, weathering to yellowish gray, clayey, soft, medium to thick bedded, with irregular interbeds of siltstone or sandstone that weather dark brown. Cleveland shale is dark gray to black, thin bedded, and weathers to thin brown-stained slaty fragments. Bedford Shale ranges in color from blue gray to maroon or black and is clayey and soft, with thin sandstone interbeds. Euclid Sandstone Member is blue gray, fine grained, and locally up to 30 feet thick. Rocks assigned to bedrock unit I crop out extensively on the Lake Plain, in the wave-cut cliff along the lakeshore, in steep-sided cliffs along major river valleys, and along the lower part of the Escarpment

End moraine. Areas of generally thicker till forming linear ridges of hummocky topography. Includes Defiance Moraine in southeastern and south-central part of county, the gravelly moraine complex in the southeastern part of the county, and the lake escarpment moraines (Euclid and Brooklyn Moraines)

Location of erratic cobbles and boulders. Erratics range from several inches to over 6 feet in diameter, and include granite, gneiss, quartzite, greenstone, dolomite, and sandstone

Wave-cut cliff. In bedrock and glacial deposits along the present lakeshore, or in bedrock along North Ridge and along the base of the Escarpment from East Cleveland to Euclid; cut by waters of former higher glacial lakes

Gravel pit

Gravel pit, small or abandoned

Boundary of deposit, dashed where approximate

600

Contour on bedrock surface; contour interval 100 feet

1:24,000 U.S. GEOLOGICAL SURVEY TOPOGRAPHIC QUADRANGLE MAPS COVERING CUYAHOGA COUNTY (DATES IN PARENTHESES INDICATE DATE OF NEGATIVES USED TO COMPILE BASE)

1 0 1 2 miles

1 0 1 2 kilometers

CONTOUR INTERVAL 5 AND 10 FEET
DATUM IS MEAN SEA LEVEL

10,000-ft. grid based on Ohio coordinate system, north zone

CONTOURS ON BEDROCK SURFACE BY JOEL D. VORMELKER

JAMES A. BROWN, CARTOGRAPHER

PHOTOTYPESETTING BY JEAN M. LESHER

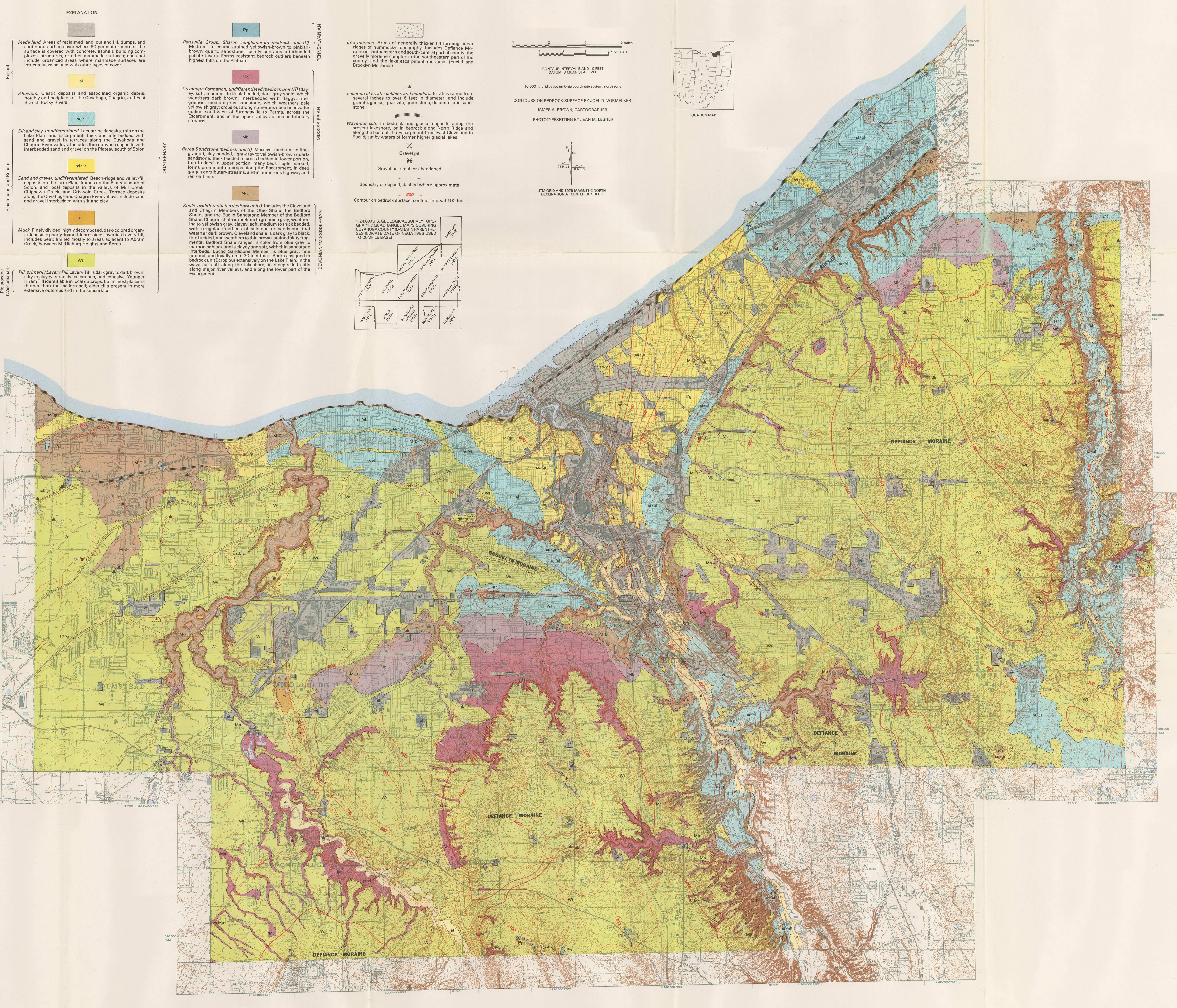
MN GN

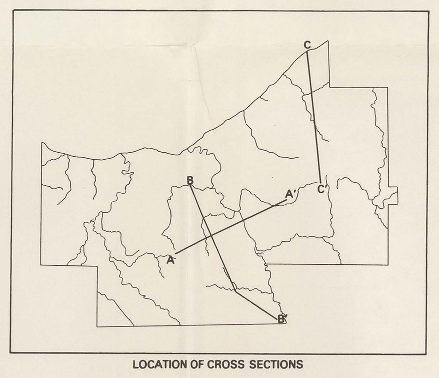
4° 71 MILS

0°27' 8 MILS

UTM GRID AND 1979 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

LOCATION MAP





LOCATION OF CROSS SECTIONS