STATE OF OHIO
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SAND AND GRAVEL RESOURCES OF MONTGOMERY COUNTY, OHIO

by Richard A. Struble
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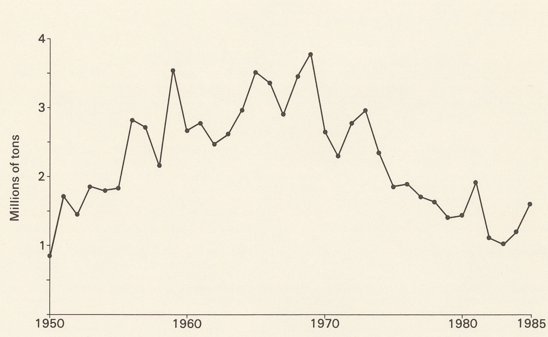

FIGURE 1.—Montgomery County sand and gravel production for the years 1950-1985 (Ohio Department of Industrial Relations, 1951-1981, and Ohio Division of Geological Survey, 1983-1986).

ABSTRACT

The sand and gravel resources of Montgomery County, Ohio, appear to be adequate to meet the demands for construction aggregate and fill materials well into the next century if population and industrial-expansion projections prove accurate. Laboratory analyses of samples from widely spaced localities within the county indicate that a large portion of the remaining mineable resource will provide good-quality coarse and fine construction aggregate for use in Montgomery County and surrounding areas.

INTRODUCTION

Population growth and industrial expansion, so common because of today's rapidly changing, mobile society, place great demands upon the extractive industries. Adequate supplies of nearby and easily extractable resources are essential for expansion and maintenance of Ohio's transportation network, dam and airfield construction, and remodeling and new construction projects. Southwestern Ohio is fortunate that large quantities of glacially derived sands and gravels were deposited within the drainage area of the Great Miami, Little Miami, and the Ohio River valleys. This resource can be traced southward from the Mad River and Buck Creek valleys in Logan, Champaign, Clark, and Greene Counties, to the Great Miami River valley through Butler and Montgomery Counties, and on to the confluence of the Great Miami and Ohio Rivers in Hamilton County. This inventory of sand and gravel resources in Montgomery County is one of a series of county reports which define the distribution, quantity, and quality of the sand and gravel deposits in Ohio.

A large portion of the sand and gravel resource in Montgomery County occurs within high-level outwash terraces along major drainageways. These terraces, above the highest historical flood levels, provide excellent sites for residential and industrial construction and the extraction of sand and gravel. However, because of pressures from established neighborhoods and developers, land-use competition and subsequent zoning regulations now make it difficult for the extractive industries to produce high-quality construction aggregates from these terraces within easy reach of the construction market. Construction aggregate is a low-cost-per-unit commodity which cannot absorb large transportation costs. In order to make the most efficient use of the remaining available resource, it is in the best interest of the citizenry that municipal authorities and planners have available detailed maps and reports which define the quality, quantity, and distribution of sand and gravel as well as other mineral resources. The Montgomery County sand and gravel resource map and report and other county geologic reports are important source documents for regional planners, engineers, civil authorities, aggregate producers, and property owners who must make decisions relating to land use and the extraction and management of this important resource.

Montgomery County, located in southwestern Ohio, is rural in nature, but farming is no longer the primary source of employment for the county. Dayton, the county seat and largest city, is 50 miles north of Cincinnati, in Hamilton County, and 70 miles southwest of Columbus, in Franklin County. Production statistics (Division of Geological Survey, 1986) show Montgomery County ranked fifth in the state in 1985 in overall sand and gravel production. In southwestern Ohio, Montgomery County ranked third in production behind Hamilton and Butler Counties. Between 1950 and 1955, sand and gravel production in Montgomery County increased from around 800,000 tons to 1.9 million tons, with an average production of 1.5 million tons per year (fig. 1). Construction of Ohio's interstate transportation system and the accompanying residential and commercial development between 1955 and 1975 pushed sand and gravel production to a yearly average of 2.8 million tons, with peak production of 3.8 million tons in 1969. Since 1975, production has averaged 1.5 million tons. Production will likely remain in the range of 1.7 million tons per year for the remainder of the century if projections of a moderate population growth of 2 percent for Montgomery County through the year 2000 are accurate (Ohio Department of Health, 1977).

GEOLOGICAL OCCURRENCE

The land surface of Montgomery County is composed almost entirely of unconsolidated glacial materials of Wisconsinan age. Deposits of three earlier glaciations (Kansan, Nebraskan, Illinoian) are found south of Montgomery County, in northern Kentucky, and in southeastern Indiana. These earlier glaciations disrupted much of the preglacial drainage system in Ohio and played an important part in the establishment of the present-day drainage system in the state. Drainage modifications documented by a network of buried river valleys are the only evidence of earlier glaciations in Montgomery County. Deposits from earlier glaciations either have been eroded or are buried beneath glacial materials of Wisconsinan age. Wisconsinan-age glacial features in southwestern Ohio suggest that the ice sheets spread southwestward across western Ohio in two lobes. Montgomery County is situated in the westernmost lobe, the Miami Lobe, which is bounded on the south by the Hartwell Moraine. The Hartwell Moraine, which straddles the Butler-Hamilton County line, defines the southernmost position of the Wisconsinan ice sheet in southwestern Ohio approximately 20,000 years ago. The morphological features which dominate the Montgomery County landscape are considered to be the result of processes associated with the retreat of the Wisconsinan ice sheet from the county. Except for the few bedrock outcrops along stream or road cuts, Montgomery County is blanketed by unconsolidated materials deposited by glacial ice or glacial meltwaters. Glacial and postglacial features which dominate the landscape of Montgomery County are (1) end moraines, (2) ground moraine, (3) outwash terraces, (4) kames and eskers, and (5) modern alluvium.

The end moraines in Montgomery County, the Farmersville and Camden Moraines, occupy approximately one-quarter of the surface area of the county and have a lobate configuration. They trend east-southeast from the western boundary of the county to the Great Miami River, but just west of the river the end moraines swing sharply to the northeast. The surface of the end moraines is characterized by low relief except in local areas where the glacial cover is thin and the topography is controlled by the underlying bedrock. The moraines are composed chiefly of glacial till, which is a heterogeneous mixture of clay, silt, sand, pebbles, and boulders. The Farmersville Moraine runs through central Montgomery County and is characterized by a high density of large boulders ranging from 1 foot to 5 feet in diameter.

End moraines mark a stationary position of an ice sheet and are believed to form when forward movement of glacial ice is in balance with melting along the ice front, or by thrust stacking of glacial debris upon the stagnant ice along the ice margin. If either of these conditions persists over a long period of time, materials incorporated within the ice accumulate as hummocky ridges—end moraines—along or near the front of the glacier. End moraines in Montgomery County rise only slightly above the elevation of the ground-moraine surface.

Ground moraine covers approximately one-half of the surface area of Montgomery County, primarily in the northwestern quarter, the extreme southern half, and the extreme eastern part of the county. Ground moraine consists of till similar in composition to the end-moraine tills but generally thinner. Ground moraine forms when materials carried in the base of the ice sheet are plastered on the land surface during glacial advances or are dropped to the ground as the enclosing ice melts during glacial retreats. Ground moraine forms a flat to slightly hummocky surface.

Areas of end moraine and ground moraine are not shown on the sand and gravel resource map of Montgomery County. Because of high clay and silt content, tills are not considered as good sources of sand and gravel. Although thin, irregular lenses or pockets of sand and gravel commonly are incorporated within end moraine or ground moraine, because of their erratic distribution these deposits have not been included as part of the resource. There are, however, local areas in Montgomery County where thick deposits of glacial outwash occur beneath glacial till. Where the glacial till is less than 25 feet thick the sands and gravels have been included in the resource inventory. Areas of till over gravel are shown on the resource map (1) in the southeastern quarter of the county east of the Great Miami and Mad River valleys in Washington, Van Buren, and Mad River Townships, (2) 1 mile west of Huber Heights along the east bank of the Great Miami River in Mad River and Wayne Townships, (3) west of downtown Dayton southwest of Wolf Creek in Harrison and Madison Townships, (4) along the west bank of Opossum Creek and on the east bank of Bear Creek northwest of West Carrollton in Jefferson Township, (5) 1 mile west of the village of Little York along the west bank of Stillwater Creek in Randolph Township, and (6) in southwestern Montgomery County along the west bank of Little Twin Creek in Jackson and German Townships approximately 4 miles northwest of Germantown. The resource of sand and gravel interpreted to lie beneath less than 25 feet of till in the areas described above makes up approximately 10 percent of the total resource of the county.

Surficial glacial-outwash deposits constitute the greatest source of sand and gravel in Montgomery County. Outwash occurs in two morphologic types, outwash plains and valley trains. Outwash-plain deposits generally are restricted to the broad upland interfluve areas of the county. During advances and retreats of the ice sheet the coarse materials incorporated within the ice are deposited across the upland areas as fans or coalescing fans along the margins of the thin, melting ice front. Outwash-plain deposits in Montgomery County are generally thin, ranging in thickness from a few feet to 20 feet, and show little lateral continuity. Gravel lenses, interpreted as outwash-plain deposits, which occur in the moraine-covered interfluve areas of the county have not been included in the resource inventory. An area 1 mile west of Englewood in Randolph Township is interpreted to be an outwash-plain deposit and has been mapped as a hypothetical resource. This deposit makes up less than 1 percent of the total Montgomery County resource.

Outwash valley-train deposits in Montgomery County occur as a series of matched terrace levels along the valleys of the Great Miami, Mad, and Stillwater Rivers; Twin, Bear, Opossum, and Wolf Creeks and Dry Run; and the larger streams tributary to the major drainageways. Valley-train deposits form when large quantities of coarse glacial debris incorporated in the ice sheet are discharged into meltwater streams and deposited in valleys leading away from the ice front as the glacier retreats from the drainage basin. Surficial valley-train deposits account for approximately 53 percent of the Montgomery County resource.

Another important source of outwash sand and gravel in Montgomery County lies beneath the alluvial deposits on the floodplains of the postglacial streams. The alluvial deposits themselves—stratified fine sands, silts, and clays—are not generally considered as sources for large deposits of sand and gravel but are shown on the resource map because some alluvium (river wash) has been mined locally for coarse and fine aggregate. Alluvial materials deposited on the floodplains in Montgomery County average about 10 feet. Outwash sands and gravels occurring beneath the alluvium of modern floodplains make up an important part of the total resource for the county. Where the thickness of alluvial overburden is less than 25 feet the sands and gravels have been mapped and are included in the resource inventory. Outwash under alluvium occurs in valleys where valley-train deposits were entrenched by modern streams and later covered by alluvium during periods of postglacial aggradation. Because floodplains are subject to periodic flooding, land-use competition is not as intense as on the outwash terraces. For this reason the extractive industries have experienced more favorable rulings by local zoning boards for operations within the floodplains than on the higher outwash terraces. Because of urbanization and commercial development on the outwash terraces, the greatest potential for future extraction of sand and gravel appears to be within the floodplains. Approximately 31 percent of the sand and gravel resource of Montgomery County lies within the floodplains.

Kame and esker deposits cover only a small part of the Montgomery County landscape. Kames are hills composed of sand and gravel, which in Montgomery County rise from a few feet to 200 feet above the land surface. Isolated (moulin) kames form when coarse materials carried by meltwaters are deposited in holes in the ice or at the intersections of fractures in the ice sheet. Kame terraces form when tongues of ice extend down deep valleys beyond the ice front. As the tongues of ice begin to melt and retreat from the valleys, some of the coarse material incorporated within the ice is transported laterally from the apex of the ice tongue to the margins of the valleys to form kame terraces. An extensive kame in Washington and Van Buren Townships, 1 mile east of Moraine, is approximately 5 miles long and 1 mile wide and is composed predominantly of sand, but many thick lenses and large, irregular pockets of well-graded gravel make this deposit a good source of both sand and gravel. Another large kame is located in Mad River Township approximately 3 miles east of downtown Dayton. Smaller kames in the county are located in Harrison Township just northwest of the village of Shiloh and along the Greene-Montgomery County line in northeastern Van Buren Township.

Eskers, similar to kames in composition, are elongate ridges, which in Montgomery County rise to a maximum of 10 feet above the ground-moraine surface. Eskers form when debris carried by glacial meltwaters is deposited in tunnels at the base of or within the ice sheet. Only one feature in the county has been interpreted as an esker; an elongate hill approximately 2,000 feet long with a relief of less than 10 feet is located 1 mile northwest of the village of Union in secs. 4 and 9, Randolph Township. Approximately 6 percent of the sand and gravel resource of Montgomery County lies within kame and esker deposits. Irregular lenses or pockets of till are common inclusions in both kame and esker deposits.

RESOURCES

The distribution of the sand and gravel resources of Montgomery County, differentiated by type of deposit, is shown on the accompanying map. For mapping purposes eskers and kames are mapped together, and outwash includes both outwash-plain and valley-train deposits. The resource categories used in the sand and gravel inventory are defined below:

Measured resources include all sands and gravels within a deposit that is within a ½-mile radius of a control point. Control points are locations where information on the thickness of the sand and gravel resource has been determined from: (1) a measured stratigraphic section, (2) logs from water wells that have penetrated the deposit, or (3) verbal communications from pit or dragline operators. The thickness data are used to estimate the thickness of each mapped unit. Where there are multiple control points within a single deposit the average of the combined data is taken as the thickness of the unit.

Indicated resources are sands and gravels associated with and contiguous with measured resources but which occur farther than ½ mile from a control point. An indicated resource is assumed to have the same thickness as the associated contiguous measured deposit. Where an indicated resource is bounded by more than one measured resource, the thicknesses of the measured resources are averaged to define the thickness of the indicated resource.

Inferred resources are those sand and gravel deposits which are not contiguous with a related measured resource but which are interpreted to exist from analysis of aerial photographs or soil surveys. Inferred resources in Montgomery County occur only within kame and esker deposits and have been assigned thicknesses of 10 feet for eskers and 20 feet for kames.

Hypothetical resources are designated where geologic interpretation suggests an occurrence of sand and gravel but reliable data are not available to verify the occurrence. Because no thickness data were available within the designated hypothetical-resource area of outwash in Randolph Township, a thickness of 10 feet was assigned for this resource.

The distribution of the sand and gravel resources of Montgomery County as shown on the map was determined from analysis of data derived from field examination, air-photo interpretation, soil surveys, and water-well logs. The 7½-minute (1:24,000) series of quadrangle maps was used as the mapping base for compiling field, water-well, and soil data. In each township the thickness of sand and gravel in each resource category was estimated from water-well-log and measured-section data. The estimated thickness and the number of acres within each resource category provided the data needed to calculate the tonnage-per-township volume estimates (table 1). The tonnages shown in table 1 represent an estimate of the original resource of sand and gravel deposited at the surface or beneath less than 25 feet of glacial till or alluvium and in no way reflect the quantities of sand and gravel currently available for extraction. Previously extracted sand and gravel and the amount of the resource lost to production because of zoning regulations and residential and industrial expansion have not been taken into consideration in the tonnage calculations.

This report provides general information regarding the distribution, quality, and thickness of the sand and gravel resources of Montgomery County and should not be used as a substitute for the detailed site-specific investigations necessary to determine the potential of an area as a site for a commercial sand and gravel operation. However, fairly reliable thickness data are available from the water-well logs and measured sections included in the report.

ANALYSIS OF MATERIALS

Eighty-four samples of sand and gravel weighing 15 to 20 pounds each were collected for laboratory analysis from stream and road cuts, all active gravel pits, and most semi-active, intermittently active, and abandoned commercial sand and gravel pits in Montgomery County. Letter designations following location numbers indicate multiple samples taken from the face of a pit or stockpile samples dredged from different elevations below the water level in a pit. All samples were air dried prior to splitting and subsequent sieve analysis. Material passing the No. 5 U.S. Sieve Series was sieved on a Ro-Tap mechnical shaker for 15 minutes. Materials retained on the No. 5 U.S. Sieve Series were hand sieved for up to 10 minutes. Sieve-analysis results are given in table 2.

To determine the percentage of constituent rock types represented in the gravels, 100 pebbles 1 to 2 inches in diameter were collected at 40 widely separated sampling locations (road and stream cuts and active and inactive gravel pits). These samples were washed, broken, and examined under a binocular microscope to determine the rock type of each. The percentage of constituent rock types for each site is shown in table 3.

The pebble-count and sieve-analysis data show that most of the sand and gravel resource of Montgomery County is suitable for many types of construction materials. The composition and texture of the deposits in the Great Miami, Mad, and Stillwater River valleys and the lower reaches of Twin, Bear, Opossum, and Wolf Creeks and Dry Run indicate that the sand and gravel resources in these drainageways would, with only a minimun of preparation, meet specifications for use in concrete aggregate, mortar, aggregate for flexible pavement, base materials, and fill.

CONCLUSIONS

Much of the resource of sand and gravel in Montgomery County is lost to production because of urban and industrial sprawl. However, this resource inventory indicates that deposits not already lost to urbanization are sufficient to meet the needs of the county and surrounding areas for a long period of time if population growth projections are accurate. Because much of the remaining extractable resource exists in rural areas or within the floodplains of the major stream valleys, development of the resource may not be subject to the intense land-use competition so evident on the outwash terraces in the metropolitan and industrial areas of the county. The texture and composition of the sands and gravels suggest that most of the deposits will be good sources for high-quality aggregates.

ACKNOWLEDGMENTS

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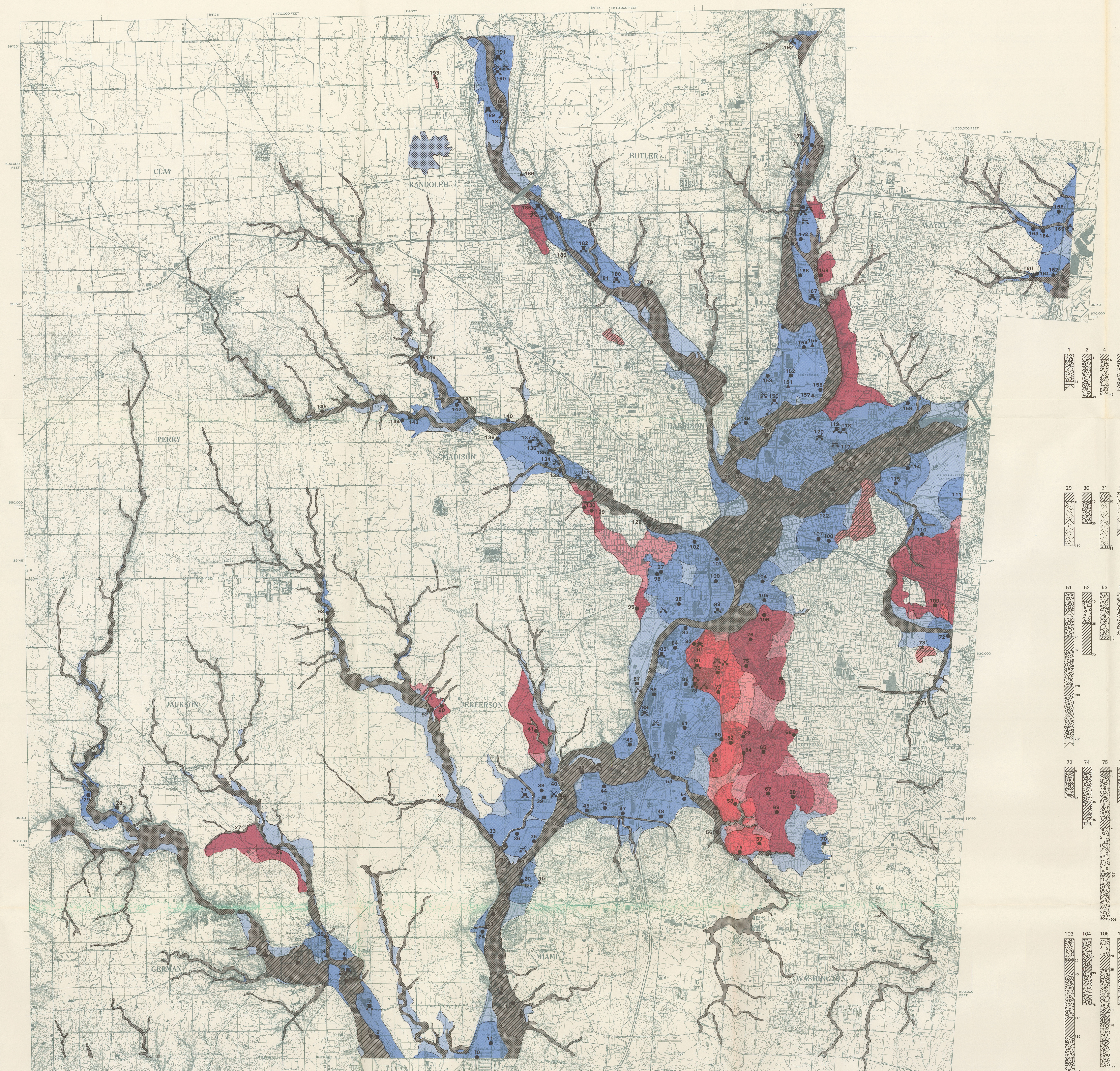


10,000-foot grid based on Ohio coordinate system, south zone

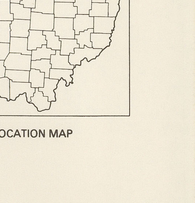
Area east of the Great Miami River lies within the Between the Miamis
Area west of the Great Miami River lies within the Miami River Survey
Land lines based on the Great Miami River Base

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

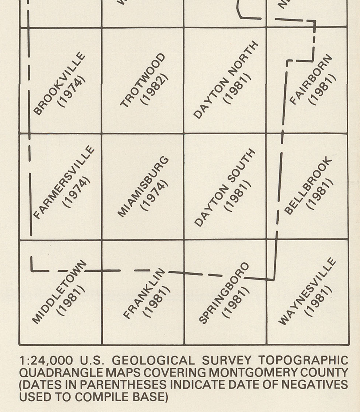
Scale: 1 0 1 2 3 miles; 1 0 1 2 3 kilometers

MN GN 3° 53 MILS 1°43' 31 MILS

UTM GRID AND 1974 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET



LOCATION MAP



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

PHOTOTYPESETTING BY JEAN M. LESHER

Outwash resources: Measured; Indicated; Hypothetical

Kame/esker resources: Measured; Indicated; Inferred

Outwash resources underlying less than 25 feet of till: Measured; Indicated

Outwash resources underlying less than 25 feet of alluvium: Measured; Indicated

Alluvium

Gravel pit, active (as of January 1985)

Gravel pit, inactive or intermittently active (as of January 1985)

Boundary of deposit

Water-well location

Measured-section and sample location

Sample location only

Water-well logs

Measured sections

EXPLANATION

Clay
Sand
Gravel
Shale
Limestone
C Covered interval

20 — Water-well or measured-section number
Depth in feet to unit contact
Sample interval (measured sections only; asterisk indicates stockpile sample)
Water table (measured sections only; information not available for all sections)

VERTICAL SCALE

Water-well logs: 0 feet–0; 50–15; 100 feet–30 meters

Measured sections: 0 feet–0; 20–6; 40 feet–12 meters

TABLE 1.—*Estimated sand and gravel resources, Montgomery County*

Township	Outwash: Measured	Outwash: Indicated	Outwash: Hypothetical	Outwash underlying <25 feet of till: Measured	Outwash underlying <25 feet of till: Indicated	Outwash underlying <25 feet of alluvium: Measured	Outwash underlying <25 feet of alluvium: Indicated	Kames and eskers: Measured	Kames and eskers: Indicated	Kames and eskers: Inferred	Total
Butler	133,744,000	30,696,300				38,613,500	42,504,600				245,558,400
German	57,722,400	43,119,000		14,544,700	2,713,800	106,661,000	64,931,000				289,691,900
Harrison	551,239,800	228,634,500		9,974,800	47,383,300	39,842,600	71,518,600			2,134,400	950,728,000
Jackson	25,436,000	40,697,500		16,892,600	91,500	6,835,400	101,781,400				191,734,400
Jefferson	74,078,800	136,176,600		28,217,500	3,438,600	22,101,400	64,994,600				329,007,500
Madison	59,774,800	21,575,100		7,267,600	1,311,200	8,401,400	24,221,800				122,551,900
Mad River	432,842,200	188,105,800		138,155,800	4,990,700	530,719,600	26,670,000	1,078,100		14,048,100	1,336,610,300
Miami	500,777,700	129,208,400				296,810,200	85,436,400	10,134,200	8,984,300		1,031,351,200
Perry		233,000				17,486,000	20,697,100				38,416,100
Randolph	61,365,000	17,295,100	7,731,900	13,078,500		10,488,200	11,952,900			193,800	122,105,400
Van Buren	164,086,200	29,759,100		145,033,000	71,021,300	7,693,800	58,029,500	166,360,900	60,524,900	2,652,800	705,161,500
Washington	11,421,400	27,045,300		62,667,600	16,030,000	3,567,600	3,861,600	51,281,000	7,170,000		183,044,500
Wayne	97,624,100	8,771,500		13,940,300	188,200	94,453,500	16,483,700				231,461,300
TOTAL	2,170,112,400	901,317,200	7,731,900	449,772,400	147,168,600	1,183,674,200	593,083,200	228,854,200	76,679,200	19,029,100	5,777,442,400

Sand and gravel resources (tons)

TABLE 2.—*Results of sieve analyses*

Grain size (% retained). ASTM scale: Boulders and cobbles; Gravel; Sand; Silt. Wentworth scale: Boulders and cobbles (-4.0"+3.0", -3.0"+2.5"); Pebbles (-2.5"+4, -4+5); Granules (-5+10); Coarse to very coarse sand (-10+35); Medium sand (-35+60); Fine to very fine sand (-60+200, -200+230); Silt and clay (-230).

Sample no.	-4.0"+3.0" U.S. Sieve Series[1] (3.0-4.0 inch diameter)	-3.0"+2.5" U.S. Sieve Series (2.5-3.0 inch diameter)	-2.5"+4 U.S. Sieve Series (0.187-2.5 inch diameter)	-4+5 U.S. Sieve Series (0.157-0.187 inch diameter)	-5+10 U.S. Sieve Series (0.0787-0.157 inch diameter)	-10+35 U.S. Sieve Series (0.0197-0.0787 inch diameter)	-35+60 U.S. Sieve Series (0.0098-0.0197 inch diameter)	-60+200 U.S. Sieve Series (0.0029-0.0098 inch diameter)	-200+230 U.S. Sieve Series (0.0025-0.0029 inch diameter)	-230 U.S. Sieve Series (<0.0025 inch diameter)	Total
3			59.7	3.0	9.1	22.2	4.8	0.9	0.0	0.3	100.0
5A			61.7	3.6	14.7	15.7	3.4	0.6	0.0	0.2	99.9
5B		3.6	66.7	2.1	6.7	11.1	5.6	3.4	0.1	0.6	99.9
7			56.6	2.5	9.8	17.9	8.1	3.1	0.2	1.7	99.9
16		9.9	50.5	2.7	11.6	18.4	4.4	2.0	0.1	0.6	100.2
17			45.0	3.8	13.2	18.7	14.1	4.1	0.1	0.9	99.9
18			50.0	2.7	12.3	24.2	9.3	1.2	0.0	0.3	100.0
23			67.3	3.2	8.4	9.6	4.6	3.2	0.2	3.6	100.1
37A		4.3	60.0	1.6	6.0	17.2	8.7	1.9	0.0	0.3	100.0
37B		8.9	55.1	2.1	7.5	13.2	9.4	2.8	0.1	0.9	100.0
37C		5.7	55.8	2.6	9.7	15.1	8.8	1.8	0.1	0.5	100.1
73			16.1	2.5	11.4	34.7	12.4	11.7	1.8	9.3	99.9
78			8.7	0.5	4.2	28.4	23.1	29.5	1.7	4.1	100.2
79			0.3	0.1	2.2	10.7	30.2	46.3	3.0	7.7	100.5
80			8.5	0.7	3.8	11.4	19.9	39.0	1.8	14.6	99.7
81A			58.7	2.5	9.5	18.3	7.3	2.7	0.2	0.8	100.0
81B			55.8	2.8	7.6	18.1	10.9	4.0	0.2	0.6	100.0
81C			9.4	2.8	18.2	46.3	14.7	6.7	0.4	1.4	99.9
85			52.5	1.7	6.9	28.0	8.2	1.6	0.1	0.9	99.9
87			64.3	3.6	9.9	13.3	6.0	1.7	0.1	1.1	100.0
89A			0.1	1.5	21.6	41.6	23.8	9.3	0.2	1.8	99.9
89B		6.3	58.0	1.6	4.8	14.4	13.3	1.4	0.0	0.2	100.0
89C			65.5	2.5	8.6	16.5	5.7	0.8	0.0	0.2	99.8
89D			49.6	4.4	15.6	20.1	7.8	1.6	0.1	0.8	100.0
92		12.6	56.4	2.4	9.5	12.3	3.3	1.8	0.1	1.6	100.0
99			27.2	3.2	16.8	30.9	13.8	6.3	0.2	1.7	100.1
112	8.0	12.3	56.7	2.2	5.9	9.4	4.2	0.9	0.0	0.4	100.0
116A			65.4	2.8	10.9	16.5	2.5	0.6	0.0	1.1	99.8
116B			61.2	2.9	8.0	12.8	10.2	2.9	0.1	1.8	99.9
117A			78.9		9.0	3.9	5.7	1.4		0.8	99.7
117B		17.8	55.4		7.9	6.0	10.1	2.1		0.3	99.6
118A			59.0	2.0	6.3	11.8	15.1	3.8	0.1	1.4	99.9
118B	10.0		60.6	2.1	5.8	8.8	9.7	2.2	0.1	0.7	100.0
119A			72.2		13.4	7.4	4.7	0.1		0.1	97.9
119B			67.7		22.7	3.9	4.3	0.7		0.4	99.7
119C			73.0		12.6	7.4	4.5	1.2		0.7	99.4
119D			53.8		10.1	8.6	22.5	3.1		1.3	99.4
119E			21.1		12.4	17.9	40.7	7.3		0.3	99.7
120A			66.2	2.7	9.1	15.1	4.8	1.2	0.1	0.9	100.1
120B			56.9	2.8	9.1	17.8	7.7	3.0	0.1	2.4	99.8
132			88.8	1.4	4.1	2.7	1.8	0.9	0.0	0.4	100.1
135A			34.7		15.1	16.1	28.9	4.6		0.5	99.9
135B			24.5		15.9	20.3	30.4	7.8		0.5	99.4
135C			22.1		19.3	26.5	29.4	2.1		0.3	99.7
136			46.7	3.4	14.4	19.4	9.1	5.2	0.2	1.6	100.0
141			55.8	2.4	9.6	12.2	12.6	4.8	0.2	2.4	100.0
150A			18.8	2.1	8.1	26.9	38.3	4.8	0.1	0.8	99.9
150B			60.6	5.3	15.8	14.8	1.8	0.9	0.0	0.6	99.8
151			49.0	3.1	11.1	24.4	7.4	2.1	0.1	2.7	99.9
155			46.9	3.2	13.1	22.8	9.5	2.3	0.1	2.2	100.1
157			57.0	3.2	10.1	14.9	6.3	3.8	0.2	4.4	99.9
165			48.0	4.2	13.1	22.0	8.8	2.9	0.1	0.8	99.9
167A			54.9	1.0	3.8	21.8	12.1	3.7	0.2	2.5	100.0
167B			35.2	1.4	7.9	36.8	16.4	1.4	0.0	0.6	99.7
170A		4.0	63.4	2.3	7.8	15.1	6.2	0.9	0.0	0.2	99.9
170B			36.3	2.4	10.5	34.5	14.4	1.5	0.0	0.3	99.9
170C		7.1	44.8	1.6	8.0	26.9	9.6	1.5	0.0	0.5	100.0
170D			38.9	3.3	14.1	27.8	13.3	2.3	0.0	0.3	100.0
173A		4.8	51.5	2.7	12.0	23.3	3.9	1.3	0.0	0.4	99.9
173B		14.5	44.0	2.6	10.3	16.8	3.8	2.4	0.2	5.4	100.0
179			39.0	2.9	10.8	22.1	11.1	8.7	0.4	5.0	100.0
180			53.1	2.5	10.0	19.7	10.2	3.5	0.1	0.8	99.9
182	7.9	4.9	41.5	2.7	9.9	15.5	5.7	5.2	0.4	6.3	100.0
183			52.7	2.8	11.2	21.6	5.6	2.7	0.2	3.2	100.0
185A		4.9	53.3	2.1	8.1	24.5	4.6	1.2	0.1	1.2	100.0
185B			27.6	2.5	20.2	33.6	6.5	3.8	0.2	5.5	99.9
185C		9.3	57.3	2.3	7.5	10.4	9.3	3.3	0.0	0.4	99.8
186			33.6	2.1	7.8	34.2	15.8	4.6	0.1	1.3	99.5
187A			56.6	2.7	8.1	19.1	11.0	1.7	0.1	0.6	99.9
187B			64.3	2.3	8.2	17.9	5.7	1.2	0.0	0.4	100.0
187C	8.9	7.5	48.7	2.1	8.9	17.9	4.2	1.0	0.0	0.7	100.0
189			57.9		5.6	7.8	26.9	1.3		0.5	100.0
190A		5.3	54.3	2.2	8.3	20.3	6.8	1.6	0.0	0.8	99.6
190B		4.5	59.7	2.6	8.6	12.9	7.5	2.3	0.1	1.6	99.8
190C		5.5	59.1	2.2	8.0	15.6	6.6	2.0	0.1	0.9	100.0
190D			46.7	3.2	10.3	24.6	12.0	2.4	0.1	0.7	100.0
190E		8.8	39.5	3.3	11.5	23.7	9.4	2.7	0.1	1.2	100.2
191A			35.6		10.8	13.8	37.3	2.1		0.3	99.9
191B			49.8		10.7	12.3	25.2	1.7		0.2	99.9
191C			21.2		8.9	13.9	53.2	2.4		0.2	99.8
191D			44.7		4.8	9.2	37.6	2.9		0.8	100.0
191E			42.9		24.3	19.8	10.1	1.5		1.4	100.0
192		12.6	38.7	2.8	9.7	20.8	10.4	3.8	0.1	1.2	100.1
193		19.1	48.1	2.3	8.2	7.8	3.1	5.6	0.4	5.4	100.0

[1] - indicates particle passes through mesh; + indicates particle retained on mesh.

TABLE 3.—*Results of pebble counts*

Sample no.	Igneous and metamorphic: Count	%	Carbonate: Count	%	Sandstone: Count	%	Siltstone: Count	%	Chert: Count	%	Ironstone: Count	%	Shale: Count	%	Clay clasts: Count	%	Total: Count	%
3	8	8	81	81	6	6	1	1	4	4							100	100
5	8	8	86	86	4	4			1	1	1	1					100	100
7	7	7	90	90	2	2			1	1							100	100
16	6	6	82	82	2	2	7	7	3	3							100	100
18	8	8	85	85	4	4	1	1	2	2							100	100
23	6	6	85	85	4	4	2	2	3	3							100	100
37	6	6	85	85	6	6	1	1	2	2							100	100
73	8	8	78	78	7	7	5	5	2	2							100	100
78	10	10	88	88					1	1					1	1	100	100
79	9	9	86	86	5	5											100	100
80	7	7	90	90	2	2			1	1							100	100
81	7	7	88	88	5	5											100	100
85	11	11	83	83	4	4	1	1	1	1							100	100
87	14	14	83	83	2	2			1	1							100	100
89	12	12	80	80	6	6			2	2							100	100
92	12	12	82	82	4	4	1	1	1	1							100	100
99	9	9	83	83	5	5	1	1	1	1			1	1			100	100
112	8	8	86	86	5	5			1	1							100	100
116	7	7	84	84	5	5	1	1	3	3							100	100
118	5	5	93	93	1	1			1	1							100	100
120	7	7	87	87	4	4	1	1	1	1							100	100
132	3	3	88	88	5	5	4	4									100	100
136	5	5	91	91	3	3	1	1									100	100
141	1	1	92	92	6	6									1	1	100	100
150	13	13	81	81	4	4			2	2							100	100
151	9	9	80	80	9	9	2	2									100	100
155	9	9	85	85	3	3	2	2	1	1							100	100
157	9	9	87	87	3	3			1	1							100	100
165	7	7	88	88	4	4			1	1							100	100
167	12	12	79	79	6	6	3	3									100	100
170	11	11	85	85	4	4											100	100
173	10	10	80	80	4	4	4	4	2	2							100	100
179	5	5	90	90	4	4	1	1									100	100
180	7	7	88	88	3	3	2	2									100	100
182	6	6	88	88	2	2	4	4									100	100
183	7	7	88	88	3	3	2	2									100	100
185	9	9	89	89	1	1	1	1									100	100
187	12	12	79	79	5	5	2	2	2	2							100	100
190	8	8	83	83	5	5	2	2	1	1							100	100
192	12	12	79	79	7	7	1	1	1	1							100	100

Rock type. Deleterious: Chert, Ironstone, Shale, Clay clasts.

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