AGGREGATE RESOURCES OF BIG BLUE RIVER VALLEY IN EAST-CENTRAL INDIANA

Special Report 20

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Department of Natural Resources
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Aggregate Resources of the Big Blue River Valley in East-Central Indiana

By CURTIS H. AULT *and* MICHAEL C. MOORE

DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY SPECIAL REPORT 20

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Introduction

NEED FOR INCREASE IN AGGREGATE RESERVES

Quarry and gravel-pit operators in search of new mining sites are faced with a dilemma. How may aggregate producers mine near a city, where most of the product is sold, and still cope with local taxes, environmental laws, and zoning regulations? There is great economic advantage, both to the producer and the consumer, in locating an aggregate plant near an urban center, because aggregate is a heavy, bulky product that is expensive to transport.

Unfortunately, aggregate reserves are not always where they are needed. Producers are well aware that while commercial deposits of quarry rock and sand and gravel are common and widespread, they are by no means ubiquitous. Zoning boards have given this fact less than due consideration. Thus arises the dilemma. The most desirable sites, already limited by fixed geologic factors, are further restricted by regulation and competition with other land uses.

Local zoning ordinances that severely restrict mining activites are commonly enacted as urban populations spread into outlying areas. The need for aggregate may be more readily recognized by a regional board that supersedes separate metropolitan and rural planning groups. But the competition for space is still intense, and many times large aggregate reserves are lost because of development of the land for other uses. High land costs accompanying urbanization can also effectively prohibit producers from purchasing and exploiting nearby aggregate reserves. Sequential land use, whereby surface mining is followed by reclamation and reuse of the land, is a good way to obtain the full potential of the land surface. But for this to work, planning agencies must have local and regional resource studies to make effective decisions.

The Indianapolis urban area is well on the way to covering Marion County. The population of the county increased 14 percent (to nearly 800,000) between 1960 and 1970. As with most large urban areas, growth is neither steady nor direct in Marion County and surrounding counties. It proceeds mostly by leapfrog patterns, with more distant subdivisions attracting the affluent and expanding middle class. These are the areas that undergo large commercial development.

Since most growth in Indianapolis is toward the outlying areas, a knowledge of the aggregate reserves in those areas is paramount. The Indiana Geological Survey has published a report on the sand and gravel resources in eastern Johnson County and western Shelby County (Carr, 1966). As Indianapolis continues to grow in other directions, gathering data on aggregate reserves in undeveloped areas is imperative. A part of the Big Blue River valley was chosen as a special study area (fig. 1) for detailed investigation of aggregate resources because large deposits of sand and gravel and high-quality limestone and dolomite might be found in the same places. The Big Blue River is not unique, as several other streams, notably Little Blue River, Flatrock Creek, and Brandywine Creek, also carried outwash (now potential sand and gravel deposits) and have areas of thin drift where stone quarries might be opened. But the Big Blue River is the closest to metropolitan Indianapolis and is served by excellent highways (fig. 1).

Interstate 74 passes north of Shelbyville, just 5 miles south of the area, Interstate 70 crosses the northern boundary of the area,

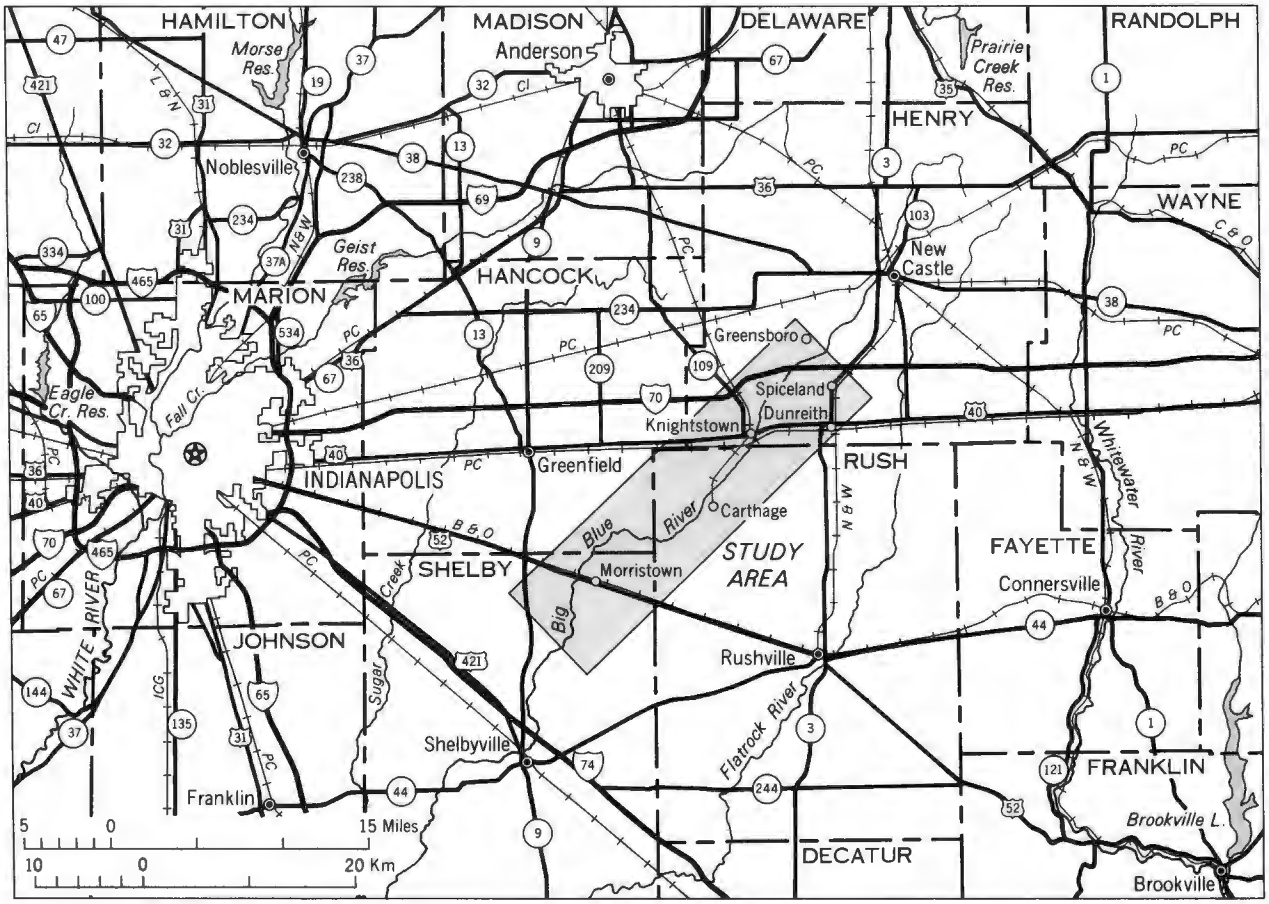


Figure 1. Index map showing location of the study area and major transportation routes.

and within the area four-lane U.S. 40 and U.S. 52 lead to Knightstown and Rushville. All these highways are accessible to the Interstate 465 by-pass around Indianapolis. Indiana Highways 9, 209, 109 and 3 provide north-south connections between the highways which radiate from Indianapolis. Rail service is nearly as extensive. Penn-Central rail lines parallel U.S. 40 and go north of Interstate 70 and south of Interstate 74. Carthage is connected to Knightstown and Rushville by a Penn-Central track. The B. & O. tracks parallel U.S. 52.

Included in the study area are parts of Hancock, Henry, Rush, and Shelby Counties and Morristown, Carthage, Knightstown, Greensboro, Spiceland, and Dunreith. Just to the west, toward Indianapolis, is Greenfield; to the south, Shelbyville; and to the northeast, New Castle.

SOURCES OF DATA

Information gleaned from earlier published reports was supplemented with data collected during an extensive field-sampling program. Active and abandoned gravel pits and natural exposures were visited and sampled, but most information came from subsurface sampling. Bedrock cores obtained by drilling equipment of the Indiana Geological Survey form the basis of our evaluation of the crushed limestone and dolomite reserves in the study area. These cores were sampled and described (appendix 4). Split halves of the cores were used for paleontologic analysis and chemical analysis, the latter performed by the Geochemistry Section of the Survey. The other core halves were filed in the Survey's core library.

The Survey's 4-inch power auger was used to obtain sand and gravel samples at 47 points along the valley. Samples were taken at irregular intervals, and grain-size and pebble-count studies were made. The coring rig was used to determine depth to bedrock at three places.

Driller's logs of all water wells drilled since July 1, 1959, are on file in the Division of Water, Indianapolis. These logs are usually made by staff not trained or experienced in describing geologic materials and are of variable quality. Nevertheless, they are valuable tools in searching for shallow bedrock and bodies of thick sand and gravel and were used extensively in this study. The water-well logs also helped in interpreting the subsurface geology of the unconsolidated materials (pl. 1*A*, *B*).

Seismic-refraction techniques were used to obtain depth to bedrock at eight places across the present Big Blue River valley southwest of Carthage. Other seismic determinations of depth to bedrock were taken throughout the study area.

History of Roads and Use of Aggregate

Most of the Big Blue River valley was a wilderness before its purchase in 1818 from the Delaware and other Indian tribes. The first white settlers arrived in the Big Blue River valley in 1819. Within 3 years, they had laid out wagon roads near the new town of Knightstown on the Big Blue River. In the 1820's and 30's other towns sprang up, and adjacent land was quickly purchased or homesteaded. The Old National Road (now U.S. 40) was cleared east of Indianapolis and was under construction in Hancock County by 1827, but little or no stone aggregate had yet been used to surface the roads. Most roads were not much more than cleared paths through the forests and swamps.

Abundant wood in Indiana in the mid 1800's encouraged the construction of plank roads, which were hailed as the latest thing in road building. Indeed, they were a great improvement over mud roads, but repairs were expensive, the wood rotted, and in 6 or 7 years most of the roads reverted to their original rutted state. Beginning about 1853, gravel was used instead of planking to build the Old National Road in Henry County (Blatchley, 1906). This is the first mention of the use of aggregate for roads near the Big Blue River valley; sand and gravel from the valley were probably used on the Old National Road near Knightstown.

The use of sand and gravel near the Big Blue River increased in the late 1800's, but most roads were still dry-weather roads even as late as 1883. Elrod (1884) summed up the condition of most roads in Rush County: "The ordinary dirt roads are good, expecially for Indiana, and in summer nothing could be nicer, but in winter they are fearfully muddy."

The only stone quarry in the study area was 3 miles north of Knightstown by the Big Blue River (SW¼SW¼ sec. 12, T. 16 N., R. 9 E.). It was in operation before 1838 and possibly as early as 1822. A history of Henry County (Anonymous, 1884) mentioned a canal authorized in 1838 from "the stone quarry four miles north of Knightstown to the town." Pleas (1871) wrote of a road authorized in 1822 "from New Castle via Teas mill, the stone quarry, and Elm Grove," but he may have been using 1871 landmarks to describe the 1822 route. The quarry produced dimension stone, but as far as is known, no road aggregate was produced there.

Road building and repair from about 1850 to 1890 were accomplished mostly by small private corporations which built and maintained graveled toll roads throughout much of central Indiana. By 1886, Shelby County had only 153 miles of graveled roads.

The use of sand and gravel for roads near the Big Blue River became widespread in the early 1900's, and many sand and gravel pits were used for short times to gravel nearby roads. A few larger pits were operated for extended periods near Morristown and Knightstown.

In June 1979 two sand and gravel producers were operating within the study area. The Caldwell Gravel Sales, Inc., near Morristown was shipping sand and gravel by truck, mostly to local markets, and intermittent service was being provided by Davis Gravel, 2 miles north of Knightstown.

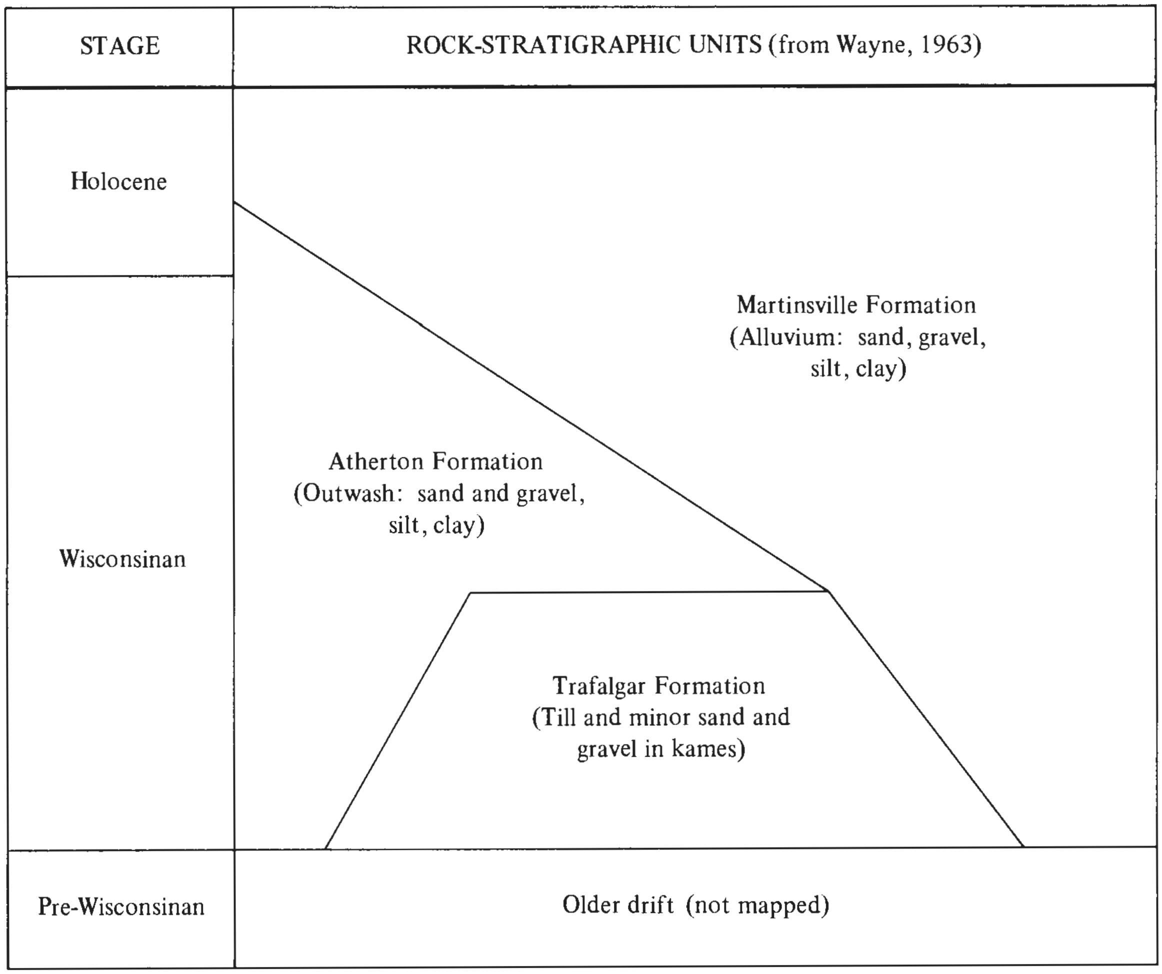


Figure 2. Unconsolidated units of Pleistocene age in the study area.

Unconsolidated Sources of Aggregate

All the area included in this study was covered by one or more glacial ice advances during the Pleistocene Epoch (Quaternary Period). But only a part of the sediments of Wisconsinan and Holocene age are exposed at the land surface; older formations may be buried beneath the youngest glacial drift or recent sediments. Wayne (1963) formally named the formations (fig. 2) which correspond to the mapped materials shown on plate 1*C*.

QUATERNARY SYSTEM

MARTINSVILLE FORMATION

The youngest deposits in Indiana are those formed by the action of wind and water on glacial and bedrock materials since the retreat of the last glacier. These sediments are, in general, thinner, finer grained, and less weathered than are the materials deposited under similar conditions in glacial times. Because deposition in many places has been continuous since glacial times, the lower parts of many Martinsville deposits are Pleistocene in age and the upper parts are of Holocene age. The Martinsville Formation can conveniently be divided into two facies or aspects: alluvial and paludal. Wayne (1970, p. 107) stated:

> The alluvial facies consists of muds, silts, sands, and gravels that are primarily fluviatile sediments of nonglacial origin deposited on modern floodplains throughout the state. The paludal facies is comprised of peat, gyttja, marl, clay, and silt, which are nonglacial sediments deposited in quiet water environments of sloughs, lakes, and bogs.

The maximum thickness of the Martinsville Formation in the flood plain of the Big Blue River exceeds 20 feet. Schneider and Gray (1966, p. 16) described the deposits as follows:

Because of their occurrence along stream courses, sediments of the Martinsville Formation are partly transient in nature, much of the material being subject to frequent scouring and redeposition farther downstream. . . .The upper part of the unit (about 1 to 3 feet thick) tends to be finer grained than the material below particularly in flood-plain environments. Here also the finer materials (fine sand, silt, and clay) commonly are high in organic matter and consequently are dark brown to black. Channel deposits, on the other hand, tend to be coarser textured and yellowish brown or brownish yellow.

The Martinsville Formation and the mostly older Atherton Formation have a gradational contact, and since the materials are quite similar, the contact is generally drawn at the break in slope between the Martinsville-covered flood plain and the incised terrace underlain by Atherton outwash sand and gravel. Soil patterns may also help to distinguish the two, although their characteristic development overlaps. Schneider and Gray (1966) summarized the relationship of soil groups to glacial parent materials.

ATHERTON FORMATION

The most important rock unit in the Big Blue River valley, as far as sand and gravel resources are concerned, is the Atherton Formation of Wisconsinan age. It consists of intertonguing and interrelated bodies of unconsolidated sediments that resulted from glacial action but that were deposited extraglacially. These sediments, gravel, sand, silt, and clay, were sorted and deposited by glacial-meltwater currents or the wind. Of the four distinct facies of the formation that are recognized in Indiana, only the outwash facies is economically important in this stretch of the Big Blue River valley.

Much of the Atherton outwash facies is found in stream valleys that once carried great volumes of glacial meltwater. Today these valleys are occupied by streams that are much smaller than they were during glacial times. The Big Blue River is an example of a stream that is tremendously underfit for the size of its valley. Deposits of the Martinsville Formation cover the Atherton, which is generally exposed in terraces near the modern-stream flood plain. Schneider and Gray (1966, p. 17) stated:

In general the terraces in this area are low, commonly being no more than 10 or 15 feet above the adjacent flood plains, and there is little topographic break between terrace and flood plain. For this reason, and because there is some similarity between the outwash facies of the Atherton Formation and the Martinsville Formation, the boundary between the two units in many places is not well defined. The most prominent terraces are those along the course of the Big Blue River between Shelbyville and New Castle, especially upstream from the confluence of the Big Blue with Sixmile Creek west of Carthage. In this part of the drainageway the valley is narrower and better defined than farther downstream; the terrace treads are higher and much more sharply separated from the flood plain than farther downstream.

The composition of the Atherton Formation, mineralogically and lithologically, reflects the source materials: local bedrock, durable exotic crystalline rocks from Canada, and similar materials from deposits of previous glaciers. The amount of weathering also influences Atherton outwash composition. At depth the sands, and especially the gravels, are generally calcareous, but the upper 2 to 5 feet may be leached of all fine-grained carbonate rock. Finer materials may be leached to even greater depths.

As is common in fluvial environments, the maximum grain size of the Atherton decreases downstream. Most of the gravel is found near the glacial margin (Carr and Webb, 1970) where the drop in maximum grain diameter is sharp.

TRAFALGAR FORMATION

The Trafalgar Formation is the most widespread unconsolidated unit in the Big Blue River basin. It is made up of till, a heterogeneous mixture of sand, silt, clay, and gravel. The upper part of this till in most places is leached of calcareous material to a depth of 80 to 125 cm and oxidized to a brownish or yellowish shade. It may be as much as 100 feet thick, but it generally averages 30 to 60 feet in thickness in the Big Blue River basin.

Trafalgar till is characterized by its sandy texture, high density, and low clay content. Mechanical analyses of scattered samples of the till from within the study area had sand/silt/clay percentages ranging from 33/36/31 to 58/27/15. The highest sand content seems to be associated with samples from the axis of the valley. Carbonate content of the Trafalgar till ranges from less than 10 to nearly 50 percent, and dolomite is the major constituent. The surficial till of the moraine northwest of Knightstown, however, has a distinctly higher carbonate content (Gooding, 1973). This may be attributed to the path of the glacier over carbonate bedrock and the nearness of the moraine to that source area. Similar till from Marion County was shown to have insignificant lithologic variation among different till sheets at various points throughout the county (Harrison, 1959). Trafalgar till is extremely compact, with densities of about 140 lb per cu ft and unconfined compressive strengths of more than 25 tons per sq ft.

All glacial-till deposits may have interbedded sand, gravel, or silt, as well as isolated pockets of these materials. Tills in contact with sand may contain a high percentage of sand near the contact, and tills in contact with bedded clays and silts may contain high percentages of these constituents near the contact. In contrast to this type of variability, portions of the Trafalgar may be classified as kame facies, which show evidence of ice stagnation and water washing of the deposits. In kames, layers of till may be interbedded randomly with sands, gravels, silts, and some clay, and the resulting topography may be very irregular. Soils developed on kame and esker deposits in the Upper East Fork Drainage Basin have been mapped (Schneider and Gray, 1966) as the Bellefontaine series (Baldwin and others, 1922; Tharp and Simmons, 1930; Simmons, Kunkel, and Ulrich, 1937; Ulrich and others, 1948). The depth to fresh gravel commonly ranges between 2½ and 4 feet.

SUBSURFACE CORRELATION IN UNCONSOLIDATED MATERIALS

It is possible to make tentative stratigraphic correlations in local areas by using water-well driller's logs, but the control is neither abundant enough nor reliable enough to trace units the length of the study area. It is difficult to correlate across drainages, both recent and buried, although several general trends are evident from the more than 200 well records and 47 auger borings (appendixes 1 2, and 3) in and immediately surrounding the area. The buried horizons slope to the south as does the present drainage (pl. 1*A*), but at a rate about three times as great. The subsurface units also slope toward the present stream valley of Big Blue River (pl. 1*B*).

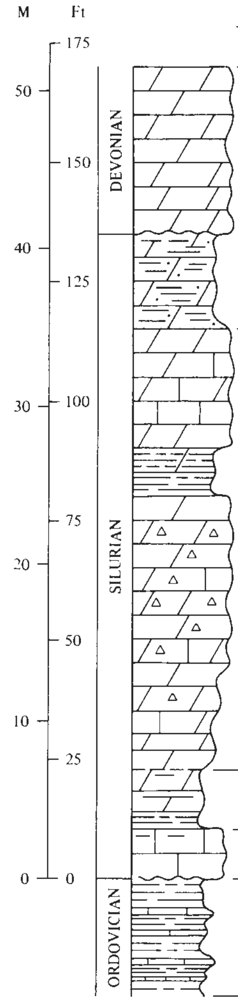
In the flood plain of Big Blue River there is a fairly consistent thickness of 10 to 40 feet of sand and gravel beneath a few feet of soil for the entire length of the study area. But in the subsurface beneath the valley walls, sand and gravel are abundant only in the area near Carthage and to the south. There is a greater percentage of sand and gravel in the unconsolidated materials in the south than in those in the north. The lateral extent of buried sand units is much wider in the south than it is in the north.

The thickest sands seem to be on the west side of Big Blue River. This thickening appears to represent a proglacial outwash plain which was overridden by the ice advance that deposited the Knightstown Moraine (Wayne, 1965). Outwash in the valley fill is thick east of Morristown, but there is little sand on the east side of the stream north of that area.

Beneath the high terrace west of Knightstown there is thick sand. It may be associated with a buried minor tributary at that point, or it may be an accumulation in a bedrock low. Many of the thicker sands in the south are within broad bedrock channels which probably controlled drainage.

Bedrock Sources of Aggregate

Dolomite and limestone of Silurian and Devonian age are at the bedrock surface in most of the study area (pl. 1*D*). Interbedded thin shale and limestone of Cincinnatian (latest Ordovician) age form the bedrock surface in the northeast corner of the area. Within the Big Blue River valley, carbonate rocks are present at depths of less than 20 feet to about 200 feet beneath unconsolidated sediments (pl. 1*E*). Where limestone and dolomite are found near the surface,



FORMATION	POSSIBLE COMMERCIAL USES	LIMITATIONS
Jeffersonville Limestone Geneva Dolomite Member	Crushed stone for all aggregate use; chemical uses requiring high-magnesium dolomite.	Absorption exceeds 3 percent in part of the formation (fig. 2), which may make the dolomite unsuitable for concrete and bituminous mixes.
Wabash Formation Mississinewa Shale Member	Very limited aggregate use.	Highly argillaceous; unsound, although basal dolomite of the rock unit may be durable enough for limited aggregate use.
Louisville Limestone	Crushed stone for all aggregate use; some chemical use.	Magnesium carbonate content may not be high enough for high-magnesium chemical uses.
Waldron Shale	Fill material.	Unsuitable for road or concrete aggregate.
Salamonie Dolomite Laurel Member	Crushed stone for most aggregate use; limited chemical use.	Contains variable amount of porous chert which, in parts of the formation, exceeds the amount allowable for use in concrete and bituminous mixes. In parts where chert is absent, the formation may be pure enough for some chemical uses.
Salamonie Dolomite Osgood Member	Very limited aggregate use.	Interbedded limestone and shale make this unit unsuitable for most aggregate.
Brassfield Limestone	Limited aggregate use.	Depth (100 to 200 ft) and limited reserves (about 10 ft thick) offer little commercial potential. Contains some shaly laminations.
Cincinnatian rocks	Fill material, flagstone, and cement raw material.	Interbedded limestone and shale.

Figure 3. Generalized columnar section showing bedrock units and their commercial uses and limitations.

open-pit quarries may be economically feasible, and where commercial sand and gravel overlie the carbonate rock, exploitation of the bedrock may be possible.

Because not all carbonate strata are equally suited for aggregate (fig. 3), knowledge of the extent, lithology, thickness, and chemical and physical properties of the rocks is necessary to evaluate them adequately for various crushed-stone uses. Following is a description of rocks at or near the bedrock surface (pl. 1*F*) in the Big Blue River valley. Detailed descriptions and chemical analyses of Silurian and Devonian rocks from core tests are given in appendixes 4 and 5.

DEVONIAN SYSTEM

The Geneva Dolomite Member is buff and brown fine- to medium-grained dolomite which is calcareous in part and contains light-colored calcite crystals in vugs. The Geneva is 34 feet thick near Morristown where it was encountered at a depth of 26 feet below the surface in Survey drill hole (SDH) 216. It is 20 feet thick in SDH 11, north of Morristown.

The Geneva is quarried for class A aggregate in several places in southeastern Indiana, but its absorption value may exceed 3 percent, the maximum normally allowed by the Indiana State Highway Commission for

Table 1. Specific gravity, absorption, and resistance to abrasion of selected core samples of Geneva dolomite from Survey drill hole 216

Thickness of sampled interval (ft)	Number of samples	Specific gravity[1]		Absorption[1]		Resistance to abrasion	
		Range	Average	Range (pct)	Average (pct)	Thickness (ft)	Loss (pct)
3.3	2	2.58-2.62	2.60	7.13- 7.52	7.32	11.2	36
7.9	4	2.54-2.80	2.69	1.55- 3.59	2.40		
9.2	6	2.59-2.76	2.68	3.15-18.40	6.68	18.6	32
9.4	6	2.69-2.76	2.74	1.64- 4.40	3.00		
Total sample 29.8	18	2.54-2.80	2.70	1.55-18.40	4.15		34

[1]Sample weights ranged from 20 to 45 grams. The samples were heat dried for 24 hours before weighing dry and soaked for 72 hours or more before determining loss of weight in water on a Krauss Jolly balance or before weighing to determine absorption values.

aggregate for concrete or bituminous mixes. The Highway Commission has permitted the use of Geneva dolomite, however, from several quarries on the basis of past performance.

Physical-test results of the Geneva from SDH 216 indicate that absorption may be the limiting factor in using the rock for most aggregate (table 1).

The Geneva forms much of the bedrock in the southwestern half of the study area. It was cored beneath 24 feet of overburden containing about 20 feet of sand and gravel in SDH 216, 3 miles southwest of Morristown in the Big Blue River valley. The extent of shallow bedrock near the drill hole has not been defined. Seven shallow test holes (auger holes 13, 14, 15, 16, 17, 46, 47; appendix 3) drilled with the Survey power auger indicate a potentially commercial deposit of sand and gravel near SDH 216.

SILURIAN SYSTEM

MISSISSINEWA SHALE MEMBER OF WABASH FORMATION

The Mississinewa ranges in thickness from 8 feet in SDH 11 northeast of Morristown, to 38 feet in SDH 216, 3 miles southwest of Morristown. It underlies the Geneva and is not generally suitable for aggregate because of its poor durability. But it is less clayey near its base than the overlying rock and might have limited use as aggregate.

The Mississinewa is gray fine-grained dolomite containing clay and quartz silt. Its thickness varies as a result of erosion before the deposition of the overlying Geneva. The Mississinewa is at the bedrock surface, mostly on the sides of the bedrock valley, in the southwestern half of the study area.

LOUISVILLE LIMESTONE

Louisville limestones are dolomitic, are buff to gray mottled, and mostly contain thin clayey laminations and small amounts of silica. The formation is 24 feet thick in SDH 205 near Carthage, where it is at the bedrock surface, and 27 feet thick in SDH 11 and SDH 216, where full, uneroded sections of limestone are present. Near Carthage in the SE¼ sec. 24, T. 15 N., R. 8 E. seismic and drilling data indicate that the Louisville is overlain by less than 20 feet of overburden (pl. 1*C*).

The Louisville is overlain by 38 feet of Mississinewa shaly dolomite and 34 feet of Geneva dolomite in SDH 216, 3 miles southwest of Morristown. The Mississinewa is not generally suitable for aggregate, and open-pit quarrying of the underlying Louisville in this area might not be economical. North of Knightstown, a thin section of

Louisville limestone may be present above the Waldron (pl. 1*D*), but this has not been substantiated by drilling.

WALDRON SHALE

The Waldron consists of gray calcareous shaly dolomite or dolomitic shale that is unsuitable for aggregate. It is 7 to 15 feet thick in core holes drilled in the study area. Waldron shale overlies limestone of the Laurel Member of the Salamonie Dolomite in much of the area and would have to be removed before the Laurel could be quarried.

LAUREL MEMBER OF SALAMONIE DOLOMITE

Laurel limestone is at or near the bedrock surface in much of the valley in the northeastern half of the study area (pl. 1*G*). The Laurel is gray to tan calcareous dolomite and dolomitic limestone containing abundant chert nodules and bands. It may contain thin argillaceous bands or laminations, especially near its base, where it grades into the shaly Osgood Member. The Laurel is thickest northeast of Knightstown; 82 feet of limestone was measured in a core from SDH 123 near Spiceland, but only 43 feet was cored in SDH 216 near Morristown, where it is overlain by more than 100 feet of younger rocks of Silurian and Devonian age.

Only the Laurel Member has been quarried in the Big Blue River valley. Prior to 1900, foundation stone for a nearby mill was taken from the quarry (now filled in) 3 miles north of Knightstown. The stone was probably also used for foundations of nearby homes. Laurel limestone from this quarry was calcined for lime (Ault, Rooney, and Palmer, 1974, appendix), but most of the Laurel is not pure enough for modern uses of lime.

The Laurel contains a variable amount of chalky, porous chert, which, in parts of the formation, exceeds 3 percent of the rock volume, the maximum amount accepted by the Indiana State Highway Commission for aggregate to be used in concrete or bituminous mixtures.

Less than 20 feet of unconsolidated sediments have been mapped near the quarry north of Knightstown and in the area east of Knightstown (pl. 1*E*). In other areas of thin overburden where the Laurel underlies the Louisville Limestone and the Waldron Shale, the Laurel may have commercial potential if the Waldron can be removed economically.

OSGOOD MEMBER OF SALAMONIE DOLOMITE

The Osgood Member is composed of interlayered gray to gray-green limestone and dolomite and calcareous or dolomitic shale. It is a poor source of aggregate. Thin shaly laminations are found in many places within the limestone and dolomite. The Osgood ranges from about 5 to 17 feet in thickness.

BRASSFIELD LIMESTONE

The Brassfield in the Big Blue River valley averages about 10 feet in thickness. It is coarse-grained gray limestone containing large crystals of yellow to brassy calcite. It commonly contains some thin shale bands or partings. The Brassfield might be used for small amounts of aggregate, but the overlying shaly Osgood would have to be wasted. It is not found near the surface in the study area, and its potential for commercial use is poor.

ORDOVICIAN SYSTEM

Cincinnatian rocks subjacent to the Brassfield Limestone consist of interbedded shale and limestone. The fossiliferous limestone beds exceed half a foot in thickness in few places and contain significant amounts of shale and argillaceous laminae. The rock is unsuitable for aggregate.

CHEMICAL COMPOSITION OF SILURIAN AND DEVONIAN ROCKS

The carbonate rocks of Silurian and Devonian age in the Big Blue River valley are mostly dolomite or dolomitic limestone. Much of the Geneva dolomite in SDH 11 and SDH 216 and the Louisville dolomite in SDH 205 is high purity, containing 95 percent or more $CaCO_3 + MgCO_3$ (appendix 5). Sixteen feet of Geneva dolomite in SDH 11 and 20 feet in SDH 216 average nearly 42 percent $MgCO_3$, suitable for many chemical uses for dolomite. Although the Louisville dolomite in SDH 205 is not high magnesium (more than 42 percent $MgCO_3$), it may be suitable for some chemical uses. (See discussion of uses of dolomite in Rooney, 1970, and Industrial Minerals, 1976.) Other rock units having potential for commercial chemical use, mostly dolomite and limestone of the Laurel Member, contain varying amounts of impurities. Chert is the main contaminant in the Laurel.

Economic Considerations

ACQUISITION OF RESERVES

Prices for crushed stone and processed sand and gravel in Indiana usually reflect the cost of producing and transporting the stone much more than they reflect the cost of land acquisition, but exploitable reserves may be more valuable where commercial stone reserves are scarce. Scarcities can be caused by (1) thick overburden over much of the bedrock, (2) limited areal extent of good-quality stone reserves, (3) land-use pressures, and (4) zoning restrictions.

Only a few areas in the Big Blue River valley have good sources of crushed stone near the surface. Sand and gravel, however, are more plentiful and can be found in commercial quantities in several parts of the valley. There is an increasing trend for companies mining sand and gravel to open quarries in the base of sand and gravel pits if the underlying bedrock is suitable for aggregate. This method of exploitation could be practiced in several parts of the Big Blue River valley.

It is unlikely, then, that the scarcity of crushed-stone sources at or near the surface will cause an increase in land values in the valley. We have observed that land for new quarry sites in rural areas in Indiana is seldom purchased for much more than its value as farmland, and we can foresee no land-use or zoning problems that would seriously block the purchase of aggregate reserves.

TRANSPORTATION

Class A crushed stone is now trucked into the market area east of Indianapolis and near the study area from quarries as far distant as Bartholomew and Madison Counties. Commercial crushed stone used primarily for road metal is imported from southern Hamilton County. Sand and gravel, however, are seldom shipped so far, although specialty products, such as mason's sand, may be transported a distance of 20 miles if there is the possibility of carrying a return load.

In the fall of 1972, a market survey in Greenfield and other towns near the study area revealed that common sizes of crushed stone could be purchased from local suppliers for $2.50 to $3.50 per ton, depending mostly on the distance of the local distribution point from the quarries where the crushed stone was obtained. Handling and transportation charges were then added for local delivery, except for the $3.50 charge, which included delivery within a few miles of Shelbyville. Two distributors added 50 cents per ton handling charge for the first 5 miles, 10 cents per ton for the sixth mile, and 5 cents per ton for each additional mile. One supplier charged 15 cents per ton-mile for local distribution. Trucking charges for sand and gravel were the same as for crushed stone, but common sizes of sand and gravel could be purchased at several localities for as little as $1.00 per ton f.o.b. the processing plant. Since this survey, inflation and higher costs for fuel have affected production and transportation costs in the aggregate industry, and some of the above figures have undoubtedly increased.

Our figures confirm the high cost of transportation reported for crushed stone and sand and gravel in Indiana in other recent studies (Carr, French, and Ault, 1971; French, 1969). In fact, the cost of truck transportation can approach or exceed the cost of production in about 30 miles, and few quarries can compete with other quarries that are beyond this distance.

We believe that crushed-stone products from a quarry in the Big Blue River valley would find a ready market east of Indianapolis, near Greenfield, and in and near the study area, especially since the prices of crushed stone presently used in this area must include high transportation costs. The opportunity to sell the sand and gravel overlying the stone would certainly enhance the prospects for such a quarry.

Prospective Source Areas for Aggregate

SAND AND GRAVEL

All areas labeled "outwash sand and gravel" on the surficial geologic map (pl. 1*C*), mostly exposures of the Atherton Formation, have excellent potential for sand and gravel. Ten to forty feet of sand and gravel are found beneath a few feet of soil for the entire length of the study area; however, there is a greater percentage of sand and gravel in the unconsolidated materials in the southern part of the study area than in the northern part.

Shallow sand and gravel interbedded with till, silts, and some clay are found in the area labeled "kame complex" directly southwest of Spiceland (pl. 1*C*). Our drill data here are sparse, and detailed test drilling would be necessary to outline any commercial deposits.

LIMESTONE AND DOLOMITE

Limestone and dolomite sources of crushed-stone aggregate are known to be less than 20 feet from the surface in three areas (pl. 1*E*): 3½ miles northeast of Knightstown in parts of secs. 12 and 13, T. 16 N., R. 9 E., 1 mile northeast of Knightstown in sec. 26, T. 16 N., R. 9 E., and one-half mile southwest of Carthage in sec. 24, T. 15 N., R. 8 E.

In the two areas near Knightstown, the Laurel Limestone Member has been core-drilled or quarried at or near the surface. Parts of the Laurel contain chert which may make the stone unsuitable for some uses of crushed stone. Louisville dolomite, a potential source of high-quality aggregate, was core-drilled from a depth of 19 to 43 feet in the area near Carthage.

Thirty-four feet of Geneva dolomite, another potential source of high-quality aggregate and possibly chemical stone, was cored from a depth of 26 to 60 feet south of Morristown in sec. 26, T. 14 N., R. 7 E. The bedrock in this area is overlain by sand and gravel, which makes possible a combined aggregate operation using both the sand and gravel and the underlying Geneva dolomite and perhaps deeper rock formations.

COMBINED SOURCES

Combined operations are possible wherever commercial deposits of sand and gravel make economical the removal of unconsolidated sediments from bedrock formations that can be used for crushed-stone products. The three areas with 40 feet or less of unconsolidated materials (pl. 1*E*), that is, north of Knightstown, at Carthage, and south of Morristown, have good potential for combined operations. Test drilling of the bedrock formations at any specific location would be necessary to determine their thickness and suitability for aggregate.

Influx of water through sand and gravel or bedrock fractures and solution channels could be a problem in deeply excavated pits because the water table in the valley is near the surface and interconnected porous bodies of sand and gravel may allow migrations of water from wide recharge surfaces or from the Big Blue River itself. Well-planned mining operations, however, can minimize and control the influx of water. Some operators have found it possible to control water problems in quarries that have as much as 100 feet of unconsolidated material above bedrock.

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Appendix 1. Descriptions of material encountered in auger borings

Auger hole 1 — Rush County

SW cor. sec. 17, T. 15 N., R. 9 E. Surface elevation, 905 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	8
Coarse- to medium-grained gravel		8	4
Medium-grained gravel and crumbly clay		12	3
Medium-grained gravel and coarse-grained sand		15	5
Coarse-grained sand and fine-grained sandy gravel		20	10
Sandy gravel		30	13
	Total depth	43	

Auger hole 2 — Rush County

SW cor. SE¼SE¼NE¼ sec. 19, T. 15 N., R. 9 E. Surface elevation, 911 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	5
Fine- to coarse-grained gravel		5	10
Coarse-grained gravel		15	3
Sand and hard black clay (shale?)		18	4
No penetration; bedrock or boulder bed		22	0
	Total depth	22	

Auger hole 3 — Rush County

NE cor. NW¼ sec. 30, T. 15 N., R. 9 E. Surface elevation, 895 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	5
Medium- to coarse-grained gravel		5	3
Clay and sand		8	15
No penetration; bedrock or boulder bed		23	0
	Total depth	23	

Auger hole 4 — Rush County

NW cor. sec. 30, T. 15 N., R. 9 E. Surface elevation, 882 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	5
Coarse-grained gravel		5	7
Fine-grained gravel		12	3
Clay, gray		15	7
No penetration; bedrock or boulder bed		22	0
	Total depth	22	

Appendix 1—Continued

Auger hole 5 – Rush County

SW cor. SE¼SW¼SE¼ sec. 24, T. 15 N., R. 8 E. Surface elevation, 860 ft

Material	Depth (ft)	Thickness (ft)
Soil and sand	0	10
Sand	10	6
No penetration; boulder bed	16	0
Total depth	16	

Auger hole 6 – Rush County

SE cor. SE¼SW¼NW¼ sec. 25, T. 15 N., R. 8 E. Surface elevation, 870 ft

Material	Depth (ft)	Thickness (ft)
Soil and clay	0	10
Clay, brown to black, crumbly but hard	10	8
Total depth	18	

Auger hole 7 – Shelby County

NW¼NW¼SW¼ sec. 26, T. 14 N., R. 7 E. Surface elevation, 802 ft

Material	Depth (ft)	Thickness (ft)
Soil	0	3
Sand	3	3
Gravel	6	16
Till, gray, pebbly	22	2
Total depth	24	

Auger hole 8 – Shelby County

SE¼NW¼SW¼NW¼ sec. 26, T. 14 N., R. 7 E. Surface elevation, 802 ft

Material	Depth (ft)	Thickness (ft)
Sandy alluvial soil	0	5
Sand	5	2
Gravelly sand, muddy, medium-grained, shaly	7	5
Sand; some medium-grained gravel	12	5
Sand?	17	6
Sand?	23	4
Hard; no sample	27	1
Coarse-grained gravel; no penetration	28	0
Total depth	28	

Appendix 1—Continued

Auger hole 9 — Shelby County

NW cor. SE¼NW¼SW¼ sec. 26, T. 14 N., R. 7 E.

Surface elevation, 800 ft

Material	Depth (ft)	Thickness (ft)
Soil	0	5
Sand, gray	5	5
Gravel	10	12
Till, hard	22	5
Sand	27	1
No penetration	28	0
Total depth	28	

Auger hole 10 — Henry County

NE¼NW¼NE¼ sec. 6, T. 16 N., R. 10 E.

Surface elevation, 995 ft

Material	Depth (ft)	Thickness (ft)
Soil	0	5
Gravel and coarse-grained sand	5	2
Gravel, coarse-grained, to 1½ in.	7	5
Sand, coarse-grained; becomes finer below	12	3
Sand, medium- to coarse-grained; some clay	15	2
Sand, medium- to coarse-grained; some clay increasing below	17	6
Gravel, coarse-grained	23	2
Till, gray, sandy, very hard	25	2
Total depth	27	

Auger hole 11 — Henry County

SE¼NE¼SE¼SW¼ sec. 6, T. 16 N., R. 10 E.

Surface elevation, 940 ft

Material	Depth (ft)	Thickness (ft)
Soil	0	5
Gravel, coarse-grained	5	2
Gravel, to ½ in., well-sorted, muddy; finer grained below	7	13
Clay	20	2
Till, gray, sandy, hard and dry	22	5
Total depth	27	

Auger hole 12 — Henry County

SE¼SE¼SE¼NW¼ sec. 1, T. 16 N., R. 9 E.

Surface elevation, 985 ft

Material	Depth (ft)	Thickness (ft)
Soil	0	7
Coarse-grained sand grading to gravel	7	5
Sand?; no sample; hard at 16	12	5
Total depth	17	

Appendix 1—Continued

Auger hole 13 – Henry County

NE¼SW¼NW¼NW¼ sec. 12, T. 16 N., R. 9 E.

Surface elevation, 960 ft

Material		Depth (ft)	Thickness (ft)
Soil, clayey		0	7
Gravel, very coarse grained; difficult to drill		7	5
Sand?, soft		12	3
Sand, brown, medium- to fine-grained; hard at top		15	3
Till, gray, pebbly		18	8
	Total depth	26	

Auger hole 14 – Henry County

NE¼NE¼SW¼SE¼ sec. 26, T. 16 N., R. 9 E.

Surface elevation, 942 ft

Material		Depth (ft)	Thickness (ft)
Clay, gray, pebbly		0	15
No penetration; bedrock?		15	0
	Total depth	15	

Auger hole 15 – Henry County

SW¼NE¼SW¼ sec. 26, T. 16 N., R. 9 E.

Surface elevation, 930 ft

Material		Depth (ft)	Thickness (ft)
Clay, brown, dry		0	13
Clay, gray, hard		13	5
No penetration		18	0
	Total depth	18	

Auger hole 16 – Henry County

NW¼NE¼SE¼SE¼ sec. 27, T. 16 N., R. 9 E.

Surface elevation, 918 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	4
Sand and gravel; becomes coarser below		4	10
No penetration; bedrock or hard till		14	0
	Total depth	14	

Auger hole 17 – Henry County

SE¼SE¼NW¼NE¼ sec. 27, T. 16 N., R. 9 E.

Surface elevation, 914 ft

Material		Depth (ft)	Thickness (ft)
Clay		0	6
Sand; some gravel		6	6
Sand; coarse-grained gravel		12	3
Clay, sandy		15	12
No penetration		27	0
	Total depth	27	

Appendix 1—Continued

Auger hole 18 – Henry County

SW¼NW¼SE¼ sec. 14, T. 16 N., R. 9 E.

Surface elevation, 955 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	5
Gravel		5	5
Clay, brown; some gravel		10	10
Clay, gray		20	3
	Total depth	23	

Auger hole 19* – Henry County

SE¼SW¼SE¼ sec. 15, T. 16 N., R. 9 E.

Material
Sand and gravel

*Abandoned; sample from stockpile at McNew gravel pit.

Auger hole 20 – Henry County

SE¼SW¼SW¼NE¼ sec. 27, T. 16 N., R. 9 E.

Surface elevation, 945 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	4
Gravel and sand		4	13
Gravel		17	13
Clay, gray, sandy, hard		30	3
	Total depth	33	

Auger hole 21 – Rush County

SW¼SW¼NE¼NW¼ sec. 4, T. 15 N., R. 9 E.

Surface elevation, 905 ft

Material		Depth (ft)	Thickness (ft)
Clay and sandy clay		0	10
Gravel, medium-grained		10	2
Clay, hard		12	2
	Total depth	14	

Auger hole 22 – Rush County

NE¼NW¼NE¼NE¼ sec. 8, T. 15 N., R. 9 E.

Surface elevation, 918 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	4
Sand; some clay and fine-grained gravel		4	11
Gravel and sand		15	5
Clay, sandy		20	10
Clay; some gravel		30	3
	Total depth	33	

Appendix 1—Continued

Auger hole 23 – Rush County

SE¼NE¼NW¼ sec. 17, T. 15 N., R. 9 E. Surface elevation, 905 ft

Material		Depth (ft)	Thickness (ft)
Soil and sand		0	5
Sand and fine-grained gravel		5	10
Sand		15	10
Sand and clay		25	2
	Total depth	27	

Auger hole 24 – Rush County

NW¼SW¼NE¼NE¼ sec. 17, T. 15 N., R. 9 E. Surface elevation, 933 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	5
Sand and gravel		5	4
Gravel, coarse-grained; boulders		9	2
No penetration; boulders crop out in farm road		11	0
	Total depth	11	

Auger hole 25 – Rush County

NE¼NW¼NE¼SW¼ sec. 17, T. 15 N., R. 9 E. Surface elevation, 908 ft

Material		Depth (ft)	Thickness (ft)
Clay, sand, and some gravel		0	10
Clay, dark-gray; becoming sandy		10	8
	Total depth	18	

Auger hole 26 – Rush County

SW¼SW¼SW¼SW¼ sec. 24, T. 15 N., R. 8 E. Surface elevation, 897 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	4
Gravel and sand		4	13
No penetration		17	0
	Total depth	17	

Auger hole 27 – Rush County

SE¼NE¼SE¼SE¼ sec. 27, T. 15 N., R. 8 E. Surface elevation, 880 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	4
Gravel, coarse-grained		4	2
Clay; some fine-grained gravel		6	3
Clay, brown; fine-grained gravel		9	4
Clay, gray, hard		13	11
	Total depth	24	

Appendix 1—Continued

Auger hole 28 — Rush County

NE¼NE¼NE¼ sec. 10, T. 14 N., R. 8 E.

Surface elevation, 905 ft

Material		Depth (ft)	Thickness (ft)
Clay, brown		0	7
Clay, brown, sandy		7	3
Till, gray		10	7
	Total depth	17	

Auger hole 29 — Rush County

SE¼NE¼NE¼ sec. 35, T. 15 N., R. 8 E.

Surface elevation, 912 ft

Material		Depth (ft)	Thickness (ft)
Soil, reddish, sandy		0	9
Sand, coarse-grained; clay and gravel		9	6
Clay?		15	2
Till, gray		17	3
	Total depth	20	

Auger hole 30 — Hancock County

SE¼SE¼SE¼SE¼ sec. 28, T. 15 N., R. 8 E.

Surface elevation, 855 ft

Material		Depth (ft)	Thickness (ft)
Soil, red, clayey; becoming sandy at base		0	7
Clay, brown, hard		7	6
Till, gray, hard		13	1
	Total depth	14	

Auger hole 31 — Hancock County

SW¼SE¼SE¼NE¼ sec. 28, T. 15 N., R. 8 E.

Surface elevation, 857 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	3
Gravel, clayey		3	7
Gravel, coarse-grained; 3 to 4 in. in diameter		10	5
Sand		15	5
Till, gray		20	3
	Total depth	23	

Auger hole 32 — Hancock County

SW¼SW¼SW¼SW¼ sec. 28, T. 15 N., R. 8 E.

Surface elevation, 841 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	5
Clay, gravel		5	5
Gravel, clean, coarse-grained		10	8
Clay		18	0
	Total depth	18	

Appendix 1—Continued

Auger hole 33 – Hancock County

NE¼NE¼NE¼SW¼ sec. 32, T. 15 N., R. 8 E. Surface elevation, 848 ft

Material	Depth (ft)	Thickness (ft)
Soil	0	5
Gravel, fine-grained, and sandy clay	5	7
Gravel	12	3
Clay (till?)	15	2
Gravel	17	1
Clay (till), gray	18	5
Total depth	23	

Auger hole 34 – Hancock County

NE¼NE¼NE¼SW¼ sec. 31, T. 15 N., R. 8 E. Surface elevation, 842 ft

Material	Depth (ft)	Thickness (ft)
Soil	0	3
Gravel, medium- to coarse-grained	3	7
Gravel, coarse-grained	10	3
Clay	13	17
Total depth	30	

Auger hole 35 – Shelby County

SW¼SW¼SW¼SE¼ sec. 2, T. 14 N., R. 7 E. Surface elevation, 835 ft

Material	Depth (ft)	Thickness (ft)
Soil, brown, clayey	0	3
Clay, red-brown	3	4
Gravel, medium-grained	7	5
Gravel, coarse-grained	12	6
Gravel, medium- to fine-grained	18	5
Till, clayey	23	0
Total depth	23	

Auger hole 36 – Hancock County

NW¼NE¼NE¼SE¼ sec. 35, T. 15 N., R. 7 E. Surface elevation, 846 ft

Material	Depth (ft)	Thickness (ft)
Clay, brown	0	5
Clay, gravelly; coarse-grained gravel; very hard at 8 to 10 ft	5	5
Gravel	10	8
Gravel, coarse-grained; becomes finer grained below; very hard at 28 ft	18	10
Total depth	28	

Appendix 1—Continued

Auger hole 37 — Hancock County

NE¼NW¼SE¼ sec. 36, T. 15 N., R. 7 E. Surface elevation, 830 ft

Material	Depth (ft)	Thickness (ft)
Soil	0	3
Clay and gravel	3	4
Clay, gray; grading to muck	7	5
Gravel, coarse-grained	12	6
Clay, stiff	18	2
Total depth	20	

Auger hole 38 — Shelby County

SW¼SE¼SE¼SW¼ sec. 1, T. 14 N., R. 7 E. Surface elevation, 841 ft

Material	Depth (ft)	Thickness (ft)
Clay, red, pebbly	0	5
Gravel, coarse-grained; becoming coarser grained below	5	37
Till, red-brown, clayey; gray till on bit	42	0
Total depth	42	

Auger hole 39 — Shelby County

SW¼SE¼SW¼SE¼ sec. 11, T. 14 N., R. 7 E. Surface elevation, 820 ft

Material	Depth (ft)	Thickness (ft)
Fill	0	5
Could not penetrate subgrade; moved 10 ft and still could not penetrate	5	0
Total depth	5	

Auger hole 40 — Shelby County

SW¼NE¼NW¼ sec. 14, T. 14 N., R. 7 E. Surface elevation, 820 ft

Material	Depth (ft)	Thickness (ft)
Soil, red; sandy clay	0	10
Gravel	10	2
Gravel, medium-grained, muddy	12	11
Clay	23	2
Total depth	25	

Auger hole 41 — Shelby County

SE¼SE¼NW¼ sec. 23, T. 14 N., R. 7 E. Surface elevation, 815 ft

Material	Depth (ft)	Thickness (ft)
Soil, red, clayey	0	4
Gravel; hard to drill at 10 ft	4	11
Clay; some very coarse grained gravel	15	3
Total depth	18	

Appendix 1—Continued

Auger hole 42 – Henry County

SE¼SE¼SW¼NE¼ sec. 28, T. 16 N., R. 9 E. Surface elevation, 962 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	5
Gravel		5	5
Sand and gravel		10	2
Gravel; cobbles		12	1
No penetration		13	0
	Total depth	13	

Auger hole 43 – Rush County

NW¼NW¼NE¼ sec. 5, T. 15 N., R. 9 E. Surface elevation, 935 ft

Material		Depth (ft)	Thickness (ft)
Soil and sand		0	5
Sand and gravel		5	9
Clay, hard		14	1
	Total depth	15	

Auger hole 44 – Rush County

SE¼SE¼SW¼SE¼ sec. 7, T. 15 N., R. 9 E. Surface elevation, 935 ft

Material		Depth (ft)	Thickness (ft)
Soil and sand		0	6
Sand and gravel		6	4
Gravel, coarse-grained		10	1
Clay, very hard, sandy		11	2
	Total depth	13	

Auger hole 45 – Hancock County

SW¼SW¼SE¼SE¼ sec. 36, T. 15 N., R. 7 E. Surface elevation, 842 ft

Material		Depth (ft)	Thickness (ft)
Soil		0	4
Gravel and sand		4	6
Sand; some gravel		10	8
Sand and gravel		18	11
Gravel?, coarse-grained		29	1
	Total depth	30	

Appendix 1—Continued

Auger hole 46 — Shelby County

SW¼SW¼SW¼NW¼ sec. 26, T. 14 N., R. 7 E. Surface elevation, 805 ft

Material	Depth (ft)	Thickness (ft)
Soil	0	3
Sand and gravel; yellow mud	3	4
Gravel, coarse-grained, and brown sand	7	5
Gravel and sand; no penetration at 14 ft	12	2
Total depth	14	

Auger hole 47 — Shelby County

SE¼SE¼SE¼NE¼ sec. 27, T. 14 N., R. 7 E. Surface elevation, 810 ft

Material	Depth (ft)	Thickness (ft)
Soil	0	3
Gravel, coarse-grained; no penetration beyond 7 ft	3	4
Total depth	7	

Auger hole 48 — Shelby County

NE¼NE¼SW¼ sec. 27, T. 14 N., R. 7 E. Surface elevation, 800 ft

Material	Depth (ft)	Thickness (ft)
Fill, gravel	0	5
Sand, gray	5	2
Gravel, medium- to coarse-grained	7	7
No penetration	14	0
Total depth	14	

Survey drill hole 203 — Rush County

NW¼NE¼ sec. 25, T. 15 N., R. 8 E. Surface elevation, 875 ft

Material	Depth (ft)	Thickness (ft)
Fill	0	6
Clay, sandy	6	6
Sand and gravel	12	4
Till, hard, gray, sandy	16	9
Sand and till	25	24.5
Chert	49.5	.5
Total depth	50	

Appendix 1—Continued

Irving pit – Henry County

NW¼SW¼ sec. 7, T. 16 N., R. 10 E. — Surface elevation, 1,050±? ft

Material	Depth (ft)	Thickness (ft)
Soil, sand, and gravel	0	2
Till, brown, pebbly, blocky	2	4
Sand, fine-grained	6	.1
Gravel, medium-grained	6.1	3.9
Sand, medium-grained	10	2
Gravel, medium- to coarse-grained, bedded	12	3
Total depth	15	

Survey drill hole 215 – Rush County

SW¼SW¼SW¼ sec. 4, T. 15 N., R. 9 E. — Surface elevation, 881 ft

Material	Depth (ft)	Thickness (ft)
Sand, muddy, brown; some gravel, noncalcareous	0	5
Sand and gravel, brown, very muddy, noncalcareous	5	5
Sand, gray, very muddy, calcareous	10	10
Gravel, medium-grained (½ in.); limestone and crystalline rock pebbles	20	9
Limestone bedrock	29	0
Total depth	29	

Appendix 2. Gradations of sand and gravel samples from augering

Auger hole	1	2	2	2	3	3	4	10	10
Depth (ft)	4-12	10-15	15-18	18-22	5- 8	8-15	12-15	5-10	16-20
Coarse fraction									
Size									
+ 1 in.	18.2	6.6	9.8	0	3.1	58.4	0		
+ ½ in.	27.5	43.9	64.9	43.1	45.0	28.6	33.9		
+ 3/8 in.	54.3	49.5	25.3	56.9	51.9	13.0	66.1		
Total % coarse	100.0	100.0	100.0	100.0	100.0	100.0	100.0		
Ratio of fine (sand)/coarse (gravel)	64/36	44/56	49/51	80/20	36/64	16/84	57/43	92/ 8	99/ 1
Fine fraction									
U.S. standard sieve									
+ No. 4	19.2	37.0	30.8	9.9	21.7	11.5	30.8	6.1	6.9
+ No. 10	33.9	31.1	29.4	52.4	21.1	17.8	33.4	23.8	15.3
+ No. 18	20.3	10.9	16.3	22.3	13.6	16.6	14.4	41.8	16.9
+ No. 35	11.1	8.6	11.6	5.6	11.9	15.9	7.6	20.8	31.0
+ No. 70	6.0	6.1	5.7	2.6	12.2	14.0	3.7	4.3	22.4
+ No. 100	2.5	1.6	1.6	1.9	8.1	8.9	1.9	.5	1.9
pan	7.2	4.8	4.3	5.2	11.9	14.6	8.2	3.0	4.3
Total % fine	100.2	100.1	99.7	99.9	100.5	99.3	100.0	100.3	98.7

Appendix 2—Continued

Auger hole	12	16	16	17	18	20	20	21	22
Depth (ft)	12-16	8-12	12-14	6-12	5-10	5-12	12-17	2-12	4- 5
Coarse fraction									
Size									
+ 1 in.	0			0		0	13.8		16.1
+ ½ in.	23.6			45.5		18	50.8		49.3
+ 3/8 in.	76.4			54.5		82	35.7		34.1
Total % coarse	100.0			100.0		100	100.3		99.5
Ratio of fine (sand)/coarse (gravel)	66/34	81/19	94/ 6	70/30	86/14	54/46	68/32	78/22	78/22
Fine fraction									
U.S. standard sieve									
+ No. 4	38.8	19.7	12.5	12.6	26.9	32.2	43.0	36.8	21.1
+ No. 10	32.0	20.0	30.2	26.0	33.7	35.0	27.9	37.3	30.5
+ No. 18	15.8	15.9	26.5	31.0	19.3	16.7	14.4	12.4	22.9
+ No. 35	7.7	23.0	17.2	20.3	10.4	6.5	6.9	4.8	12.9
+ No. 70	2.9	14.0	7.3	5.6	4.3	3.3	2.8	2.3	9.3
+ No. 100	.6	1.8	1.1	.9	.8	1.1	.6	.9	.9
pan	2.1	4.9	3.9	3.4	4.0	6.3	3.5	4.6	2.5
Total % fine	99.9	99.3	98.7	99.8	99.4	101.1	99.1	99.1	100.1

Appendix 2—Continued

Auger hole	23	24	29	36	36	38
Depth (ft)	15-25	5-11	9-12	5- 8	10-28	5-12
Coarse fraction						
Size						
+ 1 in.			0	6.1		21.1
+ ½ in.			75	59.3		56.9
+ 3/8 in.			25	34.8		22.0
Total % coarse			100	100.2		100.0
Ratio of fine (sand)/coarse (gravel)	99/ 1	85/15	87/13	42/58	65/35	34/66
Fine fraction						
U.S. standard sieve						
+ No. 4	3.3	15.3	14.5	18.6	57.0	20.0
+ No. 10	7.2	23.1	24.7	21.1	17.4	31.8
+ No. 18	7.2	20.5	19.1	25.9	9.0	22.7
+ No. 35	10.3	23.5	11.4	19.4	7.1	16.4
+ No. 70	44.5	13.9	14.7	8.7	3.6	5.2
+ No. 100	14.6	.9	3.6	2.0	.9	.8
pan	11.3	2.1	8.2	5.7	4.6	3.2
Total % fine	98.4	99.3	96.2	101.4	99.6	100.1

Appendix 2—Continued

Auger hole	40	41	42	43	44	44	45
Depth (ft)	10-23	5-15	5-10	5-14	6-10	10-11	6-10
Coarse fraction							
Size							
+ 1 in.		22.0	46.4			24.3	
+ ½ in.		50.4	45.8			54.6	
+ 3/8 in.		27.7	7.9			20.1	
Total % coarse		100.1	100.1			99.0	
Ratio of fine (sand)/coarse (gravel)	98/ 2	72/28	34/66	82/18	79/21	67/33	53/47
Fine fraction							
U.S. standard sieve							
+ No. 4	3.1	27.8	26.0	22.5	42.8	26.5	29.9
+ No. 10	14.7	31.9	23.0	28.4	33.1	37.1	25.1
+ No. 18	29.4	16.9	14.6	17.3	10.4	21.3	16.1
+ No. 35	27.4	11.0	12.6	11.3	4.1	6.6	13.3
+ No. 70	18.1	4.8	11.2	15.2	2.7	2.8	7.0
+ No. 100	3.0	1.1	4.0	2.0	1.0	0.7	1.3
pan	4.6	5.9	8.0	2.6	5.3	4.3	5.2
Total % fine	100.3	99.4	99.4	99.3	99.4	99.3	97.9

Appendix 2–Continued

Auger hole	45	46	48	50*	55*	56*	57*	59*
Depth (ft)	10-18	4-14	5-14					
Coarse fraction								
Size								
+ 1 in.	26.8	20.5	61.7		11.0	20.9	46.7	36.8
+ ½ in.	45.0	44.5	26.6		53.2	49.8	26.8	39.9
+ 3/8 in.	28.2	35.0	11.6		35.8	29.3	27.3	23.2
Total % coarse	100.0	100.0	99.9		100.0	100.0	100.8	99.9
Ratio of fine (sand)/coarse (gravel)	79/21	75/25	46/54	97/ 3	89/11	78/22	85/15	77/23
Fine fraction								
U.S. standard sieve								
+ No. 4	21.5	26.6	36.9	7.5	14.9	19.3	29.9	17.8
+ No. 10	29.2	28.2	22.0	21.4	19.5	25.5	35.6	20.7
+ No. 18	19.9	19.9	17.5	28.6	17.4	18.4	19.1	17.4
+ No. 35	12.7	12.4	13.1	29.5	20.0	18.9	7.6	17.1
+ No. 70	8.0	9.0	6.3	11.4	21.9	14.2	3.3	24.2
+ No. 100	3.9	1.0	.9	.6	3.0	1.5	1.4	1.6
pan	3.8	2.5	2.9	.8	2.3	1.9	2.7	.8
Total % fine	99.0	99.6	99.6	99.8	99.0	99.7	99.6	99.6

*Samples from outcrops in gravel pits and excavations: 50, Irving; 55, Kennedy; 56, Alexander; 57, Goose Creek Dam; 59, Hartman Materials.

Appendix 3. Lithology of selected samples

	Auger hole							
	2	3	10	12	16	18	20	22
Depth of sample (ft)	3- 8	3- 8	5-17	12-16	9-14	5-10	5-12	4-15
Dolomite (pct)	60.6	54.5	60.8	52.4	45.4	59.1	56.7	46.0
Limestone (pct)	15.4	14.7	12.4	18.8	20.4	17.4	16.6	24.0
Chert (pct)	6.5	3.9	10.3	8.8	10.2	6.8	8.7	8.0
Igneous and metamorphic (pct)	8.6	14.7	9.3	8.2	13.9	9.8	7.9	18.0
Quartz and quartzite (pct)	2.9	0.9	0.0	4.1	3.7	3.0	3.1	2.0
Sandstone and conglomerate (pct)	2.5	8.2	5.2	2.9	3.7	1.3	3.4	2.0
Siltstone (pct)	0.7	1.2	0.0	0.0	0.9	0.0	1.9	0.0
Shale (pct)	2.5	0.0	2.1	3.5	0.9	2.1	1.2	0.0
Unidentifiable and others (pct)	0.4	1.7	0.0	0.0	0.9	0.4	0.5	0.0
Total (pct)	100.1	99.8	100.1	98.7	100.0	99.9	100.0	100.0
Number of pebbles counted	279	231	97	170	108	235	416	113

APPENDIX 3

of sand and gravel from augering

Auger hole											
29	34	36	36	38	41	42	43	44	45	46	48
9-17	3-13	5- 8	15-18	5-12	4-12	10-12	5-14	10-12	4-10	3-14	5-14
58.2	45.0	58.6	50.0	51.7	56.0	46.0	56.8	56.4	47.6	47.0	52.2
13.7	19.0	14.8	19.0	16.1	9.6	16.8	19.7	14.7	21.4	12.0	19.0
7.7	19.0	7.0	13.0	9.3	13.6	12.4	7.1	9.0	8.5	23.0	12.1
7.1	10.0	10.9	12.0	12.8	10.6	17.7	7.4	12.3	13.6	8.0	10.8
6.6	4.0	2.3	2.0	3.4	3.5	0.0	2.9	2.8	3.4	5.0	2.2
4.4	1.0	5.5	1.0	4.7	4.5	4.4	3.2	3.3	3.7	1.0	0.4
1.1	2.0	1.6	1.0	0.6	0.0	0.9	1.0	1.4	0.0	1.0	0.9
1.1	0.0	0.0	0.0	0.0	0.0	0.9	1.3	0.0	0.3	1.0	1.7
0.0	0.0	0.0	0.0	1.3	0.0	0.9	0.0	0.0	0.0	1.0	0.0
99.9	100.0	100.7	98.0	99.9	97.8	100.0	99.4	99.9	98.5	99.0	99.3
182	280	128	181	149	198	113	310	211	294	322	232

Appendix 4. Descriptions of Devonian, Silurian, and Ordovician rocks in the Big Blue River valley

Section 1. Log of samples and core from Survey drill hole 123 near Spiceland (150 ft FSL × 160 ft FWL sec. 12, T. 16 N., R. 9 E.). Modified from a description by Robert R. French, August 1964. Surface elevation, 917 ft.

	Depth (ft)	Thickness (ft)
Silurian System:		
Salamonie Dolomite, Laurel Member, 82.3 ft:		
1. Dolomite, gray to tan, porous; brachiopod molds and crinoid columnals in part; chert, white to gray, weathered and chalky in part	11.0	52.9
2. Dolomite, gray to blue-gray, vuggy, stylolitic; slightly mottled and cherty in basal 10 ft	63.9	29.4
Salamonie Dolomite, Osgood Member?, 12.3 ft:		
3. Dolomite, dark-gray, fine- to medium-grained; shaly laminae; glauconite; very shaly in lower 3 ft	93.3	11.0
4. Shale, gray-green	104.3	1.3
Brassfield Limestone, 8.5 ft:		
5. Limestone, dolomitic, light-brown to brown, coarse-grained, crystalline, shaly at top, stylolitic, fossiliferous; pyrite; chert at base	105.6	8.5
Ordovician System:		
Cincinnatian rocks, 2.1 ft cored:		
6. Shale, gray to green, very fossiliferous	114.1	2.1
Total depth	116.2	

Section 2. Log of core from Survey drill hole 214 near Knightstown (1,100 ft FSL × 200 ft FWL SW¼SW¼ sec. 26, T. 16 N., R. 9 E.). Surface elevation, 915 ft.

	Depth (ft)	Thickness (ft)
Silurian System:		
Waldron Shale, 0.5 ft cored:		
1. Shale, gray to green-gray, calcareous in part, pyritic, soft. (Samples indicate Waldron Shale may have been drilled from about 20 ft to where coring was started at 30.0 ft.)	30.0	0.5
Salamonie Dolomite, Laurel Member, 80.9 ft:		
2. Dolomite, gray, mostly fine-grained, porous and vuggy in part; recrystallized with many dolomite rhombs; fossil relicts	30.5	6.3
3. Dolomite, similar to above; a few clayey bands; chert which is chalky in part	36.8	38.7
4. Dolomite, mostly blue-gray and very fine grained; small vugs in part; a few thin shale laminae; chert nodules at 80.0 and 100.5 ft	75.5	35.9
Salamonie Dolomite, Osgood Member?, 4.2 ft:		
5. Dolomite and shale, interbedded; gradational contacts. Dolomite is gray green and clayey; shale is dolomitic; fine-grained pyrite and quartz silt are present	111.4	4.2
Brassfield Limestone, 9.2 ft:		
6. Limestone, dolomitic in part, gray and tan to brassy yellow, medium- to coarse-grained, crystalline; small shells and fossil hash in part; clayey near base	115.6	9.2

Appendix 4–Continued

Section 2–Continued

	Depth (ft)	Thickness (ft)
Ordovician System:		
Cincinnatian rocks, 35.2 ft cored:		
7. Limestone, tan to green; very shaly with thin shale laminations and bands throughout; large brachiopods and other shell fragments	124.8	5.6
8. Mudstone, shale, and limestone, interbedded; shale and mudstone are gray; contains brachiopods and other shells in part; limestone is blue gray, skeletal, and shaly	130.4	29.6
Total depth	160.0	

Section 3. Log of core from Survey drill hole 205 near Carthage (22 ft FSL X 275 ft FEL SE¼SW¼ sec. 24, T. 15 N., R. 8 E.). Surface elevation, 863 ft.

	Depth (ft)	Thickness (ft)
Silurian System:		
Louisville Limestone, 23.8 ft:		
1. Dolomite, calacareous to very calcareous, light-brown, faintly mottled, fine-grained; a few vugs; stylolites	19.0	5.2
2. Dolomite, very calcareous, blue-gray to light-brown mottled, fine-grained; some vugs, pyrite, and stylolites	24.2	18.6
Waldron Shale, 10.2 ft:		
3. Dolomite, calcareous, clayey with gray bands; pyrite; apparent worm-borrow structures	42.8	10.2
Salamonie Dolomite, Laurel Member, 61.5 ft:		
4. Dolomite, calcareous, blue-gray to gray, slightly mottled; fine- to coarse-grained crystals; a few vugs and fossil outlines; pyrite; stylolites	53.0	4.8
5. Dolomite, calcareous; light-tan to gray; similar to above; contains porcelaneous and weathered chert ranging from less than 10 percent to nearly 30 percent of rock volume	57.8	31.2
6. Dolomite, calcareous, blue-gray to gray, fine-grained; a few vugs and a trace of pyrite	89.0	25.5
Salamonie Dolomite, Osgood Member?, 4.9 ft:		
7. Dolomite, very calcareous, gray and green-gray, fine-grained, clayey	114.5	4.9
Brassfield Limestone, 15.3 ft:		
8. Shale and bands of limestone. Shale is green gray and calcareous in part with a few shell fragments. Limestone is brassy yellow, coarse grained, and crystalline; contains glauconite	119.4	6.4
9. Limestone, dolomitic in part, gray to brown, fossiliferous in part, coarse-grained and crystalline in part; clay laminations; glauconite	125.8	8.9
Ordovician System:		
Cincinnatian rocks, 45.3 ft cored:		
10. Limestone, light-gray, very fine grained; shell fragments; a few clayey thin laminae	134.7	1.7
11. Shale, gray to gray-green, slightly calcareous, very silty in part; trace of pyrite	136.4	16.5
12. Shale and limestone, interbedded; shale is green gray, calcareous, and fossiliferous in part; limestone is skeletal and shaly	152.9	27.1
Total depth	180.0	

Appendix 4—Continued

Section 4. Log of core from Survey drill hole 11 (10 ft FNL X 330 ft FEL NE¼SE¼ sec. 28, T. 15 N., R. 8 E.). Surface elevation, 852 ft. Modified from logs by Robert H. Shaver (Shaver and others, 1961, p. 61, 62) and John B. Patton, August 1963.

	Depth (ft)	Thickness (ft)
Devonian System:		
Jeffersonville Limestone, Geneva Dolomite Member, 20.1 ft cored:		
1. Dolomite, tan and brown, granular; bedding absent or indistinct; has crystalline calcite intercalations; vuggy in part; becomes very sandy in bottom few feet	50.2	20.1
Silurian System:		
Wabash Formation, Mississinewa Shale Member, 8.5 ft:		
2. Dolomite, argillaceous, silty, gray, very fine grained, pyritic; bedding absent or indistinct	70.3	8.5
Louisville Limestone, 27.0 ft:		
3. Limestone, dolomitic, and calcareous dolomite; gray and tan, mottled and banded, fine grained, stylolitic	78.8	27.0
Waldron Shale, 14.7 ft:		
4. Limestone, dolomitic, very argillaceous, silty, gray, fine-grained, fossiliferous in part	105.8	13.9
5. Shale, very calcareous, gray and gray-green	119.7	0.8
Salamonie Dolomite, Laurel Member, 45.0 ft:		
6. Limestone, dolomitic, and calcareous dolomite; in several discernible units as much as a few feet thick; variably light gray, dark gray, gray, and tan mottled, gray; cherty and noncherty; fine grained to coarse grained; stylolitic in part	120.5	45.0
Salamonie Dolomite, Osgood Member?, 17.2 ft:		
7. Limestone, dolomitic, banded and mottled gray and tan to tan throughout, dense and argillaceous to coarse-grained; thin bedded in part	165.5	10.0
8. Interbedded shale and dolomitic limestone; shale is green, calcareous, fossiliferous, and thinly interbedded in part with argillaceous limestone	175.5	7.2
Brassfield Limestone, 9.6 ft:		
9. Limestone, tan, dark-gray-brown and tan, medium- to coarse-grained, glauconitic, fossliferous and stylolitic in part; has wavy argillaceous partings	182.7	9.6
Ordovician System:		
Cincinnatian rocks, 28.0 ft cored:		
10. Shale, green-gray, calcareous, fossiliferous; has thin intercalations of fossiliferous limestone	192.3	3.1
11. Shale, grayish-olive-green, noncalcareous	195.4	19.7
12. Shale and limestone, thinly interbedded, fossiliferous; shale is gray and calcareous; limestone is dark gray and coarse grained	215.1	5.2
Total depth	220.3	

Appendix 4—Continued

Section 5. Log of core from Survey drill hole 216 near Morristown (280 ft FNL × 440 ft FWL NW¼SW¼ sec. 26, T. 14 N., R. 7 E.). Surface elevation, 798 ft.

	Depth (ft)	Thickness (ft)
Devonian System:		
Jeffersonville Limestone, Geneva Dolomite Member, 33.8 ft:		
1. Dolomite, calcareous at top, brown, fine-grained, sucrosic-textured; euhedral dolomite rhombs; vuggy; recrystallized fossils; calcite filling in some vugs	26.0	33.8
Silurian System:		
Wabash Formation, Mississinewa Shale Member, 38.4 ft:		
2. Dolomite, argillaceous to very argillaceous, calcareous in part, gray and green-gray, slightly mottled, dense to very fine grained	59.8	18.4
3. Dolomite, similar to above; green gray; becoming less argillaceous toward base; zones of dolomitic limestone; glauconite; pyrite	78.2	20.0
Louisville Limestone, 26.5 ft:		
4. Limestone, dolomitic in part, blue-gray to tan, mottled, mostly dense to fine-grained; clayey laminations and coatings; slightly fossiliferous	98.2	26.5
Waldron Shale, 7.3 ft:		
5. Limestone, dolomitic, buff, dense to very fine grained; gray and green argillaceous bands; unit becomes more shaly toward base	124.7	7.3
Salamonie Dolomite, Laurel Member, 43.3 ft:		
6. Dolomite, calcareous, and dolomitic limestone; light buff, dense to fine grained; sparsely fossiliferous; trace of pyrite	132.0	9.8
7. Dolomite, similar to above; contains 10 to 15 percent chert, which is mostly chalky and occurs as nodules and bands as much as 1½ in. thick	141.8	2.2
8. Limestone, dolomitic, blue-gray to buff, mottled, dense to medium-grained, fossiliferous in part; slightly argillaceous in part; stylolitic in part	144.0	31.3
Salamonie Dolomite, Osgood Member, 16.6 ft:		
9. Limestone, dolomitic; shaly laminations and bands; most of the limestone is buff, dense to medium grained, fossiliferous in part; some dolomitic zones are fine grained with sucrosic texture; some chalky chert	175.3	16.6
Brassfield Limestone, 8.1 ft:		
10. Limestone, dolomitic at base, gray to brown and buff, fine- to medium-grained; fossiliferous in part; shaly laminae; glauconite	191.9	8.1
Ordovician System:		
Cincinnatian rocks, 20.0 ft cored:		
11. Shale-mudstone, gray, slightly laminated, slightly calcareous	200.0	7.5
12. Shale and limestone, interbedded; shale is gray green with calcitic lenses; limestone is buff to blue gray with shale included; contains many fossils, mostly shells and small corals	207.5	12.5
Total depth	220.0	

Appendix 5. Spectrochemical analyses (in percent) of Devonian and Silurian rocks

Survey drill hole 123
150 ft FSL × 160 ft FWL sec. 12, T. 16 N., R. 9 E.

Rock unit and sample number		Depth (ft)	Thickness (ft)	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	S	Chemical CO_2
Salamonie Dolomite,		11.0	9.0[1]									
Laurel Member	RF64-331	20.0	9.0	36.8	29.9	32.2	.27	.31	nd[2]	.014	.087	30.6
	330	29.0	2.8	55.4	39.9	3.45	.35	.30	nd	.017	.10	45.2
	329	31.8	4.2	44.5	29.7	24.8	.22	.29	nd	.014	.094	35.1
		36.0	4.0[3]									
	328	40.0	4.7	45.3	28.5	24.8	.48	.45	nd	.014	.10	34.8
		44.7	19.2[3]									
	327	63.9	2.7	55.1	37.8	5.08	.85	.67	.065	.020	.23	44.2
	326	66.6	3.4	55.2	37.6	5.31	.76	.55	.077	.021	.19	44.4
	325	70.0	7.3	54.4	38.9	4.81	.76	.61	.065	.025	.25	44.7
	324	77.3	2.6	53.1	39.1	5.39	1.04	.69	.095	.026	.38	43.8
	323	79.9	2.5	54.1	36.9	6.73	1.02	.58	.096	.025	.25	43.7
	322	82.4	5.8	55.8	37.1	5.13	.91	.47	.082	.023	.21	44.0
	321	88.2	0.2	13.5	1.61	83.3	.71	.27	.079	nd	.12	7.3
	320	88.4	4.9	55.2	38.8	4.25	.60	.47	.070	.029	.12	45.2
Salamonie Dolomite,	319	93.3	2.7	51.4	36.2	9.85	1.01	.91	.070	.028	.46	42.0
Osgood Member?		96.0	0.8[4]									
	318	96.8	4.8	53.9	34.6	7.49	1.68	1.15	.090	.038	.36	42.6
	317	101.6	0.3	54.7	35.2	5.57	.97	2.99	nd	.040	4.52	41.7
	316	101.9	0.3	50.1	33.9	9.60	2.72	1.47	.13	.038	.68	40.3
	315	102.2	0.2	28	18	37	9.5	3.8	.5	.03	2.63	20.7
	314	102.4	1.8	42.1	26.8	19.5	6.09	2.16	.27	.032	1.07	32.4
	313	104.2	0.1	59.0	30.3	6.12	1.81	1.70	.10	.036	.69	41.8
	312	104.3	1.3	30	20	32.2	10.4	2.76	.54	.032	1.19	22.0
Brassfield Limestone	311	105.6	3.3	60.1	28.8	6.79	1.82	1.31	.099	.033	.63	40.9
	310	108.9	1.4	84.2	11.8	2.19	.63	.71	nd	.028	.34	43.2
	309	110.3	1.3	93.5	3.65	.76	.17	1.70	nd	.024	1.57	42.5
	308	111.6	2.3	82.2	15.6	.45	.11	1.35	nd	.033	.68	44.3
	307	113.9	0.2	63.3	15.4	12.0	2.02	6.13	.10	.038	9.62	34.4
Weighted average:												
Laurel Member	RF64-331 through 320	20.0	50.1[5]	49.7	35.0	13.7	.71	.47	.045	.022	.17	40.1

[1] Rotary samples; not analyzed.

[2] nd – not detected.

[3] Core loss.

[4] Sample for geophysical tests; not analyzed.

[5] Includes only intervals analyzed.

Appendix 5—Continued

Survey drill hole 214
1,100 ft FSL × 200 ft FWL SW¼SW¼ sec. 26, T. 16 N., R. 9 E.

Rock unit and sample number		Depth (ft)	Thickness (ft)	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	S	P_2O_5
Salamonie Dolomite, Laurel Member	CA71-121	30.5	1.0	52.5	37.7	5.64	1.49	1.84	0.015	trace	0.97	0.007
	122	31.5	3.0	56.6	40.8	1.75	0.17	0.41	0.004	trace	0.20	0.006
	123	34.5	1.5	55.9	42.3	1.16	0.21	0.20	0.003	trace	0.095	0.004
	124	36.0	0.8	55.3	40.9	2.70	0.34	0.40	0.008	trace	0.25	0.008
	125	36.8	3.8	41.3	32.5	24.9	0.44	0.47	0.025	trace	0.11	0.010
	126	40.6	5.9	35.9	28.5	34.9	0.18	0.23	0.005	trace	0.019	0.005
	127	46.5	6.0	35.6	28.0	35.5	0.22	0.34	0.010	trace	0.035	0.006
	128	52.5	6.0	38.7	28.2	32.2	0.28	0.31	0.010	trace	0.041	0.006
	129	58.5	4.0	48.2	38.0	13.1	0.19	0.20	0.007	trace	0.041	0.004
	130	62.5	3.9	47.0	38.6	13.6	0.23	0.23	0.005	trace	0.046	0.006
	131	66.4	4.6	40.3	30.5	28.1	0.28	0.43	0.016	trace	0.10	0.007
	132	71.0	4.5	31.4	23.4	44.3	0.27	0.35	0.010	trace	0.054	0.005
	133	75.5	4.5	55.7	39.8	3.02	0.49	0.59	0.017	trace	0.25	0.009
	134	80.0	0.3[1]								0.041	0.002
	135	80.3	0.4	52.1	42.0	4.39	0.50	0.55	0.042	trace	0.16	0.011
	136	80.7	5.8	54.5	40.2	3.89	0.48	0.49	0.042	trace	0.24	0.007
	137	86.5	5.5	53.7	40.8	3.68	0.57	0.71	0.061	trace	0.30	0.010
	138	92.0	5.5	52.7	41.5	3.97	0.74	0.56	0.061	trace	0.21	0.007
	139	97.5	5.5	53.7	41.4	3.42	0.56	0.46	0.045	trace	0.16	0.008
	140	103.0	5.5	52.3	38.3	6.14	1.28	1.21	0.052	trace	0.62	0.040
	141	108.5	2.5	55.7	37.9	3.55	0.78	1.48	0.038	trace	0.51	0.11
	142	111.0	0.4	50.9	34.7	6.68	1.53	5.29	0.095	trace	0.29	0.19
Salamonie Dolomite, Osgood Member?	143	111.4	3.0	35.1	23.7	26.0	8.01	3.20	0.47	trace	1.08	0.079
	144	114.4	1.2	46.2	29.7	15.2	4.62	1.92	0.27	trace	0.64	0.16
Brassfield Limestone	145	115.6	4.4	87.2	6.33	3.97	1.10	0.72	0.051	trace	0.32	0.069
	146	120.0	2.4	93.0	5.60	0.34	0.092	0.71	nd[2]	trace	0.35	0.16
	147	122.4	0.8	72.6	16.5	5.16	0.96	4.08	0.050	trace		0.25
	148	123.2	0.7	82.1	4.01	8.22	2.27	2.17	0.11	trace		0.92
	149	123.9	0.9	94.6	0.74	2.84	0.84	0.45	0.038	trace		1.18
Weighted averages:												
Laurel Member	CA71-121 through 124	30.5	6.3	55.6	40.6	2.34	0.41	0.58	0.006	trace	0.30	0.006
	CA71-133 through 142	75.5	35.6[3]	53.8	40.1	4.04	0.66	0.77	0.047	trace	0.31	0.013

[1]Chert; not analyzed.

[2]nd – not detected.

[3]Includes only intervals analyzed.

Appendix 5—Continued

Survey drill hole 205
22 ft FSL × 275 ft FEL SE¼SW¼ sec. 24, T. 15 N., R. 8 E.

Rock unit and sample number		Depth (ft)	Thickness (ft)	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	S	P_2O_5	Chemical CO_2
Louisville Limestone	CA71- 1	20.0	4.2	63.6	32.9	2.45	0.35	0.30	0.20	trace	0.008	0.005	45.4
	2	24.2	4.1	67.8	28.3	2.53	.59	.36	.034	trace	.12	.005	44.2
	3	28.3	4.1	63.5	31.6	3.35	.72	.32	.050	trace	.18	.010	43.7
	4	32.4	4.2	65.6	30.5	2.70	.45	.41	.028	trace	.16	.007	45.0
	5	36.6	4.1	67.8	27.8	2.71	.61	.60	.043	trace	.27	.007	44.0
	6	40.7	2.1	63.1	30.3	3.88	.80	1.41	.055	trace	.87	.010	42.6
Waldron Shale	7	42.8	3.9	38.6	28.3	20.2	7.35	2.00	.36	trace	.91	.031	30.2
	8	46.7	4.3	42	29	17	6.7	1.6	.3	trace	.78	.036	31.6
	9	51.0	2.0	39.0	25.9	23.1	6.60	2.24	.26	trace	1.2	.03	30.0
Salamonie Dolomite, Laurel Member	10	53.0	4.8	62.8	32.7	3.17	.38	.51	.026	trace	.22	.010	45.1
	11	57.8	3.0	42.8	26.9	29.2	.38	.34	.026	trace	.078	.007	31.1
	12	60.8	3.9[1]								.10	.005	23.1
	13	64.7	3.8	46.4	33.4	19.0	.45	.42	.024	trace	.092	.010	36.0
	14	68.5	1.9	52.3	36.0	10.6	.42	.30	.026	trace	.095	.007	41.2
	15	70.4	3.9[1]								.11	.008	23.3
	16	74.3	5.7[1]								.061	.002	22.7
	17	80.0	2.0	39	31	28	.8	.4	.04	trace	.15	.006	31.9
	18	82.0	4.4	38	28	32	.8	.7	.04	trace	.18	.009	27.9
	19	86.4	2.6	36	28	34	.7	.6	.04	trace	.20	.008	28.6
	20	89.0	4.7	61.4	32.4	4.17	.89	.48	.058	trace	.17	.011	43.6
	21	93.7	3.8	63.9	30.9	3.42	.81	.38	.054	trace	.15	.011	43.4
	22	97.5	2.9	65.0	29.9	3.36	.73	.49	.052	trace	.19	.011	43.9
	23	100.4	4.1	61.5	31.1	5.48	.84	.50	.079	trace	.16	.011	42.9
	24	104.5	3.8	63.7	30.1	4.36	.78	.50	.061	trace	.18	.008	42.8
	25	108.3	3.0	70.1	25.4	2.96	.68	.38	.043	trace	.086	.010	44.2
	26	111.3	3.2	73.8	18.9	5.45	.69	.84	.044	trace	.60	.016	41.9
Salamonie Dolomite, Osgood Member?	27	114.5	3.0	66.7	22.2	7.28	1.81	.95	.079	trace	.30	.10	40.0
	28	117.5	1.9	65.6	27.0	4.37	.83	1.57	.056	trace	.86	.060	42.8

Appendix 5–Continued

Survey dril hole 205–Continued

Rock unit and sample number		Depth (ft)	Thickness (ft)	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	S	P_2O_5	Chemical CO_2
Brassfield Limestone	CA71- 29	119.4	0.2[2]								.71	.070	23.9
	286	119.6	1.3[2]								.73	.073	23.9
	30	120.9	0.3	86.8	1.48	7.58	1.92	1.17	.081	trace	.30	.096	38.6
	31	121.2	1.5[2]								.66	.072	21.3
	32	122.7	3.1[2]								.49	.11	23.3
	33	125.8	2.2	85.3	4.48	6.78	1.64	.88	.094	trace	.14	.12	39.5
	34	128.0	2.0	94.5	1.31	2.45	.61	.64	.045	trace	.21	.12	42.1
	35	130.0	3.6	90.3	7.29	1.02	.17	.94	nd[3]	trace	.13	.087	43.5
	36	133.6	1.1	83.7	10.1	3.16	.72	1.78	.032	trace	.69	.092	41.7
Weighted averages:													
Louisville Limestone	CA71- 1 through 6	20.0	22.8	65.4	30.2	2.85	.57	.49	.07	trace	.26	.007	44.3
Laurel Member	CA71- 20 through 25	89.0	22.3	63.9	30.2	4.04	.80	.48	.059	trace	.18	.010	43.4

[1]Cherty dolomite; not analyzed.

[2]Shale; not analyzed.

[3]nd – not detected.

Appendix 5—Continued

Survey drill hole 11
10 ft FNL × 330 ft FEL NE¼SE¼ sec. 28, T. 15 N., R. 8 E.

Rock unit and sample number		Depth (ft)	Thickness (ft)	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	S	P_2O_5	Chemical CO_2
Jeffersonville Limestone,	P54-24	50.2	15.9	55.1	41.9	2.20	.11	.21		.023	.10	.005	46.1
Geneva Dolomite Member	25	66.1	4.2	38.6	30.3	30.3	.12	.20		.018	.13	.002	33.7
Wabash Formation, Mississinewa Shale Member	26	70.3	8.5	46.4	36.0	12.5	3.06	.76	.18	.019	.41	.019	37.4
Louisville Limestone	27	78.8	1.3	56.0	30.2	9.85	1.73	.59	.088	.023	.41	.011	40.8
	28	80.1	.7	58.3	27.6	10.5	1.90	.52	.099	.022	.24	.028	39.4
	29	80.8	14.6	80.6	14.1	3.91	.50	.28	.053	.019	.22	.008	43.8
	30	95.4	5.1	66.4	25.6	5.54	1.32	.51	.066	.017	.33	.019	42.3
	31	100.5	5.3	68.8	24.8	4.06	.69	1.13	.056	.018	.41	.008	42.6
Waldron Shale	32	105.8	1.5	58.7	9.69	22.9	5.40	2.05	.23	.012	1.65	.021	29.2
	33	107.3	12.4	73.5	3.60	15.4	4.34	.97	.18	.0066	.42	.038	30.2
	34	119.7	.8	37.1	11.4	36.8	1.07	1.75	.25	.013	.75	.040	21.8
Salamonie Dolomite,	35	120.5	1.1	62.5	21.9	12.6	.53	1.47	.051	.019	1.23	.020	38.8
Laurel Member	36	121.6	20.9	51.3	18.2	29.2	.30	.41	.035	.011	.21	.012	31.9
	37	142.5	15.5	75.0	20.4	3.45	.34	.31	.043	.016	.17	.009	43.0
	38	158.0	7.5	75.8	19.0	3.71	.57	.31	.061	.019	.15	.010	42.9
Salamonie Dolomite,	39	165.5	4.6	84.5	11.3	2.79	.45	.37	.049	.031	.27	.011	42.7
Osgood Member?	40	170.1	2.4	74.9	13.0	8.42	1.78	.81	.094	.031	.37	.054	39.2
	41	172.5	3.0	77.3	15.8	4.68	.80	.81	.06	.034	.35	.067	42.5
	42	175.5	4.2	52.8	4.81	29.6	8.88	1.85	.034	.017	.34	.15	24.5
	43	179.7	3.0	57.1	8.85	24.1	5.94	1.63	.51	.021	.42	.088	27.9
Brassfield Limestone	44	182.7	3.7	90.8	2.04	4.86	1.05	.62	.071	.025	.20	.12	40.7
	45	186.4	3.3	96.2	2.39	.41	.15	.60		.032	.10	.080	43.4
	46	189.7	2.6	85.4	5.12	6.10	1.08	1.30		.029	.59	.042	41.6
Weighted averages:													
Geneva Dolomite Member	P54-24 and 25	50.2	20.1	51.7	39.5	8.07	.11	.21		.022	.11	.004	43.5
Louisville Limestone	P54-27 through 31	78.8	27.0	73.8	19.5	4.7	.79	.51	.059	.019	.29	.011	43.0
Laurel and Osgood Members	P54-37 through 39	142.5	27.6	76.8	18.5	3.41	.42	.32	.049	.019	.18	.010	42.9

Appendix 5—Continued

Survey drill hole 216
280 ft FNL X 440 ft FWL NW¼SW¼ sec. 26, T. 14 N., R. 7 E.

Rock unit and sample number		Depth (ft)	Thickness (ft)	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	S	Chemical CO_2
Jeffersonville Limestone,	CA71-239	30.0	11.2	55.7	42.7	0.89	0.11	0.30	nd[1]	trace	0.04	46.3
Geneva Dolomite Member	240	41.2	9.2	57.8	40.6	0.89	0.093	0.41	nd	trace	.19	46.0
	241	50.4	9.4	56.1	37.6	5.42	0.12	0.48	nd	trace	.23	43.2
Wabash Formation,	242	59.8	3.2	50	31	13	3	2	0.2	trace	.32	36.0
Mississinewa Shale Member	243	63.0	5.0	41	29	22	4	2	0.4	trace	.29	30.7
	244	68.0	5.0	29	22	35	7	3	0.6	trace	.59	21.8
	245	73.0	5.2	41	24	25	5	2	0.4	trace	.60	28.1
	246	78.2	5.0	62	20	13	2	1	0.2	trace	.39	36.6
	247	83.2	5.0	58	19	17	3	1	0.2	trace	.30	33.8
	248	88.2	5.0	78.4	9.64	8.68	1.70	0.57	0.12	trace	.26	37.6
	249	93.2	5.0	80.3	8.32	8.45	1.52	0.53	0.10	trace	.15	39.1
Louisville Limestone	250	98.2	5.0	94.1	2.13	2.69	0.40	0.29	0.038	trace	.10	40.4
	251	103.2	5.3	92.6	3.58	2.45	0.46	0.46	0.034	trace	.27	42.2
	252	108.5	2.5	83.8	6.16	6.44	1.95	0.61	0.048	trace	.28	39.7
	253	111.0	6.5	69.9	22.1	5.75	1.01	0.56	0.059	trace	.10	41.4
	254	117.5	2.0	88.6	6.28	3.74	0.47	0.46	0.042	trace	.15	41.1
	255	119.5	5.2	76.8	15.4	5.38	1.08	0.70	0.053	trace	.19	42.6
Waldron Shale	256	124.7	7.3	63.0	5.01	19.6	7.37	1.50	0.28	trace	.41	27.7
Salamonie Dolomite,	257	132.0	5.0	67.4	19.5	9.79	1.49	0.87	0.088	trace	.21	38.6
Laurel Member	258	137.0	4.8	77.1	16.7	4.50	0.75	0.41	0.049	trace	.07	39.6
	259	141.8	2.2	61.5	26.3	10.1	0.93	0.58	0.064	trace	.14	39.4
	260	144.0	6.0	83.6	11.5	3.46	0.57	0.36	0.046	trace	0.12	43.3
	261	150.0	4.0	71.7	21.8	4.39	0.64	0.94	0.054	trace	.41	
	262	154.0	5.0	76.2	17.3	4.71	0.91	0.34	nd	trace	.07	42.1
	263	159.0	6.2	72.9	21.1	3.71	0.58	1.28	0.042	trace	.82	40.8
	264	165.2	2.8	87.4	8.83	2.45	0.52	0.33	0.039	trace	.12	43.3
	265	168.0	2.2	86.9	8.26	2.94	0.77	0.59	0.040	trace	.25	41.5
	266	170.2	3.4	76.0	12.7	7.48	1.98	0.75	0.074	trace	.29	40.4
	267	173.6	1.7	74.4	20.1	3.44	0.64	0.91	0.039	trace	.38	42.8

Appendix 5—Continued

Survey drill hole 216—Continued

Rock unit and sample number		Depth (ft)	Thickness (ft)	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	S	Chemical CO_2
Salamonie Dolomite, Osgood Member	CA71-268	175.3	2.7	64	14	15	3.8	1.1	0.21	trace	.29	33.5
	269	178.0	1.2	80	5.1	11	2.5	0.8	0.1	trace	.24	35.3
	270	179.2	1.6	74.4	5.27	15.4	2.75	0.77	0.16	trace	.16	35.6
	271	180.8	1.6	80.2	9.91	7.19	1.29	0.60	0.076	trace	.11	39.5
	272	182.4	1.7	72	8.9	16	1.7	0.7	0.1	trace	.12	34.4
	273	184.1	1.9	81.2	4.31	10.2	2.33	0.63	0.14	trace	.13	37.0
	274	186.0	2.1	81.9	6.20	8.39	1.84	0.61	0.095	trace	.14	38.5
	275	188.1	1.9	78	5.9	12	2.1	0.7	0.1	trace	.18	34.9
	276	190.0	1.9	82.0	3.27	9.89	2.64	0.80	0.13	trace	.32	37.2
Brassfield Limestone	277	191.9	1.7	89.2	2.89	5.64	0.99	0.60	0.053	trace	.23	40.2
	278	193.6	1.5	96.7	0.82	1.31	0.28	0.53	0.034	trace	.36	41.8
	279	195.1	3.2	85.2	3.60	2.62	5.37	0.73	0.029	trace	.25	40.4
	280	198.3	1.7	78.9	8.83	7.63	1.71	1.91	0.099	trace	1.31	38.1
Weighted average: Geneva Dolomite Member	CA71-239 through 240	30.0	20.4	56.7	41.8	0.89	0.10	0.35	nd	trace	.11	46.2

[1] nd – not detected.

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OVERSIZED DOCUMENT

The following pages are oversized and need to be printed in correct format.

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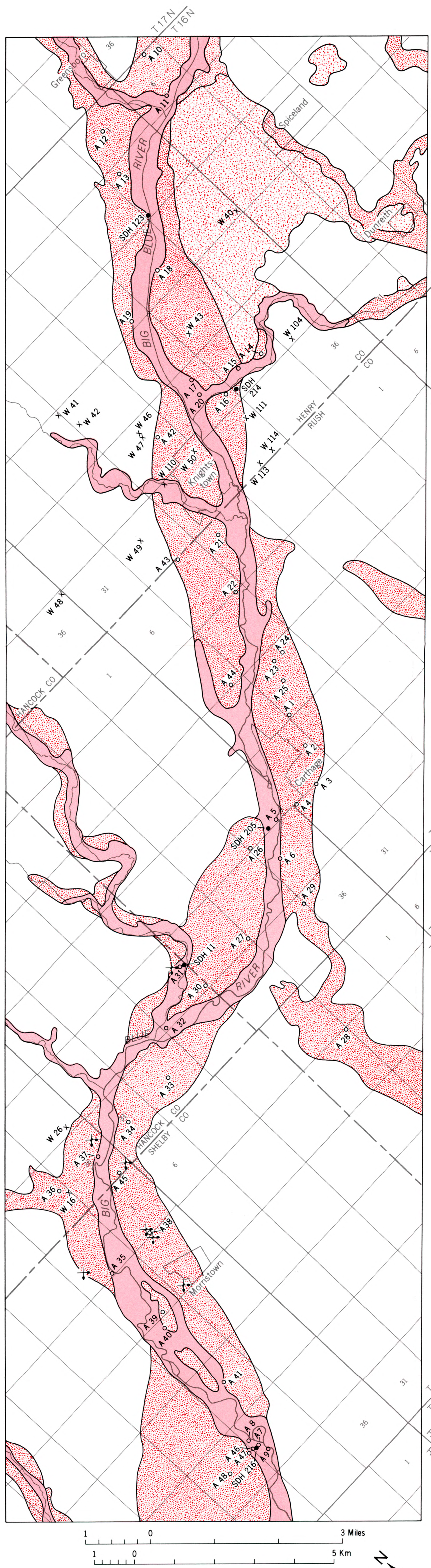
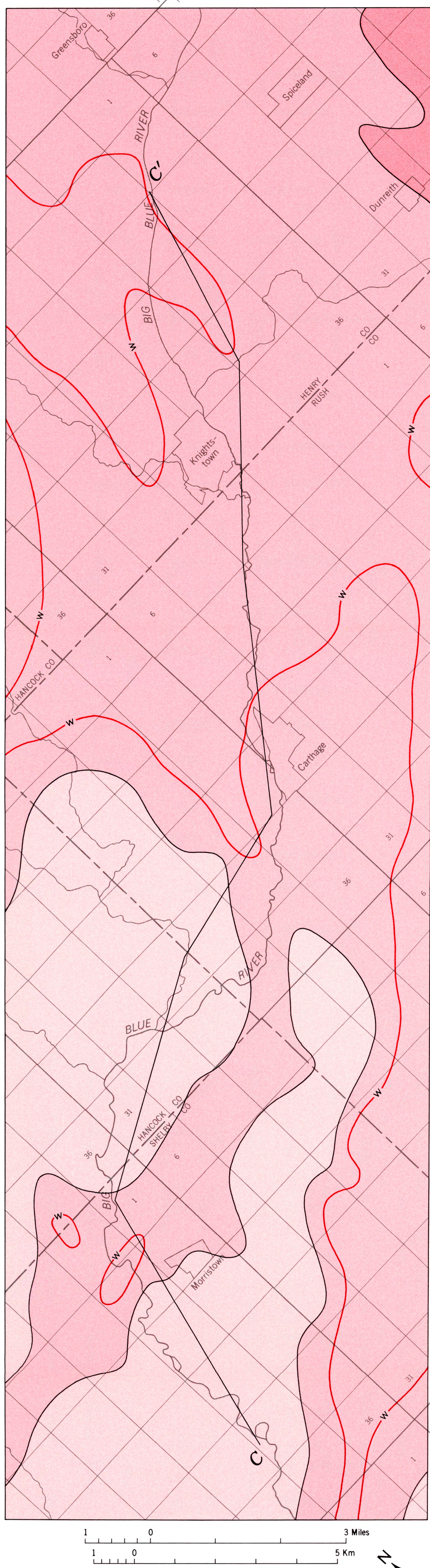
JOSEPH D. CLOUD, DIRECTOR



EXPLANATION

- Indiana Geological Survey auger hole
- Indiana Geological Survey drill hole
- Water well
- Active gravel pit
- Abandoned gravel pit
- Alluvium — *Mostly Martinsville Formation*
- Outwash sand and gravel — *Atherton Formation*
- Kame complex — *Sand, gravel, and clay mixed. Trafalgar Formation*
- Till — *Mostly Trafalgar Formation*

C. MAP SHOWING SURFICIAL MATERIALS

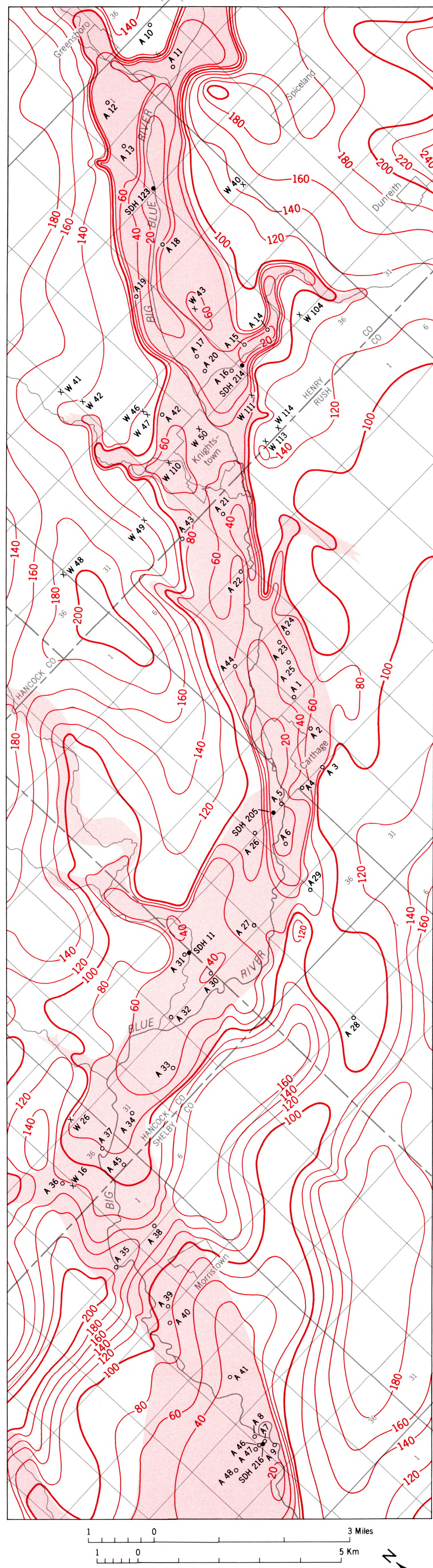


EXPLANATION

- Devonian rocks — *Dolomite*
- Silurian rocks — *Dolomite, limestone, and shale. W, top of Waldron Formation*
- Ordovician rocks — *Interbedded shale and limestone*

Cross section C-C′ is shown on plate 1G

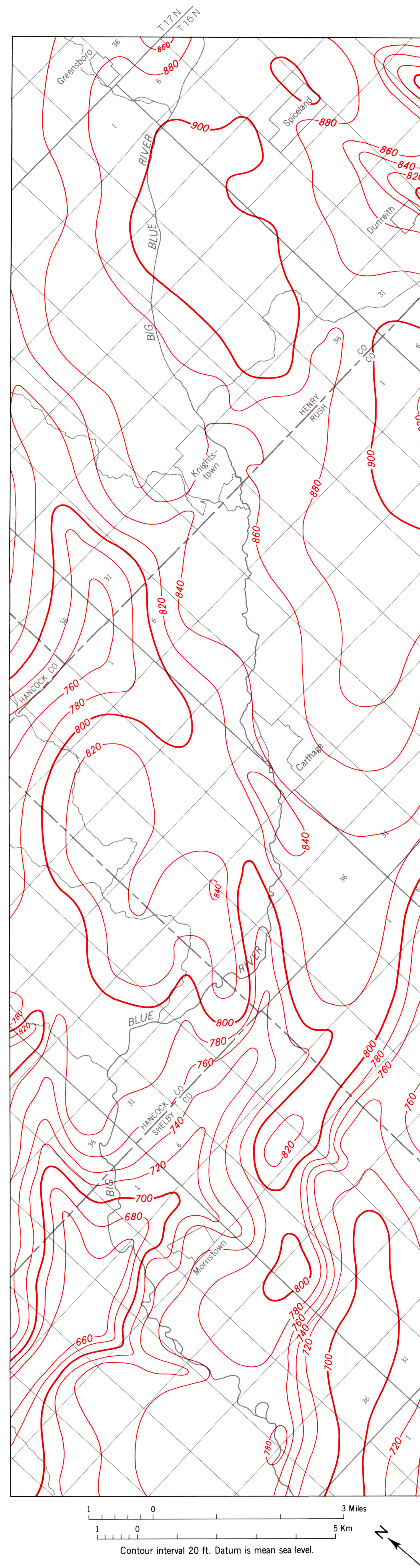
D. MAP SHOWING BEDROCK GEOLOGY



EXPLANATION

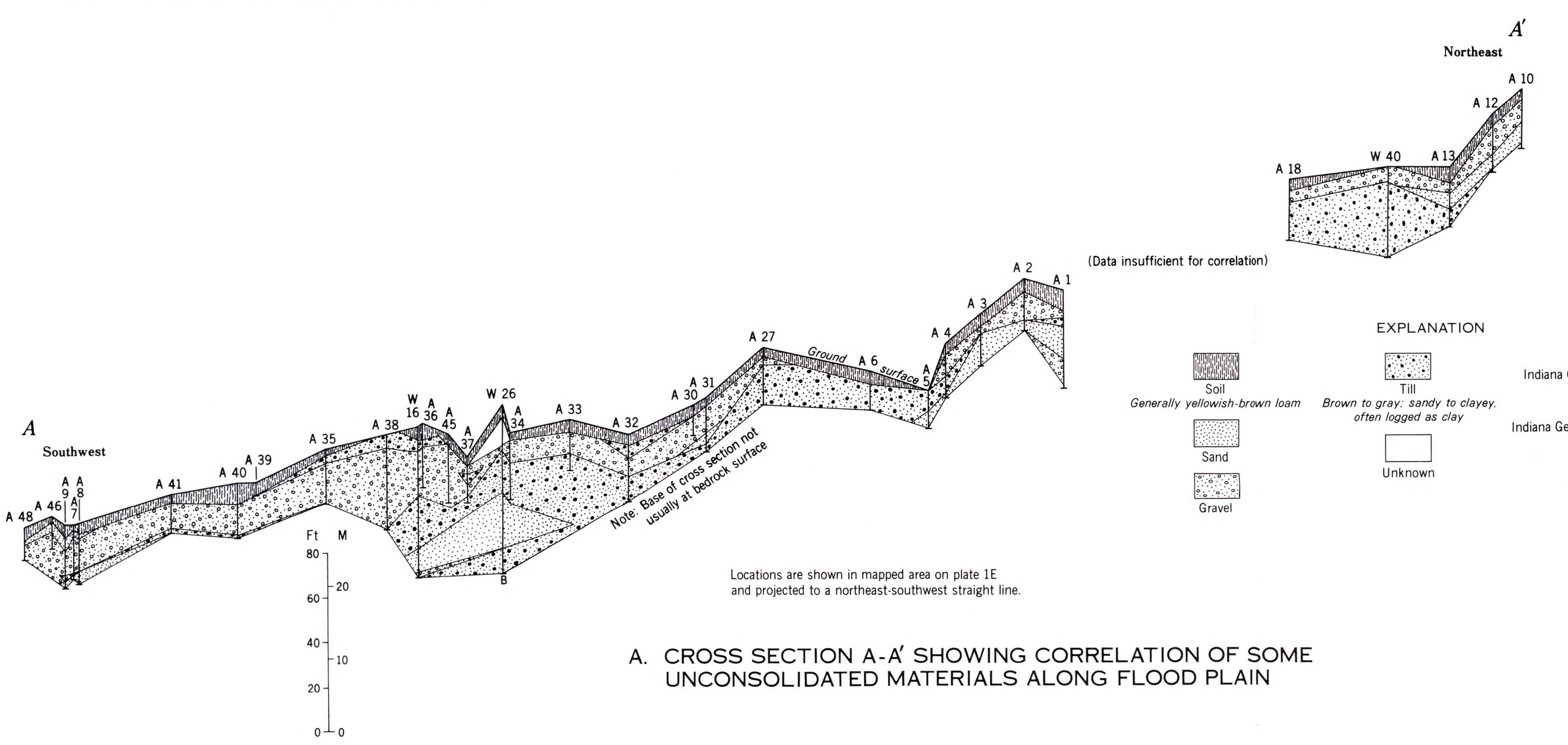
- Indiana Geological Survey auger hole
- Indiana Geological Survey drill hole
- Water well
- Big Blue River valley
- Isopach contours — *Contour interval 20 ft*

E. MAP SHOWING THICKNESS OF UNCONSOLIDATED SEDIMENTS

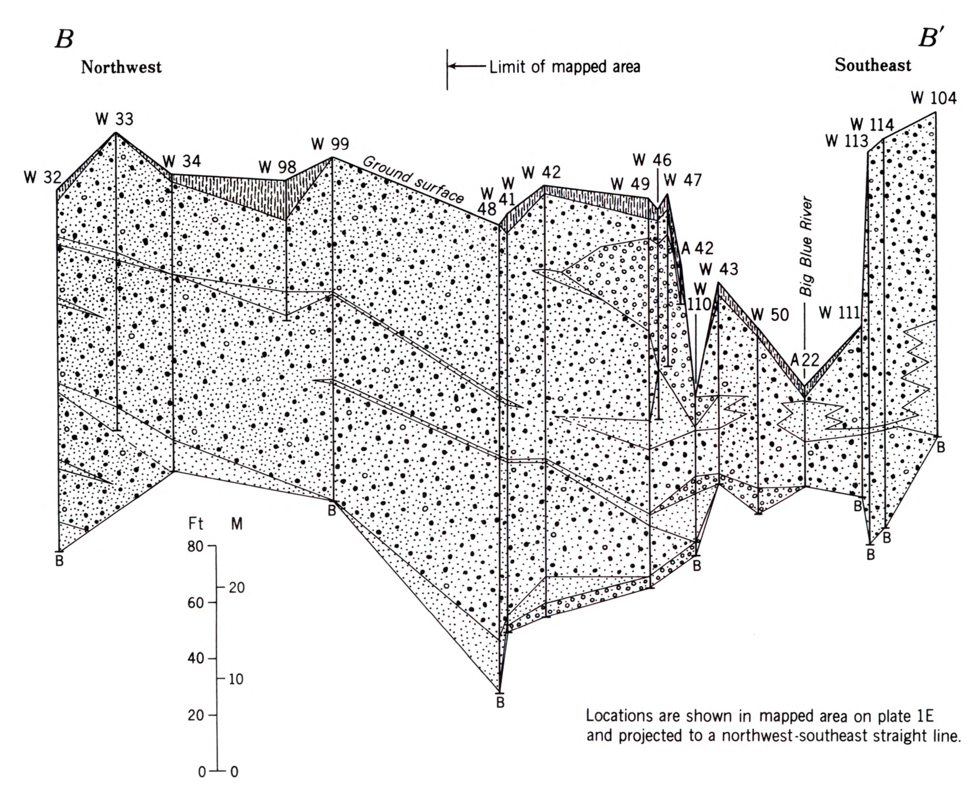


Contour interval 20 ft. Datum is mean sea level.

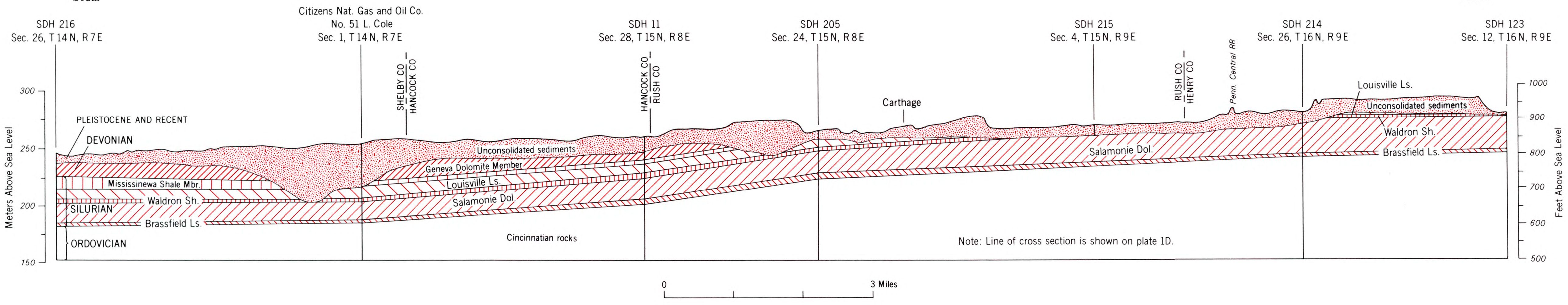
F. MAP SHOWING BEDROCK TOPOGRAPHY



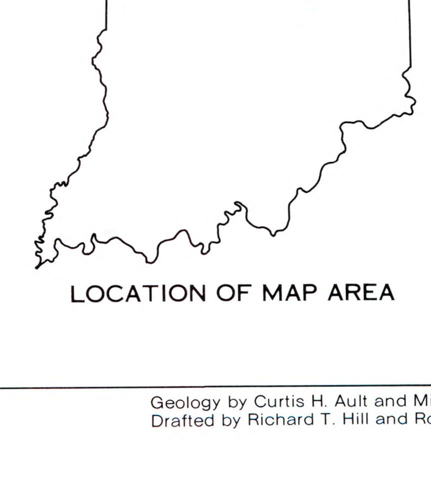
A. CROSS SECTION A-A′ SHOWING CORRELATION OF SOME UNCONSOLIDATED MATERIALS ALONG FLOOD PLAIN



B. CROSS SECTION B-B′ SHOWING CORRELATION OF SOME UNCONSOLIDATED MATERIALS IN KNIGHTSTOWN REGION



G. CROSS SECTION C-C′ SHOWING BEDROCK UNITS



LOCATION OF MAP AREA

Geology by Curtis H. Ault and Michael C. Moore
Drafted by Richard T. Hill and Roger L. Purcell

MAPS AND CROSS SECTIONS SHOWING SURFICIAL AND BEDROCK GEOLOGY IN BIG BLUE RIVER VALLEY, EAST-CENTRAL INDIANA

By Curtis H. Ault and Michael C. Moore

1980