GEOLOGY OF THE HURON AREA, SOUTH-CENTRAL INDIANA

by

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Indiana Department of Conservation

GEOLOGICAL SURVEY

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GEOLOGY OF THE HURON AREA, SOUTH-CENTRAL INDIANA

BY HENRY H. GRAY, ROBERT D. JENKINS, AND ROBERT M. WEIDMAN

ABSTRACT

The Huron area is approximately 85 miles south-southwest of Indianapolis and includes approximately 117 square miles of area in the physiographic province known as the Crawford Upland. Nearly flat-lying sedimentary rocks of late Mississippian and early Pennsylvanian age underlie the hilltops and slopes, and unconsolidated silts, sands, and gravels, mostly of Pleistocene age, partly fill the major valleys.

Exposed rocks of late Mississippian age are assigned to the Blue River, West Baden, and Stephensport Groups (new names), in ascending order. Of the Blue River Group, which includes three formations that consist largely of limestone, only the upper 70 feet is exposed. The West Baden Group is approximately 115 feet thick and consists of five formations which are made up principally of shales but include also some sandstones and limestones. The Stephensport Group is approximately 140 feet thick and consists of almost equal parts of limestones, sandstones, and shales belonging to five formations.

Between rocks of late Mississippian age and the rocks of early Pennsylvanian age that overlie them is an unconformity that represents a period of erosion of sufficient duration to have beveled the older rocks and then carved into them valleys as much as 100 feet deep. Statistical analysis of available observations indicates that sandstone deposits in the lower part of the Mansfield Formation are not concentrated at the unconformity and that limestone is not more abundant immediately under the unconformity than would be expected from the percentage of limestone in the rocks on which the unconformity was developed, but highly aluminous clays are concentrated at the unconformity, probably as a residual deposit.

Rocks of early Pennsylvanian age in the area are assigned to the Mansfield Formation, have a maximum exposed thickness of approximately 250 feet in the southwest corner of the area, and consist of sandstones, shales, and mudstones and thin and discontinuous beds of coal and clay. The Mansfield Formation is divisible into two parts, a lower part consisting largely of cross-bedded sandstones and an upper part made up principally of mudrocks and thin-bedded sandstones that have gray shale partings.

Coal, crushed limestone, whetstones and grindstones, iron ore, dimension sandstone, and clay have been produced from the rocks of the area, but are no longer of economic importance. The only mineral raw material now produced in quantity is gypsum, which is taken from rocks of middle Mississippian age in underground mines in the western part of the area.

INTRODUCTION

LOCATION AND GENERAL DESCRIPTION OF AREA

The area of study (fig. 1) is in south-central Indiana, approximately 85 miles south-southwest of Indianapolis and 65 miles northeast of Evansville, between the parallels 38°30′ and 38°45′

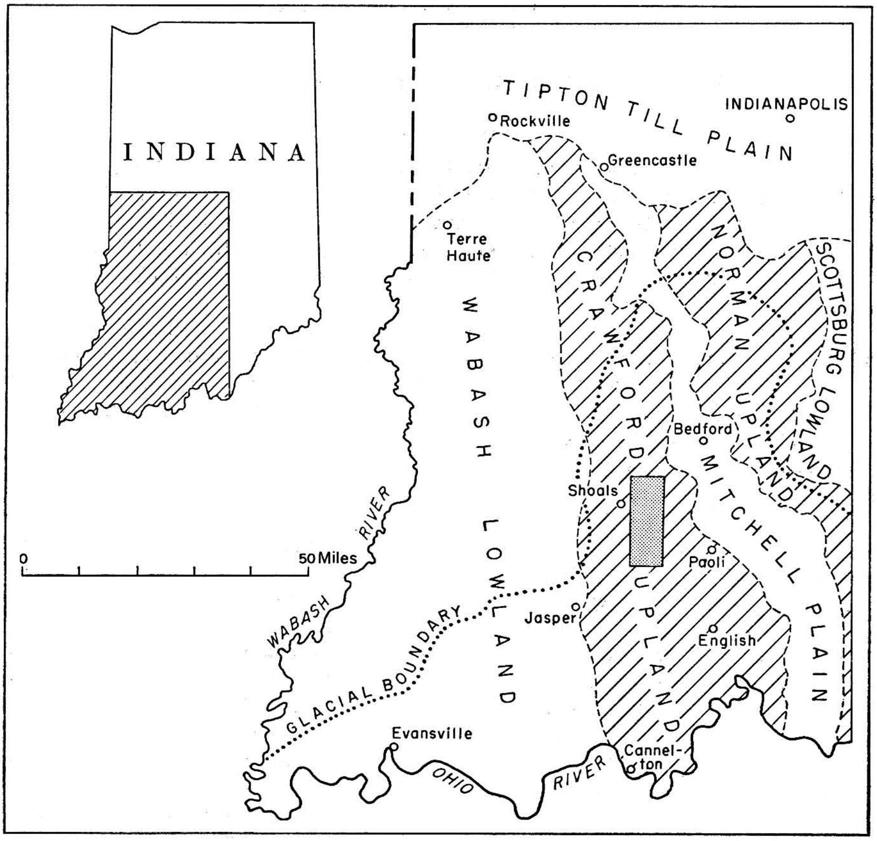


Figure 1.—Map of southwestern Indiana showing Huron area (stippled) in relation to major physiographic units. In part after Malott, 1922, pl. 2.

north latitude and the meridians 86°37′30″ and 86°45′ west longitude. Approximately 117 square miles in northeastern Dubois County, southeastern Martin County, southwestern Lawrence County, and northwestern Orange County are included in the area, which is shown on the Huron and Hillham 7½-minute topographic quadrangle maps of the U. S. Geological Survey (pl. 1). In this report this will be referred to as the Huron area, with reference to the principal settlement, the village of Huron, in the north-central part.

The area is predominantly hilly, and the principal rocks exposed are sandstones, shales, and limestones of Mississippian and Pennsylvanian age. Mineral resources produced from these rocks now or in the past are (approximately in order of their total economic importance): gypsum, coal, crushed limestone, whetstones and grindstones, iron ore, dimension sandstone, and clay.

PURPOSE AND SCOPE OF THE REPORT

The principal objective of this study is to describe the relationships of rocks associated with the Mississippian-Pennsylvanian unconformity in a typical area in southwestern Indiana. Description of the rocks and interpretation of the geologic history of the area are essential to an understanding of the geologic occurrence and geographic distribution of rock and mineral deposits associated with the unconformity. In this report, however, the emphasis is on description and geologic interpretation rather than on economic evaluation.

This particular area was chosen for study because it is generally representative of the part of the Crawford Upland crossed by the Mississippian-Pennsylvanian unconformity from the vicinity of English (fig. 1) to the area southwest of Greencastle. Conclusions reached as a result of this study should generally be applicable over this larger area as well as the area studied. Outside the larger area the character of the rocks and the problems involved in identifying and mapping the Mississippian-Pennsylvanian unconformity are considerably different; to the north of Greencastle rocks of Pennsylvanian age rest on limestones and siltstones of middle Mississippian age, from which they are readily distinguished wherever outcrops are available, whereas from English southward Pennsylvanian rocks rest on several formations of late Mississippian age which are identifiable and distinguishable from Pennsylvanian rocks only with difficulty.

PREVIOUS GEOLOGIC WORK

David Dale Owen, who was engaged in 1837 by the State Legislature to make a geological reconnaissance of Indiana, visited the Huron area during that year and briefly surveyed Dubois, Martin, Lawrence, and Orange Counties (Owen, D. D., 1859, part 1). In 1838 he returned to Jasper and French Lick, and in his report specific reference is made to the whetstones, limestones, coals, and mineral springs of the southeastern part of the Huron area (Owen, D. D., 1859, part 2, p. 14-17). In 1859 and 1860 the area was visited by Richard Owen, who also remarked on the whetstone quarries (Owen, R. D., 1862, p. 144-145) and the iron ore (ibid., p. 173).

Geologic reports of a more detailed nature covering the relevant counties were published in following years (Martin County, Cox, 1871, p. 81-112; Dubois County, Cox, 1872, p. 192-237; Lawrence County, Collett, 1874, p. 260-314; and Orange County, Cox, 1876, p. 203-239). Subsequent reports that make mention of this area deal specifically with whetstones (Kindle, 1896), coal (Ashley, 1899), iron ores (Shannon, 1907), and clays (Logan, 1919; Whitlatch, 1933). The most recent publication in which the general geologic setting of the area is discussed is a guidebook published in connection with a geologic field conference (Indiana Geological Survey, 1957). Many other publications contain geologic information on specific localities within the area (for instance, Malott, 1952), and still others illustrate with maps the distribution of rocks in parts of the area (for instance, Perry and Smith, 1958).

FIELDWORK

Geologic fieldwork was begun in the north half of the area by R. M. Weidman and Eugene Callaghan in 1948. This became the basis of a thesis (Weidman, 1949) but was not further prepared for publication. In 1955 and 1956 R. D. Jenkins mapped the south half of the area, also as the basis for a thesis (Jenkins, 1956).

A review of the geology of the area and adjacent regions was begun by H. H. Gray in 1954 and continued through subsequent years to 1959. The work of both Weidman and Jenkins has been reviewed, supplemented, and modified by Gray. The Mississippian-Pennsylvanian boundary was completely remapped, and mapping of unconsolidated deposits has been considerably revised.

Mapping was carried out by locating and identifying rock exposures. Observation points were located directly on the topographic base map by inspection; vertical control of locations was achieved by measuring altitudes from recoverable base points (road or stream intersections, bench marks, etc.) by means of altimeter or hand level. An attempt was made to establish two control points or more per square mile on each mapped geologic boundary. In some places this was not possible; in others additional control was needed. The line classification of geologic boundaries shown on the map is based principally on adequacy of local control, degree of regularity shown by each boundary, and nature of local topography. This classification is somewhat subjective but does reflect the relative horizontal accuracy of location of the boundaries.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Mr. George Lagenour, Mr. Amos Quinn, and Mr. Jasper Nicholson, who fur-

nished information on coal mines of the area, to Mr. William Cassidy, for information on the whetstone quarries, and to Mr. Lagenour and Mr. Harry Hendrix, who granted permission to drill diamond-cored stratigraphic test holes on their properties.

No discussion of the geology of this region would be complete without mention of the late Dr. Clyde A. Malott, whose work on Mississippian and Pennsylvanian rocks in this and adjacent areas in Indiana from 1919 until the time of his death in 1950 contributed immeasurably to the present understanding of the stratigraphy of these rocks and of the nature of the Mississippian-Pennsylvanian unconformity.

PHYSIOGRAPHY AND GEOGRAPHIC SETTING

The Huron area is the unglaciated part of Indiana (fig. 1), entirely within the physiographic unit called the Crawford Upland by Malott (1922, p. 98-102). The Crawford Upland is a submaturely dissected area of moderate relief that extends from the Ohio River northward to near the town of Rockville (fig. 1). North of Rockville the Crawford Upland is indistinguishable because its characteristic topography is deeply covered by the glacial deposits that underlie the gently rolling surface of the Tipton Till Plain.

The Crawford Upland is one of the two groups of hills that cross southern Indiana in a nearly north-south direction (fig. 1). Adjoining these regions are plains or lowlands of lesser relief. The upland areas are hilly because they are underlain partly by rocks that are relatively resistant to erosion; in the Crawford Upland, the resistant rocks are sandstones of early Pennsylvanian and late Mississippian age. The limestones of middle Mississippian age that underlie the Mitchell Plain are not resistant to erosion in humid climates, and they therefore are reduced to rather low topographic relief. The Wabash Lowland is underlain by rocks of middle and late Pennsylvanian age, which are mainly soft, easily eroded shales; in addition, much of that area has been glaciated, and in the process valleys have been filled, hilltops have been scraped down, and topographic relief has been reduced still further.

The major streams of southern Indiana, such as East Fork of White River and Lost River, do not follow the lowlands but cut across the grain of the topography almost at right angles. These streams must have been consequent upon an earlier westward-sloping surface, possibly the original depositional slope of the basin in which the rocks themselves were deposited, some 200 million years ago, or perhaps an ancient peneplain that beveled all the rocks, resistant or not. This accounts for the highly dissected topography of the upland areas; had the major streams followed the lowlands, the uplands would have been left as broad plateaus untrenched except by minor streams.

Topographic relief in the Huron area is typical of the Crawford Upland. A little over two-fifths of the area is in relatively level upland surfaces whose slopes average considerably less than 20 percent; approximately a fifth of the area is in valley bottoms of similar low slope; the remaining two-fifths is in steep slopes generally in excess of 20 percent and averaging approximately 30 percent. The highest point within the area is Mount Airie (906 feet above sea level; sec. 28, T. 2 N., R. 2 W.). The minimum altitudes in the area are at the points of exit of East Fork of White River (approximately 445 feet; sec. 4, T. 3 N., R. 3 W.) and Lost River (approximately 445 feet; sec. 21, T. 2 N., R. 3 W.). Thus the total relief is approximately 460 feet, but the average local relief per square mile is slightly less than 260 feet.

EROSIONAL LANDFORMS

Topographic features of the Huron area are typical of the Crawford Upland and reflect the fact that the upland is underlain by a sequence of nearly flat-lying sandstones, shales, and limestones. The major valleys are relatively narrow and steep walled and have only narrow flats along the valley bottoms. Valley walls normally have been shaped into a series of benches because the horizontally bedded underlying rocks are of differing resistance to erosion. Mechanical limitations of contour mapping preclude any but the more conspicuous benches being well shown on topographic maps, but they are readily seen on aerial photographs, especially when viewed stereoscopically, and are a great aid in geologic mapping, particularly where exposures are scarce.

The uplands are characterized by a series of gently sloping stripped surfaces (fig. 2). It is doubtful that these surfaces are peneplains; they correlate readily with the upper surfaces of extensive thick sandstone beds, and they slope gently westward with the regional dip of the underlying bedrock. Little accordance of upland surface levels is to be seen other than that resulting from stripped-surface development on these resistant beds. If the area has ever been base-leveled, few if any remnants of the former surface remain. Some of the most extensive stripped surfaces in the

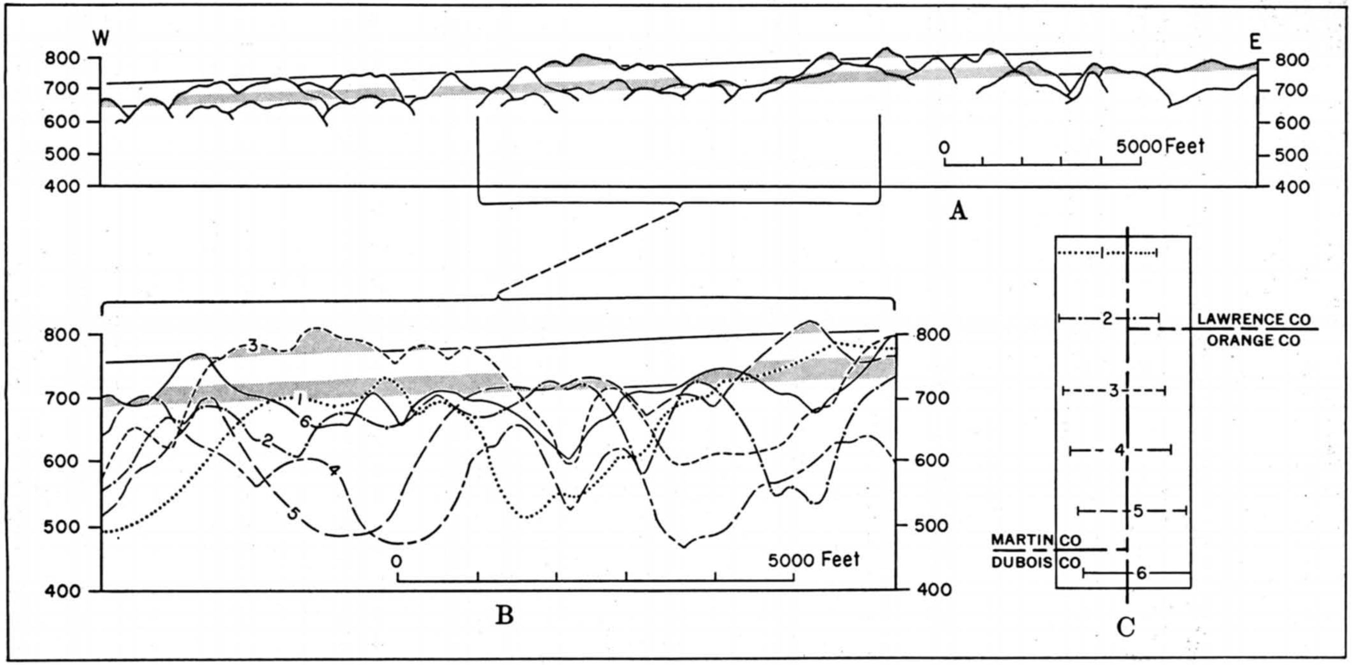


Figure 2.–Topographic profiles across Huron area showing two prominent levels of stripped-surface development in rocks of the Mansfield Formation. Shading indicates extensive zones of soft shales, mudstones, and clays. A, Composite profile. B, Central part of A (enlarged) showing profiles 1 through 6. C, Index map of Huron area (outlined) showing position of profiles from which composite was assembled; offsets compensate for regional strike.

area have been formed on sandstones near the base of the Mansfield Formation (pl. 1 and fig. 2), but others have been formed on other sandstones in the Mansfield and on sandstones of Mississippian age, especially in the Big Clifty Formation.

Impermeable shale beds underlie many of the sandstone and limestone beds in the area, and, as a result, water that seeps into the sandstones and limestones must travel horizontally in the lower parts of these permeable beds until reaching the outcrop, where it issues as springs. The ready yielding of the underlying shale to erosion undermines the sandstone or limestone bed, and thus the more resistant rock is allowed to fall. In this way a small ravine is formed and eroded headward. If the spring is large, the ravine may be developed into a steep-walled alcove of considerable size.

The most spectacular of these alcoves can be seen along the outcrop of the Beech Creek Limestone. The lower part of the Big Clifty Formation, which overlies the Beech Creek, contains much permeable sandstone which absorbs most of the water that falls on the broad stripped surfaces and benches at the top of the sandstone. This water then seeps downward into the limestone, but it cannot percolate deeper because the top of the underlying Elwren Formation is made up largely of impermeable shales and mudstones. Extensive caves and fissures are opened in the Beech Creek by solution resulting from horizontal movement of the water through the limestone, and large springs are found where the water issues from the outcrop; Tank Spring (sec. 11, T. 3 N., R. 3 W.) is a typical example. In some areas it is possible to trace the outcrop of the Beech Creek Limestone on aerial photographs merely by noting the position of these characteristic erosion features. Alcove-forming springs issue from other limestone beds and from some sandstone beds as well, but they are most characteristic of the Beech Creek Limestone.

Sinkholes and underground drainage through cavern systems are characteristic of those parts of the Crawford Upland where limestone beds lie close to the surface of the ground over relatively large areas. Valleys in the eastern part of the Huron area have cut into the thick Paoli and Ste. Genevieve Limestones in which large cavern systems have been developed. As a consequence, much of the surface water in these valleys flows into sinkholes (as, for example, in the SW¼ sec. 33, T. 4 N., R. 2 W., and vicinity) to reappear inconspicuously as stream-level springs farther down valley. Smaller sinkholes are found in areas underlain by thinner, younger limestones. Those near the hilltops in sec. 35, T. 2 N., R. 3 W., and vicinity, for instance, have been developed in the Glen Dean Limestone.

DEPOSITIONAL LANDFORMS

Although erosional landforms such as those just described dominate the area of the Crawford Upland, depositional features are not entirely absent. The flat-bottomed valley floors are not underlain directly by bedrock but by unconsolidated deposits whose thickness approximates 50 feet in the larger valleys and less in the tributaries. Topographic relief in the area was therefore somewhat greater in the past when the streams flowed largely upon bedrock. Deposition of the materials that now partly fill the bedrock valleys took place in recent geologic times.

ECONOMIC GEOGRAPHY

The topographic features just discussed influence the economic geography of the Huron area. Early commerce in the area was impeded by the rugged terrain and by the lack of navigable rivers. The building of the Ohio and Mississippi Railroad (now the Baltimore and Ohio) in 1857 opened the area to trade and commercial development. At the present time the area is traversed by the Baltimore and Ohio Railroad, a branch of the Southern Railroad, U. S. Highways 50 and 150, State Highways 56, 60, and 650, and a network of macadam and gravel-surfaced county roads.

The population of the area is estimated at approximately 2,750. Most of the inhabitants live in rural areas of low population density. Many farms have been abandoned, and many of those remaining under cultivation are worked only part time. Approximately 35 percent of the land is cleared; the remainder is in mature second-growth or scrub timber. Much of the cleared land is not in use and is slowly reverting to forest.

These facts both reflect and contribute to the diversified nature of the area's economic geography. With one exception, no single product is yielded in large quantity, but small quantities of a large variety of materials are or have been taken annually: from the forests, timber and furs; from the farms, fruit and animal products; and from the rocks, limestone, sandstone, whetstone, coal, clay, iron ore, mineral water, and the one resource yielded in large quantity, gypsum.

In 1954 two gypsum companies began development of properties along the west edge of the Huron Quadrangle. The plant of the National Gypsum Co., in the SW¼ sec. 21, T. 3 N., R. 3 W., just off the west edge of the Huron Quadrangle, began production late in 1955 and ships 30 to 35 carloads of gypsum and gypsum products daily; it employs approximately 200 men (Rock Products, 1956). Figures for the plant of the United States Gypsum Co., in the NW¼ sec. 23, T. 3 N., R. 3 W., near Willow Valley, are not available but are probably comparable. Both plants mine gypsum from the lower part of the St. Louis Limestone at depths of 350 to 500 feet.

UNCONSOLIDATED SEDIMENTS

Most of the surface of the Huron area is underlain directly by unconsolidated materials. In general, however, these are shown on the map (pl. 1) only where they are of sufficient thickness to obscure the nature of the underlying bedrock. Residual soils, colluvial or slope-wash materials, and widespread but thin windblown silt or loess were not mapped; over most of the area these are not more than a few feet in thickness. For maps indicating the distribution of these materials, see the appropriate county reports of the soils mapping program of the U. S. Department of Agriculture (Ulrich and others, 1946; Simmons and others, 1937; Tharp and others, 1928).

Unconsolidated materials have generally been mapped geologically under a variety of names that reflect either their mode of origin, their physiographic expression, their lithologic constitution, or a combination of these factors. The American Commission on Stratigraphic Nomenclature (1959, p. 666) now recommends that these units of diverse significance be replaced with geographically designated formations in much the manner that has long been standard for consolidated rocks. Such a classification, developed by Wayne (in preparation), is here adopted (fig. 3). Some of the formations recognized by Wayne are not present in the map area.

MARTINSVILLE FORMATION

Silt, sand, and gravel deposits of present streams are mapped as the Martinsville Formation (Wayne, in preparation). In places small areas of clay, muck, and peat are included in the formation. These materials are irregularly distributed along stream channels, on flood plains, and in associated lakes and swamps.

The Martinsville Formation is not of consistent thickness. Along most of the smaller streams, such as South Fork of Beaver

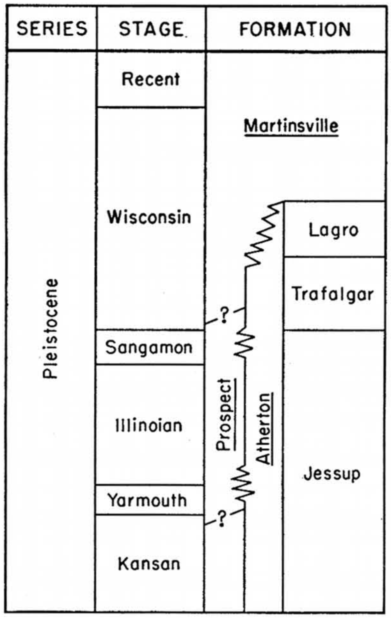


Figure 3.—Diagram showing named formations of Pleistocene age in Indiana (after Wayne, in preparation). Formations underlined are found in Huron area. Names are tentative until formal presentation.

Creek, it is probably about 6 feet thick. Along East Fork of White River the formation is 15 feet or more thick. Near the headwaters of the smallest streams the formation has not been mapped because the outcrop area is too narrow to show; in these places the Martinsville is probably less than 2 feet thick.

The Martinsville Formation overlies every bedrock formation within the Huron area at one place or another (pl. 1). Among the unconsolidated materials, it probably overlies both facies of the Atherton Formation and the lower part of the Prospect Formation. This is expectable because the Martinsville is the youngest of the formations shown. It does not, however, overlie the Lafayette Gravel because that formation is present only on isolated hilltops far above the level of present streams.

ATHERTON FORMATION

The Atherton Formation, as defined by Wayne (in preparation), includes a number of interrelated unnamed facies, all of which are a part of, or are closely associated with, the sands and gravels that were deposited along melt-water streams during the glacial ages of the Pleistocene Epoch. Only two of the major facies of the Atherton Formation are present in the Huron area, and only one of these is exposed at the surface (pl. 1).

Windblown sand facies.—Along the east side of the valley of East Fork of White River near Norman Rock Bend and Devil's Elbow are thick deposits of sand that appear to have been carried by the wind from the valley flat and deposited along the valley walls. Although the sand has an incompletely developed soil profile and otherwise appears to be of relatively recent origin, it is not now being deposited actively. It probably was laid down during the Wisconsin or latest glacial age. The thickness of the sand is not precisely known but probably does not exceed 20 feet. Smaller and thinner sand deposits are known but have not been mapped.

Associated with the sand is some silt of the same origin, known as loess. Silt particles, being smaller, are apt to be blown farther than sand grains, and deposits of windblown silt might be expected in many parts of the area. Such deposits are in fact widely present on upland surfaces, but they are thin, patchy, and difficult to distinguish from residual soils of the upland areas; for these reasons they were not mapped.

Outwash sand and gravel facies.—The only stream in the Huron area that carried glacial melt water is East Fork of White River. Outwash sand and gravel deposited by the melt water are present in the valley of White River to a depth of 60 feet or more below the present river level. The exact distribution of these deposits is not known, as they are now covered by windblown sand and by the silty and organically enriched alluvial sands of the Martinsville Formation. The age of the outwash is also in question; some no doubt represents the latest or Wisconsin age glaciation, but a part may be of Illinoian age or older.

While the sand and gravel facies of the Atherton Formation was being deposited along East Fork of White River, silts and clays of the lower part of the Prospect Formation were being deposited in tributary valleys. These deposits are now buried by younger sediments, and the nature of the boundary between the two formations is therefore unknown.

PROSPECT FORMATION

A distinctive and older set of nonglacial alluvial deposits is distinguished as the Prospect Formation (Wayne, in preparation).

This is composed of silts, sands, and fine gravels similar to those of the Martinsville Formation, but the Prospect Formation is more deeply weathered, a condition which indicates a greater age. The Prospect Formation occurs as eroded terraces 20 to 50 feet above the flood plain of present streams; this indicates that deposition took place at a time when the valleys were filled with alluvial deposits to a somewhat greater depth than they are now. On the basis of these facts it seems likely that the Prospect Formation is of early Wisconsin, Sangamon, or perhaps Illinoian age (fig. 3).

The exposed part of the Prospect Formation is about 30 feet thick, but the entire formation probably is much thicker. In the type section reported by Wayne (in preparation), 18 feet of clayey sand and gravel are exposed along U. S. Highway 150 just west of the village of Prospect, half a mile east of the east edge of the Huron area. The formation is irregularly distributed, only patches remaining in places where it has escaped erosion, but it is widespread and has been recognized in every major drainage basin within the area mapped.

The Prospect Formation is nowhere well exposed, and its relations to other unconsolidated deposits are not entirely clear, but it is known to overlie most of the bedrock formations in the area (pl. 1). It underlies parts of the Martinsville Formation and probably underlies, in part, the windblown sand facies of the Atherton Formation (pl. 1, section A-A′). The lower part of the Prospect probably intertongues with the sand and gravel facies of the Atherton Formation. The Prospect Formation and the Lafayette Gravel were not found in contact.

LAFAYETTE GRAVEL

The only unconsolidated sedimentary deposit not closely associated with present stream valleys is the Lafayette Gravel. This formation is characterized by abundant stream-worn pebbles of fossiliferous chert and whole and broken geodes and by the reddish-brown soil that results from weathering of the gravel. In the Huron area and adjacent region the Lafayette Gravel occurs in patches on hilltops approximately 150 feet above present drainage. Only one such locality is known in the area mapped, in sec. 33, T. 4 N., R. 3 W. (pl. 1). Here the gravel probably is less than 10 feet thick.

The origin and age of the Lafayette Gravel are not well understood. Probably the formation is the deposit of a major stream system that drained the area long before the present topography was shaped. It is almost certainly preglacial and is at present tentatively considered to be of Miocene to early Pleistocene age (Wayne, in preparation).

ECONOMIC EVALUATION OF THE UNCONSOLIDATED SEDIMENTS

In other parts of Indiana unconsolidated sediments are the source of much sand and gravel and smaller quantities of brick clay, peat, and marl, but no use has been made of these deposits in the Huron area. A large quantity of sand could be obtained from the Atherton Formation along the East Fork of White River, but these deposits are remote from transportation facilities, and their exploitation in the foreseeable future seems unlikely. Other unconsolidated sedimentary formations are unpromising as a source of mineral raw materials.

In the glaciated part of Indiana and along the valleys of those streams that carried glacial melt water during Pleistocene time, unconsolidated deposits are an important source of water. In general, however, the unconsolidated sediments of the Huron area are a poor source of water because most of the deposits are fine grained and relatively impermeable. The Martinsville and Prospect Formations include only small pockets of permeable sand and gravel, and finding these for a water well would present a difficult problem. The most suitable sources of underground water among the unconsolidated deposits are the outwash sands and gravels of the Atherton Formation, which is restricted to the valley of East Fork of White River. These permeable materials probably contain much water, but in this area little use has been made of this source of supply.

EXPOSED SEDIMENTARY ROCKS

MANSFIELD FORMATION

Most of the rocks that cap the hills in the Huron area belong to a stratigraphic unit known as the Mansfield Formation. This unit was originally named the Mansfield Sandstone by Hopkins (1896, p. 199-200), subsequently was better defined by Cumings (1922, p. 527-528), and finally was renamed the Mansfield Formation (Kottlowski, 1959). As now defined, the Mansfield Formation includes all rocks of Pennsylvanian age below the Lower Block Coal, which forms the base of the overlying Brazil Formation. The Lower Block Coal was not identified in the Huron area, but a probably equivalent coal bed is known a few miles west at an altitude somewhat less than that of the hilltops along the west edge of the area. Thus it appears likely that essentially the entire

Mansfield Formation is represented by the 250-foot thickness of Pennsylvanian rocks in the southwest corner of the Huron area.

In the Huron area the Mansfield Formation is divisible into two parts, here informally designated simply as lower and upper. There are two sets of criteria on which the separation may be made; the gross lithology of the lower part is different from that of the upper part, and the upper contact of a coal bed or the equivalent stratigraphic horizon serves as a key for separation of the two parts.

The lower part of the Mansfield Formation contains a greater proportion of sandstone than does the upper part (table 1), and the sandstones of the lower part characteristically show trough and wedge crossbedding, in contrast to those of the upper part which commonly have somewhat wavy thin bedding (table 2). Both criteria withstand statistical analysis; that is, the differences are significant and are unlikely to be merely the result of sampling variation. Both of these differences are reflected in the extensive development of topographic benches in the upper part of the Mansfield (fig. 2).

Table 1.—*Relative abundance of principal rock types in the Mansfield Formation*[1]

Formation	Sandstones (all types) (pct.)	Mudrocks (all types) (pct.)	Covered intervals (pct.)	Total thickness (feet)
Mansfield Formation, upper part	35 (117 ft)	46 (156 ft)	19 (65 ft)	338
Mansfield Formation, lower part	58 (185 ft)	21 (65 ft)	21 (68 ft)	318
Total thickness of measured sections summarized				656

Table 2.—*Relative abundance of principal sandstone types in the Mansfield Formation*[1]

Formation	Light yellow-brown sandstone with even thin bedding (pct.)	Brown sandstone with trough- and wedge-shaped crossbedding (pct.)	Sandstone with gray shale partings and wavy thin bedding (pct.)	Total thickness (feet)
Mansfield Formation, upper part	15 (18 ft)	34 (40 ft)	51 (59 ft)	117
Mansfield Formation, lower part	11 (21 ft)	63 (116 ft)	26 (48 ft)	185
Total thickness of sandstone in measured sections summarized				302

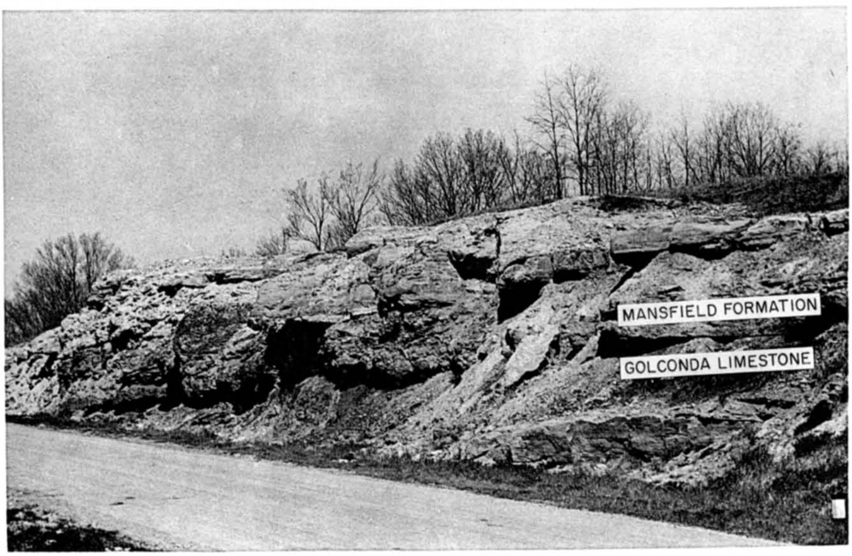
[1] Summarized from six representative measured sections.

The boundary between the lower and upper parts of the Mansfield is placed at the top of the Pinnick Coal or at the inferred equivalent horizon where the coal is absent. The Pinnick Coal lies 50 to 150 feet above the base of the Mansfield Formation in the Huron area. The coal bed itself is generally thin and is difficult to trace, as it is not exposed in many places, but associated rocks aid in picking its position. The well-known whetstone beds (pl. 2A) lie just below the Pinnick Coal, and a thin slightly ferruginous sandstone bed lies immediately above the coal. A thicker sandstone that in places is strongly ferruginous lies 50 feet above the Pinnick, and a discontinuous zone of ironstone is present approximately 50 feet below. Each of these overlies a thin coal bed of small extent (columnar section, pl. 1). In many places part or all of the sequence of rocks just above and below the Pinnick Coal consists of a very light-gray mudstone which erodes readily into badlands-type topography on a small scale. The contrast in resistance to erosion between these mudstones and the underlying sandstones of the lower Mansfield is responsible for the development of the extensive lower topographic bench illustrated in figure 2.

Although the boundary between lower and upper Mansfield cannot everywhere be mapped with great precision, observation of the features described above over an area of a square mile or so will usually permit placing the contact within a few feet.

Upper part of the Mansfield Formation.—The lithologic unit referred to in this report as the upper part of the Mansfield Formation is present extensively in the western part of the Huron area, but in only one place, near West Baden, does it extend to the east edge of the area (secs. 28 and 33, T. 2 N., R. 2 W.). This unit lies on the hilltops and consequently is not well exposed in many places. Only three sections of the upper Mansfield have been measured in the area (see Appendix, sections 11, 12, and 13), but additional information was obtained from the records of two core-drill holes (Appendix, well records 2 and 3). These records, all in the southern part of the area, reveal that the upper Mansfield is dominantly shale and mudstone (table 1) and contains relatively little sandstone. Most of the sandstones have wavy thin bedding, are carbonaceous and micaceous, and have sparse to abundant very thin gray shale partings (table 2). In some places, however, there are extensive beds of resistant ledge-forming crossbedded sandstone, as, for instance, along the hilltops from Red Quarry School

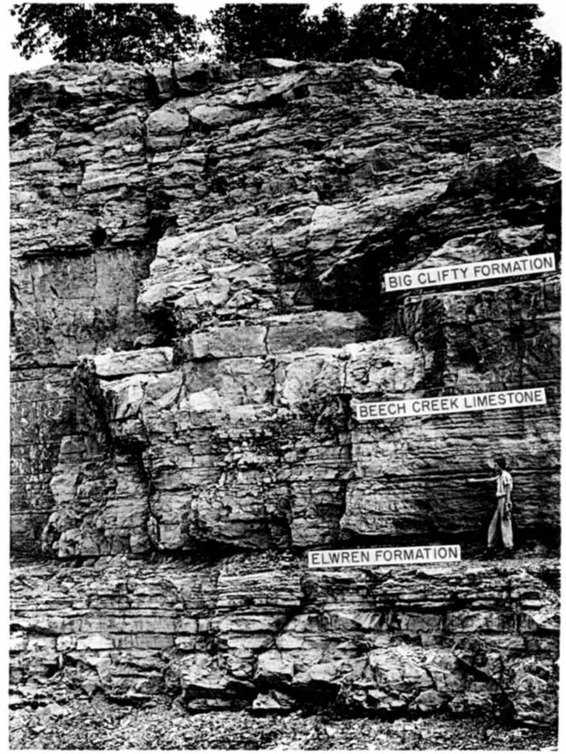
A. EVENLY THIN-BEDDED SILTSTONE BEDS OF MANSFIELD FORMATION IN ABANDONED WHETSTONE QUARRY IN THE NE¼SW¼ SEC. 7, T. 2 N., R. 2 W., NORTHWEST OF NEW ANTIOCH CHURCH.



B. FERRUGINOUS MASSIVE SANDSTONE OF MANSFIELD FORMATION OVERLYING SHALY AND SILTY GOLCONDA LIMESTONE IN CUT ON STATE HIGHWAY 650, IN THE S½SW¼ SEC. 15, T. 3 N., R. 3 W., NEAR CENTER POINT SCHOOL.

MANSFIELD FORMATION

A. GLEN DEAN LIMESTONE OVERLAIN BY SHALE AND SANDSTONE OF MANSFIELD FORMATION IN ABANDONED QUARRY IN THE SW¼NE¼ SEC. 22, T. 1 N., T. 3 W., 1½ MILES SOUTHWEST OF HILLHAM. (SEE APPENDIX, SECTION 14.)



B. BIG CLIFTY FORMATION, BEECH CREEK LIMESTONE, AND ELWREN FORMATION IN DEEP CUT ON STATE HIGHWAY 650, IN THE NW¼NW¼ SEC. 23, T. 3 N., R. 3 W., JUST SOUTH OF WILLOW VALLEY.

LIMESTONE EXPOSURES

(SW¼ sec. 32, T. 2 N., R. 2 W.) to the hill on State Highway 56 which is 2 miles west of the French Lick city limits (NW¼ sec. 17, T. 1 N., R. 2 W.).

Near the southwest corner of the Huron area the upper part of the Mansfield Formation is approximately 160 feet thick. Its precise thickness cannot be determined because the top of the Mansfield cannot be identified in the area, but it is probable that very nearly the entire thickness of the upper Mansfield is present. (See p. 22-23.)

One of the important marker beds in the upper part of the Mansfield Formation is the Blue Creek Coal. This bed, named for exposures at the headwaters of Blue Creek (secs. 9 and 10, T. 1 N., R. 3 W.), is here recognized as a member of the Mansfield Formation; the type section is included in the Appendix (section 12). The Blue Creek Coal lies approximately 100 feet above the base of the upper Mansfield in a sequence of sandstones with wavy thin bedding. The position of the coal is well marked by 50 mines or more around its outcrop. This bed, or a coal bed at very nearly the same stratigraphic position, extends from the Coal Mine Ridge area northwestward to within 2 miles of Shoals, a few miles west of the Huron area.

The Blue Creek Coal is present over an area of approximately 5 square miles in the southwest corner of the Huron area (pl. 1) and there is reported in thicknesses as great as 7 feet, but it is absent in many places within its principal area of occurrence. For example, Indiana Geological Survey drill hole 47 (Appendix, well record 3) was drilled approximately 400 feet south of the mine for which the 7-foot thickness was reported, and yet this drill hole penetrated only a thin streak of coal at the position of the Blue Creek bed. East of the Coal Mine Ridge area the Blue Creek Coal has not been recognized. Most of the hills are not high enough to reach this stratigraphic position, but available evidence indicates that the coal bed probably never extended much farther east than the area in which it is now found.

Lower part of the Mansfield Formation.—The rock unit here referred to as the lower part of the Mansfield Formation is present throughout the Huron area on hilltops in the eastern part and on upper hillslopes in the western part. In general it is better exposed on the slopes than on the hilltops. The listed measured sections are all from the western half of the area (Appendix, sections 2, 3, 9, 10, 11, and 14); in addition, one core-drill hole penetrated the entire unit (Appendix, well record 2). The lower Mansfield is dominated by sandstone (table 1), most of which is crossbedded (table 2).

The lower boundary of the lower Mansfield (pl. 2B) is at an erosional unconformity, a buried land surface that had 50 to 100 feet of topographic relief before it was covered by Mansfield sediments. Because of the irregularity of this boundary, the lower Mansfield is variable in thickness. The minimum thickness recognized is approximately 50 feet (NW¼ sec. 12, T. 2 N., R. 3 W., and NW¼ sec. 36, T. 2 N., R. 3 W.); the maximum is somewhat more than 150 feet (secs. 27 and 28, T. 3 N., R. 3 W.). Direct measurements of the thickness of this unit are possible in only a few places, as top and bottom are rarely exposed in the same locality. The thicknesses stated above are interpreted. Two direct measurements in the southern part of the Huron area yield thicknesses of 133 feet (Appendix, section 11) and 85 feet (Appendix, well record 2).

The Pinnick and French Lick Coals, the only beds that serve as stratigraphic markers or key beds in the lower part of the Mansfield Formation, were named by D. W. Franklin (1939). Although these names were not proposed in accordance with the suggestions of the Committee on Stratigraphic Nomenclature (1933), they have been unofficially accepted by many geologists working in this area (for instance, Guennel, 1958). These names are here accepted as formal names for members of the Mansfield Formation because it is desirable to have a name for these two marker units and because these names have had reasonably common and consistent usage over the past 20 years.

Franklin's type section for the Pinnick Coal, a small mine on the Pinnick property in the SE¼SW¼ sec. 32, T. 2 N., R. 2 W. (Franklin, 1939, p. 9-10), is apparently no longer exposed, but the coal may be seen above the whetstones in parts of the old Braxton Quarries in the SE¼SE¼ sec. 32, T. 2 N., R. 2 W., and in the NE¼NE¼ sec. 5, T. 1 N., R. 2 W., at approximately 750 feet altitude; other exposures here identified as Pinnick, but at some distance from the type locality, are found at 710 feet altitude just northeast of Robinson Cemetery in the NW¼NE¼ sec. 24, T. 1 N., R. 3 W., at old mine openings at 680 feet in the NW¼NW¼ sec. 14, T. 1 N., R. 3 W., and in the SW¼SW¼ sec. 13, T. 2 N., R. 3 W., at 740 feet altitude (table 3). The average thickness of the Pinnick Coal, where present, is probably about 1 foot. Ashley (1899,

p. 1086) reported a maximum thickness of 4 feet for this coal, which he called Coal Ia; the location at which this observation was made is unknown.

The French Lick Coal, or a coal bed occupying approximately the same stratigraphic position, is extensive enough to show on the map (pl. 1) only in and around sec. 32, T. 2 N., R. 2 W., sec. 10, T. 3 N., R. 3 W., and sec. 29, T. 3 N., R. 2 W. Franklin's type section for the French Lick Coal, in the SW¼NW¼ sec. 4, T. 2 N. (sic), R. 2 W. (Franklin, 1939, p. 9), could not be found. The quarry and mine to which Franklin refers are probably those in the NE¼NE¼ sec. 5, T. 1 N., R. 2 W. (pl. 1), approximately 1 mile west of the town of French Lick, for which the coal was named. This coal may be observed also at 705 feet altitude in the road cut in the NW¼NW¼ sec. 4, T. 1 N., R. 2 W.; other exposures here identified as French Lick are found in road cuts at the following localities: NE¼NE¼ sec. 4, T. 1 N., R. 3 W., at an altitude of 605 feet (Appendix, section 11); NE¼NE¼ sec. 4, T. 2 N., R. 3 W., at 620 feet; and NE¼NE¼ sec. 10, T. 3 N., R. 3 W., at 670 feet. The average thickness of the French Lick Coal, where present, is approximately 1 foot. Ashley (1899, p. 1084), who designated this as Coal I, reported a maximum thickness of 2.7 feet for a small mine, probably the one shown on the map (pl. 1) in the NW¼ sec. 29, T. 3 N., R. 2 W.

The nature and stratigraphic relations of the Pinnick and French Lick Coals are illustrated in section 11 and well record 2 (Appendix).

Economic evaluation of the Mansfield Formation.—The mineral products of the Mansfield, the most widespread formation in the Huron area, are interestingly varied but of small economic consequence. All have played their part in the settlement and development of this region and are thus of historic interest, but none is likely to be of great value again unless and until larger and more profitable deposits elsewhere are depleted and abandoned.

Some of the localities at which the economic products of the Mansfield Formation were formerly exploited are listed in table 3. No attempt has been made to make this table complete; the hills are dotted with abandoned mines, quarries, and prospect pits, all record of which is now lost. Only the better documented and larger enterprises representative of each of the mineral products of the Mansfield Formation are tabulated.

Table 3.—*Localities at which mineral raw materials have been produced from the Mansfield Formation*

Mineral raw material	Location			Operator's name	Horizon	Years operated (approximate)
	Sec.	T.	R.			
Dimension sandstones[1]	NE¼NE¼ 9	1N	2W	French Lick Sandstone Co.	Lower Mansfield	1950-53
Grindstones[1]	NW¼SW¼ 9	1N	2W	Benjamin Case	Lower Mansfield	1863-93
Whetstones[2]	NW¼NE¼ 5	1N	2W	Brown Moore	Lower Mansfield	1845- ?
	NE¼SW¼ 7	2N	2W	Dougherty (New Antioch)	do.	1880-1954
	SW¼SW¼ 28	2N	2W	Buerk (Mt. Airie)	do.	?
	SW¼NE¼ 31	2N	2W	Cassidy	do.	?
	SW¼SE¼ 32	2N	2W	Braxton	do.	1840- ?
	NW¼SW¼ 32	3N	2W	Ritter	do.	?
Iron ore[3]	SW¼ 1	3N	3W	Globe Furnace Co. (Pridemore)	Lower Mansfield	1873-1906?
Coal[4]	NE¼SW¼ 3	1N	3W	Quinn	French Lick	?
	SE¼SE¼ 3	1N	3W	Quinn	Blue Creek	1956-58
	SW¼NW¼ 10	1N	3W	Freeman (strip)	do.	1943
	SE¼NW¼ 10	1N	3W	Worthington	do.	1865-1920?
	NW¼SW¼ 10	1N	3W	St. Clair	do.	1880-1910?
	NW¼NW¼ 15	1N	3W	Lagenour	do.	1923-33
	NW¼NE¼ 16	1N	3W	Lyons	do.	1870-1946
	SE¼NE¼ 16	1N	3W	Taggart	do.	1880-1920
	SE¼NE¼ 32	2N	2W	French Lick Springs Hotel	French Lick	?
	SW¼SW¼ 13	2N	3W	Powell	Pinnick	?

[1] Maximum annual production not estimated.
[2] Maximum annual production estimated at 200 tons (year of 1894) (Kindle, 1896, p. 341).
[3] Maximum annual production estimated at 500 tons (year of 1906) (Shannon, 1907, p. 413).
[4] Maximum annual production estimated at 10,000 tons (year of 1905).

There is little reason to suppose that any of the mineral raw materials listed in table 3 will, in the foreseeable future, again be produced in this area in quantity. Dimension sandstone of better quality is available from formations of Mississippian age in the area or nearby. Grindstones and whetstones cannot now compete economically with mass-produced artificial abrasives. Iron ores of the area are of low grade (Bundy, 1956) and are of insufficient quantity to justify expensive beneficiation procedures at the present time.

There may be a considerable amount of coal of minable thickness remaining in the map area, especially in the vicinity of Coal Mine Ridge, but most of the easily accessible coal has been mined. Of the many mines once operating, only one or two remain active, and these are worked infrequently and only for local use. Fifty years or more ago coal was shipped from this area to French Lick and eastward, but with the building of the French Lick branch of the Southern Railroad in 1907 and the gradual improvement of highway transportation, coal was obtained more economically from larger mining districts to the west, and production in the Huron area gradually diminished.

Small supplies of water sufficient only for domestic and farm use can be obtained in most places from sandstones of the Mansfield Formation. Only the coarser grained and better sorted sandstones are likely to produce much water; the shaly sandstones and those that contain much clay as matrix are not sufficiently permeable to permit passage of much water through the sandstone into a spring or well. All the sandstones occur as discontinuous lenses partly or completely enclosed in less permeable siltstones or shales, so that accurate prediction of the existence of a water-bearing sandstone beneath the surface of the ground at any particular spot is impossible. There are, however, many such lenses, particularly in the lower part of the Mansfield Formation, so that probably one or more exist beneath any spot underlain by more than a few feet of the formation. Most wells driven 50 to 150 feet into the Mansfield are likely to produce a small amount of water, but no large supplies are available.

THE MISSISSIPPIAN-PENNSYLVANIAN UNCONFORMITY

The irregular surface of contact between the Mansfield Formation, the oldest formation of Pennsylvanian age in Indiana, and the still older rocks of Mississippian age that underlie the Mansfield is an unconformity. This unconformity represents an interval of erosion between two episodes of deposition—one in late Mississippian time and one in early Pennsylvanian. How much time is represented by this erosion surface is not precisely known; in other regions many hundreds of feet of sediments were deposited during this interval that is here represented by a surface of no thickness at all. Some of the broader aspects of this unconformity in Indiana and Illinois have been discussed by Malott (1951, p. 239-246) and Siever (1951); the unconformity has also been the subject of a recent field conference (Indiana Geological Survey, 1957).

In the Huron area, rocks of Pennsylvanian age are somewhat tilted, having a strike direction of approximately N. 10° W. and a westerly dip of approximately 28 feet per mile. This generalization, computed from data on the Pinnick Coal, is not particularly accurate because of the many local structural irregularities and the uncertainty of identification of the coal, but it serves for comparison with the N. 10° W. strike and westerly dip of 30 feet per mile of the unconformity surface (fig. 4A). Identification of this surface is less difficult, but it is so irregular that the generalized figures here also cannot be very accurate. These data indicate, however, that there is a slight convergence of the overlying rocks upon the unconformity, so that the rocks at the base of the Mansfield Formation are progressively younger eastward.

The general structural attitude of the rocks of Mississippian age that underlie the unconformity is rather different from that of the unconformity and the rocks above (fig. 4B). The strike of these older rocks is approximately N. 16° W., and the dip is southwesterly at approximately 33 feet per mile. This divergence strongly influences the general pattern of distribution of the rocks immediately beneath the unconformity; older rocks are found in the northeastern part of the area, and younger rocks are found in the southwestern part.

The surface of the unconformity is of topographic origin, and contours drawn on it might therefore be expected to resemble those of a modern topographic map. Contours shown on the map (fig. 4A) are smooth and generalized, however, owing primarily to lack of information; the number of points at which the unconformity may be observed directly is rather small (table 4). The entire data are inadequate to define any but the major valley system, and the contours are therefore drawn with a minimum of interpretation. A similar map of an adjacent area, drawn with a strong topographic interpretation, is found in Malott (1931, fig. 4).

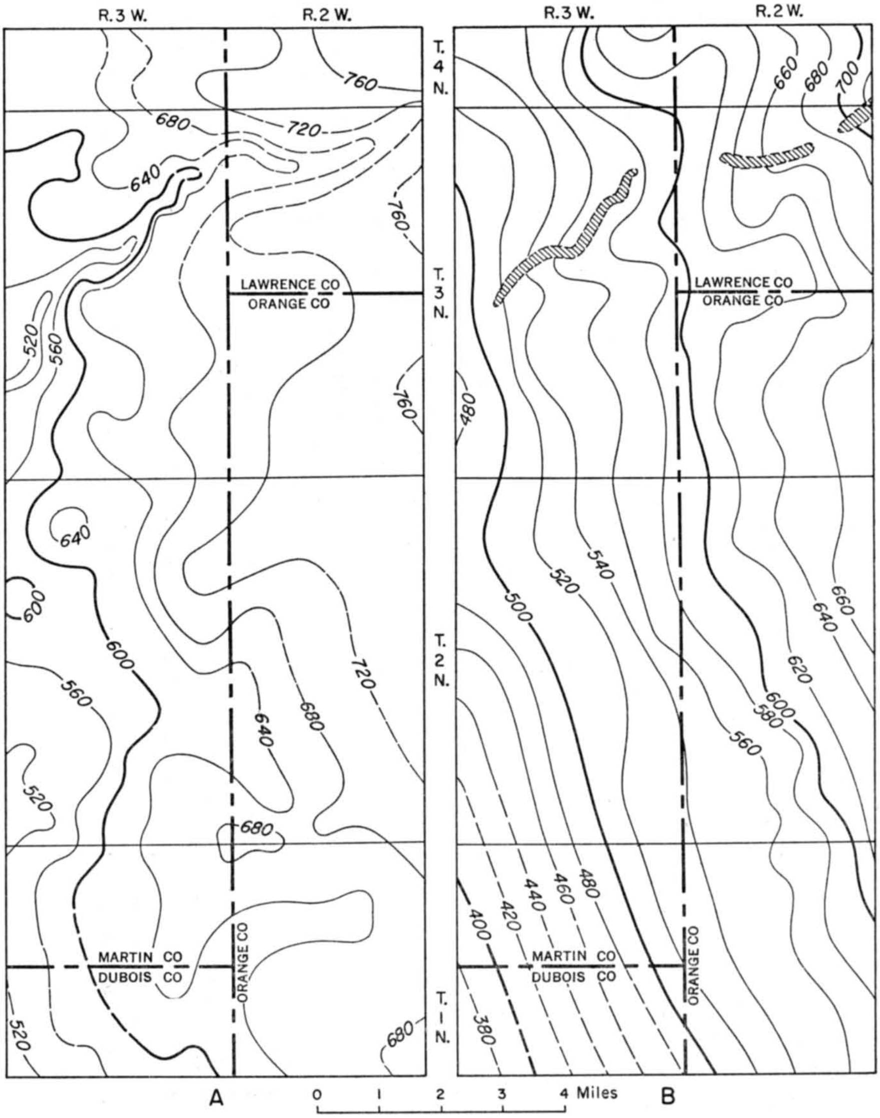


Figure 4.—Altitude-contour maps of Huron area. Contours dashed in areas of little information. Datum is mean sea level. A, Base of the Mansfield Formation. Contour interval 40 feet. B, Base of the Beech Creek Limestone (Stephensport Group). Contour interval 20 feet. Within shaded areas limestone has been removed by pre-Pennsylvanian erosion.

Table 4.—*Observations of Mississippian-Pennsylvanian contact*

Location			Description	Basal Mansfield lithology	Altitude	Underlying formation
Sec.	T.	R.				
SW¼NE¼ 22	1N	3W	Limestone quarry	Gray shale	553	Glen Dean (limestone)
NE¼SW¼ 32	2N	2W	Core hole	Sandstone with clay chips	683	Glen Dean (limestone)
NW¼NW¼ 33	2N	2W	Ravine beside road	Crossbedded sandstone	702	Hardinsburg (shale)
NE¼NE¼ 3	2N	3W	South of road	Dark-gray shale	611	Golconda (limestone)
SW¼NW¼ 13	2N	3W	West of highway	Thin-bedded sandstone	670	Glen Dean (limestone)
NW¼NE¼ 28	2N	3W	Ravine east of road	Ferruginous sandstone	555	Glen Dean (limestone)
SE¼SE¼ 33	2N	3W	Ditch west of road	Green-gray shale	530*	Golconda (limestone)
NW¼NW¼ 36	2N	3W	Bank southwest of road	Red-brown clay	673	Glen Dean (limestone)
SE¼NW¼ 29	3N	2W	Drill-hole samples	Greenish-gray shale	724	Golconda (limestone)
NW¼SW¼ 12	3N	3W	East of creek	Ferruginous sandstone	565*	Elwren (shale)
N½SE¼ 15	3N	3W	North bank of highway	Ferruginous sandstone	643	Golconda (limestone)
NE¼SE¼ 15	3N	3W	Northwest of highway	Dark-gray shale	591*	Big Clifty (shale)
NE¼NE¼ 25	3N	3W	Ravine east of road	Dark-gray shale	680	Golconda (limestone)
SE¼SW¼ 26	3N	3W	Ditch west of road	Thin conglomerate	618	Big Clifty (shale)
SE¼SE¼ 27	3N	3W	Limestone quarry	Uneven-bedded sandstone	642	Hardinsburg (clay)
SW¼NE¼ 28	3N	3W	Railroad cut	Ferruginous sandstone	535*	Big Clifty (siltstone)
NE¼SW¼ 36	4N	3W	Ravine south of cemetery	Silty shale	707	Big Clifty (shale)

* These exposures are significantly lower than normal for their locality, both topographically and stratigraphically, and therefore represent valleys in the unconformity surface.

It has sometimes been stated that the basal sediment of the Mansfield Formation is most commonly sandstone. At 9 of the 17 listed localities (table 4), the basal sediments are sandstone or conglomerate; at the others they are siltstone and shale. The data of table 1 indicate that 58 percent or more of the lower part of the Mansfield Formation is sandstone. Statistical comparison of these two sets of data shows that sandstone is no more abundant at the base of the Mansfield Formation than it is in the entire lower part of the Mansfield. Thus, on the basis of the rather small number of available observations, there appears to be no extraordinary concentration of sandstone immediately above the unconformity.

Casual inspection of the data presented in table 4 might lead to the conclusion that the rock type on which the Mansfield Formation most commonly rests is limestone. The Mississippian formations from Elwren to Glen Dean, on which the Mansfield rests in the Huron area, consist of limestone, shale and siltstone, and sandstone in almost equal abundance. Statistical comparison of this with the data listed in table 4 shows that the various rock types underlying the unconformity are represented essentially in proportion to their abundance among all the rocks of all the formations on which the Mansfield Formation rests. Thus limestone is not extraordinarily abundant immediately beneath the unconformity, at least insofar as indicated by the sampling of exposures available.

Economic evaluation of the Mississippian-Pennsylvanian unconformity.—The function of the Mississippian-Pennsylvanian unconformity as a control of economic mineral deposits in the Huron area may be resolved into two parts. First, there is the aspect of the unconformity as an uneven surface of contact that transects rock beds both above and below it and therefore laterally terminates beds of limestone or sandstone; this is here referred to as the *positional* aspect of the unconformity. Secondly, there is the aspect of the unconformity as a former topographic surface that may serve either to influence directly the distribution of certain rock types at or near the unconformity or to concentrate certain rock types at some preferred level on the irregular surface; this is here referred to as the *primary* aspect of the unconformity.

As previously noted, the unconformity does not preferentially rest on limestone and does not preferentially have sandstone directly above it. Because this is as true of former valley areas (table 4) as for the entire surface, it may be concluded that the distribution of the major rock types is independent of the primary aspect of the unconformity and that information on the unconformity will therefore be of no positive help in finding deposits of sandstone or limestone. Evaluation of known deposits will be facilitated, however, by knowledge of the position of the unconformity with respect to the deposits concerned, but in a negative way; that is, such knowledge will assist in predicting the limits of a known deposit.

The only economically valuable mineral resource of the region that appears to be genetically related to the Mississippian-Pennsylvanian unconformity is the endellite-halloysite clay that was mined 40 years or more ago near Huron and at Gardner Mine Ridge, just outside the area to the northeast. Callaghan (1948) described the Gardner Mine Ridge area in some detail; in his opinion the clay is the altered remains of soil that was formed on the Mississippian rocks before their burial by Pennsylvanian sediments. Known clay deposits in the Huron area are associated with a well-developed pre-Pennsylvanian valley (compare pl. 1 and fig. 4A), but those at Gardner Mine Ridge are on a relatively flat and high part of the pre-Pennsylvanian surface. It therefore seems unlikely that topography of the unconformity directly influenced development of the clay. The deposits are restricted, however, to areas in which the basal Pennsylvanian rocks lie on the Beech Creek Limestone or on the upper part of the Elwren Formation, and they therefore are probably related to the weathered products of these rocks.

The clay deposits, though of unusual character, are of small extent, and little of the clay is suitable for ordinary ceramic products, but some future use may be made of the clay because of its high alumina content (Callaghan, 1948, p. 43). Two abandoned clay mines are known in the Huron area, in the SW¼SE¼ sec. 5 and in the NW¼NE¼ sec. 8, both in T. 3 N., R. 2 W.

Absence of Mississippian rocks younger than Glen Dean Limestone.—In southernmost Indiana some 250 feet of shales, sandstones, and limestones of late Mississippian age intervene between the Glen Dean Limestone, the youngest Mississippian formation of the Huron area, and the base of the Mansfield Formation. These rocks either were never deposited in this area or, more likely, were removed by pre-Mansfield erosion.

In the southeastern part of the Huron area, at the southwest portal of Burton Tunnel (NE¼NW¼ sec. 20, T. 1 N., R. 2 W.), is an exposure that Malott (1925, p. 129; 1951, p. 243) assigned to the Tar Springs Formation, which overlies the Glen Dean Limestone. In this and other nearby exposures sandstone with wavy thin bedding rests on Glen Dean Limestone (as here restricted, see p. 38) of less than normal thickness, and the interbedded limestone and shale that characteristically lie directly above the Glen Dean are lacking. A massive sandstone that overlies the thin-bedded sandstone, also identified as Tar Springs by Malott, extends widely into adjacent areas in which the Glen Dean is very thin or absent altogether, and the top of this massive sandstone can be recognized southward for many miles by a stripped surface at exactly the position of the topographic bench that marks the break between the lower and upper parts of the Mansfield Formation. We therefore are of the opinion that at Burton Tunnel and vicinity all rocks above the limestone should be assigned to the Mansfield Formation rather than to the Tar Springs.

PROBLEMS OF NOMENCLATURE IN ROCKS OF LATE MISSISSIPPIAN AGE

In southern Indiana rocks of the Chester Series, of late Mississippian age, have been subdivided into many formations, most of which are too thin to map on scales ordinarily used. (See columnar section, pl. 1.) Probably these should originally have been designated members rather than formations, but they constitute perhaps the most firmly established set of stratigraphic names in Indiana geologic literature, and we consider it best to form mapping units by combining the formations into groups rather than to alter these established names. We are therefore reviving, with some modifications, group names proposed casually by Cumings (1922, p. 514), and we are proposing one new group name. We also are proposing minor changes (table 5) in those few formation boundaries that are difficult to identify with accuracy.

Table 5.—*Stratigraphic names used in this report for rocks of late Mississippian age*

	Most recent previous usage (Indiana Geological Survey, 1957, pls. 2 and 3)	Wabash Valley subsurface usage (Indiana Geological Survey, 1957, pl. 3)			This paper
	Absent	Seven upper Chester formations			Absent
upper Chester	Tar Springs Formation	Tar Springs Formation			
middle Chester	Glen Dean Limestone	Glen Dean Limestone		Stephensport Group	Glen Dean Limestone
	Hardinsburg Formation	Hardinsburg Formation			Hardinsburg Formation
	Golconda Formation	Golconda Limestone			Golconda Limestone
	Big Clifty Formation	Jackson Formation			Big Clifty Formation
lower Chester	Beech Creek Limestone	Barlow lime			Beech Creek Limestone
	Elwren Formation	Cypress Sandstone		West Baden Group	Elwren Formation
	Reelsville Limestone	Paint Creek Formation	Upper Paint Creek Limestone		Reelsville Limestone
	Sample Formation				Sample Formation
	Beaver Bend Limestone		Lower Paint Creek Limestone		Beaver Bend Limestone
	Bethel Formation	Bethel Formation			Bethel Formation
	Paoli Limestone	Renault Formation		Blue River Group	Paoli Limestone
	Aux Vases Formation				
	Ste. Genevieve Limestone	Ste. Genevieve Limestone			Ste. Genevieve Limestone
	St. Louis Limestone	St. Louis Limestone			St. Louis Limestone

STEPHENSPORT GROUP

Cumings (1922, p. 514) suggested the name Stephensport as a group name to include formations now known as Glen Dean, Hardinsburg, Golconda, and Big Clifty. The name also had been used earlier in a somewhat different sense. Neither usage has found much acceptance; instead, the semiformal usage of "middle Chester" favored by Stuart Weller (1920) has become common (for instance, Perry and Smith, 1958). Such usage of time-rock terms in a strict rock-unit sense is now unacceptable in stratigraphic nomenclature; hence we propose to revive Cumings' group name, Stephensport.

The Stephensport Group is here redefined (table 5) as consisting of the following formations, in descending order: Glen Dean Limestone (restricted), Hardinsburg Formation (shale and sandstone), Golconda Limestone (restricted), Big Clifty Formation (shale and sandstone), and Beech Creek Limestone (columnar section, pl. 1). This group is named for the town of Stephensport, Breckinridge County, Ky., in the vicinity of which all the formations of the group are well exposed.

The average thickness of the Stephensport Group in the Huron area is approximately 140 feet, as indicated by seven measurements that range from 128 to 158 feet. The group is overlain unconformably by the Mansfield Formation in this area, and its thickness is therefore somewhat less than the original thickness; but measurements in places where pre-Mansfield erosion has greatly reduced the thickness of the group are not included in the figures above, and these values are therefore close estimates of the full original thickness of the group.

With the addition of the Beech Creek Limestone to the formations included by Cumings in the Stephensport, the group includes the three thickest and most widely recognizable limestones in this part of the stratigraphic column. The unit is thick enough to map on conventional scales and is suitable for many types of stratigraphic investigation. The top and bottom of the group are readily identified from surface data and are commonly and reliably picked from subsurface data. The group is distinct lithologically: it consists approximately one-third of limestones, substantially more than overlying and underlying groups; the darker gray shales of the group contrast with the generally more varicolored shales of groups above and below; and the principal sandstone member, the lower part of the Big Clifty Formation, is far more uniformly distributed than sandstones in groups above and below.

Glen Dean Limestone (restricted).—The uppermost formation of the Stephensport Group is the Glen Dean Limestone. In recent usage (Indiana Geological Survey, 1957) this formation has included a lower or main limestone member and an upper interbedded shale and limestone member. We propose to restrict the name Glen Dean to the more persistent main limestone member of the formation and thus make the upper contact less equivocal and more consistent and the lithologic term limestone more truly descriptive of the formation. In the Huron area only the main limestone is present; in other areas this restriction will reduce the Glen Dean to approximately half its former thickness. The interbedded shale and limestone formerly assigned to the upper part of the Glen Dean should be placed in the overlying Tar Springs Formation.

In the Huron area the Glen Dean Limestone as restricted is as much as 30 feet thick in some places (Appendix, section 14). The upper contact is at an erosional surface, however; the formation, wherever present, is unconformably overlain by the Mansfield Formation, and the thickness of the limestone is therefore not the full original thickness. It is probable, however, that the original thickness was not much more than 30 feet.

The Glen Dean consists principally of limestone in which abundant coarsely crystalline fossil fragments are set in a finely crystalline matrix. The fresh rock is gray to light pink in color, and it weathers to a mottled light yellow brown. Two features distinguish the Glen Dean from other limestones of late Mississippian age: it is commonly thick bedded, even lacking visible evidence of bedding (pl. 3A), and on some exposures it weathers into small slabs that peel off parallel to the weathered surface rather than parallel to the bedding. Small caves are found in the Glen Dean in a few places, springs locally mark its outcrop, and in a few areas sinkholes have been formed in upland surfaces underlain by the limestone, but these features are not particularly characteristic.

The Glen Dean Limestone forms few natural outcrops and is best seen in artificial exposures such as road cuts and quarries. It rests on the Hardinsburg Formation, apparently conformably, but the actual contact is seen in few places other than drill-hole cores (Appendix, well record 2).

Many different types of fossils are known from the Glen Dean (Horowitz and Perry, 1956; Indiana Geological Survey, 1957, p. 27-28), including brachiopods, crinoids, blastoids, corals, and bryozoans.

Hardinsburg Formation.—Beneath the Glen Dean Limestone is the Hardinsburg Formation. This rock unit consists mostly of gray shales, siltstones, and mudstones and in places includes thin-bedded fine-grained sandstones, some of which are ledge forming. The thickness of the formation ranges from 62 feet in an area in which the Hardinsburg is mostly sandstone (NE¼SE¼ sec. 19, T. 1 N., R. 2 W.) to 43 feet in a drill hole in which the formation is mostly shale (Appendix, well record 2). Only these two measurements are available, and so the average thickness of the Hardinsburg in the Huron area cannot be stated with much certainty. The formation generally does not crop out and is not well exposed even in quarries and road cuts; we therefore believe that the Hardinsburg in most of the area consists largely of shale.

The contact between the Hardinsburg Formation and the underlying Golconda Limestone is transitional; in many places there are thin beds of limestone in the lower few feet of the Hardinsburg or thin beds of shale in the upper part of the Golconda. Probably the contact between the two formations is not everywhere picked at precisely the same stratigraphic position, but the zone of uncertainty through which the contact may range is commonly no more than 5 or 10 feet.

Golconda Limestone (restricted).—In Indiana as recently as 1957 (Indiana Geological Survey, 1957) rocks considered to belong to the Golconda Formation have included an upper limestone member and a lower shale member. The shale, however, appears to be more closely related to the sandstone unit that underlies it (Big Clifty) than to the limestone, and we therefore consider it proper to restrict the name Golconda to the limestone. The lithologic name "limestone" then becomes proper, and we shall refer to the formation as the Golconda Limestone (table 5).

The Golconda Limestone is characterized by fine-grained somewhat silty or shaly sparsely fossiliferous limestone, but finely crystalline limestone with abundant fossil fragments is common and in some places makes up most of the formation. The weathered color ranges from light gray to medium yellow brown, the latter being somewhat more conspicuous near the top of the formation. In the shaly parts of the limestone thin bedding is the rule, but elsewhere the bedding is generally indistinct, irregular, and thick. Five measurements of the thickness of the Golconda in the Huron area range from 19 to 32 feet and average 25 feet. The limestone is well exposed in quarries and road cuts, but the underlying and overlying formations are generally poorly exposed, and thus reliable thickness measurements of the Golconda are difficult to obtain.

Few caves are found in the Golconda, and few springs issue from its outcrop. Probably the shaly character of the overlying Hardinsburg Formation and shale partings common in the Golconda prevent downward percolation of water into the formation. The limestone is readily soluble, however, as shown by the characteristic weathering of outcrops into rounded projecting ledges and anvil-shaped blocks.

The Golconda Limestone rests with apparent conformity on shale assigned to the upper part of the Big Clifty Formation. One of the few places at which this contact may be observed is in the NW¼NE¼ sec. 28, T. 3 N., R. 3 W., in the cut along the railroad spur leading to the plant of the National Gypsum Co. (Indiana Geological Survey, 1957, p. 14-16).

A variety of fossils are found in the Golconda, including crinoids, brachiopods, bryozoans, and locally abundant blastoids. Many of these have been replaced by silica, and as a consequence they accumulate in the clay soil as the more soluble limestone is removed during weathering.

Big Clifty Formation.—This formation (including the shale unit formerly considered to be the lower part of the Golconda Formation) consists of an upper unit of sparsely fossiliferous gray shale (Appendix, section 2), a middle zone of mixed lithology (Appendix, well record 2, units 33-36), and a lower unit consisting mainly of very fine-grained sandstone (Appendix, section 7). The shale is soft, generally poorly exposed, and approximately 10 feet thick. It is transitional downward into the zone of mixed lithology, which includes thin beds of shale, sandstone, siltstone, limestone-conglomerate, and nodular silty limestone. This zone is generally about 5 feet thick and is transitional downward into the lowest unit, a clean quartz sandstone approximately 35 feet thick that commonly exhibits honeycomb weathering. This is the most prominent and widespread ledge-forming stratigraphic unit in the area. The upper surface of the sandstone unit is peculiarly scalloped on a large scale, but the transitional nature of the contact shows that this is not an erosion surface.

The relations outlined above summarize our reasons for including the fossiliferous gray shale in the Big Clifty rather than in the Golconda. The entire thickness of the formation as redefined ranges from 42 to 56 feet, but it is not directly measurable at many places; we estimate the average thickness of the formation at 50 feet, but this is not to be regarded as very reliable.

The sandstone in the lower part of the Big Clifty Formation has so often been mistaken for sandstones of the Mansfield Formation that it is worth discussing some of the principal differentiating characteristics. Sandstone of the Big Clifty is, on the average, somewhat finer grained, somewhat better sorted, somewhat more quartzose, and somewhat less rich in iron oxides than sandstones in the Mansfield, but none of these characteristics is sufficiently clear cut to permit ready distinction. Sandstone of the Big Clifty is considerably more uniform in its occurrence and characteristics than sandstones in the Mansfield; whereas Mansfield sandstones are notably discontinuous, the Big Clifty forms miles and miles of almost continuous ledge and is nowhere within the Huron area known to be absent from its expectable stratigraphic position except, of course, where it has been removed by pre-Mansfield erosion. Perhaps the best criterion for spot identification is the bedding character: the bedding of the Big Clifty is thin to medium and even or slightly wavy, and there is some low-angle planar crossbedding of modest scale; ledge-forming Mansfield sandstones of superficially similar appearance commonly exhibit either great sweeping sets of slightly concave crossbedding that locally attains rather high angles of inclination or extremely irregular, disordered, even somewhat disturbed crossbedding.

At the base of the Big Clifty Formation, but rarely seen on outcrop, is a very thin bed of black pyritic shale. The Big Clifty rests with apparent conformity on the lowermost formation of the Stephensport Group, the Beech Creek Limestone.

Beech Creek Limestone.—One of the best known, most widespread, and most reliable marker beds in rocks of Mississippian age is the Beech Creek Limestone, the lowest formation in the Stephensport Group. This formation extends almost continuously throughout the Illinois Basin; in very few places is it known to be absent from its normal position in the rock sequence except where it has been removed by pre-Mansfield erosion. Consistency of occurrence, character, and thickness makes this limestone one of the more readily identifiable formations both on the surface and in the subsurface. Petroleum geologists and drillers know it as the "Barlow lime" (table 5).

The full thickness of the Beech Creek Limestone may be observed in many places in the Huron area. It averages 15 feet, as shown by 12 measurements ranging from 12 to 18 feet. The upper part of the formation is generally light-gray or light yellow-brown medium-crystalline abundantly fossiliferous limestone. The lower part commonly is finely crystalline sparingly fossiliferous limestone, medium gray on fresh exposure and medium yellow brown on weathered surfaces (pl. 3B). These divisions are characteristic of the formation throughout most of its extent (Malott, 1952, p. 14).

The Beech Creek Limestone is well exposed in the Huron area, generally beneath overhanging ledges of sandstone of the Big Clifty Formation, in quarries, road cuts, ravines, and alcove springs. The characteristic weathered outcrop of the Beech Creek is a series of continuous rounded ledges. Extensive cavern systems have been formed in the limestone, but the overlying sandstone is thick and strong, and sinkholes are not common in upland surfaces underlain by the limestone.

Fossils of the Beech Creek are considerably less varied than those of the Golconda or Glen Dean Limestones. Most of the fossils are crinoid columnals, some of which are as much as 15 millimeters in diameter. Columnals of such size are unknown from other limestones in this region and are of value in the identification of the Beech Creek. Crinoid heads are poorly represented; other than the columnals, the fauna consists essentially of several species of brachiopods, mostly of productid types.

The Beech Creek Limestone rests conformably on shales and mudstones of the upper part of the Elwren Formation. Because more data are available on the Beech Creek than on any other formation, it has been chosen as a representative horizon for structure contouring (fig. 4B).

Economic evaluation of the Stephensport Group.—Within the Huron area the Stephensport Group includes two rock types of economic value. Limestone has been quarried at many places, and dimension sandstone has been taken from the Big Clifty Formation.

Limestone quarries, mostly small and all abandoned perhaps 20 years or more, punctuate the outcrops of the three limestones in the Stephensport Group. It has been practicable to show only the larger and more important of these on the map; if all the excavations from which limestone was once taken for road building or other purposes were known, there would probably be on the order of a hundred quarries in each of these limestones. Little stone has been taken since the late 1930's when a number of the larger openings were made for the Works Progress Administration for county road improvements.

Prospects for future development of these limestones for road metal or agricultural limestone are not especially favorable. The Glen Dean Limestone produces rock that is commonly soft and somewhat impure. Stone from quarries in the Golconda Limestone is apt to contain undesirable shaly material. The best stone, crystalline, shale free, and relatively pure, may be obtained from the Beech Creek Limestone, but this formation is so thin as to be unworkable economically, and its normal occurrence on steep slopes overlain by the ledge-forming sandstone in the lower part of the Big Clifty Formation makes development on a large scale unlikely.

Within the past 10 years interest in sandstone as a building material has been increasing, and several quarry operators in Indiana have begun producing cut- and split-face ashlar stone for sandstone veneer construction. Sandstone finished at the mills of the Indiana Sandstone Co., Leonard Sandstone Co., and Spice Valley Sandstone, Inc., located along U. S. Highway 50 near Huron, comes from the Big Clifty Formation, from several quarries in and about the northern parts of secs. 29 and 30, T. 4 N., R. 2 W., just north of the Huron area. The French Lick Sandstone Co., of French Lick, also has quarries in the same area. Large reserves of stone suitable for quarrying are known, but in only a few places does the stone possess, apparently as a result of weathering, the variation in color and pattern that seems to be favored by the building trade at the present time.

Supplies of water sufficient for domestic and very light industrial use may be obtained in many places from rocks of the Stephensport Group. Springs issue from some of the sandstones and from most of the limestones, and wells driven into these strata will produce in most places moderate amounts of water. In general the largest supplies come from the Beech Creek Limestone; most springs and wells having this as their source can be depended upon for a fairly constant supply of water at the rate of a few gallons a minute.

WEST BADEN GROUP

Cumings (1922, p. 514) originally suggested West Baden as a group name to include, in descending order, formations now known as Beech Creek Limestone, Elwren Formation, Reelsville Limestone, Sample Formation, Beaver Bend Limestone, Bethel Formation, and Paoli Limestone. The name appears not to have found any use, semiformal names such as "lower Chester" having been used in its stead (Perry and Smith, 1958; Malott, 1952). The latter is a time-rock term and is not an acceptable name for a group of rocks, and therefore we propose to revive Cumings' name, West Baden.

The West Baden Group is here redefined (table 5) as consisting of the following formations in descending order: Elwren Formation, Reelsville Limestone, Sample Formation, Beaver Bend Limestone, and Bethel Formation (columnar section, pl. 1). The group is named for the town of West Baden, Orange County, Ind., which is just off the east edge of the Huron area. All formations of the group are well exposed at many places within a few miles of the named locality. Almost the entire group is excellently exposed in the Baltimore and Ohio Railroad cut just east of Huron (NE¼SW¼ sec. 5, T. 3 N., R. 2 W.). (See Malott, 1952, p. 103-104, and Indiana Geological Survey, 1957, p. 10-12.)

The average thickness of the West Baden Group in the Huron area is approximately 115 feet, as indicated by five measurements which range from 105 to 135 feet. Measurements were not taken in those places where pre-Mansfield erosion has removed a part of the group (fig. 4B), and the thicknesses listed above are considered representative of the full original thickness.

The Beech Creek Limestone is here removed from Cumings' suggested grouping and placed in the overlying Stephensport Group for reasons already stated (p. 37). The Paoli Limestone, as modified (p. 49-50), is placed in the underlying Blue River Group because of its close lithologic and economic affinity to rocks of that group. The West Baden Group, as thus restricted, consists primarily of gray and varicolored shale, sandstone, and discontinuous beds of limestone of variable thickness. Its predominantly clastic nature and the irregularity of the limestone formations that it includes distinguish this group from groups above and below. Its thickness is adequate for mapping on commonly used scales, and it is suitable for other types of stratigraphic studies as well. In the Wabash Valley area, rocks equivalent to the West Baden Group are referred to informally by petroleum geologists as "Bethel-Cypress."

Elwren Formation.—At the top of the West Baden Group is the Elwren Formation. Approximately two-thirds of this formation consists of green-gray, red-brown, and olive-gray shales, siltstones, and mudstones that are notably different from the drab gray shales of the Stephensport Group and therefore serve as reliable distinguishing features. The remainder of the formation is mostly unevenly thin-bedded very fine-grained sandstone that contains some thick lenses of crossbedded fine-grained sandstone. Four measurements of the thickness of the Elwren Formation in the Huron area range from 37 to 52 feet and average 44 feet. Good natural outcrops of the formation are rare because only the crossbedded sandstones are resistant to erosion, but artificial exposures are common (Appendix, sections 1, 5, and 7).

The contact between the Elwren Formation and the underlying Reelsville Limestone is apparently conformable wherever the limestone is present. In many places, however, the Reelsville is absent or unrecognizable, and at such places the Elwren cannot be distinguished from the underlying Sample Formation (Appendix, section 8).

Reelsville Limestone.—The most variable and erratic limestone formation in the Huron area is the Reelsville. At different exposures this appears as fossiliferous oolitic limestone, crossbedded sandy limestone, fossiliferous calcareous sandstone, crossbedded quartzitic sandstone, or ferruginous fossiliferous siltstone. Some of these phases are described in the Appendix (sections 1 and 5; well record 2); others are discussed elsewhere (Indiana Geological Survey, 1957). Despite the known variation in lithology, the Reelsville is appropriately referred to as a limestone because it is never recognized in the absence of limestone or limy and fossiliferous rocks.

The thickness of the Reelsville Limestone in the Huron area is approximately 5 feet, as shown by five measurements that range from 3 to 7 feet. The limestone or recognizably equivalent rocks are absent, however, in perhaps one-third of the localities at which stratigraphically equivalent rocks are exposed. These localities are not included in the thickness figures listed above.

Because of the variation in its thickness and character the Reelsville Limestone is an unreliable stratigraphic marker. Its absence is probably due to nondeposition rather than to erosion after deposition (Gray and Perry, 1956). Natural outcrops are not common, but roadside exposures are numerous in ditches and cuts, where the limestone is mostly exposed as a row of large projecting rounded blocks that weather red brown. The fossil assemblage of the Reelsville Limestone includes crinoid stems, brachiopods, corals, and a few bryozoans and crinoid heads. The contact between the limestone and the underlying Sample Formation is conformable.

Sample Formation.—This formation is essentially similar to the Elwren in nature and relative abundance of the various rock types that it contains. Approximately 60 percent of the formation consists of varicolored shales, siltstones, and mudstones; the remainder is mostly thin-bedded and crossbedded sandstone. Only three measurements of the thickness of the Sample Formation are available; these range from 22 to 36 feet and average approximately 29 feet. There is some evidence that this formation is thicker than average where the proportion of sandstone is high (Appendix, section 5). The formation generally does not crop out naturally, but roadside exposures are common (Appendix, sections 1 and 5; see also well record 2).

Where the Reelsville Limestone is absent and the Sample and Elwren Formations are indistinguishable, the average thickness of the combined formations is approximately 85 feet, as indicated by three measurements that range from 78 to 89 feet. This thickness is sufficiently greater than the sum of the average thicknesses of the individual formations to support the conclusions of Gray and Perry (1956) that the local absence of the Reelsville Limestone is not the result of erosion shortly after deposition. On the contrary, it suggests that the Reelsville is absent where clastic sedimentation was heaviest, the limestone deposition being restricted to those areas in which carbonate sediment could form because clastic deposition was slight.

The contact between the Sample Formation and the underlying Beaver Bend Limestone is seen in few exposures but appears to be conformable.

Beaver Bend Limestone.—The thicker and more continuous of the two limestones in the West Baden Group is the Beaver Bend Limestone. This consists mainly of very light brown-gray oolitic and fossiliferous limestone (Appendix, section 8 and well record 2). The upper few feet of the formation is in many places somewhat shaly (Appendix, well record 2), and the fossils in this part are generally better preserved and more abundant than in the remainder of the limestone. In fresh exposures the limestone weathers into large angular slabs; irregular rounded projecting ledges characterize the more deeply weathered outcrops.

In the Huron area the Beaver Bend Limestone is less regular in thickness than it is in adjoining areas. Three representative measurements made in the map area range from 8 to 27 feet in thickness and average approximately 17 feet. The most common thickness for the limestone in most of its outcrop area in Indiana is 10 to 14 feet (Malott, 1952, p. 13), and the average given above may therefore be somewhat too large. The limestone is well over 20 feet thick, however, in parts of secs. 9, 16, 17, and 21, T. 2 N., R. 2 W., and it may also be thicker than normal over much of the rest of the area.

The Beaver Bend Limestone is moderately fossiliferous; crinoid columnals, brachiopods, and blastoids are the most commonly found remains of former life. The contact between the Beaver Bend and the underlying Bethel Formation appears everywhere to be conformable.

Bethel Formation.—Lowermost in the West Baden Group is the Bethel Formation. This is distinctly different from other formations of late Mississippian age in the Huron area, being made up of soft light-gray shale, sandstone with wavy thin bedding, and beds of coal that are generally less than half a foot thick. Plant fossils are common in the sandstone, and small root impressions are found in the clayey shale that underlies the coal.

No well-exposed sections of the Bethel Formation are to be found in the area. A section that is now covered was measured several years ago by Malott (1952, p. 102) in the SE¼ sec. 4, T. 3 N., R. 2 W., near Connerly's (sic) Cavern. This shows 26 feet of Bethel, only half of which was exposed. The dominant lithology is gray shale; some sandstone and two thin beds of coal were also seen. This appears to be the normal thickness and constitution of the Bethel in this area; other measurements range from 16 feet to approximately 35 feet in thickness.

The contact between the Bethel Formation and the underlying Paoli Limestone is exposed in only a few places in the area but appears to be conformable.

Economic evaluation of the West Baden Group.—Little mineral wealth is represented by the rocks of the West Baden Group. Of the limestones, only the Beaver Bend is sufficiently thick for use. A few quarries, some of moderate size, have been operated in this limestone in the Huron area, but all are now shut down because limestone is available from larger and more efficient quarries in older limestones a few miles east of the area.

Attempts have been made to produce dimension stone from the sandstones of the Sample and Elwren Formations, but these rocks lack the desired color range, being mostly light to medium yellow brown. Sandstone in the Bethel Formation is in most places criss-crossed by veins of iron oxides that quarry operators consider undesirable. Attempts to mine the coal in the Bethel Formation have not been successful. This coal is high in ash and too thin to mine.

Small supplies of water, adequate only for domestic use, may be expected from rocks of the West Baden Group in the Huron area. Most of the sandstones of the group are relatively impermeable; only the crossbedded sandstones of the Elwren and Sample Formations are likely to produce much water, and these are found only in small areas. Springs from the discontinuous and thin Reelsville Limestone are very small. Somewhat larger springs issue from the Beaver Bend Limestone, but few of these flow as much as a gallon per minute during normal dry seasons.

BLUE RIVER GROUP

The Blue River Group is here named and defined (table 5) as consisting of the following formations in descending order: Paoli Limestone (as amended, see p. 49-50), Ste. Genevieve Limestone, and St. Louis Limestone (columnar section, pl. 1). At the suggestion of Ned M. Smith, Industrial Minerals Section, Indiana Geological Survey, this group is named for Blue River, which drains parts of Washington, Harrison, and Crawford Counties, Ind., along the banks of which the formations of the group are well exposed. Excellent exposures are to be found in quarries in the vicinity of Milltown, Crawford County.

The entire thickness of the Blue River Group cannot be seen at the surface in the Huron area because the lower part of the Ste. Genevieve and the entire St. Louis Limestone are not exposed. The records of test wells for oil and gas in the area show that the group is approximately 400 feet thick (Appendix, well record 1); only the top 70 feet of the group is exposed (Appendix, section 4).

The formations of the Blue River Group are difficult to separate one from another, and they form an economic unit, as they most commonly are quarried together. The contacts between the formations are transitional and in most places must be rather arbitrarily established. The group possesses lithologic unity and is distinct from groups above and below; it is a workable unit which can be recognized from surface and subsurface data, thick enough to map on any common scale, and adaptable to a variety of stratigraphic studies. The boundary between the Chester Series and the underlying Meramec Series comes somewhere within the group, but the uncertainty with which this boundary may be drawn confirms our belief in the independence of rock-defined and time-defined boundaries.

The Blue River Group consists principally of thin- to thick-bedded very finely crystalline sparingly fossiliferous limestone. In the upper part of the group some of the limestones are oolitic, and there are a few discontinuous beds of limestone breccia and several extensive beds of calcareous shale and siltstone. In the middle part there are widespread beds of chert and zones of abundant chert nodules. Towards the base some of the limestones are shaly and some are dolomitic, and there are widespread beds of gypsum and anhydrite a few feet thick which, being water soluble, are nowhere exposed at the surface but are recognized in many test wells drilled for oil and gas (Appendix, well record 1).

Paoli Limestone.—The uppermost formation in the Blue River Group is the Paoli Limestone. This consists principally of light-gray very finely crystalline sparingly fossiliferous limestone. In the lower two-thirds of the formation are some light green-gray to light yellow-brown calcareous siltstones and shales, and in places there are thin beds of limestone breccia. Typically the limestone weathers to low rounded continuous ledges of medium-gray color.

The Paoli Limestone has for some time been defined essentially as we here define it; we wish to include in the Paoli, however, what previously (Malott, 1952, p. 11-12) has been known in Indiana as the Aux Vases Formation. This bed is generally not over 3 feet thick, and in many places it is altogether lacking. It bears little resemblance to the Aux Vases Sandstone of southeastern Missouri, with which it was formerly correlated, and for some years it has been apparent that this correlation was probably incorrect (Swann and Atherton, 1948, p. 270). For these reasons we reject the name Aux Vases for use in Indiana. The calcareous siltstones and shales of this unit are similar to others included in the Paoli Limestone, and we therefore propose that strata formerly called Aux Vases Formation in Indiana be now regarded, where present, as the basal unit of the Paoli Limestone.

In the Huron area the Paoli Limestone, as redefined, ranges from 29 to 38 feet in thickness, as shown by five measurements that average 32 feet. It underlies the floors or lower walls of most of the valleys in the eastern part of the area. Areas underlain by the limestone are characterized by numerous sinkholes and subterranean drainage (for example, SW¼ sec. 33, T. 4 N., R. 2 W., and NW¼ sec. 4, T. 3 N., R. 2 W.).

Fossils are less abundant in the Paoli than in the younger limestones already discussed, but brachiopods, mostly of productid types, and a few corals, crinoids, and blastoids are found. Collecting these is difficult because they do not weather free of the enclosing rocks; in most places one often sees only cross sections on broken surfaces of the stone. The lower contact of the Paoli is sharp and slightly irregular, but without clear evidence of unconformity. It is not certain that the contact is everywhere picked at the same stratigraphic position.

In the Wabash Valley area rocks equivalent to the Paoli and the upper part of the Ste. Genevieve are referred to by petroleum geologists as the Renault Formation (table 5).

Ste. Genevieve Limestone.—The oldest formation exposed in the Huron area is the Ste. Genevieve Limestone, of which only the upper part is seen. The remainder of the formation, as well as formations beneath it, may be observed east of the area, where the older rocks are brought to the surface as a consequence of the normal westerly regional dip. Within the area the Ste. Genevieve is probably 150 to 175 feet thick; of this only the upper 35 feet or so is exposed, the maximum being in the vicinity of New Dougherty School (NE¼ sec. 9, T. 2 N., R. 2 W.; Appendix, section 4).

The exposed part of the Ste. Genevieve Limestone consists principally of very finely crystalline sparingly fossiliferous light-gray limestone that weathers shades of medium gray and light yellow brown. In places there are beds of sandy and silty limestone, and some of the limestone is oolitic. Thin silty shales are found near the top of the formation, and at the very top is a discontinuous bed of somewhat cherty brecciated limestone approximately 1 foot thick which is known as the Bryantsville Breccia Bed. This by definition marks the top of the Ste. Genevieve Limestone, but unfortunately there are other similar breccia beds in the upper part of the Ste. Genevieve and the lower part of the overlying Paoli Limestone, and in a few places it is not possible to determine positively which of these is the Bryantsville.

Scattered spiny crinoid columnals of oval cross section, a few colonial corals, some solitary corals, and two types of brachiopods are the characteristic fossils of the part of the Ste. Genevieve Limestone that is exposed in the area.

Economic evaluation of the Blue River Group.—More limestone for road metal and agricultural limestone is produced from rocks of the Blue River Group than from any other rock unit in Indiana. In the Huron area, however, quarrying operations have been limited because these rocks are exposed low in the valleys and operations cannot proceed far without encountering water or thick overburden. The few small quarries once operated in the area are now abandoned. Large quarries are working these rocks a few miles east of the area near Paoli, Orleans, and Mitchell, where the rocks lie topographically higher and are therefore more accessible.

Wherever exposed, rocks of the Blue River Group exhibit a well-developed set of fractures or joints through which water moves readily. Because the limestones are relatively pure they are easily soluble in moving water; the joints are thus enlarged, and their flow capacity is increased. In this way cavities of a wide range of sizes, some large enough to call caves, are formed in the limestones. Wells drilled into the limestones are likely to tap these enlarged joint systems, which may prove to be the source of large amounts of water. The water is likely to be hard because of the dissolved limestone that it contains; it may be contaminated because rapid concentrated flow through large openings is not an effective filter; and it may fluctuate with the season because water flows so rapidly through the joint systems that relatively little is stored against a dry season. Nevertheless, such water may be adequate for light industrial use; some of the stone mills near Huron use water from wells in the Blue River rocks.

CONSOLIDATED ROCKS NOT EXPOSED AT THE SURFACE

Rocks below the upper part of the Ste. Genevieve Limestone are not exposed in the Huron area, but their thickness and general character may be inferred from the records of the five test wells for oil and gas that have been drilled in the area (table 6). All these wells were dry and are now abandoned. Most of the depth figures in table 6 were supplied by Arthur P. Pinsak, of the Petroleum Section, Indiana Geological Survey.

BLUE RIVER GROUP

The Blue River Group is approximately 400 feet thick and consists of the Paoli, Ste. Genevieve, and St. Louis Limestones. The lower part of the Ste. Genevieve and the entire St. Louis are known in the Huron area only from subsurface data (Appendix, well record 1). These rocks have been described previously (p. 48-49). Large quantities of gypsum and anhydrite are now being mined from the lower part of the Blue River rocks along the west-central edge of the Huron area.

Table 6.—*Test wells for oil and gas*

Location			Operator and well name	Completion date	Surface altitude	Depth to top of selected rock units					Total depth (feet)
Sec.	T.	R.				Renault	Salem	Borden	New Albany	Devonian limestones	
3	1N	3W	Wheeler No. 1 Quinn[1]	1925	662						3,200?
18	3N	2W	Jones No. 1 Calvert	1955	668	170	587	850?	1,285	1,388	1,703
19	3N	2W	Bedford Devel. No. 1 Brothers	1944	560	65	458?	758?	1,170	1,273	1,517
29	3N	2W	Hays No. 1-A Baker	1939	798	295	705	1,035?	1,400	[a]1,520	3,226
12	3N	3W	Ruble No. 1 Sutton	1951	560	86	—	—	—	—	385

[1] No record is available for the Wheeler No. 1 Quinn well.

[a] The Hays No. 1-A Baker reached Silurian rocks at 1,657 feet, Ordovician rocks at 2,080 feet, the Trenton Limestone at 2,568 feet, and the St. Peter Sandstone at 3,219 feet.

SALEM AND HARRODSBURG LIMESTONES

The top of the Salem Limestone is marked by a zone of yellow-brown very finely crystalline dolomitic and argillaceous limestone (Appendix, well record 1). The remainder of the Salem consists mostly of clastic limestone composed mainly of microfossils and fossil fragments, which is transitional downward into the argillaceous and cherty limestones that constitute most of the Harrodsburg Limestone. The contact between these formations is difficult to place, and the two are therefore grouped as a unit that in this area is approximately 300 feet thick.

BORDEN GROUP

The upper part of the Borden Group at the outcrop some 20 miles east of the Huron area consists of calcareous siltstones and fine-grained sandstones, but in the Huron area the upper Borden contains much limestone that strongly resembles that of the Harrodsburg (Appendix, well record 1). This change in facies apparently takes place very abruptly as test wells only a mile or two east of the area show the upper Borden to be largely siltstone. The middle part of the Borden Group consists mainly of siltstone and in the lower part of the group is a widespread shale unit. Total thickness of the group is approximately 400 feet. The base of the group is marked in some wells by the thin Rockford Limestone.

NEW ALBANY SHALE AND DEVONIAN LIMESTONES

The New Albany Shale, a well-recognized subsurface marker, is a black shale here just a little more than 100 feet thick. Most of this formation is of Devonian age, but the upper 10 or 15 feet is probably of Mississippian age. Below the New Albany is a sequence of limestones of middle and possibly early Devonian age. These limestones are the objective of most test wells for oil and gas in this part of Indiana, and subsurface data on deeper rocks is comparatively sparse.

OLDER ROCKS

The deepest test well in the Huron area was drilled in 1939 to the St. Peter Sandstone (table 6 and Appendix, well record 1). This well passed through approximately 140 feet of limestones and dolomites of middle Devonian age, 420 feet of dolomites and limestones of Silurian age, nearly 500 feet of shales, limy shales, and limestones of late Ordovician age, 600 feet of Trenton and Black River Limestones, 60 feet of Joachim Dolomite, and into the St.

Peter Sandstone at a depth of 3,219 feet. In Indiana the St. Peter is generally considered the deepest potential reservoir rock of much promise, and few wells are drilled farther, although in the Huron area approximately 5,000 feet of sedimentary rocks lie between the St. Peter and the igneous and metamorphic rocks that make up the "basement complex" of Precambrian age (T. A. Dawson, Petroleum Section, Indiana Geological Survey, personal communication).

ECONOMIC EVALUATION OF THE SUBSURFACE ROCKS

Gypsum is mined in the western part of the Huron area from the lower part of the St. Louis Limestone, a limestone-dolomite-gypsum-anhydrite sequence that here is 100 to 150 feet thick and contains 5 to 20 percent gypsum and anhydrite (McGregor, 1954). The top of the gypsum-bearing unit is approximately 350 feet below the valley floor of Beaver Creek. The gypsum and anhydrite occur in beds a fraction of a foot to a foot thick; only the thicker and more extensive beds are mined. Production and reserve figures are not made public, but reserves are probably adequate for many years of production at the current rate.

The petroleum possibilities of the Huron area have by no means been thoroughly tested, but the area does not appear to be as favorably situated in this respect as other regions somewhat farther west. Of the 22 zones that produce or have produced oil or gas at one place or another in the Illinois Basin (Swann and Bell, 1958, p. 455), 14 are exposed at the surface in the Huron area or have been removed by pre-Mansfield erosion. The remaining eight zones are present in the subsurface. No major flexures interrupt the normal westerly dip of the Mississippian rocks (fig. 4B), but it is possible that the structural configuration of older rocks is somewhat different. The scarcity of subsurface data in the area does not permit the suggestion of depositional wedges or other stratigraphic traps, but some that could be found by additional drilling may exist.

The southern two-thirds of the Huron area have been tested by only one well, the record of which is not available (table 6). It would seem that this large area is worthy of further investigation because scattered production is found only a few miles southwest and south, in Dubois and Crawford Counties.

GEOLOGIC HISTORY OF THE HURON AREA

In the Huron area the oldest rocks of which there is much knowledge are the igneous and metamorphic rocks that make up the "basement complex." In all of Indiana the complex is reached by only a handful of test wells and little is known of it; in the Huron area the top of the complex lies about 7,500 feet below sea level. The surface that separates the rocks of the complex from the overlying younger sedimentary rocks is an unconformity that represents an interval of erosion of unknown but considerable duration. The sedimentary rock sequence deposited on this surface, as inferred from data gathered in other areas, records at least three major cycles of submergence and marine deposition, separated by intervals of emergence and erosion, before the introduction of a new type of sedimentary pattern in late Devonian time.

Beginning with the deposition of the carbonaceous muds that became the New Albany Shale (Appendix, well record 1) the general mode of sedimentation in this area changed from dominantly chemical to dominantly clastic. This apparently reflects events taking place as far east as the Appalachian region in central Pennsylvania, where the same type of change took place at approximately the same time, apparently as a result of mountain-building movements and accelerated erosion in the area from which the sediments were derived. Although in Indiana sediments older than the New Albany Shale appear to have come from the northwest (Gutstadt, 1958, p. 82-83), younger sediments seem to have come from the northeast (Swann, Frund, and Saxley, 1953; Potter and others, 1958; Potter and Siever, 1956). From late Devonian through Mississippian and Pennsylvanian time clastic deposition dominated the sedimentary pattern, with only one notable exception.

The thick limestone sequence that was deposited during middle Mississippian time, including the Harrodsburg and Salem Limestones and the Blue River Group, marked a temporary return to the open-sea lime accumulations of earlier times. Many of these limestones consist largely of fossil fragments, which denote that the limestones were formed in shallow waters as a fossil-hash or lime-sand similar to that of the modern Bahamas Banks, but others are so finely crystalline and lacking of fossil remains that they seem likely to have been either the secretion of microorganisms or a direct chemical precipitate in somewhat deeper and undisturbed waters. The deposits are those of open water on a well-aerated, well-lit ocean floor, except for the gypsum that occurs near the middle of the limestone sequence in the lower part of the Blue River Group, which indicates the temporary introduction of the restricted-basin environment requisite to such evaporite deposits.

In late Mississippian time, with the deposition of the sands and muds that now constitute the Bethel Formation, large quantities of clastic sediments were again introduced into the area. Through most of the remainder of late Mississippian time clastic and chemical sedimentation alternated in a rudimentary cyclic pattern. Probably the majority of these sediments were marine in origin; all the limestones contain marine invertebrate fossils, some of the gray shales are sparsely fossiliferous, and a few marine fossils have been found in some of the sandstones. The sandstones with wavy bedding and the sandstones with gray shale laminae, such as those of the Bethel, Big Clifty, and Hardinsburg Formations, strongly resemble modern tidal flat deposits; the associated cleaner thin-bedded sandstones may be beach deposits. The varicolored mudstones and crossbedded sandstones of the Sample and Elwren Formations suggest fluvial and flood-plain environments. There are subtle differences in the character of the various limestones, but most appear to have been deposited in shallow open-water normal marine environments. It seems, therefore, that this entire sequence of rocks was deposited along or near the shorelines that probably transgressed and regressed across the area once for each of these minor sedimentary cycles.

After deposition of the youngest Mississippian rocks and probably toward the close of Mississippian time, the Huron area was raised above sea level, tilted slightly to the southwest, and subjected to a long period of erosion. The resulting land surface truncated the underlying formations; younger rocks thus were exposed in the southwestern part of the area, and older rocks were exposed in the northeastern part. The rocks of Mississippian age that underlay this surface had at that time a strike of approximately 30 or 40 degrees west of north and a southwesterly dip of perhaps 5 feet per mile.

The deeper valleys in this old land surface (fig. 4A) were probably cut during a subsequent cycle of uplift and erosion, which was interrupted in early Pennsylvanian time by subsidence and consequent deposition of the clastic materials that now make up the Mansfield Formation. Thus the Huron area in late Mississippian and early Pennsylvanian time had a geologic history similar to that of south-central Illinois (Siever, 1951), except that in the Huron area erosion probably began earlier and ended later than it did in the region to the southwest.

The wide variety of rocks present in the Mansfield Formation and the lack of lateral persistence of most individual beds lead to the conclusion that in early Pennsylvanian time many environments of deposition must have existed in this area simultaneously. The occurrence of most of these rock types at various horizons within the formation leads to the conclusion that these environments appeared again and again throughout Mansfield time. The geographic distribution of these environments cannot be worked out on the basis of available information, and there are no data to indicate whether similar environments tended to persist in a given area for any great length of time or whether different environments succeeded each other in any sort of orderly sequence. Rudimentary aspects of cyclic sedimentation of the type common to younger Pennsylvanian rocks in Illinois and western Indiana are present, but sedimentation does not appear to be dominantly cyclic in nature.

The general character of the rocks suggests that during Mansfield time the Huron area was a coastal plain similar perhaps to parts of the present coast of the Gulf of Mexico. Modern environments possibly analogous to the various rock types present in the Mansfield Formation are listed in table 7, with brief statements supporting the analogy. The lack of marine fossils in the Mansfield in the area does not prove that these beds are entirely of nonmarine origin. Although geochemical studies of the type carried out by Degens and others (Degens, Williams, and Keith, 1957 and 1958) could here be of value in confirming or rejecting some of the environmental assignments of table 7, chemical analyses are not available here, and the stated conclusions are therefore based entirely on megascopic aspects of the rocks.

Table 7.—*Environmental interpretations of rock types in the Mansfield Formation*

Rock type	Environment	Evidence
Trough and wedge crossbedded sandstone	Stream and delta distributary channels	Variable bedding character and variable grain size indicate variable character of depositing currents; abundant plant fossils indicate lack of oxidizing capacity in depositional environment.
Sandstone with even thin bedding	Well-drained flood plain and natural levee	Even bedding and fine grain size indicate deposition in fairly quiet water; lack of plant fossils indicates deposition in oxidizing environment.
Light-gray mudstone	Poorly drained flood plain	Light color indicates oxidizing environment; lack of bedding and common plant fossils and limonite concretions indicate quiet fresh-water environment.
Laminated light-gray siltstone	Flood-plain lake (open water)	Evidence similar to thin-bedded sandstone and mudstone above; standing tree trunks and laminated bedding indicate quiet fresh-water environment.
Light-gray clay	Fresh-water swamp (restricted circulation)	Related to mudstones; lack of bedding and abundant root impressions indicate swamp deposition.
Coal	Toxic-water swamp	Preservation of large quantity of plant debris indicates absence of ordinary decay and oxidizing agencies; lack of inorganic material indicates stagnant-water environment.
Sandstone with gray shale laminae and wavy thin bedding	Tidal flat, delta apron, offshore-bar apron	Wavy bedding, fine grain size, poor sorting, and shale laminae indicate deposition in fairly quiet water; abundant carbon flakes (shredded plant debris) indicate short transport.
Gray shale	Do., farther offshore	Sparse sandstone laminae with wavy thin bedding indicate close relation to wavy-bedded sandstones; small sand content and fine-grained carbon flakes indicate farther transport and deposition in deeper water.

The occurrence and distribution of younger Pennsylvanian rocks to the west of the Huron area indicate that depositional conditions similar to those suggested for the Mansfield Formation probably continued for some time beyond that represented by the youngest Mansfield rocks present in the area. Deposition of the sediments that became the bedrock of the Huron area eventually ceased, however, in late Paleozoic time, and the geologic events of much of the time that followed are not clearly recorded. During this long period, which lasted from approximately 200 million years ago until perhaps only 3 or 4 million years ago, the rocks were uplifted, tilted slightly to the southwest, and subjected to perhaps many cycles of erosion and deposition of which there is no record. The geologic history begins to be clearer in Miocene or later time when the Lafayette Gravel was deposited. To the nature of the landscape then there is only one clue: the coarseness of the gravels indicates a stream of somewhat steeper gradient or greater capacity than modern streams in the region; thus the topography may have been more rugged generally than it is today.

By middle Pleistocene time the general features of the present landscape were well established, and their geologic history becomes more abundantly documented. The recent sequence of events leading up to the present can be tabulated as follows:

1. East Fork of White River and its tributaries eroded bedrock valleys to an altitude of 400 feet or somewhat lower, probably before onset of glaciation during Illinoian time (fig. 3).

2. White River filled its valley with outwash sand and gravel belonging to the Atherton Formation, of Illinoian age, to a depth of 50 feet or more. Tributary streams were ponded, and lake sediments and alluvium of the Prospect Formation were deposited along these streams. The most extensive glaciation in Indiana was during Illinoian time, when the ice at its maximum reached down the upper valley of the East Fork almost to within a few miles of Bedford (fig. 1).

3. The flow of outwash dwindled as the glacier melted and disappeared, but valley filling continued, and deposits of the Prospect Formation spread over the valley of White River. The large valley meander in and adjacent to sec. 33, T. 4 N., R. 3 W., was abandoned as the river cut through a narrow bedrock neck in sec. 34 (pl. 1). The present course of the East Fork was thus established. These events probably date back to Sangamon time

(fig. 3), when no glacial melt water followed the course of the White River.

4. East Fork of White River and its tributaries again excavated their valleys to or near the 400-foot level, and deposits of the Prospect Formation were left as terraces. This probably took place early in Wisconsin time (fig. 3) while glaciers were advancing across northern Indiana.

5. Sands and gravels of the Atherton Formation were deposited in the valley of White River; alluvial and lake deposits of the Martinsville Formation were laid down in tributary streams as the level of deposits along White River was raised. These events took place approximately midway in Wisconsin time, when the last glacier stood at its maximum, discharging melt water that carried outwash sands and gravels into the upper tributaries of the East Fork of White River southeast of Indianapolis.

6. Valley filling continued as the glaciers receded late in Wisconsin time. At about this time valley meanders were cut off on Beaver Creek in sec. 21, T. 3 N., R. 3 W., northwest of U. S. Highway 50 and on Lost River in sec. 24, T. 2 N., R. 3 W. (pl. 1). The wide alluviated valleys through these cutoffs indicate that the cutoffs were accomplished not by lateral erosion of the streams but primarily by valley filling and burial of what had been narrow low necks in the bedrock valleys similar to that now known as the Narrows (sec. 22, T. 2 N., R. 3 W.).

7. At the present time most streams in the Huron area are neither deepening nor filling their valleys. The larger streams flow in valleys that show evidence of greater activity in the past; only White River fits its valley reasonably well. Lost River in particular illustrates by its aimless and odd meanderings that it occupies a valley which was excavated by a stream perhaps twice the size of the present one. Deforestation of much of the area since the coming of the white man has accelerated erosion, particularly in the upland areas, but artificial clearing of the streams appears to have made them competent to carry away the increased sedimentary load.

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APPENDIX

MEASURED SECTIONS

[Descriptions by Henry H. Gray, unless otherwise designated]

Section 1. NW¼NW¼ sec. 12, T. 3 N., R. 3 W., in Baltimore and Ohio Railroad cut, Martin County

Mississippian System:

Elwren Formation: 22 ft exposed — Ft

5. Sandstone, light yellow-brown; thin even bedding; principally quartz, subordinate clays as sand-sized aggregates; very fine grained; forms weak ledge near top of cut 1.5
4. Shale, medium-gray at base, grading upward through green-gray and brown-gray to olive-gray and red-brown silty shale and siltstone at top 16.5
3. Sandstone, light olive-gray; thin uneven bedding; principally quartz, subordinate clays as sand-sized aggregates; fine grained; forms weak and discontinuous ledge 4.0
   (Altitude 534 ft)

Reelsville Limestone: 6 ft

2. Limestone, gray; thick uneven bedding; abundant oolites and coarsely crystalline fossil fragments in a finely crystalline matrix; forms ledge in lower part of railroad cut......... 6.0

Sample Formation: 5 ft exposed

1. Sandstone, light yellow-brown; thin uneven bedding; principally quartz; very fine grained; poorly exposed......... 5.0
   Base of exposures in ditch beside track.

Section 2. SE¼SW¼ sec. 26, T. 3 N., R. 3 W., along west side of gravel road just north of intersection at altitude of 708 ft, Martin County

Pennsylvanian System:

Mansfield Formation, lower part: 90 ft exposed — Ft

9. Sandstone, light yellow-brown; thin uneven bedding; principally quartz, subordinate clays as grains and matrix; very fine grained; poorly exposed.......................... 22.0
8. Sandstone, light-gray to medium yellow-brown; thin to thick uneven crossbedding; principally quartz, subordinate clays as coatings on quartz grains and as matrix, locally heavy concentrations of clay-limonite mixtures; medium to coarse grained; poor sorting; forms strong ledge and is well exposed on west bank of road; bottom contact sharp and even 27.0
7. Sandstone, light-gray to light yellow-brown; thin uneven bedding; principally quartz, subordinate clays as grains; very fine grained 11.0
6. Sandstone, light yellow-brown; medium uneven crossbedding; principally quartz; medium grained; good sorting; forms weak ledge on west bank of road; bottom contact sharp and even 2.0
5. Sandstone, light-gray to light yellow-brown; thin uneven bedding; principally quartz, subordinate clays as grains; very fine grained 10.0

4. Covered; probably underlain by sandstone similar to that of unit 5 .... 18.0
3. Conglomerate, dark yellow-brown; bedding absent; principally quartz sand, subordinate quartz pebbles as much as 5 mm in diameter and clay pebbles as much as 10 mm in diameter, in a matrix of clays and clay-limonite mixtures; loose fragments only seen 0.3
(Altitude 618 ft)

Mississippian System:
Big Clifty Formation: 50 ft exposed
2. Shale, medium-gray; thin even bedding; soft, smooth, plastic; platy fracture in lower part, hackly fracture at top; poorly exposed in ditch west of road.......... 16.5
1. Sandstone, light yellow-brown; thin uneven crossbedding; principally quartz; fine grained, fair sorting; well exposed in strong ledges west of road.......... 33.5
Base of exposures on hill slope west of road.

Section 3. SE¼SE¼ sec. 27, T. 3 N., R. 3 W., in abandoned quarry just north of county road near bench mark at 678 ft altitude, Martin County

Pennsylvanian System:
Mansfield Formation, lower part: 7 ft exposed — Ft
9. Sandstone, light yellow-brown; thin uneven bedding; principally quartz, subordinate clays as chips and as sand-sized aggregates; medium grained; forms prominent ledge at top of overburden in quarry; bottom contact sharp and uneven; thickness ranges from 4 to 10 ft as result of relief on base.. 7.0

Mississippian System:
Hardinsburg Formation: 13 ft
8. Clay, dark-gray; bedding absent; weathers to covered slope; thickness ranges from 1 to 7 ft as result of uneven upper contact 4.0
7. Limestone, clayey, light yellow-brown; nodular; very finely crystalline; forms discontinuous weak ledge.......... 0.3
6. Shale; light-gray at base grading upward to olive gray; very thin even bedding; forms covered slope above working face of quarry 8.5
(Altitude 629 ft)

Golconda Limestone: 28 ft exposed
5. Limestone, silty, medium yellow-brown; uneven bedding; abundant brachiopods and crinoid columnals; forms double ledge; bottom contact sharp and somewhat irregular..... 5.0
4. Shale, dark-gray; thin even bedding; poorly exposed........ 1.2
3. Limestone, silty, light-gray; thin uneven bedding; finely crystalline; includes several lenticular beds of gray calcareous shale 5.3
2. Limestone, light-gray; thick uneven bedding; abundant coarsely crystalline fossil fragments in a finely crystalline matrix; well exposed on quarry face.......... 10.7

1. Limestone, silty, light-gray; very thick bedding; finely crystalline; sparse fossils, including brachiopods, corals, crinoid columnals, and Bryozoa; some beds contain abundant fossil fragments 5.5
Base of exposures at quarry floor.

Remarks: Units 6 through 8 are assigned to the Hardinsburg rather than to the Mansfield not so much on the basis of the unconformity between them and unit 9 as for the lack of evidence of weathering at the top of unit 5 and because no rocks similar to unit 7 are known in the Mansfield Formation in this area.

Section 4. NW¼SE¼ sec. 4, T. 2 N., R. 2 W., in road ditch and abandoned quarry east of county road at bench mark, 494 ft altitude, Orange County

Mississippian System:

	Ft
Bethel Formation: 2 ft exposed	
13. Sandstone slabs, slumped	2.0
Paoli Limestone: 32 ft	
12. Mostly covered; scattered limestone slabs at top..........	12.0
11. Partly covered; scattered limestone slabs..........	6.0
10. Limestone, light yellow-brown; thick even bedding; finely crystalline; abundant fossil fragments; forms prominent ledge	6.5
9. Siltstone, calcareous, very light yellow-brown; thick bedding..	2.2
8. Siltstone, very light green-gray; thin uneven bedding; weathers to covered slope; bottom contact gradational within 1 ft...	2.5
7. Shale, silty, very light-gray; thin even bedding; weathers to covered slope; bottom contact sharp and even.......... (Altitude 516 ft)	3.0
Ste. Genevieve Limestone: 34 ft exposed	
6. Limestone, finely brecciated, very light-gray; thin uneven bedding; abundant fossil fragments and some small flakes of green-gray shale; forms ledge at top of working face of quarry; thickness ranges from 0.5 to 1.5 ft; bottom contact uneven; *Bryantsville Breccia Bed*	1.0
5. Limestone, light yellow-brown to light-gray; thick fairly even bedding; very finely crystalline; sparingly fossiliferous; upper 1 ft locally brecciated; lower 0.5 ft slightly silty....	7.5
4. Shale, silty, light green-gray; weathers back, forming conspicuous notch in quarry wall	0.3
3. Limestone, sandy, light-gray; thin incline bedding; principally quartz, calcareous oolites, and calcite cement with sparse green shale flakes; fine grained; lower contact slightly irregular	2.4
2. Limestone, light yellow-brown to light-gray; thick fairly even bedding; very finely crystalline; sparingly fossiliferous...	15.3
1. Limestone, silty, light yellow-brown; poorly exposed in ditch east of road	7.5

Base of exposures near bridge north of quarry.

Section 5. S½SW¼ sec. 20, T. 2 N., R. 2 W., exposures on the north side of U. S. Highway 150 just east and west of intersection at 530 ft altitude, Orange County

Mississippian System:

Elwren Formation: 22 ft exposed — Ft

5. Sandstone, light yellow-brown; thin uneven bedding; principally quartz, subordinate clays; fine grained; forms strong ledge; bottom contact sharp and somewhat uneven........ 21.5
   (Altitude 550 ft)

Reelsville Limestone: 6 ft

4. Limestone, medium-gray; thin crossbedding; abundant fossil fragments in finely crystalline matrix; exposed in road cut and small quarry 6.0

Sample Formation: 36 ft exposed

3. Sandstone, light yellow-brown; thin uneven bedding; principally quartz, subordinate clays; very fine grained; forms small ledge 10.5
2. Covered 9.0
1. Sandstone, light yellow-brown; thin uneven bedding; principally quartz; fine grained; forms strong ledge........... 16.0
   Base of exposures on highway bank.

Section 6. N½SW¼ sec. 21, T. 2 N., R. 2 W., exposures on north side of U. S. Highway 150 just west of intersection at 485 ft altitude, Orange County

Mississippian System:

Bethel Formation: 11 ft exposed — Ft

6. Shale, dark-gray; very thin even bedding; bottom contact sharp and even; exposed in ditch 5.5
5. Sandstone, silty, light yellow-brown; bedding poorly developed; principally quartz, subordinate clays, locally ferruginous; poorly exposed in ditch 3.0
4. Covered; probably sandstone 2.0
   (Altitude 510 ft)

Paoli Limestone: 19 ft exposed

3. Limestone, light-gray; thick uneven bedding; finely crystalline; sparingly fossiliferous; forms weak ledge........... 9.0
2. Shale, light olive-gray to light yellow-brown; bedding poorly developed; weathers to covered slope 4.5
1. Siltstone, shaly, light yellow-brown to light olive-gray; bedding poorly developed; weathers to covered slope 5.5
   Base of exposures in ditch north of highway.

Section 7. SW¼NE¼ sec. 12, T. 2 N., R. 3 W., in creek at bridge on abandoned county road, Martin County

Mississippian System:

Big Clifty Formation: 33 ft exposed — Ft

4. Sandstone, yellow-brown; thin even bedding; principally quartz; fine grained; well exposed on north bank of creek.. 33.0

Beech Creek Limestone: 14 ft

3. Limestone, light brown-gray; thin uneven bedding; medium crystalline and sparingly fossiliferous at base, grading upward into abundantly fossiliferous at top; well exposed at falls just below bridge and in creek bed above bridge; bottom contact transitional within 1 ft 8.5
2. Limestone, medium yellow-brown; thin bedding; finely crystalline; sparingly fossiliferous; well exposed in ledge at waterfall; bottom contact sharp 5.5
(Altitude 575 ft)

Elwren Formation: 6 ft exposed

1. Mudstone, very light green-gray to medium red-brown; bedding poorly developed; forms covered slope beneath overhanging limestone ledge 5.5
Base of exposures in creek bed.

Section 8. W½SE¼ sec. 13, T. 2 N., R. 3 W., exposures along south bank of U. S. Highway 150 and east of abandoned road just south of highway near bridge over Sams Creek, Martin County

Mississippian System:

Sample and Elwren Formations undifferentiated: 48 ft exposed — Ft

5. Shale, silty, olive-brown to red-brown; thin even bedding; poorly exposed at curve in highway.................... 11.0
4. Covered 13.0
3. Shale, silty, green-gray to red-brown; bedding poorly developed; poorly exposed on south bank of highway 4.0
2. Sandstone, light-gray; medium uneven bedding; principally quartz, clay chips and plant fragments locally abundant at base; fine grained; forms conspicuous ledge on hillside south of highway 20.0
(Altitude 476 ft)

Beaver Bend Limestone: 8 ft exposed

1. Limestone, light-gray; very thick bedded; abundant oolites and coarsely crystalline fossil fragments in a finely crystalline matrix; exposed at spring just west of old road and about 100 yd south of highway bridge...................... [illegible]
Base of exposures at spring.

Remarks: In the absence of the Reelsville Limestone, it is impossible to differentiate the Sample and Elwren Formations. The expectable position of the Reelsville in the section above is in the upper part of unit 4 or the lower part of unit 5. It is therefore not certain that the Reelsville is absent here, but it has not been found in the vicinity.

Section 9. NW¼NW¼ sec. 13, T. 2 N., R. 3 W., west bank of U. S. Highway 150 just south of hillcrest at altitude of 737 ft, Martin County

Pennsylvanian System:

Mansfield Formation, lower part: 65 ft exposed — Ft

6. Sandstone, silty, light yellow-brown; thin uneven crossbedding; principally quartz, subordinate clays and locally some concentrations of clay-limonite mixtures; very fine grained; poor sorting; bottom contact sharp and uneven.......... 28.0

5. Sandstone, shaly, light-gray; thin wavy bedding; principally quartz, subordinate clays; very fine grained; poor sorting; many thin beds and lenses as much as 0.5 ft thick of carbonaceous shale and shaly coal (probable position of French Lick Coal); bottom contact sharp 5.7
4. Sandstone, light yellow-brown; bedding absent; principally quartz, subordinate clays; very fine grained; poor sorting; carbonaceous impressions of plant rootlets common; forms weak ledge; bottom contact sharp and uneven............ 1.5
3. Sandstone, very light-gray; thin uneven crossbedding; principally quartz, subordinate clays; very fine grained; poor sorting 13.5
2. Sandstone, light yellow-brown; thin even bedding; principally quartz, subordinate clays, slightly carbonaceous; very fine grained; poor sorting; poorly exposed 16.0
(Altitude 670 ft)

Mississippian System:

Glen Dean Limestone: 12 ft exposed

1. Limestone, light yellow-brown; thick bedding; abundant small crinoid columnals in a fine-grained matrix; poorly exposed 12.0
Base of exposures in ditch west of highway.

Section 10. NW¼NW¼ sec. 36, T. 2 N., R. 3 W., exposures along county roads just west of intersection at 647 ft altitude, Martin County

Pennsylvanian System:

Mansfield Formation, lower part: 3 ft exposed — Ft

6. Sandstone, yellow-brown; fine grained; loose blocks only..... 2.0
5. Clay, dark red-brown; poorly exposed 1.0
(Altitude 673 ft)

Mississippian System:

Glen Dean Limestone: 8 ft exposed

4. Limestone, light yellow-brown; thick bedding; abundant coarsely crystalline fossil fragments in a finely crystalline matrix; forms weak ledge 8.0

Hardinsburg Formation: 18 ft exposed

3. Covered; probably underlain by soft clay 1.5
2. Sandstone, white; medium even bedding; principally quartz, subordinate clays; very fine grained; abundant root? impressions; forms small ledge 1.0
1. Sandstone, medium brown-gray; thin even bedding; principally quartz, subordinate clays, trace of mica and carbonaceous flakes; very fine grained; well exposed in graded ditch and bank just west of road intersection 15.5
Base of exposures in ditch.

Section 11. N½NE¼ sec. 4, T. 1 N., R. 3 W., and SE¼SE¼ sec. 33, T. 2 N., R. 3 W., along gravel roads west and north of intersection at 668 ft altitude, Martin County

Pennsylvanian System:

Mansfield Formation, upper part: 30 ft exposed — Ft

	15. Sandstone, light yellow-brown; bedding absent; principally quartz; fine grained; well sorted; forms small ledge......	11.0
	14. Covered	14.0
	13. Sandstone, medium yellow-brown; thin uneven bedding; principally quartz, subordinate clays; very fine grained; poorly exposed in ditch northeast of roads at intersection....... (Altitude 663 ft)	5.0
Mansfield Formation, lower part: 133 ft		
	12. Covered	4.0
	11. Mudstone, light-gray; bedding absent; abundant clay-ironstone concretions	17.0
	10. Covered	17.0
	9. Mudstone, medium brownish-gray; bedding poorly developed; abundant clay-ironstone concretions, many of which enclose well-preserved plant fossils; poorly exposed	19.0
	8. Coal, thin-banded, black; poorly exposed; *French Lick Coal*...	1.0
	7. Mudstone, shaly, light yellow-brown; very thin uneven bedding; poorly exposed in ditch east of road; plastic and clayey at top	3.0
	6. Covered	12.0
	5. Sandstone, medium yellow-brown; thin uneven crossbedding; principally quartz, subordinate clays; very fine grained; poorly exposed in bank west of road	22.0
	4. Covered	28.0
	3. Mudstone, olive-gray; poorly exposed; contains some poorly preserved plant fossils	3.0
	2. Shale, green-gray; soft; poorly exposed	7.0
Mississippian System:		
Golconda Limestone: 3 ft exposed		
	1. Limestone, light-gray; thick bedding; abundant coarsely crystalline fossil fragments in a finely crystalline matrix; loose blocks only seen .... Base of exposures in ditch west of road.	3.0

Remarks: The shale and mudstone of units 2 and 3 are assigned to the lower part of the Mansfield Formation rather than to the Hardinsburg because similar rocks in the lower part of the Hardinsburg Formation commonly are somewhat fossiliferous and in most places there are thin beds of limestone within the lower few feet of the formation. In addition, the fragmental plant fossils in unit 3, although not diagnostic, are to some extent indicative of identification with the Mansfield.

Section 12. SW¼NW¼ sec. 10, T. 1 N., R. 3 W., in abandoned strip mine at west end of ridge, Martin County

[Section measured by R. D. Jenkins]

		Ft
Pennsylvanian System:		
Mansfield Formation, upper part: 20 ft exposed		
	4. Sandstone, very light yellowish-brown; thin wavy bedding; very fine grained; thinly interbedded with very dark-gray shale	6.5

3. Shale, dark-gray; clayey in lower part, carbonaceous in upper part 8.2
   (Altitude 740 ft)
2. Coal, upper part shaly; *Blue Creek Coal*.................... 4.8
1. Clay, white; top only seen 1.0
   Base of exposures in strip mine floor.

Section 13. NE¼SE¼ sec. 16, T. 1 N., R. 3 W., along dirt road near east line of section to hilltop 300 ft east of intersection at 750 ft altitude, Dubois County

Pennsylvanian System:

Mansfield Formation, upper part: 102 ft exposed — Ft

4. Sandstone, light yellow-brown; indistinct thin uneven cross-bedding; principally quartz, subordinate clays and clay-limonite mixtures; very fine grained; fair sorting; exposed on north bank of road at crest of hill 3.0
3. Mostly covered; probably sandstone 27.0
2. Sandstone, medium yellow-brown; medium even bedding; principally quartz, subordinate clays and clay-limonite mixtures; very fine grained; fair sorting; poorly exposed on east bank of road. Bottom contact transitional within several feet into unit below 28.0
1. Sandstone, light yellow-brown; thin even bedding; principally quartz, subordinate clays and clay-limonite mixtures; very fine grained; interbedded with: shale, dark-gray; very thin even bedding; micaceous, carbonaceous. Mostly sandstone in upper part, grading downward to mostly shale in lower part. Poorly exposed on east bank of road............. 43.5
   (Altitude 668 ft)
   Base of exposures near curve in road.

Section 14. SW¼NE¼ sec. 22, T. 1 N., R. 3 W., in abandoned quarry just north of State Highway 56 at 517-ft intersection, Dubois County

Pennsylvanian System:

Mansfield Formation, lower part: 23 ft exposed — Ft

3. Sandstone, medium yellow-brown; thin uneven bedding; principally quartz, subordinate clays; very fine grained; clay chips and plant fossils locally abundant; forms overhanging ledge at top of overburden; bottom contact sharp and somewhat uneven 6.0
2. Shale, medium-gray; thin even bedding; several zones of clay-ironstone nodules as much as 0.1 ft thick; weathers to covered slope; bottom contact sharp and even........... 17.0
   (Altitude 553 ft)

Mississippian System:

Glen Dean Limestone: 30 ft exposed

1. Limestone, light-gray to medium yellow-brown; thick uneven bedding; sparse coarsely crystalline fossil fragments in a finely crystalline matrix; fossils include crinoid columnals,

brachiopods, corals, and Bryozoa; well exposed in quarry face 30.0
Base of exposures in quarry floor.

Remarks: The shale of unit 2 is assigned to the Mansfield Formation despite the lack of evidence of weathering at the top of the limestone because clay-ironstone nodules of such size and abundance are not common in rocks of Mississippian age.

WELL RECORDS

[Descriptions by Henry H. Gray, unless otherwise designated]

Well record 1. Hays No. 1-A Baker, permit no. 235. SE¼NW¼ sec. 29, T. 3 N., R. 2 W., 500 ft south of bench mark at 760 ft altitude, Orange County [Altitude of surface 798 ft]

[Rock-bit samples; summarized from sample log described by Andrew J. Hreha, Petroleum Section, Indiana Geological Survey]

	Thickness (ft)	Depth (ft)
Pennsylvanian System:		
Mansfield Formation, lower part: 74 ft drilled		
1. No samples	25	25
2. Shale, green	49	74
Mississippian System:		
Golconda Limestone: 21 ft		
3. Limestone, light-tan, slightly cherty	21	95
Big Clifty Formation: 60 ft		
4. No samples	30	125
5. Sandstone, light-tan	30	155
Beech Creek Limestone: 20 ft		
6. Limestone, white	10	165
7. Limestone, gray	10	175
Elwren and Sample Formations, undivided: 65 ft		
8. Shale, gray, green, and red-brown, and some sandy limestone; poor samples	65	240
Beaver Bend Limestone: 25 ft		
9. Limestone, tan, fossiliferous, oolitic	25	265
Bethel Formation: 30 ft		
10. Shale, gray	30	295
Paoli Limestone: 30 ft		
11. No samples	20	315
12. Limestone, light-tan, slightly oolitic	10	325
Ste. Genevieve Limestone (Indiana outcrop usage): 165 ft		
13. Limestone, tan to brown, dolomitic, cherty*	165	490
St. Louis Limestone: 210 ft		
14. Limestone, brown, cherty*	70	560
15. Limestone, brown, and some gypsum*	140	700
Salem Limestone: 135 ft		
16. Limestone, brown, dolomitic*	50	750
17. Limestone, brown, fossiliferous*	85	835

* Some samples are missing from those intervals marked with an asterisk.

Harrodsburg Limestone: 200 ft		
18. Limestone, gray, fossiliferous*	65	900
19. Limestone, white, cherty	40	940
20. Limestone, gray, argillaceous	20	960
21. Limestone, white, cherty*	75	1,035
Borden Group: 365 ft		
22. Sandstone, gray, calcareous	10	1,045
23. Limestone, gray, cherty, argillaceous and sandy*	85	1,130
24. Siltstone, shale, and some gray calcareous sandstone*	220	1,350
25. Shale, gray	50	1,400
Mississippian and Devonian Systems, undivided:		
New Albany Shale: 120 ft		
26. Shale, black*	120	1,520
Devonian System: 140 ft		
27. Limestone, tan	50	1,570
28. Limestone, white, cherty*	30	1,600
29. Limestone, tan, dolomitic	60	1,660
Silurian System: 420 ft		
30. Dolomite, tan, cherty	65	1,725
31. Limestone, tan, cherty, dolomitic	25	1,750
32. Dolomite, tan, cherty	40	1,790
33. Dolomite, gray*	60	1,850
34. Dolomite, tan, slightly cherty*	65	1,915
35. Limestone, tan, slightly dolomitic	110	2,025
36. Limestone, tan, cherty	55	2,080
Ordovician System:		
Cincinnatian Series: 490 ft		
37. Limestone, gray, and some green shale*	175	2,255
38. Limestone, gray, fossiliferous, and some gray calcareous shale	45	2,300
39. Shale, gray, calcareous, and some gray limestone*	270	2,570
Trenton Limestone: 110 ft		
40. Limestone, tan*	110	2,680
Black River Limestone: 475 ft		
41. Limestone, light-brown to tan, slightly silty*	420	3,100
42. Limestone, gray, dolomitic, argillaceous	55	3,155
Joachim Dolomite: 64 ft		
43. Limestone, tan to light-gray, silty, and argillaceous*	64	3,219
St. Peter Sandstone?: 7 ft drilled		
44. Sandstone, white, unconsolidated	7	3,226
Total depth 3,226 ft		

* Some samples are missing from those intervals marked with an asterisk.

Well record 2. Indiana Geological Survey drill hole 48. NE¼SW¼ sec. 32, T. 2 N., R. 2 W., 100 ft south of road and 300 ft west of house, property of Harry Hendrix, Orange County [Altitude at surface 825 ft]

	Thickness (ft)	Depth (ft)
Pennsylvanian System:		
Mansfield Formation, upper part: 57 ft drilled		
(Rock-bit samples; driller's log)		
1. Surface silt and sand	14.0	14.0
2. Sandstone	2.0	16.0
3. Shale, gray, soft	2.0	18.0
4. Sandstone	2.0	20.0
(Core samples)		
5. Siltstone, shaly; light purplish brown; uneven thin bedding; sparse root impressions	2.3	22.3
6. Sandstone, white to medium yellowish-brown; thin bedded; principally quartz, subordinate clays; fine grained; locally cemented by iron oxides	30.7	53.0
7. Shale, dark- to medium-gray; even very thin bedding	3.6	56.6
8. Soft black pyrite? band	0.1	56.7
Mansfield Formation, lower part: 85 ft		
9. Clay, light-gray; fragments of coal intermixed; probable position of *Pinnick Coal*	1.6	58.3
10. Oolitic ironstone?, medium greenish-gray	0.2	58.5
11. Clay, shaly, medium olive-gray	0.5	59.0
12. Sandstone, gray; contorted thin bedding; abundant gray shale partings	2.5	61.5
13. Shale, carbonaceous, black; even very thin bedding	0.4	61.9
14. Clay, light olive-gray	3.6	65.5
15. Siltstone, light olive-gray; uneven thin bedding; interbedded with shale	3.6	69.1
16. Siltstone, gray; thin bedded; abundant gray shale partings. Considerable loss of core in parts of unit.	37.2	106.3
17. Coal, shaly; *French Lick Coal*	1.0	107.3
18. Mudstone, gray; contains abundant root impressions	2.2	109.5
19. Sandstone, white; wavy thin bedding; abundant gray shale partings	6.6	116.1
20. Loss of core	9.6	125.7
21. Sandstone, white; bedding obscure; dominantly quartz, subordinate clays; very fine grained; abundant very thin gray shale partings; clay and shale chips at base	15.8	141.5
Mississippian System:		
Glen Dean Limestone: 2 ft		
22. Limestone, yellowish-brown to gray; abundant coarsely crystalline fossil fragments in a finely crystalline matrix	1.8	143.3

Hardinsburg Formation: 43 ft		
23. Shale, dark- to medium-gray; very thin even bedding; carbonaceous flakes on bedding surfaces; sparse thin beds of siltstone	18.9	162.2
24. Mudstone, greenish-gray to reddish-brown	9.4	171.6
25. Siltstone, light greenish-gray; bedding absent; chips of greenish-gray and reddish-brown shale abundant in lower part	4.3	175.9
26. Shale, medium-gray; even very thin bedding; interbedded with gray siltstone	10.2	186.1
Golconda Limestone: 19 ft		
27. Limestone, yellowish-brown to gray; coarsely crystalline fossil fragments in a finely crystalline matrix; shale partings abundant at top	3.5	189.6
28. Shale, dark-gray; even very thin bedding; fossiliferous	0.3	189.9
29. Limestone, medium- to dark-gray; uneven bedding; sparse coarsely crystalline fossil fragments in a finely crystalline matrix; abundant very thin shaly partings	4.7	194.6
30. Limestone, yellowish-brown to gray; abundant coarsely crystalline fossil fragments in a finely crystalline matrix	6.2	200.8
31. Limestone, shaly, medium-gray; uneven thin bedding; abundant coarsely crystalline fossil fragments in a finely crystalline matrix	4.5	205.3
Big Clifty Formation: 56 ft		
32. Shale, medium-gray; uneven very thin bedding; very thinly interbedded with light-gray siltstone	17.7	223.0
33. Limestone conglomerate, light reddish-brown; limestone pebbles as much as 25 mm in diameter	0.5	223.5
34. Mudstone, medium greenish-gray; scattered limestone nodules	6.5	230.0
35. Siltstone, light-gray to white; wavy thin bedding; dark-gray shale partings	6.8	236.8
36. Mudstone, dark greenish-gray	0.9	237.7
37. Sandstone, white; wavy thin bedding; dark-gray shale partings common; very thin bed of pyritic shale at base	23.7	261.4
Beech Creek Limestone: 14 ft		
38. Limestone, light yellowish-brown; finely crystalline; sparse fossils	8.5	269.9
39. Limestone, dark yellowish-brown, shaly	0.2	270.1
40. Limestone, medium yellowish-brown; very finely crystalline	5.7	275.8
Elwren Formation: 38 ft		
41. Siltstone, light-gray; uneven very thin bedding; abundant dark-gray shale partings	0.5	276.3
42. Mudstone and shale, greenish-gray to reddish-brown to gray	20.2	296.5

43. Shale, gray; even very thin bedding	1.4	297.9
44. Siltstone, light-gray; wavy thin bedding	1.9	299.8
45. Sandstone, white; uneven thin bedding; very fine grained	1.1	300.9
46. Siltstone, greenish-gray to reddish-brown to gray	7.0	307.9
47. Loss of core	5.4	313.3
Reelsville Limestone: 5 ft		
48. Limestone, light brownish-gray; coarsely crystalline fossil fragments in a finely crystalline matrix	1.6	314.9
49. Sandstone, white; in part quartzitic, in part calcareous; very fine grained	2.3	317.2
50. Limestone, light-gray; abundant coarsely crystalline fossil fragments in a finely crystalline matrix	0.8	318.0
Sample Formation: 28 ft		
51. Siltstone, light-gray; wavy thin bedding; abundant medium-gray shale partings	5.1	323.1
52. Shale and mudstone, greenish-gray and reddish-brown	13.1	336.2
53. Siltstone, medium-gray; very thin even bedding; abundant medium-gray shale partings	5.8	342.0
54. Shale, dark-gray; even very thin bedding; fossiliferous	3.7	345.7
Beaver Bend Limestone: 15 ft drilled		
55. Limestone, shaly, medium-gray; even thin bedding; abundant fossils	2.8	348.5
56. Limestone, light yellowish-brown; coarsely crystalline fossil fragments in a finely crystalline matrix	12.8	361.3
Total depth 361.3 ft		

Well record 3. Indiana Geological Survey drill hole 47. NE¼NE¼ sec. 16, T. 1 N., R. 3 W., just north of dirt road and 300 ft east of house on top of Coal Mine Ridge, property of George Lagenour, Dubois County [Altitude at surface 795 ft]

Pennsylvanian System:	Thickness (ft)	Depth (ft)
Mansfield Formation, upper part: 150 ft drilled		
(Rock-bit samples)		
1. Surface silt and sand	6.0	6.0
2. Shale and siltstone, gray	7.0	13.0
3. Sandstone, reddish-brown, fine-grained	1.0	14.0
4. Coal	0.5	14.5
5. Sandstone, gray, fine-grained	3.0	17.5
6. Ironstone	0.1	17.6
7. Clay, light-gray	1.9	19.5
8. Sandstone, white	5.5	25.0
9. Clay, blue-gray	5.0	30.0
10. Shale, gray; thinly interbedded with sandstone	30.0	60.0
(Core samples)		

11. Sandstone, light-gray; very thin wavy bedding; very fine grained; thinly interbedded with dark-gray carbonaceous shale; grades into unit below	13.8	73.8
12. Shale, medium-gray; very thin even bedding; sparse very thin even beds of very fine-grained light-gray sandstone	8.6	82.4
13. Shale, as above, with several thin bands of coal; probable position of *Blue Creek Coal*	0.1	82.5
14. Shale, medium-gray; very thin even bedding; sparse very thin even beds of very fine-grained light-gray sandstone	9.1	91.6
15. Sandy ironstone conglomerate; ironstone pebbles, fusain flakes, and chips of carbonaceous shale in matrix of coarse clayey sand	0.8	92.4
16. Shale, medium-gray; very thin even bedding; irregularly interbedded with light-gray very fine-grained sandstone. Shale predominant near top of unit; sandstone predominant near base	15.2	107.6
17. Ironstone, dark-gray	0.2	107.8
18. Shale, dark-gray; very thin bedded; carbonaceous	1.2	109.0
19. Coal, bright, brittle; thin dirty band near base	1.6	110.6
20. Clay, light green-gray; abundant root impressions	6.2	116.8
21. Shale, medium-gray; bedding poorly developed	10.2	127.0
(Rock-bit samples)		
22. Shale, silty, gray; soft	20.0	147.0
23. Siltstone, light-brown; flaky	1.0	148.0
24. Sandstone, white; fine grained	2.0	150.0

Total depth 150 ft

GEOLOGICAL SURVEY
JOHN B. PATTON, STATE GEOLOGIST

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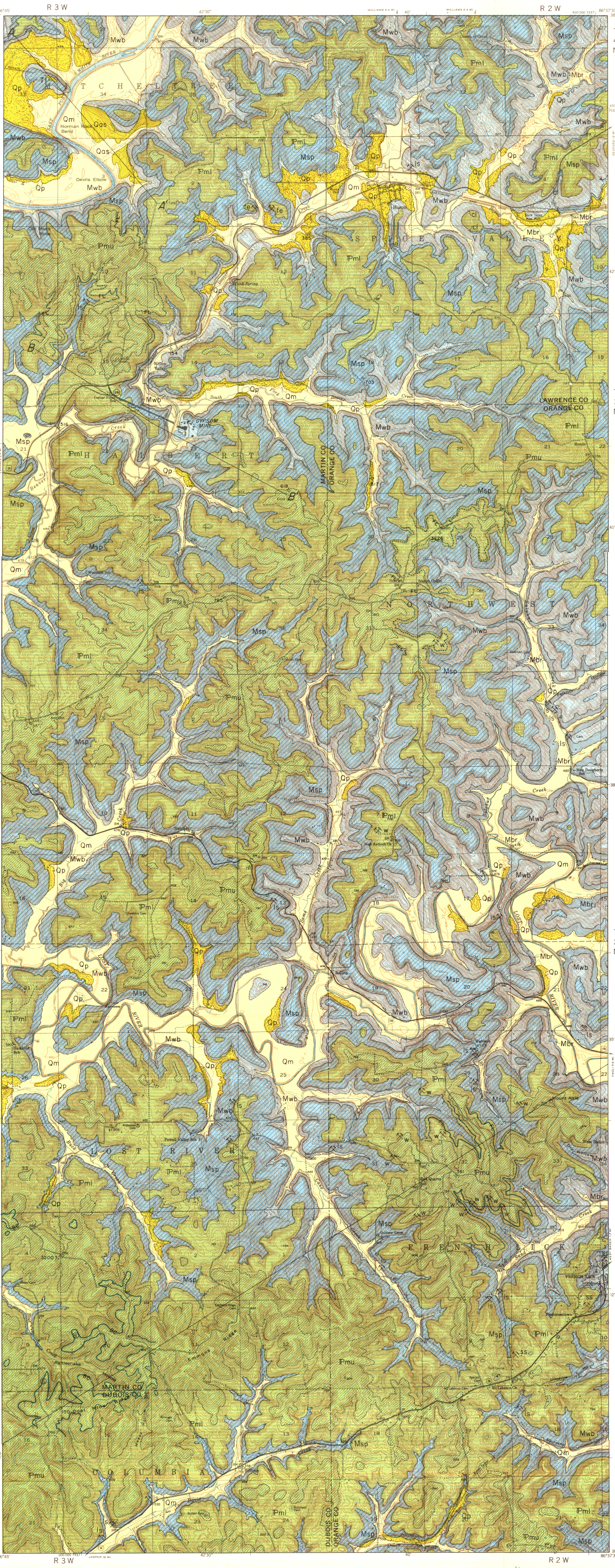


SCALE 1:48000
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

APPROXIMATE MEAN DECLINATION, 1948

EXPLANATION

PLEISTOCENE

- **Qm** — Martinsville Formation. *Silt, sand, and gravel deposits on floodplains of present streams.*
- **Qas / Qao** — Atherton Formation. *Windblown sand (Qas) on valley slopes along East Fork of White River. Outwash sand and gravel (Qao) shown on cross section only.*
- **Qp** — Prospect Formation. *Deeply weathered silt, sand, and gravel in terraces 20 to 50 feet above present floodplains.*

MIOCENE TO PLIOCENE

- **Tl** — Lafayette Gravel. *High-level remnant of coarse gravel containing quartz geodes and geode fragments.*

PENNSYLVANIAN

- **Pmu / Pml** (BC, FL) — Mansfield Formation. *Sandstone and shale with thin beds of coal and clay. Upper part (Pmu) includes Blue Creek Coal (BC). Lower part (Pml) includes Pinnick Coal at top, laminated siltstone (whetstone), and French Lick Coal (FL).*

MISSISSIPPIAN

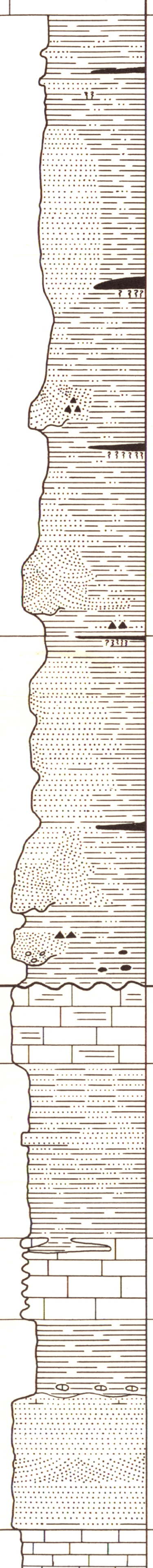
- **Msp** — Stephensport Group. *Argillaceous limestone, thin-bedded shaly sandstone, crystalline limestone, gray shale, cliff-forming quartzose sandstone, and crystalline limestone.*
- **Mwb** — West Baden Group. *Reddish- and greenish-gray mudstone, shaly sandstone, quartzose sandstone, sandy limestone, oolitic limestone, and soft gray shale containing one or two thin beds of shaly coal.*
- **Mbr** — Blue River Group. *Finely crystalline limestone. Near top includes thin beds of brecciated limestone and lenses of calcareous siltstone.*

Geologic boundary

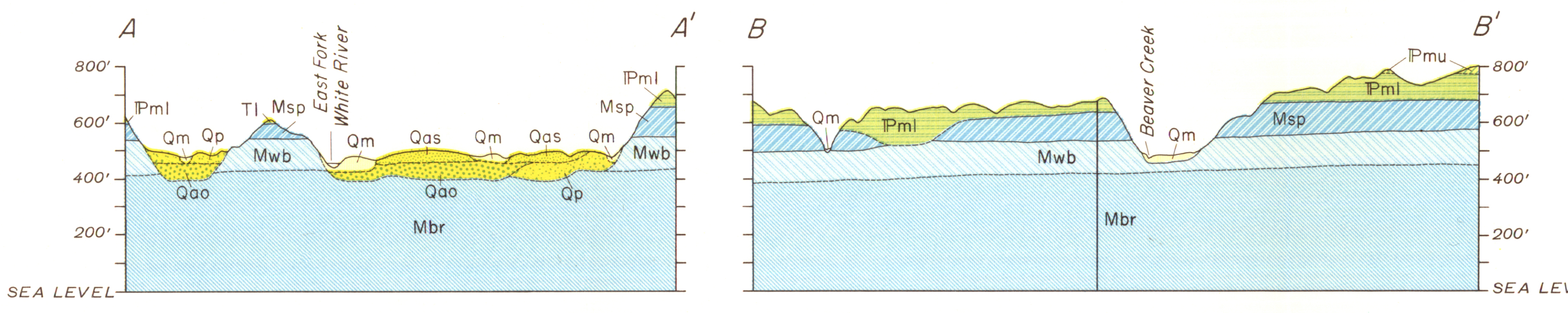
BC — FL
Outcrop of named coal bed
Solid lines where accurately located, dashed lines where approximately located, short-dashed lines where inferred. BC, Blue Creek Coal; FL, French Lick Coal.

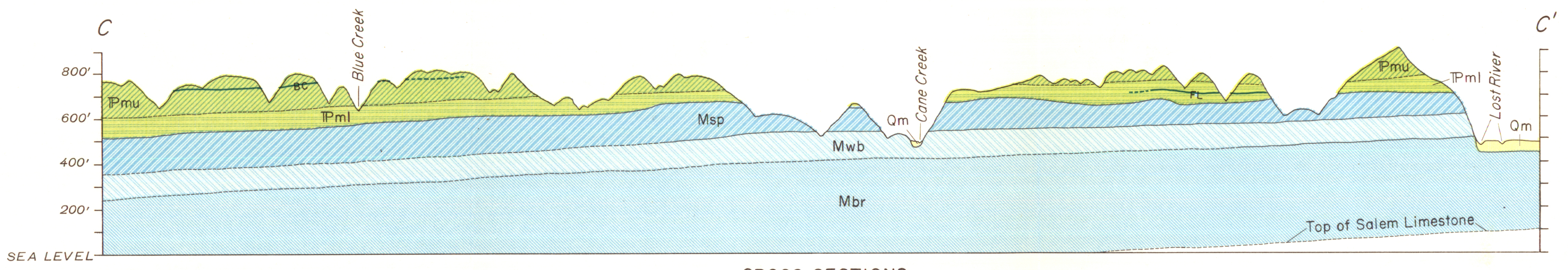
Drift or slope mine — *Coal; or clay, cl*
Strip mine — *Coal*
Quarry — *Limestone, ls; sandstone, ss; whetstone w; iron ore, fe*
3226 Drill hole — *Figure indicates total depth*

GENERALIZED COLUMNAR SECTION SHOWING OUTCROPPING CONSOLIDATED ROCKS



SYSTEM	SERIES		ROCK UNIT	LITHOLOGY	DESCRIPTION
PENNSYLVANIAN	POTTSVILLE		Mansfield Formation (upper part) 160+ feet		Gray soft shale, gray shale very thinly interbedded with sandstone, medium-bedded and crossbedded sandstone that is locally ferruginous, and thin beds of coal and clay. Blue Creek Coal, 0-7 feet thick, locally present approximately 100 feet above base of unit.
PENNSYLVANIAN	POTTSVILLE		Mansfield Formation (lower part) 50–150 feet		Gray soft shale that locally contains ironstone nodules near base, thin-bedded siltstone (whetstone), mudstone, crossbedded sandstone that is locally ferruginous, and thin beds of carbonaceous shale, coal, and clay. Pinnick Coal, 0–3 feet thick, locally present at top of unit. French Lick Coal, 0-2 feet thick, locally present approximately 50 feet below top. Thickness variation mainly in lower part of unit due to relief on base.
			UNCONFORMITY		
MISSISSIPPIAN	CHESTER	STEPHENSPORT GROUP	Glen Dean Ls. 30+ feet		Yellow-brown thick-bedded finely crystalline fossiliferous limestone. Weathers to scaly slabs.
MISSISSIPPIAN	CHESTER	STEPHENSPORT GROUP	Hardinsburg Fm. 43–62 feet		Gray thin-bedded fine-grained sandstone and soft carbonaceous shale. Generally poorly exposed.
MISSISSIPPIAN	CHESTER	STEPHENSPORT GROUP	Golconda Ls. 19–32 feet		Thick- to thin-bedded finely crystalline fossiliferous limestone. Weathers to rounded ledges.
MISSISSIPPIAN	CHESTER	STEPHENSPORT GROUP	Big Clifty Fm. 42–56 feet		Gray soft fossiliferous shale, underlain by yellow-brown thin-bedded fine-grained sandstone; lower part of sandstone is locally shaly. Shale is generally poorly exposed; sandstone forms conspicuous extensive cliffs that weather to a honeycombed surface.
MISSISSIPPIAN	CHESTER	STEPHENSPORT GROUP	Beech Creek Ls. 12–18 feet		Brown-gray medium-bedded finely crystalline fossiliferous limestone.
MISSISSIPPIAN	CHESTER	WEST BADEN GROUP	Elwren Formation 37–52 feet		Red-brown, green-gray, and olive-gray shale and siltstone, and yellow-brown thin-bedded fine-grained sandstone that is locally crossbedded.
MISSISSIPPIAN	CHESTER	WEST BADEN GROUP	Reelsville Ls. 0–7 ft.		Gray sandy fossiliferous limestone.
MISSISSIPPIAN	CHESTER	WEST BADEN GROUP	Sample Formation 22–36 feet		Green-gray and red-brown siltstone and shale and yellow-brown thin-bedded fine-grained sandstone that is locally crossbedded.
MISSISSIPPIAN	CHESTER	WEST BADEN GROUP	Beaver Bend Ls. 8–27 feet		Brown-gray thick-bedded finely crystalline fossiliferous limestone.
MISSISSIPPIAN	CHESTER	WEST BADEN GROUP	Bethel Formation 16–35 feet		Gray soft shale and yellow-brown fine-grained sandstone. Locally contains thin beds of shaly coal and clay.
MISSISSIPPIAN		BLUE RIVER GROUP	Paoli Limestone 29–38 feet		Gray thick-bedded finely crystalline sparingly fossiliferous limestone. Yellow-brown calcareous siltstone and gray shale near middle of unit and locally at base.
MISSISSIPPIAN		BLUE RIVER GROUP	Ste. Genevieve Ls. 35+ feet		Gray thick- to medium-bedded very finely crystalline sparingly fossiliferous limestone. Gray brecciated limestone, Bryantsville Breccia bed, locally at top.





CROSS SECTIONS
SHOWING LAND SURFACE AND POSITION OF MAPPED ROCK UNITS BELOW SURFACE
Vertical exaggeration approximately 7 times

INDEX MAP SHOWING LOCATION OF HURON AREA

Base modified from U.S. Geological Survey topographic quadrangle maps, scale 1:24000

Williams & Heintz Map Corporation Washington 27, D. C.

Geologic mapping by the authors and Eugene Callaghan, 1948 and 1954-59. Drafted by John E. Peace.

GEOLOGIC MAP OF HURON AREA, SOUTH-CENTRAL INDIANA

By Henry H. Gray, Robert D. Jenkins, and Robert M. Weidman

1960