Bedrock Geology and Mineral Resources of Putnam County Indiana

By JOHN R. HILL, MICHAEL C. MOORE, *and* JOHN C. MACKEY

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Abstract
Bedrock units from the Mansfield Formation (Pennsylvanian) to the Edwardsville Formation (Mississippian) crop out throughout Putnam County. Their present distribution is largely due to erosion and nondeposition. These rocks are on the northeast edge of the Illinois Basin and dip westward about 25 feet per mile. Local structural anomalies, such as small-scale monoclinal and synclinal features, punctuate the otherwise flat-lying strata in some places. The Mississippian-Pennsylvanian unconformity is evident in areas where the Mansfield Formation (Pennsylvanian) overlies rocks as old as the Edwardsville Formation (lower Middle Mississippian) and as young as the Elwren Formation (lower Upper Mississippian).

The minerals industry of Putnam County is based almost entirely on limestone. Five quarries produce limestone raw materials for Class A through C aggregate, pulverized limestone, agricultural limestone, and cement. Sand and gravel from valley-train deposits of Wisconsinan age are the only other geologic commodities currently produced (1982). The once-healthy clay-shale industry is now dormant, though moderately extensive deposits of both raw materials remain throughout the county. Minor shows of fair-quality to poor-quality coal are exposed along the Pennsylvanian outcrop, but these deposits are not considered to be commercially valuable.

Introduction
Putnam County is about midway between Indianapolis and Terre Haute, two large metropolitan communities that are expanding into adjacent rural areas. Interstate 70 and U.S. Highway 40 are critical in making this expansion possible. Essential to this rural growth are available industrial minerals: limestone, sand and gravel, and clay, which provide such commodities as aggregate, animal-feed additives, agricultural soil conditioner, high-calcium limestone, limestone and clay for cement raw material, roadway ballast, and fill. Rocks of Mississippian and Pennsylvanian age, cropping out where the glacial drift is thin, provide most of the potential industrial minerals in the county. Clays and limestones come mainly from Mississippian rocks. Minor coal deposits are in the area of Pennsylvanian outcrop, and sand and gravel are in the glacial drift.

Field mapping of the bedrock was the basis of this study. Geologic contacts, at the group level, were first compiled on 7½-minute U.S. Geological Survey topographic quadrangle maps. The demarcation of buried contacts was verified wherever possible by information from water-well drilling, seismic study, and petroleum-exploration drilling. Although the stratigraphic nomenclature applicable to this region was not changed, previous bedrock mapping was considerably refined, especially along the Mississippian-Pennsylvanian contact.

The discussion of the surficial and bedrock geology that follows emphasizes identification and description of the bedrock units. The rest of this report discusses the available industrial minerals and their production potential.

Character of the Landscape
The surface of the county is agreeably diversified, combining in a high degree the useful and agreeable, as rocky scenery, with romantic views of plain and woodland, rich in interest to the economist, all uniting to tell a long story, recorded on rock and plain, of the earth's past, laden with promises of the future. (Collett, 1880, p. 398)

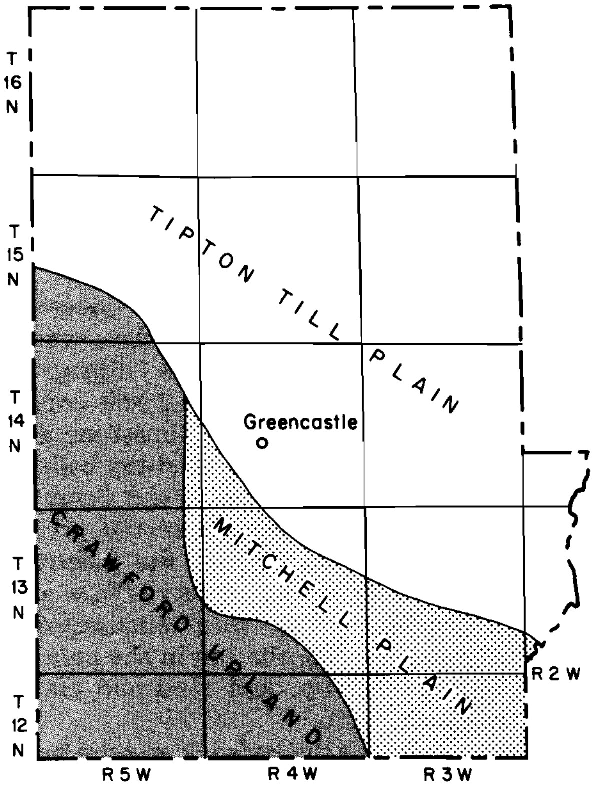


Figure 1. Map of Putnam County showing physiographic units. From Malott, 1922.

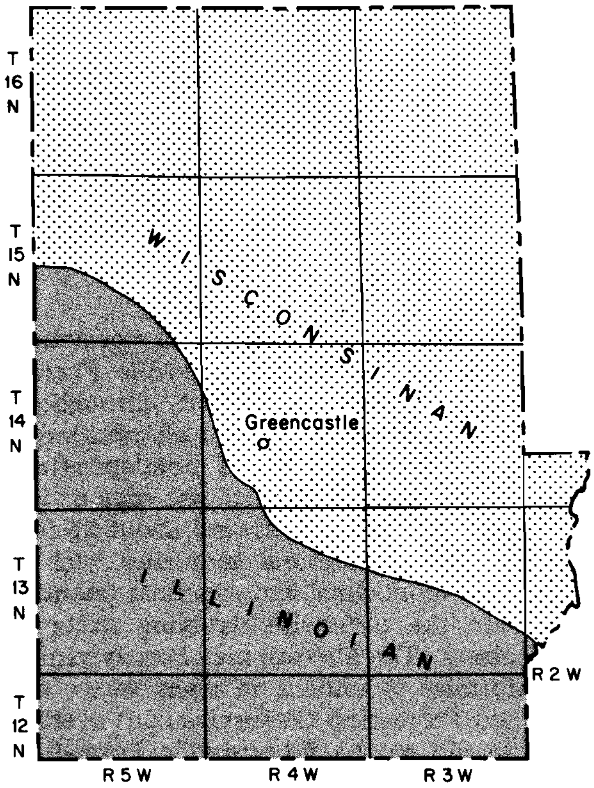


Figure 2. Map of Putnam County showing general distribution of Wisconsinan and Illinoian glacial deposits. Modified from Malott, 1922.

PHYSIOGRAPHY

Most of Putnam County is covered by glacial drift ranging in thickness from 0 to nearly 200 feet where preglacial drainageways have been filled. Bedrock outcrops, mostly along the major streams and their tributaries, are common, especially in the southern half of the county where the glacial drift thins.

Three major physiographic areas (fig. 1) are recognizable. Each of these areas is characterized by its typical landforms and general surface topography. More than half of the county, essentially from the Wisconsinan glacial margin (fig. 2) northward and eastward, consists of gently rolling till plain, which has major topographic relief due to postglacial stream erosion. Known as the Tipton Till Plain (fig. 1), this area is typical of the landscape throughout most of central Indiana. South and west of the Wisconsinan margin lies the relatively thin Illinoian drift sheet (fig. 2). The bedrock topography has considerable surface extent in this area because of the thin drift cover. The western subdivision of the Illinoian drift sheet, called the Crawford Upland (fig. 1), is characterized by great diversity of surface form and relief. East of the Crawford Upland, Mississippian rocks form the westward-sloping Mitchell Plain (fig. 1). Although this limestone contains abundant solution features, sinkholes and caves are uncommon in Putnam County.

DRAINAGE

Putnam County is drained by four major streams and their tributaries that belong to the Wabash River drainage basin. They are: (1) Big Raccoon Creek in the northwestern part of the county and its tributaries covering Russell and Franklin Townships; (2) Big Walnut Creek, which, with its tributaries, is the major drainage system of the county; it enters in Jackson Township and joins Mill Creek in Washington Township to form the Eel River; (3) Deer Creek, which drains Marion and Warren Townships and part of Washington Township and debouches into

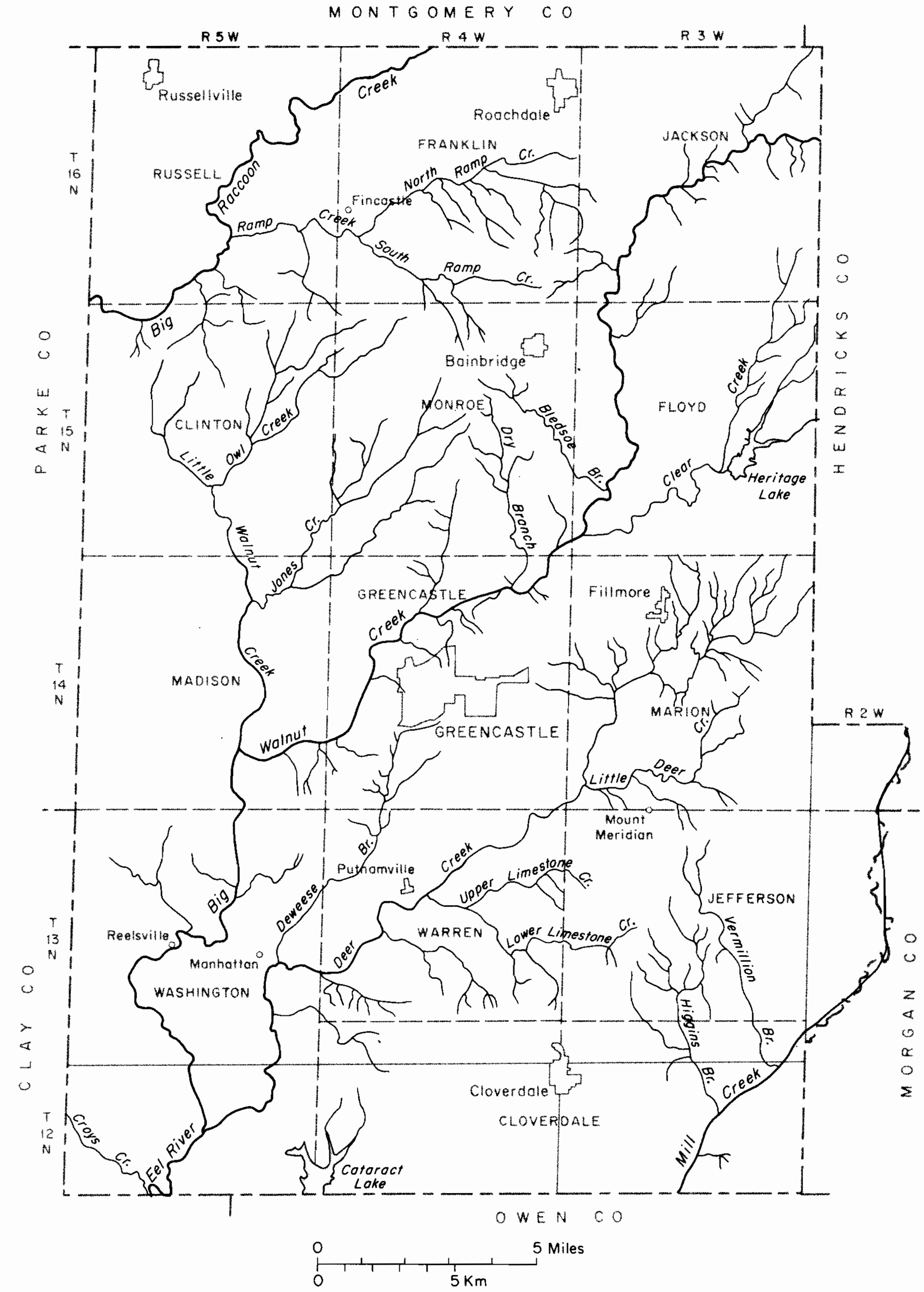


Figure 3. Map of Putnam County showing drainage network.

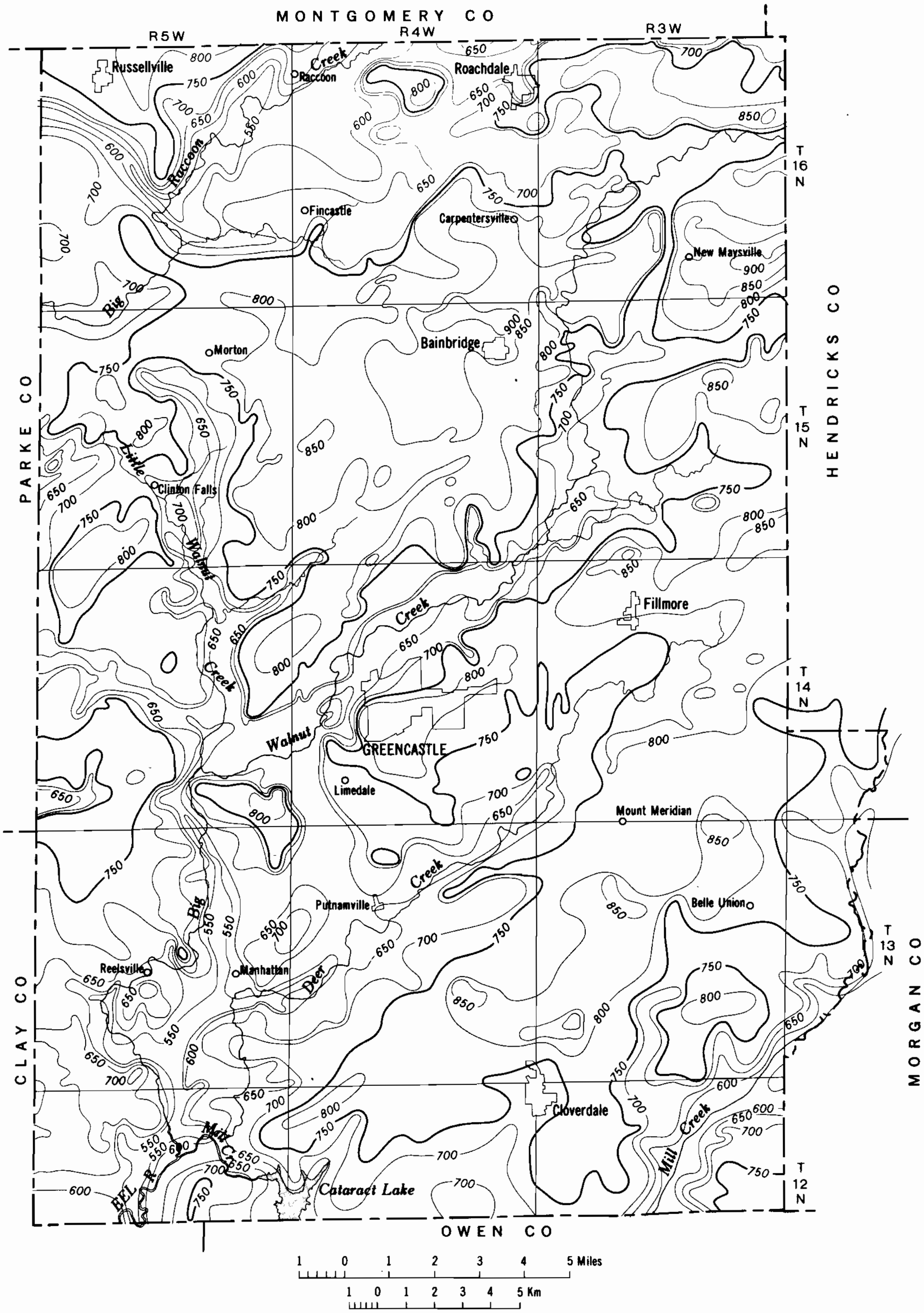


Figure 4. Map of Putnam County showing bedrock topography. Contour interval is 50 feet.

Mill Creek just above the confluence with Big Walnut Creek; and (4) Mill Creek in Jefferson, Cloverdale, and Washington Townships; it forms Cagles Mill Lake (a manmade reservoir) before it is joined by Deer Creek just above its merger with Big Walnut Creek.

Present drainage approximates the preglacial drainage as illustrated in figures 3 and 4. In the northwest corner of the county, where drift is thickest, the present course of Big Raccoon Creek partly follows the buried channel of its precursor. The valleys of Big Walnut Creek and its main tributary, Little Walnut Creek, deviate only in minor detail from their preglacial counterparts.

Man's alteration of the natural surface drainage includes damming Clear Creek in Floyd Township to produce Heritage Lake, constructing Cataract Lake on Mill Creek in Cloverdale and Washington Townships, and extensively rechanneling Mill Creek in Cloverdale Township where topography is subdued. Although there are no natural lakes in the county, numerous artificial farm ponds and flooded gravel pits dot the landscape.

Glacial Geology

As stated above, two distinct glacial stages are represented by till and other glacial (drift) deposits: the Wisconsinan and the Illinoian Stages. By such till analyses as mineral provenance, magnetic susceptibility, and texture, the most recent Wisconsinan drift is known to have been deposited by the Ontario-Erie Lobe of the Wisconsinan glacier. Wayne (1963) classified the Wisconsinan till as the Center Grove Till Member of the Trafalgar Formation. The Center Grove most commonly forms rolling ground moraine (Qt, fig. 5), but in west-central Putnam County, it becomes the more prominent Shelbyville terminal moraine (Qte, fig. 5). The till texture is sandy loam to silty clay but is most typically loam. Intratill sand lenses occur within both the ground moraine and end moraine but are most common in the end moraine.

Sand and gravel deposits of valley-train origin in Wisconsinan outwash (Qgv, fig. 5) are found along parts of all major streams. They provide the major source of sand and gravel in the county. A discontinuous northeast-southwestward-trending ice-channel fill (Qgk, fig. 5) traverses two and a half sections in Floyd Township 3½ miles northwest of Coatesville.

The Illinoian till (Qti, fig. 5) has been assigned to the Jessup Formation (Wayne, 1963). Deeply weathered, the Illinoian till, like its Wisconsinan counterpart, came from a northeastern source. Postdepositional erosion during both the Sangamonian interglacial interval and the Wisconsinan glacial interval reduced any exposed evidence of end-morainal features and thinned and subdued the ground moraine. The few samples analyzed suggest that the Jessup Formation is texturally a loam.

Lacustrine deposits of Illinoian age (Qsl, fig. 5), covering several square miles in southern Cloverdale Township, are the remnant of glacial Lake Quincy. These sediments are predominantly silt, even well beneath the loess cap.

Loess of varying thickness, where not stripped by erosion, mantles the entire county. It is thickest on the Illinoian drift and thins abruptly to the northeast on the younger Wisconsinan drift. The maximum thickness of loess is not expected to exceed 6 feet anywhere in the county, and the probable average thickness is less than 2 feet.

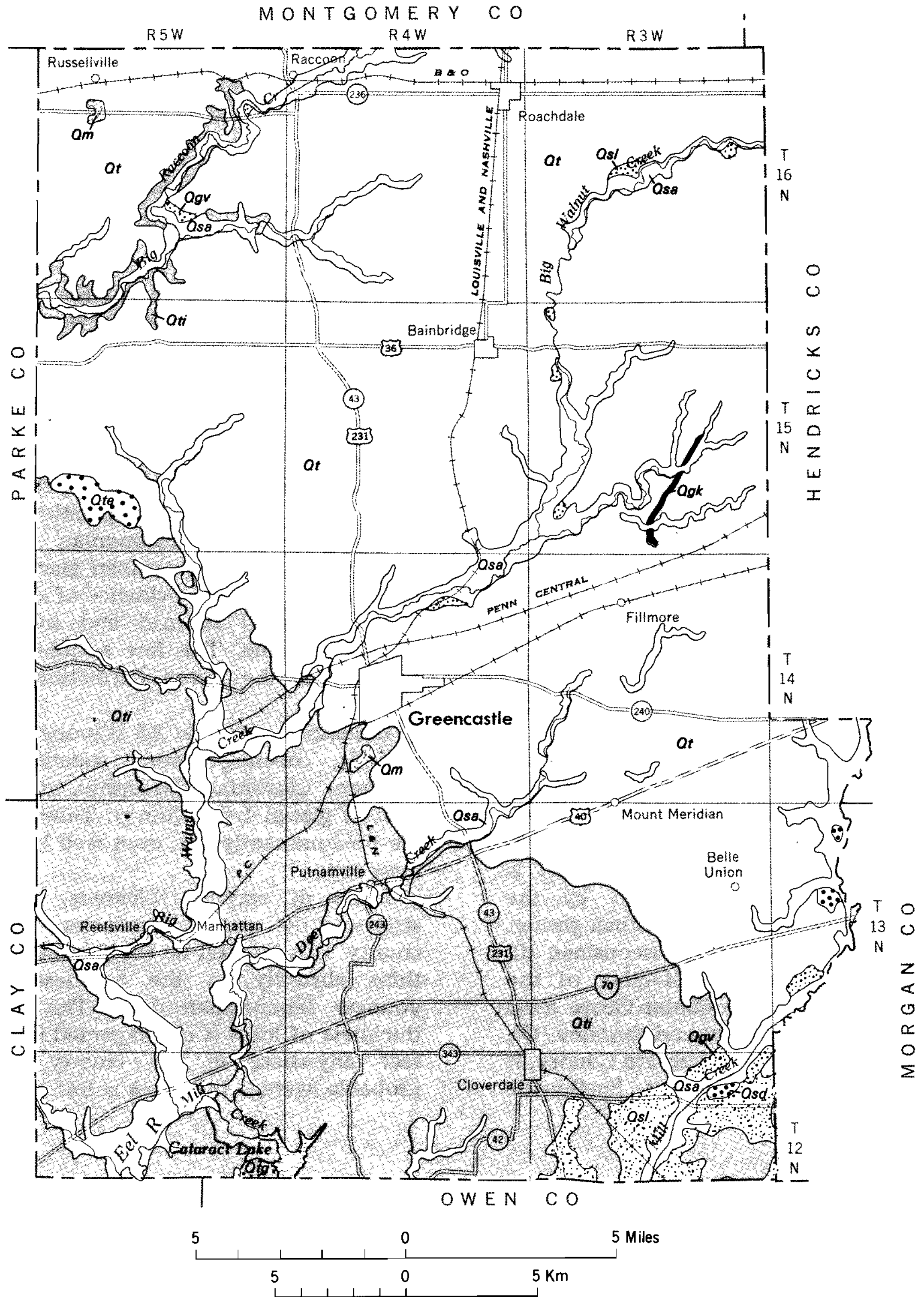
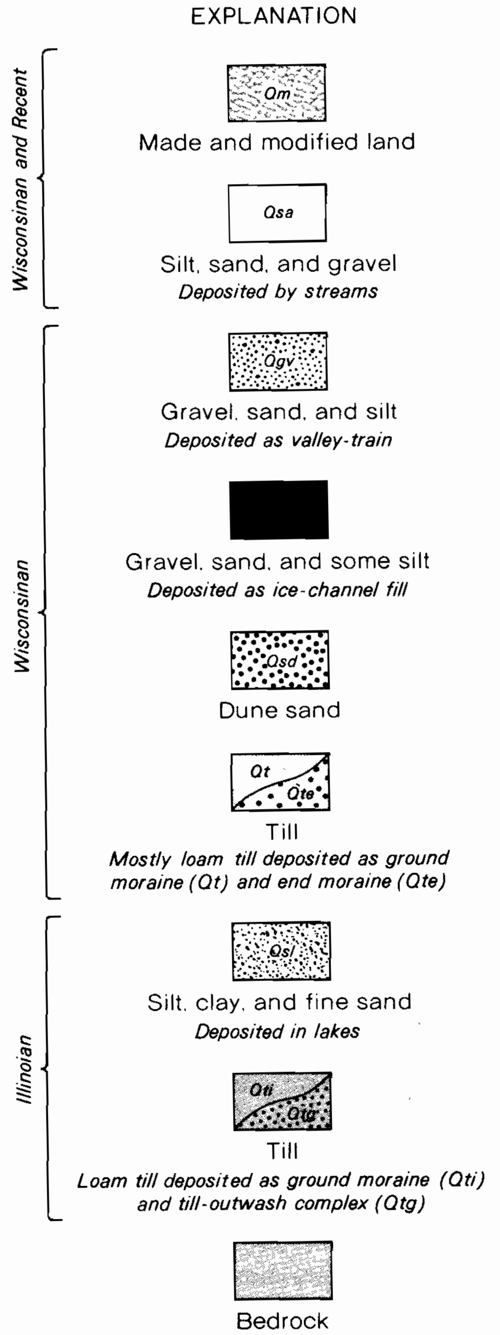


Figure 5. Map of Putnam County showing unconsolidated deposits. Modified from Gray and others, 1979.



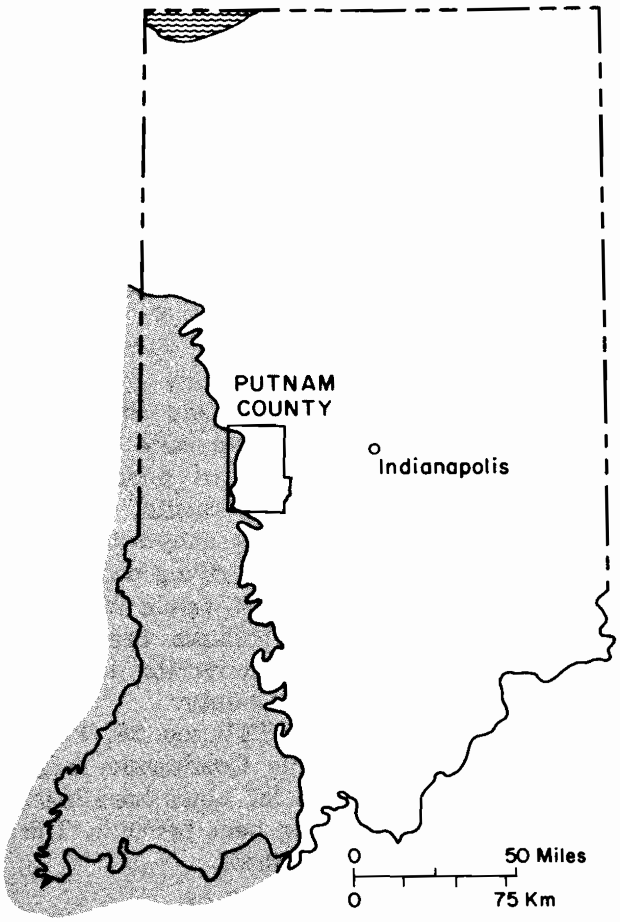


Figure 6. Map of Indiana showing the eastern part of the Illinois Basin.

Bedrock Geology

STRUCTURE

Putnam County is on the northeast edge of the Illinois Basin (fig. 6). The bedrock units that crop out in this part of Indiana dip westward about 25 feet per mile. But variations in steepness of dip and even dip reversals are common (Gray, 1962). For example, Hutchison (1976) found that Pennsylvanian rocks in the Catlin-Mansfield area dip to the southwest at an average of 35 to 45 feet per mile and that local irregularities, such as anticlines, synclines, monoclines, basins, and domes, are superimposed on the regional dip. Examples of these local structural anomalies are scattered throughout the county. In a gully behind the Reelsville Methodist Church (NW¼SE¼NE¼ NW¼ sec. 21, T. 13 N., R. 5 W., Reelsville Quadrangle), the Beaver Bend Limestone forms a small waterfall in the creekbed. On the west side of the creek, the Beaver Bend dips westward at about 20°. Just upstream, the Beaver Bend floors the creek and dips roughly southeastward. Though poorly exposed, the Sample Formation and the Reelsville Limestone lie above the Beaver Bend in a similar manner. The structure is apparently a small syncline with a northeast-southwestward-trending axis.

Along the west side of Peter's Creek 1.6 miles southeast of Fincastle (SW¼NW¼NE¼ NW¼ sec. 36, T. 16 N., R. 5 W., Russellville Quadrangle), a large section of the Salem Limestone crops out; it strikes N. 74.5° E. and dips from 8° to 12° to the southeast. A few hundred feet up the gully, near the contact between the Salem and St. Louis Limestones, is a well-exposed zone of gray breccia composed of clasts of micrite and chert cemented by sparry calcite. Similar breccia zones resulting from anhydrite solution and later collapse of overlying beds have been observed in the lower St. Louis. Whether this is an example of collapse breccia is conjectural, however, as anhydrite deposits are not known in Putnam County.

Also, in the NW¼NE¼SW¼ sec. 29, T. 16 N., R. 5 W., Russellville Quadrangle, large limestone blocks of the St. Louis have been tilted from the flat-lying beds beneath. The cause of the tilting is unknown.

STRATIGRAPHY

The stratigraphic interval discussed in this report consists of all bedrock units that crop out in the county (fig. 7) from the Edwardsville Formation of the Borden Group to the Mansfield Formation of the Raccoon Creek Group. Descriptions of these units at their type localities, subordinate nomenclature, and correlation information are provided in Shaver and others (1970), Hutchison (1976), Gray (1962), Nicoll and Rexroad (1975), and Carr and others (1978). Although each formation encountered during field reconnaissance of this study is discussed separately, final mapping was done by groups (fig. 8).

BORDEN GROUP AND EDWARDSVILLE FORMATION

As currently understood in Indiana, the Borden Group (M_1, fig. 8) comprises (in ascending order) the New Providence Shale, the Locust Point Formation, the Carwood Formation, and the Edwardsville Formation (Shaver and others, 1970, and Nicoll and Rexroad, 1975). In Putnam County the oldest exposed rocks belong to the Edwardsville Formation. Exposed Borden rocks attain thicknesses of 90 feet or more in Putnam County.

This report uses the stratigraphic definition of the Edwardsville given by Nicoll and Rexroad (1975, p. 3). Those interested in more information about the origin and evolution of the term Edwardsville Formation are referred to Stockdale (1931, p. 220) and Shaver and others (1970).

The Edwardsville of Putnam County is dominantly siltstones, shales, and sandstones (Appendix, Section 9). The siltstones are bluish gray to gray and thin bedded, contain fine-grained muscovite, and are generally noncalcareous. The shale units are gray and thin bedded. The sandstone units are generally brown, fine grained, massive, noncalcareous, and in places contain fossil molds. At some localities, the sandstone sequences show crossbedding and current ripples, which indicates, along with the overall sand-body geometry, that the deposits are channel fills. A channellike deposit of coarse crinoid fragments in a sparry-calcite cement is in the SE¼NE¼SE¼ sec. 1, T. 16 N., R. 4 W., Russellville Quadrangle. The feature is possibly biohermal.

The Edwardsville Formation is at least 90 feet thick in Putnam County and possibly much thicker. Where present, the Ramp Creek Formation (Sanders Group) conformably overlies the Edwardsville. Otherwise the Edwardsville is unconformably overlain by the Mansfield Formation (for example, in the SE¼SE¼NE¼ sec. 10, T. 16 N., R. 5 W., Russellville Quadrangle). There are excellent exposures of the Edwardsville Formation in small stream valleys on the west side of Big Walnut Creek in sec. 6, T. 15 N., R. 3 W., Roachdale Quadrangle.

SANDERS GROUP

The Sanders Group (M_2, fig. 8) originally included the Harrodsburg and Salem Limestones (Smith, 1965). In our report, however, the Ramp Creek Formation is considered to be the base of the Sanders Group in accord

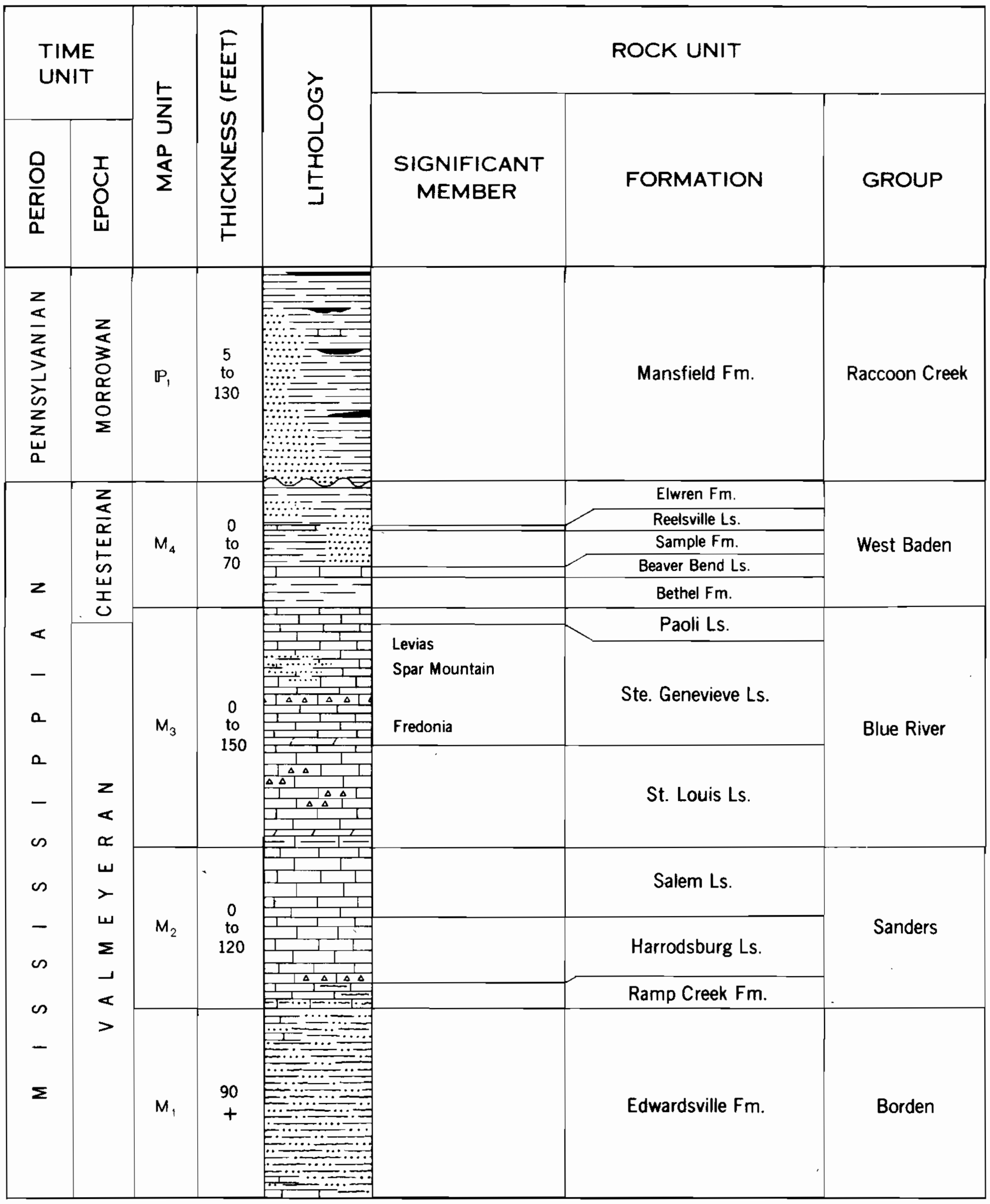


Figure 7. Columnar section of bedrock stratigraphic units exposed in Putnam County. Modified from Gray and others, 1979. Map units refer to figure 8.

with Nicoll and Rexroad (1975). The Sanders Group now consists (in ascending order) of the Ramp Creek Formation, the Harrodsburg Limestone, and the Salem Limestone. The maximum thickness of the Sanders in this area is about 120 feet.

RAMP CREEK FORMATION

The Ramp Creek Formation as used in this report follows the discussion of Nicoll and Rexroad (1975, p. 5). The early definition and regional correlations of the Ramp Creek were provided by Stockdale (1929) and Shaver and others (1970).

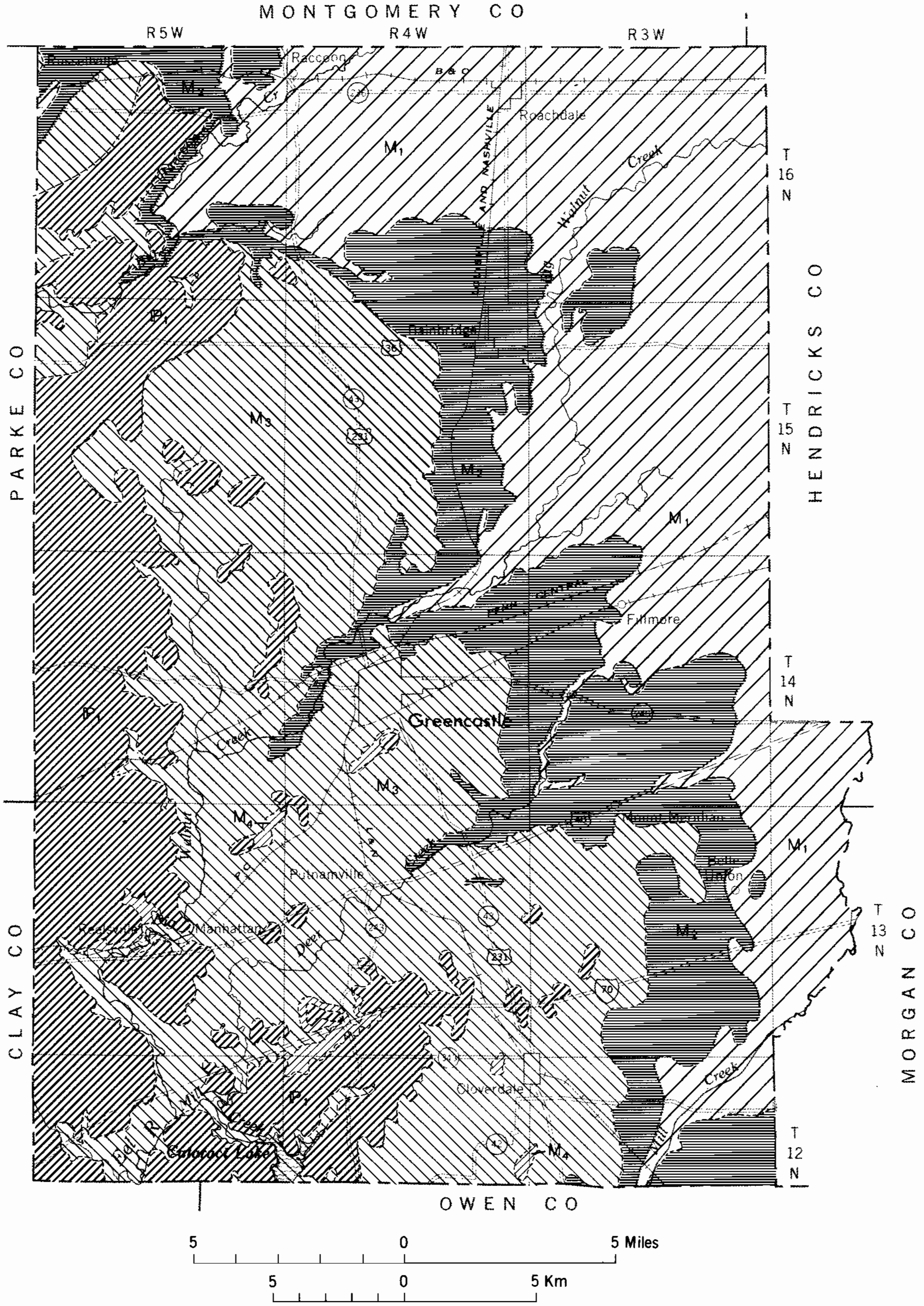
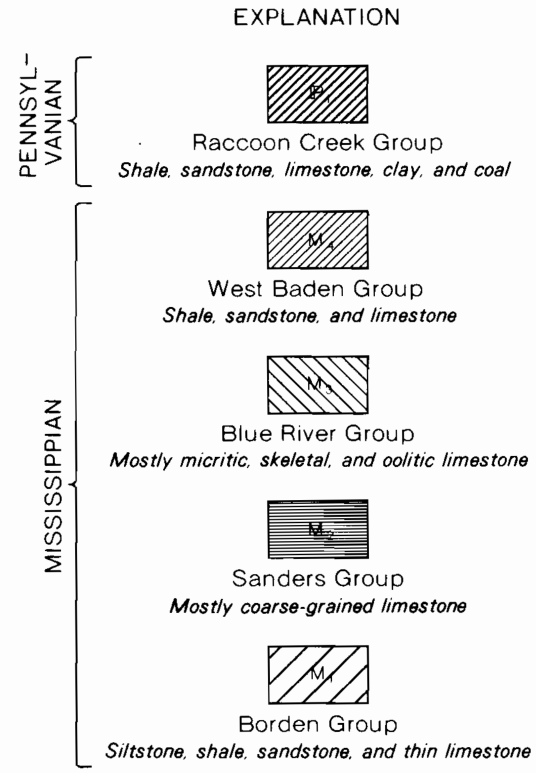


Figure 8. Map of Putnam County showing areal distribution of bedrock units. Modified from Gray and others, 1979.



In Putnam County the Ramp Creek Formation consists of interbedded dolosiltite and limestone (Appendix, Section 9). The dolosiltite is blue gray to gray and thin bedded and contains finely divided muscovite. Scattered geodes are present but are less common than at the type section of the Ramp Creek in Monroe County. The limestone units are dark gray with common ferruginous staining, coarse grained, and thin bedded near the base but become thicker bedded higher in the section. Some limestone beds are highly fossiliferous and contain chert, glauconite, and commonly pyrite. The clasts are primarily crinoid columnals with sparry calcite as the cementing agent.

Locally, the Ramp Creek is 20 to 30 feet thick. Individual units are traceable over a limited areal extent, and in some places the entire Ramp Creek Formation consists only of dolosiltite.

The Ramp Creek is conformably overlain by the Harrodsburg Limestone or unconformably by the Mansfield Formation. An example of Ramp Creek lithologies in Putnam County is in the NE¼NW¼SE¼ sec. 31, T. 16 N., R. 3 W., Roachdale Quadrangle.

HARRODSBURG LIMESTONE

The Harrodsburg is recognized as defined by Nicoll and Rexroad (1975) for rocks between the Salem Limestone and the Ramp Creek Formation. The term Harrodsburg was originally used in Indiana by Hopkins and Siebenthal (1897).

The Harrodsburg of Putnam County is generally bluish-gray to gray thick-bedded bioclastic calcarenite or calcirudite. The upper beds are somewhat less coarse grained and lighter in color than the lower beds, which tend to be darker and coarser grained and contain variable amounts of chert. The upper part of the formation contains thick beds of fenestrate-bryozoan coquina. In some localities, the upper 15 feet of the Harrodsburg lithology appears identical to that of the Salem, which makes formational boundaries difficult to define.

The Harrodsburg Limestone is 30 to 40 feet thick in Putnam County and thickens slightly toward the southeast. Where the Harrodsburg is overlain by the Salem Limestone, the boundary is gradational. The unconformity between the Mansfield and the Harrodsburg can be seen in the NW¼NE¼NW¼ sec. 25, T. 16 N., R. 4 W., Russellville Quadrangle. An excellent exposure of the Harrodsburg Limestone is in an abandoned quarry in the NW¼SE¼ sec. 13, T. 14 N., R. 3 W., Coatesville Quadrangle.

SALEM LIMESTONE

Use of the term Salem Limestone in Putnam County follows the commonly accepted definition of the Salem as those rocks that lie between the St. Louis Limestone and the Harrodsburg Limestone as originally proposed by Cumings (1901).

Locally, the Salem is gray to light-gray coarse-grained massive calcarenite composed of fossil fragments cemented by sparry calcite (Appendix, Section 10). Other units in the Salem contain beds that are composed of poorly sorted calcirudite, large whole macrofossils, and, near the Salem-St. Louis boundary, intercalated beds of calcarenite, dismicrite, and some black chert (for example, in the NE¼NW¼NW¼ sec. 20, T. 14 N., R. 4 W., Clinton Falls Quadrangle).

The Salem Limestone thins rapidly northward in Putnam County, possibly as a result of pre-St. Louis erosion or nondeposition. The formation averages 50 feet in thickness in the central part of the county, but it is only 13 feet thick at the Russellville Quarry near the Putnam-Montgomery county line. The contact between the Salem and St. Louis Limestones appears to be conformable, but the Mansfield-Salem contact is unconformable.

BLUE RIVER GROUP

As defined by Gray and others (1960), the Blue River Group consists (in ascending order) of the St. Louis Limestone, the Ste. Genevieve Limestone, and the Paoli Limestone. The Blue River Group is about 150 feet thick in Putnam County.

ST. LOUIS LIMESTONE

The St. Louis Limestone as used in this report follows the description by Pinsak (1957). Discussions of the definition and correlation of the St. Louis Limestone can be found in Engelmann (1847), Ulrich (1904), and Shaver and others (1970).

In Putnam County the St. Louis can be divided into an upper part and a lower part (Appendix, Sections 5 and 6). The upper part is gray thin-bedded micrite or biomicrite containing much dark-gray chert in nodules or beds. Parts of the upper unit are fossiliferous and contain many chert-replaced fossils (for example, in the NW¼SW¼NE¼ sec. 28, T. 15 N., R. 5 W., Clinton Falls Quadrangle). Pelmicrite beds are also common and can easily be confused with oolite beds of the overlying Ste. Genevieve Limestone.

The lower part of the St. Louis is gray to tan and brown thin-bedded micrite. Beds of dolomite, argillaceous limestone, and greenish calcareous shales are common; but the deposits of gypsum or anhydrite, which are common in southwestern Indiana, are absent from this area. A marker bed of orange macrocrystalline porous dolomitic limestone persists throughout the lower St. Louis in Putnam County and is a key bed for identifying stratigraphic position. This marker bed is well exposed in the S½NW¼SE¼NE¼ sec. 21, T. 14 N., R. 5 W., Clinton Falls Quadrangle.

The St. Louis is between 80 and 90 feet thick in the county and is overlain by the Ste. Genevieve Limestone or by the Mansfield Formation. An example of St. Louis limestone in Putnam County is at Vermillion Falls in the NE¼SW¼NE¼ sec. 36, T. 15 N., R. 5 W., Clinton Falls Quadrangle (privately owned land).

STE. GENEVIEVE LIMESTONE

The currently accepted description and stratigraphic position of the Ste. Genevieve Limestone, as discussed by Gray and others (1960), Shaver and others (1970), and Carr and others (1978), is used in this report.

In Putnam County the Ste. Genevieve contains three recognizable members, which are (in ascending order) the Fredonia Member, the Spar Mountain Member, and the Levias Member (Appendix, Sections 5, 6, and 8). The Fredonia Member is light-gray to white medium-bedded to massive biomicrite that also contains scattered beds of biosparite. Throughout most of the outcrop belt of the Blue River in Indiana, the Lost River Chert Bed marks the base of the Fredonia. In Putnam County, however, numerous chert beds within the underlying St. Louis Limestone make differentiation by chert bed difficult. The Fredonia is between 9 and 14 feet thick in Putnam County.

The dominant lithology of the Spar Mountain Member is crossbedded calcarenite in which the allochems are oolites, quartz grains, or rounded carbonate detritus. The framework is in a matrix of silt-sized calcite grains and sparry calcite. The Spar Mountain ranges from 4 to 7 feet in thickness in this part of Indiana.

The Levias Member consists of gray thin- to medium-bedded micrite or biomicrite and thin beds of shale. The top of the Levias is marked by the Bryantsville Breccia Bed, which is typically composed of 1 to 3 feet of angular to subangular clasts of micrite or chert in a calcite or silica matrix. The beds thin northward and are in only a few places north of T. 14 N. in Putnam County. Where it is not eroded, the unit is 16 to 29 feet thick.

Figure 9. Photograph of the Ste. Genevieve Limestone at a large road cut east of Little Walnut Creek in the NE¼ sec. 27, T. 14 N., R. 5 W. Note the crossbedding in the Spar Mountain Member (upper third of photograph).

The overall thickness of the Ste. Genevieve Limestone ranges from 28 to 48 feet on exposure; in the subsurface near Cloverdale, however, the Ste. Genevieve is more than 80 feet thick. A well-exposed section showing all three members (fig. 9) is in the SW¼NW¼ NE¼ sec. 27, T. 14 N., R. 5 W., Clinton Falls Quadrangle, at a large road cut east of Little Walnut Creek. The Ste. Genevieve is paraconformably overlain by the Paoli Limestone or unconformably by the Mansfield Formation.

PAOLI LIMESTONE

The Paoli Limestone as used in this report follows the definition of Shaver and others (1970). The term was originally applied to Indiana rocks by Elrod (1899).

Locally, the Paoli Limestone consists of an upper unit of white or light-gray medium-grained thin-bedded oosparite; a middle unit of calcareous thin-bedded white shale; and a lower unit of gray thin-bedded micrite underlain by green calcareous shale (Appendix, Sections 1-3, 7, and 8). The formation is generally less than 15 feet thick and is absent in some places. The Paoli is conformably overlain by the Bethel Formation or unconformably by the Mansfield Formation. A representative section is exposed in a gully in the N½SE¼NW¼NW¼ sec. 32, T. 13 N., R. 4 W., Reelsville Quadrangle.

WEST BADEN GROUP

Although the West Baden Group was first defined by Cumings (1922), the usage of Gray and others (1960) is followed here. The West Baden Group (M_4, fig. 8) comprises (in ascending order) the Bethel Formation, the Beaver Bend Limestone, the Sample Formation, the Reelsville Limestone, and the Elwren Formation. The outcrop of the West Baden Group is as much as 70 feet thick in Putnam County.

BETHEL FORMATION

The current usage of the Bethel is that of Shaver and others (1970) and applies to Putnam County as well as other areas of outcrop in Indiana. The original definition and correlation of the Bethel with other rocks can be found in Butts (1917) and Shaver and others (1970).

Dominantly dark-gray thin-bedded shale, the Bethel Formation of Putnam County is capped by about 2 feet of hard fine-grained brown sandstone (Appendix, Sections 1 and 2). Locally, beds of coal and micritic limestone nodules are intercalated with the gray shale.

Formational thicknesses range between 5.5 and 18.0 feet. The Bethel is overlain either conformably by the Beaver Bend Limestone or unconformably by the Mansfield Formation. A typical exposure of the Bethel Formation in Putnam County is in the NE¼NE¼SE¼NW¼ sec. 2, T. 12 N., R. 5 W., Reelsville Quadrangle.

BEAVER BEND LIMESTONE

The definition of the Beaver Bend Limestone as introduced by Malott (1919) and modified by Gray and others (1960) has been adopted for this report. Putnam County is the northernmost area of outcrop of the Beaver Bend in Indiana.

Locally, the Beaver Bend is gray coarse-grained biosparite, oosparite, or biomicrite exposed in massive beds (Appendix, Sections 1-3), and it displays much superficial ferruginous red staining. The Beaver Bend averages 7 to 12 feet in thickness but has been recognized in outcrops as thin as 1 foot. It is conformably overlain by the Sample Formation or unconformably by the Mansfield Formation. A typical exposure is in the SE¼NW¼SE¼SW¼ sec. 2, T. 12 N., R. 5 W., Reelsville Quadrangle.

SAMPLE FORMATION

The Sample Formation as described by Gray and Perry (1956) has been adopted for this report. The original definition of the Sample and later modifications can be found in Butts (1917), Cumings (1922), Gray and Perry (1956), and Shaver and others (1970).

In Putnam County the Sample Formation is dominated by dark-gray thin-bedded shale (Appendix, Sections 1-3). It is 4 to 16 feet thick and is overlain either conformably by the Reelsville Limestone or unconformably by the Mansfield Formation. An example of the Sample is exposed in the NE¼SE¼SW¼ NW¼ sec. 2, T. 12 N., R. 5 W., Reelsville Quadrangle.

REELSVILLE LIMESTONE

The Reelsville Limestone was named by Malott (1919), and a type section was designated in the W½SE¼NE¼ sec. 21, T. 13 N., R. 5 W., Reelsville Quadrangle, Putnam County. At the type section, the Reelsville is gray biomicritic ferruginous limestone. In many places it is sandy and thin bedded, and in others it is a calcarenite (Appendix, Sections 1-3). It is 1 to 5 feet thick and is overlain conformably by the Elwren Formation or unconformably by the Mansfield Formation.

ELWREN FORMATION

The Elwren Formation as defined by Gray and Perry (1956) applies to the youngest Mississippian rocks exposed in Putnam County. The original definition of the Elwren can be found in Malott (1919) and Shaver and others (1970).

In Putnam County the Elwren is dominantly brown thin-bedded sandstone containing scattered macrofossil molds (Appendix, Sections 1 and 2). Thickness ranges from a foot or less to as much as 25 feet. The formation is unconformably overlain by the Mansfield Formation, but the contact is difficult to recognize because the two lithologies are similar. The Elwren is well exposed in the SE¼NW¼NE¼NW¼ sec. 21, T. 13 N., R. 5 W., Reelsville Quadrangle.

RACCOON CREEK GROUP AND MANSFIELD FORMATION

The term Raccoon Creek Group (P_1, fig. 8) was introduced by Wier and Gray (1961) as part of the terminology used in the bedrock mapping for the original Indianapolis 1° X 2° Regional Geologic Map. The group comprises (in ascending order) the Mansfield Formation, the Brazil Formation, and the Staunton Formation. In Putnam County only rocks of the Mansfield Formation are present; younger Pennsylvanian rocks are absent because of nondeposition and erosion.

The definition of the Mansfield of Kottlowski (1959) has been adopted for this report. The first designation of the name and its correlation with other rocks can be found in Hopkins (1896) and Shaver and others (1970).

The Mansfield of Putnam County is characteristically brownish-orange (on outcrop) coarse-grained massive quartz sandstone containing variable amounts of muscovite (Appendix, Sections 1 and 2). The next most abundant lithology is dark-gray to black thin-bedded shale that in places is also carbonaceous and contains muscovite. Lesser amounts of siltstone, underclay, and coal and siderite beds are also found. Limestones and dolomites characteristic of the Mansfield in other parts of Indiana are not found in Putnam County.

The Mansfield is a few feet to as much as 130 feet thick in southwestern Putnam County. This range in thickness results from local relief along the unconformity and from postdepositional erosion. Because the Mansfield unconformably overlies rocks as old as the Edwardsville Formation (lower Middle Mississippian) and as young as the Elwren Formation (lower Upper Mississippian), relief along the basal Mansfield contact with older rocks can be measured in tens of feet in a square-mile area. In places the unconformity is marked by a quartz-pebble and chert conglomerate (for example, in the NE¼NW¼ NW¼NW¼ sec. 4, T. 12 N., R. 5 W., Russellville Quadrangle).

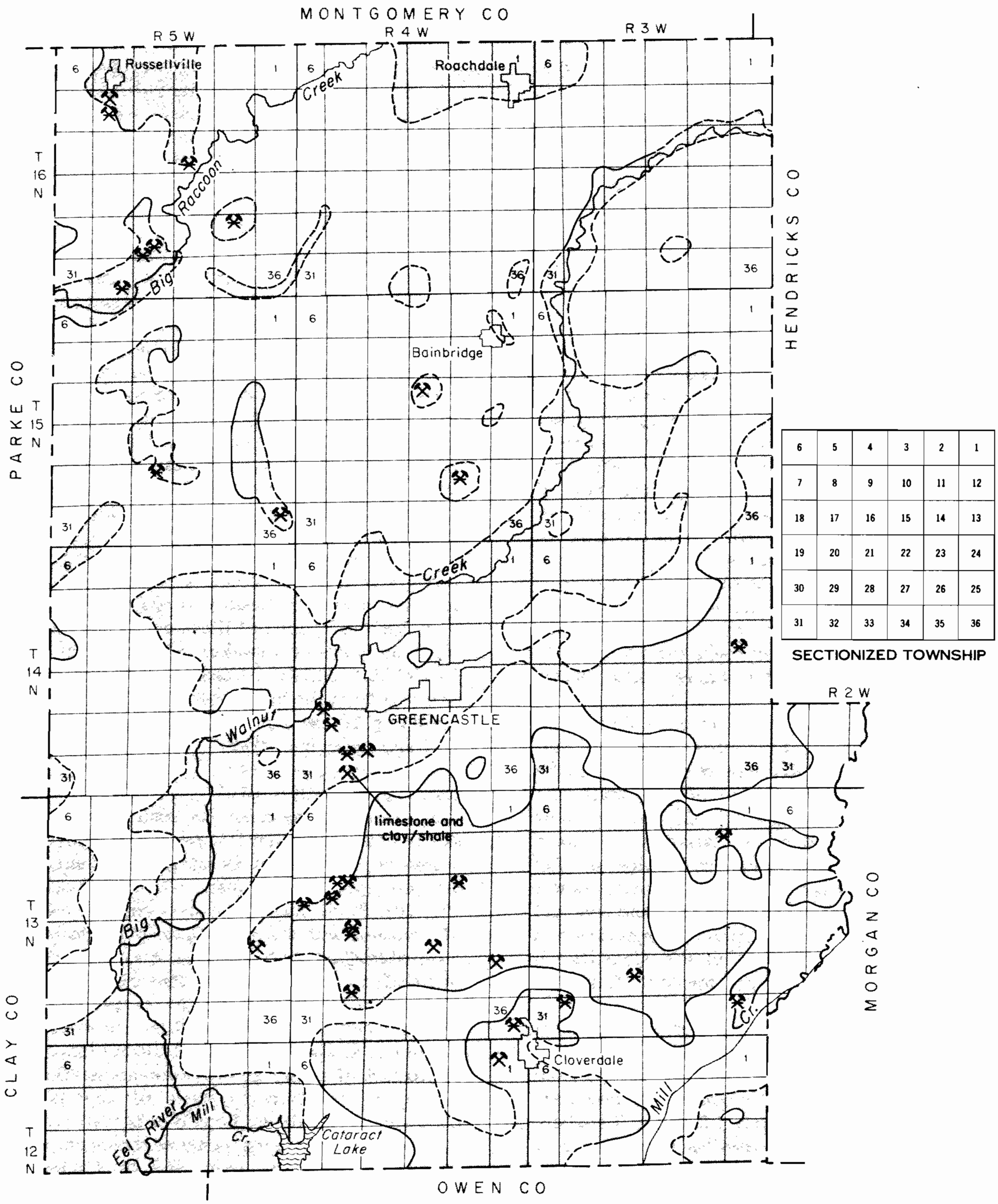
Industrial Minerals

The geologic materials of potential economic value in Putnam County are industrial minerals that are relatively abundant and widespread in their distribution. Local mineral production includes limestone, clay, and sand and gravel. The commercial value of these deposits ranges from poor to excellent and depends on such factors as lithologic composition, lateral and vertical uniformity of the geologic unit, water-table elevation, thickness of overburden, and economic variables related to market demand and transportation costs.

The combined output of six quarries and two gravel pits that comprised all industrial minerals in Putnam County in 1977 was more than 2,876,000 tons of limestone, shale, and sand and gravel at a market value in excess of $6,700,000. Ninety percent of that production was from the limestone industry, and the remaining 10 percent was from the clay and sand and gravel industries.

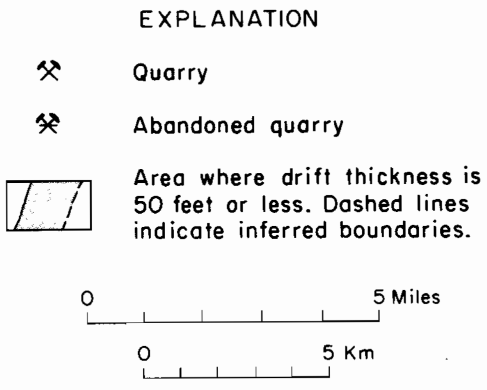
LIMESTONE RESOURCES

Limestone raw materials for such commodities as Class A through C aggregate, pulverized limestone, agricultural limestone, and cement are produced at five quarries in the county (fig. 10). Stone passing the state requirements of abrasion and soundness loss and deleterious-material content for Class A aggregate is quarried at four localities. Pulverized limestone, which is used mostly in preparing animal feeds, is manufactured by the France Stone Co. at Greencastle. Agricultural lime, a byproduct of nearly all limestone-preparation plants, is common to each of the five currently active plants. Lone Star Industries is one of four remaining cement producers in Indiana and is the only one in Putnam



6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Figure 10. Map of Putnam County showing active (1982) and abandoned limestone and shale quarries.



County. For the reader interested in more background information concerning the cement, clay and shale, crushed-stone, and high-calcium limestone industries, the following publications can be obtained from the Publications Section, Indiana Geological Survey, 611 North Walnut Grove, Bloomington, IN 47405: "Cement Raw Material Resources of Indiana" (Bulletin 42-K) by L. F. Rooney and D. D. Carr; "Clay and Shale Resources of Indiana" (Bulletin 42-L) by G. S. Austin; "Crushed Stone Aggregate Resources of Indiana" (Bulletin 42-H) by D. D. Carr, R. R. French, and C. H. Ault; and "High-Calcium Limestone and High-Magnesium Dolomite Resources of Indiana" (Bulletin 42-B) by L. F. Rooney.

Limestone is produced (1982) from several Mississippian stratigraphic levels ranging from the Beaver Bend Limestone through the Harrodsburg Limestone. Although a thin section of Beaver Bend (about 10 feet) is being removed at two of the quarries (France Stone Co. and Lone Star Industries) and the Salem and Harrodsburg Limestones (about 22 feet) are being quarried at the Russellville Stone Co., most of the limestone is being removed from the Blue River Group, particularly the Paoli and Ste. Genevieve Limestones.

Future production of limestone will, of course, depend heavily on market demand and production and shipping costs. Accessibility, chemical and lithologic purity of reserves, and efficiency of future mining and quarrying techniques will also determine later trends in the local limestone industry. New markets for such a commodity as high-calcium limestone could make subsurface mining a profitable addition to or a substitute for the open quarry, especially in areas where problems of the environment and of quarrying efficiency exist.

BEAVER BEND LIMESTONE

The Beaver Bend Limestone averages between 7 and 12 feet in thickness but can be as thin as 1 foot and pinches out north of Greencastle. Although the unit is suitable as a source of Class A aggregate, it is not commonly quarried because it is too thin and is bounded above and below by shales of the Sample and Bethel Formations.

PAOLI LIMESTONE

From 0 to 15 feet thick, the Paoli Limestone is similar in appearance and composition to part of the underlying Ste. Genevieve Limestone, and north of U.S. Highway 40, the two formations cannot be readily distinguished from one another. The Paoli Limestone is considered a potential source of high-calcium limestone (Carr and others, 1978) as well as Class A aggregate. A thin-bedded shale occurs within the Paoli, and a greenish calcareous shale is at the base of the formation on outcrop. The Paoli is not quarried separately from the Ste. Genevieve anywhere in Putnam County at present, nor is it likely to be unless limited quantities of aggregate are needed in an area where the Paoli is at or near the surface.

STE. GENEVIEVE LIMESTONE

The Ste. Genevieve Limestone ranges from 28 to 48 feet in thickness on outcrop but attains thicknesses of nearly 70 feet in the subsurface (Appendix, Section 10) and where it is exposed in the quarry of the France Stone Co. at Cloverdale and in quarries of Lone Star Industries and Martin Marietta Aggregates. Three distinct members are recognized in the Ste. Genevieve. (See p. 12.) From the top the Ste. Genevieve ranges from medium-bedded to massive biomicrite through coarse-bedded oolitic limestone to thin- to medium-bedded micrite or biomicrite containing numerous shale beds. Deleterious chert is in both the upper and lower parts of the formation. Except for the cherty zones, the Ste. Genevieve is suitable as Class A aggregate.

Table 1. Chemical analyses in percent of thick units of high-calcium limestone in the Paoli and Ste. Genevieve Limestones of Putnam County[1]

Location			Thickness[2] (ft)	$CaCO_3$ + $MgCO_3$	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3
Sec.	T.	R.							
20	14N	4W	16	95.9	95.0	.88	2.98	.42	.28
14	13N	4W	14	96.4	95.5	.90	2.64	.38	.19
17	13N	4W	14	97.2	96.5	.67	2.19	.17	.21
17	13N	4W	34	95.8	95.1	.68	3.25	.32	.22
21	13N	5W	11	96.1	95.5	.62	2.58	.46	.57
24	13N	5W	18	96.2	95.6	.58	2.85	.39	.31
24	13N	5W	13	95.6	95.0	.63	3.14	.53	.26
1	12N	4W	21	96.4	95.5	.94	2.38	.49	.28

[1]Modified from Carr and others, 1978, p. 25.

[2]Thickness refers to the total interval of stone in the exposure that is 95 percent or more calcium carbonate.

Laboratory tests of eight samples reported by Carr and others (1978) indicate that the Ste. Genevieve (along with the Paoli) is a potential source of high-calcium limestone (table 1), especially the oolitic Fredonia Member. Cement is also manufactured from Ste. Genevieve rocks at the Lone Star Industries plant. At the France Stone Co. near Greencastle, rocks including the Ste. Genevieve are trucked in from elsewhere in the county and pulverized, mostly for animal feeds.

ST. LOUIS LIMESTONE

The St. Louis Limestone, which is as much as 90 feet thick in Putnam County, is composed dominantly of upper and lower thin-bedded micrites. The upper micrite is also characterized by much chert and the lower micrite by dolomite, argillaceous limestone, and shale. Because of the extensive ball and bedded chert in the upper St. Louis and the shale in the lower part, the formation is not suitable as Class A aggregate, nor is it considered to be a source of high-calcium limestone. Also, the chert damages crushing equipment. Possible uses for the St. Louis include subbase fill and riprap materials.

SALEM LIMESTONE

Ranging in thickness from nearly 60 feet in the central part of Putnam County to 13 feet in the northwestern part, the Salem Limestone is typically coarse-grained calcarenite composed of fossil fragments that are cemented by sparry calcite. The Salem is a good source of high-calcium limestone as illustrated by two samples of the unit that were chemically analyzed (table 2) by the Indiana Geological Survey (Rooney, 1970, p. 10). The results, though certainly not representative of the entire Salem in the county, indicate that the calcium carbonate content should run at least 95 percent. As elsewhere in the state, most of the Salem Limestone is not well suited as a source of Class A aggregate because it fails the abrasion and soundness-loss tests. An exception, however, is the Salem facies quarried at the Russellville Stone Co. At that location the Salem is fine-grained calcarenite that is dense and hard and therefore is a good source of Class A aggregate. Because this localized facies of the Salem also takes an excellent polish, these rocks are a potential source of such decorative-stone products as window sills and small ornamental objects.

HARRODSBURG LIMESTONE

The Harrodsburg Limestone averages between 30 and 40 feet in thickness. It is typically thick-bedded bioclastic calcarenite. The upper part tends to be finer grained than the underlying part. The lower part also contains

Table 2. Chemical analyses in percent of high-calcium limestone in the undifferentiated Salem and Harrodsburg Limestones of Putnam County[1]

Measured section	Location			Thickness[2] (ft)	$CaCO_3$ + $MgCO_3$	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	S	P_2O_5
	Sec.	T.	R.									
Ohio and Indiana Stone Co. quarry floor (core)	NW¼ 29	14N	4W	57	97.8	96.5	1.38	1.47	0.12	0.19	0.09	0.032
Keeney (Spencer, Grimes) quarry face	SE¼ 28	16N	5W	18	96.7	95.7	0.96	2.55	0.27	0.25	0.05	0.033

[1]Modified from Rooney, 1970, p. 10.

[2]Thickness refers to the total interval of stone in the exposure that is 95 percent or more calcium carbonate.

chert. Like the Salem, most of the Harrodsburg of Putnam County is unsuitable as Class A aggregate, partly because of the low density of the formation and its later susceptibility to high abrasion losses. Chert further contributes to its unsuitability as Class A aggregate. The Harrodsburg is, however, a potential source of chemically pure high-calcium limestone and could be quarried or mined along with the Salem for that purpose (table 2).

PRODUCTION POTENTIAL

The best prospects for limestone production are those areas where rocks of the Blue River Group are at or near the surface. Accessibility of the Paoli and Ste. Genevieve Limestones depends, besides overburden thickness, largely on local and regional dip of the strata and the extent of erosion along the Mississippian-Pennsylvanian unconformity. At some localities, subsurface mining of the Blue River Group and possibly the Sanders Group may be practical and even preferable to conventional quarrying techniques.

The area of subcrop (and isolated outcrop) of the Blue River Group covers about 40 percent of Putnam County. Only a quarter of this area is overlain by less than 50 feet of glacial drift (fig. 11). Most of the readily exploitable reserves are in Madison, Greencastle, Washington, Warren, Jefferson, and Cloverdale Townships. As notable thinning of the Paoli and the Ste. Genevieve occurs to the north along strike, the best quarry sites for depositional thickness are most likely in the southern third of the county. The thickest known section of the Paoli and the Ste. Genevieve is in the subsurface near Cloverdale (Appendix, Section 10), where these formations are nearly 100 feet thick. Much of the variation in thickness of Blue River rocks is due, however, to erosion along the Mississippian-Pennsylvanian unconformity. At the Harris Stone Service quarry (sec. 15, T. 15 N., R. 4 W.), for example, the Paoli Limestone is absent and the Ste. Genevieve is only 11 feet thick. And so prediction of Blue River thickness (or that of any of the Mississippian formations down to the Edwardsville) is not reliable without subsurface control.

Regional dip and surface topography are the major factors that determine the depth at which a given formation is encountered. While surface topography is an extremely variable factor, the effect of regional dip on the elevation of the St. Louis-Ste. Genevieve contact, for example, is clearly illustrated when the regional dip between the quarries of the Manhattan Stone Co. and the Ohio and Indiana Stone Corp. is compared. The distance between these two quarries (measured normal to the regional strike) is 4.25 miles. At a regional dip of 25 feet per mile (see p. 7) to the west-southwest, a bedrock contact should be 106 feet lower at the Manhattan quarry than at the Ohio and

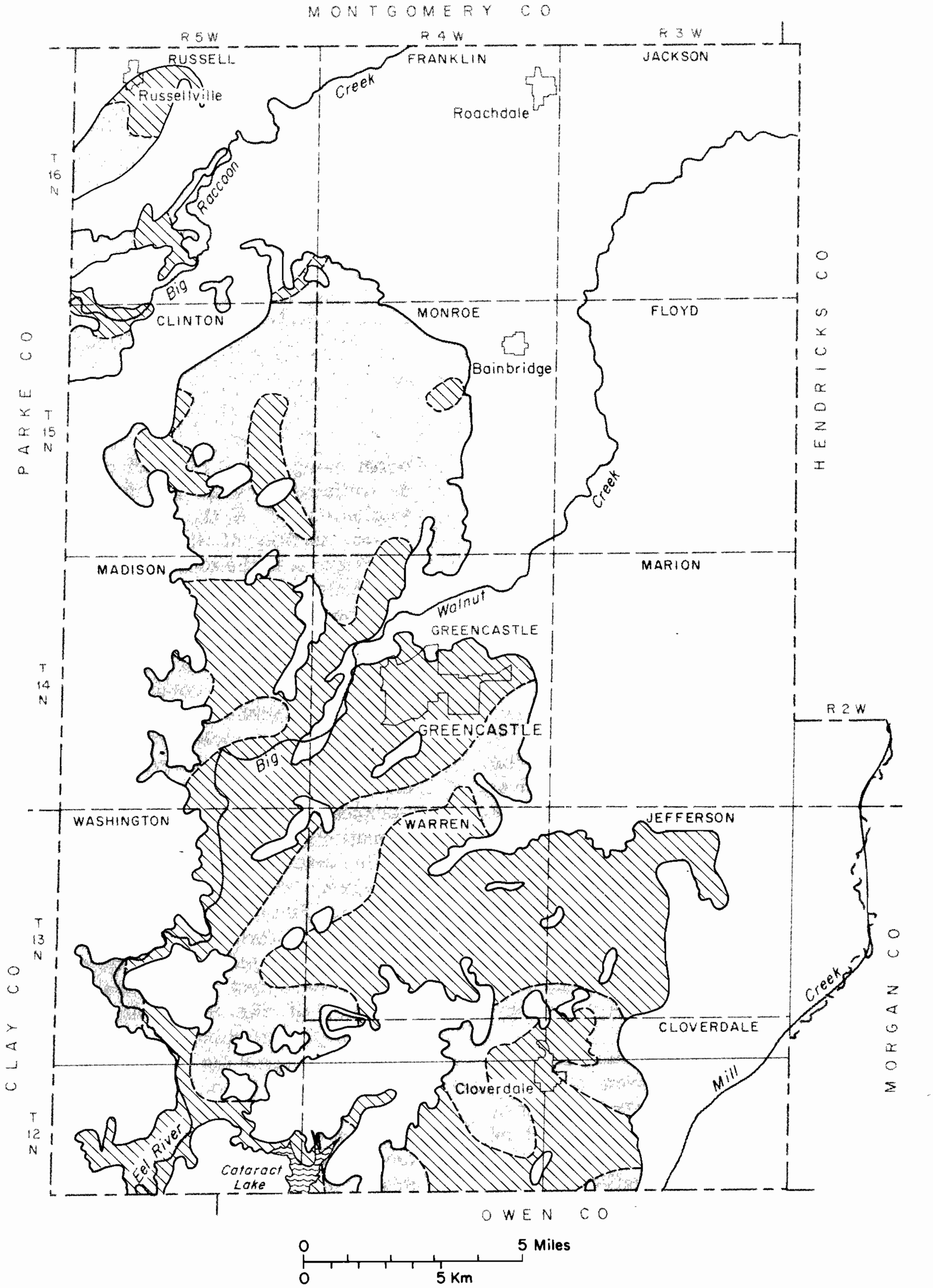


Figure 11. Map of Putnam County showing subcrop and outcrop boundaries of the Blue River Group. Patterned area is where drift thickness is expected to be 50 feet or less.

Indiana quarry. Actual measurement of the elevation of the Ste. Genevieve-St. Louis contact at the two quarries indicates that this contact is 99 feet lower at the Manhattan quarry, a figure that is reasonably close to the predicted value.

According to Rooney and Carr (1971, p. 8), "the most important fact about underground mining of limestone is that it is done." Numerous factors are influential in deciding whether limestone will be mined or quarried. All of these factors may be reduced to the major one of cost-effective production of the commodity.

Whether underground mining of limestone will ever be undertaken in Putnam County is highly conjectural, especially considering the ever-rising costs of such operations, the abundant supply of quarried stone in the county, and increasingly restrictive federal regulations on mining procedures. Some potential advantages, however, could make subsurface mining an attractive alternative to quarrying. These include:

(1) In areas where the Paoli-Ste. Genevieve section is covered by sufficiently thick bedrock that is considered largely waste and would have to be stripped and discarded in a quarry operation, tunneling beneath such bedrock to the desired formation could be advantageous. This also applies in areas where high-calcium limestone of the Salem Limestone is overlain by the chert-laden St. Louis Limestone. Using the St. Louis is expensive because it damages crushing equipment. Therefore, mining the Salem and maintaining a roof of the St. Louis could solve the problem.

(2) Underground mining, particularly of chemically pure limestone, avoids contamination of the product common to surface-removal techniques.

(3) Underground mining permits year-round production with uniform temperature and moisture. (Temperatures generally range between 55° and 59°F.)

(4) Selective removal of specific beds and zones of high-purity rocks or particularly durable stone within a given unit is possible in subsurface mining, but in quarry operations such selectivity may not be practical.

(5) The objectionable environmental factors inherent in quarry operations are largely overcome in underground mining, and the resulting excavation may afford a variety of valuable uses, such as storage facilities, office space, and air-raid shelters.

(6) Drift mines in the sides of quarries require little extra expenditure of capital.

Some disadvantages to underground mining are:

(1) Unstable, structurally weak roof rock. Joints, solution ways, shale partings, and low rock strength contribute to potential roof failure.

(2) Flooding by ground water. If the mine is at or below the water table, expensive measures to ensure safe and dry working conditions must be undertaken. Excavation of in-mine sumps, drainage-conduit placement, and the use of high-volume pumps could run an expensive operation into the red.

(3) Present mining laws require room-to-pillar ratio of 1:1 throughout the mine. This requirement results in an effective loss of 40 percent of the reserves. But where reserves are nearly unlimited, this is a small factor.

(4) Shaft mines require large initial expenditures of capital before the removal of any rock.

SAND AND GRAVEL RESOURCES

Active sand and gravel production and development potential in Putnam County are modest. Only three gravel pits are operating (fig. 12) in the county (1982). The combined annual production for two of them is less than 120,000 tons (1977 figures). Future sand and gravel production is likely to be near a clearly defined market and will probably be in valley-train or reworked outwash deposits along major streams and their tributaries.

Deposits of sand and gravel are primarily on and beneath the flood plains of Big Raccoon, Big Walnut, and Mill Creeks and the Eel River. These deposits are chiefly valley-train sequences emplaced by meltwaters of the waning Wisconsinan ice sheet. The valley-train sediments have been reworked by recent drainage, which now occupies floodways established by the glacial meltwaters. In all but a few isolated localities, the valley-train sand and gravel is covered with varying thicknesses of Holocene alluvium. Other sand

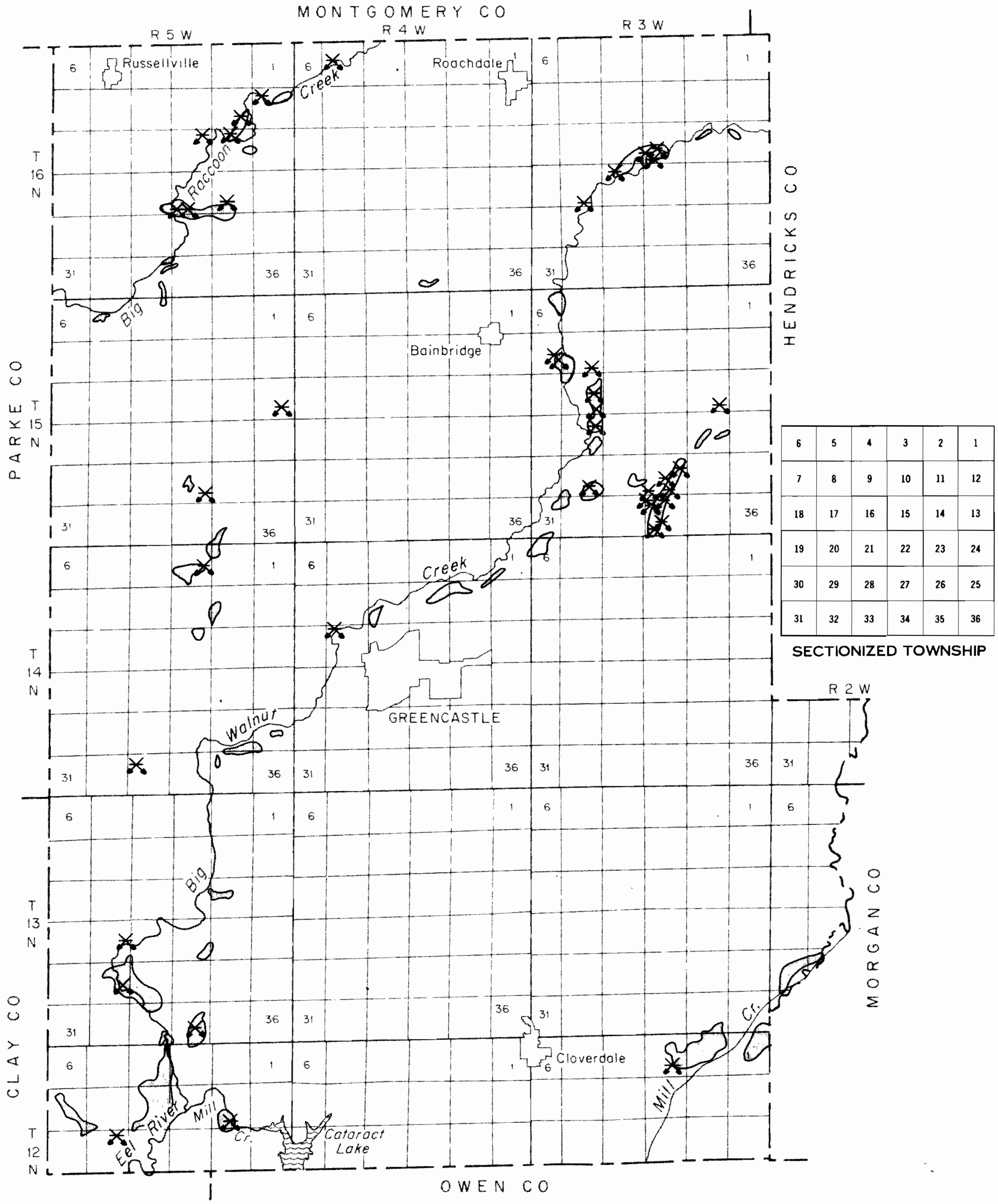
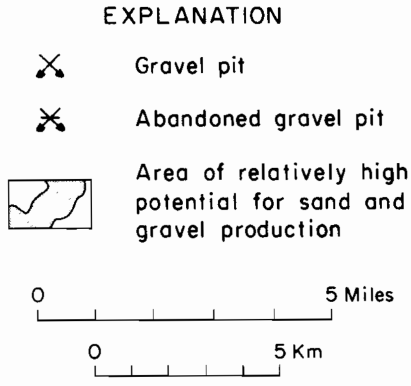


Figure 12. Map of Putnam County showing active (1982) and abandoned gravel pits and areas of relatively high potential for sand and gravel production.



and gravel bodies of possible valley-train origin and of probable Illinoian age are along the valley walls of Eel River and Big Walnut Creek in Washington Township. These deposits are patchy in areal distribution, but they also are locally extensive as illustrated by an exposure in the abandoned gravel pit in the SE¼NE¼SW¼ sec. 34, T. 13 N., R. 5 W., where a 40- to 50-foot face of weakly cemented graded sand and fine-grained gravel was worked recently (before 1980). The Illinoian valley train, deposits which occupy elevated terraces, has an advantage to producers over lower lying Wisconsinan sand and gravel units. The valley-train deposits are above the water table and therefore afford a relatively dry product with year-round accessibility. The secondary calcareous cement that is commonly present, however, is not a desirable property of these sediments, because in some places disaggregation and screening operations can be hindered.

A ridge of sand and gravel that trends northeast-southwestward across secs. 27 and 34, T. 15 N., R. 3 W., has provided a source of aggregate from nearly a dozen gravel pits (fig. 12), although no pits are currently (1982) being operated in the area. This feature is probably an esker or other fill of a subice channel.

All three currently active sand and gravel pits in Putnam County, two of which are A and C Enterprises, Inc. (NE¼SE¼ sec. 29, T. 13 N., R. 5 W.) and Bainbridge Sand and Gravel (NE¼SE¼ sec. 7, T. 15 N., R. 3 W.), are mining Wisconsinan valley-train deposits (fig. 12) along Big Walnut Creek. Removal operations at A and C Enterprises consist of a single dredge operating in Big Walnut Creek. Sampling of the gravel deposits at this locality is not possible because aggregate is being removed from a section that is under water.

Four grab samples were taken from the pit face of the Bainbridge Sand and Gravel pit and analyzed for grain-size distribution and mineralogy. It is apparent from these analyses and a general inspection of sediment distribution in the pit that the exposed part of the valley train at this locality is dominantly a quartz-rich sand of coarse to medium texture. Coarse gravel and some cobbles are in poorly sorted layers that also contain abundant coarse sand but account for about a tenth or less of the total deposit. The mineralogy of the gravel is primarily limestone and dolomite. Metamorphic and igneous rocks are next in abundance. Chert, which is potentially deleterious, is in both the gravel and the coarse sand.

Sampling and inspection of an Illinoian outwash deposit exposed at an inactive gravel pit in the SE¼NE¼SW¼ sec. 34, T. 13 N., R. 5 W. (fig. 12), indicate that the pit-face materials at this locality are mostly a medium quartz sand and account for 70 to 80 percent of the exposed sediments. Fine gravel, in minor amounts, is composed mainly of quartz, chert, limestone, and dolomite. Nearly all sediments in the pit face are in well-sorted layers that are moderately to strongly cemented with secondary calcium carbonate.

The outwash at this locality appears to be a terrace remnant of Illinoian valley-train origin that escaped postdepositional late Wisconsinan and Holocene erosion. Other similar Illinoian outwash deposits are at isolated localities along Eel River and the southern reaches of Big Walnut Creek, but the exposure discussed above is the largest and best example of pre-Wisconsinan outwash known in Putnam County.

Future exploitation of sand and gravel is possible along parts of Raccoon, Big Walnut, and Mill Creeks (see fig. 12), but the most extensive deposits are in secs. 28, 29, 33, and 34, T. 12 N., R. 5 W., and secs. 4 and 9, T. 12 N., R. 5 W. In northern Putnam County, the valley train along Raccoon Creek in secs. 22 and 23, T. 16 N., R. 5 W., appears to offer the best potential sand and gravel production. The esker in secs. 27 and 34, T. 15 N., R. 3 W., has provided aggregate from nearly a dozen small pits. Consisting mostly of poorly

Table 3. Mineralogic, textural, and ceramic analyse

Sample No.	Location			Thickness (ft)	Mineralogic analysis (pct)				
	Sec.	T.	R.		Illite	Chlorite	Montmorillonite	Kaolinite	Mixed laye
S-1[1]	W½SW¼SE¼ 22	14N	5W	1	53	11	-----	34	2
S-2	W½SW¼SE¼ 22	14N	5W	?	33	----	-----	59	8
S-3	W½SW¼SE¼ 22	14N	5W	1	45	8	Trace	33	14
S-4	NW¼SE¼NW¼ 21	13N	5W	2	36	8	1.0	37	18
S-5	NW¼SE¼NW¼ 21	13N	5W	5	36	11	Trace	32	21
S-6	SE¼SE¼NW¼ 13	12N	5W	3.5	40	13	1.0	27	19
S-7	SE¼SE¼NW¼ 13	12N	5W	2	27	0	1.0	63	9
W-1[2]	SE¼SW¼ 14	12N	5W	2	----	----	-----	----	----
W-2	NW¼SW¼ 13	12N	5W	2	----	----	-----	----	----
W-3	SE¼SW¼ 11	12N	5W		----	----	-----	----	----
W-4	NW¼SW¼ 13	12N	5W	3	----	----	-----	----	----
W-5	NW¼SW¼ 13	12N	5W	----	----	----	-----	----	----
W-6	11	13N	4W	----	----	----	-----	----	----
HM-1[3]	SE¼ 18	13N	4W	20	30	5	-----		5
HM-2	SE¼ 18	13N	4W	35	20	5	-----		Trace

[1]Samples collected by Nelson R. Shaffer of the Indiana Geological Survey.

[2]Samples taken by Whitlatch (1929).

[3]Samples taken by Harrison and Murray (1964).

sorted sand and gravel, this deposit may still be a limited source of aggregate.

CLAY AND SHALE RESOURCES

Use of clay and shale in Putnam County is currently (1982) limited to the Bethel Formation that is providing the clay and shale needed by Lone Star Industries, Inc., for manufacturing cement. As of mid-1982, there were no known producers of brick and of clay and shale samples from Putnam County

Texture (pct)			Firing shrinkage (pct)	Volatile loss (pct)	Fired porosity (pct)	Fired color	Remarks
Sand	Silt	Clay					
13	23	64	-------	---------	-------	----	Light-gray weathered underclay just below Mansfield coalbed.
21	38	41	-------	---------	-------	----	Grab sample of highly weathered shale; covered interval above Mansfield coal.
18	44	38	-------	---------	-------	----	Highly weathered gray to brown shale atop sandstone cliffs above streambed.
23	26	51	-------	---------	-------	----	Dark-gray shale of Reelsville Fm. or Sample Fm. on west side of ravine below drainage entry.
6	49	45	-------	---------	-------	----	Green-gray shale above Beaver Bend Ls. in ravine behind Reelsville Church.
16	43	41	-------	---------	-------	----	Underclay below Mansfield coal at northwest side of Cagles Mill spillway.
34	19	47	-------	---------	-------	----	Shale below Mansfield coal at northwest side of Cagles Mill spillway.
----	----	----	2.08	5.30	14.0	Light gray	Medium-quality bisque; moderate refractoriness.
----	----	----	2.08	5.70	18.3	Near white	Excellent hard strong ware of beautiful appearance.
----	----	----	8.33	5.80	1.0		High shrinkage requires use of grog if clay is used for ceramics.
----	----	----	2.08	8.00	15.2	Red	Sample taken at confluence with Mill Creek; fair to poor quality; suited for bricks only.
----	----	----	2.08	6.40	19.3	Light gray; speckled	Sample taken 1,000 ft downstream from W-2 on same outcrop; good-quality yellowware obtainable from this clay.
----	----	----	4.16	6.10	11.1	Tannish gray	From State Farm; results in fired product of good quality and free from defects.
----	----	----	9.4	27.50	23.4	Brown	Fair plasticity, softer than steel.
----	----	----	-------	---------	-------	----	

ceramic products in Putnam County. Modest supplies of good-quality to fair-quality Pennsylvanian shales and underclays and thin shale formations of Mississippian age have limited potential for making clay products.

Whitlatch (1929, p. 72) stated more than 50 years ago: "The available clay deposits of commercial importance are few in Putnam County, as such clays do not occur in abundance in a limestone area." Perhaps the best known, and certainly the most extensively exploited, clay-shale deposit in the county is that exposed on the Indiana State Farm at Putnamville. In 1917 the State Geologist, W. N. Logan, made a survey of the farm to determine if there were industrial minerals on the property (Whitlatch, 1933). Because of his findings and later recommendations, a quarry was opened on the farm, and clay and shale were removed and processed by the inmates into brick, draintile, building tile, and floor tile. Other rock products unrelated to ceramic manufacture also came from the quarry. The State Farm continued to produce these commodities until 1972, when the brick and ceramic works stopped operation. This ended an era of unique service both to the inmates of the farm and to local residents who used the products made by them. Although there may have been other small brick and ceramic plants in the county, the operation at Putnamville is the only one of record.

Not all users of clay and shale are concerned with the ceramic properties of these commodities. Lone Star Industries, for example, uses the shale in the Bethel Formation to supply silica and alumina, compounds essential to manufacturing cement. About 20 percent of Lone Star's required clay comes from the Bethel Formation; the rest is brought into the county.

Potential sources for clay and shale are Pennsylvanian underclays and shales of both Pennsylvanian and Mississippian age (for example, the Mansfield, Sample, and Bethel Formations). Local glacial deposits, some moderately rich in clay, are generally not considered suitable raw material for ceramic products or brick because of relatively high concentrations of calcium carbonate throughout the clay. The lacustrine sequence of Illinoian age that covers part of Cloverdale Township (for example, NE¼ sec. 33, T. 12 N., R. 4 W.) may be a limited potential source of low-grade ceramic material because the upper parts of these sediments are likely to have been leached of carbonates since they were deposited.

In 1928 George Whitlatch conducted a clay-shale sampling program of various localities in Indiana, including six in Putnam County (Whitlatch, 1929). Laboratory analyses of Whitlatch's samples (table 3) included general ceramic properties, such as color, shrinkage, cone tests, loss of volatiles, porosity, and specific gravity. In 1964, in a report on clay and shale in Indiana, Harrison and Murray included detailed laboratory analyses of two samples from a shale unit in the Mansfield Formation in Putnam County (table 3). Samples of underclays and shales collected during mapping for our study were analyzed for clay mineralogy and texture. Ceramic properties were not analyzed because the only known deposit of sufficient quality and size to be a suitable source for clay products was on state-owned land at Cagles Mill Spillway (table 3).

Results of the various sample tests and field-mapping information show that the Pennsylvanian underclays apparently are the best sources of clay. One of the more promising clay-shale exposures reportedly crops out in the NW¼SW¼ sec. 13, T. 12 N., R. 5 W., along the valley wall of a stream below an abandoned coal mine (Whitlatch, 1929, p. 74-75). The underclay from this particular outcrop is capable of producing strong ware of fine quality (Whitlatch, 1929, p. 75). In general, the clay-shale deposits in and under the Mansfield Formation, especially in the areas just west and north of Cataract Lake, have the greatest potential as commercially exploitable sources of raw material for manufacturing bricks and ceramics. The most likely sources of shale are in the Bethel and Sample Formations, which crop out in some areas mapped as the West Baden Group. (See fig. 8.) It should be remembered that erosion of Mississippian rocks before the Mansfield Formation was deposited has left only a relatively small part of the lower Chesterian sequence, which includes the West Baden Group.

COAL RESOURCES

Lenses and pods of coal occur throughout much of the Mansfield Formation, but coal deposits in Putnam County are too limited to be of much commercial value. Coal is not currently (1982) being mined in the county, although small private mines may be operated sporadically for home-heating fuel.

Most of the coals in Putnam County are discontinuous lenses dispersed throughout the Mansfield Formation, and most of these lenses are underlain by thin clay deposits. The geometry and distribution of these coals suggest coalification of small isolated swamp deposits as the likely form of origin. Few of the coalbeds are more than 2 feet thick, and fewer still can be traced more than a few hundred feet along any given horizon.

Chemical analyses of five samples from some of the more extensive coals (Hill, 1980) indicate sulfur content as high as 9.8 percent at one locality in the SW¼SE¼ sec. 22, T. 14 N., R. 5 W., and as low as 1.51 percent in the coal at the Cagles Mill Spillway dam. The average sulfur content for the five samples is 4.67 percent, well within the range of high-sulfur coals. Heat values of the coal samples range from a low of 8,885 Btu for the coal at the shale pit on the Indiana State Farm to a high of 10,798 Btu for a half-foot-thick coal seam that crops out in a road cut along U.S. Highway 40 in the NE¼SW¼ sec. 16, T. 13 N., R. 5 W. The average heat value for the five samples is 10,056 Btu. Extremely low-heat and sulfur values may be the result of sampling from the weathered zone. Chemical weathering of coal results in the leaching of some compounds, such as iron pyrite, and the oxidation of others, mainly the organic compounds. This results in anomalously low sulfur and heat values.

Production of the coals in Putnam County, except for the coal mined at the Indiana State Farm, has been limited to small-scale mining operations for the needs of blacksmiths or for local heating fuel. Ironically, the rising costs of conventional heating fuels, such as oil and natural gas, may cause some residents of the county to return to wood and coal to augment the more expensive fuels used in heating their homes. Individuals interested in determining if there is coal on their property are referred to Preliminary Coal Map 16, available from the Publications Section, Indiana Geological Survey, 611 North Walnut Grove, Bloomington, IN 47405. This map shows, among other things, all known localities where coals crop out in Putnam County.

The limited thickness, lack of areal continuity, and generally poor quality of the coals indicate that there are no reserves suitable for large-scale mining in the county. Coal will probably be used only as a heating fuel.

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Appendix — Measured Sections

Section 1. Exposure in a gully about 0.5 mile west of the junction of Indiana Highway 243 and Interstate 70 in the E½NW¼NW¼NW¼ sec. 32, T. 13 N., R. 4 W., Reelsville Quadrangle.

	Elevation of unit top in feet	Thickness in feet
Pennsylvanian System, 10.0 ft measured:		
Raccoon Creek Group, 10.0 ft measured		
Mansfield Formation, 10.0 ft measured:		
1. Sandstone, brown, medium-grained, massive	781.0	10.0
Mississippian System, 56.0 ft measured:		
West Baden Group, 41.0 ft measured:		
Elwren Formation, 3.0 ft:		
2. Sandstone, bright-orange, medium-grained, calcareous, massive	771.0	3.0
Reelsville Limestone, 2.0 ft:		
3. Limestone, light-gray with yellow-orange mottles, coarse-grained; unit forms massive beds composed of fossil-fragmental to oolitic biosparite	768.0	2.0
Sample Formation, 11.0 ft:		
4. Shale, dark-gray, silty, thin-bedded	766.0	11.0
Beaver Bend Limestone, 12.0 ft:		
5. Limestone, dark-gray to pinkish-gray, coarse-grained, oolitic, fossiliferous; unit is massive oosparite or biosparite	755.0	12.0
Bethel Limestone, 13.0 ft:		
6. Shale, gray with orange mottling, silty, thin-bedded	743.0	13.0
Blue River Group, 15.0 ft measured:		
Paoli Limestone, 15.0 ft measured:		
7. Limestone, dark-gray, medium-grained; unit is thin bedded with well-developed oolites in a sparry-calcite cement; an oosparite	730.0	15.0

Section 2. Exposure in a ravine 0.25 mile northeast of the confluence of Mill and Deer Creeks in the W½SE¼SW¼ sec. 2, T. 12 N., R. 5 W., Reelsville Quadrangle.

	Elevation of unit top in feet	Thickness in feet
Pennsylvanian System, 40.0 ft measured:		
Raccoon Creek Group, 40.0 ft measured:		
Mansfield Formation, 40.0 ft measured:		
1. Sandstone, dark-orange, fine-grained; unit is cliff forming and in massive beds	700.0	20.0
2. Shale, gray, silty, argillaceous; unit is thin bedded and in some places crops out as a massive underclay	680.0	5.0
3. Sandstone, brown, medium-grained, massive, crossbedded	675.0	15.0
Mississippian System, 45.0 ft measured:		
West Baden Group, 25.0 ft measured:		
Beaver Bend Limestone, 7.0 ft:		
4. Limestone, dark-gray, coarse-grained, fossiliferous; unit forms massive beds of fossil fragments cemented by sparry calcite to form calcirudite or biosparite	660.0	7.0
Bethel Formation, 18.0 ft:		
5. Shale, bluish-gray with orange mottling, silty; unit is thin bedded, and lower beds contain gray micrite nodules	653.0	18.0
Blue River Group, 20.0 ft measured:		
Paoli Limestone, 20.0 ft measured:		
6. Limestone, light-gray, medium-grained; unit forms massive beds of oolite framework in calcareous muddy matrix	635.0	20.0

Section 3. Exposure in a ravine just north of Interstate 70, 0.25 mile southwest of Deer Creek in the SE¼SE¼NW¼ sec. 2, T. 12 N., R. 5 W., Reelsville Quadrangle.

	Elevation of unit top in feet	Thickness in feet
Mississippian System, 28.0 ft measured:		
West Baden Group, 17.7 ft measured:		
Reelsville Limestone, 2.7 ft:		
1. Limestone, grayish-brown to black; unit is medium bedded and composed of fossil fragments cemented by sparry calcite to form a calcirudite or biosparite	667.7	2.7
Sample Formation, 4.0 ft:		
2. Shale, gray, finely silty, thin-bedded	665.0	4.0
Beaver Bend Limestone, 5.7 ft:		
3. Limestone, orangish-gray, finely crystalline; some crinoid fragments; unit is a massive biomicrite	661.0	5.7
Bethel Formation, 5.3 ft:		
4. Shale, grayish-blue, mottled; unit is thin bedded with scattered orange mottles	655.3	5.3
Blue River Group, 10.3 ft measured:		
Paoli Limestone, 10.3 ft measured:		
5. Shale, white, calcareous, thin-bedded	650.0	2.0
6. Limestone, yellow to black, brecciated; unit consists of one medium bed containing much angular chert and limestone fragments in a microcrystalline calcareous matrix	648.0	1.8
7. Limestone, light-gray, oolitic; unit is massive and coarse grained	646.2	6.5

Section 4. Exposure at a waterfall just south of Interstate 70 on Higgins Branch in the SE¼NE¼ sec. 28, T. 13 N., R. 3 W., Eminence Quadrangle.

	Elevation of unit top in feet	Thickness in feet
Mississippian System, 38.6 ft measured:		
Blue River Group, 38.6 ft measured:		
St. Louis Limestone, 38.6 ft measured:		
1. Limestone, gray, argillaceous, micritic	792.5	30.0
2. Limestone, gray, medium-grained, fossiliferous; unit is medium-bedded calcarenite with fossil-fragmental framework cemented by calcite	762.5	1.8
3. Limestone, medium-gray, finely crystalline; single massive bed; micrite	760.7	0.5
4. Dolomite, yellow-tan, finely crystalline, medium-bedded; stylolites near base	760.2	2.0
5. Limestone, dark-gray, finely crystalline, thin-bedded, micritic	758.2	1.0
6. Limestone, medium-gray, coarse-grained, fossil-fragmental; unit is medium bedded and muddy and exhibits some graded bedding	757.2	1.0
7. Limestone, gray, massive, biomicritic; fine allochems in muddy matrix	756.2	0.5
8. Limestone, gray, medium-grained, fossil-fragmental, stylolitic; fossil fragments are bound in calcareous muddy matrix; biomicrite	755.7	1.3
9. Limestone, grayish-brown, coarse-grained, fossil-fragmental; allochems cemented by sparry calcite or lime mud	754.4	0.5

Section 5. Exposure in a valley wall in the SW¼NE¼ sec. 21, T. 14 N., R. 5 W., Clinton Falls Quadrangle.

	Elevation of unit top in feet	Thickness in feet
Mississippian System, 53.0 ft measured:		
Blue River Group, 53.0 ft measured:		
Ste. Genevieve Limestone, 28.0 ft measured:		
Levias Member, 13.0 ft:		
1. Limestone, light-gray, microcrystalline, thin-bedded; unit interbedded with light-gray coarse-grained muddy massive limestone	742.0	13.0
Spar Mountain Member, 5.5 ft:		
2. Limestone, white, medium-grained, oolitic; unit forms thin beds composed of an oolitic or fossil-fragmental limestone with sparry-calcite cement	729.0	5.5
Fredonia Member, 9.5 ft:		
3. Limestone, olive-gray, microcrystalline, thin-bedded, fossiliferous; unit is predominantly a bryozoan biomicrite with isolated patches of oolites	723.5	2.0
4. Limestone, light-gray, microcrystalline, medium-bedded; unit is interbedded with medium-gray coarse-grained fossiliferous limestone	721.5	7.5
St. Louis Limestone, 25.0 ft measured:		
5. Limestone, white, microcrystalline, fossiliferous; unit has thin beds of dark chert	714.0	8.0
6. Limestone, white, fine-grained, argillaceous, thin-bedded	706.0	11.0
7. Limestone, burnt-orange, fine-grained to crystalline, porous, vuggy, massive	695.0	6.0

Section 6. Exposure along a streambed on the Jordan Farm in the W½SW¼ sec. 22, T. 14 N., R. 5 W., Clinton Falls Quadrangle.

	Elevation of unit top in feet	Thickness in feet
Mississippian System, 50.0 ft measured:		
Blue River Group, 50.0 ft measured:		
Ste. Genevieve Limestone, 50.0 ft measured:		
Levias Member, 16.0 ft:		
1. Sandstone, white, calcareous, coarse-grained; quartz and chert grains in milky-white calcite matrix	730.0	1.0
2. Covered interval	729.0	4.0
3. Limestone, medium-gray, microcrystalline, massive	725.0	5.0
4. Limestone, light-yellowish-tan, coarse-grained, thin-bedded; allochems are generally coated fossil fragments; local lenses or small beds of biomicrite common	720.0	4.0
5. Limestone, gray, finely crystalline, fossiliferous; one thin bed	716.0	0.5
6. Limestone, medium-gray, finely crystalline, massive	715.5	1.5
Spar Mountain Member, 4.0 ft:		
7. Limestone, white, fine- to medium-grained, massive; allochems are oolites or rounded and coated grains cemented by sparry calcite; steep crossbeds	714.0	4.0
Fredonia Member, 15.0 ft:		
8. Limestone, gray, microcrystalline, medium-bedded	710.0	6.5
9. Limestone, gray to reddish-gray, medium- to coarse-grained, medium-bedded; unit is crossbedded calcarenite composed of coated fossil fragments	703.5	2.0

	Elevation of unit top in feet	Thickness in feet
Mississippian System—Continued		
Blue River Group—Continued		
Ste. Genevieve Limestone—Continued		
Fredonia Member—Continued		
10. Limestone, gray, argillaceous, finely crystalline; single bed . . .	701.5	1.5
11. Limestone, white, coarse-grained, thin-bedded; unit is a fossil-fragmental limestone with a muddy calcareous matrix .	700.0	5.0
St. Louis Limestone, 15.0 ft measured:		
12. Limestone, gray, microcrystalline, thin-bedded; unit is fossiliferous and contains much black chert in beds and balls	695.0	15.0

Section 7. Exposure along a streambed east of Bald Hill in the W½SW¼SE¼ sec. 22, T. 14 N., R. 5 W., Clinton Falls Quadrangle.

	Elevation of unit top in feet	Thickness in feet
Pennsylvanian System, 80.0 ft measured:		
Raccoon Creek Group, 80.0 ft measured:		
Mansfield Formation, 80.0 ft measured:		
1. Sandstone, burnt-orange, medium-grained, crossbedded, cliff-forming	820.0	50.0
2. Shale, gunpowder-gray, carbonaceous, thin-bedded	770.0	10.0
3. Coal, black, blocky, pyrite-bearing	760.0	2.0
4. Underclay, white with orange mottling, thin-bedded	758.0	5.0
5. Shale, gunpowder-gray, thin-bedded	753.0	3.0
6. Covered interval	750.0	5.0
7. Sandstone, gray, medium-grained, weakly cemented, carbonaceous locally, massive	745.0	5.0
Mississippian System, 8.0 ft measured:		
Blue River Group, 8.0 ft measured:		
Paoli Limestone, 8.0 ft measured:		
8. Limestone, light-gray, coarse-grained, massive; unit has well-developed oolites with chert and (or) quartz nuclei cemented by sparry calcite	740.0	8.0

Section 8. Exposure in a streambed south of Clinton Falls in the SW¼NE¼SE¼ sec. 28, T. 15 N., R. 5 W., Clinton Falls Quadrangle.

	Elevation of unit top in feet	Thickness in feet
Pennsylvanian System, 25.0 ft measured:		
Raccoon Creek Group, 25.0 ft measured:		
Mansfield Sandstone, 25.0 ft measured:		
1. Sandstone, orange, medium-grained, massive, cliff-forming; quartz arenite	805.0	25.0
Mississippian System, 56.0 ft measured:		
Blue River Group, 56.0 ft measured:		
Paoli Limestone, 25.0 ft measured:		
2. Limestone, white, medium-grained, massive; unit contains oolites in a sparry-calcite matrix	780.0	4.0
3. Limestone, gray, microcrystalline, medium-bedded	776.0	2.0

Mississippian System—Continued	Elevation of unit	Thickness
Blue River Group—Continued	top in feet	in feet
Paoli Limestone—Continued		
4. Limestone, greenish-gray, shaly, calcareous, thin-bedded	774.0	2.0
5. Limestone, blue-gray, microcrystalline, argillaceous, thin-bedded	772.0	1.0
6. Limestone, white, medium-grained, thin-bedded, oolitic	771.0	2.0
7. Limestone, light-gray, microcrystalline, thin-bedded	769.0	1.0
8. Limestone, light-gray, microcrystalline, thin-bedded	768.0	2.0
Ste. Genevieve Limestone, 31.0 ft measured:		
Levias Member, 16.0 ft:		
9. Limestone, gray, brecciated, cherty, microcrystalline; clasts made of angular pieces of micrite; chert is black and bedded; Bryantsville Breccia Bed	766.0	1.0
10. Limestone, dark-gray, finely crystalline, argillaceous, medium-bedded	765.0	5.0
11. Limestone, gray, microcrystalline, cherty, fossiliferous	760.0	3.0
12. Limestone, light-gray, finely crystalline, slightly fossiliferous, slabby	757.0	7.0
Spar Mountain Member, 6.0 ft:		
13. Limestone, light-gray, medium-grained, crossbedded, slabby; allochems are poorly defined oolites or pellets	750.0	6.0
Fredonia Member, 9.0 ft:		
14. Limestone, olive-gray, microcrystalline, massive	744.0	4.0
15. Chert, light-brown to yellow-gray, microcrystalline; three beds; Lost River Chert Bed?	740.0	3.0
16. Limestone, olive-gray, microcrystalline, medium-bedded, fossiliferous; fossils are mostly gastropods and brachiopods	737.0	2.0

Section 9. Exposure in the valley wall of a tributary to Big Walnut Creek in the NE¼NW¼SE¼ sec. 31, T. 16 N., R. 3 W., Roachdale Quadrangle.

Mississippian System, 92.0 ft measured:	Elevation of unit	Thickness
Sanders Group, 29.0 ft measured:	top in feet	in feet
Ramp Creek Formation, 29.0 ft measured:		
1. Limestone, white with orange stains, coarse-grained, fossiliferous; unit is in medium beds that contain brachiopod and bryozoan fragments cemented by calcite; biosparite	872.0	7.0
2. Siltstone, dark-gray, calcareous, thin-bedded	865.0	18.5
3. Limestone, dark-gray, coarse-grained, fossiliferous; unit is thin bedded and contains pyrite and chert; biosparite	846.5	3.5
Borden Group, 63.0 ft measured:		
Edwardsville Formation, 63.0 ft measured:		
4. Siltstone, bluish-gray, massive; some muscovite	843.0	47.5
5. Shale, gray, calcareous, thin-bedded	795.5	0.5
6. Siltstone, bluish-green, thin-bedded; some muscovite; local lens of crinoid fragments	795.0	15.0

Section 10. Core from Indiana Geological Survey drill hole 199 on the Ohio and Indiana Stone Corp. property in the NW¼NW¼SW¼ sec. 1, T. 12 N., R. 4 W., Cloverdale Quadrangle.

Surface elevation: 826 ft (altimeter survey)
Total depth: 1,060.8 ft
Electric logs: self-potential and resistivity (not included in this report)

Core begins at 20.0 ft.

	Depth (ft)
Mississippian System, 1,040.8 ft cored:	
West Baden Group, 2.0 ft cored:	
Bethel Formation, 2.0 ft cored:	
1. Siltstone and shale, gray and black, interbedded, platy	22.0
Blue River Group, 188.6 ft cored:	
Paoli Limestone, 13.5 ft:	
2. Limestone, brown-gray and dark-brown-gray, mottled, detrital and micritic; upper 0.8 ft contains fractures and contorted laminae of green-gray siltstone; lower 0.5 ft grades to oolitic micrite	23.4
3. Limestone, brown-gray, oolitic-pelletal, fine-grained; grades to very coarse grained at base	24.5
4. Dolomite, green-gray, silty, soft; few scattered clasts of detrital limestone	25.6
5. Limestone, brown-gray and dark-brown-gray, mottled, brecciated and conglomeratic, oolitic with clasts of dark micritic contorted bands, possibly algal in origin; few scattered fractures filled with green-gray siltstone	27.0
6. Limestone, light-brown-gray, oolitic, medium-grained; few scattered fractures filled with green-gray siltstone	32.0
(Loss 3.5 ft; driller reported green shale)	35.5
Ste. Genevieve Limestone, 81.5 ft:	
7. Limestone, light-brown-gray, oolitic, medium-grained, grading to oolitic-micritic near base of unit	38.5
8. Limestone, brown-gray, micritic; scattered laminae of green-gray shale mostly concentrated at base of unit	40.0
9. Limestone, light-brown-gray, pelletal and micritic, very fine grained	44.5
10. Limestone, light-brown-gray and green-gray; interbedded with calcareous siltstone	45.8
11. Limestone, light-brown-gray, oolitic and skeletal, fine- to coarse-grained; few scattered thin laminae of gray shale	55.5
12. Limestone, brown-gray, micritic and pelletal; numerous scattered thin laminae of gray shale in upper half of unit; few dark-brown contorted laminae in lower half of unit, possibly algal in origin	62.6
13. Limestone, green-gray, silty, detrital; scattered medium quartz sand; one chert nodule (0.1 ft long)	63.1
14. Limestone, light-brown-gray, skeletal and skeletal-micritic; several scattered sets of green-gray clay laminae (0.2 ft thick); 7¾ in. removed at 65 ft for testing	73.1
15. Limestone, light-brown-gray, micritic-skeletal; few scattered thin laminae of green-gray shale	80.1
16. Limestone, light-brown-gray, skeletal; few scattered thin clay laminae	84.0
17. Limestone, brown-gray, skeletal-micritic; grades to micritic at base of unit; 0.3-ft band of green-gray argillaceous laminae at 84.6 ft; light- and dark-gray mottled dense chert nodules (0.2 ft long) at 86.5 ft; thin elongate chert pebbles at base of unit; scattered pyrite and calcite crystals fill small fractures in lower half of unit	87.1
18. Limestone, brown-gray, micritic, dense; argillaceous laminae at base of unit	89.3
19. Limestone, brown-gray, pelletal and micritic; pellet-size chert nodules in upper 0.5 ft of unit; argillaceous laminae at 89.3 and 90.0 ft	96.2

	Depth (ft)
Mississippian System—Continued	
Blue River Group—Continued	
Ste. Genevieve Limestone—Continued	
20. Limestone, light-brown-gray, skeletal, very coarse grained; thin laminae of green-gray clay at 0.2-ft intervals; a lamina and a thin bed of light- and dark-gray chert at top of unit (Lost River Chert Bed); thin chert nodule at 97.7 ft; chert contains abundant skeletal debris, largely bryozoans; few scattered sand- and pebble-size grains of chert near base of unit	100.0
21. Limestone and chert (ratio: 90/10); light-gray-brown skeletal-micritic limestone; few scattered argillaceous laminae; few scattered inclusions of pyrite crystals; mottled light-gray and dark-gray chert; skeletal debris not as abundant as in unit 20	107.5
22. Limestone, light-brown-gray, skeletal with thin beds of pellets; few scattered laminae of brown-gray argillaceous clay	109.7
23. Dolomite, brown-gray, very finely crystalline, silty	110.8
24. Limestone, as unit 22; one small chert nodule near top; thin bed of oolitic limestone near middle	115.5
25. Limestone, light-green-gray, detrital, fine- to medium-grained; green-gray calcareous shale	116.4
26. Dolomite, dark-gray-brown, microcrystalline; green-gray argillaceous laminae near middle of unit	117.0
St. Louis Limestone, 93.6 ft:	
27. Limestone, gray, pelletal-micritic, slightly argillaceous	117.5
28. Dolomite, very light brown, silty, moderately soft; few laminae and thin beds of brown and dark-brown silty dolomite; few scattered green clay laminae; few fractures filled with calcite crystals in lower quarter of unit	129.8
29. Dolomite, dark-brown-gray, silty; grades to light-gray dolomitic siltstone from 132.0 to 134.5 ft	137.2
30. Limestone, gray-brown, micritic; few thin green clay laminae	137.7
31. Dolomite, green-gray, silty; mottled light and dark green gray near base of unit	139.8
32. Dolomite, light-brown, silty; burrow structure in upper part	140.8
33. Limestone, light-brown-gray, micritic, dense; few scattered clay laminae	145.0
34. Dolomite, light-brown grading to green-gray in middle part; silty, argillaceous	146.9
35. Limestone, brown-gray, micritic; grades to argillaceous dolomite	151.5
36. Dolomite, light-gray and green-gray, mottled, calcareous in places	154.6
37. Limestone, dark-brown-gray, micritic, dense	156.3
38. Dolomite, light-gray and green-gray, silty; in part a dolomitic siltstone	159.8
39. Limestone, brown-gray, micritic; few scattered sets of argillaceous laminae	162.6
40. Shale, green-gray, calcareous; grades to argillaceous detrital limestone near base of unit	163.0
41. Limestone, as unit 39; few small light-gray porous chert nodules at 166.0 ft	167.6
42. Limestone, brown-gray, skeletal-micritic, fine-grained	169.9
43. Dolomite, light-brown-gray and green-gray, mottled, silty	177.5
44. Limestone, light-brown-gray, oolitic, skeletal; oolites mainly superficial; several thin beds of pelletal-micritic material; stylolites every 0.5 ft	189.2
45. Limestone, as unit 44; medium to coarse grained; numerous inclined beds	201.5
46. Limestone, light-brown-gray, skeletal-micritic, slightly silty	206.2
47. Dolomite, light-gray, silty; gradational with unit 48	206.4
48. Limestone, light-brown-gray, skeletal, medium-grained	210.6
Sanders Group, 100.2 ft cored:	
Salem Limestone, 38.2 ft (core not described in detail below):	
49. Shale, black, calcareous, with interlaminations of fine- to medium-grained detrital limestone; stylolite at base of unit	210.7
50. Limestone, light-brown-gray, skeletal; grains calcite coated; numerous inclined beds	240.5
51. Limestone, light-green-gray, skeletal-micritic, slightly argillaceous; grades into unit 52	245.1
52. Limestone, green-gray, detrital, argillaceous	248.8

	Depth (ft)
Mississippian System—Continued	
Sanders Group—Continued	
Harrodsburg Limestone, 32.0 ft	
Ramp Creek Formation, 30.0 ft	
Borden Group, 720.0 ft cored:	
Carwood and Locust Point Formations, 572.0 ft	
New Providence Shale, 148.0 ft	
Unassigned to group, 30.0 ft cored:	
Rockford Limestone, 4.0 ft	
New Albany Shale, 26.0 ft	
Total depth	1,060.8