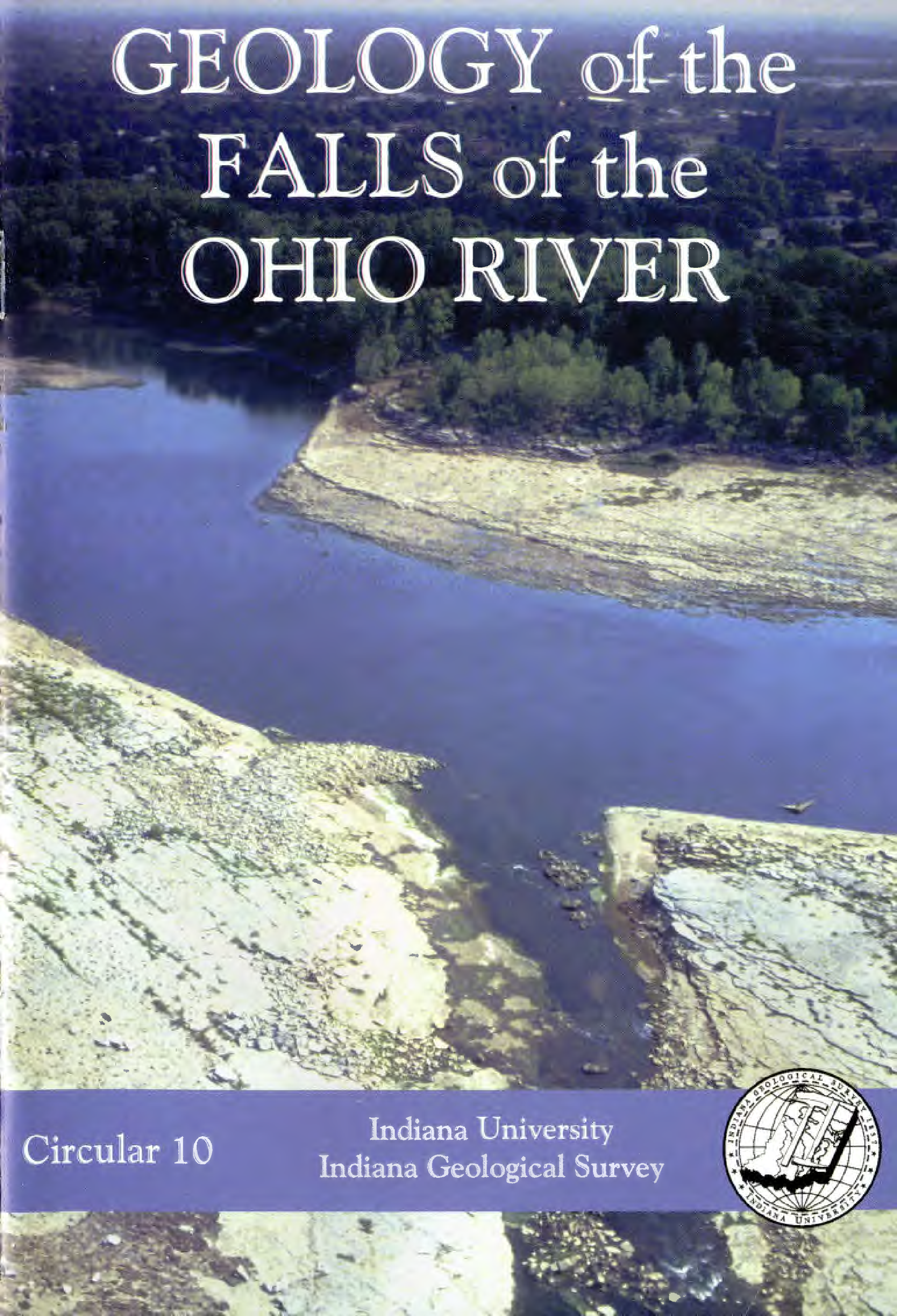
GEOLOGY of the FALLS of the OHIO RIVER



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Geology of the Falls of the Ohio River

By Richard L. Powell

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Cover photograph: A view of the Falls of the Ohio, looking north up the Ohio River. (Photo by Richard Fields.)

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Geology of the Falls of the Ohio River

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INTRODUCTION

The Falls of the Ohio River is at the McAlpine Dam between Louisville, Ky., and Jeffersonville and Clarksville, Ind. The Falls is essentially within the state of Kentucky, since the state boundary was established along the north bank of the Ohio River, but access to the Falls is now almost exclusively through Jeffersonville.

The Falls of the Ohio was a strategic location during the early history of the Midwestern United States, for it was the only place along "La Belle Riviere" that required a portage for boats and served as a natural fording place. Evidence of Indians traveling in the area has been found, especially along the wide path known as the Buffalo Trace that was used by early explorers and animals. George Rogers Clark, en route to his capture of Kaskaskia and Vincennes, established the first settlement at the Falls in 1771. The "Falls Cities" (Clarksville, Jeffersonville, Louisville, and New Albany) were platted within the next few decades because abundant waterpower, timber, building stone, flatlands, and virgin soils were available as many migrants came down the Ohio and through the Cumberland Gap. Most shipping down the Ohio was forced to portage at the Falls. Many travelers remained in this frontier community that became a gateway to the West.

The Falls Cities, with a population of half a million, are still an important transportation and industrial center. Present-day canalization of the Ohio River is claimed to have facilitated the movement of more tonnage than passes through the Panama Canal, and railways and modern highways that cross the river near the Falls make the area a modern gateway between the North and the South.

The early discovery of the coral beds at the Falls of the Ohio River aroused the interest of laymen and scientists in visiting the area to collect and study the profuse accumulation of fossils imbedded in the rocks. The site was soon recognized as a major fossil-collecting locality, and proof of the correlation of strata at the Falls with strata of Devonian age in Europe and in the Eastern United States that contained similar fossils was quickly established. The strata exposed at the Falls of the Ohio (fig. 1), particularly the coral beds, became more significant as more was learned of the extent of rocks of Devonian age in North America, for nowhere else were such well-preserved fossils present in such profusion. Consequently, about 75 papers have been written by scientists to describe the

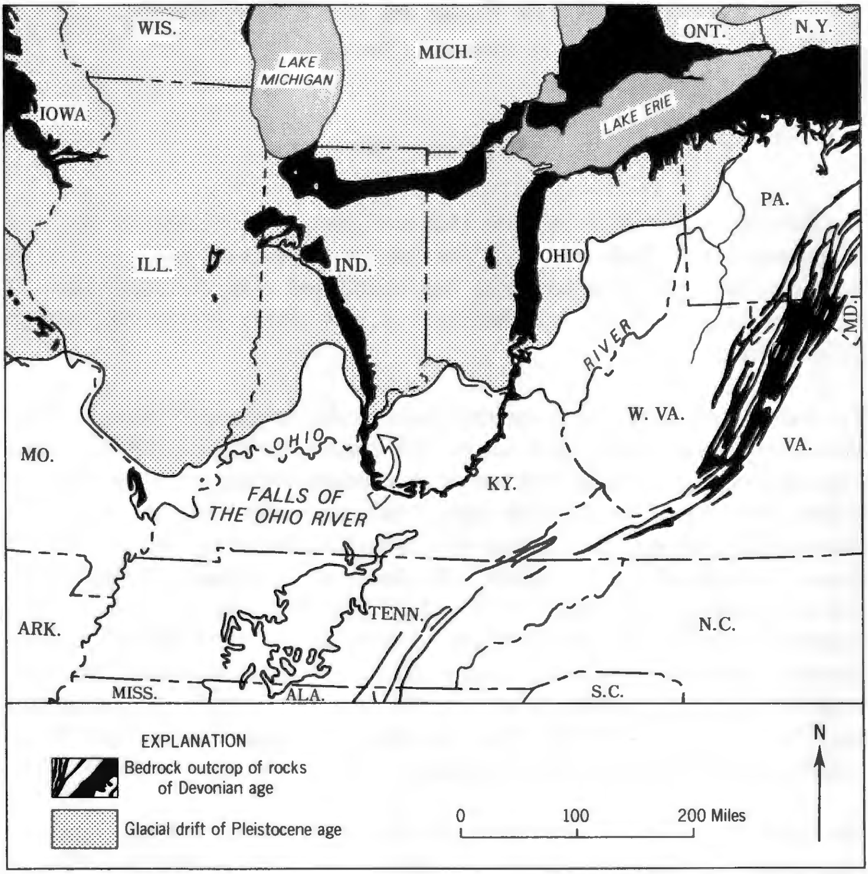


Figure 1. Map of the Midwestern United States showing the location of the Falls of the Ohio River, the bedrock outcrop of rocks of Devonian age, and the area covered with glacial drift of Pleistocene Age.

more than 600 species of fossils found in the various rock strata exposed at the Falls of the Ohio River. About two-thirds of the species were type specimens, described for the first time, substantiating the claim that more new specimens have been named from the Falls of the Ohio than from any other single locality in the world.

The only place along the entire Ohio River where bedrock was exposed entirely across the bed of the river is at the Falls of the Ohio. The depth to bedrock in the Ohio River is in most places about 100 feet because the channel is filled with outwash deposits of clay, sand, and gravel from the ice sheets that blanketed North America during the Pleistocene Epoch. The Ohio River as we know it is a very young stream. It was formed by drainage westward along the southern margin of ice sheets that integrated the headwater portions of several streams; these streams had formerly drained northward into the area the ice sheets had covered. The channel of the Ohio River was modified by several episodes of flooding caused by glacial meltwaters and outwash filling. The last time the channel filled, during the Wisconsin Age, it buried the bedrock ridge on which the Falls of the Ohio River is now located. The river then ceased to receive meltwater as the ice sheets melted entirely, and the smaller stream shifted its channel in the soft sediments into a position above the buried bedrock ridge. The river eroded away some of the Pleistocene sediments during Recent time and has worked its way down into the bedrock ridge, which has become a resistant ledge across the channel, to form the Falls of the Ohio River.

That prolific fossil beds are present within the strata of the Devonian System exposed at the only rapids or falls in the entire Ohio River is indeed a unique happenstance, even though the geologic reasons seem evident.

The construction of the dam across the Falls of the Ohio River greatly improved navigation on the river. Prior to construction of the Shippingport Canal, large rafts and boats were forced to wait for high water to negotiate the channels or chutes over the falls.

A map showing the extent of rock exposures at the Falls before dam construction was surveyed by T. J. Cram in 1843 (fig. 2, compare with fig. 10). However, the impoundment has submerged about five-sixths of the area where rocks were previously exposed when the river was below flood stage.

Figure 2. Map showing the extent of rock exposures at the Falls before dam construction was surveyed by T. J. Cram in 1843.

GEOMORPHOLOGY OF THE FALLS OF THE OHIO RIVER AND VICINITY

REGIONAL SETTING

The Falls of the Ohio River is within a lowland area that lies between a high plateau with a steep eastward-facing escarpment on the west and gently westward-sloping upland on the east. The Ohio River flows from northeast to southwest across the area within a wide valley in the lowland and a deep, narrow valley in the uplands (fig. 3).

The Knobs: The most outstanding landform in the Falls area is the distant bedrock escarpment west of the lowland. The continuous escarpment was named the Knobstone Escarpment in Indiana north of the Ohio River (Newsom, 1898, p. 253) (fig. 4A), but it is called Maldraugh Hill southeastward from the Ohio River in Kentucky (Miller, 1919, p. 97). Isolated hills or groups of hills along the escarpment or slightly east of it have long been called The Knobs (McFarlan, 1943, pp. 194–199).

Stream valleys have cut through the Knobstone Escarpment in only a few places, notably the Ohio River southwest of the Falls, the Rolling Fork and Salt River in Kentucky, and the two forks of White River in Indiana. The crest of the escarpment is a nearly continuous drainage divide between tributaries of the Ohio River. The crest of the Knobstone Escarpment in Indiana, which rises about 600 feet above the Ohio River, is generally above 900 feet in altitude and is about 1,000 feet above sea level in a few places. Muldraugh Hill in Kentucky is generally at an altitude of more than 700 feet and in some places more than 800 feet. Some isolated knobs south of Louisville are well above 800 feet in altitude, and a few are more than 900 feet above sea level.

The steep escarpment is the east edge of a westward-sloping plateau that is capped with limestone and underlain by westward-dipping shale strata of Mississippian age. The plateau is called the Mississippian Plateau in Kentucky (McFarlan, 1943, pp. 184–185), but it is named the Norman Upland in Indiana. Streams that flow westward from the crest of the escarpment have downcut into the dipslope of the limestone and shale as much as 200 feet within a few miles of their heads; steeper streams flowing eastward down in the face of the escarpment descend 400 to 500 feet to the general level of the lowland.

Scottsburg Lowland: The comparatively smooth lowland area east of the Knobstone Escarpment, north of New Albany and Jeffersonville and west of the drainage divide between Fourteenmile and Silver Creeks in Indiana, has been

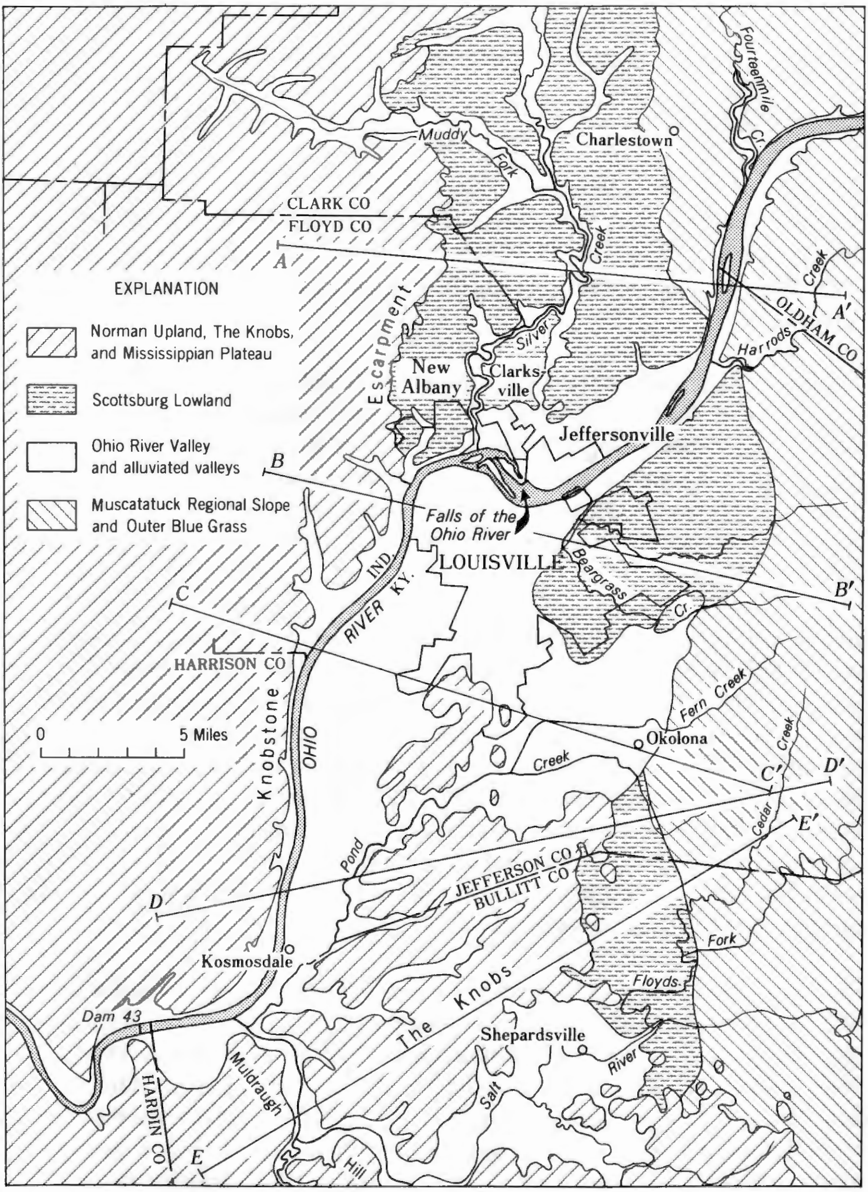


Figure 3. Physiographic map of the vicinity of the Falls of the Ohio River. Lines A–A' through E-E' represent the cross sections shown in figure 4.

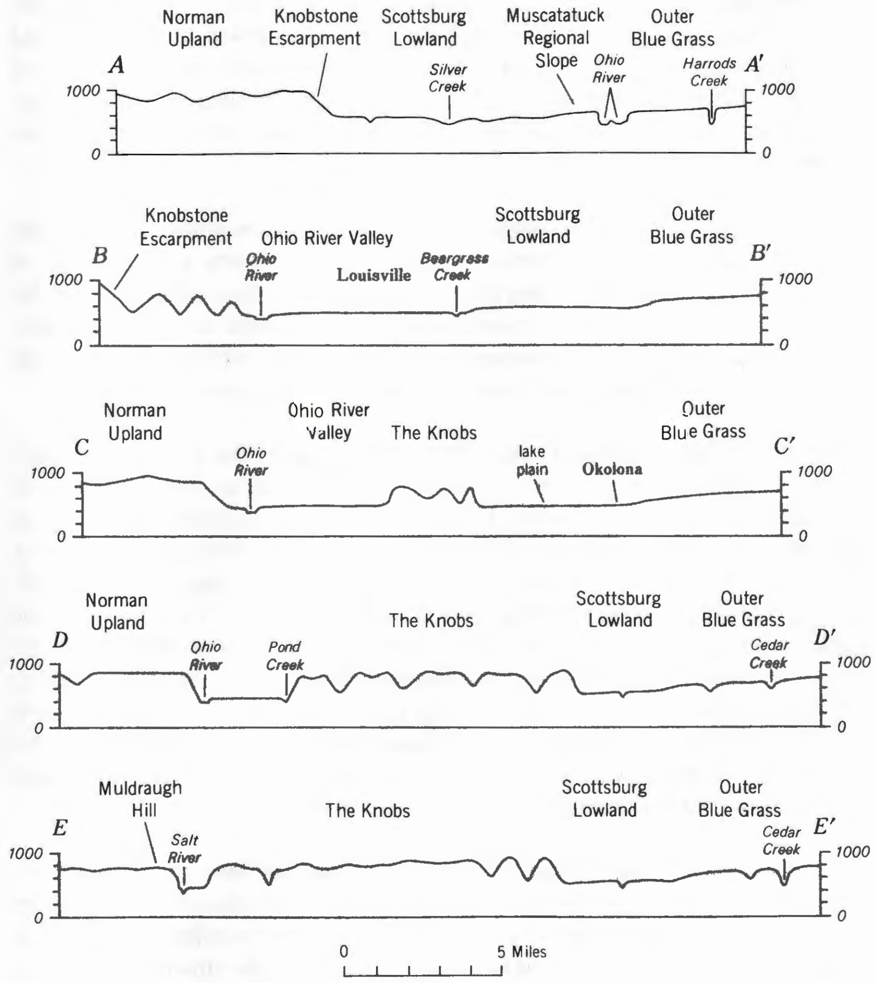


Figure 4. Cross sections of the vicinity of the Falls of the Ohio River. Locations of lines of sections are indicated in figure 3.

named the Scottsburg Lowland (Malott, 1922, pp. 86–88). The Scottsburg Lowland extends southward into Kentucky in several small areas south of Louisville (fig. 3).

The Scottsburg Lowland lies generally at altitudes between about 500 and 600 feet above sea level and about 120 feet above the Ohio River, well above flood level. The lowland has little relief except along the streams that have downcut about 60 to 100 feet below the adjacent land. The intrastream areas in the Scottsburg Lowland are generally about 50 to 80 feet above the floodplains of the Ohio River and its tributaries.

The Scottsburg Lowland is underlain by easily eroded shales of the Devonian and Mississippian Systems. In Indiana the area is veneered with a thin mantle of glacial drift. The streams that drain the Indiana portions of the lowland parallel the outcrop of the strata and flow southwestward along the length of the lowland into the Ohio River. In Kentucky, however, some streams head to the east on an upland and flow westward through the lowland to join the Ohio River.

Muscatatuck Regional Slope and Outer Bluegrass: The gently westward-sloping upland east of the Scottsburg Lowland is called the Muscatatuck Regional Slope in Indiana (Malott, 1922, pp. 86–88) and the Outer Blue Grass in Kentucky (McFarlan, 1943, pp. 167–174) (fig. 3). The Muscatatuck Regional Slope and the Outer Blue Grass are developed on the dipslopes of westward-dipping limestones of the Silurian and Devonian Systems. The dipslopes are capped in places on the interfluves along their western margin with patches of shale of Devonian age. The western margins of the upland areas are at about 600 to 700 feet in altitude, and the land slopes up gently eastward to above 800 feet in altitude (fig. 4D). The upland tracts are separated by streams that head to the east and become deeply entrenched, as much as 200 feet, as they follow incised meandering courses westward.

The major streams in the Muscatatuck Regional Slope and the Outer Blue Grass, within the study area, are tributary to the Ohio and Salt Rivers. Fourteenmile Creek, which flows southward into the Ohio River, is the principal stream in the Indiana portion. Harrods Creek in Kentucky flows across the strata to empty into the Ohio River. Floyds Fork and Salt River head on the Outer Blue Grass and converge within the narrow strip of the southernmost area of the Scottsburg Lowland. Salt River from there flows westward through a notch in The Knobs.

Ohio River Valley: The valley of the Ohio River is a distinct land type that cuts across the other three major areas in the vicinity of the Falls of the Ohio. This area contains the flattest land in contrast to all adjacent areas. The Ohio River flows into the area from the northeast through a deep trench cut into the Outer Blue Grass and Muscatatuck Regional Slope (fig. 4A). The trench averages about three-quarters of a mile wide and 250 feet deep for a distance of about 12 miles upstream from Harrods Creek. The river averages about a half a mile wide, and as a result the narrow floodplain is mostly a narrow strip on one side of the river or the other.

The valley widens to a breadth of about 5 miles below Harrods Creek where the river cuts through the Scottsburg Lowland. Much of the city of Louisville is built on the wide Ohio River floodplain just south of the Falls. The Ohio River flows along the north side of the wide valley at Louisville, turns southwestward just downstream from the Falls, and flows along the west side of the valley and at the base of the Knobstone Escarpment (fig. 4B). The very flat land southeast of Louisville, which is old lake beds, and the wide flat valleys of immediately adjacent tributaries to the Ohio River are in the Ohio Valley area (fig. 4C).

The valley of the Ohio River narrows from about 4 miles wide west of The Knobs south of Louisville to about 1½ miles wide where the Ohio River enters a gorge through the Knobstone Escarpment and Muldraugh Hill. The gorgelike character of the valley, similar to the gorge above Twelvemile Island, is retained for many miles downstream as the Ohio flows through the plateau capped with Mississippian limestones. Salt River also flows through a tapering notch similar to that of the Ohio River before uniting in a broad, flat valley with the Rolling Fork of Salt River. Rolling Fork and Salt River parallel the east slope of Muldraugh Hill, similar to the way the Ohio follows along the Knobstone Escarpment, separating the plateau from The Knobs, which have been left as erosional remnants or outliers.

The Ohio River Valley is mainly an area of unconsolidated sediments that consist mostly of alluvial and glacial outwash clays, sands, and gravels of Recent and Pleistocene age. Bedrock is seen only where the river flows against the valley walls, or at the Falls of the Ohio River. The Falls of the Ohio is the only place along the entire river, from Pittsburgh to its mouth, where bedrock was exposed entirely across the bottom of the present river channel. Otherwise, the bedrock valley bottom is covered with many feet of sediments, mostly of late Pleistocene age.

PREGLACIAL DRAINAGE PATTERNS

The tops of the higher ridges in Indiana and Kentucky, including the crests of the Knobstone Escarpment and Muldraugh Hill, have been described as remnants of an ancient erosion surface called the Lexington (Highland Rim) Peneplain (Fenneman, 1938, p. 432). The relief of this surface was very low, but it was sufficient to divide the region into two major drainage basins: one consisting of

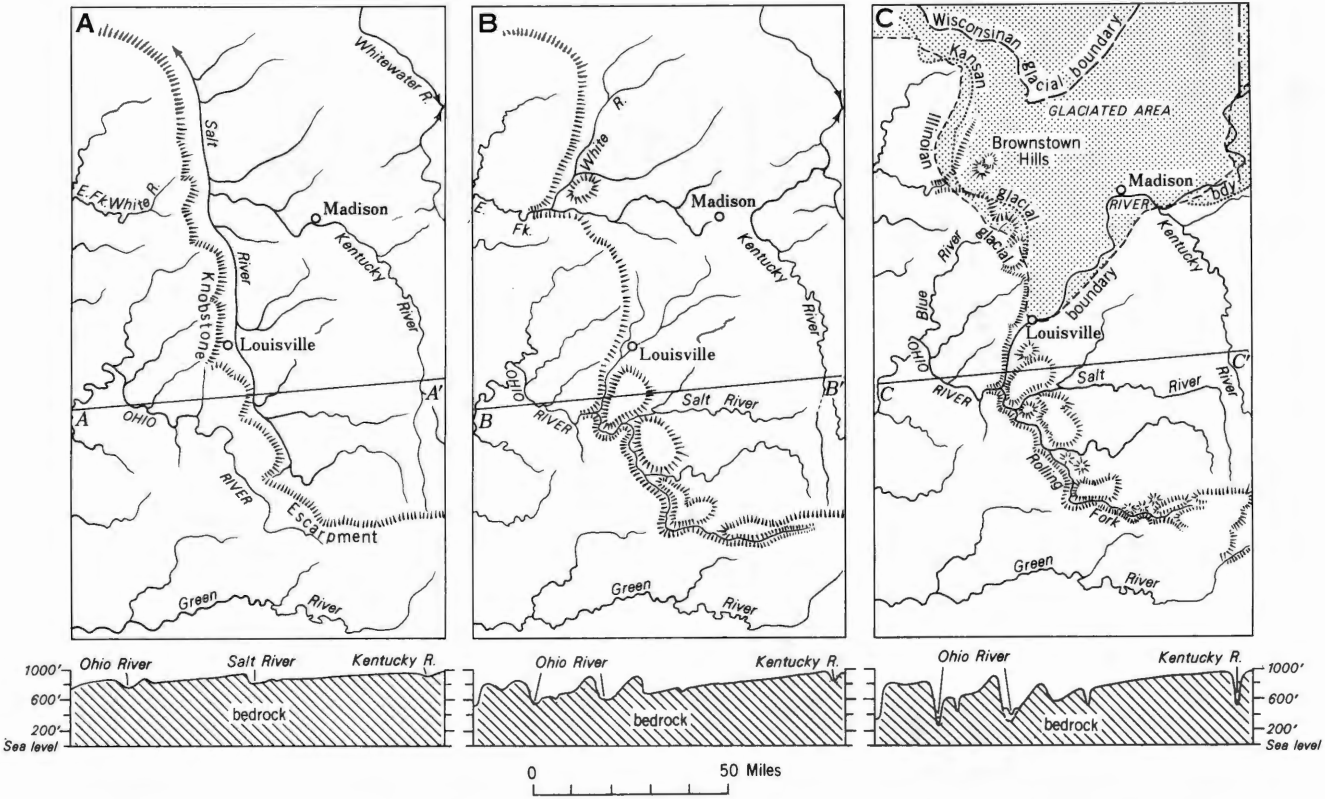


Figure 5. Maps showing the drainage routes in the vicinity of the Falls of the Ohio River during mid-Tertiary time (A), late Tertiary or early Pleistocene time (B), and Pleistocene time (C).

the present downstream Ohio River west of the Knobstone Escarpment and the other a northward-flowing Salt River drainage basin to the east of the escarpment (Fowke, 1933, p. 134) (fig. 5A). The streams were not deeply entrenched at this time but flowed just below the peneplain level. The Knobs south of Louisville were probably still attached to the Norman Upland along the crest of the Knobstone Escarpment, and thus the escarpment was continuous. Drainage that flowed westward from the escarpment entered into what is now the lower Ohio River. Drainage that flowed northward along the east side of the escarpment through the Scottsburg Lowland was an ancestral Salt River. The main headwater tributaries of Salt River flowed westward from the Outer Blue Grass. This erosion surface is considered to be Miocene or early Pliocene in age (Thornbury, 1965, p. 191). Previously it was considered to be of an earlier Tertiary age (Eocene) (Malott, 1922, p. 130). Considerable doubt remains as to whether the Kentucky River united with the Salt River or flowed northeastward into a preglacial valley, now a buried valley, in Ohio because of a possible divide at Madison, Ind. (Wayne,1952, pp. 576–579). The possibility that the pre-entrenchment Kentucky River was at one time the upper reach or a tributary of the preglacial Muscatatuck and Salt Rivers has been proposed (Gray and Powell, 1965, p. 22). The pre-entrenchment valley of the Kentucky River has clearly been shown to have joined with the Miami River near Cincinnati, Ohio, prior to glaciation (Swadley, 1971; and Campbell et al., 1974, pp. 17–24), an abandoned high level valley, separate for the most part from the valley of the modern Ohio River, is present from south of Carrolton, Kentucky, to the mouth of the Great Miami River at the Indiana–Ohio state line (fig 5 B).

After the development of the Lexington surface, the Midwest was elevated with respect to sea level, and streams actively cut down and eroded away part of the Lexington Peneplain. Abandoned high-level stream channels, stream deposits, different symmetry of drainage basins, and changes in stream profiles indicate that several stages of uplift and erosion took place. The exact age of several erosion levels is not known, but these levels are preglacial (pre-Nebraskan?; Ray, 1974, pp. 22–23). The present bedrock uplands were beveled by erosion prior to the deposition of thick unconsolidated material that is capped with gravel like that of the Lafayette Gravel. This gravel deposit is considered to be late Tertiary (Pliocene) in age. Streams then downcut through these deposits into the bedrock prior to the glaciations of middle Pleistocene age (Powell, 1964). Some tributaries of the Ohio and Wabash Rivers eroded notches through the Knobstone Escarpment during this episode of erosion and captured or diverted part of the drainage from the formerly northward-flowing Salt River (fig. 5B).

The bedrock surface within the drainage basin of Silver Creek is covered with Illinoian and, perhaps, Kansan drift, an indication that the shape of the basin was

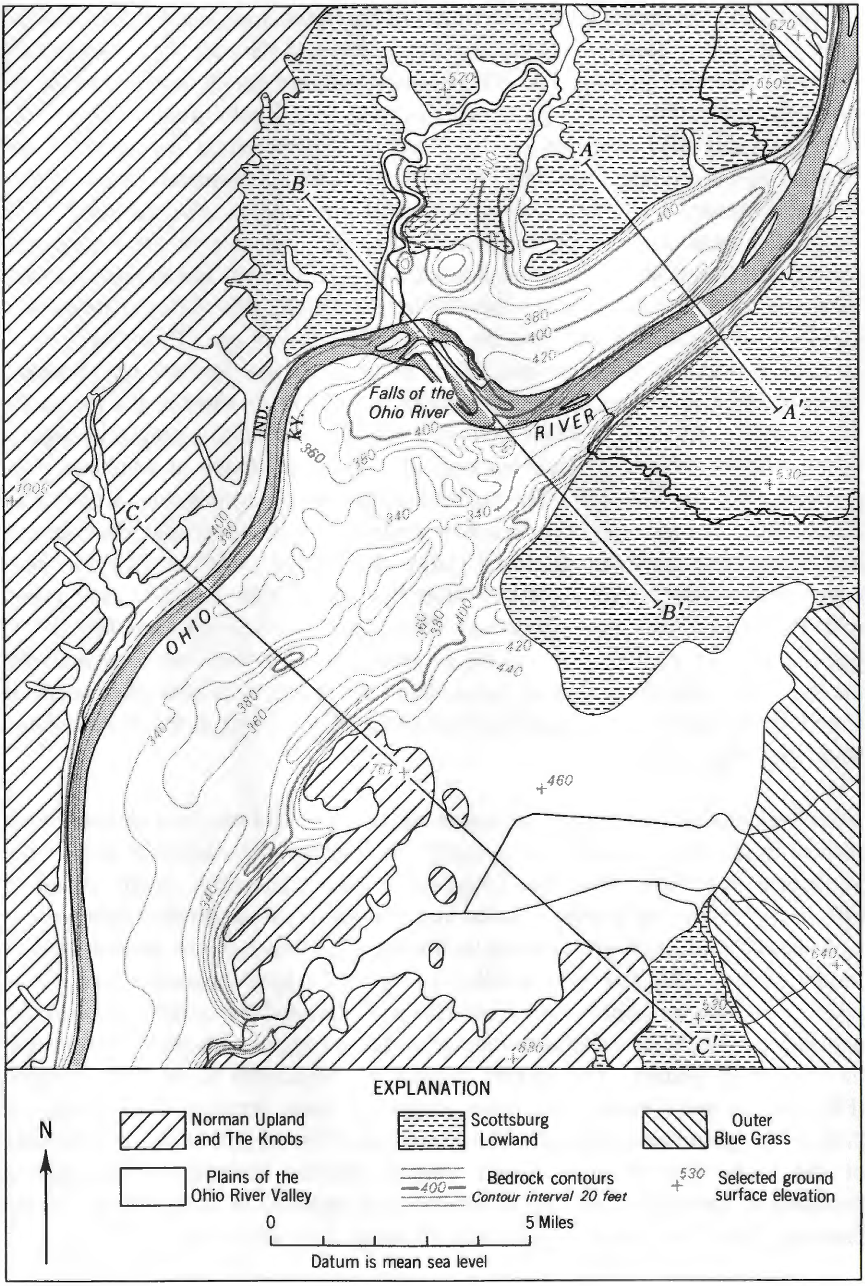


Figure 6. Bedrock topographic map of the Ohio River Valley in the vicinity of the Falls of the Ohio River. Lines A–A' through C–C' represent the cross sections shown in figure 7.

established prior to the advances of the ice sheets. The hypothetical gradient of the basin suggests that the notch in the Knobstone Escarpment that is now occupied by the Ohio River southwest of the Falls was eroded to about the level of the present stream prior to glaciation. The notch developed on the East Fork of the White River at the Brownstown Hills for the drainage basin of the Muscatatuck and its tributaries. Available information does not indicate which way the Kentucky River flowed at this time, but it eventually was diverted into the Ohio River by glacial action.

GLACIAL ORIGIN OF THE OHIO RIVER

The glacial ice sheets that covered most of North America during middle Pleistocene time extended southward to about the present position of the Ohio River. The southern margin of the ice-covered deposits is very irregular because of the lobate nature of the ice sheets and the dissection of these deposits by erosion; thus, there is some uncertainty concerning extent and age of the original deposits. This uncertainty is particularly true for some of the older deposits in northern Kentucky. Leverett (1929) presented considerable evidence to establish the fact that the Ohio River in the area in Indiana, Kentucky, and Ohio had been modified by glaciation during at least three glacial ages: an early age, presumably by the Kansan Age, the Illinoian Age of middle Pleistocene time, and the Wisconsin Age of the late Pleistocene time. Ray (1974) indicated a Nebraskan age for some of the earliest known glacial deposits in northern Kentucky along the pre-glacial Kentucky River channel.

The exact extent of the Kansan glaciation is unknown, but Kansan drift underlies the Illinoian drift in several places within a few miles of the Illinoian drift margin. This indicates that the two ice sheets had somewhat the same extent (fig. 5C). Leverett suggested that the numerous scattered erratics beyond the Illinoian drift boundary in northern Kentucky, including the Epworth Boulder, which weighed 16 tons, were of early glacial origin (Leverett, 1929, pp. 33–47).

The ice sheets of the Illinoian Age extended southward east of the Knobstone Escarpment to about the present position of the Ohio River. Exposures of Illinoian drift are common on the north side of the river. Only scattered patches of drift have been found in Kentucky, all northeast of the Falls of the Ohio River area. Available evidence suggests that in the immediate vicinity of the Falls meltwater charged directly off the ice sheet into the Ohio River Valley.

The middle Pleistocene ice sheets more or less buried the bedrock topography of the areas that they covered with drift and thus blocked or disrupted any preglacial drainage routes. Streams that had drained northward were ponded by the ice front, and temporary lakes within the local drainage basins were created. As the lakes filled with water they spilled over the lowest divide into another basin. These spillways were rapidly deepened by meltwater from the ice sheet, and ponded segments of the former independent drainage basins were integrated. The glacial outwash quickly cut down the bedrock channel to a level below present stream level. The bedrock valley at Louisville lies about 100 feet below present stream level of the Ohio River (figs. 6 and 7). The south-easternmost buried bedrock channel at Louisville probably represents one phase of glacial scouring, and the deepest channel represents another (fig. 7C). The deep bedrock valley was partly filled with outwash deposits as the meltwater abated. With each succeeding glacial advance and retreat, the bedrock channel was scoured of old deposits, perhaps deepened or widened, and partly refilled with new outwash.

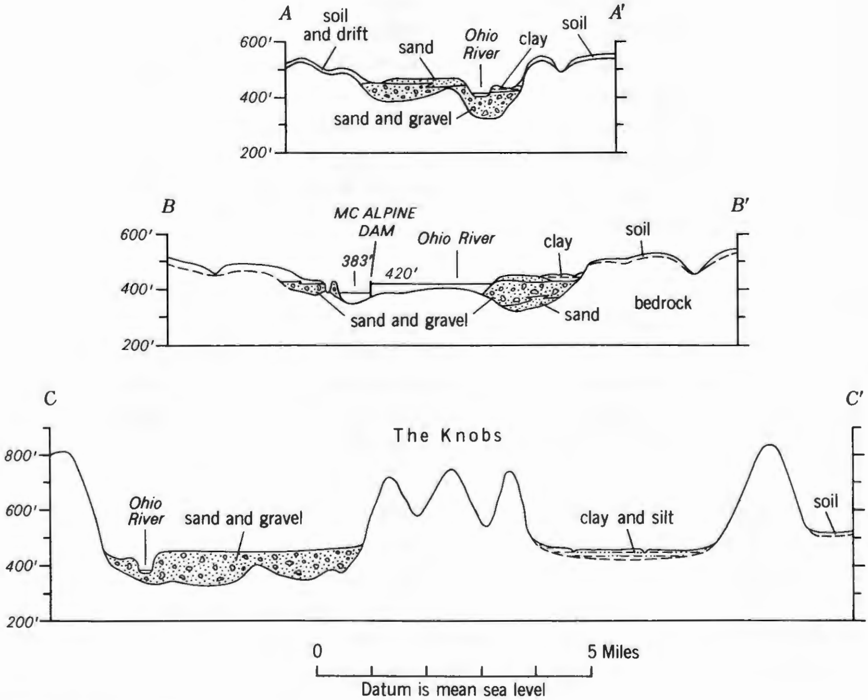


Figure 7. Cross sections of the deep channel of the Ohio River. Locations of lines are indicated in figure 6.

The last glaciation into southern Indiana, the Wisconsin glaciation, did not approach closer than about 60 miles north of the Falls, but Wisconsin meltwaters were discharged into the Ohio River, where they washed away most of the older outwash deposits. The waning phases of the Wisconsin meltwater deposited most of the sediments now present in the valley at the Falls. The meltwater and outwash deposits also caused ponding of tributaries to the Ohio. The clay and silt deposits in the very flat area north of Clarksville, around Okolona, and within the valley of the Salt River are Wisconsin lake sediments.

The deepest part of the bedrock valley of the Ohio River more or less underlies the present stream where it flows through the narrow bedrock gorges upstream from Harrods Creek and downstream from the mouth of Salt River. The present stream shifts from along the south bedrock wall to the north bedrock wall within the Scottsburg Lowland (figs. 7A and 7B), and the deep buried channel lies near the center of the bedrock valley beneath the city of Louisville. The great width of the filled valley at Louisville is due to sedimentation of the buried mouths of several tributary streams, for example, the Silver, Pond, and Beargrass Creeks. The lower ends of these streams had eroded down to a slope with the channel before the valley was partly filled with sediments. The depth to bedrock within the Louisville area ranges from a few feet near the Falls and adjacent to the bedrock valley walls to more than 100 feet in the deepest part of the buried channel.

The sediments in the Ohio River Valley in the Falls area are mostly glacial outwash and lake deposits of late Pleistocene (Wisconsin) age, but they do include some alluvial deposits of Recent age. The complicated character of the deposits, which consist of overlapping and interbedded sheet and channel deposits of clays, sands, gravels, and cobbles, has been indicated by Price (1964). In general, the outwash clays, sands, and gravels lie within the main valley, the lake clays are along backwater tributaries, and the Recent alluvial deposits, except overbank or flood deposits, are limited to the present stream channels (figs. 6 and 7).

ORIGIN OF THE FALLS OF THE OHIO RIVER

The Falls of the Ohio River is the only place along this stream where bedrock is exposed entirely across the river bottom. This situation is due to a sequence of events late in geologic time: valley filling and burial of a bedrock ridge, shifting of the stream to a position overlying the ridge, and finally, erosion and removal of sediments to reexpose the top of the bedrock ridge. As a result, rapids or falls were formed across the river bottom.

The origin of the deep bedrock valleys near the Falls of the Ohio has been discussed (p. 13). The Illinoian ice sheet, and perhaps the Kansan, occupied a position at or near the falls and discharged into the Ohio meltwater and outwash that eroded a deep channel into the bedrock (fig. 8A). This outwash was later eroded and partly removed.

The maximum amount of deposition of Wisconsin outwash deposits in the Ohio River Valley at Louisville was as much as about 470 feet in altitude, or about 50 feet above the top of the buried ridge in which the Falls of the Ohio is now situated. The amount of water in the valley decreased as the meltwaters from the Wisconsin ice sheet abated, and as a result a smaller stream flowed on top of the deep outwash sediments (fig. 8B). Once the meltwaters stopped carrying outwash into the Ohio River Valley, the water in the stream that had collected from the vast headwaters areas upstream began to erode and remove some of the sediments in the valley. The stream was relatively free to shift laterally within the bedrock valley walls as it eroded away the sediments during the past 10,000 years. In the area of the present Falls it shifted to a position above the bedrock ridge before eroding down in its channel. The present channel bottom of the Ohio River is about 70 feet below the adjacent areas of outwash or floodplain deposits and has incised 10 to 20 feet into the bedrock (fig. 8C). The bedrock at the Falls of the Ohio happened to be the very fossiliferous lower Devonian limestones, including the coral beds of the Jeffersonville Limestone.

STRATIGRAPHY OF THE DEVONIAN ROCKS AT THE FALLS

The Falls of the Ohio River is a scenic attraction and certainly a place of historical significance. But in addition, the Falls offers a unique opportunity to study the fauna of an extensive fossil coral bank of Devonian age (approximately 300 million years ago), for nowhere else are similar rocks exposed over such a large area. The excellent exposures have been studied for more than 175 years by such geologists and paleontologists as Rafinesque and Clifford (1820), Lapham (1828), Hall (1842), Lyon (1860), Borden (1874), and Kindle (1899). In addition, fossil specimens from this world-renowned locality have been described by such notable paleontologists as Troost (1840), Yandell and Shumard (1847), D'Orbigny (1850), Milne-Edwards and Haime (1851), Hall (1883), Ulrich (1886), Davis (1885), Greene (1898–1904; 1906), Herzer (1902), Bassler (1937), and Stumm (1964). Although these scientists, and many unnamed persons, have contributed to an understanding of the exceptional rock units and fossil assemblages at the Falls, the rock-unit names established by Butts (1915) and Cumings (1922) persist to date in only slightly modified form.

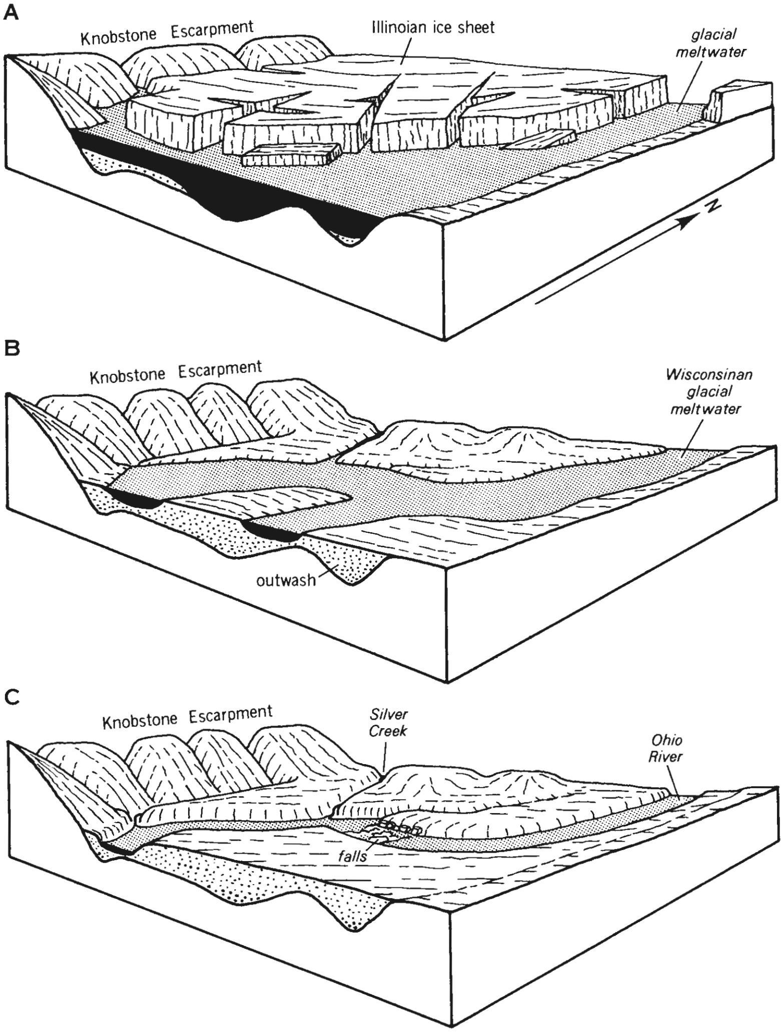


Figure 8. Block diagrams showing the progressive development of the Falls of the Ohio River. A, Possible conditions during time of maximum mid-Pleistocene glaciation when the deep channel was formed by meltwater erosion. B, Possible conditions during waning phases of Wisconsin glaciation (late Pleistocene) when outwash had been deposited across a buried rock ridge. C, Generalized block showing present conditions at the Falls of the Ohio River where the river has eroded down into the buried bedrock ridge and rapids have formed.

The rock units representing the entire sequence of strata of Devonian age now exposed at the Falls of the Ohio River and along the river banks are discussed here in ascending order from older to younger units (fig. 9). Numerous fossil species have been found in the various units at the Falls, but only a few of the more common fossil species are included in the following descriptions of rock units.

JEFFERSONVILLE LIMESTONE

The Jeffersonville Limestone was named for the bedrock exposures at the Falls of the Ohio River southwest of Jeffersonville, Ind., by E. M. Kindle (1899, p. 136). The unit had been known by several names prior to that time, primarily as the Corniferous Limestone, but most commonly was simply called the "coralline limestone" or "coral beds at the Falls of the Ohio." Abundant fossils available at the broad exposures at the Falls, and particularly the corals in the lower part of the Jeffersonville Limestone, aroused the interest of numerous scientists and became the basis for many paleontologic studies (figs. 10 and 11). More than 600 species of fossils from the rock units at the Falls have been described in about 75 different papers, and the type specimens for about two-thirds of these species have been obtained there (Horowitz, unpublished memorandum report, 1967).

Early workers, for example, Lyon (1860) and Kindle (1901), differentiated three to four units in the Jeffersonville Limestone on the basis of their distinctive fauna lithologies. These units are easily recognized in Butts's (1915, p. 104) description of the Jeffersonville, including fossil names, which is presented here with slight modifications.

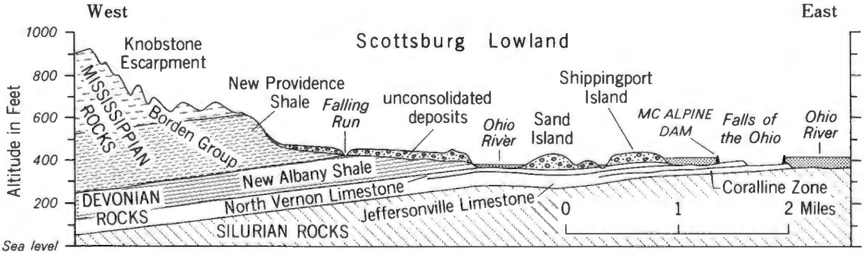


Figure 9. Generalized geologic cross section of the vicinity of the Falls of the Ohio River.

Section of Jeffersonville Limestone at the whirlpool 1 mile west of Jeffersonville

Jeffersonville Limestone:	Ft
5. Limestone, massive, rather course-grained, light-gray, a little black chert locally. Whitish and shelly on weathering. Exfoliates diagonally to the bedding. *Paraspirifer acuminatus* about in top. *Stropheodonta hemispherica*, abundant and conspicuous, Bryozoa abundant, includes bryozoan and *Elaeacrinus* subzones of authors. *P. acuminatus* Zone	9±
4. Limestone, siliceous, cherty, bluish-gray, fine-grained, very hard. *Brevispirifer gregarius*, very abundant. *Favosites turbinatus*, *Turbonopsis shumardi*, etc. *Brevispirifer gregarius* Zone	2
3. Limestone, 6 in to 1-ft layers, coarse-grained, light-pinkish, bluish, or brownish-gray. In places largely made up of stromatoporoids	7
2. Limestone, medium thick-bedded, very coarse crystalline, brownish in part. Crowded with corals. Coral layer	7±
Jeffersonville	25
1. Limestone, covered with water, not identified	3

Butts (1915, pp.103–104) did not find a complete section in the area of outcrop northeast of Louisville, and for this reason believed that the Jeffersonville thinned out and disappeared southward.

Perkins (1962) measured the thickness of the Jeffersonville as 35 feet in a detailed petrographic section (Appendix 1). His detailed description of beds of Jeffersonville Limestone exposed at the Falls divided the Jeffersonville into five faunal zones named for dominant fossils in each zone (fig. 11). The characteristics of each zone in ascending order are given below.

Coralline Zone: The oldest and lowest strata now exposed at the Falls are somewhat above Silurian strata that are now underwater but were seen by earlier workers. Devonian beds as much as 9 to 11 feet thick are presently exposed at low-water stage on both sides of the meandering channel of the Ohio River (fig. 10) and contain the abundant corals for which the Falls is noted. This fossil coral bank within the lower Jeffersonville is called the Coralline Zone. Perkins (1963, pp. 1,340–1,341) divided the Coralline Zone into two parts, upper and lower. The lower part contains many upright isolated corals, branching corals, small solitary corals, and generally small moundlike stromatoporoids; the upper part contains numerous solitary corals, matlike and moundlike stromatoporoids, a large number of fragments of branching corals, and some brachiopods. Stumm (1964, p. 7, 10–11) listed 73 species of fossil corals from the Coralline Zone (appendix 2). Among the most abundant species are *Siphonophrentis elongata* (Rafinesque and Clifford) (fig. 12), *Kionelasma manniferum* (Hall), *Emmonsia emmonsi*

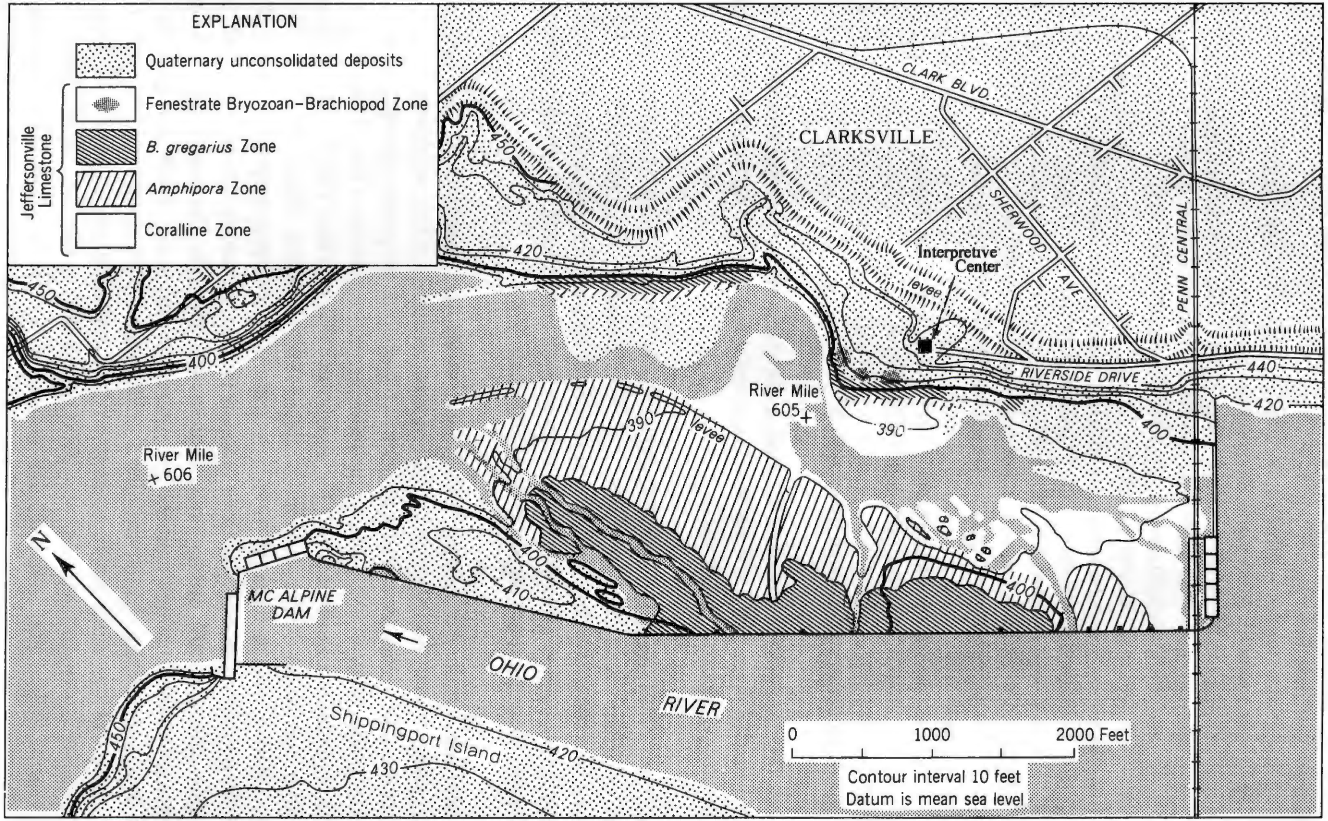


Figure 10. Geologic map of the Falls of the Ohio River showing the bedrock exposures of strata of Devonian age and areas covered with Pleistocene and Recent unconsolidated deposits. Topographic base modified from U.S. Army Corps of Engineers unpublished maps, 1964.

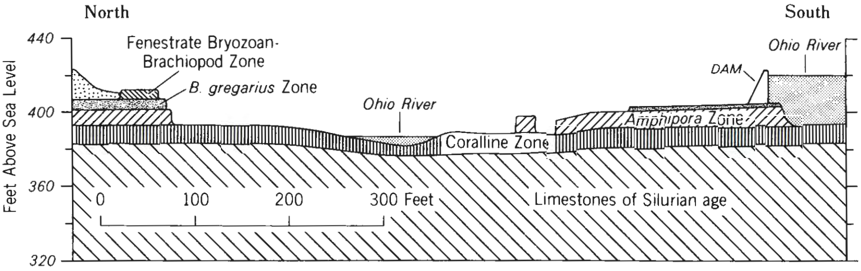
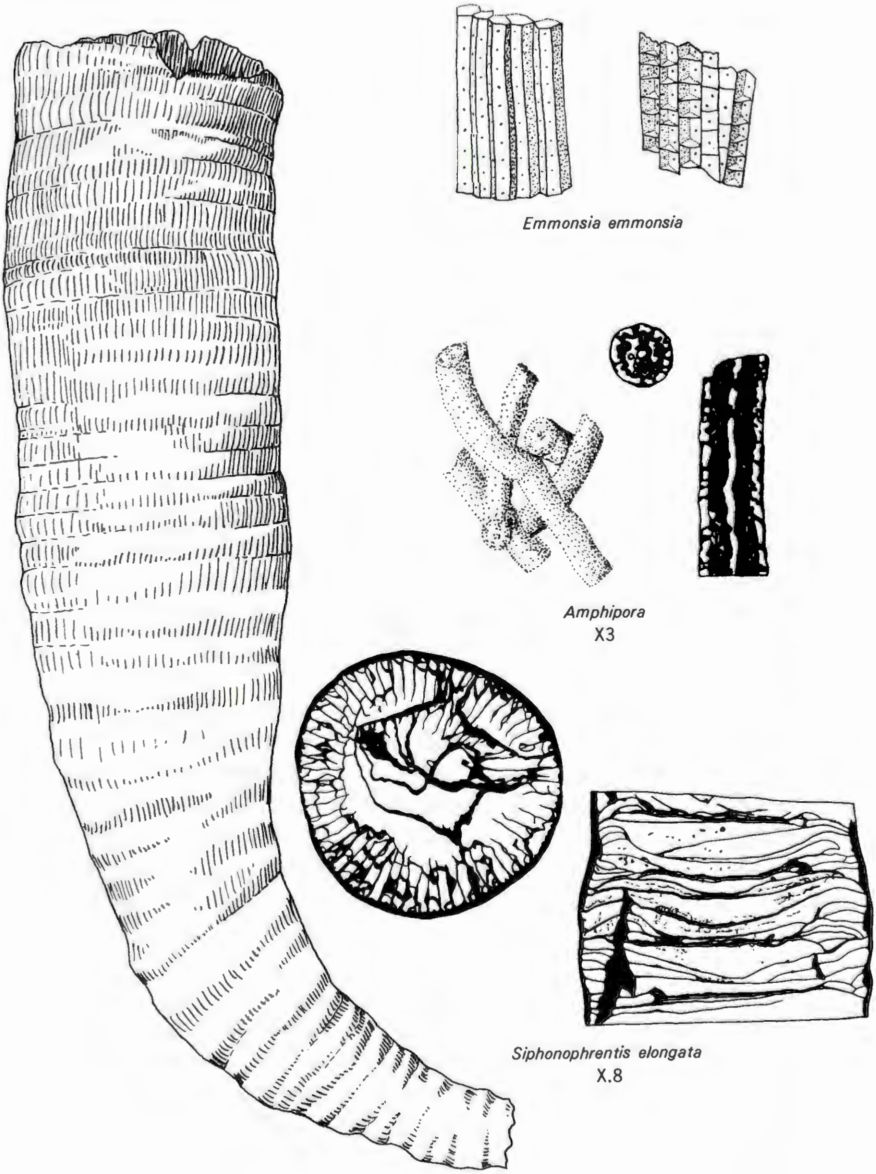


Figure 11. Generalized cross section across the Falls of the Ohio River showing the relationship of zones within the Jeffersonville Limestone.

(Rominger) (fig. 12), *Aulocystis nobilis* (Billings), *Accrophyllum oneidaense* (Billings), *Aemuliophyllum exigum* (Billings), and *Prismatophyllum cincta* (Stainbrook). The lower two feet of this zone, apparently not seen by Perkins, contains the brachiopods *Fimbrispirifer divaricatus* and *Meristella nasuta* and species of the trilobite genus *Anchiopsis* (Stumm, 1964, p. 7).

"*Amphipora*" Zone: The *Amphipora* Zone is characterized by the small ramose stromatoporoid *Amphipora* and matlike stromatoporoids (fig. 12). Colonial, branching, and solitary corals are much less abundant than in underlying Coralline Zone. The *Amphipora* Zone of Perkins (1963, p. 1,341–1,348) is the lower part of the *Brevispirifer gregarius* Zone of Kindle and other writers and the stromatoporoid unit of Butts. This zone is best exposed along the vertical sides of small cliffs and isolated blocks of limestone adjacent to the stream channel (fig. 11).

"*Brevispirifer Gregarius*" Zone: *B. Gregarius* is most common in a layer of limestone about half a foot thick that can be traced almost continuously for half a mile along the north bank of the river upstream from near Whirlpool Point (Kindle, 1901, p. 539). This layer is also now extensively exposed adjacent to the McAlpine Dam (fig. 10). According to Perkins (1963, p. 1349) the zone is characterized by abundant specimens of *B. gregarius* (fig. 11), charophyte öogonia, abundant echinodermal debris, and a lack of *Amphipora* and matlike stromatoporoids. A few moundlike stromatoporoids are found in this unit, but in general corals are smaller and fewer than in the lower two zones. Bassler (1950, p. 134) includes *Turbonopsis shumardi* (fig. 11) and *Paracyclas elliptica* as characteristic fossils.



Emmonsia emmonsia

Amphipora
X3

Siphonophrentis elongata
X.8

Figure 12A. Selected fossil corals of Devonian age from the Falls of the Ohio River. Drawings modified from Stumm (1964, pl. 13), Lecompte (1952, pl. 68), and specimens.

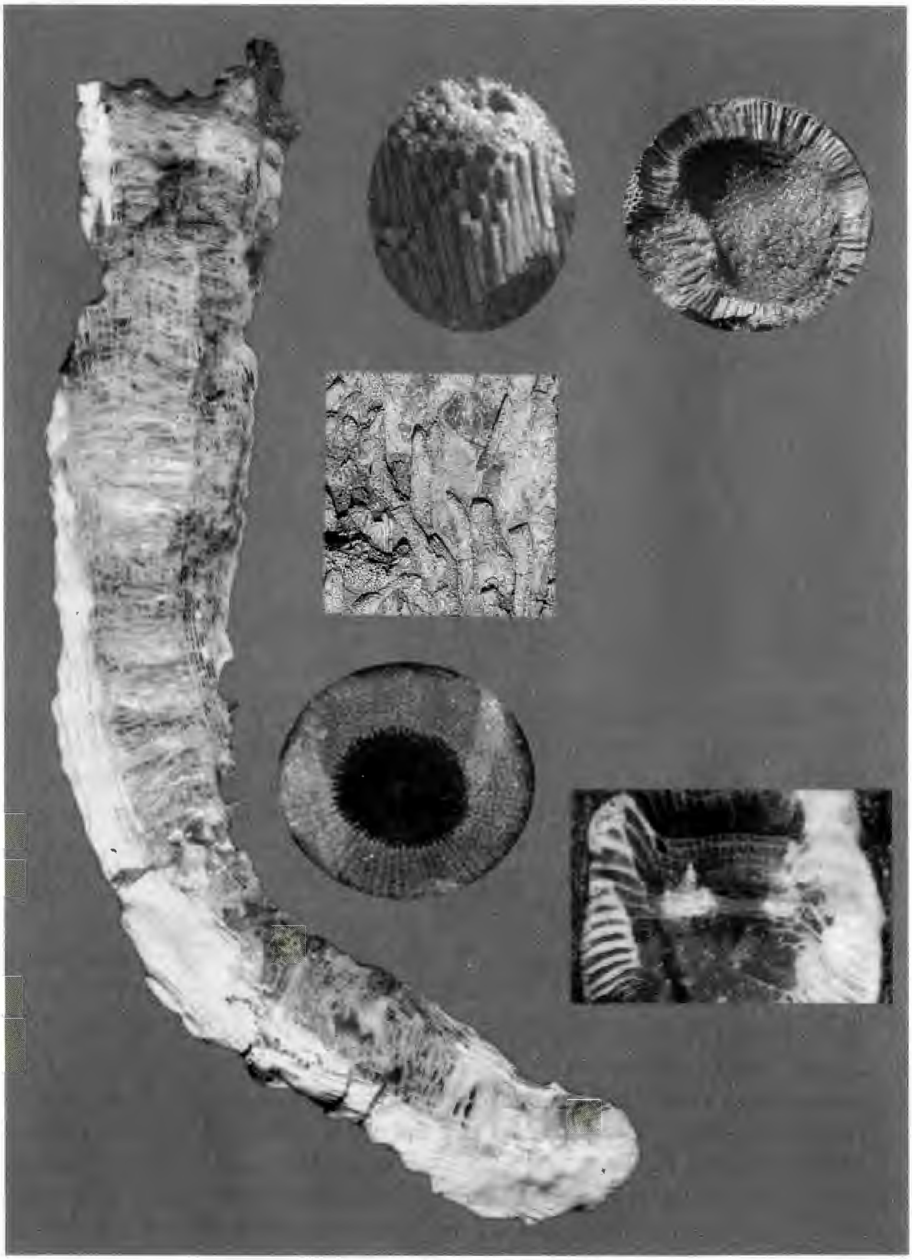


Figure 12B. Photographs of selected fossil corals of Devonian age from the Falls of the Ohio River.

The *Brevispirifer gregarius* Zone of Perkins is equivalent to the upper part of the *B. gregarius* Zone of Butts and Stumm and probably equivalent to the *Turbo* beds of early workers. Stumm (1964, p. 7) includes *Zaphrenthis phrygia* (Rafinesque and Clifford), *Eridophyllum seriale* (Edwards and Haime), and *Prismatophyllum prisma* (Land and Smith) (fig. 13) as characteristic corals of his *Brevispirifer gregarius* Zone and below the *Paraspirifer acuminatus* Zone, which includes the Amphipora Zone of Perkins.

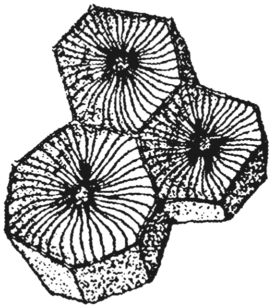
Fenestrate Bryozoan-Brachiopod Zone: The zone above the *Brevispirifer gregarius* Zone and below the *Paraspirifer acuminatus* Zone contains a diverse brachiopod fauna, abundant fenestrate bryozoan fronds and fragments, and some solitary, branching, and colonial corals. The zone lacks the two diagnostic brachiopods of the adjacent zones and contains only a few stromatoporoids. Charophytes, gastropods, trilobites, and pteropods are minor fossils (Perkins, 1963, p. 1350). The Fenestrate Bryozoan–Brachiopod Zone of Perkins includes the lower part of the *Paraspirifer acuminatus* Zone of earlier authors (Bassler, 1950, p. 134; Stumm, 1964, p. 7; Butts, 1915, p. 104) and probably is equivalent to the *Nucleocrinus* Zone of Lyon (1860, p. 104). It is exposed on the north bank of the Ohio River at the Falls (fig. 10). A particularly large number of silicified bryozoans and ostracods are found in a weathered clay at the base of the *P. acuminatus* Zone, just above the *B. gregarius* Zone.

***"Paraspirifer Acuminatus"* Zone**: Perkins (1963, p. 1352) acknowledges that his *Paraspirifer acuminatus* Zone is very similar to the underlying Fenestrate Bryozoan–Brachiopod Zone and that it differs mainly by the addition of *P. acuminatus* (fig. 13). Stumm (1964, p. 7) noted that there are many specimens of species of *Atrypa* and *Stropheodonta* and trilobite *Coronura aspectans* (Conrad) within the combined zones, which are only on the north bank of the river downstream from the area shown in figure 10.

NORTH VERNON LIMESTONE

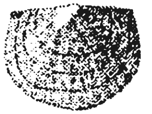
W.W. Borden (1876, p. 160–161) referred to the limestone beds that had been quarried at North Vernon as the "North Vernon blue limestone." He equated the beds at North Vernon with similar beds above the Jeffersonville in Clark County, Ind., known as the hydraulic limestone beds, that were used in manufacturing hydraulic cement (Louisville cement). Bordon also recognized that the Crinoidal Limestone, now the Beechwood Member, overlay the "Vernon beds." Currently the North Vernon Limestone is the name used for the combined unit that is exposed along the north bank of the Ohio River at the mouth of Silver Creek downstream from the Falls. It includes the Beechwood, Speed, and Silver Creek Members (Patton and Dawson, 1955, pp. 39–43) (fig. 8).

Brevispirifer gregarius

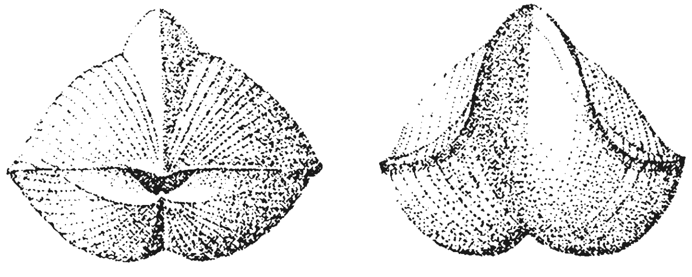


Prismatophyllum prisma

Turbonopsis shumardi



Chonetes yandellanus
X2



Paraspirifer acuminatus

Figure 13. Selected fossils of Devonian age from the Falls of the Ohio River. Drawings modified from examples published by Kindle (1901, pl. 4), Nettleroth (1889, pls. 10 and 22), Stumm (1964, pl. 38), and specimens.

Silver Creek Member: The name Silver Creek was applied by Siebenthal (1901, p. 345) to limestone exposures along Silver Creek, just northwest of the Falls. Earlier writers referred to this unit as water lime, cement rock, or hydraulic limestone. The Silver Creek Member is generally a magnesian limestone that is fine-grained, dark grey, and thick-bedded and that is 50 to 60 percent calcium carbonate, 16 to 35 percent magnesian carbonate, 10 to 25 percent silica, and 2 to 5 percent alumina (Butts, 1915, p. 119). The unit is about 15 feet thick near the Falls of the Ohio. *Chonetes yandellanus* Hall is the most characteristic fossil that is found everywhere in this unit (fig. 13). Butts (1915, p. 124) listed one species of coral, two of bryozoans, eighteen of brachiopods, three of pelecypods, and one each of gastropods and cephalopods from the Silver Creek that were probably collected from exposures along Silver Creek. Stumm (1964, p. 12) listed two species of coral from this unit at the Falls of the Ohio. The Silver Creek Member thins eastward from Louisville, and its character south of Louisville is unknown (Butts, 1915, pp. 118–119). North of the Falls of the Ohio River the Silver Creek changes character to a fossil hash named the Speed Limestone Member.

Beechwood Member: The name Beechwood was applied by Butts (1915, p. 120) to limestone exposures east of Louisville at Beechwood Station, Ky. The Beechwood Member is limestone that is generally light gray to dark gray, crystalline, and thick-bedded. Abundant black fossiliferous phosphatic nodules occur within the lowest bed of the Beechwood, just above the contact with the Silver Creek Member. The upper contact with the New Albany Shale is sharp, and the upper surfaces of the limestone is marked in most places by a thin band of pyrite (Butts, 1915, pp. 121–122). The Beechwood ranges from a few inches to about 10 feet in thickness in the Louisville area, but in most places it is 1 to 3 feet thick. The unit is about 8 feet thick near Silver Creek.

The Beechwood Member was referred to as the Crinoidal Limestone or the Encrinital Limestone by some early workers who were probably referring to the exposures at low water along the north bank of the Ohio River just above the mouth of Silver Creek. The Beechwood here contains abundant crinoid columnals and an occasional crinoid head. The unit also contains brachiopods, pelecypods, bryozoans, and many corals (Butts, 1915, p. 122; Stumm, 1964, pp. 11–12).

NEW ALBANY SHALE

The New Albany Shale is the uppermost formation of Devonian age in the Louisville area (fig. 9). W.W. Borden (1874, p. 158) named the New Albany Shale for excellent exposures along the north bank of the Ohio River. It is generally a black to gray fissile shale that contains much organic matter. Four types of rock, however, have been distinguished within the unit: black shale, greenish-gray shale, dolomite sandstone, and sandy dolomite (Lineback, 1968, pp. 1,291–1,294).

Fossils within the New Albany include both a marine fauna and plant fossils. Not all of them, however, are found immediately near the Falls of the Ohio. Butts (1915, p. 133) indicated that most of the fauna was found at the base of the New Albany, generally within the Blocher Member of present usage. He associated plant and fish remains with a calcareous sandstone zone that lies within the upper part of the Blocher Member. The lower part of the member commonly contains the brachiopods *Leiorhynchus* and *Chonetes* and the pteropods *Tentaculites* and *Styliolona* on bedding planes (Lineback, 1968, p. 1,298). The Selmier Member, which overlies the Blocher Member, contains the fossil *Spathiocaris* (arthopod or ceplepod operculum) and *Sporangites*, a plant fossil. Silicified logs of *Callixylon newberryi* occur in the overlying Morgan Trail Member and also, along with the brachiopod *Lingula* and pyritized gastropods and pelecypods, in the Camp Run Member (Lineback, 1968, pp. 1,299–1,300). The uppermost unit, the Clegg Creek Member, contains fossiliferous phosphatic nodules in its upper part. The nodules contain phosphatic and calcareous brachiopods, arthropods, fish remains, and plant fossils (Lineback, 1968, p. 1,301).

GEOLOGIC HISTORY OF THE DEVONIAN ROCKS AT THE FALLS

The Jeffersonville Limestone (Devonian) at the Falls of the Ohio rests unconformably on the Louisville Limestone (Silurian). Silurian strata younger than the Louisville that were deposited in other areas are not present, although the Mississinewa Shale Member of the Wabash Formation (Silurian) overlies the Louisville a few miles northeast of the Falls. Either the post-Louisville sediments were not deposited at the Falls, or they were eroded away (Butts, 1915, pp. 188–190). The theory that some strata of Silurian age were eroded before the Jeffersonville Limestone was deposited seems more acceptable, since an erosional surface has been recognized on the top of the Louisville Limestone (Perkins, 1962, pp. 24–25).

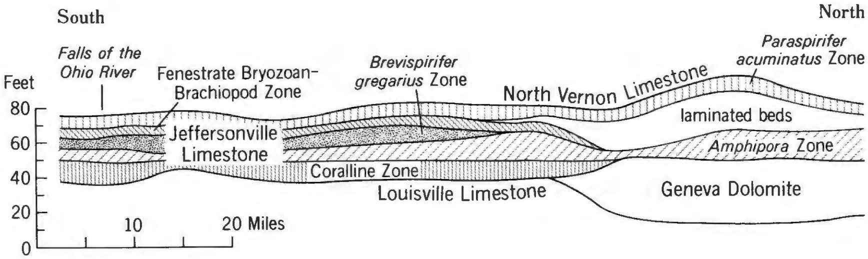


Figure 14. Generalized cross section showing the relationship of deposition of rocks of the coral zones of the Jeffersonville Limestone to other rocks.

Beds of the lower coral zone of the Jeffersonville Limestone, characterized by reef-forming large colonial coral masses and upright branching corals, were formed in a shallow sea below the turbulent base of the waves. Conversely, the broken corals and matlike stromatoporoids characteristic of the upper coral zone indicate formation within a sporadic turbulent wave-action zone. This periodic wave action destroyed the delicate coral reef growths in the upper coral zone.

Matlike stromatoporoids and *Amphipora*, diagnostic of a very shallow, but extensive, lagoon, indicate the culmination of the coral reef-building phase of the Devonian sea in this area.

Brevispirifer gregarius Zone and its associated fauna, along with some accumulation of fine-grained sediments, indicate an environment of shallow and quiet waters. Fluctuations of water level ranging from a depth which would allow corals to grow to aerial exposure of sediments, which would allow the development of mud cracks, characterized this period of sedimentation.

The fauna of the Fenestrate Bryozoan–Brachiopod Zone suggests deep water below effective wave action, an indication of a transgressing sea. Widespread distribution of *Paraspirifer acuminatus* of the succeeding zone is further evidence supporting the theory of increasing sea depth. The *P. acuminatus* Zone has a fauna nearly identical with the underlying zone (Perkins, 1962, pp. 74–77).

The Silver Creek Member of the North Vernon Limestone, which immediately overlies the Jeffersonville at the Falls, is characteristically a very argillaceous limestone and contains numerous broken fossil fragments. Immediately north of the Falls, limestone of Silver Creek type is interbedded with limestone of Speed type. The Speed is predominately composed of broken fossil fragments similar to those of the Silver Creek. The two units were probably deposited simultaneously. The Speed could have been derived from deposits similar to those of the Silver Creek, but the mud was "winnowed" or washed out and an accumulated mass of broken fossils was left. If this is true, the Speed Member must have been deposited in a somewhat turbulent sea, and the Silver Creek must have been laid down in adjacent quiet water (Murray, 1955, p. 45).

The Beechwood Member, which overlies the Silver Creek at the Falls, is a very fossiliferous limestone, an indication of deposition on a shallow marine shelf. This unit is noted for its crinoid content, mostly in the form of broken crinoid stems. This fact suggests that the sea was deep enough to allow normal growth of the crinoid stems but shallow enough to be affected by wave action. In some places the lower part of the Beechwood contains phosphatic nodules believed to be the product of a shallow sea environment in which little or no sedimentation other than the formation of the nodules took place (Butts, 1915, p. 192).

The New Albany Shale, which includes the youngest rocks of the Devonian System, was deposited as an accumulation of mud and organic matter. The black color of some of the shale is owing to a lack of oxidation of the organic material. Most of the organic material apparently was of marine origin, but, in particular, the large logs of *Callixylon newberryi* were apparently rafted from land, became waterlogged, sank, and were buried. The presence of some marine fossils suggests a shallow sea environment at certain stages during the deposition of the New Albany. Continued deposition of dark New Albany shales and marine deposition of the thin Rockford Limestone, the lowermost limestone unit of the Mississippian System, are evidence that shallow sea conditions of late Devonian time persisted into early Mississippian time. The shales and siltstones of the Borden Group (Mississippian) which overlie the Rockford are mostly marine deltaic in origin.

Sediments of Mississippian age were deposited on the Devonian rocks in the area of the Falls, but in late Mississippian time these sediments were uplifted and eroded into rugged hill and valley topography. Sediments of Pennsylvanian age were later deposited over the Mississippian topography, completely covering the older rocks, but thinning eastward on the flank of the Cincinnati Arch. Erosion has obliterated most of the evidence of geologic history from the end of Pennsylvanian deposition until about Tertiary time, when the present topography was taking shape.

ACKNOWLEDGEMENTS

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Appendices

Appendix 1

Section of the Falls of the Ohio River below the Pennsylvania Railroad bridge near Jeffersonville, Clark County, Ind. (Measured October 20, 1960, by R. D. Perkins, 1962, p. 88–91)

		Ft
Middle Devonian		
North Vernon Limestone:		
S.	Dolomite, finely crystalline, a medium-gray (N5), calcitic; rhombs abundant (0.028 mm); silicification of matrix common; highly argillaceous; carbonaceous streaks; filled burrows exposed along bedding planes. Fossils: fossil fragments few, calcispheres sparse	2.4
R.	Dolomite, finely crystalline, medium-gray (N5), calcitic; rhombs abundant (0.028 mm); scattered pyrite; few quartz grains (0.128 mm, SA-SR); highly argillaceous; burrowed; fractures conchoidally; many carbonaceous flakes. Fossils: brachiopods few	2.8
	Total thickness of measured North Vernon	5.2
Jeffersonville Limestone:		
Q.	Biomicrite, grain-supported, pale yellowish-brown (5YR 6/1); rhombs common (0.10 mm); silicification of shell material common; few quartz grains (1.128 mm, SA). Fossils: echinoderm debris abundant, fenestrate bryozoan fragments common, *Paraspirifer acuminatus* many, brachiopods many, solitary corals few, spined gastropods few	6.0±
P.	Biosparite, grading upward into biomicrite, grain-supported, light brownish-gray (5YR 6/1); sparry overgrowths common on echinoderm debris in lower part; silicification of shell material common; distinct nodular chert zones; iron-stained; few quartz grains (0.80 mm, SR). Fossils: fenestrate bryozoan fragments abundant, echinoderm debris abundant, brachiopods common, branching corals few, pteropods few, charophytes few, gastropods sparse, stromatoporoids sparse, encrusting bryozoans sparse	6.3
O.	Biomicrite, grain-supported, light brownish-gray (5YR 6/1); contains many sparry patches; spar-filled fractures common (many sediment floored); few overgrowths on echinoderm fragments; highly silicified and iron stained, stands out as distinct dark-brown band; fossil-cavity geopetals (u); few quartz grains (0.08 mm, SA-SR); scattered carbonaceous flakes; appears burrowed. Fossils: *Brevispirifer gregarius* abundant, echinoderm debris abundant, small solitary corals common, small colonial corals many, large gastropods many, stromatoporoids few, charophytes few	0.7
N.	Biosparite, light-gray (N7); many overgrowths on echinoderm fragments, large spar-filled voids; silicification of shell material common; fossil-cavity geopetals (u). Fossils: echinoderm debris abundant, *Brevispirifer gregarius* locally abundant, solitary corals many, small colonial corals many, fenestrate bryozoan fragments many, branching coral fragments few, charophytes few, stromatoporoids sparse	0.9

Jeffersonville Limestone–Continued

Ft

M. Biomicrite, grain-supported, light brownish-gray (5YR 6/1); minor silicification of shell material and micrite matrix; fossil-cavity geopetals (u); many carbonaceous flakes; few quartz grains (0.192 mm, SA). Fossils: shell debris common (mainly echinodermal), small solitary corals many, *Brevispirifer gregarius* few, branching coral fragments few, charophytes few, small colonial corals few 0.8

L. Biosparite, medium light-gray (N6); overgrowths very common on shell debris; silicification of brachiopods common; few microstylolites across fossil contacts; few quartz grains (0.16 mm, SA-SR); iron stained in places (from pyrite alteration). Fossils: fine shell debris abundant (mainly echinodermal), *Brevispirifer gregarius* common to abundant, gastropods few 0.8

K. Biomicrite, grain-supported, light brownish-gray (5YR 6/1); minor silicification of shell material, few quartz grains (0.128 mm, SA-SR); irregular carbonaceous laminae. Fossils: local lenses of coarser shell debris (mainly eciodermal), tiny *Brevispirifer gregarius* many, gastropods few, solitary corals few. 1.3

J. Biomicrudite, grain-supported, biolithite in upper 0.3 ft, medium light-gray (N6); silicification of fossils common; fossil-cavity geopetals (u); distinct solution zone at base; few fossils are iron-stained. Fossils: stromatoporoids abundant (usually mat-like, deformed, and cracked), solitary corals many, colonial corals few, ostracodes few, branching coral fragments few, small gastropods few, *Amphipora* few, calcispheres few, trilobites sparse 1.7

I. Biosparite, medium-gray (N5); few overgrowths on echinoderm debris; sheltered-void geopetals (u). Fossils: fine shell debris abundant; mat-like stromatoporoids common, solitary corals common, colonial corals common, *Amphipora* few to many, ostracodes few, branching coral fragments few, bryozoan fragments few, calcispheres few 1.0

H. Biolithite, medium-gray (N5); minor silicification of fossils, especially stromatoporoids; few microstylolites across fossil contacts. Fossils: crumpled mat-like stromatoporoids abundant, echinoderm debris common, solitary corals many, colonial corals few, *Amphipora* few, ostracodes few, branching coral fragments few, calcispheres few 1.3

G. Biosparrudite, light brownish-gray (5YR 6/1); silicification common, especially of solitary corals; sheltered-void geopetals (u); distinct solution zone at base. Fossils: *Amphipora* very abundant, fine shell debris abundant, solitary corals many, stromatoporoids few, small colonial coral few, ostracodes few, brachiopods few, small gastropods few, bryozoan fragments few. 2.3

F. Biosparite, medium-gray (N5); few overgrowths in echinoderm debris; silicification of fossils common, especially stromatoporoids. Fossils: echinoderm debris abundant, large stromatoporoids abundant (many coalescing to form small ridges), solitary corals abundant, colonial corals common (many form bioherms as much as 10 ft in diameter and extend into

	Jeffersonville Limestone–Continued	Ft
	units G and E), branching coral fragments common, *Amphipora* few to many	2.1
E.	Biosparrudite, grading upward into biomicrudite, grain-supported, medium dark-gray (N4); few overgrowths on echinoderm fragments, minor silicification of fossils; stylolitic contacts between fossils; fossil-cavity geopetals (u); highly carbonaceous; argillaceous. Fossils: branching coral fragments very abundant, solitary corals abundant (as much as 4.5 ft long), echinoderm debris abundant, stromatoporoids many, colonial corals many, ostracodes few	3.0
D.	Biomicrite, grain-supported, medium-gray (N5); few overgrowths on echinoderm debris; rhombs sparse (0.03 mm); minor silicification of shell material; few microstylolites; many carbonaceous flakes; few fossil fragments iron stained; burrowed. Fossils: echinoderm debris common, solitary corals many, colonial corals many, stromatoporoids few to many, ostracodes few, brachiopods few, calcispheres few	1.7
C.	Biomicrite, grain-supported, rudaceous in upper part, medium-gray (N5); rhombs few (0.06 mm); minor silicification of shell material; stylolitic contacts between fossils; few quartz grains (0.08 mm, SR); many carbonaceous flakes; few carbonaceous laminae. Fossils: echinoderm debris abundant, stromatoporoids many (as much as 5.0 ft in diameter), colonial corals many (as much as 10 ft in diameter), solitary corals few, branching coral fragments few	1.4
B.	Biosparite, grading upward into biomicrite, grain-supported, medium-gray (NS); overgrowths common on echinoderm fragments in lower part; rhombs sparse (0.04 mm); minor silicification of shell material; slightly carbonaceous; trace quartz (0.16 mm, SA-SR). Fossils: echinoderm debris abundant, stromatoporoids common, colonial corals common, upright branching corals many, solitary corals few, bryozoans few, calcispheres few, brachiopods few	1.1
A.	Biomicrite, grain-supported, locally sparry, medium-gray (N5); rhombs sparse (0.06 mm); minor silicification of shell material; few chalcedony spherulites in micrite matrix; few microstylolites; small amount pyrite; few quartz grains (0.19 mm, SA-SR); burrowed in lower part, slightly carbonaceous; fossils tend to increase in size and number upward in unit. Fossils: solitary corals many, echinoderm fragments many, small branching corals few, colonial corals few, stromatoporoids few, calcispheres few, ostracodes few	2.7
	Total thickness of exposed Jeffersonville	35.1
	Total thickness of measured section	40.3

Appendix 2

Fossil Corals in the Jeffersonville Limestone at the Falls of the Ohio River (Stumm, 1964, p. 10-11)

Coralline Zone of Jeffersonville Limestone

Acinophyllum davisi Stumm
Acrophyllum ellipticum Davis
A. oneidaense (Billings)
Aemuliophyllum exiguum
Alveolites asperus (Rominger)
A. constans Davis
A. expatiatus (Rominger)
A. minimus Davis
A. mordax Davis
A. squamosus Billings
A. winchellana (Miller)
Aulocystis nobilis (Billings)
A. (?) procumbens Davis
Aulopora tubiporoides (Yandell and Shumard)
Bethanyphyllum validum (Hall)
Blothrophyllum (?) greeni (Davis)
B. romingeri Stumm
Calostylis (?) trigemma (Davis)
Cayugaea subcylindrica Stumm
Chonostegites clappi Edwards and Haime
Cladionophyllum cicatriciferum (Davis)
Cladopora acupicta Davis
C. bifurca Davis
C. (?) imbricata Rominger
C. (?) robusta Rominger
Coleophyllum romingeri Hall
Compressiphyllum davisana (Miller)
Craterophyllum magnificum (Billings)
Cystiphylloides hispidum (Davis)
C. infundibuliformis (Greene)
Drymopora fascicularis Davis
Diplochone greenei (Miller)
Disphyllum synaptophylloides Stumm
Edaphophyllum bifurcatum (Hall)
E. bipartitum (Hall)
Emmonsia amplissima Davis
E. bacula (Davis)
E. convexa (Davis)
E. emmonsi (Rominger)
E. epidermata Rominger
E. radiciformis (Rominger)
E. ramosa (Rominger)
E. tuberosa (Rominger)
Favosites arbor Davis
F. biloculi Hall
F. clelandi Davis
F. impeditus Davis
F. proximatus Stumm
F. quercus Davis
F. ramulosus Davis
Hadrophyllum nettelrothi (Davis)
Heliophyllum verticale Hall
Heterophrentis irregularis (Hall)
H. (?) nitida (Hall)
Hexagonaria cincta (Stainbrook)
Homalophyllum fusiforme (Hall)
H. herzeri (Hall)
H. ungulum (Rominger)
Kionelasma coarcticum (Hall)
K. conspicuum (Hall)
K. mammiferum (Hall)
Phymatophyllum multiplicatum (Davis)
Platyaxum foliatum Davis
Platyaxum orthosoleniskum (Werner)
P. undosum Davis
Romingeria umbellifera (Billings)

Coralline Zone of Jeffersonville Limestone–Continued

Scenophyllum conigerum (Rominger)
Schlotheimophyllum typicum (Davis)
Siphonophrentis elongata (Rafinesque and Clifford)
Striatopora bellistriata Greene
Syringopora hisingeri Billings
S. perelegans Billings
Thamnopora limitaris (Rominger)

Above Coralline Zone of Jeffersonville Limestone

Aulopora edithana Davis
Aulacophyllum mutabile Davis
A. perlamellosum (Hall)
A. pinnatum Hall
A. sulcatum (d'Orgingny)
Bethanyphyllum arctifossa (Hall)
B. pocillum (Davis)
Blothrophyllum sinuosum Hall
B. tripinnatum (Hall)
B. trisulcatum (Hall)
Bucanophyllum ohioense (Nicholson)
Chonostegites tabulatus (Edwards and Haime)
Cladopora (?) gracilis Davis
Craterophyllum (?) latiradium (Hall)
Cystiphylloides plicatum (Davis)
C. pustulatum (Hall)
Eridophyllum apertum (Hall)
E. coagulatum (Davis)
E. conjunctum (Davis)
E. seriale Edwards and Haime
Favosites mundus Davis
F. patellatus Stumm
F. pirum Davis
Heliophyllum denticulatum Hall
H. incrassatum Hall
H. latericrescens Hall
H. venatum Hall
Heterophrentis duplicata (Hall)
H. inflata (Hall)
H. rafinesqui (Edwards and Haime)
Hexagonaria bella (Davis)
H. curta Stumm
H. ovoidea (Davis)
H. partita (Greene)
H. prima (Lang and Smith)
Pleurodictyum cylindricum (Michelin)
P. maximum (Troost)
P. (Procteria) michelinoidea (Davis)
P. (Procteria) papillosa (Davis)
P. (Procteria) spiculata (Greene)
Romingeria commutata Beecher
R. fasciculata Davis
R. uva Davis
Siphonophrentis planima (Hall)
S. yandelli (Edwards and Haime)
S. elongata (Rafinesque and Clifford)
Skoliophyllum squamosum (Nicholson)
Stereolasma (?) exile (Davis)
S. parvulum (Davis)
Striatopora (?) alba Davis
S. cavernosa Rominger
Trachypora tuberculata Stumm
Zaphrentis aequus (Hall)
Z. phrygia Rafinesque and Clifford

Jeffersonville Limestone (Undifferentiated)

Acrophyllum rugosum Greene
Amplexiphyllum cruciforme (Hall)
A. (?) simplex (Hall)
A. tenue (Hall)
Aulocystis (?) incrustans (Davis)
Bethanyphyllum depressum (Hall)
B. vesiculatum (Hall)
Billingsastraea yandelli (Rominger)
Blothrophyllum bellicinctum Greene
Cylindrophyllum compactum (Hall)
Cystiphylloides nanum (Hall)
Cystiphylloides quadrangulare (Hall)
C. tenuiradium (Hall)
Disphyllum cohaerens (Hall)
Emmonsia cymosa (Davis)
Heliophyllum agassizi Greene
Heterophrentis annulata (Hall)
H. cyathiformis (Hall)
H. ovalis (Hall)
H. trisutura (Hall)
Hexagonaria ponderosa Stumm

GLOSSARY

argillaceous limestone: Limestone having clay in its composition.

alluvial: Material (e.g., ore or sediment) deposited by running water.

bivalve: Aquatic invertebrates of the class Bivalvia, phylum Mollusca (e.g., clams, oysters, mussels). Bivalves get their name from their bivalve shells. Most are filter feeders, many burrow in soft sediments (clams), though some live attached to hard surfaces (mussels) or travel on the surface (oysters). Ordovician–present.

brachiopod: Marine invertebrates of the phylum Brachiopoda (lamp shells). Brachiopods possess a circular feeding structure surrounded by tentacles known as a lophophore. They resemble bivalve molluscs in having a two-valved shell, but this resemblance is only superficial. Brachiopods were especially abundant in the Paleozoic and Mesozoic. Cambrian–present.

calcareous: A substance containing calcium carbonate. A calcareous substance will fizz in a weak acid, such as vinegar.

cephalopod: Marine invertebrates of the class Cephalopoda, phylum Mollusca (e.g., octupuses, nautili, squid). Cephalopods have a mouth surrounded by arm-like tentacles. The largest invertebrates are cephalopods; giant squid reach lengths of 16 meters. Present-day cephalopods have an internal shell; some extinct species had univalve external shells. Extinct nautiloids and ammonoids provide valuable index fossils. Cambrian–present.

charophyte: Stoneworts (green algae in the order Charales).

columnal: Segments in the vertical stem or column of an echinoderm.

crinoid: Member of the class Crinoidea, phylum Echinodermata (sea lilies). Crinoids have an attachment stalk (stem or column), a pentaradial disc-shaped body, and five arms extending out from the body. Whereas present-day crinoids are relatively small, some fossil crinoids had stalks 20 meters long. Crinoids were abundant during the Paleozoic. Ordovician–present.

Devonian: A period in the Paleozoic era, following the Silurian and preceding the Mississippian. The Devonian lasted from 410 million years ago until 360 million years ago.

dipslope: A slope in the surface of the land, corresponding with the slope of the rocks under the soil.

drift: Gravel, silt, clay, and boulders transported by a glacier.

echinoderm: Marine invertebrates of the phylum Echinodermata (e.g., sea stars, sea urchins, crinoids). Echinoderms are pentaradially symmetrical and they possess an internal skeleton of calcareous plates or ossicles. They also possess a water vascular system of coelomic canals, which is used for locomotion.

erosion remnant: A feature of the topography (e.g., a hill or butte) that is left behind when erosion removes the surrounding material.

erratic: A fragment of rock moved by a glacier.

escarpment: A cliff, rock face, or steep slope that extends a long distance in one direction. Escarpments can result from erosion or from faulting.

fenestrate: Possessing openings or perforations.

gastropod: Invertebrates of the class Gastopoda, phylum Mollusca (e.g., snails, nudibranchs). Gastropods have a head and eyes, a feeding organ called a radula, and they generally have a single whorled shell. Fifteen thousand fossil forms have been discovered. Cambrian–present.

glacial scouring: Erosion by the movement of a glacier, including the removal of surface material and the abrasion of the bedrock by the rocks carried by the glacier.

gorge: A narrow valley enclosed by steep rock walls.

Illinoian stage: The third North American glacial stage of the Pleistocene, following the Yarmouthian interglacial stage and preceding the Sangmonian interglacial stage.

incised: The result of a stream cutting into the surface of the land as a result of stream rejuvenation.

interfluve: An area between two rivers.

Kansan stage: The second North American glacial stage of the Pleistocene, following the Aftonian interglacial stage and preceding the Yarmouthian interglacial stage.

lowland: Low-lying area of land.

Mississippian Period: A period of the Paleozoic era, following the Devonian and preceding the Pennsylvanian. The Pleistocene lasted from 360 million years ago until 330 million years ago.

Miocene Epoch: An epoch of the Tertiary period, following the Oligocene and preceding the Pliocene. The Miocene lasted from 24 million years ago until 5 million years ago.

Nebraskan stage: The first North American glacial stage of the Pleistocene, preceding the Aftonian interglacial stage.

oogonium: Thallophyte (nonvascular plant such as algae) female sex organs.

ostracod: Marine and freshwater invertebrates of the subclass Ostrocoda, class Crustacea, phylum Arthropoda (seed shrimps). Ostracods have a calcified bivalve carapace that fossilizes easily; as a result, there is an extensive and continuous fossil record of over 10,000 ostracod species. Cambrian–present.

outcrop: An exposure of geologic formations at the surface of the land.

outlier: An area of outcrop of rocks of one age that are surrounded by rocks of an older age.

peneplain: Large, low, undulating region of land smoothed by long continued erosion.

phosphatic nodules: Rounded masses of calcium phosphate, that surround corals, sponge spicules, bones, shells, sand, or mica. Phosphatic nodules are gray, brown, or black.

physiography: The study of landforms.

Pleistocene Epoch: An epoch of the Quaternary period, following the Pliocene and preceding the Holocene. The Pleistocene lasted from 1.8 million years ago until 10,000 years ago.

Pliocene Epoch: An epoch of the Tertiary period, following the Miocene and preceding the Pleistocene. The Pliocene lasted from 5 million years ago until 1.8 million years ago.

pteropod: Marine invertebrates in two orders within the subclass Opisthobranchia, phylum Mollusca. Some are shelled (order Thecosomata) and some are unshelled (order Gymnosomata). Cretaceous–present.

pyritization: Replacement by pyrite of material in hard parts of fossilized organisms.

ramose: Having branches.

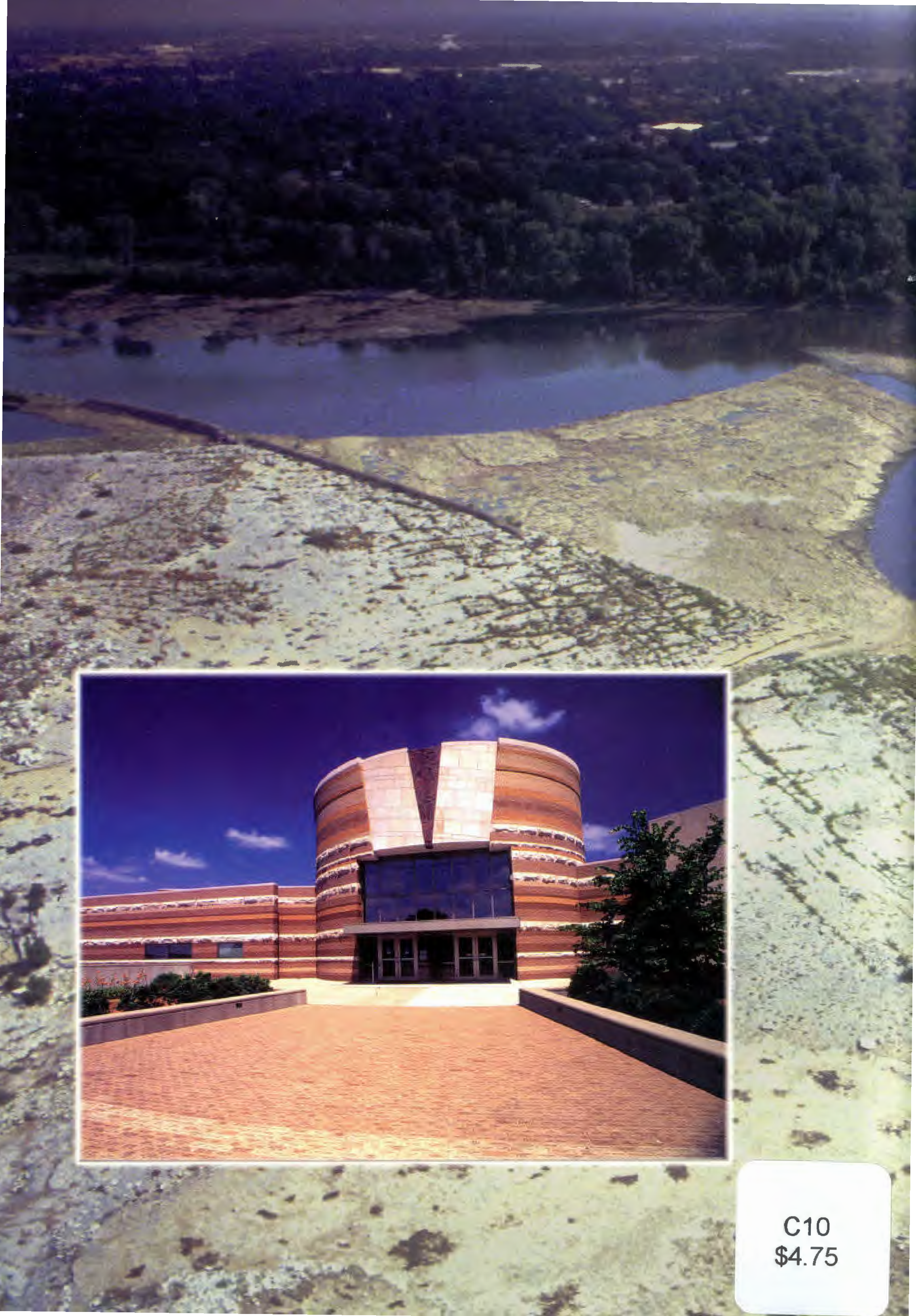
stromatoporoids: Extinct marine invertebrates with calcareous exoskeletons and indeterminate taxonomy.

Tertiary: A period of the Cenozoic era, following the Cretaceous and preceding the Quaternary. The Tertiary lasted from 65 million years ago until 1.8 million years ago.

trilobite: Extinct marine invertebrates of the class Trilobita, phylum Arthropoda. Trilobites had a three-lobed exoskeleton. More than 10,000 fossil species have been discovered. Cambrian–Permian.

upland: Elevated land sitting above lower areas.

Wisconsin stage: Fourth North American glacial stage in the Pleistocene Epoch, following the Sangamonian interglacial stage and preceding the Holocene Epoch.



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