Kentucky Geological Survey
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University of Kentucky, Lexington

History and Geology of Madison, Indiana, and Clifty Falls State Park

Compiled By:
Richard A. Smath, Frank R. Ettensohn, and Margaret Luther Smath

Guidebook 1

Series XIII, 2017

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Geological Society of Kentucky
Fall Field Trip, November 5, 2016

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Guidebook 1 Series XIII, 2017

Our Mission

Our mission is to increase knowledge and understanding of the mineral, energy, and water resources, geologic hazards, and geology of Kentucky for the benefit of the Commonwealth and Nation.

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Technical Level

General Intermediate Technical

Statement of Benefit to Kentucky

The 2016 Geological Society of Kentucky field trip in the Clifty Falls area of the Cincinnati Arch region covers Ordovician-Silurian stratigraphy, paleontology, and the influence of these rocks on the lay of the land (landform geomorphology). As an example of how local geology impacted human progress in the area, the field trip examines Brough's Folly, a railroad tunnel built during the 1850s that failed because engineers of the day did not fully consider the geologic implications. The field trip is an excellent outdoor laboratory in which to learn about the geology of the Cincinnati Arch region and mirrors geology on the Kentucky side of the Ohio River.

On the cover: Tunnel entrance, looking into the Laurel Dolomite roof and Osgood Shale. Photo by Richard A. Smath.

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History and Geology of Madison, Indiana, and Clifty Falls State Park

Compiled by
Richard A. Smath, Frank R. Ettensohn, and Margaret Luther Smath

Introduction

Frank R. Ettensohn

The area of this field trip was chosen because of the variety of geologic features and experiences in the Clifty Falls area. The area, on the western flank of the Cincinnati Arch (Fig. 1), is sometimes called the Cincinnati Arch area or the Ohio-Kentucky-Indiana Tri-State area, and is known worldwide for its hundreds of exposures of Upper Ordovician rocks and exceptional fossil collecting. These rocks are part of the Upper Ordovician Cincinnatian Series, and throughout the Tri-State, this series of rocks offers many opportunities to collect different kinds of fossils in different environmental settings. This trip examines fossils from Richmondian rocks, uppermost Ordovician rocks that represent end-Ordovician deposition in a time of global sea-level lowering. That process of sea-level lowering is readily visible in the rocks at the first stop. Also at the same stop is the Ordovician-Silurian unconformity, and although very subtle, it represents a period of major erosion and nondeposition during a period of glaciation and global cooling. The overlying Silurian section at this stop has Lower Silurian rocks that are very different from the Ordovician rocks below in that they are largely dolostones and shales and not as fossiliferous as the Ordovician rocks below.

These same rocks can be observed at the next several stops in Clifty Falls State Park, but at stop 1, it is the rocks' weathering qualities that are more important. Some are resistant and some are nonresistant to the forces of weathering, and it is the relative resistance of these rocks that contributes to development of major landforms such as Clifty Falls and an escarpment in the park. Although weathering at stop 1 and elsewhere has been proceeding for a very long time, the weathering and erosion that were essential for the development of these features received a real boost from Pleistocene glaciation that began about 2 million years ago. Unlike most of Kentucky, this part of Indiana has been glaciated, and remnants of the glacial till that was laid down are locally still visible. Pleistocene glaciation changed the courses of rivers and provided much precipitation and meltwater that aided in the development of nearby landforms. Some of the major changes occurred in the very area of this field trip.

Finally, the trip examines how the nature of these rocks influences human endeavors. In particular, we will examine the development of Broughs Tunnel, also called Brough's Folly, in Clifty Falls State Park. This river-to-rail project in the 1850s floundered because the engineers of that day failed to fully consider the implications of geology.

Please think safety at all times. Part of the trip takes place at a roadside exposure with much traffic. Please pull your cars onto the shoulder as far to the right as possible, and as you walk along the exposure, remember the traffic and keep as close to the exposure as possible. In a few places, you will need to take care to avoid unstable overhanging rocks. Some of the hiking trails in the park are along steep cliffs, where a wrong step could send you tumbling down the hillside. So please watch your step. From Nov. 1–April 31, the abandoned railroad tunnel is closed to protect hibernating bats. If you return some other time to walk through the tunnel, please wear sturdy shoes that you do not mind getting muddy, and bring a flashlight.

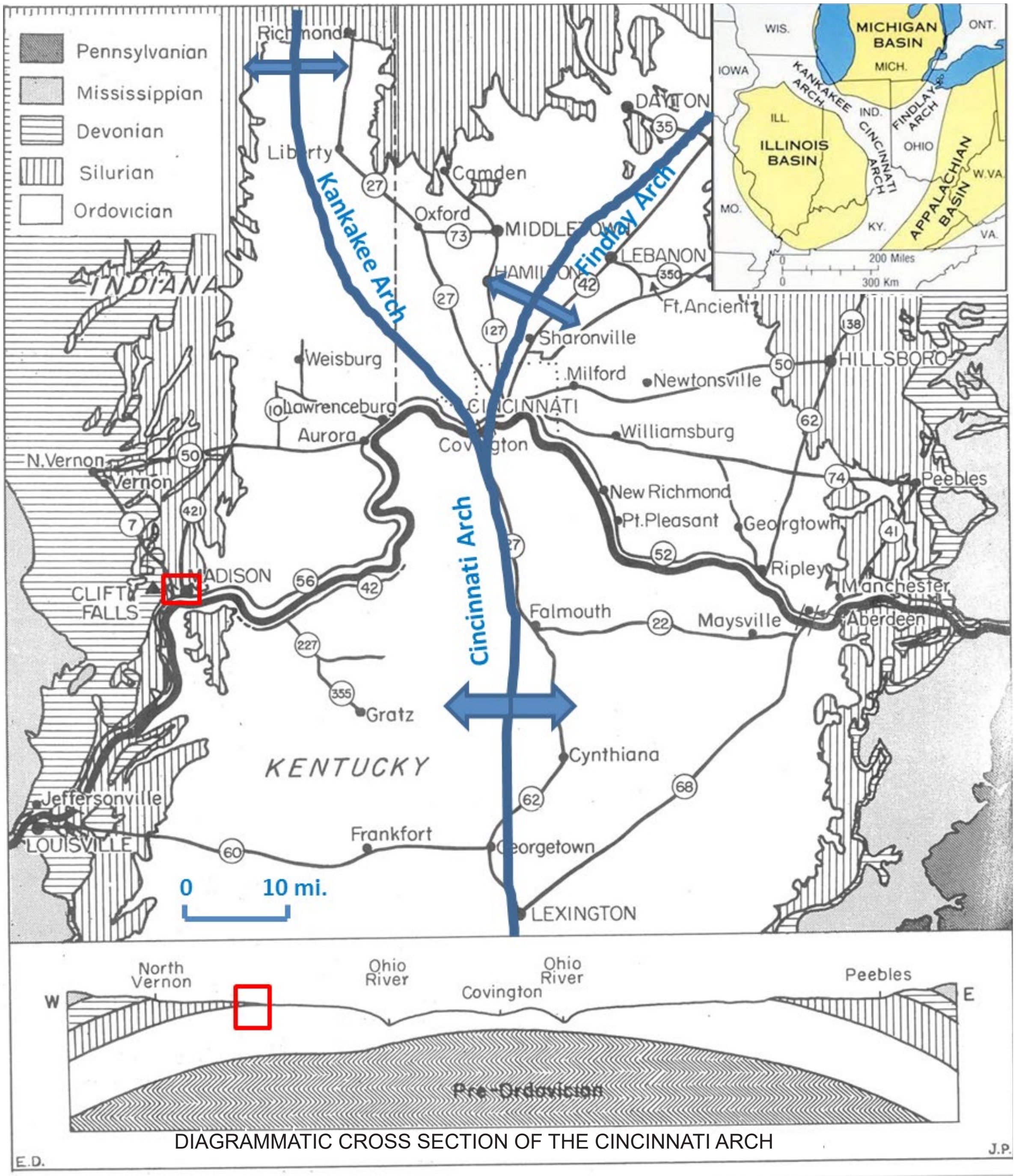

Figure 1. Generalized geology and cross section of the Tri-State area, showing the approximate positions of the Cincinnati, Kankakee, and Findlay Arches, as well as the location of the field trip area (red boxes). Adapted from Caster and others (1955); used with permission of the Cincinnati Museum of Natural History.

Geologic Framework

Structure and Tectonics. The Clifty Falls area sits on the western flank of the Cincinnati Arch, a broad basement uplift that separates the Illinois and Appalachian Basins (Fig. 1, inset map). Consequently, the rocks in the field trip area dip very gently to the west, but at an angle that is almost imperceptible. Rast and Goodmann (1994) suggested that uplift of the arch was caused by periodic inversion (uplift) of basement structures related to the East Continental Rift Basin (Fig. 2), nearly 4,000 ft deep in the subsurface, and evidence from lithofacies trends

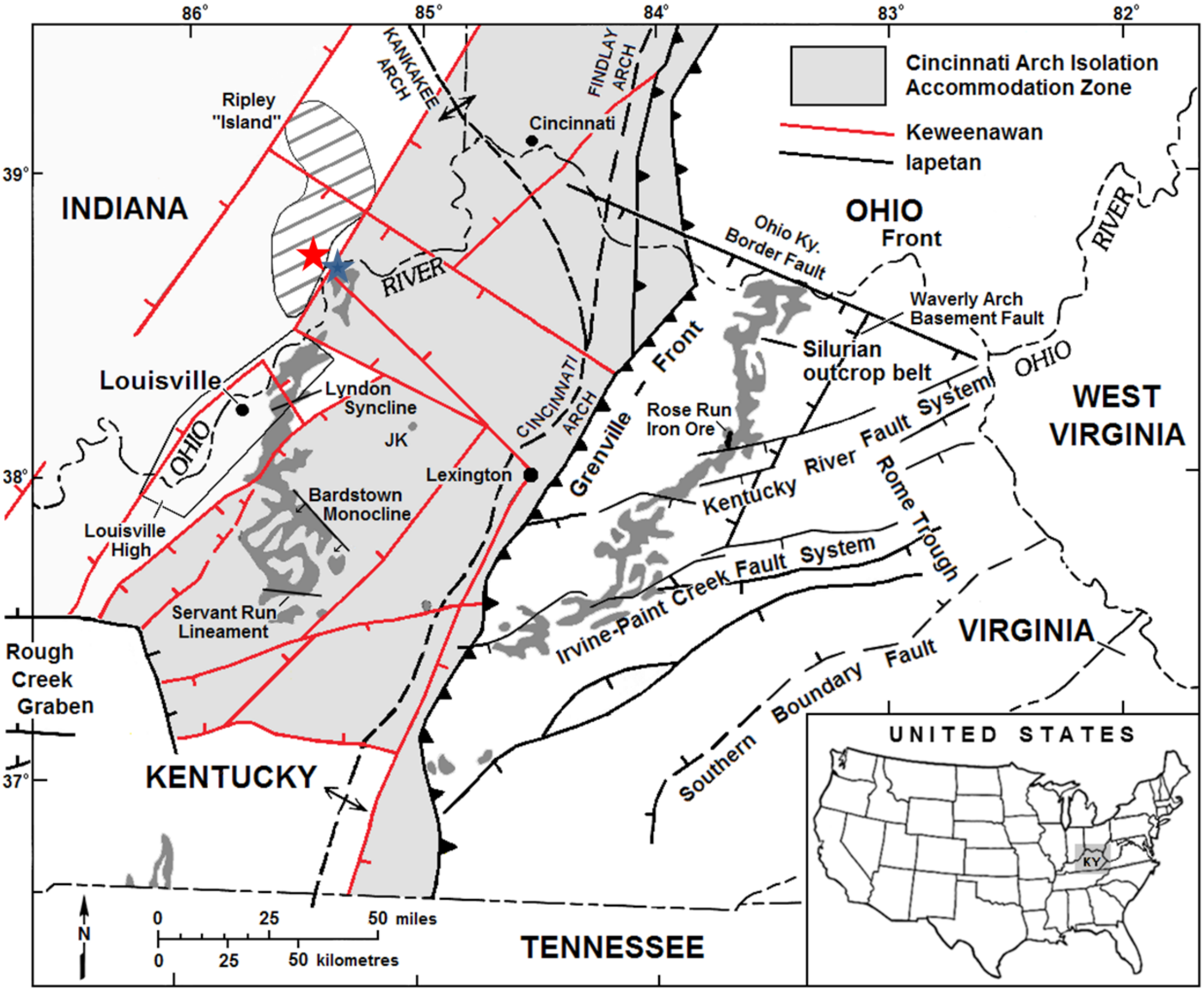

Figure 2. Major basement structures of north-central Kentucky. Faults from the Keweenawan (approximately 1.4–1.1 billion yr old) East Continent Rift Basin are colored red. This rift basin apparently acted as an isolation accommodation zone between Iapetan fault zones (Rome Trough and Rough Creek Graben faults) of opposite polarity and itself became inverted in latest Ordovician–Silurian time to form a platform-like area of deposition for Silurian rocks of the western outcrop belt. The barbed line bounding the accommodation zone on the east is the Grenville Front. Silurian rocks on the eastern outcrop belt were deposited on a ramp dipping eastward off of the high generated by the front. Reactivation of Iapetan fault zones in the east generated many stratigraphic anomalies in Silurian rocks crossing the faults. These structures may have not only influenced development of the Cincinnati Arch, but also the thicknesses and fauna of Lower Silurian strata on and off of the Ripley Island. The blue star indicates the position of Madison and stop 1, just east of the Ripley Island. The red star indicates the position of Clifty Falls on the island. Adapted from Ettensohn and others (2013); used with permission of Memoirs of the Australasian Palaeontologists.

suggests that the arch was not actively uplifted until latest Ordovician time (Weir and others, 1984). At this time, uplift was probably related to far-field stresses generated by the Taconian Orogeny, nearly 600 mi to the east. The Taconian Orogeny represented convergence of the eastern margin of Laurentia with a series of island arcs and continued into Early Silurian time (Ettensohn and Brett, 2002) (Fig. 3). As a consequence of the orogeny, a high mountain belt developed in the east, and this mountain belt shed vast amounts of clastic debris westward into the Appalachian Basin (Fig. 3A). Although Upper Ordovician rocks in eastern Kentucky on the western margin of the basin are very

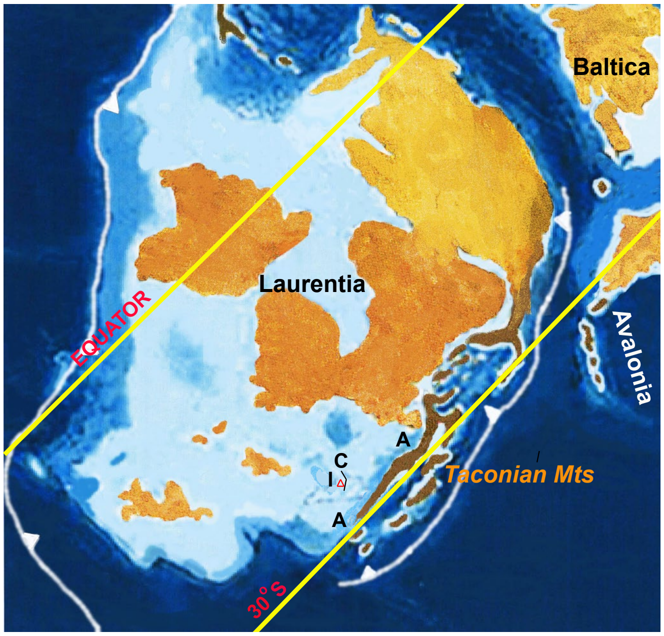

Figure 3. Paleogeographic reconstruction of Laurentia (most of North America) during Late Ordovician time (approximately 450 Ma) relative to the paleoequator and 30°S latitude. The study area (red triangle) is on the western margin of the Cincinnati Arch and was located in the arid, subtropical trade-wind belt at about 25°S latitude. Except for the area represented in dark brown on the map, most of Laurentia was covered by shallow, subtropical seas at the time; by latest Ordovician time, light brown areas west of the arch were very shallow peritidal areas. The Taconian Mountains reflect an active, ongoing, orogenic event, which continued into Early Silurian time. A = Appalachian Basin. C = Cincinnati Arch. I = Illinois Basin. Modified from Scotese (2001); used with permission of the PALEOMAP Project.

clastic-rich, rocks in the field trip area were deposited toward the western side of the arch, which sheltered the area from major clastic influx, and are dominated by carbonates. By Early Silurian time, however, facies and thickness trends indicate that the arch was even more influential (McDowell, 1983; Gordon and Ettensohn, 1984). In fact, Kolata and Nelson (1990) indicated that activity on the arch peaked during Silurian time, such that lithologies and faunas on either side are substantially different (see, e.g., Foerste, 1906, 1931, 1935; Freeman, 1951; Nicoll and Rexroad, 1968). Both Silurian and Ordovician rocks played prominent roles in developing many of the features that can be observed on this trip.

Aside from the Cincinnati Arch, other structural features in the area also played a role in the development of the Ordovician and Silurian rocks in the area. Most important are structures related to the East Continent Rift Basin (Fig. 2). In latest Ordovician and Early Silurian time, far-field forces from the Taconian and Salinic Orogenies in the east apparently uplifted these blocks, forming a broad platform area (shown in gray on Fig. 2) on which uppermost Ordovician and Lower Silurian rocks were deposited, and these rocks are much different than rocks of equivalent ages that crop out in the eastern outcrop belt (Ettensohn and others, 2013). In addition, various blocks reacted differently to far-field forces, creating various stratigraphic anomalies on the outcrop belts. One of those blocks hosted the so-called "Ripley Island" (Fig. 2), an area with reduced thicknesses of Silurian rocks and fauna different than those in other nearby Silurian rocks (Foerste, 1904; Kindle and Barnett, 1909). Parts of this field trip include areas both on and off the island, demonstrating the island's probable influence.

Paleogeography and Paleoclimate

The field trip area represents Ordovician–Silurian subtropical deposition on south-central parts of Laurentia between approximately 446 and 429 ma (Cooper and Sadler, 2012; Melchin and others, 2012). The area was located at about 25°S latitude in the subtropical trade wind belt, a latitudinal belt that is favorable for carbonate deposition, especially in the absence of major clastic influx (Lees, 1975; Heckel and Witzke, 1979). Despite the subtropical climate on most of Laurentia at the time, Late Ordovician global temperatures were substantially lower (Fig. 4) because of the advent of glaciation on Gondwana (Fig. 5). Although there is much uncertainty about the beginning of Ordovician glaciation, it was certainly present by mid-Richmond time, as indicated by the Ashgill lowstand interval (Fig. 6). Late Ordovician glaciation, often called the Hirnantian glaciation, took place on Gondwana (Fig. 5) and resulted in a major marine extinction and a sea-level drop of at least 50 m (Berry and others, 1995; Finnegan and others, 2011). The Ordovician-Silurian unconformity, or Cherokee unconformity, is largely the result of this major drop in sea level (Dennison, 1976; Ettensohn, 1994). As water is taken up into the ice sheets via precipitation, sea level drops, giving rise to a lowstand interval, but during any glaciation,

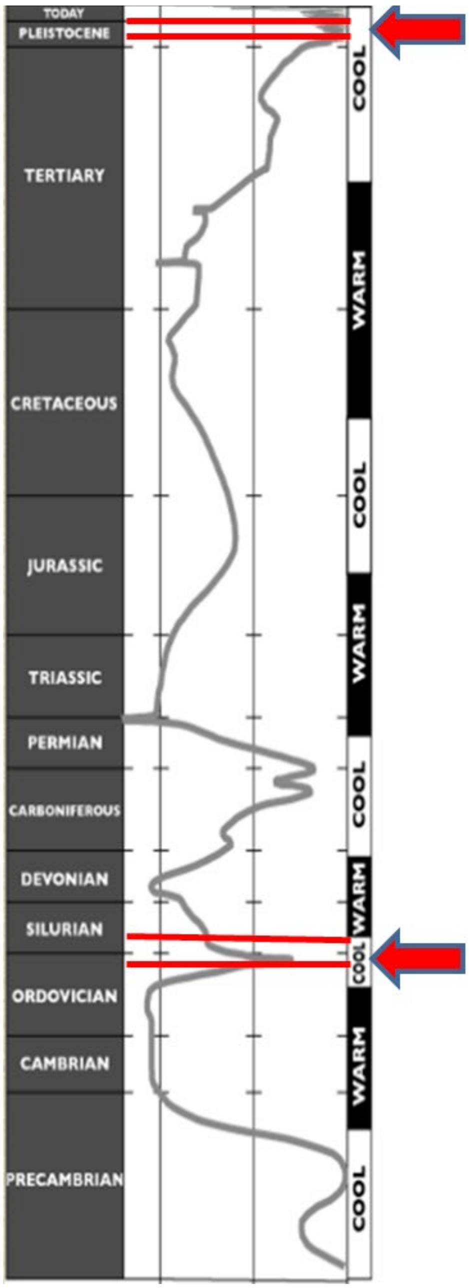

Figure 4. Late Precambrian–Phanerozoic global temperature curve. The red-centered arrows point to the time intervals and their approximate global temperatures, represented by the rocks and effects examined on this trip. The Ordovician–Silurian (446–429 Ma) and Pleistocene (less than 2 Ma) both represent cool or icehouse periods, characterized by glaciation and sea-level fluctuations. Modified from Scotese (2001); used with permission of the PALEOMAP Project.

glaciers will melt and then reform, generating multiple sea-level fluctuations on a global scale. One of those fluctuations—from higher sea level to lower sea level—is apparent in the sequence of rocks at stop 1 and is probably responsible for the Ordovician-Silurian unconformity that ends Ordovician parts of the section (Fig. 6).

Stratigraphic Framework

Because this field trip is taking place in the Tri-State area, each state has its own particular stratigraphic nomenclature. Moreover, the names that are commonly used, especially by fossil collectors, comprise a set of old Cincinnati stratigraphic names based on fossil zonation, which are not formal stratigraphic names at all. The old Cincinnati terminology (Fig. 7) was developed by Dr. Walter H. Bucher, a professor of geology at the University of Cincinnati. He later became famous for his work on cryptovolcanic structures, mountain building, and a pulsatory theory of Earth development, and was president of the Ohio Academy of Sciences, the New York Academy of Sciences, the American Geophysical Union, and the Geological Society of America. Bucher's stratigraphy was based largely on the distribution of fossils in the rocks around Cincinnati, and it was used across the entire Tri-State area for Ordovician stratigraphy. Because his stratigraphy was really biostratigraphy, however, and not suitable for geologic mapping, in the 1960s and 1970s when these states began remapping their geology, his nomenclature was abandoned in favor of lithostratigraphy. A copy of his original stratigraphy from Bucher and others (1945) for the rocks in this area is included as Figure 7, and a comparison of the old Cincinnati nomenclature with recent Kentucky and Indiana nomenclature, relative to the section at stop 1, is included as Figure 8. Because of its convenience and ease of use for fossil collecting, the old Cincinnati nomenclature continues to be used by many (see, e.g., Hartshorn and others, 2016) and is used for describing the section at stop 1.

Physiography

The present lay of the land, or physiography, is the product of interactions among different rock types, structures, and erosion during approximately 250 m.y. since the end of the Alleghanian Orogeny and the last uplift of the Cincinnati Arch. Because uplift and erosion were concentrated near the uplifted axis of the arch, younger rocks have been eroded away, revealing a core of older Ordo-

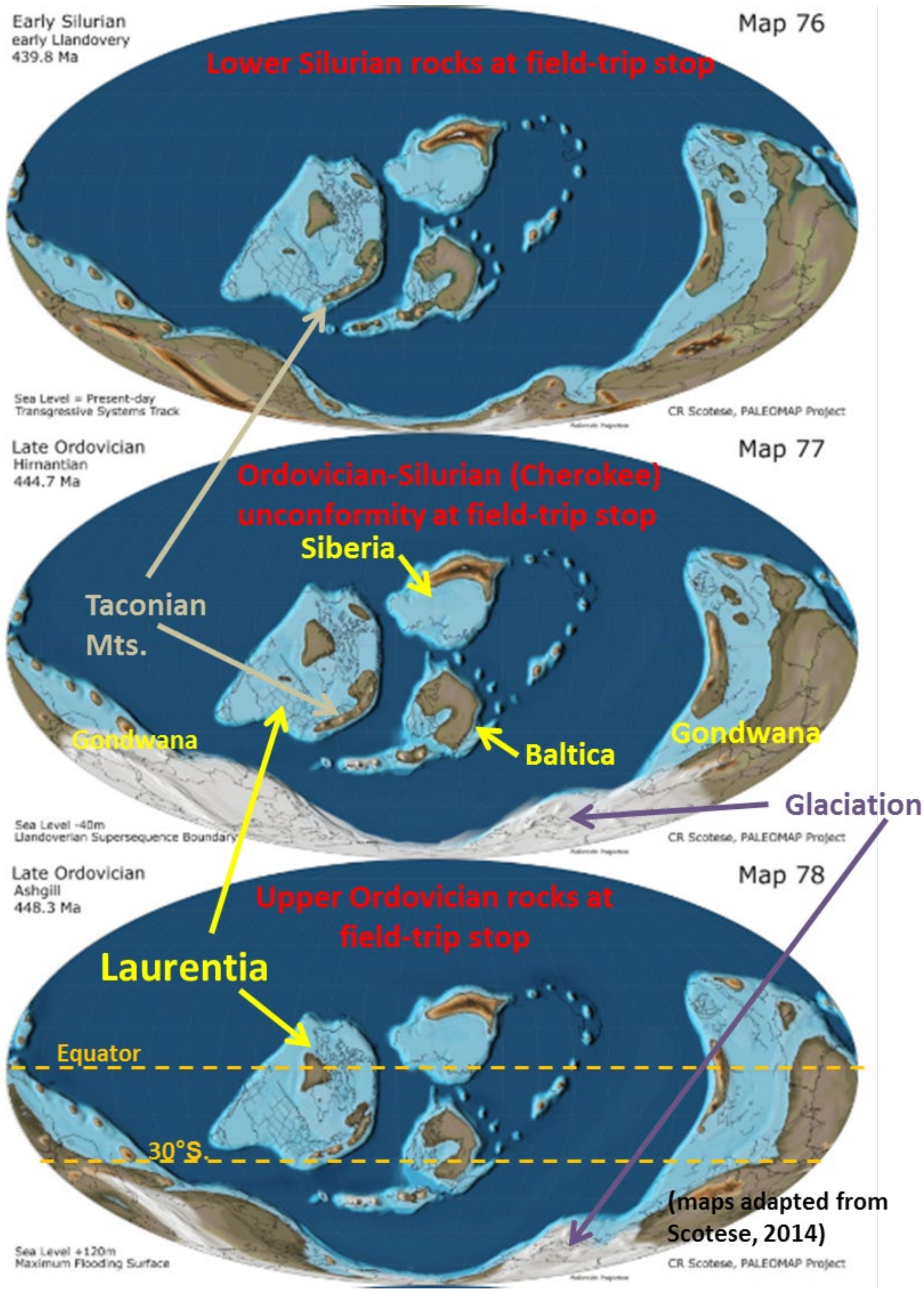

Figure 5. Paleogeographic reconstructions showing the location of major continents during the deposition of the Upper Ordovician–Lower Silurian rocks examined on this trip. Map 78 represents the position of Laurentia and nearby continents during deposition of the Upper Ordovician rocks examined on this field trip. Note the presence of glaciation on Gondwana, the southern continent; this time represents the beginning of Late Ordovician sea-level drawdown, the effects of which are present in the rocks at stop 1. Map 77 represents the time of maximum glaciation and sea-level drawdown and approximately correlates with the time of unconformity development at the Ordovician-Silurian boundary. This unconformity represents a gap in time at the unconformity of approximately 1.5 Ma. Map 76 represents a time when glaciation is nearly gone and approximately corresponds to time represented by the Lower Silurian rocks at stop 1. Modified from Scotese (2014); used with permission of the PALEOMAP Project.

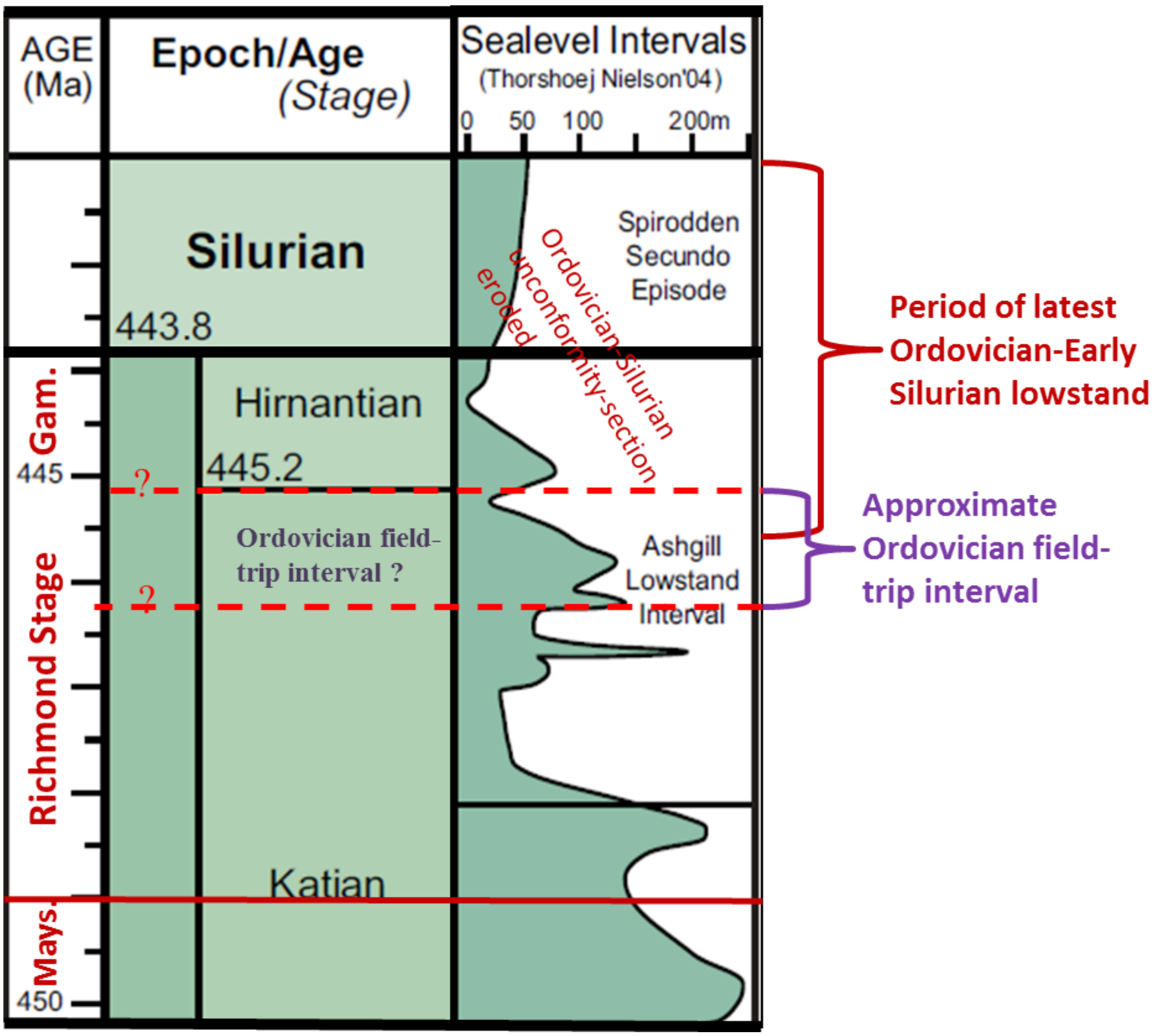

Figure 6. Absolute time scale and a sea-level curve for uppermost Ordovician parts of the section seen at stop 1. The interval contained within the red dashes represents the time interval (approximately 1 Ma) represented by Upper Ordovician rocks at stop 1. Parts of a sea-level highstand and declining sea level are recorded in the Upper Ordovician rocks at stop 1. Hirnantian (Gamachian) rocks are not represented here because of erosion or nondeposition during the major sea-level lowstand accompanying glaciation. North American stages (Maysvillian, Richmondian, and Gamachian) are shown in the far-left column. Adapted from Cooper and Sadler (2012) and Nielsen (2004); used with permission of Elsevier.

vician rocks exposed on top of and on the flanks of the arch itself (Fig. 1, cross section). The field trip area on the western flank of the arch is far enough updip from the arch axis, however, that Lower Silurian rocks are also exposed (Figs. 1, 8). The difference, however, between areas underlain by the softer Upper Ordovician shales and limestones and those underlain by the more resistant, overlying Lower Silurian dolostones is great enough that the two areas of rock generate different landforms, and hence two different physiographic provinces. The Madison, Ind., area is situated just at the border between these two areas: the Dearborn Upland and the Muscatatuck Plateau (Fig. 9). Madison itself is part of the Dearborn Upland, but the area has been greatly modified by river erosion and deposition. The Dearborn Upland is a highly dissected plateau underlain by softer Upper Ordovician limestones and shales. The region is a continuation of the Lexington Peneplain, and except for a thin veneer of pre-Illinoian till, the region is very similar to the Outer Bluegrass in Kentucky. In fact, several authors (e.g., Malott, 1922; Ray, 1974; Homoya and others, 1985) have suggested that the Kentucky

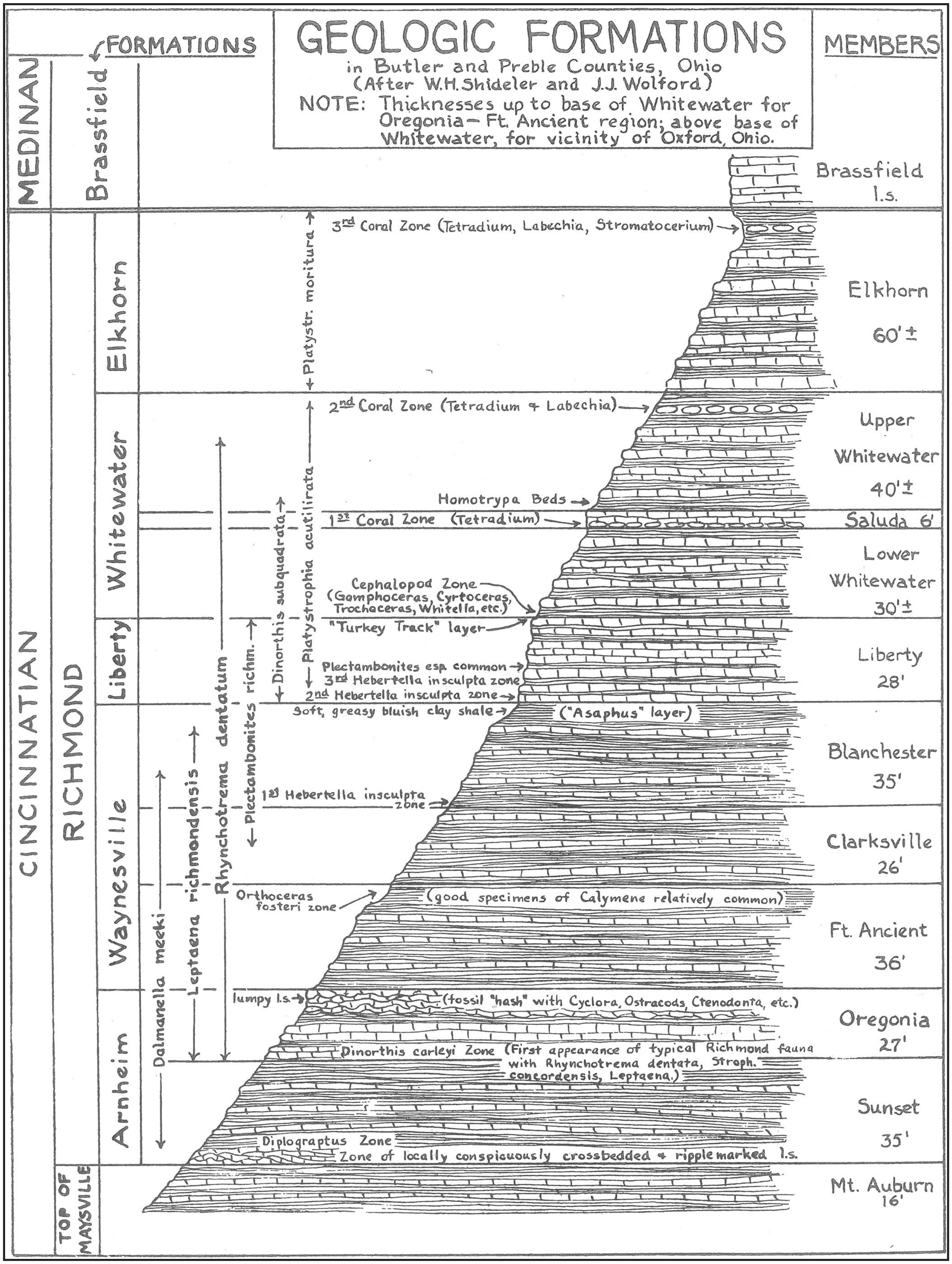

Figure 7. Bucher and others' (1945, p. 5) original nomenclature and fossil zones for Richmondian parts of the Cincinnati Group in and around Cincinnati. Stop 1 encompasses parts of the Blanchester Member of the Waynesville Formation, as well as all of the Liberty, Whitewater, and Elkhorn formations (see Figure 8 for comparison with recent lithostratigraphy). Used with permission of the Cincinnati Museum of Natural History.

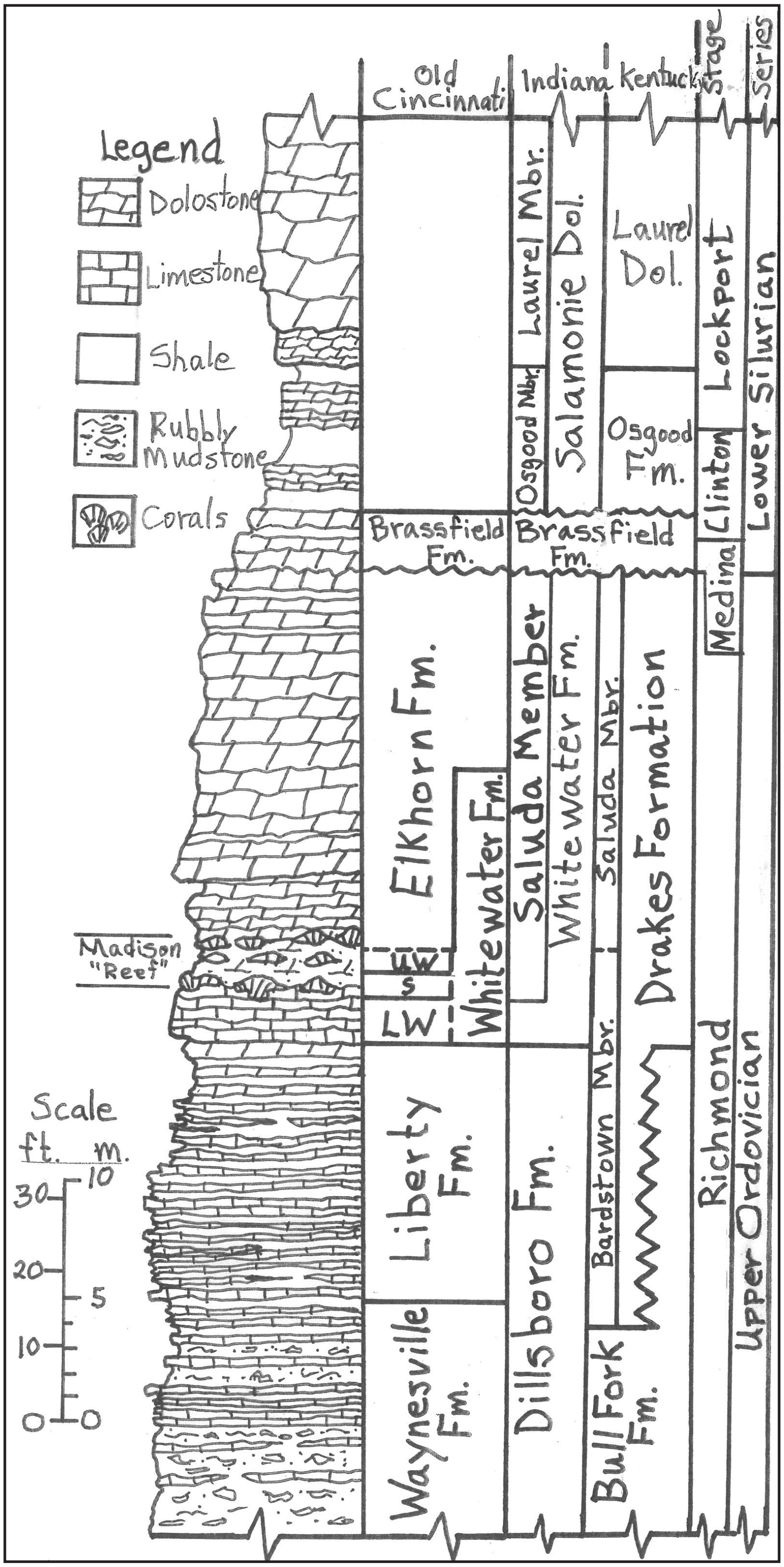

Figure 8. Field sketch showing the Upper Ordovician and Lower Silurian stratigraphy for rocks exposed along U.S. 421N on the northeast side of Madison, Ind. Three different stratigraphic nomenclatures are shown for comparison. LW = Lower Whitewater. S = Saluda. UW = Upper Whitewater.

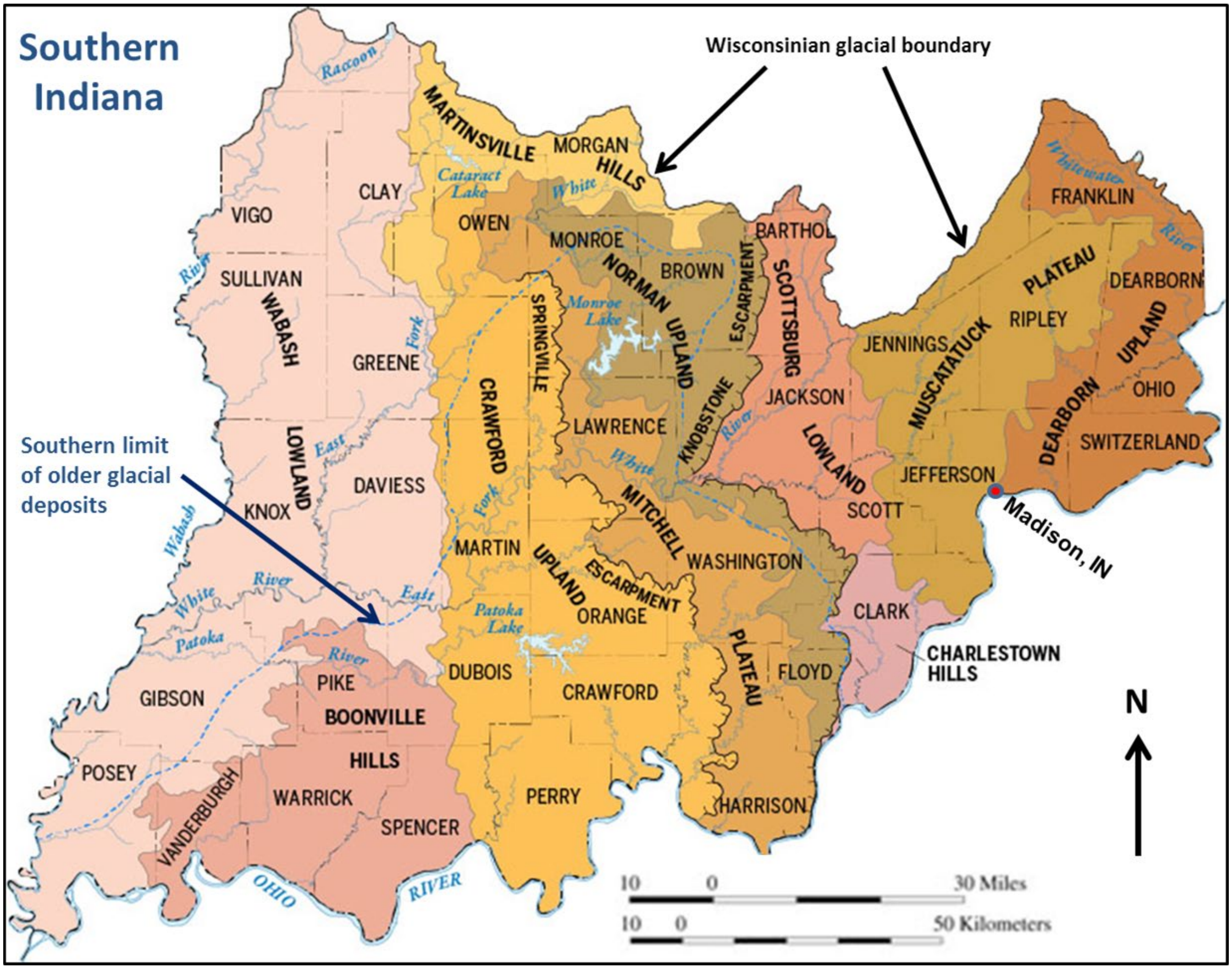

Figure 9. Physiography of southern Indiana, showing the location of Madison relative to the Dearborn Uplands and the Muscatatuck Plateau. Both physiographic areas are roughly equivalent to the Outer Bluegrass Region in Kentucky. From Gray (2001); used with permission of the Indiana Geological Survey.

Bluegrass Region continues uninterrupted into southeastern Indiana as the Dearborn Upland and Muscatatuck Plateau. This physiographic region is best observed at stop 1.

The Muscatatuck Plateau is a broad, relatively flat, west-sloping plain with steep-walled canyons entrenched by major streams; it is largely underlain by Silurian and Devonian dolostones. The top of the plain is defined by the more-resistant dolostones, which give rise to small-scale karstic features. The field trip will ascend a small escarpment, formed by some of the Upper Ordovician (Saluda) and Lower Silurian (Brassfield–Laurel) dolostones, moving from the Dearborn Upland to the Muscatatuck Plateau. This escarpment is best seen at stop 1, moving from the entrance of the park to Clifty Falls; the falls itself is part of a steep-walled canyon into the plateau. In Kentucky, this area would be included as the westernmost part of the Outer Bluegrass Region.

Local History

Brief History of Madison, Ind. Today, Madison, Ind., is the largest city between Cincinnati and Louisville on the Ohio River and has a population slightly greater than 12,000. Settlement in the area began in 1806, soon after the reorganization of the Indiana Territory into an area approximating the current size of the state. People of the Baptist denomination were prominent among the first settlers, and a lot of preaching was done up and down the river valley from Madison. On April 1, 1809, 700 acres of land was established as the town of Madison, named after President James Madison, but it was not until 1810 that Jonathan Lyon, John Paul, and Lewis Davis laid out the town. The first lots were sold in 1811 by John Paul, who is often credited with founding the town. John Paul was a pioneer who served in the Revolutionary War with George Rogers Clark and in the War of 1812 with William Henry Harrison. He was known around town as Col. Paul and established the first ferry between Indiana and Kentucky. Situated across the river from Kentucky, the town was a great spot for commerce and industry, and it grew rapidly; it was, in fact, the gateway for settlement in the vast Northwest Territory (Fig. 10).

By the 1820s, Madison had 123 homes and the population had grown beyond 1,000. Also during that time, stores and businesses lined the often-muddy dirt streets and livestock were frequently herded down Main Street. Construction of Michigan Road in the early 1830s made Madison an important transportation hub, linking the Ohio River with Indiana's interior and the rest of the former Northwest Territory. The Michigan Road, which started in Madison and ran to Michigan City, Ind., via Indianapolis, was the first "super-highway" in Indiana, and it did much to spur settlement and economic growth throughout the rest of Indiana. From 1836 to 1847, the first railroad, the Madison & Indianapolis Railroad, was built to connect the town to Indianapolis, and it ran for more than 10 yr. By the late 1850s (Fig. 10), the Civil War was on the horizon, and Madison's location across the Ohio River from Kentucky, a slave state, made it an important location in the Underground Railroad, which worked to free fugitive slaves. Prior to the Civil War, Madison attracted a great number of people of all classes, characters, and occupations. It was a new and growing town, as well as a commercial and cultural center, in a new and growing country.

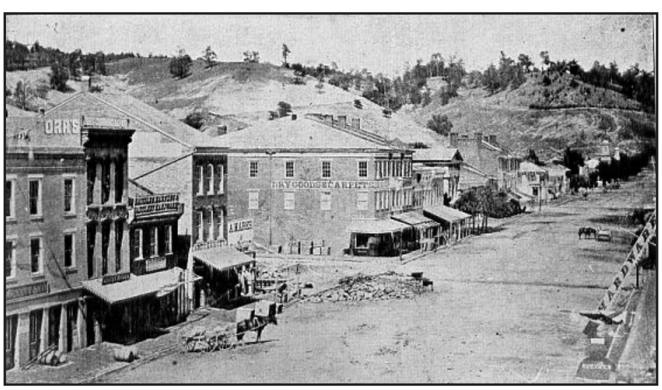

Figure 10. Madison, Ind., at about 1850. Note the hummocky topography behind the town, developed on the soft Upper Ordovician limestones and shales of the Dearborn Upland or Outer Bluegrass Region. From Jefferson County Historical Society (2011); used with permission.

The advent of the Civil War, however, changed much, and in 1862 the railroad was foreclosed and river traffic started to decline. With the decline of river traffic and the railroad, Madison's fortunes also declined, and it ceased to grow as it had in the past. After the Civil War, new railroads, which tapped into Madison's trade network, were built between Indianapolis, Cincinnati, and Louisville, and the city went into further decline. Today, Madison is an agricultural trading center that has taken advantage of its picturesque surroundings, a nearby state park, and past history to develop a substantial tourist industry.

Brief History of Clifty Falls State Park. Clifty Falls State Park is an Indiana state park on 1,416 acres in Jefferson County. On Oct. 27, 1920, citizens of Madison, Ind., gave the land for the park, 570 acres, to the State of Indiana at the suggestion of Richard Lieber (www.in.gov/dnr/history). Lieber was instrumental in founding the Indiana state park system and keeping the parks as natural as possible. With the centennial of Indiana's statehood in 1916, Lieber encouraged Indiana Gov. Samuel M. Ralston to start the State Parks Committee, and Lieber, as the chairman, and a 20-man committee started acquiring parks without any State funds.

A system of naturalist programs for Indiana state parks was started in 1927, and Clifty Falls was one of the first four with such a program.

In 1965, the park was more than doubled in size with the acquisition of adjoining fields from the Madison State Hospital.

The Clifty Inn first opened at the site in 1924. Guests at the inn could watch the local Civilian Conservation Corps in action during the Depression, building trails and walls within the park's scenic overlooks. First Lady Eleanor Roosevelt stayed at the inn. In 1974, a devastating tornado ripped through the park and destroyed a large part of the inn. The present Clifty Inn was constructed in 2006.

Stop 1

Frank R. Ettensohn and Benjamin F. Dattilo

Stop 1 is on U.S. 421N on the northeastern side of Madison, and begins at about the point where the highway bends toward the northwest (N38°46.56′, W85°21.83′). The prominent exposure on the northeast side of the road is about 3,600 ft long and ends at East Clifty Drive (Ind. 62).

The Upper Ordovician (Cincinnatian) section in the Tri-State area is typically divided into six sequences, or bodies of genetically related sedimentary units that are separated from each other by unconformities (Holland and Patzkowsky, 2007) (Fig. 11). The boundaries or unconformities are typically related to sea-level fall. The Madison section on U.S. 421N represents large parts of sequence C5, which is divided into a series of more or less distinct lithologies and faunas that represent an offshore (Waynesville) to onshore (Saluda) gradient of environments (Fig. 12); the old Cincinnati nomenclature is used (Fig. 8). The sequence begins with a major sea-level rise or flooding event that is represented by parts of the Waynesville, which reflect deeper, offshore environments. As sea level declined (perhaps because of glaciation) or the rate of sedimentation outpaced sea-level rise, the environments in this sequence become progressively shallower upward in the section. So the Waynesville represents deeper open-marine environments, still within the range of storm wave base (approximately 70 m); the overlying Liberty represents shallow open-marine environments within fair-weather wave base (approximately 10 m) and the transition to platform-lagoonal environments in the Whitewater; the Whitewater represents somewhat restricted platform-lagoonal environments and the transition to peritidal environments in the Saluda; the Saluda represents intertidal and supratidal environments, and there is evidence of

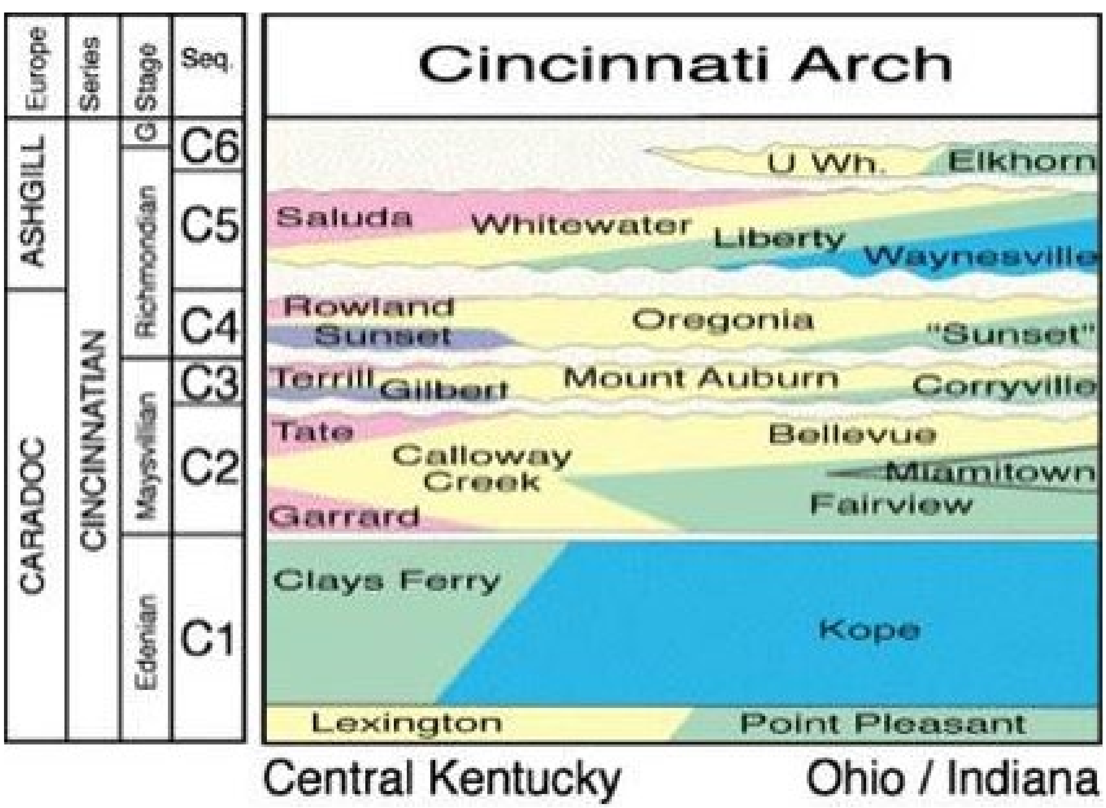

Figure 11. Standard sequences in Cincinnatian Series rocks from the Tri-State area. Upper Ordovician rocks at stop 1 represent most of sequence C5. Parts of underlying sequences are covered, and sequence C6 was probably lost to erosion on the Ordovician-Silurian unconformity. Sequence C5 shows a transition from deeper-water, offshore environments (blue) upward into very shallow onshore environments (pink). The succession of units (Waynesville–Saluda) represents a regressive, shallowing- or shoaling-upward sequence. The old Cincinnati nomenclature (Fig. 8) is used. From Holland (2017); used with permission.

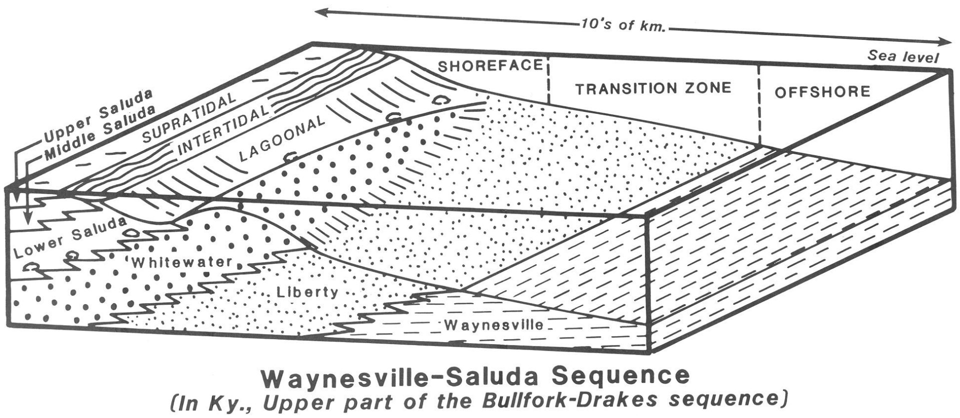

Figure 12. Offshore-to-onshore environmental interpretations for the Upper Ordovician rocks exposed at stop 1. Some of the interpretations are slightly different than those presented in the text. The circular bodies in the Whitewater–Saluda transition are coral biostromes. From Kepferle and others (1987).

exposure. Coral biostromes occur in the Whitewater-Saluda transition.

The lower 32 ft of the section represents the upper part of the Waynesville (Blanchester Member, Figs. 7–8) and are characterized by a fossiliferous, rubbly mudstone (Fig. 13). Some of the fossils are apparently in place, such as the bryozoan colony shown in Figure 14, but many are fragmented and have been churned up by storms or bioturbation. Beds become more regular in upper parts of the Waynesville, before a silty/shaly interval that defines the transition into the Liberty. The Waynesville-Liberty contact is marked by a distinct overhang of brachiopod-bearing limestones (Fig. 15). The overlying Liberty consists of very fossiliferous interbedded limestones and shales; the overall limestone content is about 50 percent. It represents a shallow, open-marine environment with a very diverse fauna, but uppermost parts of the unit exhibit unfossiliferous, blocky dolosiltites that reflect declining sea level and transition into platform-lagoonal environments. Trace fossils such as *Chondrites* and carbonized pelecypods are present locally. The sharp contact at the overhang between the Liberty and Whitewater probably represents a subtle disconformity and the initiation of a subsequence. Above the contact, three so-called "reefs" or coral/sponge biostromes are present (Fig. 16). A biostrome is a lenticular, blanket-like mass of usually massive, sedentary framework skeletons; here they are largely composed of corals and stromatoporoids. Biostromes like these are smaller and lack the relief and resistance to waves that true reefs would have, but these have nonetheless been called the "Madison reef." These biostromes are interpreted to have developed in shallow-water, nearshore environments, and many show evidence of having been overturned or transported, probably by storms. Most of the coral in these biostromes belong to the rugose coral genus *Cyathophylloides,* although some examples of the probable tabulate coral genus *Tetradium* are also present. In the old Cincin-

Figure 13. Fossiliferous rubbly mudstones from the lower Waynesville Formation at stop 1.

Figure 14. An in-place bryozoan colony and other fossil debris from the lower Waynesville Formation at stop 1.

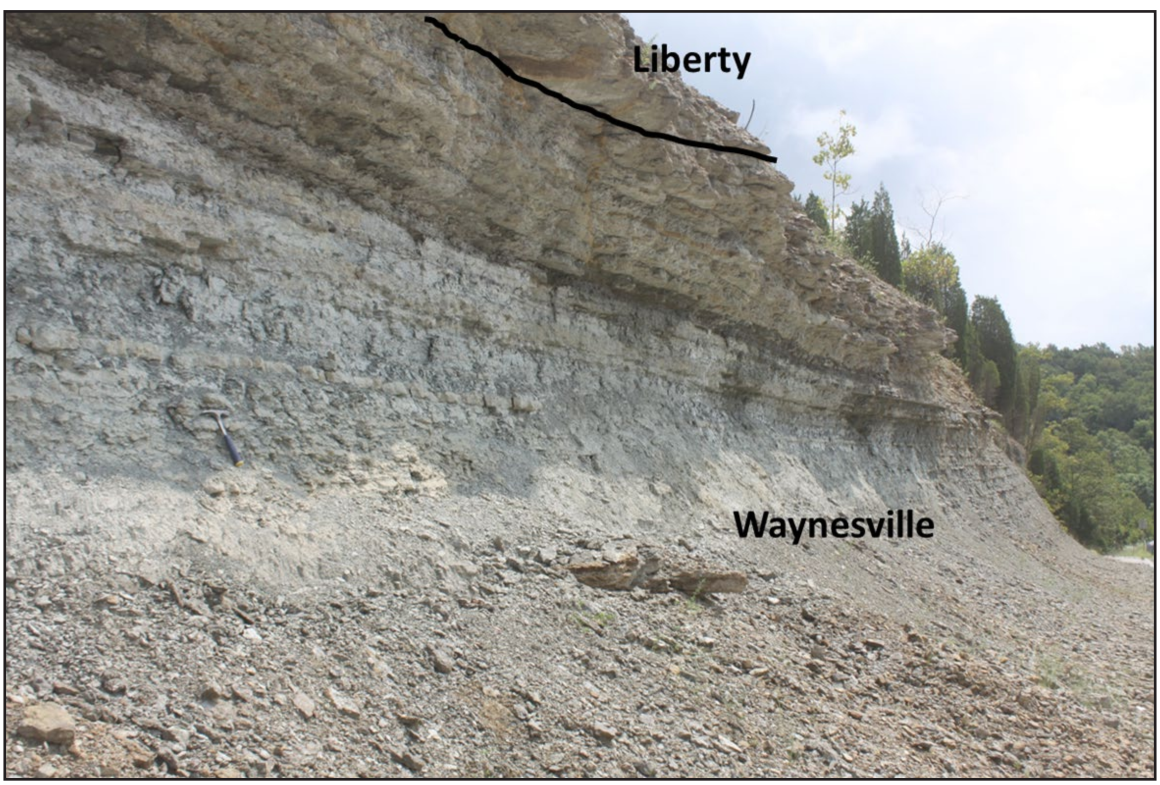

Figure 15. Waynesville-Liberty contact at stop 1.

nati nomenclature, there were three of these biostromal horizons—the Fisherville, Bardstown, and Madison reefs—each occurring in a different part of the section in more than 100 ft of section (Schmidt, 2000). The Fisherville reef occurred in the Saluda, the Bardstown reef in the upper Whitewater, and the Madison reef in the Hitz Bed of the Elkhorn (Fig. 7). At this stop, three "reefs" occur within about 10 ft of massive dolosiltite (Fig. 8). So either this section is an extremely condensed one containing all three reefs in a very short vertical interval, or the Madison reef occurs lower in the section and has an expanded vertical extent compared to equivalent reefs studied in nearby areas (Schmidt, 2000). In Indiana nomenclature, the Whitewater Formation includes all the rocks from the top of the Liberty (Dillsboro Formation) to the top of the Ordovician section, and all rocks above the lower Whitewater thin-bedded limestones, including the "reefs," are in the Saluda Member of the Whitewater (Fig. 8). No upper Whitewater (Fig. 11) is present in this exposure. The Saluda is composed of about 45 ft of massively bedded, unfossiliferous, laminated dolosiltites (Fig. 17) that weather to an orange-brown color. Horizons with occasional mudcracks and vertical burrows are found throughout, and the unit is interpreted to represent very shallow, intertidal environments during the time of major sea-level drawdown preceding the Hirnantian glaciation. Saluda dolostones are so resistant that they commonly form ledges or nickpoints in streams that can give rise to waterfalls. The Ordovician section is capped by the major regional Cherokee unconformity (Ettensohn, 1994) that separates Ordovician and Silurian rocks. Here the unconformity is very subtle, only recognized because of the contrasting golden brown color of the overlying Brassfield Dolostone. The unconformity probably has both tectonic and glacial-eustatic components (Ettensohn, 1994; Ettensohn and Brett, 2002). A subtle unconformity is also present between the Brassfield Dolostone and the Osgood Member of

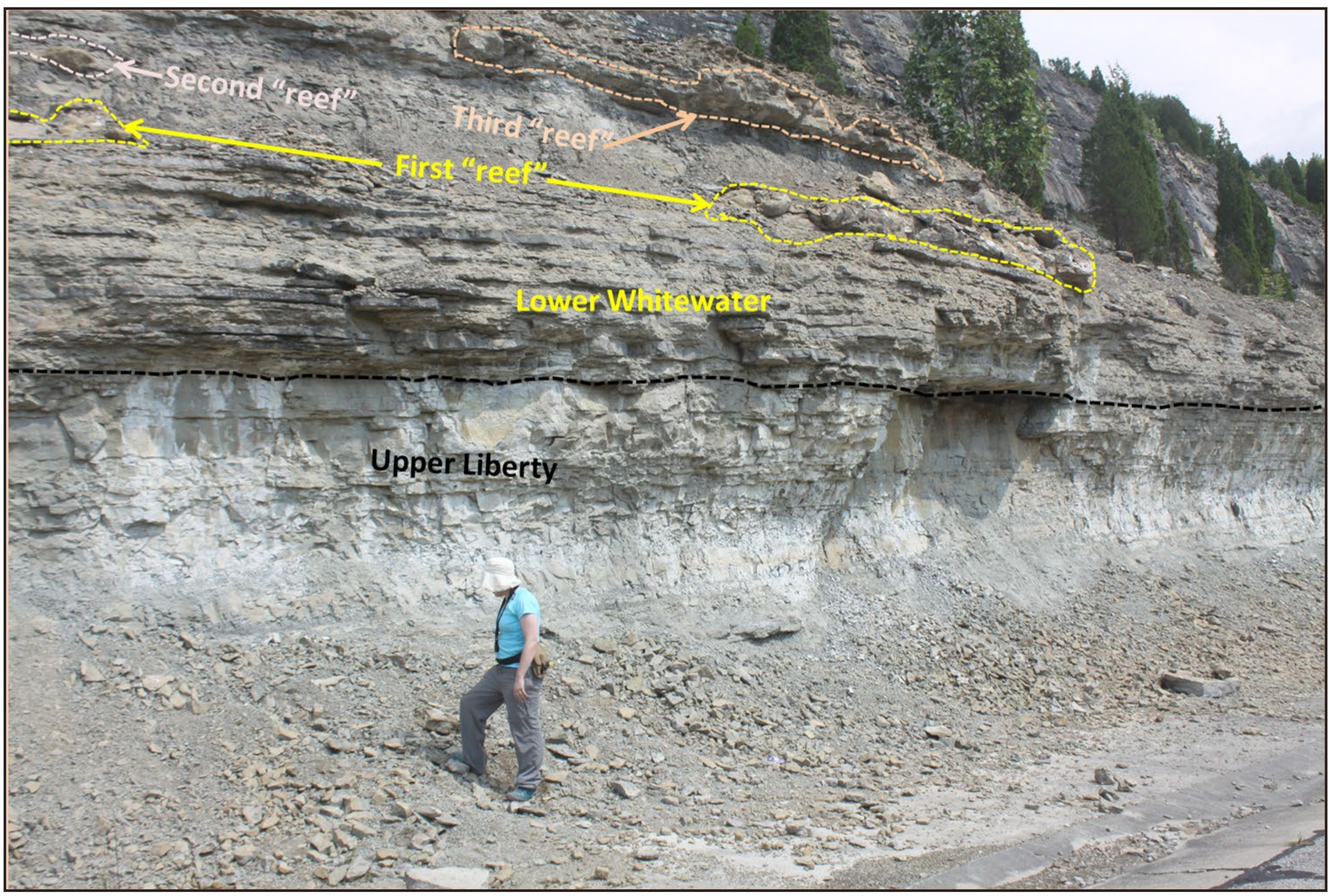

Figure 16. The Liberty-Whitewater contact (dashed black line) and the disposition of three "reefs" or biostromes in lower parts of the Saluda Member at stop 1.

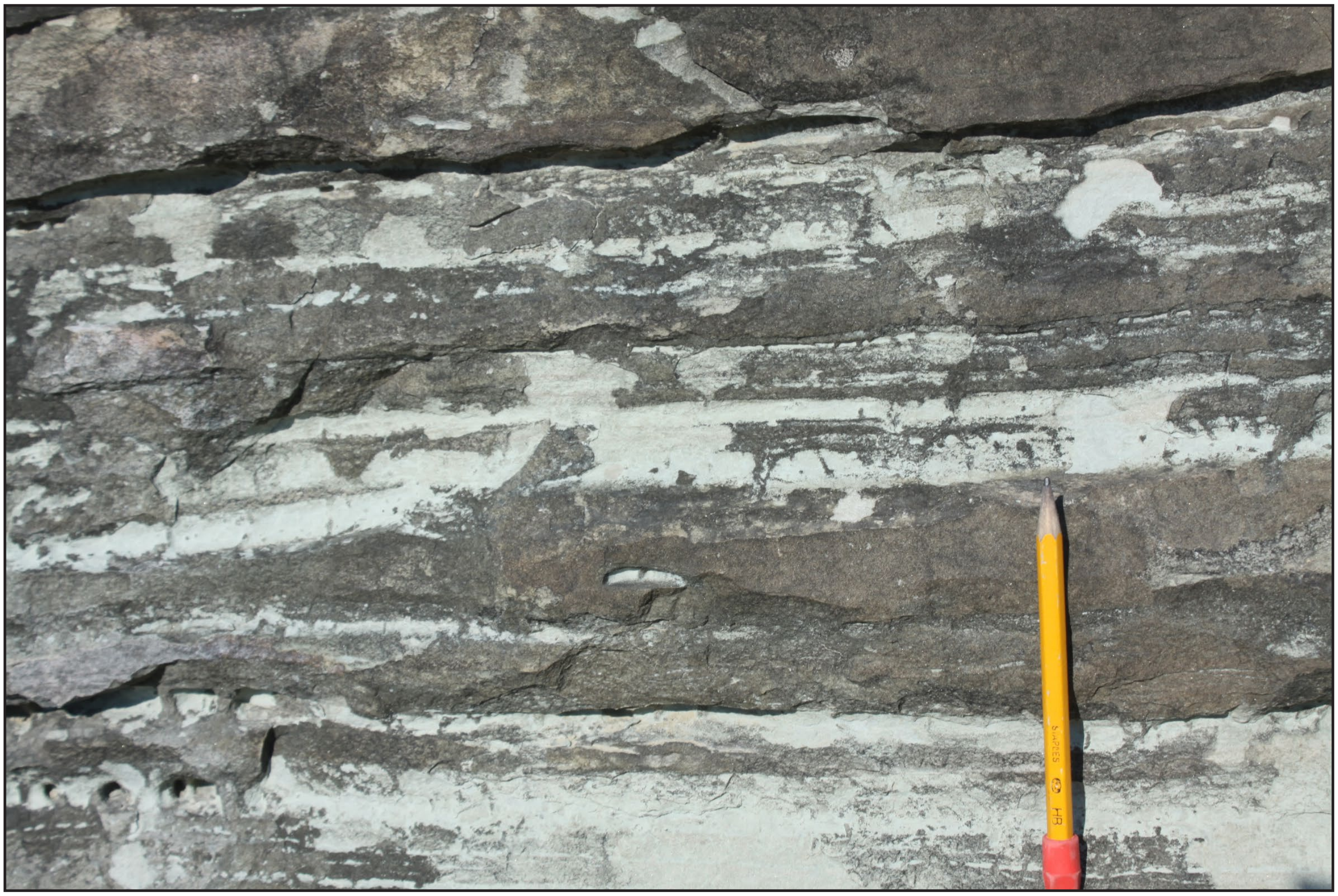

Figure 17. Massive laminated dolostones in the Saluda Member at stop 1. Thin dark lines extending down from some of the laminae are probably desiccation cracks.

the Salamonie Dolostone (Fig. 8), and this represents initiation of the Salinic Orogeny on the northeastern margin of Laurentia (Ettensohn and others, 2013) during Early Silurian time.

A detailed stratigraphic section, as well as pictures of common fossils, are shown in Plates 1–12.

Stop 2

Frank R. Ettensohn

At the corner of West Third and Mill Streets, on the southwest corner of John Paul Park, sits an unusual octagonal building constructed wholly of coral heads from the Madison reef (Fig. 18A). Nearly every head is of the genus *Cyathophylloides* (Figs. 18B–D). The building was constructed in 1913 and was used as a toolshed. Eight panels are embedded in the building's former windows, describing the history of Madison and of John Paul Park. The land was donated by city founder John Paul in 1819 for use as a cemetery, but was abandoned in 1839 in favor of a new cemetery. The former cemetery fell into neglect until 1902, when the local chapter of the Daughters of the American Revolution worked with the city to develop the former cemetery as a park named for John Paul.

Stops 3 and 4

David Dockstader and Benjamin F. Dattilo

Simplified Geology of Clifty Falls State Park, Indiana

Clifty Falls lies on the west side of the Cincinnati Arch. This means that the layers of rock dip (slope downhill) to the west so that going west from the park, the surface rocks become younger, and going east, the exposed surface rocks become older (until you get to Cincinnati). The uppermost or youngest layer exposed at Clifty Falls is known as the Laurel Dolomite. This rock is more resistant

Figure 18. The octagonal "coral house" at John Paul Park in Madison. A. Full view of the house. B. Close-up of coral heads and history panels. C. Close-up of one of the history panels. D. Close-up of one of the *Cyathophylloides* coral heads, showing its colonial nature.

to erosion than the rocks to the east and west of the park, so as erosion gradually wore away the rocks in the region, the more resistant Laurel formed a broad ridge running roughly north-south through present-day Madison and Clifty Falls State Park. This ridge created a drainage divide so that water falling east of the ridge drained east and water falling west of the ridge drained west. Water draining east joined a network of rivers, eventually running north through present-day Ohio and then westward across northern Indiana and Illinois, and is thought to have eventually joined the Illinois River to drain into the Mississippi. The main trunk of this preglacial drainage is known as the Teays River. During the ice ages, glaciers blocked this northern drainage, impounding water on the east side of the Laurel divide until it finally overtopped the divide at present-day Madison. The huge volume of impounded water rapidly rushed over the divide, cutting the channel of the modern Ohio River. This glacial history will be discussed more later in the field trip.

As the channel of the Ohio River developed, tributary systems like that of Clifty Creek also began to carve channels on the Indiana and Kentucky sides of the Ohio, feeding it with surface waters. However, these tributary streams could not compete with the volume of water from the huge drainage system of the Ohio and the rapid erosion of the Ohio channel. This left the channels of the tributaries around Madison, running over the Laurel, and then tumbling over waterfalls or down cascading rapids to get into the much deeper channel of the Ohio River.

To reach stops 3 and 4—Clifty Falls (Fig. 19) and Little Clifty Falls—drive to the north end of Clifty Falls State Park (Fig. 20). Via the North Entrance, from the intersection of U.S. 421 and Ind. 56, drive north on U.S. 421 for 3.8 mi. Turn left on Ind. 62 and go 3.9 mi, then turn left into the park. Drive straight (south) into the parking lot. Via the South Entrance, from the intersection of U.S. 421 and Ind. 56, drive west approximately 2 mi on Ind. 56 to the park entrance (just before the power plant). Turn right, drive all the way through the park (4.7 mi), and turn left into the parking lot. Either way, once in the parking lot, park as far south as space allows. Walk south into the area between the pavilion and the restrooms (we hope they are open; if not, there should be portable facilities in the parking lot) and look for familiar faces. A few steps farther will take you to an overlook of Clifty Falls. As previously mentioned, this falls was originally located where Clifty Creek tumbled over the edge of the Laurel into the Ohio River (Fig. 21). Since then it has migrated roughly 2 mi upstream through headward erosion. If you look into the gorge below the falls, you will see huge blocks of the Laurel that have fallen from the rim of the gorge. The Laurel contains many fractures, called joints. Water can easily enter these fractures, dissolving some of the rock and then freezing in the winter to pry blocks loose, so that they fall into the gorge. This mechanism gradually widens the gorge and also causes the falls to migrate upstream. Beneath the Laurel is the older Osgood Shale. The Osgood is a crumbly layer consisting mostly of compressed clay. Once the processes of weathering (disintegrating rock) and erosion (the transport of rock) have removed the overlying Laurel, they quickly work their way

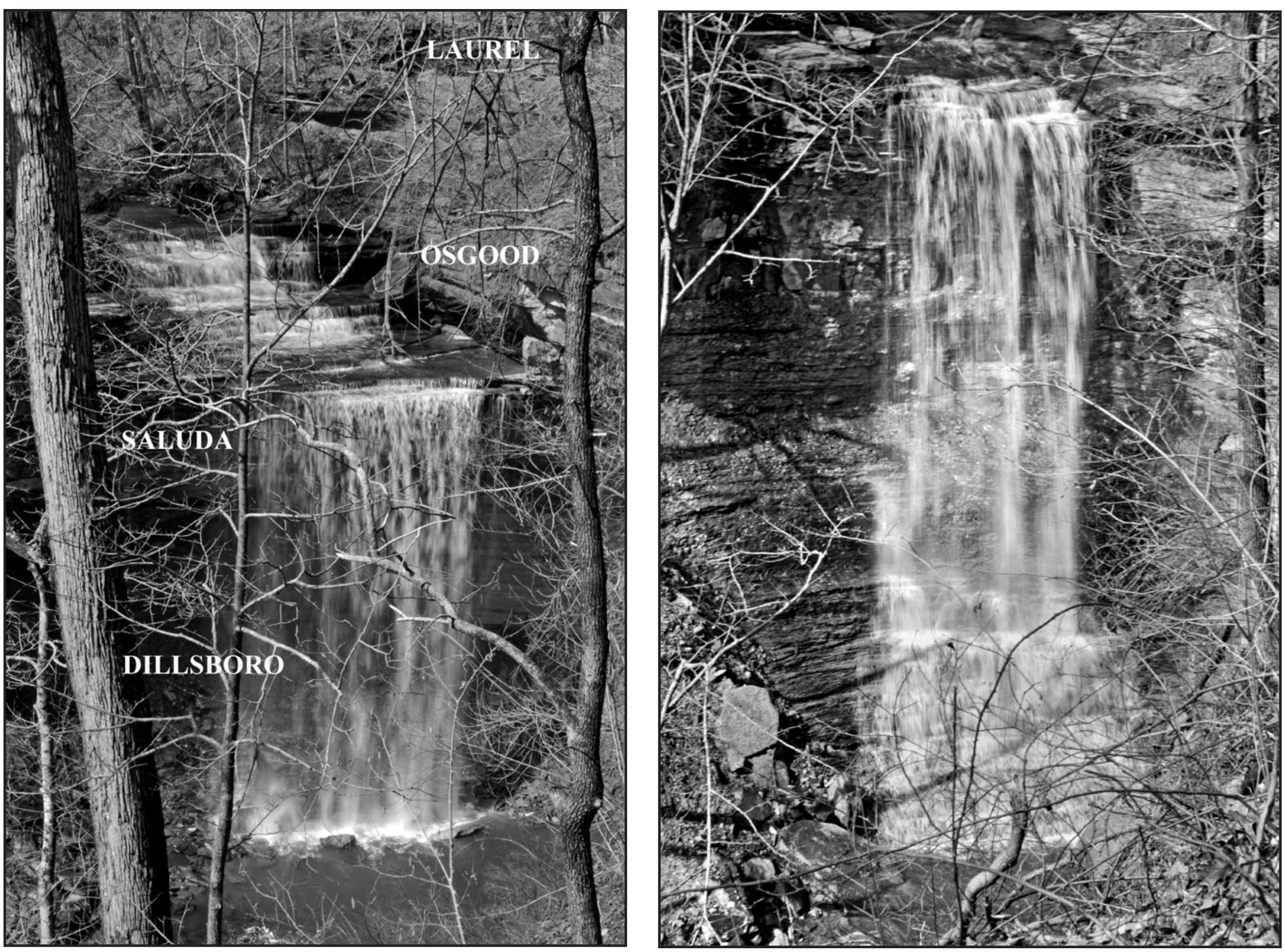

Figure 19. Clifty Falls (left) and Little Clifty Falls (right).

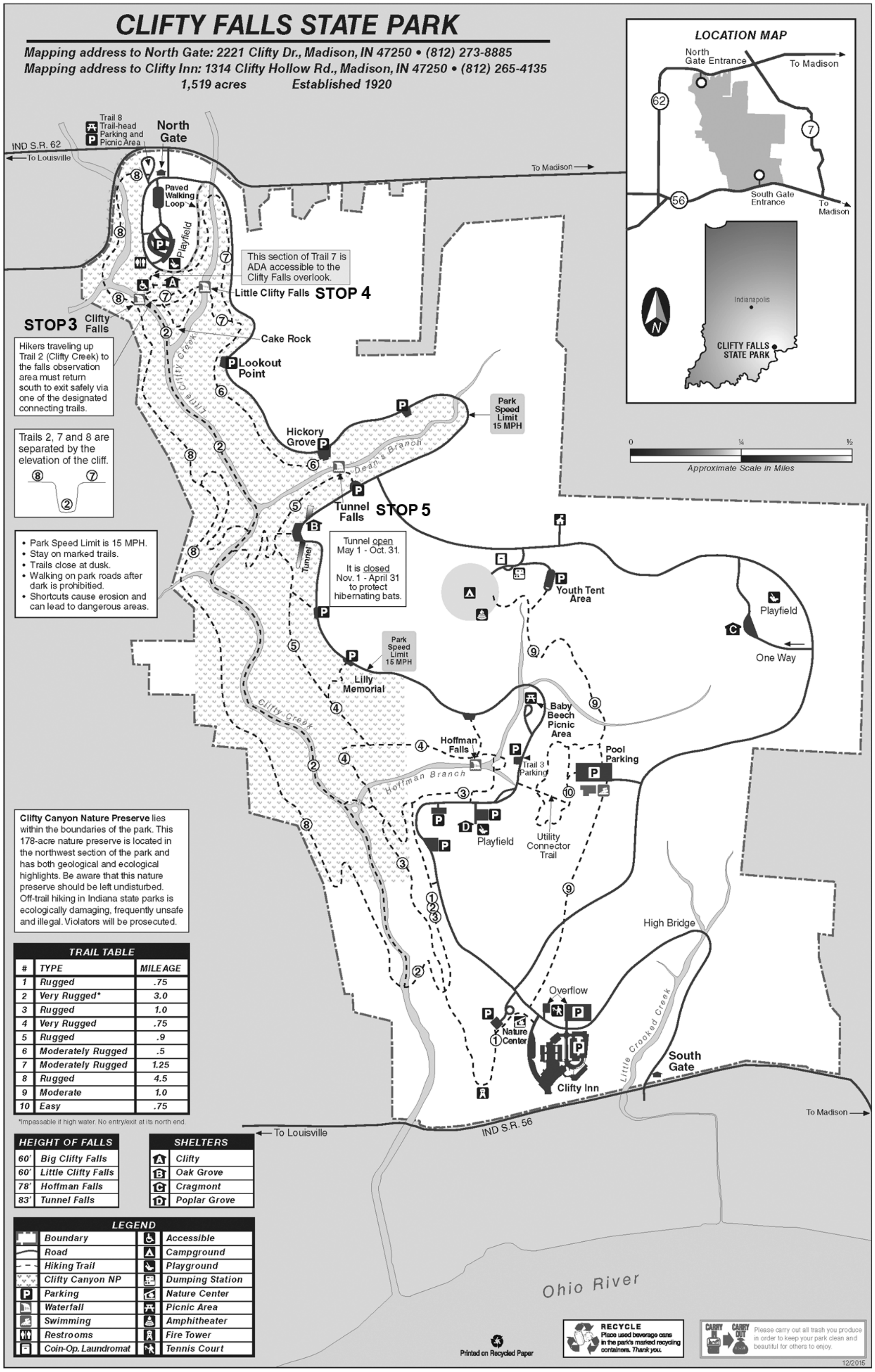

Figure 20. Clifty Falls trail map with stop locations. From Indiana Department of Natural Resources (2015); used with permission.

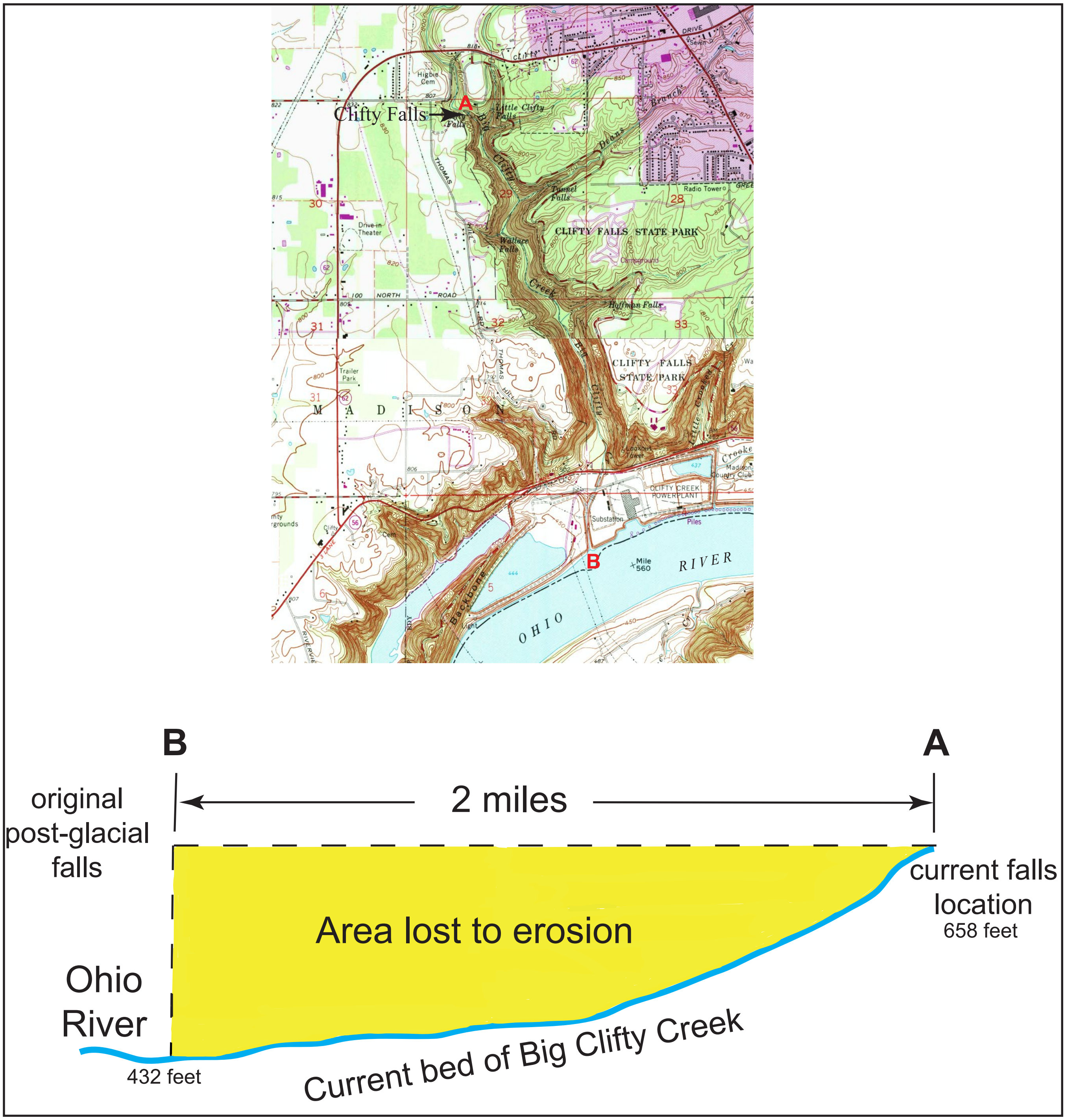

Figure 21. As Big Clifty Creek cuts down toward the Ohio River, it is eroding the soft shales undercutting the thin limestones of the Ordovician Dillsboro Formation until they can no longer support themselves and break away from under the thicker limestones of the Saluda Formation. Top: From U.S. Geological Survey (1953). Bottom: Courtesy of Indiana Department of Natural Resources; used with permission.

through the Osgood, resulting in a vertical cliff and sometimes even undercutting the Laurel.

Normally, the Brassfield Dolostone would underlie the Osgood as it does at stop 1 (Fig. 8), but in the park area, the Brassfield is missing. The absence of the Brassfield is apparently related to its position on the Ripley Island (red star on Figure 2). Because of uplift on the Ripley Island during initiation of the Salinic Orogeny in the east, the Brassfield was apparently eroded away and is substantially thinned in areas adjacent to the island.

So, underlying the Osgood is the uppermost Ordovician unit, the Saluda Dolostone Member of the Whitewater Formation (Fig. 8). Like the Laurel, the Saluda is more resistant to erosion. Unlike the Osgood, which is quickly removed once the Laurel has been breached, the Saluda is more slowly removed, and projects from the cliff wall (Fig. 22). It is the Saluda that caps the main drop of Clifty Falls below us (Fig. 22). Below the Saluda is the Dillsboro Shale (Liberty and overlying Whitewater in Figure 22), which, like the Osgood, is a crumbly shale that is easily removed, leaving the Saluda significantly undercut.

Notice the stonework along the rim of the gorge and in many of the park buildings. Most of this work was done by the Civilian Conservation Corps during the Great Depression in the 1930s (Fig. 23). Look at the wall to your right running upstream along the rim of the gorge. Once there was a trail next to the wall, but sections of the Laurel supporting the wall have fallen into the gorge, making the trail unsafe. Look to your left and you will see an adjacent viewing area that has been closed for the same reason. More areas with similar damage are visible ahead. This is the result of the natural widening of an initially narrow gorge. The bottom of the gorge from Clifty Falls toward the Ohio River gradually increases in width toward the Ohio into an older part of the gorge that has been exposed to weathering and erosion for a longer period. Even the bluffs of the Ohio are still quite steep compared to, say, the valley at Owensboro or Paducah, suggesting that this is a newer section of the Ohio River.

Turn around and exit the viewing area using the wooden steps, and then turn right. On your right you will see a sinkhole that was exposed when a block of the Laurel fell off. Sinks usually form when two fractures intersect. The intersection acts like a funnel in a drain, channeling water into the hole and dissolving away the rock. Walk toward the creek and around to the right. Here, the Laurel is about face high to the right, but below the Laurel the Osgood was eroding away, leaving the Laurel undercut, so concrete has been added to stabilize this section. In front, a concrete wall blocks the trail. Once, a wooden staircase led down to the bottom of the gorge. By the mid-1980s, this staircase was rather rickety, and it was replaced by a new one a bit closer to the falls. Unfortunately, the rocks above the staircase were not adequately examined, and just a few years later after a heavy rain a rockfall/landslide destroyed the staircase and left this end of the falls viewing area unsafe.

Go back up the stairs and follow the path on the right. Soon you will come to Cake Rock, a piece of the Laurel separated from the surrounding rock by intersecting fractures and left behind when the rest of the rock eroded away (Fig. 24). Continue to the stairs ahead and go down the stairs and across Little Clifty Creek. The best views are from the far side, looking back at the falls. In the winter there is often a column of ice the full height of the falls. This falls is defined by the same rock units seen at Clifty Falls, and headward erosion has slowly moved this falls from its original location at the junction with Clifty Creek.

Return to your cars and drive to Lookout Point. Here is a great view back up Clifty Creek to Clifty Falls. This is also a good place to observe that although there is a trail along the west side of the gorge, there is no road, no streams entering the gorge, and no waterfalls. A look at the trail map (Fig. 20) will confirm this, and you will see that there is only a narrow strip of parkland on this side of Clifty Creek. The land immediately west of the park has been used as farmland, and a number of private homes are also on it. This is a direct result of the underlying geology. Remember that the rocks here dip or slope to the west. Both surface and groundwater tend to run downdip, so surface water east of Clifty Creek tends to coalesce into streams draining into Clifty Creek. Groundwater will percolate through pores and cracks in the rocks until it hits a relatively impermeable layer like the Saluda, and then it runs downdip until it comes out as springs draining into Clifty Creek. In the winter, the eastern wall of the gorge is full of icicles and ice pillars hanging from the Saluda, formed as the spring water freezes. At the same time, the bedding planes of the rocks form planes of weakness, encouraging rocks on the eastern wall to slide downdip into the gorge; for rocks to slide on the western side would require them to slide updip, which isn't going to happen. Hence, the

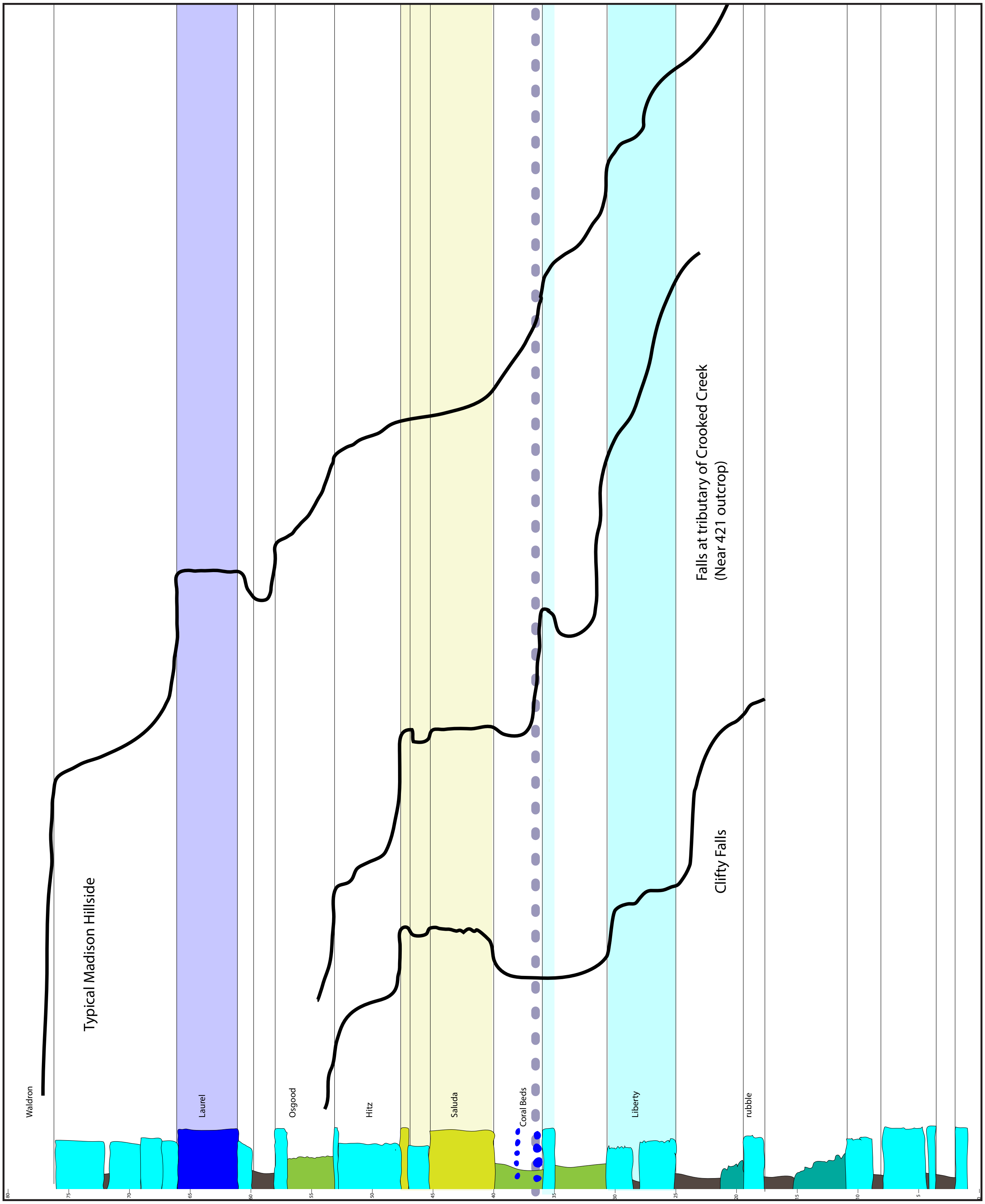

Figure 22. Typical landform slope profiles for areas around Madison relative to the stratigraphy. Notice the influence of the resistant dolostone and limestone ledges in the area. Diagram by Benjamin F. Dattilo.

western wall is much more stable and suitable for development than the eastern wall.

From Lookout Point, drive south to the Tunnel Falls parking area (if you get to Oak Grove you have gone one parking area too far) and walk down the steps to the falls viewing platform. The same rock units are here as at Clifty Falls, and Deans Branch runs over the Saluda and drops off the edge, creating Tunnel Falls (Fig. 25). Here again the Saluda is undercut so that you can actually walk behind the falls without getting wet. If you're on the platform and turn away from the falls, you will see that you have crossed a flat ledge. Walk along this ledge to the right, which was built for a railroad. The engineers who planned this paid attention to the geology. The ledge here sits on the firm, secure Saluda, which was already partly exposed from natural erosion. All that was necessary was to break up a little more of the Laurel and then knock the pieces over the edge along with some of the soft, crumbly Osgood. Most of this work could be done with just picks and shovels. The goal of this project was to make a rail connection from tracks along the Ohio River up to the top of the Laurel and on to Indianapolis, using the natural grade along Clifty Creek and Deans Branch. The turn from Clifty Creek to Deans Branch was a little too sharp for a train, and the obvious solution was to simply cut the corner. The engineers decided to do this with a tunnel, and the easiest place to cut the tunnel was in the Osgood, between the Saluda below and the Laurel above. This meant removing the soft, crumbly Osgood while leaving a naturally strong roof of Laurel and a solid base on the Saluda. The tunnel is open May 1–Oct. 31 and closed Nov. 1–April 31, but when it's closed you can still hike to the entrances. The closing is to avoid disturbing hibernating bats.

Stop 5

Ray Daniel and Frank R. Ettensohn

Broughs Trace—The Train Tunnel

There were actually two tunnels in the Clifty Creek Gorge, but to understand how these tunnels came to be, the background history of the railroad that was started, but never finished, must first be understood. All stories have a beginning, and this one began in 1837.

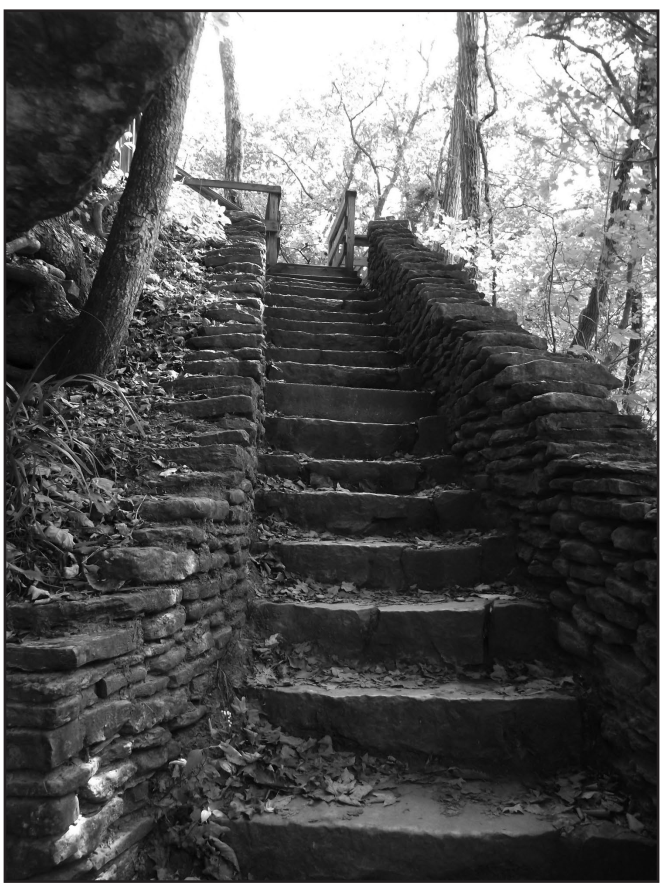

Figure 23. CCC project stairs and wall trail, Big Clifty Falls.

Figure 24. Cake Rock.

Indiana in 1836 was still on the frontier, but growing rapidly, with a population of some 200,000, mostly in the southern part of the state, calling the state home. There was no transportation infrastructure other than the waterways, however, to allow the movement of goods and people. The 1836 Internal Improvement Act of the Indiana General Assembly was intended to correct that problem. Signed into law on Jan. 27, 1836, by Gen. Noah Noble, governor of Indiana, it authorized borrowing $10 million to fund the construction of eight projects: three canals; one macadamized turnpike; two turnpikes (or railroads), depending on the results of surveys; the removal of navigational obstructions between Vincennes and the mouth of the Wabash River; and a railroad from Madison to Indianapolis. Madison was at the time the largest city in Indiana, and this may have influenced some of the governmental largesse. Most of these projects were never begun, or only partially built because of the financial Panic of 1837. Borrowing this enormous sum, equal to one-sixth of all the wealth in the state, from English interests nearly bankrupted the state (Esarey, 1915). By 1841, the State had turned over most of the projects, except for the Wabash and Erie Canal and the M&I, to its English creditors in exchange for a 50 percent reduction of the debt (Duden, 1904). In 1846, unable to pay even the interest on the remaining debt, the State repudiated the debt, an act that ruined Indiana's credit for 20 years (Esarey, 1915).

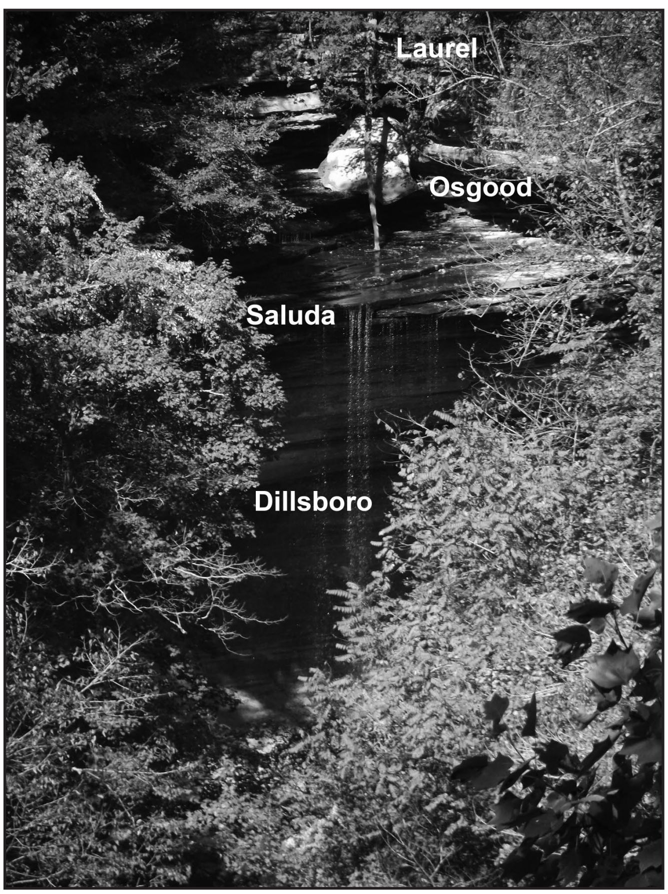

Figure 25. Tunnel Falls.

The Madison and Indianapolis, originally chartered by the Indiana General Assembly as the Madison, Indianapolis & Lafayette, would be the first railroad built in the state of Indiana and just the third to be built west of the Alleghenies. Only the building of the Lexington and Ohio, completed on April 14, 1831, and the Pontchartrain Railroad, completed on Aug. 15, 1832 (Sulzer, 1962), preceded it. Its corporate history is complex and would not be of much interest to geologists, but suffice it to say it ended up as part of the Pennsylvania Railroad, then Penn Central, and was ultimately a part of Conrail before being cast aside and bought by the city of Madison, Ind.

Surveys were immediately conducted upon the passage of the Internal Improvement Act to locate the line of road. The State began construction of the M&I at North Madison in 1836. The first rails were laid in August 1838 and they reached the town of Graham, Ind., 17 mi distant, on Nov. 29, 1838, and the line was immediately opened for business between these points. On April 27, 1839, the State of Indiana, in severe financial difficulty, leased the M&I to Robert Branham, Elias Stapp, D.C. Branham, and W.H. Branham, who continued in charge until June 1840. Under the terms of the lease, the State was to receive 40 percent of the gross receipts, the lessees to bear all the expenses of operating. The expense was not very great, as R.J. Elvin, who was connected with the road for more than 50 yr, did all the clerical work for the road, and Bartholomew Tierney did all the blacksmithing and repair work necessary in those days. John G. Sering, the state agent, was on all trains to look after the interests of the State. The trains would leave North Madison in the morning and run to Graham, returning in the evening. The gross receipts the first month were $849.38, and for the first 15 mo were $15,702, which was a good showing in that period. The next lessees were John G.

Sering and William Bust, from June 1840 to June 1841, when the State again took charge of the M&I (Sappington, 1916). There was little choice but to do this after a State investigation found that $2 million had been embezzled (Burns, 2017).

This time the State pushed the rails to Queensville, 27.8 mi from Madison, before the funds were exhausted and the work was once again stalled. This time it was John Woodburn, Victor King, and George W. Leonard, of Madison, who had started a bank in 1841, who aided the State. In a time when banks still printed their own bank notes, they issued bills (called Woodburn's bank bills) and assisted the State in building the road to Scipio, 3 mi farther north. On Feb. 21, 1843, the State sold the railroad to the Madison & Indianapolis Railroad Co., N.B. Barber, president, for $600,000, who gave mortgage to the State for the full amount, but by manipulation the company got it from the legislature for $75,000 in 5 percent State bonds worth on the market about 50 cents on the dollar, making the net cost $37,500. It was considered a clear case of thievery from start to finish. The State paid $1,624,291.93 for the building and equipment of the line to Queensville, of which $62,493.21 was from tolls. The owners of the road then completed it to Indianapolis (Sappington, 1916). The above is included to illustrate the entrepreneurial spirit of the times and to show just how many railroads were (or were not) built! For the record, here is a brief timeline of when M&I track reached important points on its line of road (Sappington, 1916):

- Graham, 17 mi from Madison, Nov. 29, 1838
- Vernon, 22 mi from Madison, June 6, 1839
- Queensville, 27.8 mi from Madison, June 1, 1841
- Scipio, 30.3 mi from Madison, June 1, 1843
- Elizabethtown, 37.3 mi from Madison, September 1843
- Columbus, 44.9 mi from Madison, July 1844
- Edinburg, 55.4 mi from Madison, Sept. 8, 1845
- Franklin, 65.5 mi from Madison, Sept. 1, 1846
- Indianapolis, 86 mi from Madison, Oct. 1, 1847.

With the railroad to augment the steamboat trade on the Ohio River, Madison had every reason to believe the future was bright. Pork packing houses and other industries rapidly developed in the area, and the city soon controlled the trade of the region (Sappington, 1916). As the railroad industry developed, however, other railroads built lines to Indianapolis and other cities that were shorter, and thus less expensive to use, than the Madison and Indianapolis. This broke the monopoly held by the M&I on traffic to Indianapolis. Over time, many of the businesses relocated. Still, after 184 years, most of the 86 mi of the Madison and Indianapolis is still in service (Fig. 26).

The Cut

The principal feature of the Madison and Indianapolis was the cut (called an inclined plane or incline at the time of its construction), built to allow trains to climb from the Ohio River at Madison to North Madison at the top of the bluff, 413 vertical feet above Madison. The M&I railroaders generally called it The Hill. The incline required one large fill and two large cuts, one of 100 ft and one of 65 ft (Sappington, 1916). The climb up the hill was 7,012 ft long at a grade of 5.89 percent, which is a rate of 5.89 in. every 100 ft (Sappington, 1916; Old Madison, 2011). That is an unbelievably steep grade for a railroad main line. This grade and the 5 percent grade on the Norfolk Southern at Saluda, N.C., are currently the steepest grades in the United States. Both are currently out of service.

Construction of the cut required the efforts of three contractors employing the labors of hundreds of Irish emigrants (Cahal, 2016), teams of horses and wagons, tons of black powder to blast through as much as 115 ft of limestone, and 5 yr. By the end of construction in 1841, roughly 500,000 tons of soil and rock had been removed, a remarkable feat for the time. A Grand Blowout and Banquet was planned. The first train up the incline was a celebration train that carried the former governor of Indiana, Noah Noble, and other luminaries up the incline to North Madison—by horsepower—on Nov. 3, 1841 (Sappington, 1916; National Park Service, no date). From North Madison to Graham and back they rode behind a steam locomotive named *The Elkhorn* at the grand speed of 8 mph. *The Elkhorn* was borrowed from the Louisville and Portland, delivered by riverboat to Madison, and pulled up the incline by five yokes of oxen power. This was necessary because the M&I's first locomotive was tossed overboard at sea by the ship's crew

Figure 26. The Madison, Ind., Railroad Station. It was built in 1850 at a cost of $4,094.32. From National Park Service (no date).

in order to save the ship during a storm (Sappington, 1916). Stables were built at the foot of the cut. Eight horse hitches were used to raise cars on the grade, with gravity and handbrakes used to lower the cars from 1841 until 1848, when a steam locomotive successfully negotiated the hill (Sappington, 1916). These were handbrakes operated by a brakeman, the advent of Westinghouse Air Brakes still being several decades into the future.

A duplicate of the locomotive was ordered to replace the one lost at sea. Like the original locomotive, this one was built by the Baldwin Locomotive Works in Philadelphia, Pa. It arrived in March of 1839, featuring four pistons, and was named *The Madison.* Its first trial run occurred on March 16, 1839, over the finished part of the railroad, and it was placed into service in April 1839. In 1841, it proved to be too light to provide the traction needed to pull cars up the incline, however, unable to pull more than one car at a time up the incline. Twenty more locomotives were bought between 1841 and 1851, but they fared little better than *The Madison,* although they were satisfactory operating on the rest of the M&I (Anderson, 2005). Disappointment with this state of affairs led to the purchase in 1847 of M&I locomotive No. 11, *The M.C. Bright* (Fig. 27). *The Bright* had five cylinders: two that operated as those on a regular locomotive; two mounted vertically above the boiler connected to a crankshaft that powered a cogwheel that meshed with a rack placed up the middle of the tracks from Madison to North Madison, enabling its use on the hill; and the fifth cylinder that raised and lowered the cog wheel (Sappington, 1916; Sulzer, 1962; Anderson, 2005). With the success of *The Bright,* the M&I rebuilt the Marion into a cog locomotive and renamed her *The John Brough,* giving the railroad two cog locomotives to negotiate the incline (Anderson, 2005). It was not, however, a perfect system. The cog would sometimes disengage

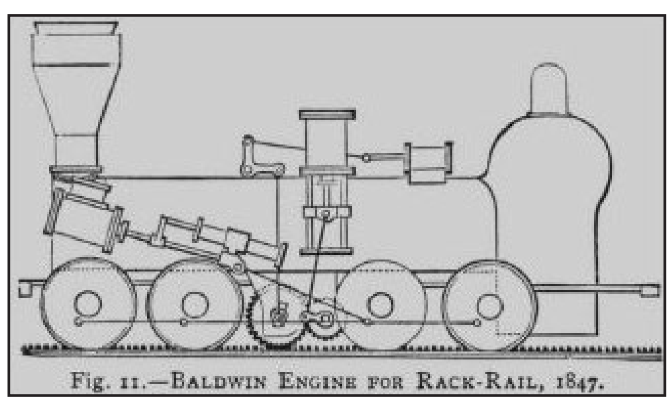

Figure 27. Line drawing of the *M.G. Bright*. From Baldwin Locomotive Works, Burnham, Parry, Williams & Co. (1881). Courtesy of Christian Halpaap of Hohenhameln-Bruendeln, Germany.

and send the locomotive hurtling down the hill at breakneck speed. The distinctive sound this made called Madison residents to gather at the bottom of the hill to observe the spectacle (Figs. 28–29)—and to offer any needed assistance, of course (Wright, 2003). Cog railroads like these can still be seen at Mount Washington, N.H., and Pikes Peak, Colo. They, of course, are modern, well built, and vastly safer versions of the M&I example.

The M&I was forced into receivership and was sold by a federal marshal on the steps of the Jefferson County courthouse on March 27, 1862. The next day, its assets were transferred to the Indianapolis and Madison Railroad Co., who issued its securities to the M&I's creditors as a reduced settlement of their claims against their predecessor.

Reorganization and changing the name of the company did not improve the company's fortunes, and the end of the Civil War found it in dire financial shape. Throughout the course of the war, the Jeffersonville Railroad had been buying up the common stock of the Indianapolis and Madison. At a board of directors meeting early in 1866, the Jeffersonville Railroad elected a majority of its candidates to the board. On May 1, 1866, the I&M was merged into the Jeffersonville Railroad to form the Jeffersonville, Madison & Indianapolis Railroad Co. (Anderson, 2005).

With the creation of the JM&I came the solution to using conventional steam locomotives on Madison Hill. Reuben Wells, the master mechanic of the JM&I, designed a locomotive that would have, by virtue of its 56-ton weight, the specific capability to conquer the incline without the use of the rack and pinion system. His design was built in the company's Jeffersonville Shops in 1868 and was named after its creator (Fig. 30). As built, *The Reuben Wells* was a wood-burning locomotive equipped with both conventional hand brakes and steam brakes that clamped the rails and carried water for its boiler in a saddle tank over the boiler and two large cylinders above the drive wheels to add additional weight for increased traction. In its first test, *The Reuben Wells* pulled itself and eight coal cars weighing 210 tons up the incline to North Madison at an average speed of 6 mph. This was the first locomotive to successfully pull freight and passenger cars by working the hill strictly by adhesion (Anderson, 2005), allowing the rack and pinion system to be retired (Sulzer, 1962). *The Rueben Wells* was permanently assigned to work the hill and did so until 1898, when she was partially retired, and continued to work the hill until 1905. She survives today as a permanent exhibit at the Indianapolis

Figure *29*. Fallen rocks on the right-of-way, April 2013. The Indiana Department of Transportation was to take bids on restoring the damage and make it safe as a walking trail in October 2013. Failing that, a rails-to-trails recreation trail may be its fate. From *Madison Courier* (2013); used with permission.

Figure 28. People walking on the incline. From Jefferson County Historical Society (2011); used with permission.

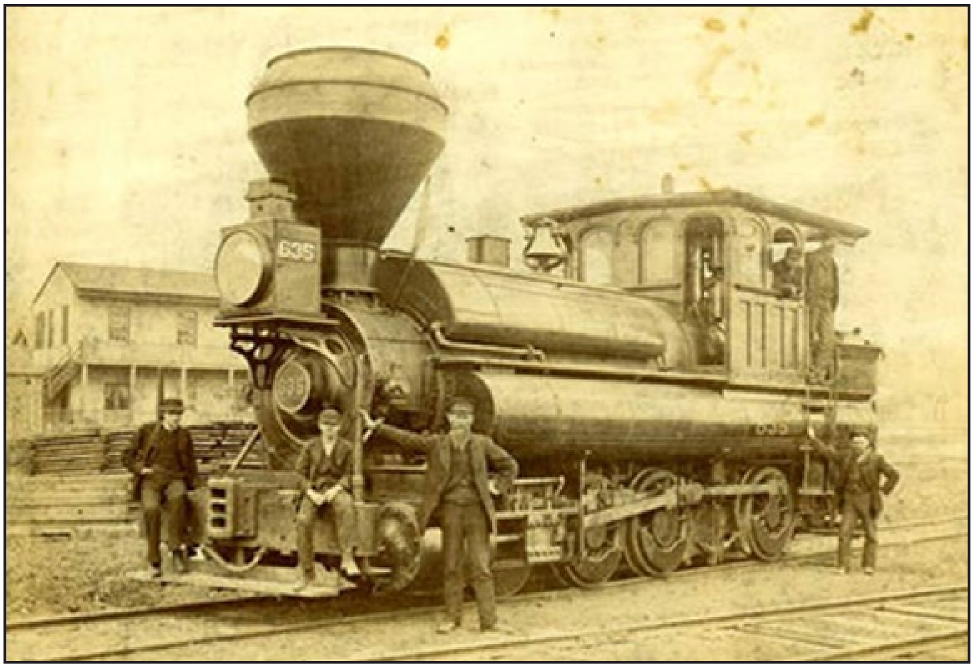

Figure 30. *The Reuben Wells* replaced the Baldwin cogwheel locomotive in 1868. Photo courtesy of the Jefferson County Public Library; used with permission.

Children's Museum (Fig. 31), but its appearance is vastly different from that in Figure 30 (Anderson, 2005).

The M&I had been an affiliate of the Pennsylvania Railroad since Dec. 26, 1871, when it was leased by the PRR for 999 years. By Dec. 31, 1873, PRR owned 19,219 shares of the JM&I's common stock. The JM&I was merged into the Pittsburgh, Cincinnati, Chicago & St. Louis Railway Co. on Oct. 26, 1890. The PCC&St.L was a shell corporation formed by the PRR, which controlled the company by holding a 50 percent interest, formed to place all its railroads southwest of Harrisburg, Pa. (Schotter, 1927). With Pennsylvania Railroad control firmly established, larger and more powerful locomotives appeared on the JM&I. Locomotives like the No. 7537 (Fig. 32) were now standard power on the old M&I line. When operating on the hill, they were always placed at the rear of the train when moving the train uphill to help prevent runaways and in accordance with the special rules applying to The Hill, operated with the front end facing upgrade to prevent boiler explosions (Sulzer, 1962).

The diesel era began on Nov. 9, 1953, when two 1,500-horsepower Electro-Motive Division SD7 locomotives were purchased specifically by the Pennsylvania Railroad to operate on the hill (Fig. 33). Numbered 8588 and 8589, they were the only two examples of this model on the PRR. They later became Penn Central No. 6550 and No. 6551, then Conrail No. 6998 and No. 6999. These locomotives had six powered axles with low gearing and were very heavily ballasted to 360,000 lb each to ensure the maximum tractive effort when pulling a train up the grade and dynamic brakes to help augment the air brakes on trains descending the grade. They were also equipped with a homemade rail-spraying device in front of the wheels to wash leaves off the rails, because this problem had caused several runaway trains on the hill. These loco-

Figure 31. *The Reuben Wells* returned to her original appearance, probably on her way to the Indianapolis Children's Museum. From OGR Publishing Inc. (no date); used with permission.

motives served this line for more than 30 years (Sulzer, 1962).

Finally—The Tunnels

It was this steep grade that induced the then-president of the M&I, John Brough (pronounced *bruff),* to embark on what would become known as Brough's Folly. For 15 yr the steep incline at Madison kept the locals interested by providing, at regular intervals, exploding steam locomotives; runaway passenger, freight, and livestock cars; and other incidents that, fortunately, resulted in relatively few fatalities and injuries to humans, but resulted in considerable damage to

Figure 32. Pennsylvania Railroad Class H8A Consolidation No. 7537, Chicago, Ill., Sept. 9, 1937. From the collection of Gary Mittner; used with permission.

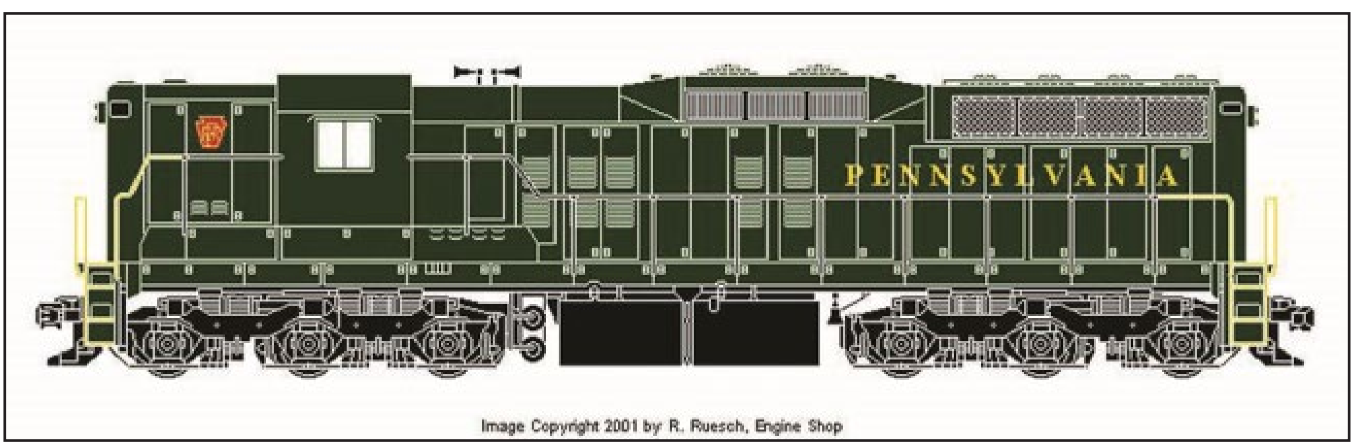

Figure 33. Top: One of the two SD7 locomotives that were permanently assigned to Madison, Ind. Photo taken by Mike Mautner in St. Louis. Bottom: Illustration of the original paint scheme she wore (used with permission of Roland Ruesch, Engine Shop).

the passenger and freight cars and entertainment of Madison's citizens. Brough, however, was not a fool. He was required by the 1852 contract that transferred the railroad from the State of Indiana to private interests to build another route for the line between Madison and North Madison. Accordingly, he set out to make improvements. To bypass the troublesome grade out of Madison, President Brough initiated the survey of a new 4.75-mi low-grade railroad and then let a contract for the construction of said line. The new line would leave Madison and ascend the face of the hills west of the city and proceed through the first tunnel into the Clifty Creek Valley. The new line would then proceed along the creek until it reached Deans Branch, which it would follow until it reached the location of the second tunnel just below what is now Tunnel Falls, whereupon it would access the second (higher) tunnel to emerge just below the top of the bluff. From this point, the track would top the bluff onto what was then called the Indiana Tableland and would proceed northeast and rejoin the original line about a mile north of North Madison (Sulzer, 1962; Old Madison, 2011). An expenditure of $390,497 in 1853 dollars was made on the construction (more than $6 million in 2016 dollars) before severe financial difficulties halted the construction forever (Old Madison, 2011). Estimates at the time indicated that it would have taken another $100,000 to complete the line (Sulzer, 1962; Old Madison, 2011). Neither of the tunnels were completed. Only a few feet of the lower tunnel was excavated, and 600 ft (National Park Service, no date) of the upper tunnel was excavated and both portals were exposed, but the cross section of the tunnel was never developed. Evidence of the construction of this line is still easily visible in the area, however, despite the vegetation growth over the last 163 yr (Fig. 34). Clifty Falls State Park allows visitors to enter the tunnel for most of the year, but the advent of White Nose Syndrome has affected access to the tunnel, especially during the winter months when bats hibernate.

In 1974, under the authority of the Regional Railroad Reorganization Act of 1973 (the 3R Act), the United States Railway Administration was created to form a plan to merge seven bankrupt railroads operating in the Northeast and Midwest into a U.S. Government–owned railroad and make it profitable. To that end, a final plan was to iden-

Figure 34. Madison and Indianapolis Railroad end of the line at North Vernon, looking north. This is the start of a 16.5-mi abandoned section of the M&I between here and Columbus, Ind. The bridges on this section are intact and there are plans for making this a rails-to-trails project. The Columbus–Indianapolis section of the M&I still survives under the ownership of the Louisville & Indiana Railroad. Photo by Greg Alexander.

tify unprofitable, and therefore unneeded, railroad trackage that was now owned by the new railroad, which would be named Conrail. This trackage would be abandoned free of the normal government reviews. The 1975 Final System Plan on Conrail was indeed created and subsequently enacted in the Railroad Revitalization and Regulatory Reform Act of 1976 (the 4R Act), which also extended the life of the USRA (Loving, 2006). Thus, Conrail was incorporated in 1976 to rise from the ashes of Penn Central and six other bankrupt northeastern railroads and create a profitable railroad out of their assets (Loving, 2006).

The 1975 Final Plan to retain profitable railroad lines did not include the Madison to North Vernon portion of the old M&I's line to Indianapolis. Indiana legislators helped Madison and other communities that faced losing railroad transportation by passing a law legalizing public ownership of short-line railroads of less than 50 mi (Cahal, 2016). Thus empowered, Madison, Ind., moved to purchase the railroad with an offer of $500,000. Conrail refused the offer and the city responded with an eminent-domain condemnation lawsuit. This was a case of diamond cut diamond, for railroads also have the powers of eminent domain. The courts ruled for the city, and Conrail sold the line to Madison for $307,000. The purchase was completed in 1981.

The Madison Railroad began operations on Sept. 1, 1978. Since then, more than $6 million has been invested in track and bridge improvements. The incline down to Madison was maintained to serve the Clifty Creek Power Plant, but the company shifted coal shipments from rail to barge. The track was refurbished at the expense of the Indiana-Kentucky Electric Corp. in 1992 so that large pieces of equipment could be delivered (Cahal, 2016). Once this was completed, the railroad declared the incline track out of service, but it is still in place.

Today, the Madison Railroad operates 25 mi of mainline to north Vernon and 17 mi of track in a 3,400-acre industrial park that was once the U.S. Army's Jefferson Proving Ground, which was used to test munitions until its closure in 1995. The park's major traffic base is composed of polyethylene, coil steel, and scrap and it makes a tidy profit storing freight cars for railroads and private leasing companies as well. That's not bad for a railroad whose oldest track was begun 179 yr ago.

Stop 6

Frank R. Ettensohn

Return to your cars and drive to the lodge, where there is a spectacular view of Madison, the Ohio River, and the new bridge between Madison, Ind., and Milton, Ky. The bridge was built in 1929 and is a continuous-truss bridge (extends without hinges or joints across three or more supports). The old bridge was replaced with a new continuous-truss bridge on temporary piers adjacent to the operational span between 2011 and 2012. Once completed, the old piers were strengthened to current bridge standards and the old span was demolished. The design/build team of Walsh Construction, Burgess & Niple, and Buckland & Taylor proposed a method of truss sliding, in which the new bridge (2,428 ft long) was slid over the river along steel rails and plates onto the existing piers. This process eliminated the need for a year-long ferry service and was much lower in cost.

From the patio area at Clifty Inn lodge, you can see that the Ohio River flows through a very narrow valley with very little floodplain development, and that the concordant bluffs and ridgetops in the area show very little dissection by erosion (Fig. 35). The relatively flat to gently rolling upland surfaces that are nearly everywhere concordant represent long periods of continuous erosion and are called peneplains (Davis, 1889; Fenneman, 1938). Peneplain development begins near base level and slowly works its way toward upland regions. The possible peneplain that we are examining is called the Lexington Peneplain, and in the Tri-State area it was developed at altitudes between 900 and 1,000 ft, although it became progressively higher toward the Appalachian highlands (Fenneman, 1938). According to Jillson (1928), the peneplain may have begun formation as early as Cretaceous time. What is so unusual about the peneplain here is that it has undergone very little dissection, compared to other parts of the Ohio River Valley. In fact, this area was part of a major regional divide called the Madison Divide (Fig. 36), and what we see preserved of the peneplain is on top of that divide. That divide served to separate the preglacial, north-flowing Teays drainage from drainage to the

Figure 35. The concordant, relatively flat-topped ridges and bluffs, looking southeast from the Clifty Inn. These flat tops are thought to have been parts of the extensive Lexington Peneplain.

west (Fig. 36). With the advent of Pleistocene glaciation from the north, that drainage was blocked, allowing the blocked rivers to pond up behind the glacial front. The rivers became large proglacial lakes, until the river basins could no longer hold all of the water and they overtopped the Madison Divide, cutting the gorge that is now occupied by the Ohio River. Other parts of the Ohio River occupy much older valleys that have undergone much erosion and downcutting; those parts of the river have broader valleys and wider floodplains. Compared to those parts of the Ohio River, the river valley here is much more youthful and the peneplain on top of the former divide is not so dissected.

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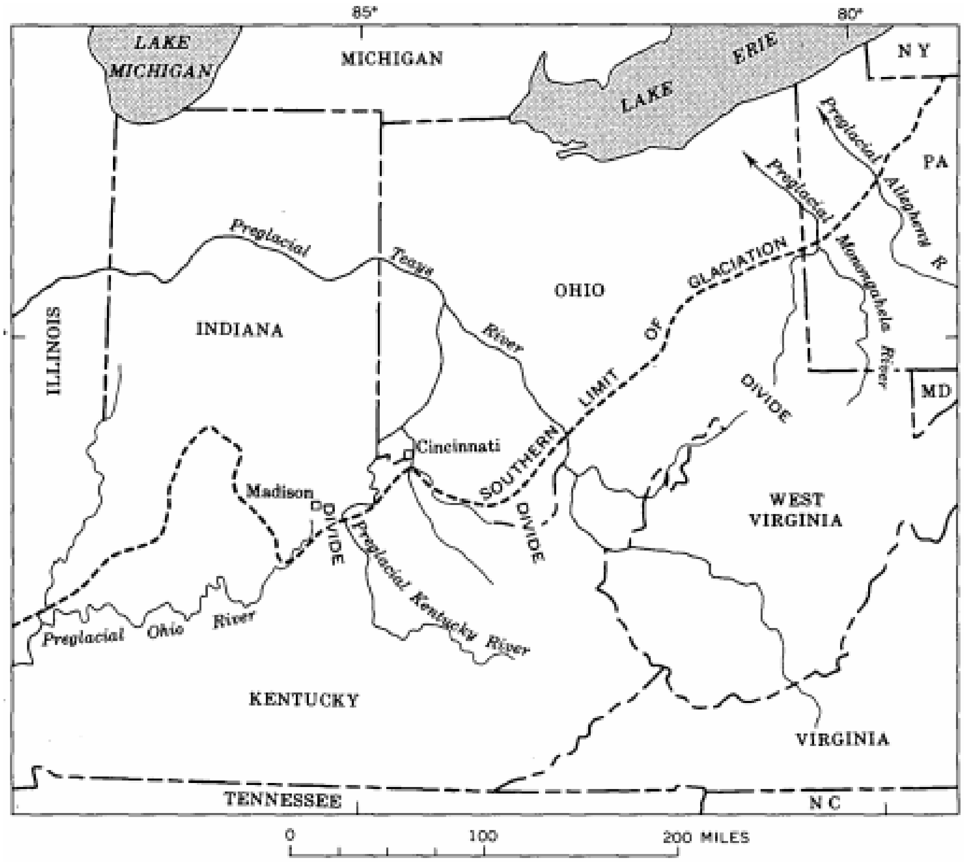

Figure 36. The Tri-State area, showing the preglacial north-flowing Teays drainage network relative to the Madison divide and the southern limit of glaciation. From Swadley (1971).

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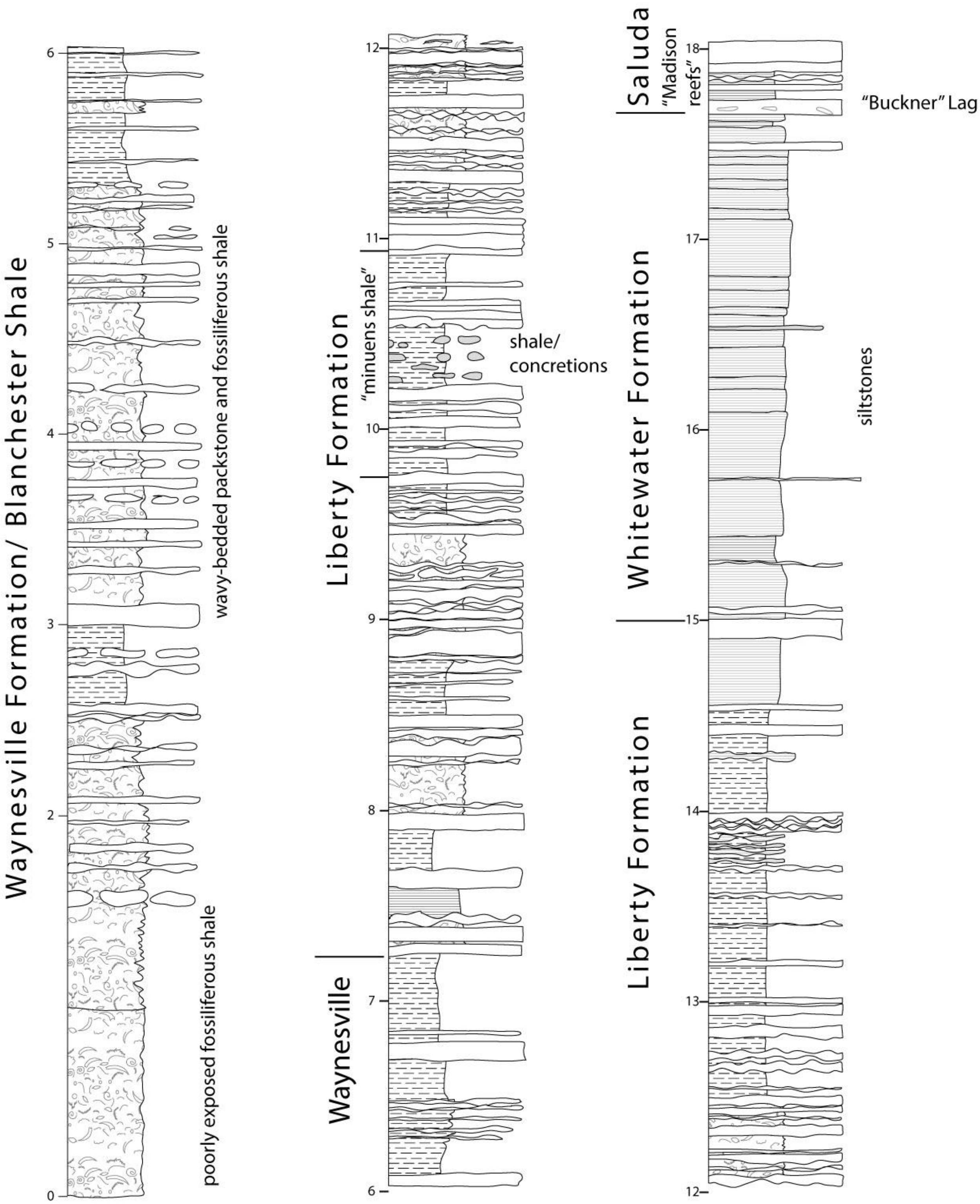

Plate 1. Madison, Ind., stratigraphic column, part 1. Courtesy of Benjamin F. Dattilo.

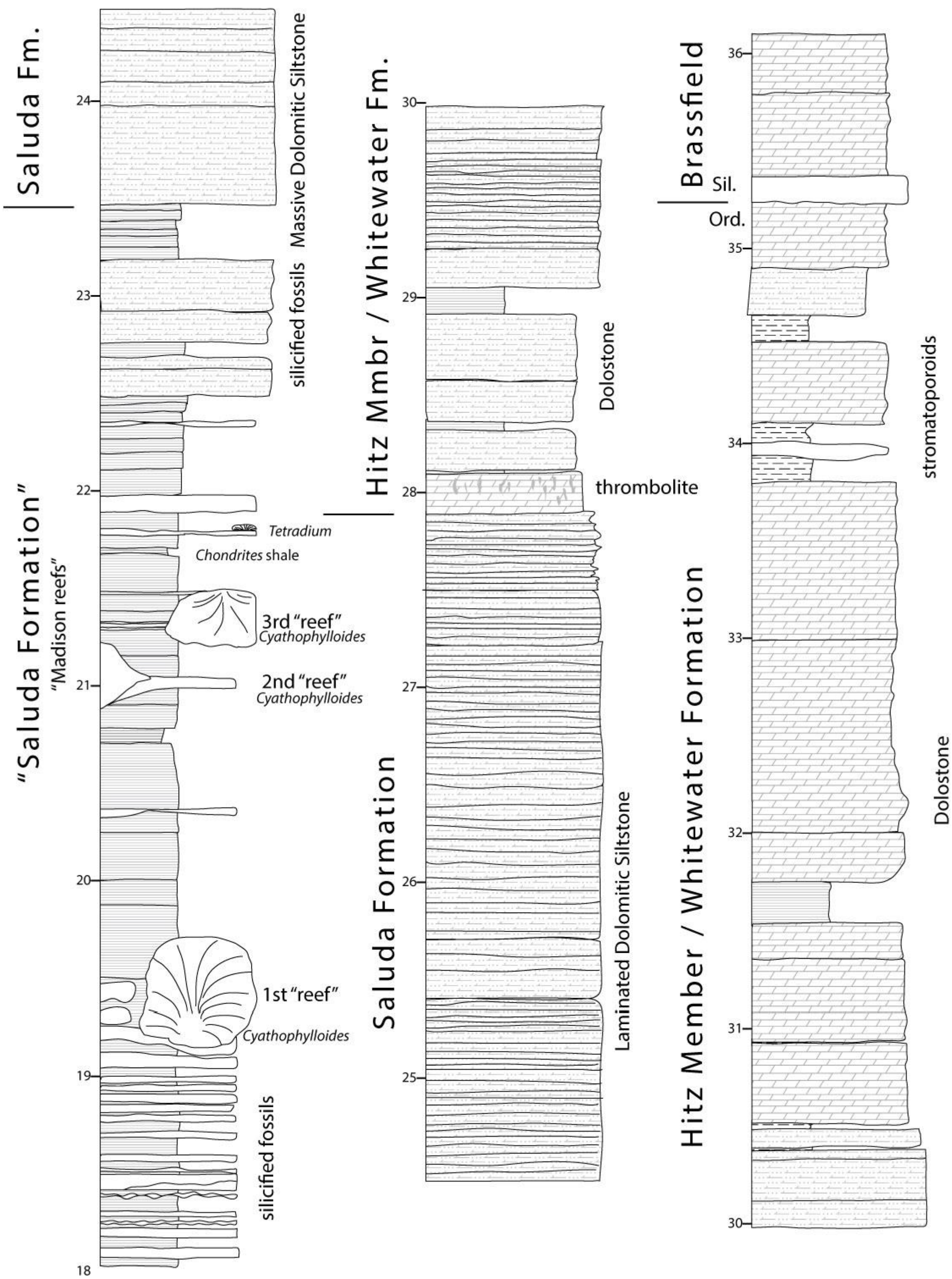

Plate 2. Madison, Ind., stratigraphic column, part 2. Courtesy of Benjamin F. Dattilo.

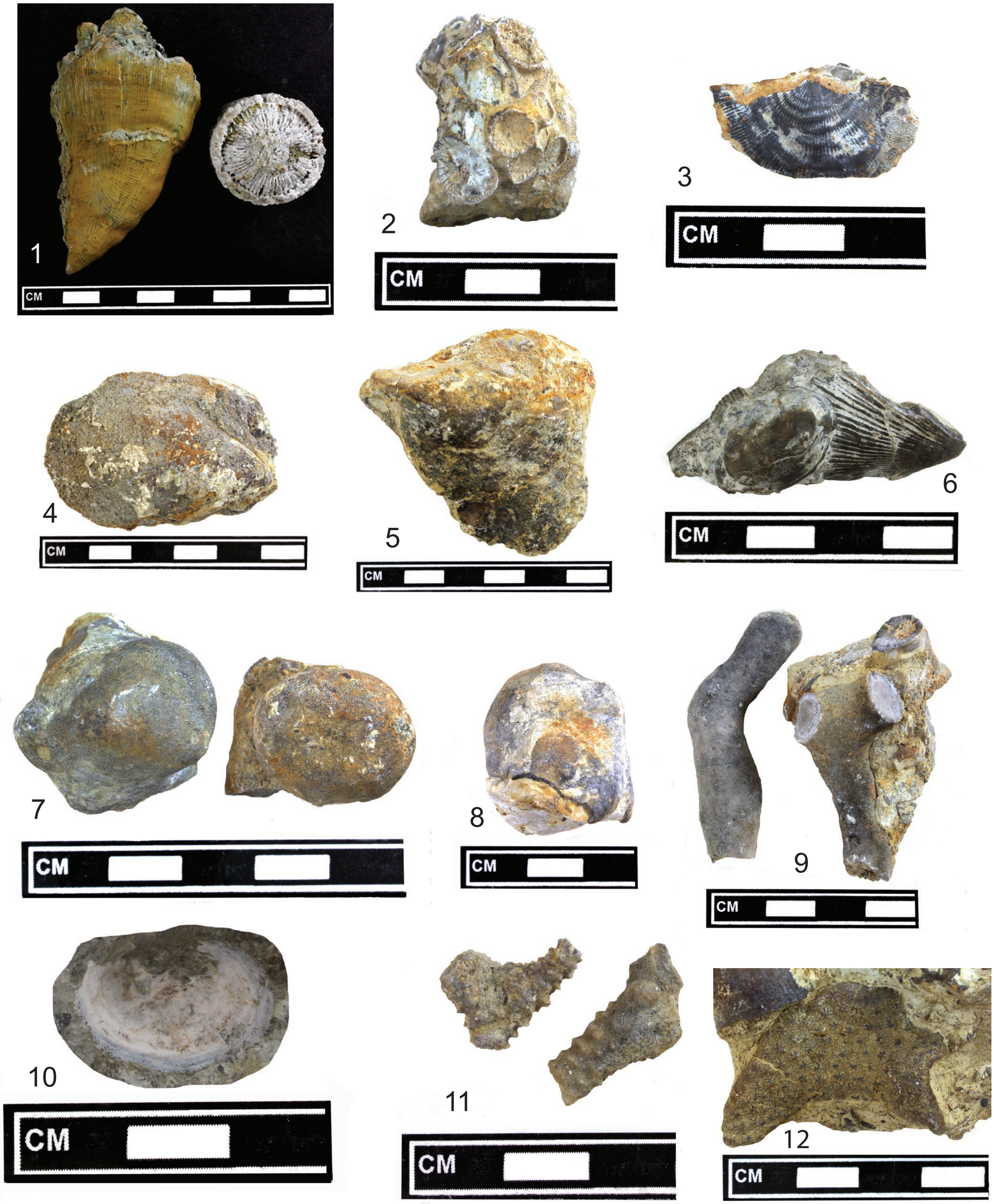

Plate 3. Common fossils at stop 1. Courtesy of Frank Ettensohn and Richard Smath. See descriptions in Plate 5.

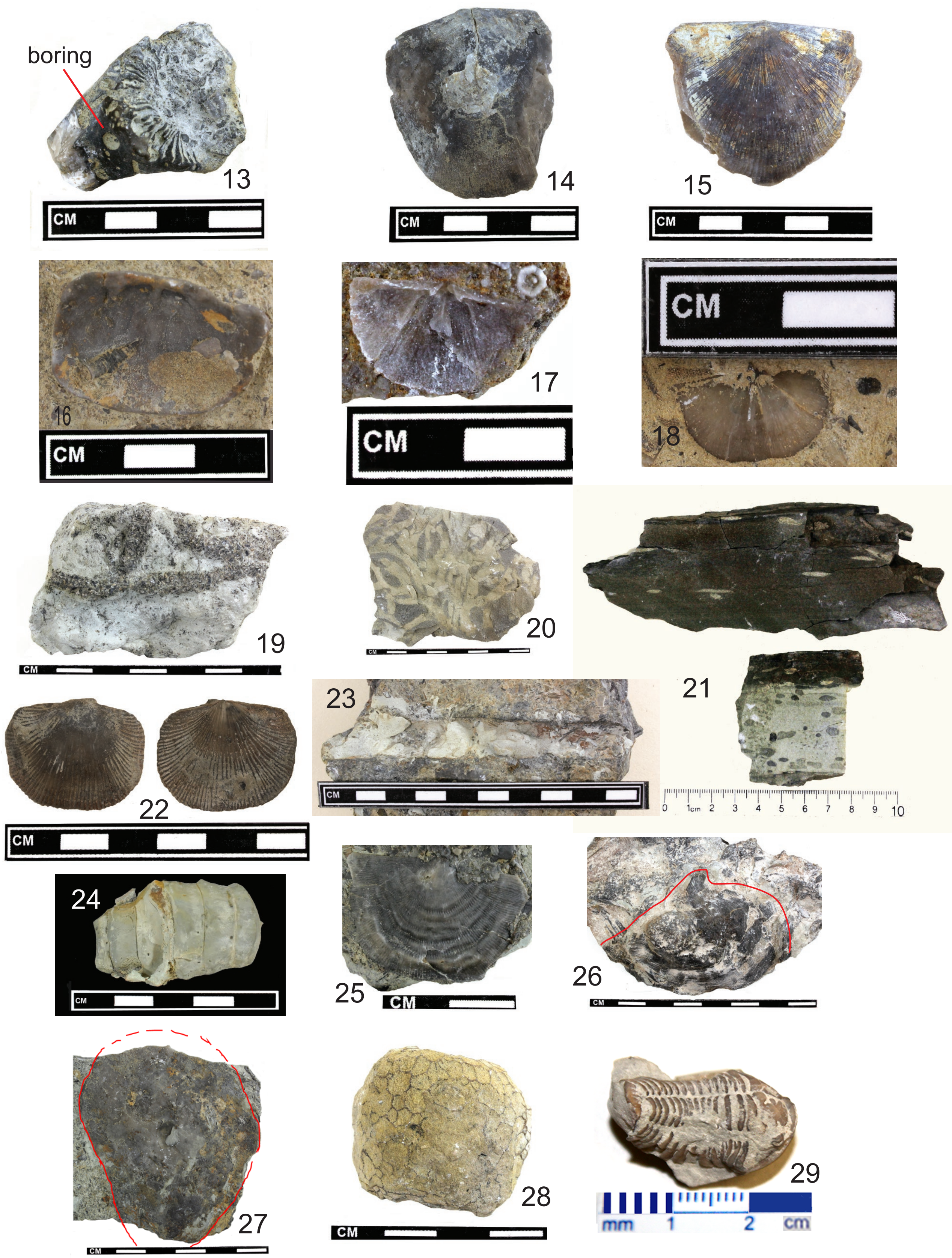

Plate 4. Common fossils at stop 1. Courtesy of Frank Ettensohn and Richard Smath. See descriptions in Plate 5.

1. *Grewingkia canadensis* (rugose coral)
2. *Strepolasma divaricans*
3. *Leptaena richmondensis* (brachiopod)
4. Clam *Ambonychia grandis* (internal mold, pelecypod)
5. Clam *Anomalodonta gigantea* (internal mold, pelecypod)
6. Monoplacaforian *Arhincella?/Monoplacepheran*
7. *Homotrypella haspitalis* (bryozoan)
8. Bryozoan mound with a bleb?
9. *Bythopora?* (ramose bryozoan)
10. *Trematis millepunctata* (inarticulate brachiopod)
11. *Hallopora* (ramose bryozoan)
12. *Constellaria* (ramose bryozoan)
13. *Trypanites* boring in *G. canadensis*
14. *Rafinesquina* (narrow form, brachiopod)
15. *Rafinesquina alternada*
16. *Cornulites* (worm tube on brachiopod shell)
17. *Eochonetes clarksvillensis* (brachiopods)
18. *Eochonetes clarksvillensis* (brachiopods)
19. Burrow fill
20. *Chrondites* burrows
21. Compacted burrows
22. *Glyptorthis insculpta* (brachiopod)
23. Internal mold, orthoconic cephalopod
24. Cephalopod (internal mold, orthoconic cephalopod)
25. *Leptaena richmondensis*
26. *Caritodens demissa* (pelecypod)
27. *Anomaodonta* (internal mold, pelecypod)
28. *Cyathophylloides* (colonial rugose coral) St
29. *Flexicalymene meeki* (trilobite)

Plate 5. Descriptions for Plates 3 and 4.

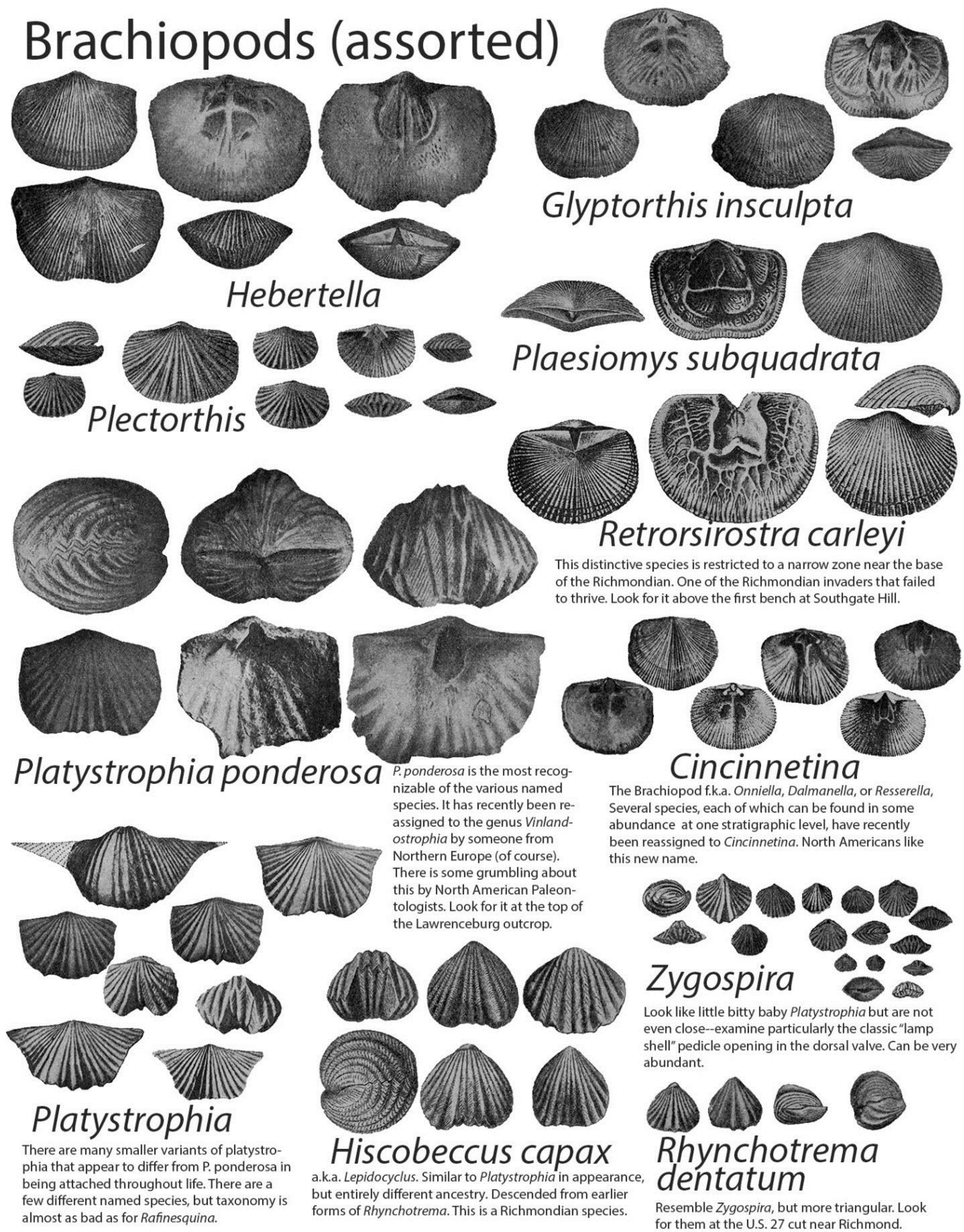

Plate 6. Fossil identification chart: assorted brachiopod fossils. From Dattilo and others (2013); used with permission of Indiana University–Purdue University Fort Wayne.

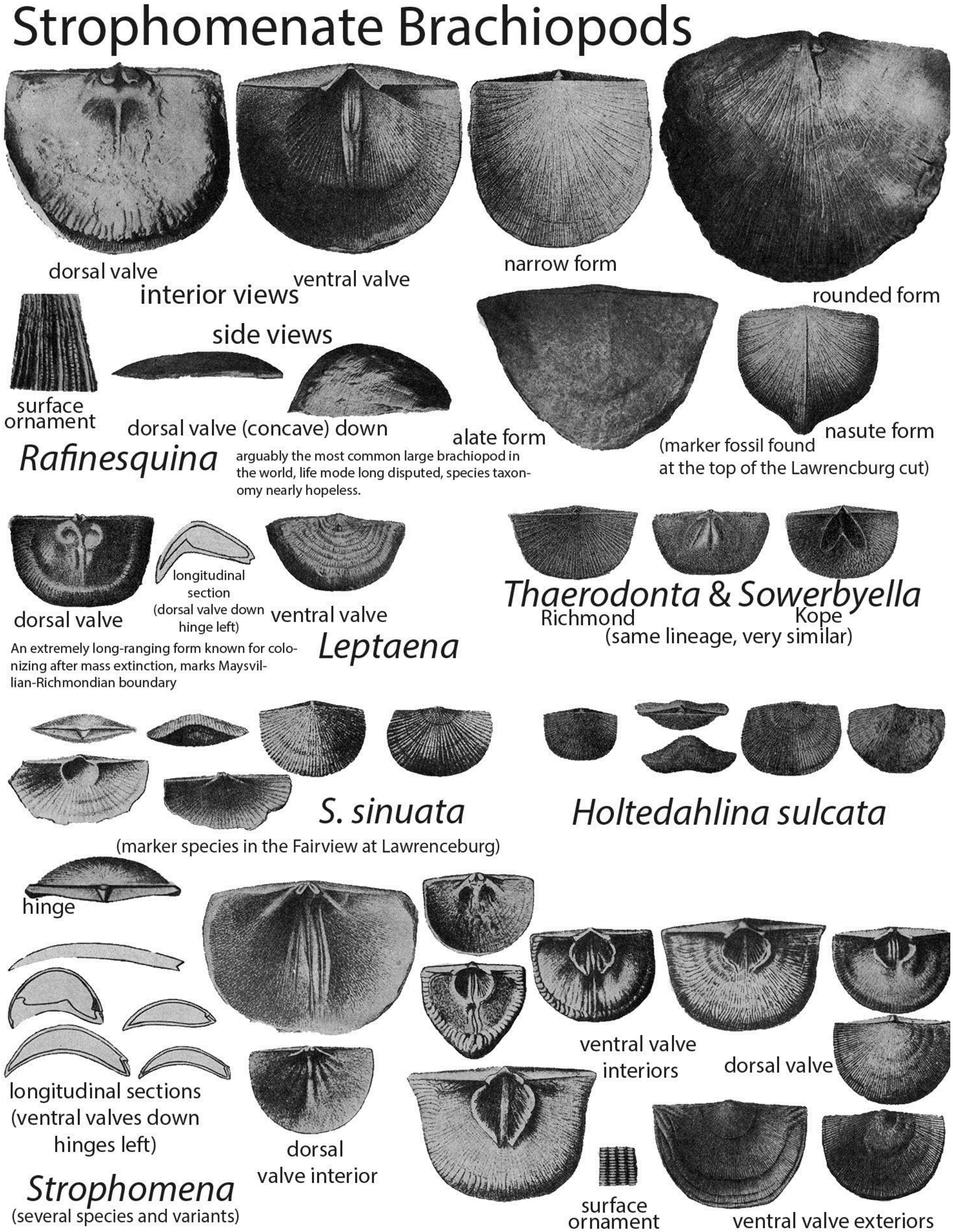

Plate 7. Fossil identification chart: strophomenate brachiopod fossils. From Dattilo and others (2013); used with permission of Indiana University–Purdue University Fort Wayne.

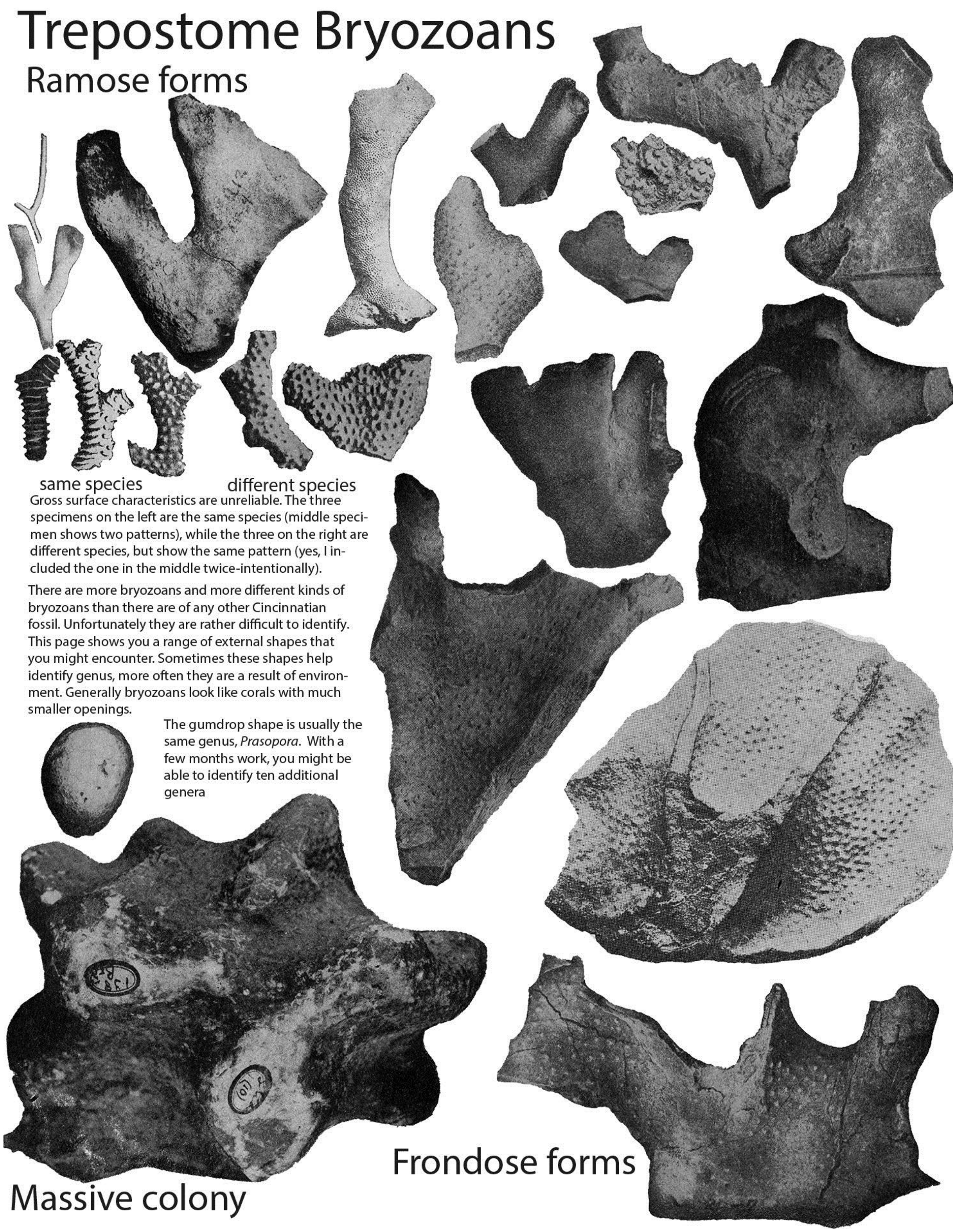

Plate 8. Fossil identification chart: trepostome bryozoan fossils. From Dattilo and others (2013); used with permission of Indiana University–Purdue University Fort Wayne.

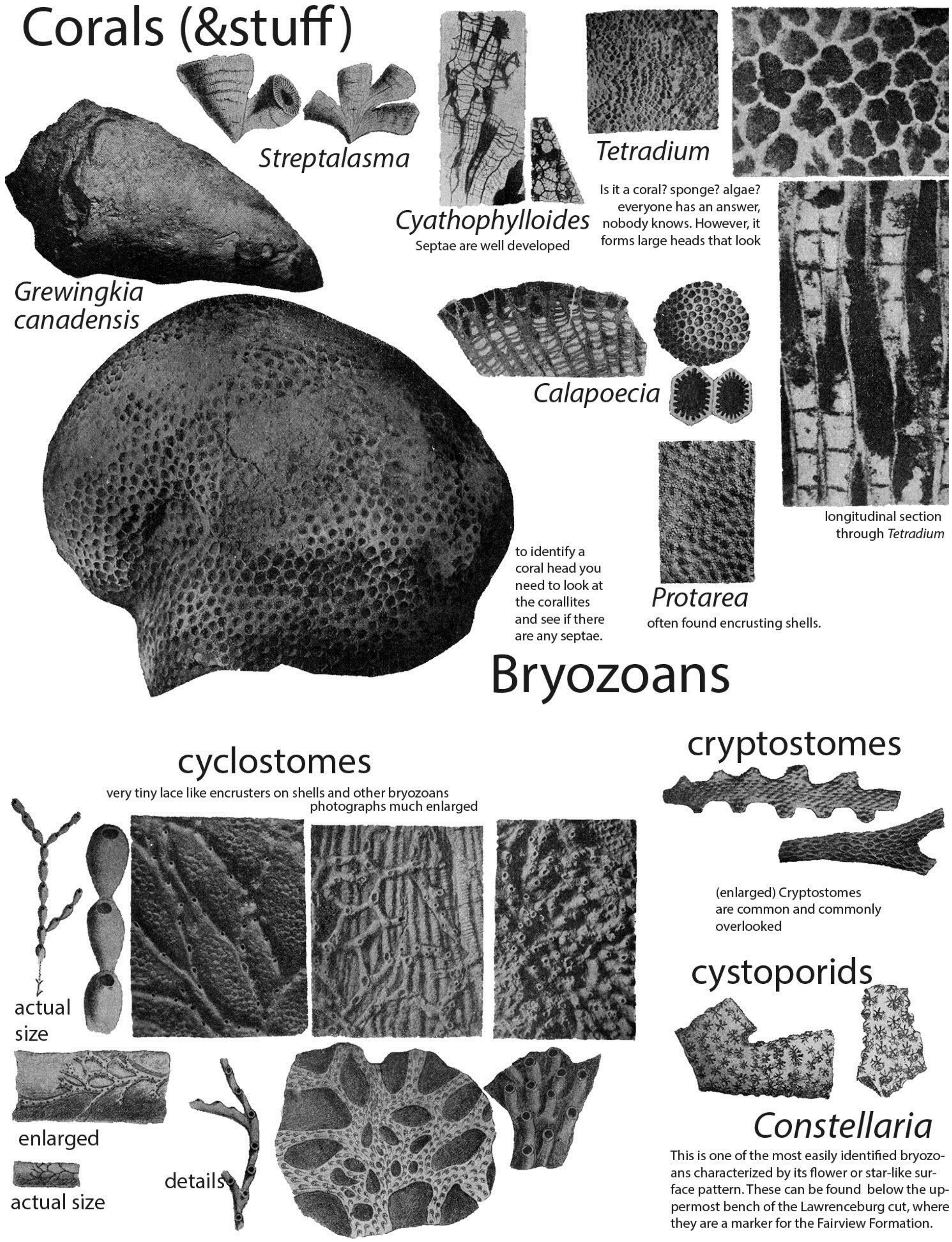

Plate 9. Fossil identification chart: corals (and stuff). From Dattilo and others (2013); used with permission of Indiana University–Purdue University Fort Wayne.

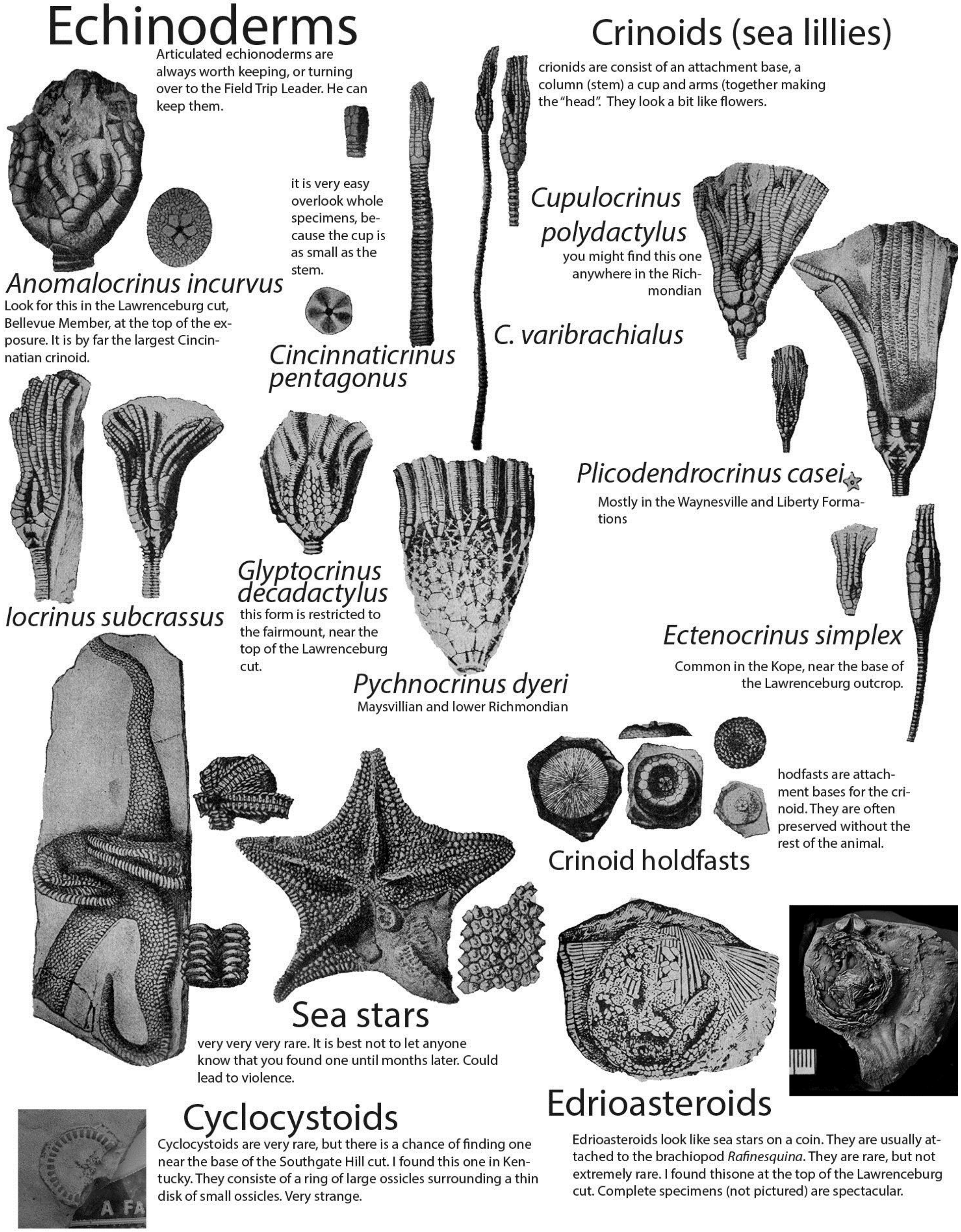

Plate 10. Fossil identification chart: echinoderms. From Dattilo and others (2013); used with permission of Indiana University–Purdue University Fort Wayne.

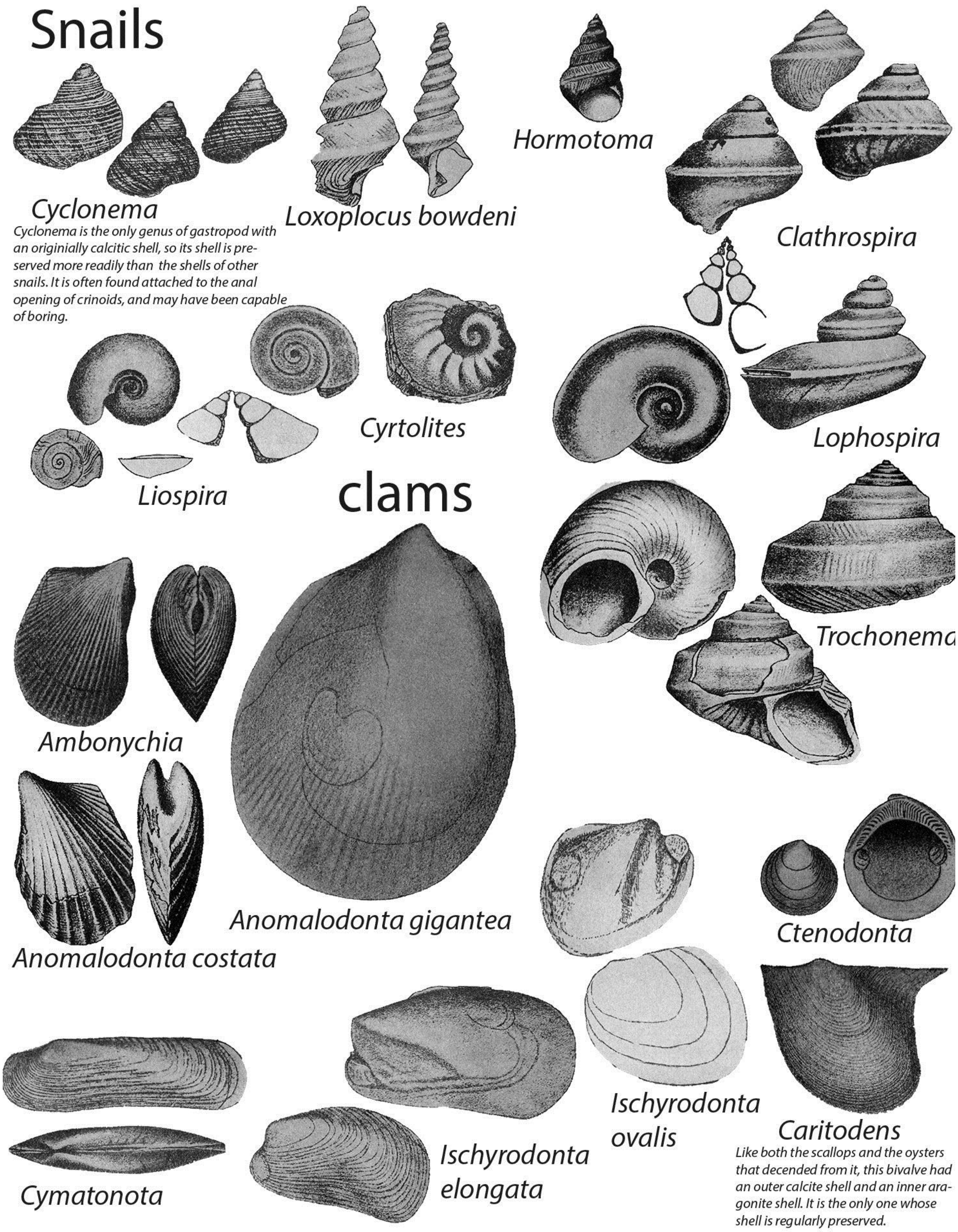

Plate 11. Fossil identification chart: snails and clams. From Dattilo and others (2013); used with permission of Indiana University–Purdue University Fort Wayne.

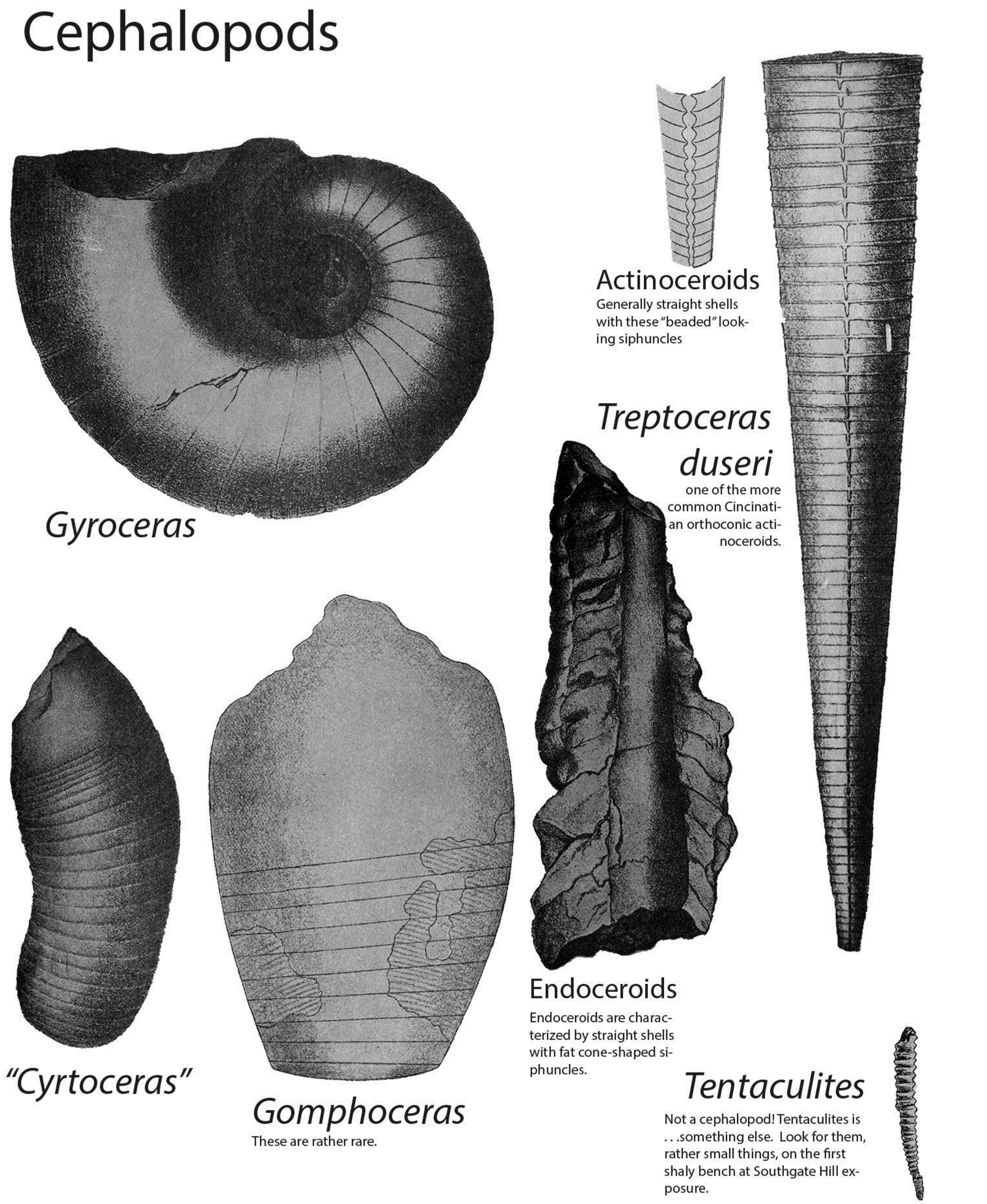

Plate 12. Fossil identification chart: cephalopods. From Dattilo and others (2013); used with permission of Indiana University–Purdue University Fort Wayne.