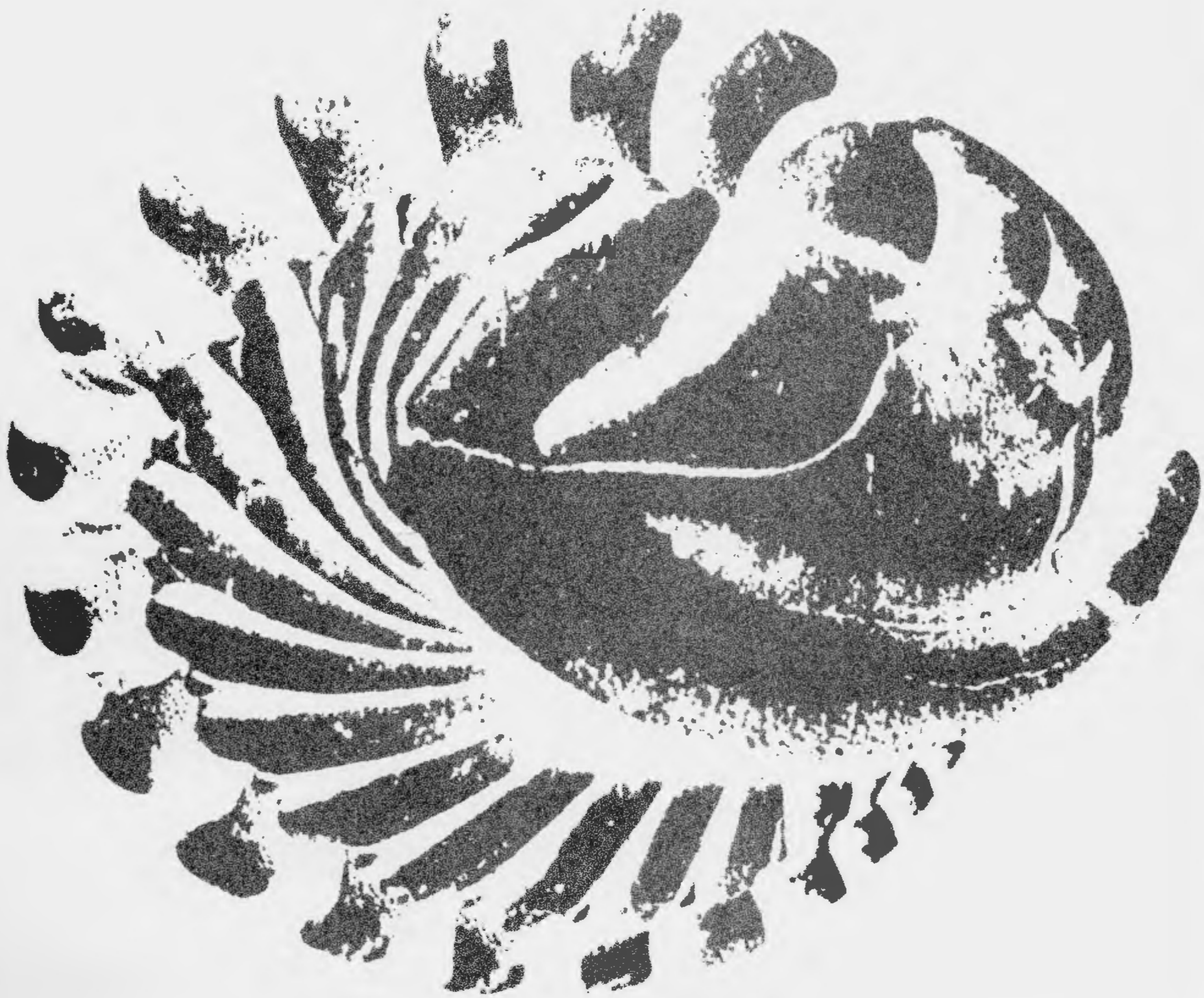
GUIDEBOOK NO. 12

EXCURSION TO CAESAR CREEK STATE PARK IN WARREN COUNTY, OHIO: A CLASSIC UPPER ORDOVICIAN FOSSIL-COLLECTING LOCALITY

by

Douglas L. Shrake



prepared for the 1992 Annual Meeting
of the Geological Society of America

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INTRODUCTION

This guide is intended to assist geologists, teachers, students, and the general public in conducting their own geological investigations at Caesar Creek State Park. Two reference sections are included in this guide: one contains the references cited in the text, and the other is an annotated list of additional reference sources which may be useful to the general public. A copy of the fossil-collecting rules for Caesar Creek State Park is located on the inside back cover.

LOCATION OF CAESAR CREEK STATE PARK

Caesar Creek State Park is located in northeastern Warren County and the adjacent portions of Greene and Clinton Counties, approximately 3 miles southeast of Waynesville, Ohio (see map on back cover). Even though there are abundant, natural rock exposures in and near the park, it is a manmade exposure that has brought recognition to the park for being a good site to collect fossils—the emergency spillway for Caesar Creek Dam. The emergency spillway was excavated through some of the most fossiliferous rocks in southwestern Ohio. Since its completion in 1978, the emergency spillway has become a well-known collecting locality to both professional geologists and the general public because of its ease of access and abundance of fossils.

The tri-state region of southeastern Indiana, north-central Kentucky, and southwestern Ohio, in which Caesar Creek State Park is located, is world renowned for the abundance and preservation of Upper Ordovician marine fossils that have been collected from the rocks exposed there. The first written report on the fossiliferous nature of the rocks of the Cincinnati region was by Drake (1825). Since that time, numerous papers on the fossils (taxa) of the Cincinnati region have been written. Table 1 lists most of the publications that have described taxa from the Cincinnatian Series of Indiana, Kentucky, and Ohio.

TABLE 1.—*Cincinnatian taxonomic publications* (after Shrake and others, 1988)

Porifera: J.F. James, 1885, 1887; Ulrich, 1889a.
Stromatoporoids: U.P. James, 1884a, 1884b; J.F. James, 1886b; Galloway and St. Jean, 1956, 1961.
Coelenterata: Nicholson, 1874a, 1874b, 1875b; J.F. James, 1888; C. James, 1940; Caster, 1942; Browne, 1964, 1965; Anstey and Chase, 1974; Elias, 1982, 1983a, 1983b.
Bryozoa: Nicholson, 1875a, 1875b, 1875c, 1880; Ulrich, 1879, 1882a, 1890b, 1895; Miller, 1880; U.P. James, 1884a; U.P. James and J.F. James, 1887; Nickles, 1902; Bassler, 1906; Utgaard and Perry, 1964; Boardman and Utgaard, 1966; Utgaard, 1968; Anstey and Perry, 1969, 1973; Anstey and Chase, 1974; Singh, 1979; Karklins, 1983, 1984; Brown and Daly, 1985.
Brachiopoda: J. Hall, 1872b; U.P. James, 1874a, 1874b, 1874c, 1874d; Miller, 1875a; Ulrich, 1889b; Nickles, 1903; Foerste, 1905, 1912; Braun, 1916; D.D. Hall, 1962; Richards, 1972; Alberstadt, 1979; Howe, 1979; Walker, 1982; Pope, 1982.
Mollusca: U.P. James, 1872, 1874c; Miller, 1874b, 1874c, 1882b, 1874d, 1875c, 1881a, 1884; Wetherby, 1881; J.F. James, 1886a; Miller and Faber, 1894; Whitfield, 1878; Ulrich, 1890a, 1892, 1893, 1897a; Foerste, 1924; Bucher, 1938; Flower, 1946; Sweet and Miller, 1958; Pojeta, 1962; United States Geological Survey, 1969; Thompson, 1970; Aronoff, 1979; Frey, 1980.
Echinodermata: Anthony, 1839a; Meek and Worthen, 1865; Meek, 1871, 1872; J. Hall, 1872a; Wetherby, 1880; Miller, 1880, 1881b, 1882a, 1882b, 1883, 1884; Ulrich, 1882b; Dyche, 1892a, 1892b, 1892c; Fenton, 1929; Caster and Macke, 1952b; Kesling and Mintz, 1961; Hotchkiss, 1970; Branstrator, 1972, 1979; Warn, 1973, 1974; Frest and others, 1976; Warn and Strimple, 1977; Kelly and others, 1978; Bell, 1979; Kelly and Pope, 1979; Parsley, 1981; Schumacher and Ausich, 1983.
Arthropoda: Miller, 1874a; Wetherby, 1879; Ulrich, 1890c, 1897b; Jones, 1890; Caster and Macke, 1952a; Kesling and Hussey, 1953; Caster and Kjellesvig-Waering, 1964; Guber, 1971; Warshauer and Berdan, 1982; Berdan, 1984.
Trilobita: Anthony, 1838, 1839b; Locke, 1838, 1842a, 1842b, 1843a, 1843b; Conrad, 1842; Taylor, 1850; J. Hall, 1872b; Miller, 1875b; Mickleborough, 1883; Woodward, 1884; Foerste, 1888, 1919; Wells, 1942; Whittington, 1956, 1969; Ross, 1967, 1979.
Scolecodonts: U.P. James, 1884c; Douglas, 1970.
Chitinozoa: Grahn and Bergström, 1985.
Graptolites: Berry, 1966; Riva, 1974; Mitchell and Bergström, 1977; Crowther and Bergström, 1980; Bergström and Mitchell, 1986.
Conodonts: U.P. James, 1884c; Sweet and others, 1959, 1971; Pulse and Sweet, 1960; Schopf and others, 1965; Bergström and Sweet, 1966, 1969; Bergström, 1971; Bergström and others, 1974; Seddon and Sweet, 1971; Sweet, 1979; Ethington and others, 1986.
Trace fossils: Osgood, 1970, 1977a, 1977b; Osgood and Szmuc, 1972.

In addition to taxonomic studies, over 50 papers concerning the sedimentology and stratigraphy of the Cincinnatian Series have been written. Excellent summaries of these works are present in Cumings (1922), Gutstadt (1958), Weiss and Norman (1960), Weiss (1961), Schumacher and others (1987), and Davis and Cuffey (1992).

Even before the construction of the emergency spillway, the region now encompassed by the park was already well known for the fossils present here. As early as 1878 the valleys of Caesar Creek and Flat Fork (fig. 1) were important collecting sites (Orton, 1878; Wolford, 1927, 1930). Prior to the damming of Caesar Creek, the entire stratigraphic section from the Arnheim formation to the Whitewater Formation was continuously exposed along Flat Fork (Wolford, 1930).

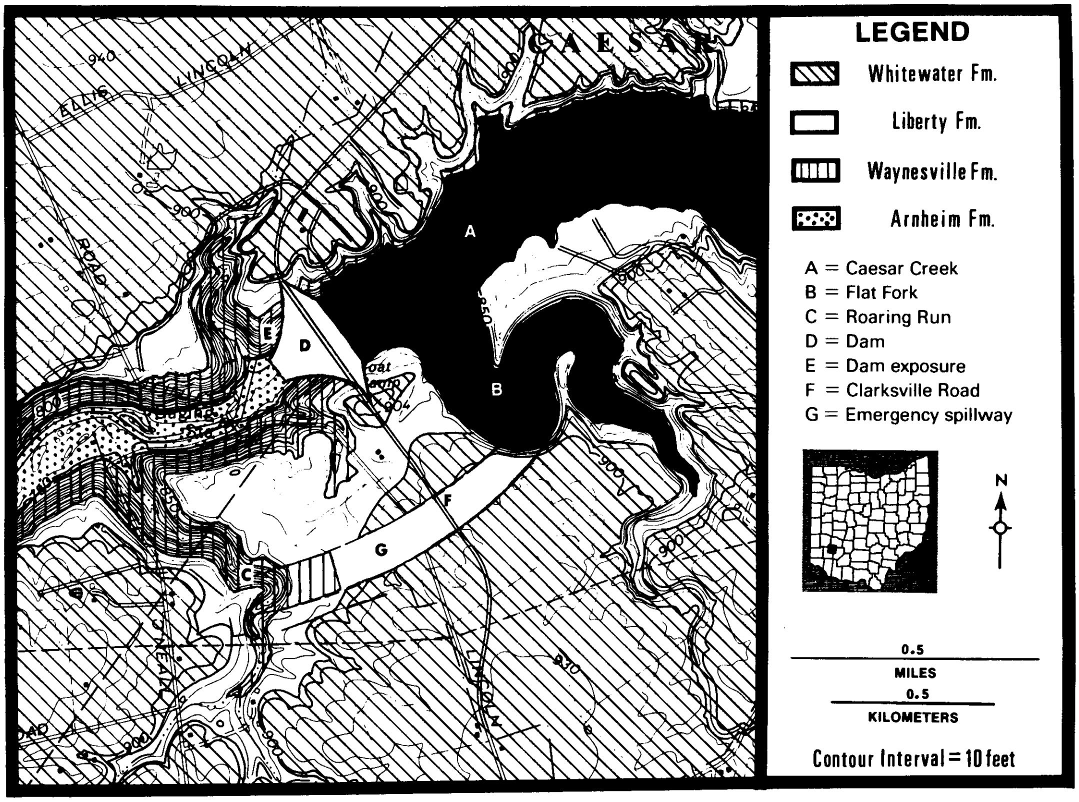

FIGURE 1.—Geologic map of the area around the Caesar Creek emergency spillway. Mapped area is located on the U.S. Geological Survey Oregonia, Ohio, 7.5-minute topographic map. Modified from Shrake and others, 1988.

THE HISTORY OF CAESAR CREEK LAKE

The construction of a dam across Caesar Creek was authorized by the Flood Control Act of 1938. Construction of the 2,750-foot-long, 165-foot-high, earth- and rock-filled embankment began in October 1971 and was finished in January 1978. An emergency spillway was constructed to allow severe floodwaters to pass around the dam and not over it. The level of the lake is controlled by a series of multilevel gates in the outlet structure located by the dam. Opening and closing the gates permits control of water quantity and quality downstream from the dam.

Caesar Creek Lake is the deepest lake in Ohio. Normal water depth is 115 feet near the dam. At normal summer pool, the lake covers 2,830 acres and is fed by a drainage area of 237 square miles. The shoreline, including inlets and bays, is 40 miles long. The dam has the capacity to hold back enough water to cover 6,110 acres.

The emergency spillway is 2,667 feet long and 450 feet wide, and runs east to west from where Flat Fork flows into the lake to Roaring Run (fig. 1). The spillway floor has an area of over 1,200,000 square feet. The spillway has an elevation of 883 feet above sea level on Clarksville Road.

CAESAR CREEK VISITOR CENTER

The Caesar Creek Visitor Center, located off Clarksville Road (see map on back cover), is staffed and maintained by the U.S. Army Corps of Engineers. The center has displays on the construction of the dam and on some of the fossils collected in the park. The fossil display includes a large specimen of the trilobite *Isotelus* collected during an excavation on the emergency spillway. The Visitor Center is also responsible for issuing the permits to allow fossil collecting on the emergency spillway. The rules for collecting are listed on the inside back cover of this guidebook.

ORDOVICIAN PALEOGEOGRAPHY OF OHIO

Paleogeographic reconstructions of Middle to Upper Ordovician landmasses place the Ohio region of North America at between 15 and 20 degrees south latitude (McElhinny and Opdyke, 1973; Ross, 1976; Scotese and others, 1979; Van der Voo, 1988) (fig. 2). Therefore, a tropical to subtropical climate (similar to the Caribbean region of today) can be assumed for this area during the Ordovician (Stearn and others, 1979). Ohio would have been near the western shore of the Taconic landmass, formed when the Iapetus Ocean began to close (Stearn and others, 1979). Water depth generally increased westward, from a deltaic and alluvial environment, to a shallow-marine shelf, to a deeper shelf (Wier and others, 1984). Southwestern Ohio was part of the shallow-marine shelf environment (fig. 3). With the exception of the Taconic landmass, most of the present-day North American midcontinent was covered by an epeiric sea during the Ordovician (Stearn and others, 1979). The Ordovician seafloor, preserved in strata exposed in southeastern Indiana, north-central Kentucky, and southwestern Ohio, has been described as having been a storm-dominated, shallow-marine ramp sloping gently to the (present-day) north (Tobin and Pryor, 1985). The concept of a northward-deeping sea is supported by the shallow-water lithologies present in Kentucky and Tennessee (Wier and others, 1984). West of southwestern Ohio, a generally deeper water environment allowed for the deposition of the shale-rich strata of the Maquoketa Group in Indiana (Gray, 1972) (fig. 3). Many sedimentary features, such as hummocky cross-stratification, storm cycles, and rapid burial events, attributable to storm processes have been described from Ordovician strata in the Cincinnati region by Bucher (1917, 1919), Anstey and Fowler (1969), Kreisa and others (1981), Tobin and Pryor (1985), and Jennette and Pryor (1986). The sea is estimated to have been 65-82 feet deep during the deposition of the basal Cincinnatian rocks (Bucher,

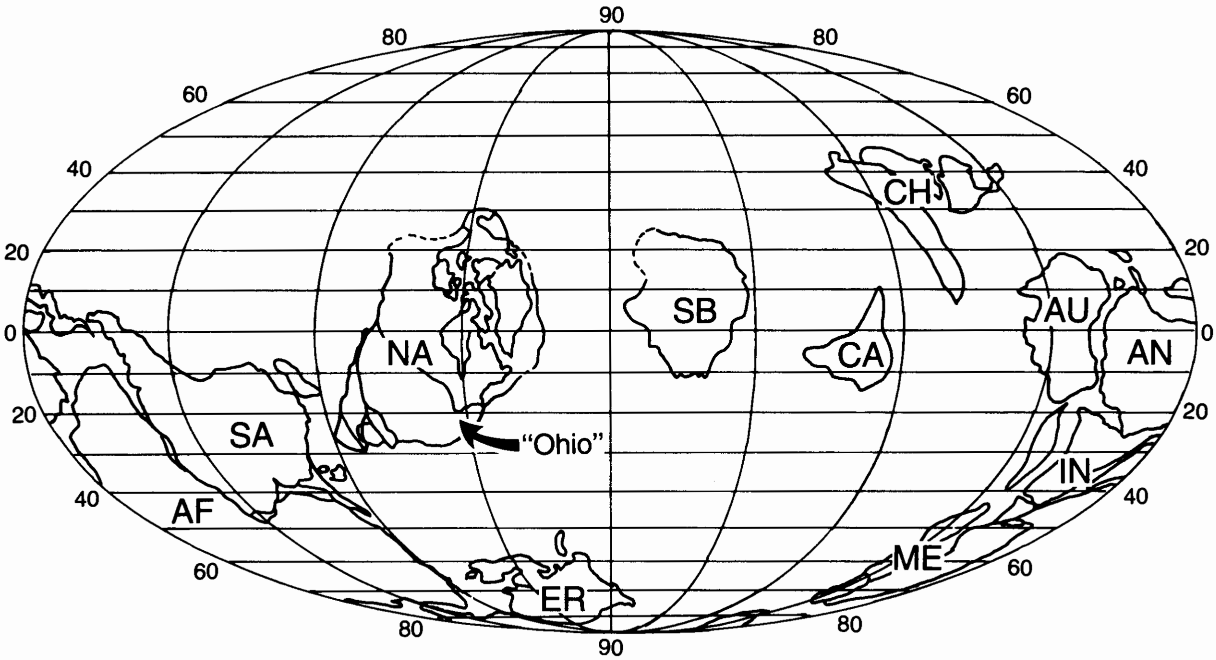

FIGURE 2.—Paleogeographical reconstruction of the Middle Ordovician (Llandeilian-earliest Caradocian) landmasses. Map is a Mollweide projection "front view." Numbers along outside of map are latitude. Arrow next to "Ohio" points to the approximate position of Ohio during this time period. Explanation of two-letter codes: AF = Africa; SA = South America; NA = North America; ER = Europe and Russia; SB = Siberia; CA = Central Asia; CH = China; AU = Australia; AN = Antarctica; IN = India; ME = Middle East. Modified from Scotese and others, 1979.

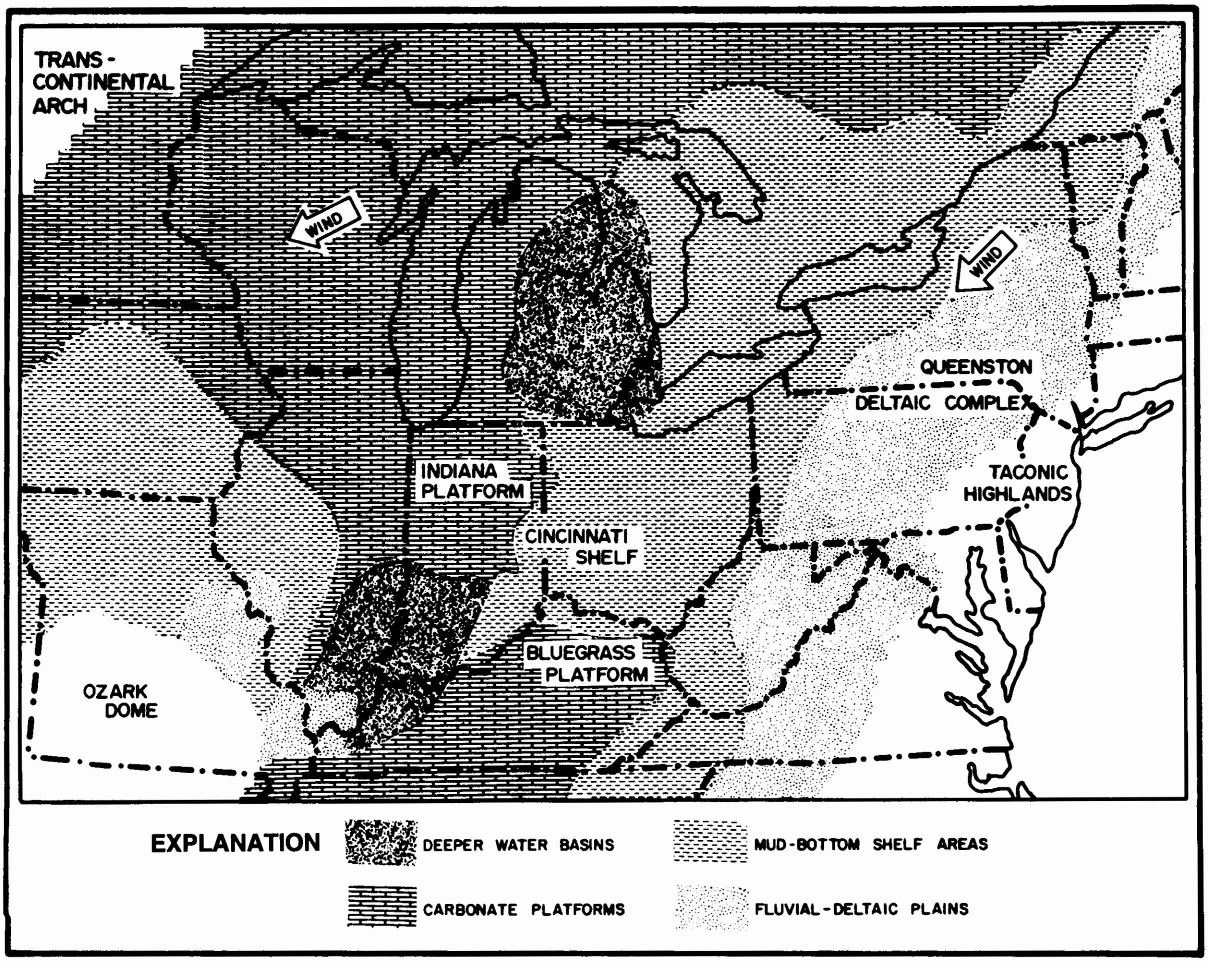

FIGURE 3.—A reconstruction of the tectonic-paleogeographical features that influenced sedimentation in Late Ordovician shelf areas in eastern North America. This map is a representation of conditions as they existed in Maysvillian-early Richmondian time. From Frey, 1987a.

1917, 1919; Weiss and others, 1965; Anstey and Fowler, 1969; Cressman, 1973; Frey, 1987a, 1987b). Variations in water depth, which in part controlled water temperature, circulation, and turbulence, resulted in local lithologic and faunal differences in the Cincinnatian rocks (Wier and others, 1984).

The onset of the closure of the Iapetus Ocean resulted in the formation of the Taconic Mountains (Stearns and others, 1979). Remnants of these mountains are located in the present-day New England-New York region of the United States. Some of the material eroded from these new mountains was carried westward. The eroded sediments carried westward from this orogenic event produced the coarse-clastic deposits present east of Ohio (Bird and Dewey, 1970). These clastics grade westward, at least partially, into the shallow-shelf carbonates of the Cincinnatian Series of southwestern Ohio. Orogenic activity in eastern North America and adjoining lands was not continuous along the entire closure zone. Fluctuations in sediment source areas caused by separate orogenic events are preserved in the Late Ordovician rocks of Ohio and Kentucky. The terrigenous sediments preserved in the Cincinnatian Series were derived from at least two source areas. One source was south-southeast of the present-day Cincinnati area, and the other was to the east-northeast (Weir and others, 1984). The carbonates in the Cincinnatian Series formed autochthonously in the Cincinnatian sea (Schumacher and others, 1987).

ERA	PERIOD	MILLIONS OF YEARS AGO
CENOZOIC	Quaternary	
		1.6
	Tertiary	
		66.4
MESOZOIC	Cretaceous	
		144
	Jurassic	
		208
	Triassic	
		245
PALEOZOIC	Permian	
		286
	Pennsylvanian	
		320
	Mississippian	
		360
	Devonian	
		408
	Silurian	
		438
	Ordovician	
		505
	Cambrian	
		570
PRECAMBRIAN		

Dates for the time scale are from Palmer (1983).

FIGURE 4.—Geologic time scale.

STRATIGRAPHY

As the geologic map of Ohio (see map at back of guidebook) shows, only rocks of the Paleozoic Era and older are present in Ohio. The oldest rocks exposed at the surface in Ohio are located in southwestern Ohio and belong to the Ordovician Period. The Ordovician lasted from approximately 505 million years ago to 438 million years ago (fig. 4). The Ordovician Period is subdivided into four series: the Ibexian, Whiterockian, Mohawkian, and Cincinnatian, from oldest to youngest, respectively (Ross and others, 1982). Only the Cincinnatian Series is extensively exposed in Ohio. The Cincinnatian Series is further subdivided into stages: the Edenian, Maysvillian, Richmondian, and Gamachian; only the first three are present in Ohio (fig. 5). The rocks exposed at Caesar Creek State Park are part of the Richmondian Stage and are thought to be approximately 445 million years old.

NORTH AMERICAN STANDARD UNITS	
SERIES	STAGES
Cincinnatian	Gamachian
	Richmondian
	Maysvillian
	Edenian
Mohawkian	Shermanian
	Kirkfieldian

FIGURE 5.—The stages of the Cincinnatian Series. Modified from Bergström and Mitchell, 1986.

The rocks comprising the three stages of the Cincinnatian Series present in Ohio consist of approximately 820 feet of generally undeformed, richly fossiliferous, interbedded carbonates (predominantly limestones) and calcareous clastics (siltstones and shales). The three stages are currently further subdivided into 10 formations and seven members (Schumacher and others, 1988). The formations and members are, in ascending order, the Clays Ferry Formation, the Kope Formation, the Fairview Formation, the Miamitown Shale, the Grant Lake Limestone (composed of the Bellevue, Corryville, and Straight Creek Members) or Grant Lake Formation (composed of the Bellevue, Corryville, and Mount Auburn Members) (Schumacher and others, 1991), the Arnheim formation (composed of the Sunset and Oregonia members), the Waynesville Formation, the Liberty Formation, the Whitewater Formation, and the Drakes Formation (fig. 6). These units are correlatable on the surface and in the subsurface throughout southwestern Ohio (Schumacher and others, 1988).

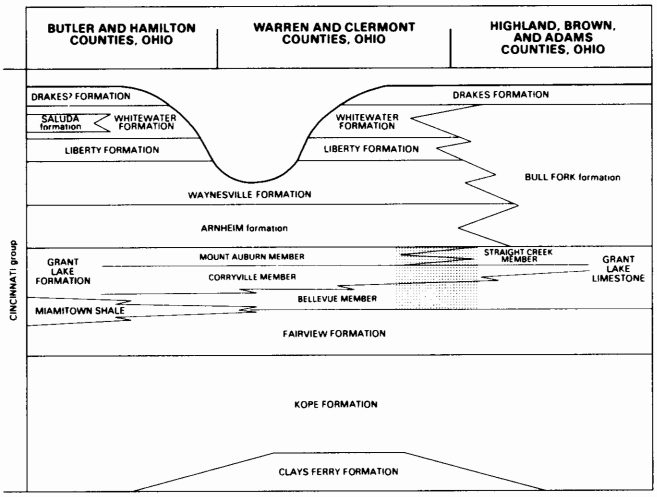

FIGURE 6.—Schematic diagram illustrating Upper Ordovician lithostratigraphic nomenclature recognized by the Ohio Geological Survey in southwestern Ohio. Formal lithostratigraphic terms are in upper-case type, informal terms are in lower-case type. The "valley" depicts post-Ordovician erosion of the Drakes, Whitewater, and Liberty Formations in Clermont and Hamilton Counties, Ohio. The stippled area represents the transition zone between the Grant Lake Formation and the Grant Lake Limestone. From Schumacher and others, 1991.

DESCRIPTIONS OF THE FORMATIONS AT CAESAR CREEK STATE PARK

The following descriptions are given in ascending stratigraphic order. They are based on field mapping and core descriptions from northeastern Warren County.

Arnheim formation

The Arnheim formation is traditionally separated into two members, the basal Sunset and overlying Oregonia (Foerste, 1910). In northeastern Warren County only the Oregonia member is generally exposed. Here the Oregonia member is approximately 18 feet thick, of which 12 feet is exposed at the dam section (fig. 7). This member averages 60 percent shale and 40 percent limestone. The limestone in the Oregonia member occurs as thin (1.5 inches), discontinuous, wavy beds and as nodules (1 to 3 inches in diameter), intermixed and interbedded with fissile shale layers. The member was named by Foerste (1910) for exposures near Oregonia, Ohio, 3 miles southwest of the park. Field mapping in Warren County indicates the uppermost portion of the Oregonia member is a consistent waterfall former and tends to have a rubbly weathering pattern.

Waynesville Formation

Approximately 40 feet of the basal Waynesville Formation overlies the Arnheim formation at the dam section (figs. 7 and 8B). The topmost 10 feet of the Waynesville are exposed along the southwestern end of the emergency spillway (fig. 8B). It is also exposed in Roaring Run at the west end of the spillway. In northeastern Warren County, the Waynesville averages 110 feet thick and 74 percent shale and 26 percent limestone. This formation has thick (5 inches), platy-parted shale layers interbedded with thin (2 inches), planar, moderately continuous limestone layers. Frey (1987b) describes the *Treptoceras duseri* or trilobite shale bed of Foerste (1912) as a 5-foot blue claystone occurring 36-43 feet above the Arnheim-Waynesville formational contact. This bed is exposed near the top of the dam section (NOTE: no collecting is permitted at this outcrop). The type area for the Waynesville Formation is based on outcrops in the vicinity of Waynesville, Ohio (Nickles, 1903).

Liberty Formation

The Liberty Formation is exposed in the emergency spillway floor and walls (figs. 7, 8A, and 8B). The formation averages 27 feet thick and 57 percent shale and 43 percent limestone. The Waynesville Formation and the Liberty Formation are distinguished by the percentage of limestone (26 vs. 43 percent) and by limestone-layer thickness (2 inches vs. 4 inches).

Whitewater Formation

The Whitewater Formation in northeastern Warren County averages 66 feet in thickness and averages 52 percent shale and 48 percent limestone. However, only the basal 30 feet is exposed along the emergency spillway wall and the overlying slope (figs. 7 and 8A); this basal section averages 45 percent shale and 55 percent limestone. Limestone layers in the Whitewater Formation are thin (2 inches), wavy bedded, discontinuous, and argillaceous. Shale layers in the Whitewater Formation are thin and fissile.

LOCATIONS OF ROCK EXPOSURES AT CAESAR CREEK STATE PARK

The best rock exposures are in the Caesar Creek gorge by the base of the dam, on the emergency spillway, and along Flat Fork (fig. 1). The following are brief descriptions of these locations and the formations present at each site.

Dam

At the northwest corner of the base of the dam,

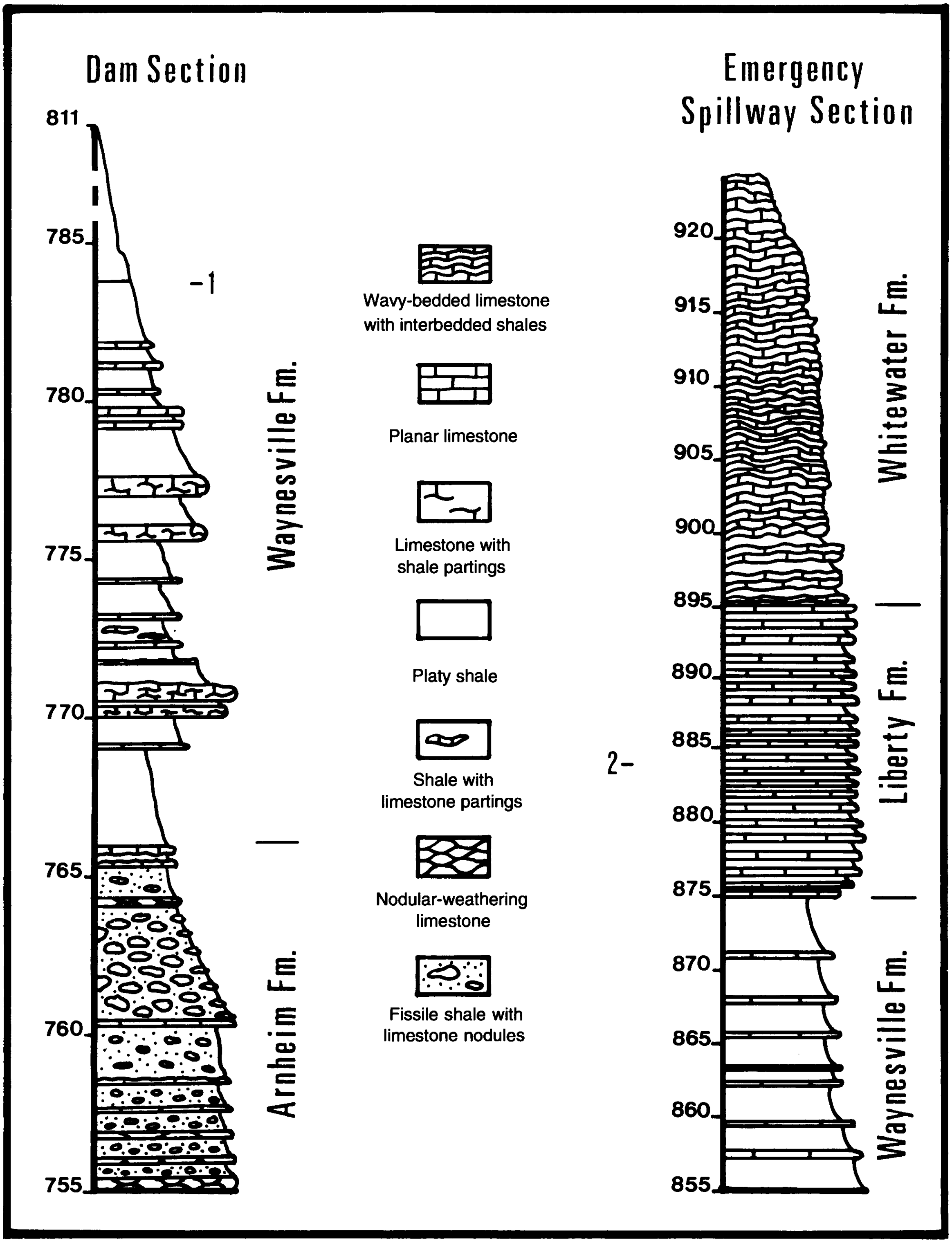

FIGURE 7.—Stratigraphic sections exposed at the Caesar Creek dam and emergency spillway. Vertical numbers indicate feet above sea level. 1 = Waynesville Formation poorly exposed above bench from about 784 feet to the top of the outcrop at about 811 feet. 2 = Clarksville Road at approximately 883 feet. Modified from Shrake and others, 1988.

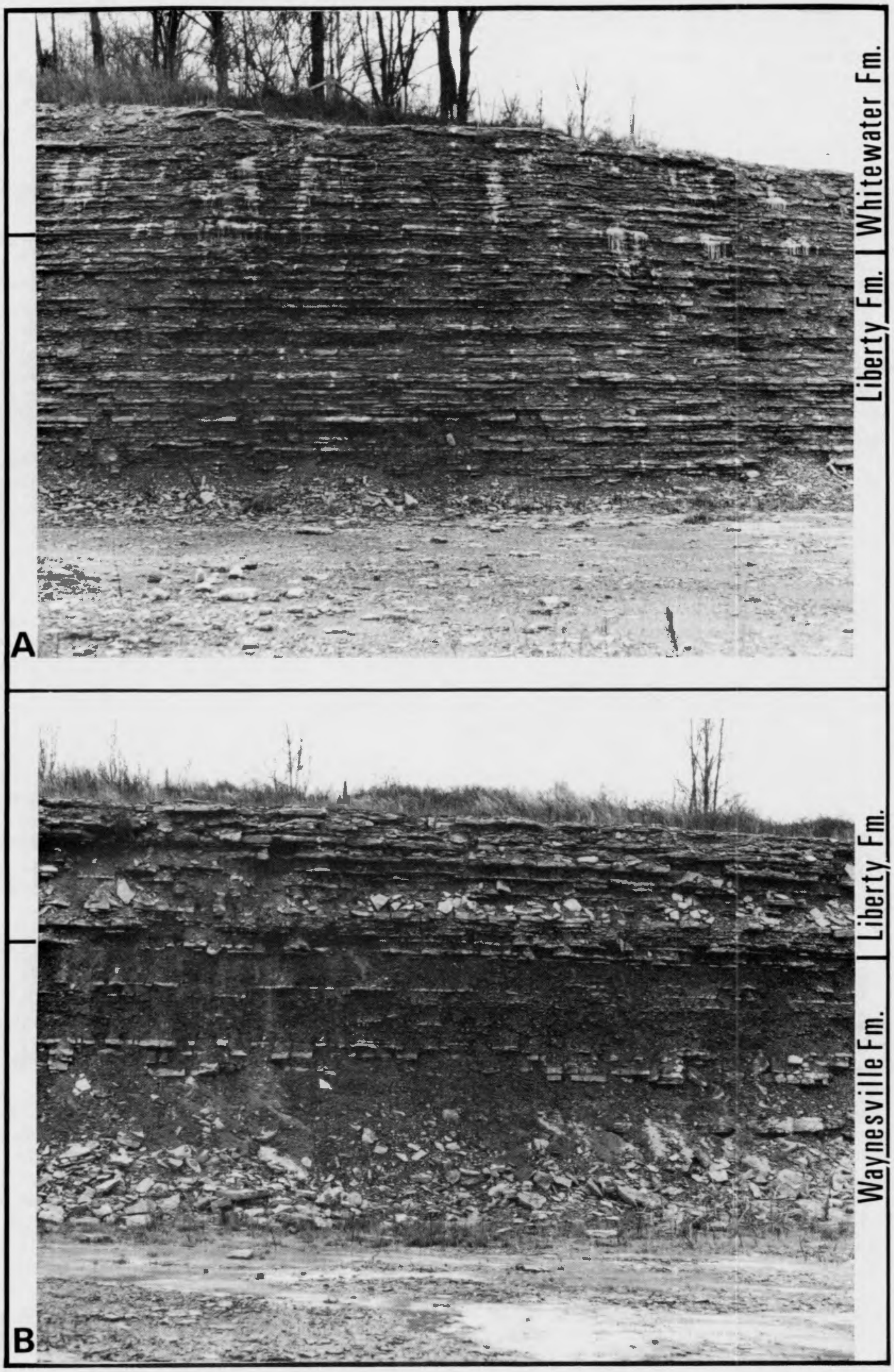

FIGURE 8.—A. Photograph of the Liberty and Whitewater Formations, south side the emergency spillway near Clarksville Road. **B.** Photograph of the Waynesville and Liberty Formations at the southwest corner of the emergency spillway. Photographs taken in early 1980 by Gregory A. Schumacher.

approximately 12 feet of the Arnheim formation and about 40 feet of the Waynesville Formation are exposed (fig. 7). This is an excellent outcrop for studying the Arnheim formation's nodular bedding, rubbly weathering nature, and its contact with the overlying Waynesville Formation.

Emergency spillway

The emergency spillway floor and walls expose the sequence from the top of the Waynesville Formation to the basal portion of the Whitewater Formation (fig. 7). The formations are distinguished by the ratio of the amount of limestone to shale in a given interval, the bedding style of the limestone layers, and the thickness of individual layers. Examination of the bedding styles visible in the spillway walls is encouraged; however, because of their unstable nature, climbing on the vertical walls is strictly prohibited by the U.S. Army Corps of Engineers. Several of the limestone layers exposed along the floor of the emergency spillway display ripple marks, which were formed when the layer was exposed on the seafloor.

Flat Fork

Prior to the damming of Caesar Creek, the entire stratigraphic section from the top of the Arnheim formation to the lower portion of the Whitewater Formation was exposed along Flat Fork (Wolford, 1930). Presently, only the topmost Waynesville Formation to the lower Whitewater Formation are visible along the creek. Access to the exposures along Flat Fork is provided by a trail originating near the southeast corner of the emergency spillway (the end nearest the lake). Please stay on the trail and do not climb on the walls . . . they can be very dangerous! The short hike is worth taking if only to see the well-preserved, wave- or current-rippled limestone layer forming the stream bed near the footbridge across Flat Fork. These features were not formed by the present-day stream flowing over the limestone.

POST-ORDOVICIAN BEDROCK GEOLOGY

The deposition of Ordovician-age sediments over Ohio ended when the shallow sea covering Ohio receded, leaving behind dry land. After an absence of about 12 million years, a sea once again covered Ohio. At this time, rocks of the Silurian Period (fig. 4 and see geologic map) were deposited. Unlike the interbedded limestones and shales deposited in the Ordovician sea, limestone was the main rock type deposited in the Silurian sea. Erosional outliers of Silurian-age rock are present in Warren County, Ohio (see geologic map). Therefore, it is almost certain that at one time Silurian rocks covered the Caesar Creek State Park region.

After the Silurian seas receded from Ohio, at least four more cycles of transgression (flooding of land) and regression (receding of sea) occurred. These cycles are responsible for deposition of the different ages and types of rock present in Ohio (see geologic map). Rocks of almost all of the Paleozoic periods can be seen in various parks throughout the state. For example, Silurian-age rocks can be seen at John Bryan State Park and Clifton Gorge Nature Preserve in Greene County; Devonian-age rocks are exposed on Kelleys Island in Erie County (Lake Erie) and at Highbanks Metro Park in Delaware County; and Mississippian- and Pennsylvanian-age rocks are exposed in the Hocking Hills State Park region. These are by no means the only places to see rock exposures in Ohio; there are many more parks, road cuts, and quarries that provide the opportunity to see the rocks of Ohio.

GLACIAL GEOLOGY OF THE CAESAR CREEK REGION

Much of Ohio's present-day landscape was produced by repeated episodes of glaciation during the Pleistocene Epoch of the Quaternary Period (also known as the Ice Age) (fig. 4). The extent to which Ohio was glaciated is shown on the *Glacial deposits of Ohio* (see map at back of guidebook). Evidence of the glaciers' ability to modify drainage in the proximity of Caesar Creek State Park are the gorges of the Little Miami River and Caesar Creek. Both gorges were eroded by the large volumes of water produced by the melting glaciers. The Little Miami River gorge is crossed by Interstate 71 approximately 9 miles south of Exit 45 (interchange of Ohio Route 73 and Interstate 71). The 0.5-mile wide gorge is spanned by the Jeremiah Morrow bridge, which is the highest bridge in Ohio at 235 feet above the valley floor. Rest areas with scenic overlooks of the bridge and gorge are located south of the bridge on both the north- and south-bound sides of Interstate 71. The Caesar Creek gorge was initiated as an interlobate meltwater channel between the Hartwell Moraine of the Miami Lobe and the Cuba Moraine of the Scioto Lobe (fig. 9). The gorges are not the only evidence that the glaciers were near Caesar Creek State Park. Glacially deposited material known as till is visible in the bluffs along the lake where Ohio Route 73 crosses the lake.

There are several glacial moraines located near the park. West of its intersection (Exit 45) with Interstate 71, Ohio Route 73 follows the axis of the Cuba Moraine, named for Cuba, Ohio, in Clinton County. This moraine is more well developed than most southwestern Ohio moraines and contains large areas of hummocky ground moraine. Where Ohio Route 73 crosses over Caesar Creek Lake (traveling westward), it passes over the front of the Hartwell Moraine. The back edge of this moraine is located near the intersection of Ohio Route 73 and Clarksville Road. Approximately 4 miles south of Exit 45, Interstate 71 passes over the northwest-southeast-trending Vandervort Moraine. This small moraine, mostly buried by the later Cuba Moraine, is the frontal moraine of the Scioto Lobe according to Teller (1967). Approximately 3 miles north of Exit 45 (near the truck weigh station) is the crest of the Wilmington Moraine. This minor northwest-southeast-trending landform has low relief and poor lateral continuity. The Reesville Moraine, located approximately 12 miles north of Exit 45 (at the Clinton-Greene County line), has a striking rise (for southwest Ohio) of 110 feet in 0.5 mile. Stratigraphic, geomorphic, and pedologic data suggest that this moraine may represent the terminal position of a major ice re-advance about 17,000 years ago.

The least visible, but perhaps most spectacular example of the glaciers' effect on the region is a glacial erratic located 3 miles southwest of Caesar Creek State Park near Oregonia (fig. 9). The erratic was first noted by Orton in his 1878 report on Warren County. This block of Brassfield Limestone had an estimated original extent of 45,000

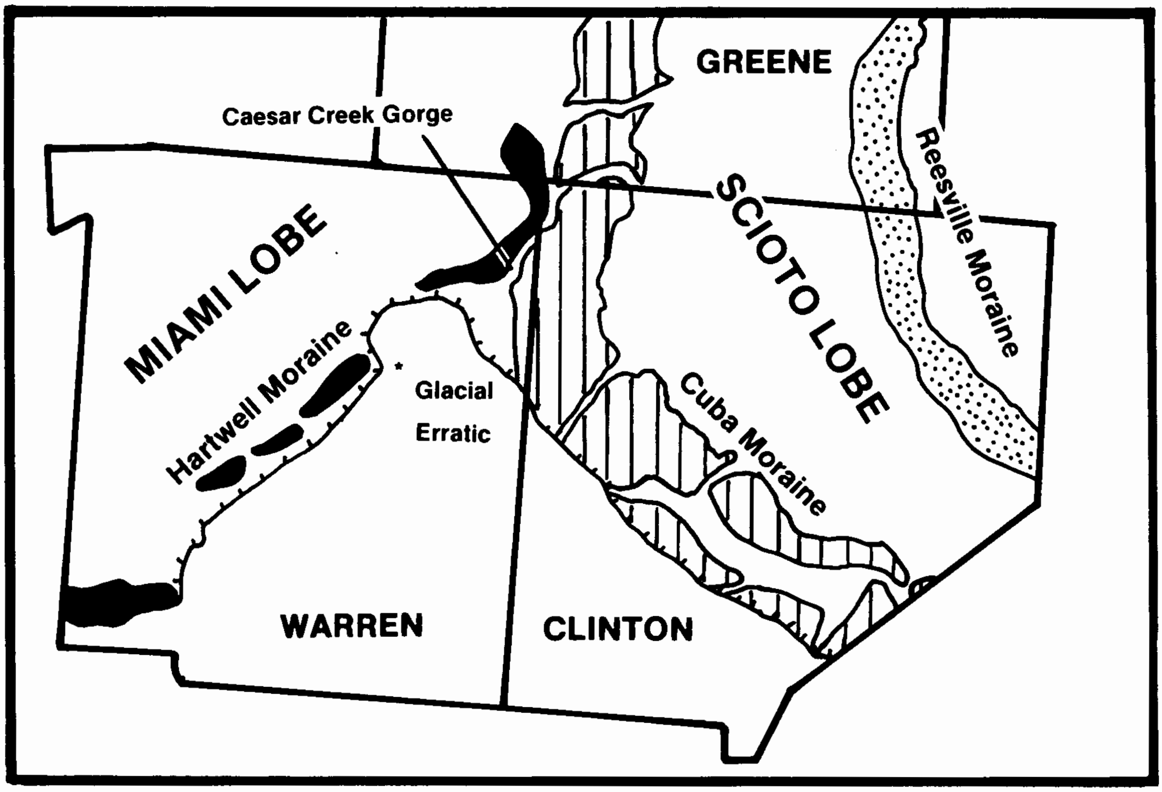

FIGURE 9.—Prominent glacial features in Warren, Clinton, and southern Greene Counties. Hachured line separates Wisconsinan deposits to the north and Illinoian deposits to the south. Modified from Shrake and others, 1987.

square feet (about 1 acre), an average thickness of 5 feet, and a maximum thickness of 17 feet, and is estimated to weigh 13,500 tons (Wolford, 1942). The erratic lies approximately 125 feet below its correct stratigraphic position and is underlain by Illinoian till (Wolford, 1942). The glacial origin of this erratic is supported by the presence of till underlying and overlying the erratic. It is hoped that the area around the erratic can be turned into a nature preserve, so that everyone can appreciate this feature.

COMMON FOSSILS OF CAESAR CREEK STATE PARK

Fossils are the remains, imprints, or traces of an organism which have been partially or completely preserved in sediments. In order for an organism to be fossilized, it generally must have hard parts (*i.e.,* bones or a shell) because soft tissue normally decays away (exceptions to this rule are the Ice Age animals preserved frozen in ice or as mummified remains), and it must be buried (either dead or alive) before decay and scavengers can disturb its skeleton.

The vast majority of the fossils found at the park belong to the group of organisms known as the invertebrates (organisms which do not have a backbone). Vertebrate organisms were just developing in the Ordovician and were not yet widespread; however, it is not improbable that remains of a vertebrate animal (*i.e.,* fish) could be found at the park. Figure 10 shows what these organisms may have looked like while alive.

Biologists and paleontologists classify past and present life using the following taxonomic divisions, from largest to smallest: kingdom, phylum, class, order, family, genus, and species (fig. 11). Some of these terms will be used in the following descriptions of the more common fossils collected in the park. Representatives of all the major invertebrate phyla (plural of phylum) can be collected in the park. Along with the physical fossils of the organisms, records of their day-to-day activities are preserved in the form of trace fossils.

The major phyla that can be collected in the park are described briefly below. Plates 1 to 9 illustrate the more common fossils collected at Caesar Creek State Park.

Phylum Porifera: Sponges. The skeletons of sponges are composed of either calcite or silica spicules (resemble grains of rice). Even though sponges were a common organism in the Paleozoic seas, they do not constitute a major element of the Cincinnatian fauna.

Phylum Coelenterata: Corals, jellyfish, hydra, and sea anemones. It is one of the oldest phyla known from the fossil record. Of the organisms in this phylum, only the corals secrete a hard structure that is easily preserved. Two types of corals, the Rugosa and the Tabulata, now both extinct, are the only members of the phylum collected in the park. The rugose coral is perhaps the easiest fossil to recognize because of its horn shape (plate 1.1). The tabulate corals remotely resemble fossilized wasp nests (plate 1.2-1.5).

Phylum Bryozoa: These creatures, also known as "moss animals," are always colonial (multiple individuals

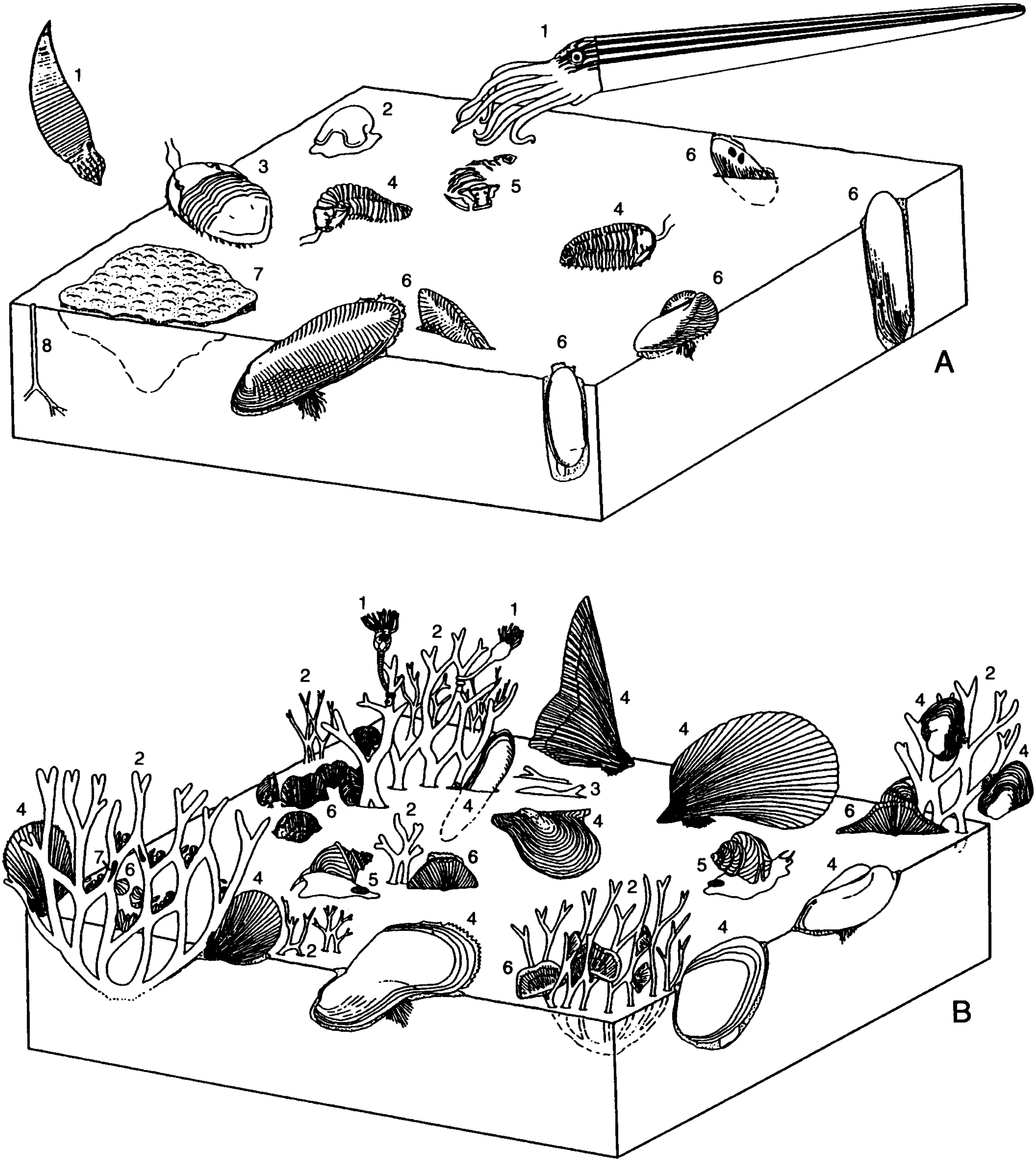

FIGURE 10.—Block diagrams of how the Ordovician seafloor may have appeared. **A.** Reconstruction of the paleocommunity associated with the claystone lithology of the *Treptoceras duseri* shale unit within the Waynesville Formation, Warren County, Ohio. (1) nautiloids, (2) monoplacophoran, (3) *Isotelus* (trilobite), (4) *Flexicalymene* (trilobite), (5) disarticulated *Flexicalymene,* (6) bivalves, (7) stromatoporoid, and (8) *Chondrites* (feeding-burrow trace fossil). **B.** Reconstruction of the trepostome bryozoan community associated with the rubbly skeletal limestones of the Whitewater Formation, Wayne County, Indiana. (1) cystoid (echinoderm), (2) ramose trepostome bryozoans, (3) bryozoan fragments, (4) bivalves, (5) gastropods, (6) brachiopods, and (7) *Cornulites.* Modified from Frey, 1987a.

living in one structure). Fossils from this phylum occur in several forms: branching (twiglike), flat lacy fans (meshlike), rounded mounds, or sheets (encrusting). One of the diagnostic features of this phylum is that the entire surface of a colony (known as a zoarium) is covered by the tiny openings of the living chambers (known as zooecia) (plate 1.6-1.19).

Phylum Brachiopoda: Despite their clamlike appearance, brachiopods (also known as lamp shells because their shape is similar to the shape of a Greek oil lamp) and clams (Phylum Mollusca) are not related. There are two classes of brachiopods: Articulata (having teeth and sockets along the hinge and a calcite shell) (plates 2, 3, and 4.1-4.22) and Inarticulata (having no teeth or sockets along the hinge and a chitinophosphatic shell) (plate 4.23-4.25). Both classes have a plane of symmetry (a line that splits an object into mirror images) perpendicular to the hinge line, and valves that are unequal in size. Although not as numerous as in the past, approximately 1,200 species of brachiopods live in the oceans today. Brachiopods are the most abundant and diverse fossils in the park.

Phylum Mollusca: The classes Gastropoda (snails), Bivalvia (also called Pelecypoda) (clams), and Cephalopoda (squids, octopus, ammonoids, and nautiloids) belong to this phylum. Representatives of all the classes are present in the park. Generally, the fossils collected in the park that belong to this phylum are in the forms of molds and casts (a mold is like a waffle iron and a cast is like a waffle).

Gastropods: typically a helically spiralled (corkscrew) shell, without partitions (plate 5.1-5.9).

Bivalves: two valves, the plane of symmetry is between or parallel to the hinge line (plate 5.10-5.18).

Cephalopods: typically a straight or planispiraled (flat coiled) shell, with partitions (septa) that divide the shell into chambers (plate 6.1-6.3).

Phylum Echinodermata: Members of this phylum include crinoids, blastoids (extinct), edrioasteroids (extinct), sea cucumbers, sea urchins, and starfish. They all have skeletons composed of small plates of calcite and possess pentameral (fivefold) symmetry. Fragments of crinoid stems (plate 6.5) constitute the majority of the echinoderm material that is collected; however, crinoid calyxes (top flowerlike portion) (plate 6.6-6.7) and starfish (plate 6.10) have been collected in the park.

Phylum Arthropoda: Members of this phylum include the insects, spiders, crustaceans (lobsters, crabs, shrimp, and ostracodes), horseshoe crabs, and trilobites (extinct). This phylum accounts for approximately 75 percent of the species in the animal kingdom. The trilobite is the only member of this phylum commonly collected at the park. Depending on the species and the age of the individual, trilobites range in size from less than 1/16 inch to over 17 inches in length. Physically, they are divided into three parts or lobes from side-to-side, hence their name tri-lobite. Trilobites are commonly preserved enrolled or curled up (plate 7.2 and 7.4). They are thought to have enrolled either for protection from predators, or the environment, or while resting, much as the pill bug does today. At least eight different species of trilobites can be collected at the park (plate 7.1-7.13). Fragments of trilobites are quite common, but entire or complete specimens are rare.

Kingdom	Animalia	Animalia	Animalia
Phylum	Chordata	Chordata	Arthropoda
Class	Mammalia	Mammalia	Trilobita
Order	Primates	Carnivora	Phacopida
Family	Hominidae	Felidae	Calymenidae
Genus	*Homo*	*Felis*	*Flexicalymene*
Species	*sapiens* "man"	*domestica* "house cat"	*meeki* *"trilobite"*

FIGURE 11.—Chart showing levels of taxonomic classification and examples of how it is used.

Phylum Graptolithina: Graptolites have a skeleton composed of chitin, and they are generally preserved as a black carbon film (similar to pencil marks) on the rock (plate 8.1-8.2). The graptolites are colonial organisms thought to be related to the Hemicordata (pre-vertebrate organisms).

Phylum Problematica: This phylum is composed of organisms that cannot be placed into an existing phylum. Some of the fossils from this phylum at Caesar Creek are *Tentaculites* (plate 8.5), *Cornulites* (plate 8.6), conulariids (plate 8.4), and stromatoporoids (plate 8.3 and 8.7).

Ichnofossils: These are trace fossils, which are any indirect (nonbody fossil) evidence of the former existence of life. Trace fossils include tracks, trails, burrows, and coprolites (fossil feces). Many varieties of trace fossils can be seen in the park (plate 7.14-7.15, plate 8.8-8.10, and plate 9). One trace fossil to look for is the trilobite resting burrow known as *Rusophycus* (plate 7.14); these have been collected with the trilobite preserved in them.

WHERE TO LEARN MORE ABOUT FOSSILS

Fossil exhibits are on display at the Cincinnati, Cleveland, and Dayton Museums of Natural History, the University of Cincinnati Geology Museum, the Miami University Geological Museum in Oxford, and the Orton Museum at The Ohio State University in Columbus. There are also numerous books that can be of help in identifying fossils. The selected references section contains a list of publications that have been annotated as to where a copy could possibly be located. Finally, if you think you have found something unusual, don't hesitate to take it to the geology department of a nearby university or to the Ohio Department of Natural Resources, Division of Geological Survey. Someone will be more than willing to assist you in identifying your specimen.

Another way to learn about Ohio's rocks, minerals, and fossils is to join one of the many groups or clubs devoted to the hobby of rock collecting. The Ohio Geological Survey has a list of such organizations in Ohio.

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SELECTED ANNOTATED REFERENCES

Bates, R. L., and Jackson, J. A., 1987, Glossary of geology, 3rd edition: American Geological Institute, Alexandria, Virginia.
- should be available in most university libraries.

Clarkson, E. N. K., 1979, Invertebrate palaeontology and evolution: Allen & Unwin Publishers, 323 p.
- a textbook for introductory paleontology courses, well illustrated. Available at most university libraries.

Davis, R. A., ed., 1985, Cincinnati fossils: an elementary guide to the Ordovician rocks and fossils of the Cincinnati, Ohio, region: Cincinnati Museum of Natural History Popular Publication Series No. 10, 61 p.
- excellent coverage of fossils found in southwestern Ohio. Available from the Cincinnati Museum of Natural History or from ODNR, Division of Geological Survey.

Davis, R. A., 1986, Cincinnati region: Ordovician stratigraphy near the southwest corner of Ohio, *in* Neathery, T. L., ed., Southeastern Section of the Geological Society of America: Centennial Field Guide, v. 6, p. 21-24.
- should be available at most university libraries.

Johnson, T. T., 1985, Trilobites of the Thomas T. Johnson collection: how to find, prepare, and photograph trilobites: Dayton, Ohio, Litho-Print, Inc., 178 p.
- very well illustrated with black and white photographs; available at the What on Earth store in Columbus.

LaRocque, Aurele, and Marple, M. F., 1955, Ohio fossils: Ohio Division of Geological Survey Bulletin 54, 152 p.
- very well illustrated; available from Ohio Department of Natural Resources, Division of Geological Survey.

Levin, H. L., 1978, The Earth through time: W. B. Saunders Publishing Co., 589 p.
- historical geology textbook; available at most university libraries.

Moore, R. C., Lalicker, C. G., and Fischer, A. G., 1952, Invertebrate fossils: McGraw-Hill, 766 p.
- covers all the invertebrate phyla; very detailed; available at all major university libraries.

Moore, R. C., ed., 1959, Treatise on invertebrate paleontology, Parts A-X: University of Kansas Press in association with the Geological Society of America.
- multivolume description of all invertebrate phyla, available at all university libraries.

Ohio Division of Parks and Recreation, 1967, The fossils of Hueston Woods: Ohio Department of Natural Resources, Division of Parks and Recreation, 16 p.
-available from the Ohio Department of Natural Resources, Division of Parks and Recreation.

Osgood, R. G., 1970, Trace fossils of the Cincinnati area: Palaeontographica Americana, v. 6, no. 41, p. 281-444.
- available at most university libraries.

Schumacher, G. A., and Ausich, W. I., 1983, New Upper Ordovician echinoderm site: Bull Fork Formation, Caesar Creek Reservoir (Warren County, Ohio): Ohio Journal of Science, v. 83, p. 60-64.
- available at most public and university libraries, or from Gregory A. Schumacher, c/o ODNR, Division of Geological Survey.

Schumacher, G. A., 1986, Ordovician echinoderm fossils: Ohio Geology, Summer 1986.
- available from ODNR, Division of Geological Survey, or from Gregory A. Schumacher, c/o ODNR, Division of Geological Survey.

Schumacher, G. A., Shrake, D. L., Swinford, E. M., Brockman, C. S., and Wickstrom, L. H., 1987, Stratigraphy and depositional environments of the Cincinnati Group of southwestern Ohio: Guidebook, 16th Annual Meeting, Eastern Section, American Association of Petroleum Geologists, Ohio Geological Society, 73 p.
- excellent Ordovician reference list and up-to-date views on the geology of southwestern Ohio. Out-of-print. May be available on interlibrary loan from Ohio State University.

Shrake, D. L., Schumacher, G. A., and Swinford, E. M., 1988, The stratigraphy, sedimentology and paleontology of the Upper Ordovician Cincinnati group of southwest Ohio: Field Trip Guidebook, 5th Midyear Meeting, Society of Economic Paleontologists and Mineralogists, Columbus, Ohio, 81 p.
- excellent Ordovician reference list and discussions on the geology and paleontology of southwestern Ohio; plates of the common Cincinnatian fossils. Available from the Society of Economic Paleontologists and Mineralogists, Catalogue #806, P.O. Box 4756, Tulsa, OK 74159-0756.

Thompson, I., 1982, The Audubon Society field guide to North American fossils: Knopf, Inc., 847 p.
- available at most book stores.

U.S. Army Corps of Engineers, Caesar Creek Lake, Ohio: Louisville District, pamphlet.
- available at the Caesar Creek State Park Visitor Center.

U.S. Army Corps of Engineers, Lakes of Louisville District: Louisville District, pamphlet.
- available at the Caesar Creek State Park Visitor Center.

Weir, G. W., Peterson, W. L., and Swadley, W C, 1984, Lithostratigraphy of Upper Ordovician strata exposed in Kentucky: U.S. Geological Survey Professional Paper 1151-E, 121 p.
- available at most university libraries.

Wolford, J. J., 1930, The stratigraphy of the Oregonia-Fort Ancient region, southwestern Ohio: Ohio Journal of Science, v. 30, p. 301-308.
- available at most public and university libraries.

REFERENCES

Albertstadt, L. P., 1979, The brachiopod genus *Platystrophia:* U.S. Geological Survey Professional Paper 1066-B, 20 p.

Anstey, R. L., and Chase, T. L., 1974, Geographic diversity of Late Ordovician corals and bryozoans in North American: Journal of Paleontology, v. 48, p. 1141-1148.

Anstey, R. L., and Fowler, M. L., 1969, Lithostratigraphy and depositional environment of the Eden Shale (Ordovician) in the tri-state area of Indiana, Kentucky, Ohio: Journal of Geology, v. 77, p. 668-682.

Anstey, R. L., and Perry, T. G., 1969, Redescription of cotypes of *Peronopora vera* Ulrich, a Cincinnatian (Late Ordovician) ectoproct species: Journal of Paleontology, v. 43, p. 245-251.

________ 1973, Eden Shale bryozoans: a numerical study (Ordovician, Ohio Valley): Michigan State University Paleontological Series, ser. 1, no. 1, 80 p.

Anthony, J. G., 1838, New trilobite, *Ceratocephala ceralepta*: American Journal of Science, v. 34, p. 379-380.

________ 1839a, Fossil encrinite: American Journal of Science, v. 35, p. 359-360.

________ 1839b, Description of a new fossil (*Calymene bucklandii*): American Journal of Science, v. 36, p. 106-107.

Aronoff, S. M., 1979, Orthoconic nautiloid morphology and the case of *Treptoceras* vs. *Orthonybyoceras:* Neues Jahrbuch fur Geologie und Palaeontologie Abhandeln, v. 158, p. 100-122.

Bassler, R. S., 1906, A study of the James types of Ordovician and Silurian Bryozoa: Proceedings of the U.S. National Museum, v. 30, p. 1-66.

Bell, B. M., 1979, Edrioasteroids (Echinodermata): U.S. Geological Survey Professional Paper 1066-E, 7 p.

Berdan, J. M., 1984, Leperditicopid ostracodes from Ordovician rocks of Kentucky and nearby states and characteristic features of the order Leperditicopoda: U.S. Geological Survey Professional Paper 1066-J, 40 p.

Bergström, S. M., 1971, Conodont biostratigraphy of the Middle and Upper Ordovician of Europe and eastern North America, *in* Sweet, W. C., and Bergström, S. M. (eds.), Symposium on conodont biostratigraphy: Geological Society of America Memoir 127, p. 83-157.

Bergström, S. M., Carnes, J. B., Ethington, R. L., Votaw, R. B., and Wigley, P. B., 1974, *Appalachignathus,* a new multielement conodont genus from the Middle Ordovician of North America: Journal of Paleontology, v. 48, p. 227-235.

Bergström, S. M., and Mitchell, C. E., 1986, The graptolite correlation of the North American Upper Ordovician Standard: Lethaia, v. 19, p. 247-266.

Bergström, S. M., and Sweet, W. C., 1966, Conodonts from the Lexington Limestone (Middle Ordovician) of Kentucky and its lateral equivalents in Ohio and Indiana: Bulletins of American Paleontology, v. 50, p. 271-441.

________ 1969, Ordovician conodont localities, southwestern Ohio: Field trip guidebook, 3rd Annual Meeting, North-Central Section, Geological Society of America, Ohio Division of Geological Survey, p. 3-1 to 3-13.

Berry, W. B. N., 1966, *Orthograptus truncatus richmondensis* (Ruedeman) in the Arnheim Formation (Ordovician) in Indiana: Journal of Paleontology, v. 40, p. 1392-1394.

Bird, J. M., and Dewey, J. F., 1970, Lithosphere plate-continental margin tectonics and evolution of the Appalachian orogen: Geological Society of America Bulletin, v. 81, p. 1031-1060.

Boardman, R. S., and Utgaard, J. E., 1966, A revision of the Ordovician bryozoan genera *Monticulipora, Peronopora, Heterotrypa,* and *Dekayia:* Journal of Paleontology, v. 40, p. 1082-1108.

Branstrator, J. W., 1972, *Lanthanaster cruciformis,* a new Upper Ordovician sea star from Cincinnati, Ohio: Journal of Paleontology, v. 46, p. 66-69.

________ 1979, Asteroidea (Echinodermata): U.S. Geologcal Survey Professional Paper 1066-F, 7 p.

Braun, E. L., 1916, The Cincinnatian Series and its brachiopods in the vicinity of Cincinnati: Cincinnati Society of Natural History Journal, v. 22, p. 18-42.

Brown, G. D., and Daly, E. J., 1985, Trepostome Bryozoa from the Dillsboro Formation (Cincinnatian Series) of southeastern Indiana: Indiana Geological Survey Special Report 33, 95 p.

Browne, R. G., 1964, The coral horizons and stratigraphy of the upper Richmond Group in Kentucky west of the Cincinnati Arch: Journal of Paleontology, v. 38, p. 385-392.

________ 1965, Some Upper Cincinnatian (Ordovician) colonial corals of north-central Kentucky: Journal of Paleontology, v. 39, p. 1177-1191.

Bucher, W. H., 1917, Large current-ripples as indicators of paleogeography: Proceedings of the U.S. National Museum, v. 3, p. 285-291.

________ 1919, On ripples and related sedimentary surface forms and their paleogeographic interpretations: American Journal of Science, v. 47, 4th ser., nos. 279, 280, p. 149-210 and 241-269.

________ 1938, A shell-boring gastropod in a *Dalmanella* bed of Upper Cincinnatian age: American Journal of Science, v. 36, 5th ser., no. 211, p. 1-7.

Caster, K. E., 1942, Two siphonophores from the Paleozoic: Palaeontographica Americana, v. 3, no. 14, 34 p.

Caster, K. E., and Kjellevig-Waering, E. N., 1964, Upper Ordovician eurypterids of Ohio: Palaeontographica Americana, v. 4, no. 32, p. 301-358.

Caster, K. E., and Macke, W. B., 1952a, An aglaspid merostome from the Upper Ordovician of Ohio: Journal of Paleontology, v. 26, p. 753-755.

________ 1952b, Concerning *Enoploura* of the Upper Ordovician and its relation to other carpoid Echinodermata: Bulletins of American Paleontology, v. 34, no. 141, 56 p.

Conrad, T. A., 1842, Observations of the Silurian and Devonian Systems of the U.S., with descriptions of new organic remains: Academy of Natural Sciences of Philadelphia Journal, v. 8, pt. 2, p. 228-235.

Cressman, E. R., 1973, Lithostratigraphy and depositional environments of the Lexington Limestone (Ordovician) of central Kentucky: U.S. Geological Survey Professional Paper 768, 61 p.

Crowther, P. R., and Bergström, S. M., 1980, Cortical bandages in an Upper Ordovician glyptograptid graptolite from Ohio: Bollettino della Societa Paleontologica Italiana, v. 19, p. 250-253.

Cumings, E. R., 1922, Nomenclature and description of the geological formations of Indiana: Indiana Department of Conservation Publication 21, p. 403-570.

Davis, R. A., and Cuffey, R. J., in press, Sampling the layer cake that isn't: the stratigraphy and paleontology of the Type Cincinnatian: Ohio Division of Geological Survey Guidebook 13.

Douglas, Dale, 1970, Midwest fossils—pt. VIII, worm fossils, conodonts: Earth Science, v. 23, no. 3, p. 127-134.

Drake, Daniel, 1825, Geological account of the Valley of the Ohio: Transactions of the American Philosophical Society, New Series, v. 2, p. 124-139.

Dyche, D. T. D., 1892a, On terminations of columns of crinoids from the Cincinnati Group: American Geologist, v. 10, no. 2, p. 130.

________ 1892b, The crinoid *Heterocrinus subcrassus:* Science, v. 20, no. 459, p. 66.

________ 1892c, Remarks on the stems and roots of crinoids from near Lebanon, Ohio: Cincinnati Society of Natural History Journal, v. 15, no. 2, p. 101.

Elias, R. J., 1982, Latest Ordovician solitary rugose corals of eastern North America: Bulletins of American Paleontology, v. 81, no. 314, p. 116 p.

________ 1983a, Late Ordovician solitary rugose corals of the Stony Mountain Formation, southern Manitoba, and its equivalents: Journal of Paleontology, v. 57, p. 924-956.

________ 1983b, Middle and Late Ordovician solitary rugose corals of the Cincinnati Arch region: U.S. Geological Survey Professional Paper 1066-N, 13 p.

Ethington, R. L., Droste, J. B., and Rexroad, C. B., 1986, Conodonts from subsurface Champlainian (Ordovician) rocks of eastern Indiana: Indiana Geological Survey Special Report 37, 32 p.

Fenton, M. A., 1929, The supposed calyx of *Lichenocrinus:* American Midland Naturalist, v. 11, p. 491-493.

Flower, R. H., 1946, Ordovician cephalopods of the Cincinnati region, pt. 1: Bulletins of American Paleontology, v. 29, no. 116, 656 p.

Foerste, A. F., 1888, Notes on Paleozoic fossils: Denison University Scientific Laboratories Bulletin, v. 3, p. 117-137.

________ 1905, Note on the distribution of Brachiopoda in the Arnheim and Waynesville beds: American Geologist, v. 36, no. 4, p. 244-250.

________ 1912, *Strophomena* and other fossils from Cincinnatian and Mohawkian horizons, chiefly in Ohio, Indiana and Kentucky: Denison University Scientific Laboratories Bulletin, v. 17, p. 17-172.

________ 1919, Notes on *Isotelus, Acrolichas, Calymene,* and *Encrinurus:* Denison University Scientific Laboratories Bulletin, v. 19, p. 65-82.

________ 1924, Notes on American Paleozoic cephalopods: Denison University Scientific Laboratories Bulletin, v. 20, p. 193-268.

Frest, T. J., Strimple, H. L., and Kelly, S. M., 1976, A new Ordovician camerate crinoid from Kentucky: Southeastern Geology, v. 17, p. 139-148.

Frey, R. C., 1980, *Vanuxemia waynesvillensis,* a new species of cyrtodontid pelecypod from the Upper Ordovician of southwest Ohio: Journal of Paleontology, v. 54, p. 740-744.

________ 1987a, The occurrence of pelecypods in early Paleozoic epeiric-sea environments, Late Ordovician of the Cincinnati, Ohio area: Palaios, v. 2, p. 3-23.

________ 1987b, The paleoecology of a Late Ordovician shale unit from southwest Ohio and southeast Indiana: Journal of Paleontology, v. 61, p. 242-267.

Galloway, J. J., and St. Jean, J., Jr., 1956, Bibliography of the order Stromatoporoidea: Journal of Paleontology, v. 30, p. 170-185.

________ 1961, Ordovician Stromatoporoidea of North America: Bulletins of American Paleontology, v. 43, no. 194, 102 p.

Grahn, Yngve, and Bergström, S. M., 1985, Chitinozoans from the Ordovician-Silurian boundary beds in the eastern Cincinnati region in Ohio and Kentucky: Ohio Journal of Science, v. 85, p. 175-183.

Gray, H. H., 1972, Lithostratigraphy of the Maquoketa Group (Ordovician) in Indiana: Indiana Geological Survey Special Report 7, 31 p.

Guber, A. L., 1971, Problems of sexual dimorphism, population structure and taxonomy of the Ordovician genus *Tetradella* (Ostracoda): Journal of Paleontology, v. 45, p. 6-22.

Gutstadt, A. M., 1958. Upper Ordovician stratigraphy in Eastern Interior Region: American Association of Petroleum Geologists Bulletin, v. 42, p. 513-547.

Hall, D. D., 1962, Dalmanellidae of the Cincinnatian: Palaeontographica Americana, v. 4, no. 29, p. 131-163.

Hall, James, 1872a, Descriptions of new species of Crinoidea and other fossils from strata of the age of the Hudson River Group and Trenton limestone: New York State Museum, 24th Annual Report, p. 205-223.

________ 1872b, Description of new species of fossils from the Hudson River Group in the vicinity of Cincinnati, Ohio: New York State Museum, 24th Annual Report, p. 225-232.

Hotchkiss, F. H. C., 1970, North American Ordovician Ophiuroidea—the genus *Taeniaster* Billings, 1858 (Protasteridae): Proceedings of the Biological Society of Washington, v. 83, no. 5, p. 59-76.

Howe, H. J., 1979, Middle and Late Ordovician plectambonitacean, rhynchonellacean, syntrophiacean, trimerellacean, and atrypacean brachiopods: U.S. Geological Survey Professional Paper 1066-C, 18 p.

James, Carolyn, 1940, Species of *Tetradium* in the Cincinnati series: American Midland Naturalist, v. 24, no. 3, p. 645-646.

James, J. F., 1885, Remarks on the genera *Lepidolites, Anomaloides, Ischadites,* and *Receptaculites* from the Cincinnati Group: Cincinnati Society of Natural History Journal, v. 8, no. 3, p. 163-166.

________ 1886a, Cephalopoda of the Cincinnati Group: Cincinnati Society of Natural History Journal, v. 8, no. 3, p. 235-253.

________ 1886b, Note on a recent synonym in the paleontology of the Cincinnati Group: Cincinnati Society of Natural History Journal, v. 9, no. 2, p. 39 (103).

________ 1887, Protozoa of the Cincinnati Group: Cincinnati Society of Natural History Journal, v. 9, no. 4, p. 244-252.

________ 1888, *Monticulipora,* a coral and not a polyzoon: American Geologist, v. 1, no. 6, p. 386-392.

James, U. P., 1872, On a new species of the fossil from the Lower Silurian (*Cyrtolites costatus*): American Journal of Science, 3rd ser., v. 3, no. 13, p. 26.

________ 1874a, Descriptions of a new species of Brachiopoda from the Lower Silurian rocks, Cincinnati Group: Cincinnati Quarterly Journal of Science, v. 1, p. 19-22.

________ 1874b, Descriptions of one new species of *Leptaena,* and two species of *Cyclonema* from the Lower Silurian rocks, Cincinnati Group: Cincinnati Quarterly Journal of Science, v. 1, p. 151-154.

________ 1874c, Descriptions of new species of fossils from the Lower Silurian formation, Cincinnati Group: Cincinnati Quarterly Journal of Science, v. 1, p. 239-242.

________ 1874d, Descriptions of new species of Brachiopoda from the Lower Silurian formation, Cincinnati Group: Cincinnati Quarterly Journal of Science, v. 1, p. 333-335.

________ 1884a, Description of three species of fossils: Cincinnati Society of Natural History Journal, v. 7, no. 1, p. 20-24.

________ 1884b, Descriptions of four new species from the Cincinnati Group: Cincinnati Society of Natural History Journal, v. 7, no. 3, p. 137-140.

________ 1884c, On conodonts and fossil annelid jaws: Cincinnati Society of Natural History Journal, v. 7, no. 3, p. 143-149.

James, U. P., and James, J. F., 1887, On the monticuliporoid corals of the Cincinnati Group, with critical revision of the species: Cincinnati Society of Natural History Journal, v. 10, no. 3, p. 118-141; v. 10, no. 4, p. 158-184, and 1888, v. 11, no. 1, p. 15-47.

Jennette, D. C., and Pryor, W. A., 1986, Storm-dominated cyclic shelf deposits in Upper Ordovician of Cincinnati Arch region (abs.): American Association of Petroleum Geologists Bulletin, v. 70, p. 609.

Jones, J. R., 1890, On some Paleozoic Ostracoda from North America, Wales, and Ireland: Geological Society of London Quarterly Journal, v. 46, p. 1-31.

Karklins, O. L., 1983, Bryozoan fauna of the upper Clays Ferry, Kope, and lower Fairview Formations (Edenian, Upper Ordovician) at Moffett Road, northern Kentucky: U.S. Geological Survey Open-File Report 83-21, 53 p.

________ 1984, Trepostome and cystoporate bryozoans from the Lexington Limestone and Clays Ferry Formation (Middle and Upper Ordovician) of Kentucky: U.S. Geological Survey Professional Paper 1066-I, 105 p.

Kelly, S. M., and Pope, J. K., 1979, A new camerate crinoid from the Upper Ordovician of Indiana: Journal of Paleontology, v. 53, p. 416-420.

Kelly, S. M., Frest, T. J., and Strimple, H. L., 1978, Additional information on *Simplococrinus persculptus:* Journal of Paleontology, v. 52, p. 1227-1232.

Kesling, R. V., and Hussey, R. C., 1953, A new family and genus of ostracod from the Ordovician Bill's Creek shale of Michigan: University of Michigan Museum of Paleontology Contributions, v. 11, no. 4, p. 77-95.

Kesling, R. V., and Mintz, L. W., 1961, Notes on *Lepadocystis moorei* (Meek), an Upper Ordovician callocystitid cystoid: University of Michigan Museum of Paleontology Contributions, v. 17, no. 4, p. 123-148.

Kreisa, R. D., Dorobek, S. L., Accorti, P. J., and Ginger, E. P., 1981, Recognition of storm-generated deposits in the Cincinnatian Series, Ohio (abs.): Geological Society of America Abstracts with Programs, v. 13, p. 285.

Locke, John, 1838, Geological report (on southwestern Ohio): Ohio Division of Geological Survey 2nd Annual Report, p. 201-286.

________ 1842a, On the fossil *Cryptolithus tesselatus:* Academy of Natural Sciences of Philadelphia Proceedings, v. 1, nos. 15 and 16, p. 186, 196-197; nos. 22 and 23, p. 236, 1843.

________ 1842b, On a new species of trilobite of very large size (*Isotelus megistos*): American Journal of Science, 1st ser., v. 42, no. 2, p. 366-368.

________ 1843a, Notice of a new trilobite *Ceraurus crosotus:* American Journal of Science, 1st ser., v. 44, no. 2, p. 346.

________ 1843b, Supplementary notice of the *Ceraurus crosotus:* American Journal of Science, 1st ser., v. 45, no. 2, p. 222-224.

McElhinny, M. W., and Opdyke, N. D., 1973, Remagnetization hypothesis discounted: a paleomagnetic study of the Trenton Limestone, New York State: Geological Society of America Bulletin, v. 84, p. 3697-3707.

Meek, F. B., 1871, On some new Silurian [Ordovician] crinoids and shells: American Journal of Science, 3rd ser., v. 2, no. 10, p. 295-299.

________ 1872, Descriptions of two new star-fishes, and a crinoid, from the Cincinnati Group of Ohio and Indiana: American Journal of Science, 3rd ser., v. 3, no. 16, p. 257-262.

Meek, F. B., and Worthen, A. H., 1865, Descriptions of new species of Crinoidea, etc., from the Paleozoic rocks of Illinois and some adjoining states: Philadelphia Academy of Natural Sciences Proceedings, v. 17, p. 143-155.

Mickleborough, John, 1883, Locomotory appendages of trilobites: Cincinnati Society of Natural History Journal, v. 6, no. 3, p. 200-206.

Miller, S. A., 1874a, Notes and descriptions of Cincinnati Group fossils: Cincinnati Quarterly Journal of Science, v. 1, p. 2-18, 147-150, 232-236, 282, 343-351, 368-375; v. 2, p. 86-87, 274-284, 378-379.

________ 1874b, Monograph of the Lamellibranchiata of the Cincinnati Group: Cincinnati Quarterly Journal of Science, v. 2, p. 211-231.

________ 1874c, Monograph of the Gastropoda of the Cincinnati Group: Cincinnati Quarterly Journal of Science, v. 1, p. 302-321.

________ 1874d, Remarks upon the genus *Anomalodonta* and the orders *Megaptera* and *Opisthoptera* and the species *gigantea* and *alata*: Cincinnati Quarterly Journal of Science, v. 1, p. 326-333.

________ 1875a, Monograph of the class Brachiopoda of the Cincinnati Group and remarks upon some described forms: Cincinnati Quarterly Journal of Science, v. 2, p. 6-62.

________ 1875b, *Acidaspis o'nealli* (Notes and descriptions of Cincinnati group fossils): Cincinnati Quarterly Journal of Science, v. 2, p. 86-87.

________ 1875c, Class Cephalopoda (Cuvier) as represented in the Cincinnati Group: Cincinnati Quarterly Journal of Science, v. 2, p. 121-134.

________ 1880, Description of four new species of Silurian (and Ordovician) fossils: Cincinnati Society of Natural History Journal, v. 3, no. 2, p. 140-144.

________ 1881a, Description of five new species of Silurian fossils, and remarks upon an undetermined form: Cincinnati Society of Natural History Journal, v. 3, no. 4, p. 314-317.

________ 1881b, Description of some new and remarkable crinoids and other fossils of the Hudson River Group and notice of *Strotocrinus bloomfieldensis:* Cincinnati Society of Natural History Journal, v. 4, no. 1, p. 69-77.

________ 1882a, Description of three new species and remarks upon others: Cincinnati Society of Natural History Journal, v. 5, no. 3, p. 116-117.

________ 1882b, Description of three new orders and four new families in the class Echinodermata and eight new species from the Silurian and Devonian formations: Cincinnati Society of Natural History Journal, v. 5, no. 4, p. 221-231.

________ 1883, *Glyptocrinus* redefined and restricted, *Gaurocrinus, Pycnocrinus* and *Compsocrinus* established, and two new species described: Cincinnati Society of Natural History Journal, v. 6, no. 4, p. 217-234.

________ 1884, Description of a beautiful starfish and other fossils: Cincinnati Society of Natural History Journal, v. 7, no. 1, p. 16-20.

Miller, S. A., and Faber, C. L., 1894, New species of fossils from the Hudson River Group and remarks upon others: Cincinnati Society of Natural History Journal, v. 17, no. 1, p. 22-23.

Mitchell, C. E., and Bergström, S. M., 1977, Three-dimensionally preserved Richmondian graptolites from southwestern Ohio and the graptolite correlation of the North American Upper Ordovician Standard: Bollettino della Societa Paleontologica Italiana, v. 16, p. 257-270.

Moore, R. C., Lalicker, C. G., and Fischer, A. G., 1952, Invertebrate fossils: New York, McGraw-Hill Book Company, Inc., 766 p.

Nicholson, H. A., 1874a, Description of species of *Chaetetes* from the Lower Silurian rocks of North America: Geological Society of London Quarterly Journal, v. 30, p. 499-515.

________ 1874b, On *Columnopora,* a new genus of tabulate corals: Geological Magazine, 2nd ser., v. 1, p. 253-254.

________ 1875a, Description of Polyzoa from the Silurian formation: Ohio Division of Geological Survey, v. 1, pt. 2, Paleontology, p. 257-268.

________ 1875b, Descriptions of species of *Hippothoa* and *Alecto* from the Lower Silurian rocks of Ohio, with description of *Aulopora arachnoidea* Hall: Annals and Magazine of Natural History, 4th ser., v. 15, no. 86, p. 123-127.

________ 1875c, Descriptions of new species of Polyzoa from the Lower and Upper Silurian rocks of North America: Annals and Magazine of Natural History, 4th ser., v. 15, no. 87, p. 177-184.

________ 1880, On the minute structure of the recent *Heteropora neozelanica* Busk and on the relations of the genus *Heteropora* to *Monticulipora:* Annals and Magazine of Natural History, 5th ser., v. 6, no. 35, p. 329-339; v. 6, no. 36, p. 414-423.

Nickles, J. M., 1902, Description of a new bryozoan, *Homotrypa bassleri,* n. sp., from the Warren beds of the Lorraine Group: Cincinnati Society of Natural History Journal, v. 20, no. 2, p. 103-105.

________ 1903, The Richmond Group in Ohio and Indiana and its subdivisions, with a note on the genus *Strophomena* and its type: American Geologist, v. 32, no. 4, p. 202-218.

Orton, Edward, 1878, Report on the geology of Warren County: Ohio Division of Geological Survey, v. 3, p. 381-391.

Osgood, R. G., Jr., 1970, Trace fossils of the Cincinnati area: Palaeontographica Americana, v. 6, no. 41, p. 281-444.

________ 1977a, Selected Cincinnatian trace fossils, *in* Pope, J. K., and Martin, W. D. (eds.), Biostratigraphy and paleoenvironments of the Cincinnatian Series in southeastern Indiana: Seventh Annual Field Conference, Great Lakes Section, Society of Economic Paleontologists and Mineralogists, Miami University, p. III-1-III-24.

________ 1977b, "Trace fossils of the Cincinnati area"—revisited, a decade later (abs.): Journal of Paleontology, v. 51, supplement to no. 2, part III, p. 19.

Osgood, R. G., and Szmuc, E. J., 1972, A trace fossil *Zoophycus* as an indicator of water depth: Bulletins of American Paleontology, v. 62, no. 271, 22 p.

Parsley, R. L., 1981, Echinoderms from Middle and Upper Ordovician rocks of Kentucky: U.S. Geological Survey Professional Paper 1066-K, 9 p.

Palmer, A. R., compiler, 1983, The Decade of North American Geology 1983 geologic time scale: Geology, v. 11, no. 8, p. 503-504.

Pojeta, John, Jr., 1962, The pelecypod genus *Byssonychia* as it occurs in the Cincinnatian at Cincinnati, Ohio: Palaeontographica Americana, v. 4, no. 30, p. 170-216.

Pope, J. K., 1982, Some silicified strophomenacean brachiopods from the Ordovician of Kentucky, with comments on the genus *Pionomene:* U.S. Geological Survey Professional Paper 1066-L, 30 p.

Pulse, R. R., and Sweet, W. C., 1960, The American Upper Ordovician Standard III. Conodonts from the Fairview and McMillan Formations of Ohio, Kentucky, and Indiana: Journal of Paleontology, v. 34, p. 237-264.

Richards, R. P., 1972, Autecology of Richmondian brachiopods (Late Ordovician of Indiana and Ohio): Journal of Paleontology, v. 46, p. 385-405.

Riva, John, 1974, A revision of some Ordovician graptolites of eastern North America: Palaeontology, v. 17, p. 1-40.

Ross, R. J., Jr., 1967, Calymenid and other Ordovician trilobites from Kentucky and Ohio: U.S. Geological Survey Professional Paper 583-B, 19 p.

________ 1976, Ordovician sedimentation in the western United States, in Bassett, M. G. (ed.), The Ordovician System: University of Wales Press and National Museum of Wales, Cardiff, p. 73-105.

________ 1979, Additional trilobites from the Ordovician of Kentucky: U.S. Geological Survey Professional Paper 1066-D, 13 p.

Ross, R. J., Jr., Adler, F. J., Amsden, T. W., Bergstrom, Douglas, Bergström, S. M., Carter, Claire, Churkin, Michael, Cressman, E. A., Derby, J. R., Dutro, J. T., Jr., Ethington, R. L., Finney, S. C., Fisher, D. W., Fisher, J. H., Harris, A. G., Hintze, L. F., Ketner, K. B., Kolata, D. L., Landing, Ed, Neuman, R. B., Sweet, W. C., Pojeta, John, Jr., Potter, A. W., Rader, E. K., Repetski, J. E., Shaver, R. H., Thompson, T. L., and Webers, G. F., 1982, The Ordovician System in the United States: International Union of Geological Sciences Publication No. 12, 73 p.

Schopf, J. M., Ehlers, E. G., Stiles, D. V., and Birle, J. D., 1965, Fossil iron bacteria preserved in pyrite: American Philosophical Society Proceedings, v. 109, no. 5, p. 288-308.

Schumacher, G. A., and Ausich, W. I., 1983, New Upper Ordovician echinoderm site: Bull Fork Formation, Caesar Creek Reservoir (Warren County, Ohio): Ohio Journal of Science, v. 83, p. 60-64.

Schumacher, G. A., Shrake, D. L., Swinford, E. M., Brockman, C. S., and Wickstrom, L. H., 1987, Stratigraphy and depositional environments of the Cincinnati Group of southwestern Ohio: Guidebook, 16th Annual Eastern Section Meeting, American Association of Petroleum Geologists and Ohio Geological Society, 73 p.

Schumacher, G. A., Swinford, E. M., and Shrake, D. L., 1988, Middle and Upper Ordovician stratigraphy of southwestern Ohio (abs.): Geological Society of America Abstracts with Program, v. 20, no. 5, p. 387.

________ 1991, Lithostratigraphy of the Grant Lake Limestone and Grant Lake Formation (Upper Ordovician) in southwestern Ohio: Ohio Journal of Science, v. 91, no. 1, p. 56-68.

Scotese, C. R., Bambach, R. K., Barton, C., Van der Voo, R., and Ziegler, A. M., 1979, Paleozoic base maps: Journal of Geology, v. 87, p. 217-277.

Seddon, George, and Sweet, W. C., 1971, An ecologic model for conodonts: Journal of Paleontology, v. 45, p. 869-880.

Shrake, D. L., 1987, Guide to the fossils and geology of Caesar Creek State Park: Ohio Division of Geological Survey Open-File Report 87-1, 20 p.

Shrake, D. L., 1989, Paleoecology of a Cincinnatian (Upper Ordovician) bryozoan-trilobite association: M.S. thesis (unpub.), Wright State University, 90 p.

Shrake, D. L., Schumacher, G. A., and Swinford, E. M., 1988, Field guidebook to the stratigraphy, sedimentology, and paleontology of the Upper Ordovician Cincinnati group of southwestern Ohio: Field trip guidebook, Society of Economic Paleontologists and Mineralogists, Fifth Midyear Meeting, Columbus, Ohio, 81 p.

Singh, R. J., 1979, Trepostomatous bryozoan fauna from the Bellevue Limestone, Upper Ordovician, in the tri-state area of Ohio, Indiana, and Kentucky: Bulletins of American Paleontology, v. 76, no. 307, p. 161-288.

Stearn, C. W., Carroll, R. L., and Clark, T. H., 1979, Geological evolution of North America, 3rd ed.: John Wiley and Sons, 566 p.

Sweet, W. C., 1979, Conodonts and conodont biostratigraphy of the post-Tyrone Ordovician rocks of the Cincinnati region: U.S. Geological Survey Professional Paper 1066-G, 25 p.

Sweet, W. C., Ethington, R. L., and Barnes, C. R., 1971, North American Middle and Upper Ordovician conodont faunas, *in* Sweet, W. C., and Bergström, S. M. (eds.), Symposium on conodont biostratigraphy: Geological Society of America Memoir 127, p. 163-193.

Sweet, W. C., and Miller, A. K., 1958, Ordovician cephalopods from Cornwallis and Little Cornwallis Islands, District of Franklin, Northwest Territories: Geological Survey of Canada Bulletin 38, 86 p.

Sweet, W. C., Turco, C. A., Warner, Earl, and Wilkie, L. C., 1959, The American Upper Ordovician Standard. I. Eden conodonts from the Cincinnati region, Ohio and Kentucky: Journal of Paleontology, v. 33, p. 1029-1068.

Taylor, J. S., 1850, Notice of trilobites in the cabinet of Dr. Julius S. Taylor: American Journal of Science, 2nd ser., v. 10, no. 28, p. 113-114.

Teller, J. T., 1967, Glacial geology of Clinton County, Ohio: Ohio Division of Geological Survey Report of Investigations 67, color map with text.

Thompson, E. H., 1970, Morphology and taxonomy of *Cyclonema* Hall (Gastropoda), Upper Ordovician, Cincinnatian province: Bulletins of American Paleontology, v. 58, no. 261, p. 219-284.

Tobin, R. C., and Pryor, W. A., 1985, Cincinnatian Series—model for cyclic and episodic deposition of carbonates and shales on a storm-dominated ramp (abs.): American Association of Petroleum Geologists Bulletin, v. 69, p. 311-312.

Ulrich, E. O., 1879, Description of a new genus and some new species of bryozoans from the Cincinnati Group: Cincinnati Society of Natural History Journal, v. 2, no. 3, p. 119-131.

________ 1882a, American Paleozoic Bryozoa: Cincinnati Society of Natural History Journal, v. 5, no. 3, p. 121-175; v. 5, no. 4, p. 232-257; 1883, v. 6, no. 1, p. 82-92; v. 6, no. 2, p. 148-168; v. 6, no. 4, p. 245-279.

________ 1882b, Descriptions of two new species of crinoids: Cincinnati Society of Natural History Journal, v. 5, no. 3, p. 175-177.

________ 1889a, Preliminary description of new Lower Silurian sponges: American Geologist, v. 3, no. 4, p. 233-248.

________ 1889b, On *Lingulasma,* a new genus, and eight new species of *Lingula* and *Trematis:* American Geologist, v. 3, no. 6, p. 377-391; v. 4, no. 1, p. 21-25.

________ 1890a, New Lamellibranchiata: American Geologist, v. 5, no. 5, p. 270-284; v. 6, no. 3, p. 173-181; v. 6, no. 5, p. 382-389.

________ 1890b, New Lower Silurian Bryozoa: Cincinnati Society of Natural History Journal, v. 12, no. 4, p. 173-198.

________ 1890c, New and little known American Paleozoic Ostracoda: Cincinnati Society of Natural History Journal, v. 13, no. 3, p. 104-137; v. 13, no. 4, p. 173-211(1891).

________ 1892, New Silurian Lamellibranchiata chiefly from Minnesota rocks: Minnesota Geological Survey Annual Report, v. 19, p. 211-248.

________ 1893, New and little known Lamellibranchiata from the Lower Silurian rocks of Ohio and adjacent states: Ohio Division of Geological Survey, v. 7, p. 627-693.

________ 1895, On Lower Silurian Bryozoa of Minnesota: Minnesota Geological Survey Final Report, v. 3, pt. 2, p. 96-332.

________ 1897a, The Lower Silurian Lamellibranchiata of Minnesota: Minnesota Geological Survey Final Report, v. 3, pt. 2, p. 475-628.

________ 1897b, The Lower Silurian Ostracoda of Minnesota: Minnesota Geological Survey Final Report, v. 3, pt. 2, p. 629-693.

U.S. Geological Survey, 1969, Cincinnati Arch Ordovician pelecypods, *in* Geological Survey research 1969: U.S. Geological Survey Professional Paper 650-A, p. A132.

Utgaard, J. E., 1968, A revision of North American genera of ceramoporoid bryozoans (Ectoprocta)—pt. 2, *Crepipora, Ceramoporella, Acanthoceramoporella,* and *Ceramophylla:* Journal of Paleontology, v. 42, p. 1444-1455.

Utgaard, J. E., and Perry, T. G., 1964, Trepostomatous bryozoan fauna of the upper part of the Whitewater Formation (Cincinnatian) of eastern Indiana and western Ohio: Indiana Geological Survey Bulletin 33, 111 p.

Van der Voo, Robert, 1988, Paleozoic paleogeography of North America, Gondwana, and intervening displaced terranes: comparisons of paleomagnetism with paleoclimatology and biogeographical patterns: Geological Society of America Bulletin, v. 100, p. 311-324.

Walker, L. G., 1982, The brachiopod genera *Hebertella, Dalmanella,* and *Heterorthina* from the Ordovician of Kentucky: U.S. Geological Survey Professional Paper 1066-M, 16 p.

Warn, J. M., 1973, The Ordovician crinoid *Heterocrinus* with reference to brachial variability in *H. tenuis:* Journal of Paleontology, v. 47, p. 10-18.

Warn, J. M., 1974, Presumed myzostomid infestation of an Ordovician crinoid: Journal of Paleontology, v. 48, p. 506-513.

Warn, J. M., and Strimple, H. L., 1977, The disparid inadunate superfamilies Homcrinacea and Cincinnaticrinacea (Echinodermata Crinoidea), Ordovician-Silurian, North America: Bulletins of American Paleontology, v. 72, no. 296, p. 1-138.

Warshauer, S. M., and Berdan, J. M., 1982, Palaeocopid and podocopid Ostracoda from the Lexington Limestone and Clays Ferry Formation (Middle and Upper Ordovician) of central Kentucky: U.S. Geological Survey Professional Paper 1066-H, 80 p.

Weir, G. W., Peterson, W. L., and Swadley, W C, 1984, Lithostratigraphy of Upper Ordovician strata exposed in Kentucky: U.S. Geological Survey Professional Paper 1151-E, 121 p.

Weiss, M. P., 1961, The American Upper Ordovician Standard V: a critical appraisal of the classification of the typical Cincinnatian beds: Geological Society of America Bulletin, v. 72, p. 645-647.

Weiss, M. P., Edwards, W. R., Norman, C. E., and Sharp, E. R., 1965, The American Upper Ordovician Standard VII: stratigraphy and petrology of the Cynthiana and Eden Formations of the Ohio Valley: Geological Society of America Special Paper 81, 76 p.

Weiss, M. P., and Norman, C. E., 1960, The American Upper Ordovician Standard II: development of stratigraphic classification of Ordovician rocks in the Cincinnati region: Ohio Division of Geological Survey Information Circular 26, 14 p.

Wells, J. W., 1942, Supposed color-markings in Ordovician trilobites from Ohio: American Journal of Science, v. 240, p. 710-713.

Wetherby, A. G., 1879, Description of a new family and genus of Lower Silurian Crustacea: Cincinnati Society of Natural History Journal, v. 1, no. 4, p. 162-166.

________ 1880, Descriptions of new crinoids from the Cincinnati Group of the Lower Silurian and the Subcarboniferous of Kentucky: Cincinnati Society of Natural History Journal, v. 2, no. 4, p. 245-253.

________ 1881, Description of new fossils from the Lower Silurian and Subcarboniferous rocks of Ohio and Kentucky: Cincinnati Society of Natural History Journal, v. 4, no. 1, p. 77-85.

Whitfield, R. P., 1878, Remarks on some lamellibranchiate shells of the Hudson River Group, with descriptions of four new species: Cincinnati Society of Natural History Journal, v. 1, no. 3, p. 137-141.

Whittington, H. B., 1969, *Platycorphe,* an Ordovician homolonotid trilobite: Journal of Paleontology, v. 34, p. 487-491.

________ 1956, Silicified Middle Ordovician trilobites: the Odontopleurida: Harvard College Museum of Comparative Zoology Bulletin, v. 114, no. 5, 288 p.

Williams, Alwyn, and others, 1965, Treatise on Invertebrate Paleontology: Pt. H, Brachiopoda, v. 1 and 2: Geological Society of America and University of Kansas Press, 927 p.

Wolford, J. J., 1927, The geology of the Oregonia-Ft. Ancient region, Warren County, Ohio: M.A. thesis (unpub.), Ohio State University, 56 p.

________ 1930, The stratigraphy of the Oregonia-Ft. Ancient region, southwestern Ohio: Ohio Journal of Science, v. 30, no. 5, p. 301-308.

________ 1942, A record size glacial erratic: American Journal of Science, 5th ser., v. 24, no. 143, p. 362-367.

Woodward, Henry, 1884, Notes on appendages of trilobites: Geology Magazine, 3rd ser., v. 1, no. 4, p. 162-165.

PLATES

The majority of the specimen photographs on the following plates were derived from Davis (1985), and are used with permission of the Cincinnati Museum of Natural History. Dr. Loren Babcock contributed several of the trilobite photographs. The trace fossils shown on plates 8 and 9 are from Osgood (1970).

PLATE 1

Phylum Coelenterata

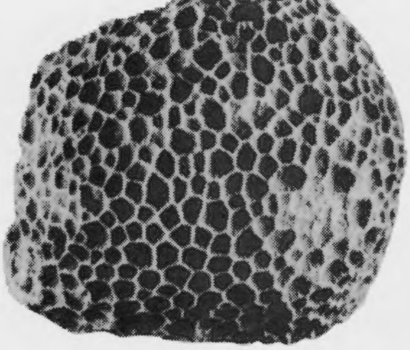
1. *Grewingkia canadensis*
2. *Favistina stellata*
3. *Calapoecia huronensis*
4. *Protarea richmondensis*, enlarged
5. *Protarea richmondensis*

Phylum Bryozoa

6. *Constellaria polystomella*
7. *Batostomella gracilis*
8. *Batostomella gracilis*
9. *Rhombotrypa quadrata*
10. *Rhombotrypa quadrata*
11. *Rhombotrypa quadrata*, enlarged
12. *Homotrypa wortheni*
13. *Peronopora vera*
14. *Homotrypa wortheni*
15. *Parvohallopora subnodosa*
16. *Parvohallopora subnodosa*, enlarged
17. *Homotrypa dawsoni*
18. *Batostoma varians*
19. *Homotrypa flabellaris*

COELENTERATA


1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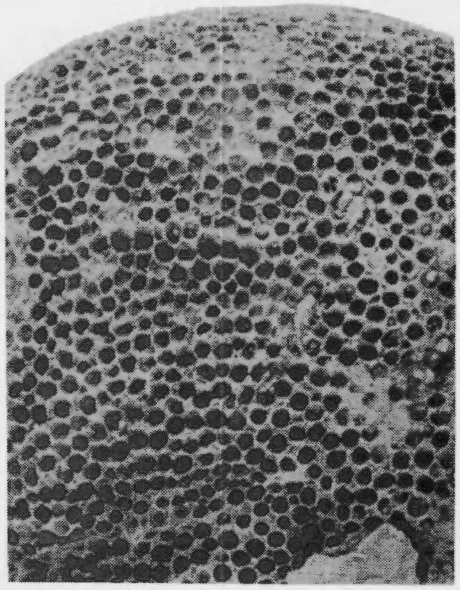
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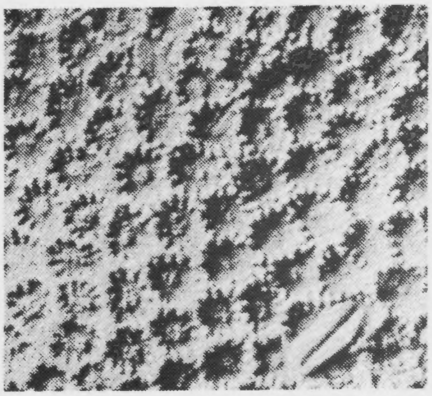
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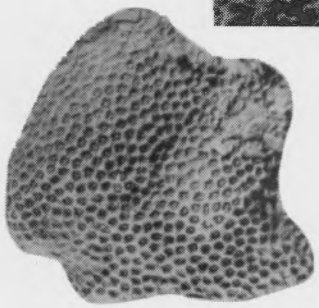
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BRYOZOA


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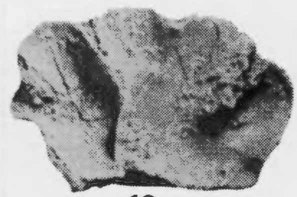
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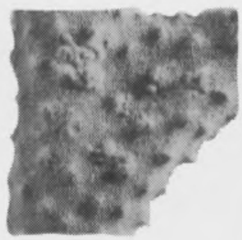
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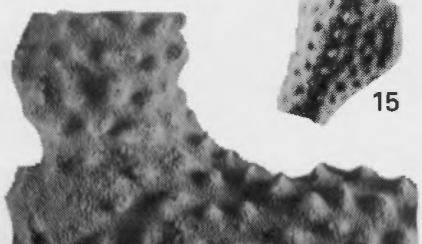
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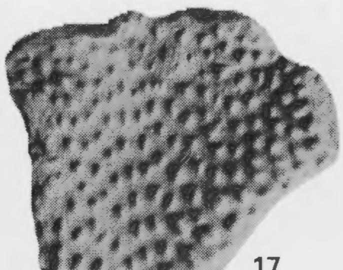
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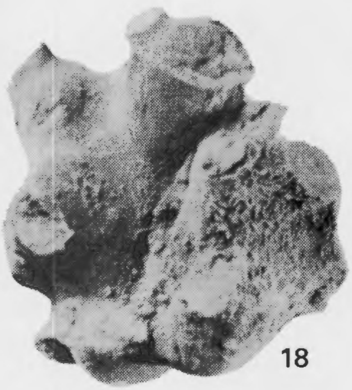
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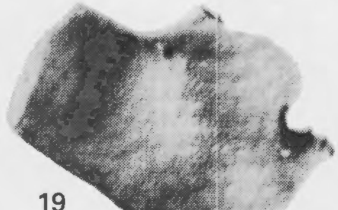
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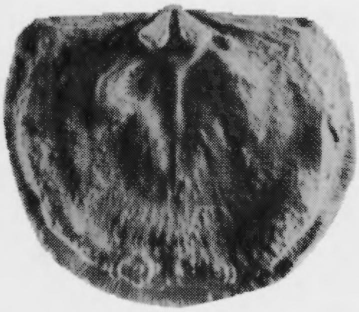
PLATE 2

Phylum Brachiopoda
Class Articulata

1. *Rafinesquina ponderosa*
2. *Rafinesquina ponderosa*
3. *Rafinesquina ponderosa*
4. *Tetraphalerella neglecta*
5. *Tetraphalerella neglecta*
6. *Tetraphalerella neglecta*
7. *Strophomena concordensis*
8. *Strophomena concordensis*
9. *Strophomena concordensis*
10. *Strophomena planumbona*
11. *Strophomena planumbona*
12. *Strophomena planumbona*
13. *Strophomena planumbona*
14. *Strophomena nutans*
15. *Strophomena nutans*
16. *Strophomena nutans*
17. *Strophomena nutans*
18. *Strophomena vetusta*
19. *Strophomena vetusta*

BRACHIOPODA
ARTICULATA



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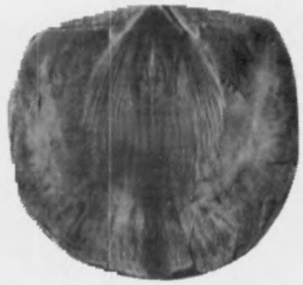

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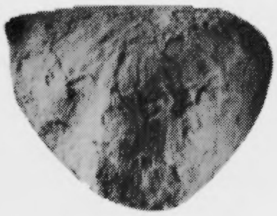

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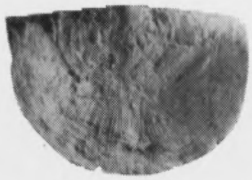

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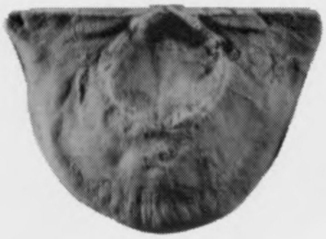

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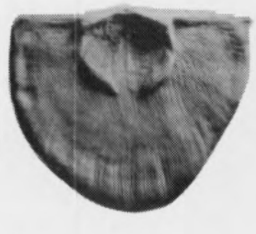

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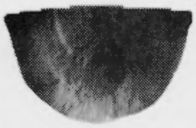

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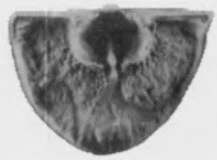

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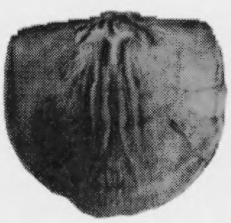

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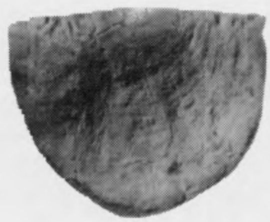

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PLATE 3

Phylum Brachiopoda
Class Articulata

1. *Hebertella occidentalis*
2. *Hebertella occidentalis*
3. *Hebertella occidentalis*
4. *Plaesiomys subquadrata*
5. *Plaesiomys subquadrata*
6. *Plaesiomys subquadrata*
7. *Onniella meeki*
8. *Onniella meeki*
9. *Onniella meeki*
10. *Onniella meeki*
11. *Glyptorthis insculpta*
12. *Glyptorthis insculpta*
13. *Glyptorthis insculpta*
14. *Glyptorthis insculpta*
15. *Leptaena richmondensis*
16. *Leptaena richmondensis*
17. *Leptaena richmondensis*
18. *Thaerodonta clarksvillensis*
19. *Zygospira modesta*
20. *Catazyga headi*
21. *Catazyga headi*
22. *Holtedahlina sulcata*
23. *Holtedahlina sulcata*

BRACHIOPODA
ARTICULATA

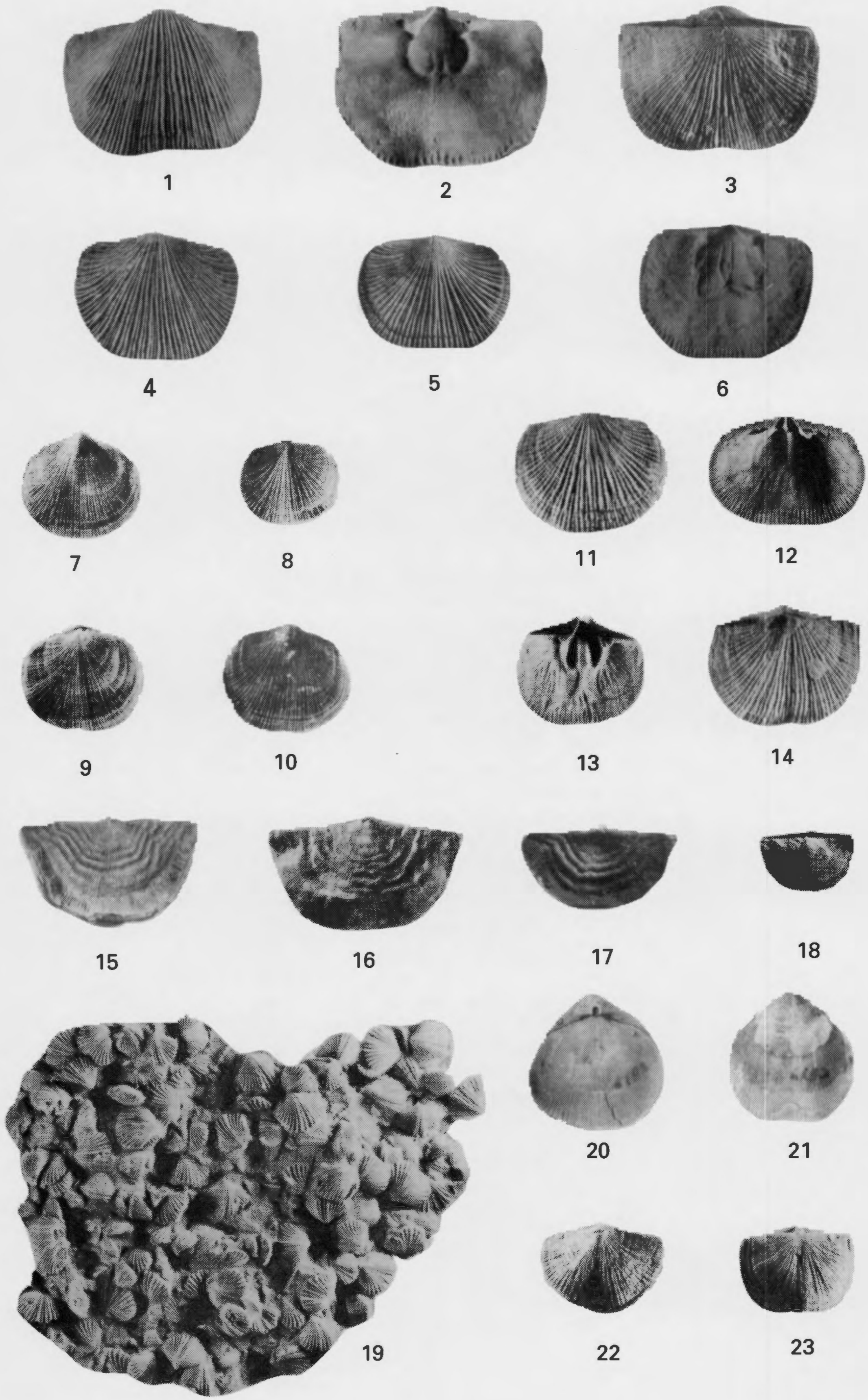


PLATE 4

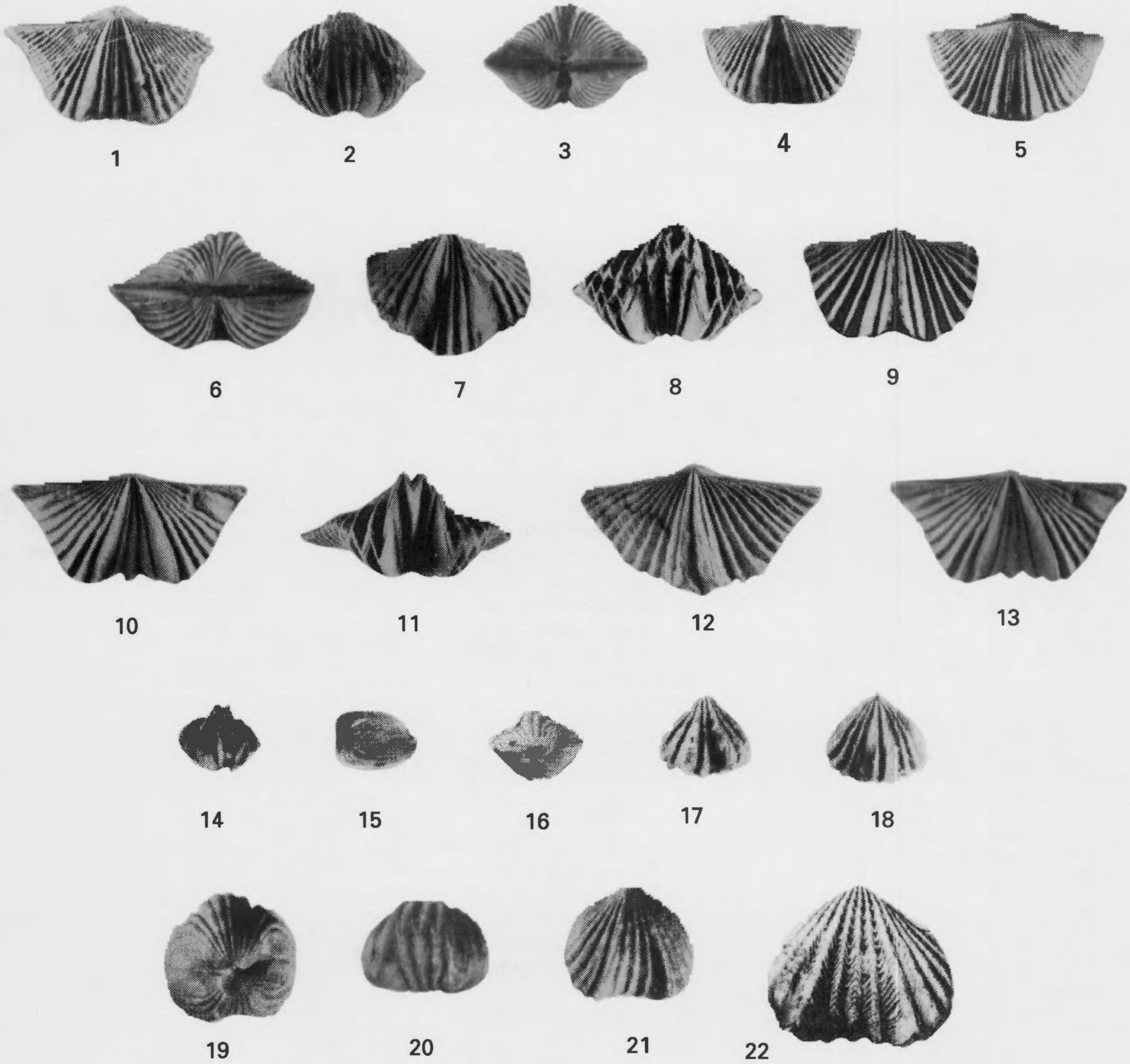
Phylum Brachiopoda
Class Articulata

1. *Platystrophia acutilirata*
2. *Platystrophia acutilirata*
3. *Platystrophia acutilirata*
4. *Platystrophia acutilirata*
5. *Platystrophia acutilirata*
6. *Platystrophia clarksvillensis*
7. *Platystrophia clarksvillensis*
8. *Platystrophia clarksvillensis*
9. *Platystrophia clarksvillensis*
10. *Platystrophia cypha*
11. *Platystrophia cypha*
12. *Platystrophia cypha*
13. *Platystrophia cypha*
14. *Rhynchotrema dentatum*
15. *Rhynchotrema dentatum*
16. *Rhynchotrema dentatum*
17. *Rhynchotrema dentatum*
18. *Rhynchotrema dentatum*
19. *Hiscobeccus capax*
20. *Hiscobeccus capax*
21. *Hiscobeccus capax*
22. *Lepidocyclus perlamellosus*

Phylum Brachiopoda
Class Inarticulata

23. *Petrocrania scabiosa*, the small circular feature on the lower left corner of the *Rafinesquina pondersoa*
24. *Pseudolingula* sp.
25. *Schizocrania filosa*

BRACHIOPODA ARTICULATA



BRACHIOPODA INARTICULATA

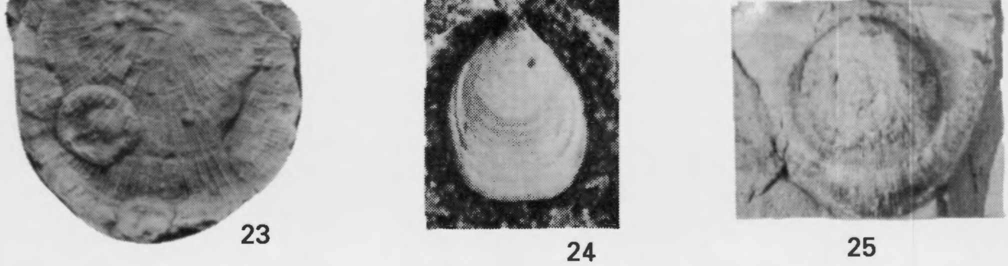


PLATE 5

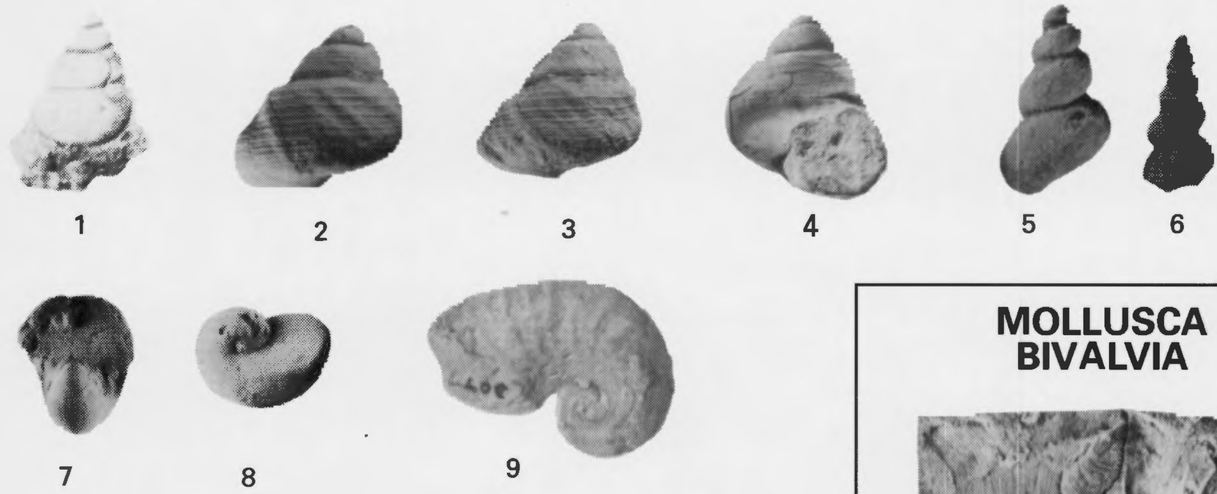
Phylum Mollusca
Class Gastropoda

1. *Cyclonema bilix lata*
2. *Cyclonema bilix lata*
3. *Cyclonema bilix lata*
4. *Cyclonema bilix lata*
5. *Loxoplocus bowdeni*
6. *Loxoplocus bowdeni*
7. *Sinuites cancellatus*
8. *Sinuites cancellatus*
9. *Cyrtolites ornatus*

Phylum Mollusca
Class Bivalvia
(also called Pelecypoda)

10. *Caritodens demissa*
11. *Anomalodonta gigantea*
12. *Ambonychia robusta*
13. *Ischyrodonta elongata*
14. *Lyrodesma major*
15. *Cymatonota typicalis*
16. *Modiolopsis modiolaris*
17. *Cycloconcha milleri*
18. *Cyrtodontula umbonata*

MOLLUSCA
GASTROPODA



MOLLUSCA
BIVALVIA

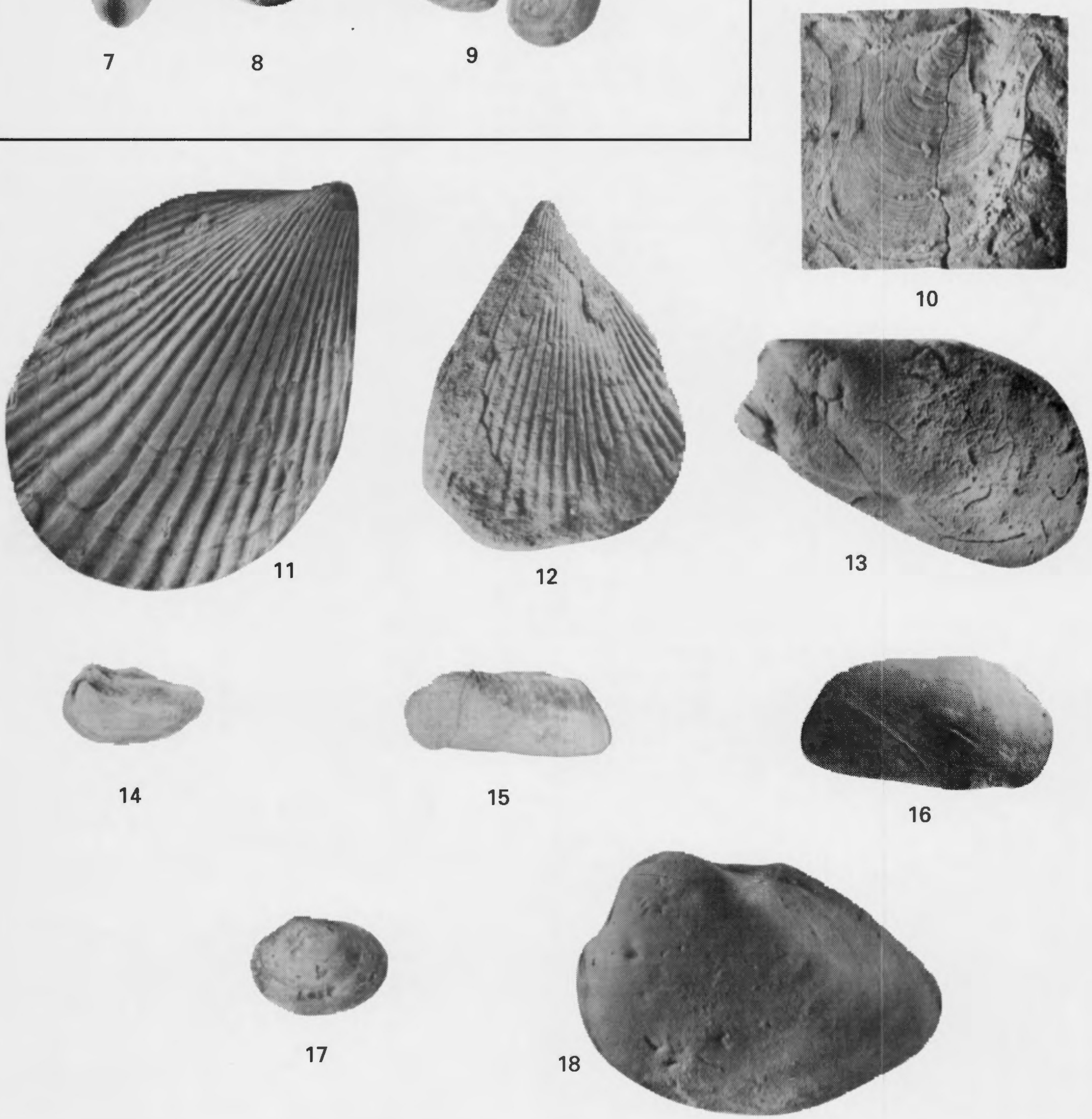


PLATE 6

Phylum Mollusca
Class Cephalopoda

1. *Endoceras proteiforme*
2. ?*Orthonybyoceras* sp.
3. ?*Orthonybyoceras duseri* (at one time genus name was *Treptoceras*)

Phylum Echinodermata
Class Crinoidea

4. *Lichenocrinus tuberculatus*
5. Fragments of crinoid stems
6. *Gaurocrinus nealli*
7. *Glyptocrinus dyeri*

Class Edrioasteroidea

8. *Carneyella pilea*
9. *Carneyella pilea* (from Moore and others, 1952)

Class Stelleroidea

10. *Xenaster,* Cincinnatian starfish (from Moore and others, 1952). Starfish species present at Caesar Creek is *Promopalaeaster* sp.

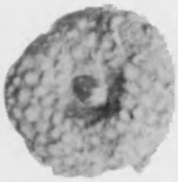
MOLLUSCA
CEPHALOPODA

1

2

3

ECHINODERMATA
CRINOIDEA



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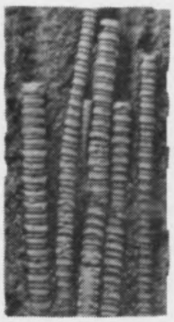

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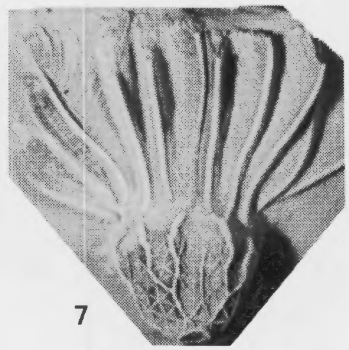

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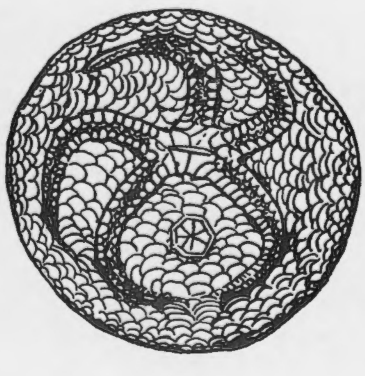
ECHINODERMATA
EDRIOASTEROIDEA

8



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ECHINODERMATA
STELLEROIDEA

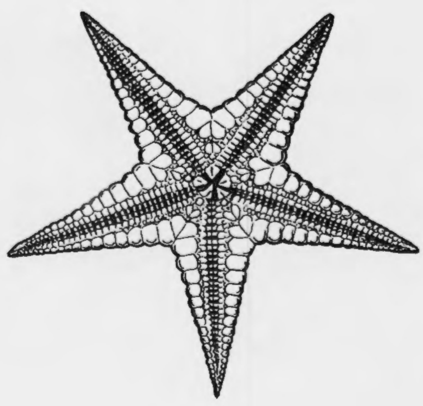

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PLATE 7

Phylum Arthropoda
Class Trilobita

1. *Flexicalymene meeki*
2. *Flexicalymene meeki,* enrolled
3. *Isotelus maximus*
4. *Isotelus maximus,* enrolled
5. *Isotelus gigas*
6. *Chasmops breviceps*
7. *Amphilichas halli*
8. *Ceraurinus icarus*
9. *Ceraurus milleranus*
10. *Ceraurus milleranus,*pygidium
11. *Acidaspis cincinnatiensis*
12. *Acidaspis cincinnatiensis,* cephalon
13. *Acidaspis cincinnatiensis*
14. *Rusophycus pudicum,* trilobite resting trace fossil (from Osgood, 1970)
15. *Diplichnites multipartum,* trilobite walking trace fossil

ARTHROPODA
TRILOBITA

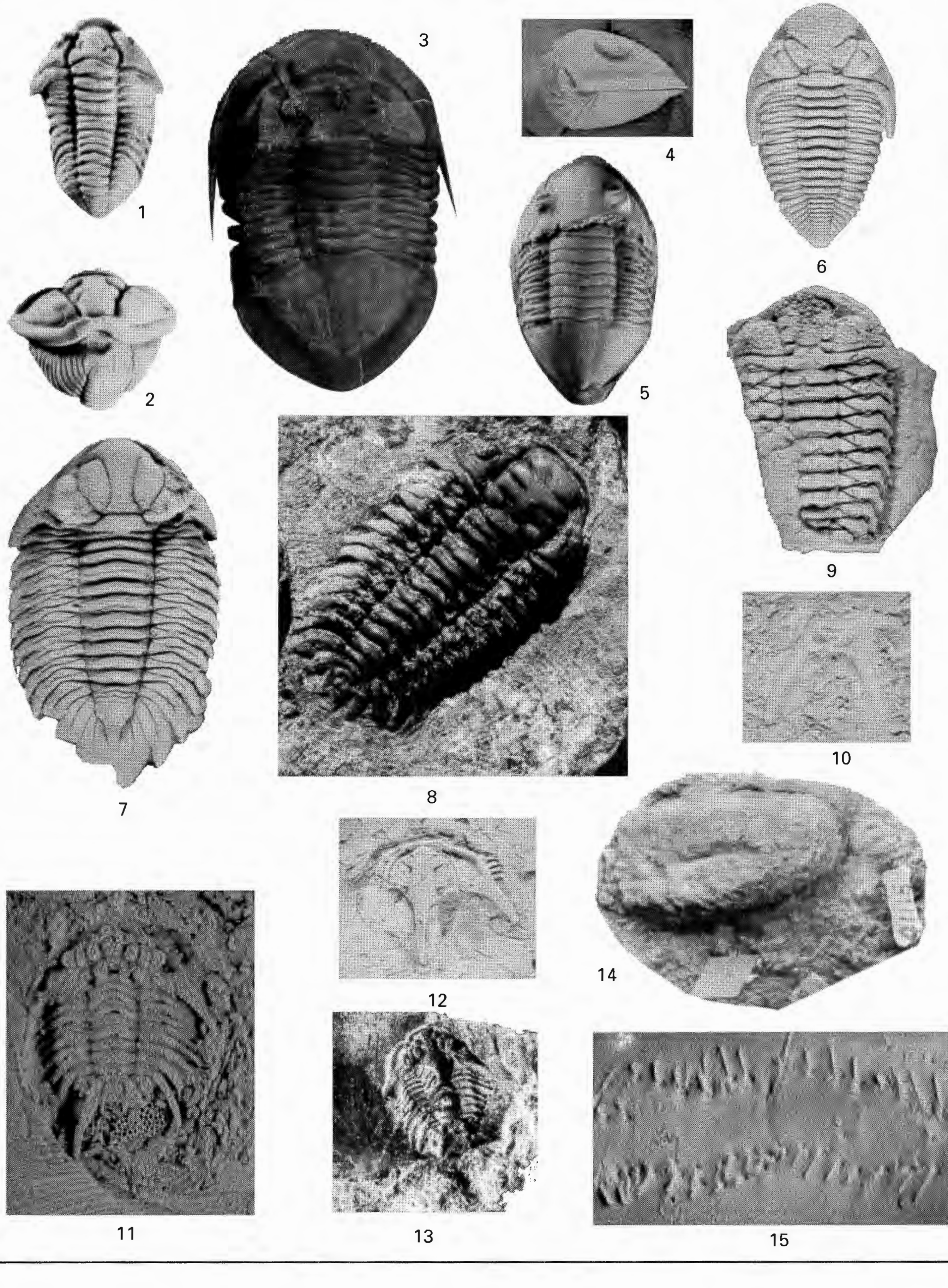


PLATE 8

Phylum Hemicordata
Class Graptolithina

1. graptolites
2. graptolites, enlarged

Phylum Problematica

3. *Labechia huronensis,* enlarged
4. *Conularia formosa*
5. *Tentaculites richmondensis*
6. *Cornulites corrugatus*
7. *Labechia huronensis*

Ichnofossils
Trace fossils

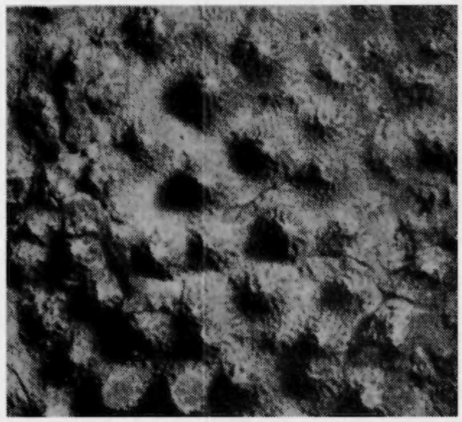
8. *Diplocraterion biclavatum*
9. *Diplocraterion biclavatum,* side view
10. *Diplocraterion parallelum* (photo from Osgood, 1970; name from Osgood, 1977b)

HEMICORDATA GRAPTOLITHINA

1

2

PROBLEMATICA



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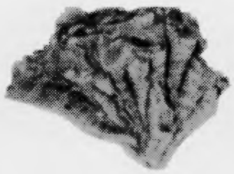

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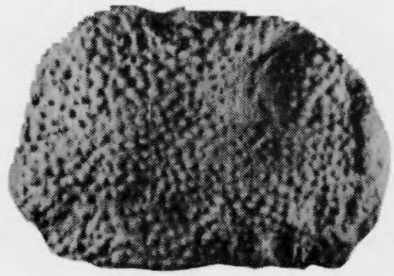

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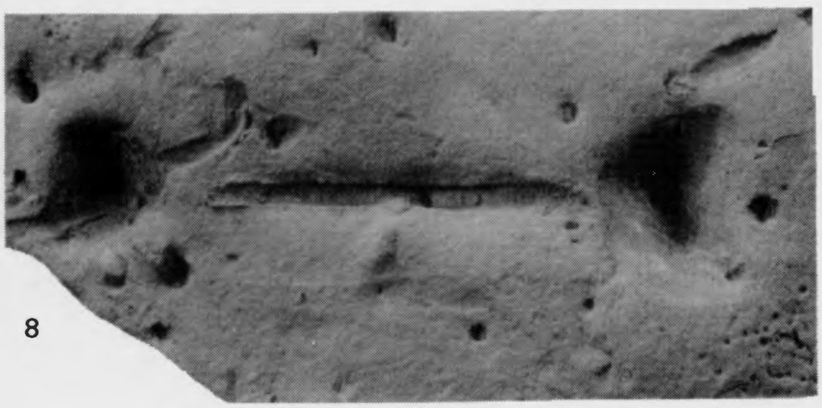
TRACE FOSSILS



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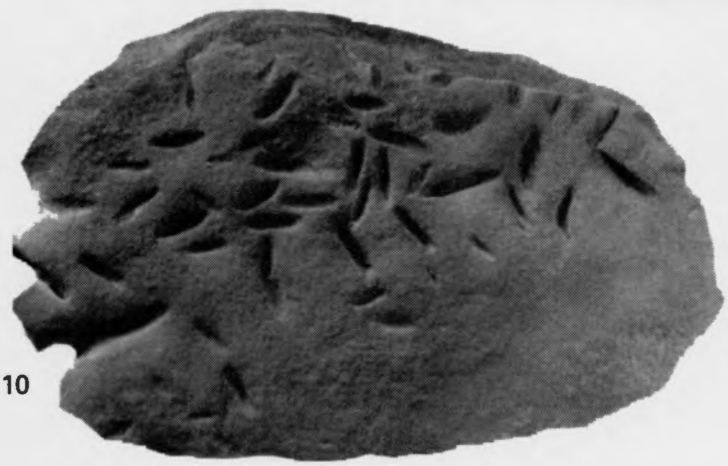

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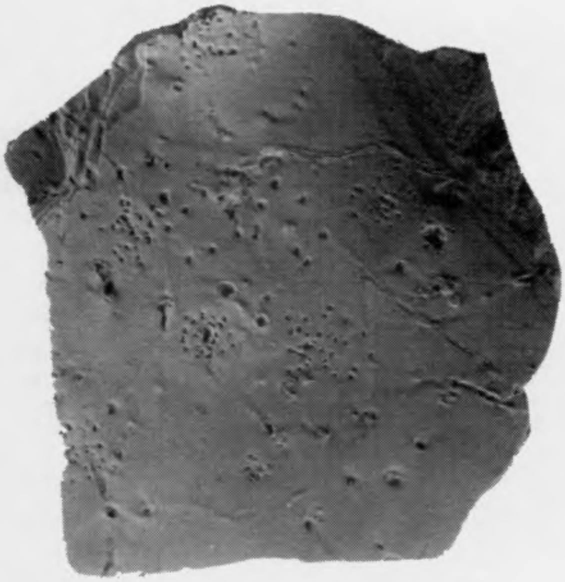
PLATE 9

Ichnofossils
Trace fossils

1. *Chondrites*
2. *Chondrites*
3. Cf. *Palaeophycus*
4. *Trichophycus venosum*

TRACE FOSSILS



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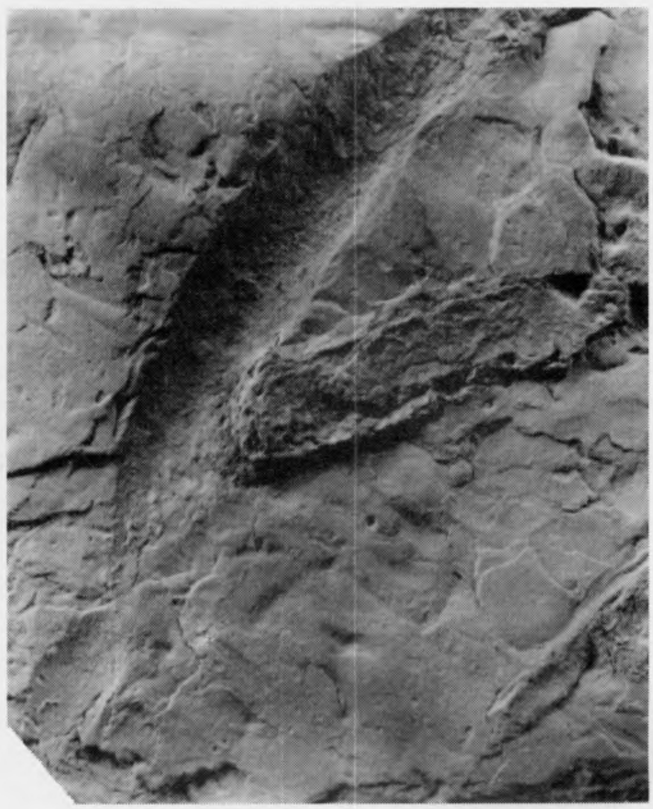


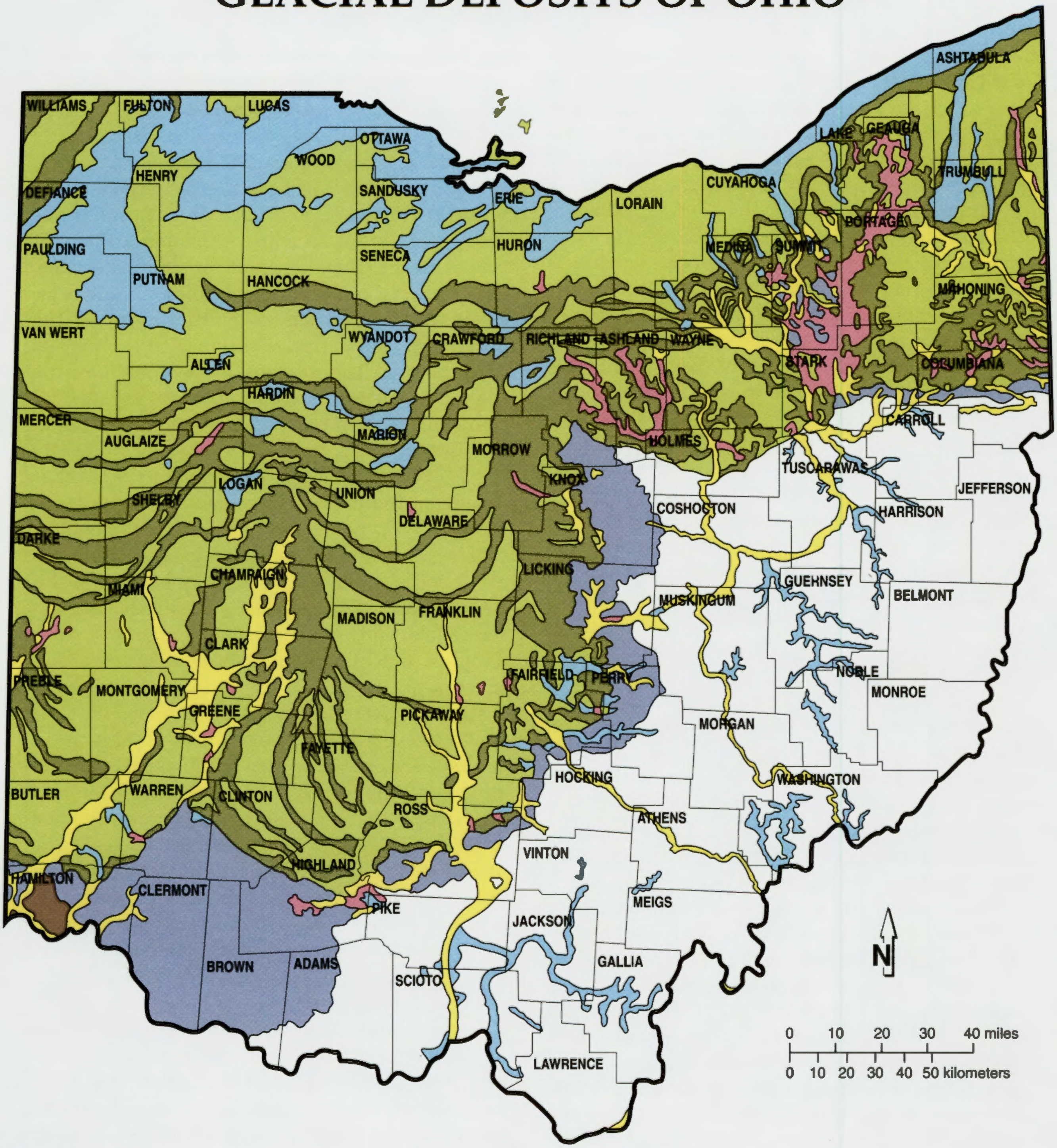
4

STATE OF OHIO
George V. Voinovich, Governor

DEPARTMENT OF NATURAL RESOURCES
Donald C. Anderson, Director

DIVISION OF GEOLOGICAL SURVEY
Thomas M. Berg, Chief

GLACIAL DEPOSITS OF OHIO



Kames and eskers

Outwash

Lake deposits

WISCONSINAN
(14,000 to 24,000 years old)

Ground moraine

End moraine

ILLINOIAN
(130,000 to 300,000 years old)

Undifferentiated morainic drift

PRE-ILLINOIAN
(older than 300,000 years)

Undifferentiated morainic drift

DIVISION OF GEOLOGICAL SURVEY
OHIO DEPARTMENT OF NATURAL RESOURCES

OHIO Department of Natural Resources

GLACIAL DEPOSITS OF OHIO

Although difficult to imagine, Ohio has at various times in the recent geologic past (within the last 1.6 million years) had almost three-quarters of its surface area covered by vast sheets of ice perhaps as much as 1 mile thick. This period of geologic history is referred to as the Pleistocene Epoch or, more commonly, the Ice Age, although there is abundant evidence that Earth has experienced numerous other "ice ages" throughout its 4.6 billion years of existence.

Ice Age glaciers invading Ohio formed in central Canada in response to climatic conditions that allowed massive buildups of ice. Because of their great thickness these ice masses flowed under their own weight and ultimately moved south as far as northern Kentucky. Oxygen-isotope analysis of deep-sea sediments indicates that more than a dozen glaciations occurred during the Pleistocene. Portions of Ohio were covered by the last two glaciations, known as the Wisconsinan (the most recent) and the Illinoian (older), and by an undetermined number of pre-Illinoian glaciations.

Because each major advance covered the deposits left by the previous ice sheets, pre-Illinoian deposits (brown area on map) are exposed only in extreme southwestern Ohio in the vicinity of Cincinnati. Although the Illinoian ice sheet covered the largest area of Ohio, its deposits (lavender area on map) are at the surface only in a narrow band from Cincinnati northeast to the Ohio-Pennsylvania border. Most features shown on the map of the glacial deposits of Ohio are the result of the most recent or Wisconsinan-age glaciers.

The material left by the ice sheets consists of mixtures of clay, sand, gravel, and boulders in various types of deposits of different modes of origin. Rock debris carried along by the glacier was deposited in two principal fashions, either directly by the ice or by meltwater from the glacier. Some material reaching the ice front was carried away by streams of meltwater to form outwash deposits (yellow areas on map). These deposits normally consist of sand and gravel. Sand and gravel deposited by water on and under the surface of the glacier itself formed features called kames and eskers (red areas on map), which are recognized by characteristic shapes and composition. The distinctive characteristic of glacial deposits that have been moved by water is that the material was sorted by the water that carried it. The large boulder-size particles were left behind and the smaller clay-size particles were carried far away, leaving the intermediate gravel- and sand-size material along the stream courses.

Clay- to boulder-size material deposited directly from the ice was not sorted. Some of the debris was deposited as ridges parallel to the edge of the glacier, forming terminal or end moraines (dark-green areas on map), which mark the position of the ice when it paused for a period of time, possibly a few hundred years. When the entire ice sheet receded because of melting, much of the ground-up rock material still held in the ice was deposited on the surface as ground moraine (light-green areas on map). The term glacial drift commonly is used to refer to any material deposited directly (*e.g.*, ground moraine) or indirectly (*e.g.*, outwash) by a glacier. Because the ice that invaded Ohio came from Canada, it carried in many rock types not found in Ohio. Pebbles, cobbles, and boulders of these foreign rock types are called erratics. Rock collecting in areas of glacial drift may yield granite, gneiss, trace quantities of gold, and, very rarely, diamonds. Most rocks found in glacial deposits, however, are types native to Ohio.

Many glacial lakes were formed during the time that ice covered Ohio. Lake deposits (blue areas on map) are primarily very fine grained clay- and silt-size sediments. The most extensive area of lake deposits is in northern Ohio bordering Lake Erie. These deposits represent early stages in the development of Lake Erie as it is presently known. Other lake deposits accumulated in stream valleys whose outlets were temporarily dammed by ice or outwash. Many outwash-dammed lake deposits are present in southeastern Ohio far beyond the glacial boundary.

Certain deposits left behind by the ice are of economic importance, particularly sand and gravel, clay, and peat. Sand and gravel that have been sorted by meltwater generally occur as kames or eskers or as outwash along major drainageways. Sand and gravel are vital to Ohio's construction industry. Furthermore, outwash deposits are among the state's most productive sources of ground water.

Glacial clay is used in cement and for common clay products (particularly field tile). The minor quantities of peat produced in the state are used mainly for mulch and soil conditioning.

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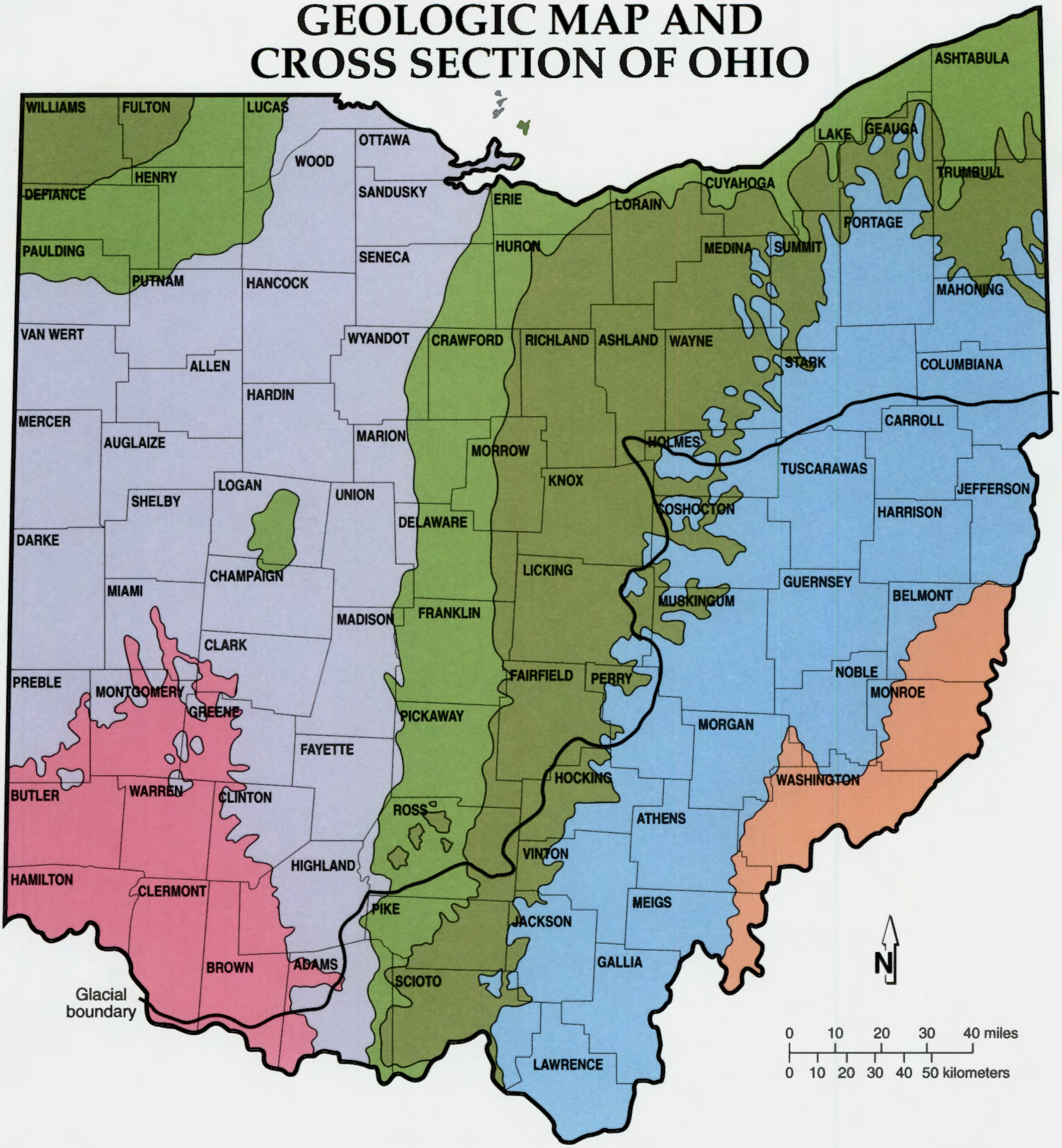
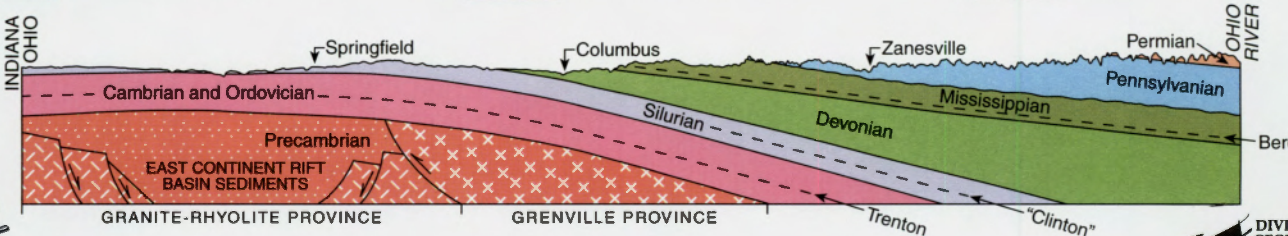
GEOLOGIC MAP AND CROSS SECTION OF OHIO



GEOLOGIC SYSTEM (million years before present)

- Permian (286-245)
- Pennsylvanian (320-286)
- Mississippian (360-320)
- Devonian (408-360)
- Silurian (438-408)
- Ordovician (505-438)



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DIVISION OF GEOLOGICAL SURVEY
OHIO DEPARTMENT OF NATURAL RESOURCES

CAESAR CREEK STATE PARK
FOSSIL COLLECTING RULES

Fossils may be observed in the Caesar Creek emergency spillway at any time. However, the collection of natural formations (*i.e.,* fossils) is prohibited without the permission of the Corps of Engineers. If you would like to collect fossils, you must *first check* in at the Corps office located at the Visitor Center. For further information call or write:

Caesar Creek Lake Visitor Center
U.S. Army Corps of Engineers
4020 N. Clarksville Road
Waynesville, Ohio 45068
Phone: (513) 897-1050

Caesar Creek Lake Ranger Station
Same address
Phone: (513) 897-1738

PLEASE OBSERVE THE FOLLOWING RULES:

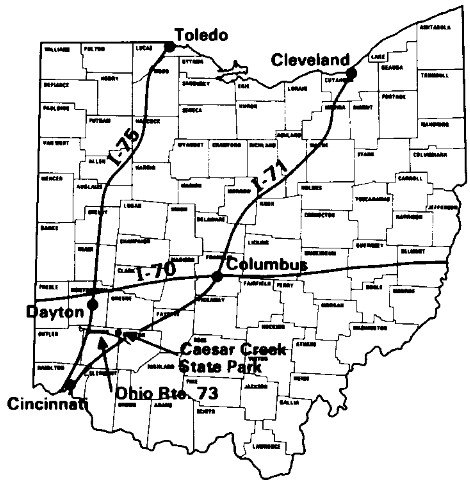
1. You must obtain a permit from the Visitor Center every time you wish to collect on the emergency spillway.
2. **NO TOOLS** may be used while you are collecting.
3. Fossils may not be collected for commercial use.
4. You may keep fossils or specimens that fit in the palm of your hand. We ask that you donate any larger specimens to the Visitor Center for others to enjoy.

FOR YOUR SAFETY:

1. Park in the designated areas on the spillway. Make sure that your vehicle is completely off the road.
2. **CLIMBING ON THE WALLS OF THE SPILLWAY IS VERY DANGEROUS.** For this reason, we ask that you collect only on the spillway floor.

FOR YOUR CONVENIENCE:

RESTROOMS are located inside and outside the Visitor Center, at the entrance to the Flat Fork picnic area, and at the base of the dam. Please be considerate of others and do not use the restroom inside the Visitor Center if your clothing or shoes are muddy or dusty.



LOCATION OF CAESAR CREEK STATE PARK