Ohio Geology

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GEOLOGY OF OHIO—THE SILURIAN

by Michael C. Hansen

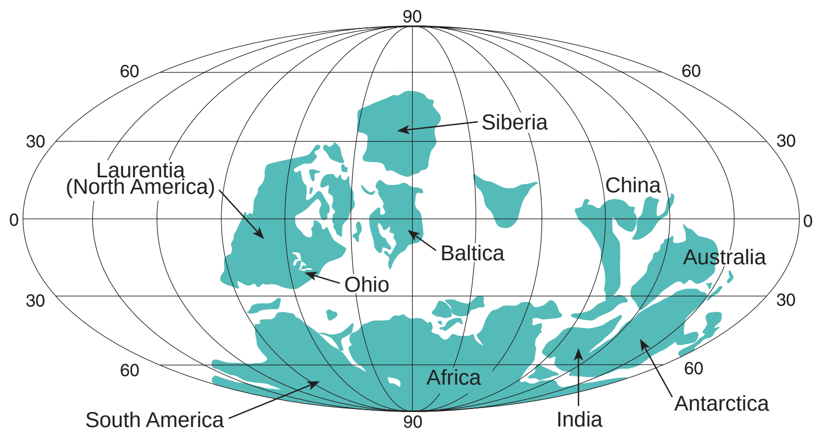
The Silurian Period occurred more than 400 million years ago in the middle of the Paleozoic Era. During this 30-million-year-long span, the climate and depositional environments were different than in any other span of time in Ohio's geologic history. Sedimentary rocks of the Silurian System dominate the bedrock surface of the western half of Ohio, although their exposures are limited because thick glacial sediments cover all but the southernmost portion of the outcrop area. Silurian rocks in Ohio are primarily carbonates—limestones and dolomites—and the many quarries in these rocks in western Ohio indicate their importance. Silurian rocks in the subsurface of eastern Ohio contain extensive deposits of salt and accumulations of natural gas and oil. In local areas in the western half of Ohio, magnificent scenery in the form of caves, cliffs, and waterfalls are unexpected benefits of Silurian rocks.

The Silurian System was named by Roderick Impey Murchison, a Scotsman who eventually became the director of the Geological Survey of Great Britain. He first studied these rocks in Wales and named them after a Celtic tribe, the Silures. His monumental work, *The Silurian System*, was published in 1838. The lower part of Murchison's Silurian System overlapped with the upper part of Adam Sedgwick's Cambrian System, a matter which became a great dispute between these two prominent geologists. It was not until 1879 that Charles Lapworth placed the contested rocks in a new system, the Ordovician (see *Ohio Geology*, Fall 1997). Ordovician rocks in Ohio were called "Lower Silurian" until 1909.

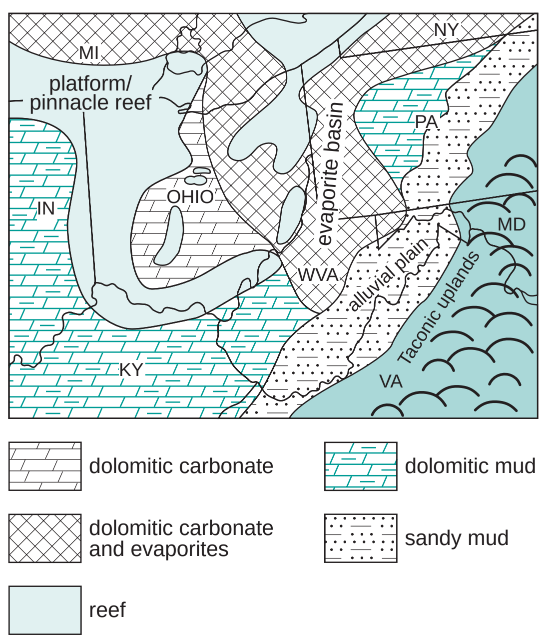
During the Silurian, Ohio was in tropical latitudes south of the Equator. Warm, shallow seas dominated the state from the beginning of the period about 438 million years ago until the end of the period about 408 million years ago. Rocks that are largely chemical precipitates—limestone, dolomite, gypsum, anhydrite, and halite (salt)—dominate the Silurian sequence in the state, indicating that upland areas were far to the east.

SILURIAN ROCKS IN OHIO

Geologic systems as we know them today were not established and defined in the early days of geological investigation in Ohio. In early 1837, Dr. John L. Riddell, professor of chemistry at the Medical College of Louisiana, in conjunction with other early geologists, reported to Governor Joseph Vance and the Ohio legislature on "the method of obtaining a complete geological survey of the state." In this report, Riddell referred to rocks we now call Silurian as the "Yellow Limestone Member," in



Continental configuration during Silurian time (modified from C. R. Scotese and others, 1979, Paleozoic base maps, Journal of Geology, v. 87, fig. 14).



Generalized paleogeographic map of Ohio and adjacent areas illustrating the distribution and relationship of Silurian reefs and platforms developed during the middle part of the Silurian Period and areas of Late Silurian accumulation of evaporites. By the middle part of the Silurian Period the Late Ordovician Taconic Mountains had been reduced by erosion and furnished very little clastic sediment to the Ohio portion of the Appalachian Basin. Evaporites, particularly salt, accumulated in basins that were restricted from circulation of open-marine waters by the earlier massive reefs and platforms. Compiled from many sources.

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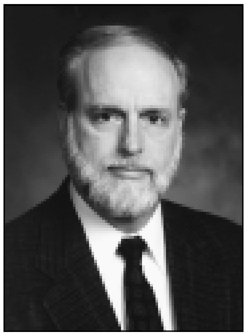

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From The State Geologist...

Thomas M. Berg

CELEBRATE EARTH SCIENCE WEEK IN OHIO!

I am very pleased to announce that Governor George V. Voinovich has issued a resolution designating the week of October 11-17, 1998, as **Earth Science Week** in Ohio. This celebration provides a week-long opportunity for all citizens to recognize the critical importance of the Earth sciences in their daily lives. Not everyone recognizes that Earth resources are crucial to our way of life and our present standard of living.

For example, every man, woman, and child in Ohio annually consumes about 10 tons of aggregate (crushed stone or sand and gravel). Try to picture all 10 tons of it in your front yard! Yet we use it in construction of our highways, railroads, shopping malls, hospitals, schools, homes, and much more. We take most of the Earth resources we use for granted. The coal we consume in the form of electricity is an important and abundant energy resource in Ohio. Our oil and gas producers are working hard to provide the energy we need to heat our homes and fuel our transportation. We don't give a whole lot of thought to the availability of water until a drought hits.

In celebrating Earth Science Week, we also recognize that humanity must achieve a wise balance between utilizing Earth materials and protecting the environment—that framework of Earth that provides us with drinking water, crops, and clean air. In order to achieve that wise balance, we citizens must become familiar with the Earth sciences and how they operate in our daily lives. Earth Science Week provides that opportunity. During the week-long celebration this October, we can learn how the earth sciences are used to understand the framework of our planet and its dynamic systems. We can learn for example, that geologic maps are critical to development of our much-needed water, minerals, and energy. They are also very important in managing pollution, waste, and geologic hazards.

I urge schools, colleges, universities, trade organizations, museums, libraries, scouting groups, civic organizations, churches, clubs, concerned citizen groups—in short, everyone—to join in celebrating Earth Science Week. Governors of other states are also proclaiming Earth Science Week. As part of its 50th anniversary, the American Geological Institute (AGI) is promoting Earth Science Week nationwide and is working to obtain national proclamations from President Clinton and the Congress. If you want to know more about AGI's efforts and obtain further information on Earth Science Week, visit their Web site at <www.earthsciweek.org>. The Web site has a lot of tips for ways to distribute materials, adopt or visit a school or classroom, create an Earth-science display, give a presentation, organize a poster or essay contest, and use AGI's press release. You may also obtain a free Earth Science Week Information Kit from: American Geological Institute, 4220 King Street, Alexandria, VA, 22302. AGI's telephone number is 703-379-2480, and their fax number is 703-379-7563.

FEEDBACK: As you develop your plans for celebrating Earth Science Week in Ohio, please let us know what you are going to do. We would greatly appreciate your sending a brief e-mail summary to the State Geologist at <thomas.berg@dnr.state.oh.us>. Or send a letter in the regular mail at our address on the back page of this issue of *Ohio Geology*. Thank you!

Regional AAPG meeting to be held in Columbus

The Eastern Section Meeting of the American Association of Petroleum Geologists will be held in Columbus October 7-10, 1998. The meeting is being co-hosted by the Ohio Geological Society and the Division of Geological Survey. Survey geologist and Petroleum Group Supervisor Lawrence H. Wickstrom is the general chair for the meeting. The 27th Annual Meeting will be held at the Ramada University Hotel in Columbus and will feature field trips to the Serpent Mound disturbance in Adams County, which has been the focus of recent research by Division of Geological Survey geologists, and the long-famous Sylvania Quarry in Lucas County, where the Middle Devonian Silica Formation yields exquisitely preserved fossils. A number of technical sessions will focus on a variety of topics of interest to petroleum and other geologists. Registration forms will be available in mid-August from Angie Bailey, Division of Geological Survey, 4383 Fountain Square Drive, Columbus, OH 43224-1362, telephone: 614-265-6585. More detailed information can be found on the Survey's Web site: <http://www.dnr.state.oh.us/odnr/geo_survey/aapg98.htm>.

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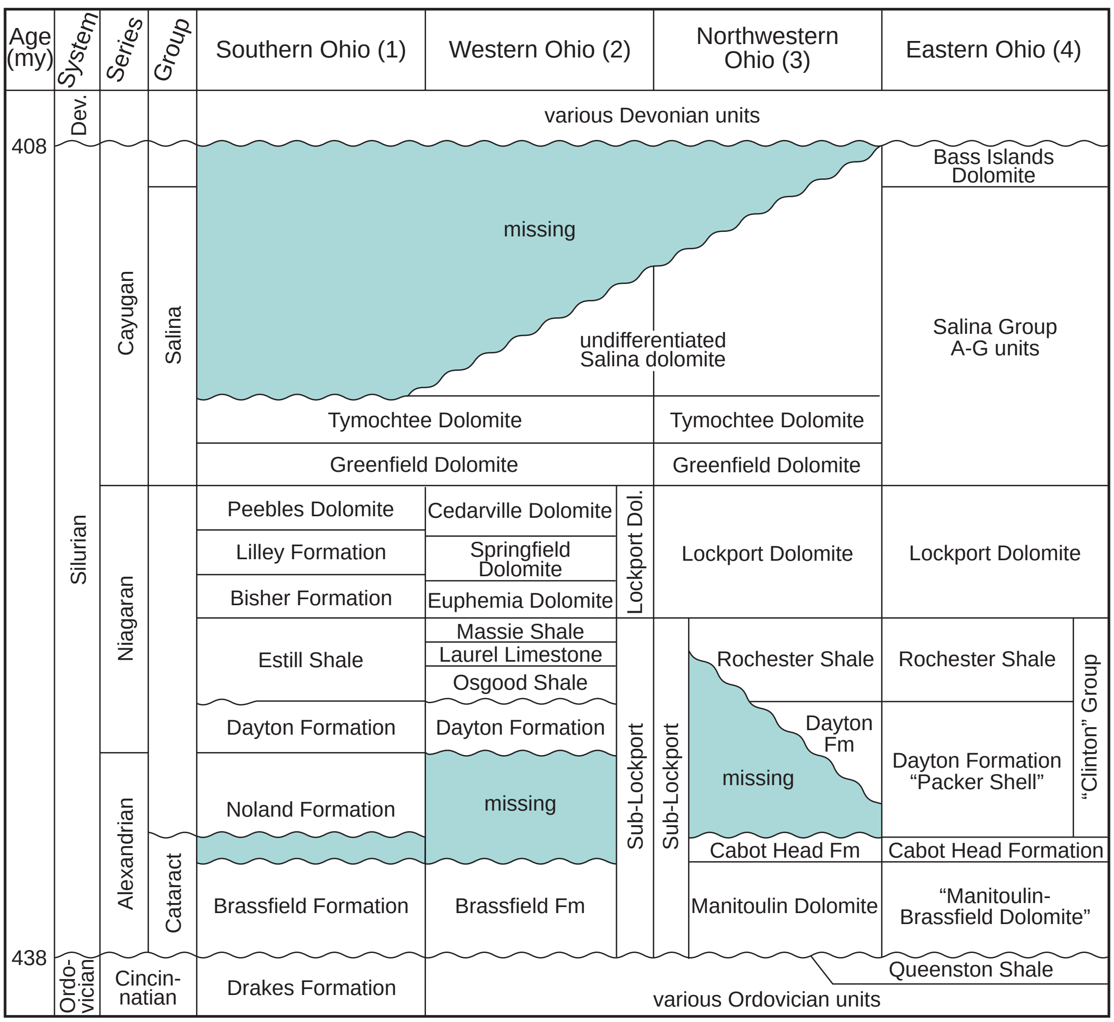
contrast to the underlying "Blue Limestone Member," which we now refer to as the Ordovician System. Dr. John Locke, in his southwestern Ohio excursions for the first Geological Survey of Ohio in 1838, made the first attempt to subdivide Silurian rocks. Locke, working in Adams County in southern Ohio, termed the lowest Silurian unit the "Flinty Limestone," a unit we now call the Brassfield Formation. Above this limestone is a calcareous shale that Locke called the "Great Marle Deposit" or just the "Marle." We now assign this unit to the Noland Formation. Locke's "Cliff Limestone," above the Marle, is one or more of the carbonate units in the Lockport Group.

Since these early investigations, the Silurian rocks have undergone much study and subdivision but are still not completely understood. There have been many nomenclatural changes and redefinition of these rocks through the years. Division of Geological Survey geologist Glenn Larsen has traced these complex changes and depicted them on an open-file chart available from the Survey (see Further reading). Part of the confusion is because of lateral changes in rock types and thicknesses and because of poor exposures throughout much of the state. The accompanying chart illustrates the currently accepted stratigraphic names in different regions of the state.

The dominance of chemical rocks—limestone, dolomite, gypsum / anhydrite, and halite—and the presence of comparatively minor amounts of fine-grained clastic rocks such as shale and sandstone indicate that Ohio was far from any rising mountains or other elevated terrain that would contribute coarser clastic material. Indeed, the Silurian was a time of relative tectonic quiesence in the episodic Paleozoic collision of North America, Europe, and Africa. To the east of Ohio were the remnants of the Taconic Mountains, formed by continental collision in the Late Ordovician. Erosion of these uplands during Early and Middle Silurian time contributed sandstone and conglomerate in New Jersey, New York, and eastern Pennsylvania, but by Late Silurian time even these areas were accumulating chemical rocks. The results of erosion and delta building far to the east extend into Early Silurian rocks in eastern Ohio and into Middle Silurian rocks in southern Ohio in the forms of beds of shale and the presence of silt and clay in many of the carbonate units. These clastics represent fine-grained sediments carried out into the sea a great distance from their source areas.

The base of the Silurian System in Ohio is everywhere bounded by an unconformity, indicat-

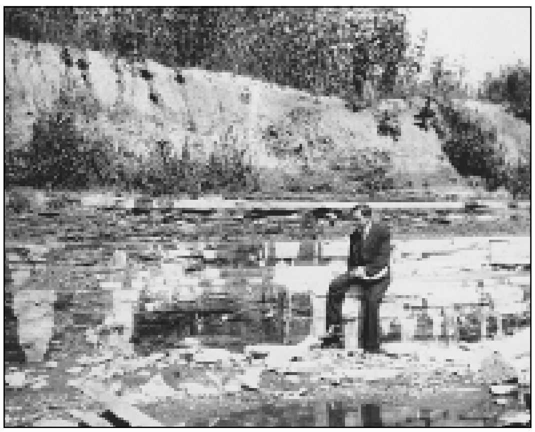


Generalized nomenclature and relationships of Silurian rocks in various parts of Ohio and their relationships to underlying and overlying geologic systems. Rocks in region 4 (eastern Ohio) are in the subsurface. Names in quotation marks are drillers' terms. my *= millions of years.*

Region of Silurian outcrop (green) and stratigraphic column areas.

ing a time of emergence and erosion of Ordovician rocks before Silurian deposition began. The most recognizable unit in Ohio at the base of the Silurian is the Brassfield Formation, which is a highly fossiliferous limestone that averages about 60 feet thick. The Brassfield is particularly well exposed in southern Ohio in Adams and Highland Counties. In northwestern and eastern Ohio, dolomite is the dominant Early Silurian rock type in the Brassfield or its equivalents.

The Dayton Formation is a limestone that is about 8 feet thick where exposed in western Ohio but which thickens eastward in the subsurface. In western Ohio, the Noland Formation lies between the Brassfield and the Dayton; in eastern Ohio, the Cabot Head Formation lies between the Brassfield and the Dayton. Oil and gas drillers call the Dayton (or its equivalent) the "Packer Shell," which, along with the overlying Rochester Shale, constitutes a package of rocks known to drillers as the "Clinton sandstone." The "Clinton" of eastern Ohio includes sandstones that have long been very productive drilling targets for natural gas in portions of eastern Ohio. This Lower Silurian unit of the Cataract/Medina Group was termed "Clinton" because early drillers correlated it with a New York rock unit of that same name. Although this correlation is incorrect, the name is widely used as an informal term. These rocks consist of interbedded sandstone, siltstone, and shale of deltaic origin.



Exposure of the Dayton Formation at the Jasper Quarry near Xenia, Greene County. Photo by J. A. Bownocker, 1909.

John Bryan State Park and Clifton Gorge State Nature Preserve exhibit spectacular scenery that is unexpected in the flat till plains of western Ohio.

Above the Rochester in the subsurface of eastern Ohio is the Lockport Dolomite, which is generally about 150 to 200 feet thick. In southern Ohio, the unit is called the Lockport Group and is divided into the Bisher Formation, Lilley Formation, and Peebles Dolomite. In western Ohio the Lockport Group is subdivided into the Euphemia Dolomite, Springfield Dolomite, and Cedarville Dolomite. The Lockport represents a time of extensive reef building in Ohio and adjacent areas. Reefs are massive accumulations of skeletal framework and debris contributed by an abundance of organisms living in the sea at a particular site. Many of these reefs are large, mound-shaped structures that exhibit steeply dipping beds on their flanks. Hundreds of individual Silurian reefs are known from the Great Lakes area.

Above the Lockport rocks is the Salina Group, which ranges in thickness from about 235 feet to 335 feet. In the eastern half of the state the Salina Group consists of dolomites and extensive beds of evaporites such as gypsum/anhydrite and halite. These rocks are divided into units A through G. In the western half of the state, the Salina Group includes the Greenfield Dolomite, which averages about 45 feet thick, and the overlying Tymochtee Dolomite, which averages about 80 feet thick. The Greenfield and Tymochtee are equivalent, in part, to the evaporite-dominated A-G units of the Salina Group in the subsurface of eastern Ohio. The Greenfield and Tymochtee were deposited in shallow water or on extensive tidal flats. The Bass Islands Dolomite is the youngest Silurian unit in the state.

THE SCENIC SILURIAN

Most Silurian rocks in the state are either deeply buried beneath younger rocks in eastern Ohio or buried beneath a thick blanket of glacial sediment in western Ohio. But there are several areas of the state where erosion-resistant Silurian rocks are exposed and form a rugged landscape of cliffs, caves, and waterfalls. The most notable area of Silurian scenery is in Greene County, where the Little Miami River and some of its tributaries are downcutting through an escarpment or cuesta of Silurian strata.

John Bryan State Park and Clifton Gorge State Nature Preserve exhibit spectacular scenery that is unexpected in the flat till plains of western Ohio. The resistant Cedarville Dolomite is the major cliff-forming unit, capping precipices more than 60 feet high that overhang the narrow gorge of the Little Miami River. Steamboat Rock is a large block of Cedarville Dolomite that has become detached from the cliff and fallen into the stream bed. There are numerous waterfalls formed by streams crossing the resistant rocks of the Silurian cuesta in this area of Greene County. In some areas blocks of resistant limestone have become isolated from the main cliff, forming pillars and natural bridges. Perhaps the most notable of these features is Pompey's Pillar, a 15-foot-tall "tea table" of Cedarville Dolomite poised on a narrower pedestal of less resistant Springfield and Euphemia Dolomites. This feature is in Glen Helen Nature Preserve near Yellow Springs.

Small caves are developed in the Cedarville Dolomite in this region. The most notable are at the commercial site known as Seven Caves, formerly called Rocky Fork Caves because of their location in

Steamboat Rock in Clifton Gorge State Nature Preserve, Greene County. This large block of Cedarville Dolomite fell from the gorge wall and came to rest in the bed of the Little Miami River in a rotated position. Photo by Wilber Stout.

the valley wall of Rocky Fork Creek in Highland County, near Bainbridge. According to former State Geologist George W. White's 1926 study of these and other caves in Ohio, there are actually 10 caves in this valley.

Caves are extensively developed in the Upper Silurian Bass Islands Dolomite on South Bass Island in Lake Erie. The contours of the floors and ceilings of these caves match, suggesting to several investigators that they formed when anhydrite beds

An erosional "flower pot" formed along the Lake Erie shore on Catawba Point, Ottawa County. The base of this feature, in which a small arch has formed, is in the Tymochtee Dolomite. The "bowl" of the feature is formed by the more resistant Bass Islands Dolomite. Photo by Charles E. Herdendorf.

converted to gypsum, thus swelling and separating the bedrock layers. Later removal of the gypsum by solution has left voids that form the caves. One cave on South Bass Island, Crystal Cave, is a giant geode, lined with crystals of celestite that are more than 18 inches long. A number of other small caves are developed in Silurian rocks in Miami, Ottawa, Ross, Shelby, and Wyandot Counties.

SILURIAN MINERALS

Silurian rocks in Ohio have long been known as a source of a variety of mineral specimens, many of them crystals of museum quality. Their characteristics and occurrences have been summarized by Ernest H. Carlson in Division of Geological Survey Bulletin 69, *Minerals of Ohio*. The most important mineral occurrences are in Silurian and Devonian carbonate rocks in northwestern Ohio in the Findlay Arch mineral district. Fresh rock exposed in quarries has pockets or vugs of celestite, fluorite, sphalerite, galena, pyrite, and marcasite, among others. The Silurian Lockport and Greenfield Dolomites are the most important hosts for these mineral specimens, which were deposited by fluids in these porous units, probably in post-Middle Devonian time. Notable localities are Clay Center in Ottawa County, Woodville in Sandusky County, and Lime City in Wood County. Unfortunately, most quarries are closed to collecting. The suite of minerals present in this area and their mode of formation is similar to Mississippi Valley mineralization. However, no commercial concentrations of economically valuable minerals have been found in the Findlay Arch district.

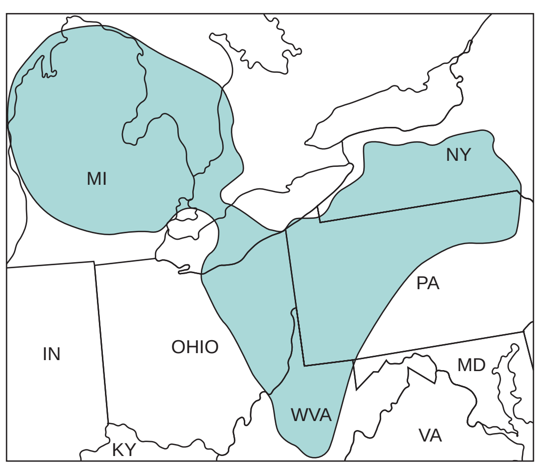
The Serpent Mound zinc district in Adams and Highland Counties in southern Ohio is a north-south-oriented area about 20 miles wide and 40 miles long centered on the Serpent Mound disturbance (see *Ohio Geology*, Winter 1994). The zinc mineral sphalerite and secondary minerals derived from the weathering of sphalerite—smithsonite, hydrozincite, and hemimorphite—are the principal collectible minerals in this area. They are found in Silurian rocks both within and peripheral to the 4-mile-diameter disturbance. Within the disturbance, most of the mineralization is along faults.

ECONOMIC GEOLOGY

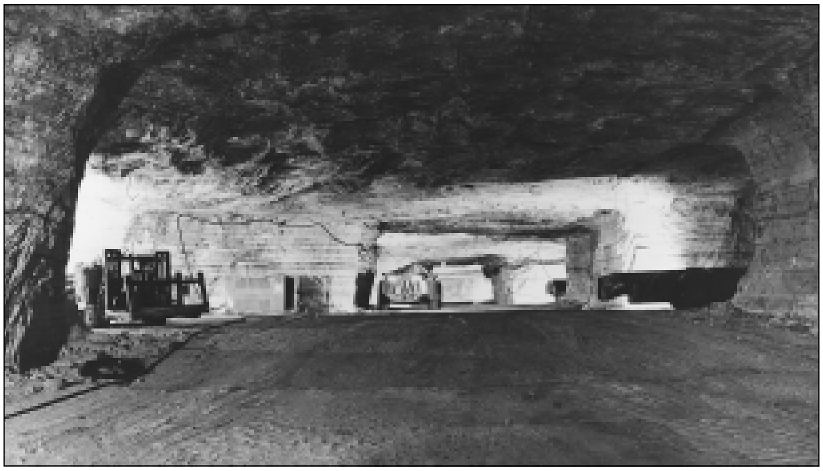
Silurian rocks yield or have yielded an important and diverse suite of mineral and energy resources that have contributed to the development and continuing economic security of the state. The area of occurrence of these rocks in the western half of Ohio, which is sometimes called the "rock-products area," is a region of extensive limestone and dolomite quarries. The Brassfield, Peebles, Cedarville, Greenfield, and Tymochtee units are currently being quarried at 44 operations in 26 counties. More than a third of the limestone and dolomite quarries in the state are in Silurian rocks. These limestones and dolomites are used for crushed stone, primarily in road construction, commercial building, and asphaltic and portland cement concrete; for lime used in the chemical industry; and for agricultural lime.

Evaporite minerals have long been important to Ohio. Gypsum was discovered in rocks of the Salina Group on the north shore of Sandusky Bay in Ottawa County in 1820, and mining of this commodity for use as plaster began the next year. Only one company currently mines gypsum in Ohio. In 1997, Ohio produced 264,154 tons of gypsum, valued at nearly $2.4 million. These deposits are in the Tymochtee Dolomite, but gypsum also has been produced from the Lockport Dolomite. These deposits are found only near the surface because gypsum forms by the hydration of anhydrite from ground water.

Ohio's most valuable evaporite mineral is halite, common salt. Extensive deposits of salt are present in the Upper Silurian Salina Group in the eastern third of the state and range in depth below the surface from about 1,350 feet in Lorain County



Extent of the salt-bearing Salina Group in the Appalachian and Michigan Basins.



Mining salt at the International Salt Company operation (now owned by Cargill) at Cleveland, Cuyahoga County. This mine extracts the Salina Group F_2 salt using the room-and-pillar method at a depth of more than 1,700 feet beneath Lake Erie.

to more than 6,500 feet in Belmont and Monroe Counties. The Ohio salt beds are more or less contiguous with salt beds in Michigan, Pennsylvania, and New York. Although natural brines had been evaporated for salt from surface seeps since the beginning of human occupation in Ohio (see *Ohio Geology*, Winter 1995), it was not until 1886 that Silurian rock salt was discovered in the Salina Group during drilling of an oil well in Cuyahoga County.

Units B, D, E, and F of the Salina Group are salt bearing, but only the D and F units are considered to have economic potential. The F unit is the most important and is subdivided into the F_1 through F_4 units. The F_1 salt is 50 to 80 feet thick and has been mined by the Morton Salt Company at Fairport Harbor in Lake County since 1959. The F_2 salt is up to 70 feet thick and is mined in Cleveland, Cuyahoga County. The International Salt Co. opened this mine in 1962; the current operator is Cargill, Inc. Both of these mines use the room-and-pillar method to extract rock salt from a depth below the surface of about 2,000 feet. The two mines are beneath Lake Erie and the mineral rights are leased from the State of Ohio. The rock salt from these mines is used for snow and ice control. Production in 1997 totaled more than 2.6 million tons.

Artificial brine operations in Summit County (Cargill) and Wayne County (Morton) pump water into the Salina Group salt to create a brine, which is pumped to the surface and evaporated to produce a pure product. This process is called solution mining. Natural brine is extracted from the "Newburg" (Lockport Dolomite) by wells of the R. H. Penick Company in Licking County.

Collectively, Silurian rocks in Ohio produced more than 3.5 million tons of salt worth nearly $35 million in 1997. This production ranked Ohio third nationally. The Survey estimates that Ohio's salt resources total more than 2.5 trillion tons, an amount that, if only one-fourth were recoverable, would supply the nation's needs for 32,000 years.

The origin of the extensive salt beds and other evaporite minerals in Silurian rocks of Ohio and adjacent areas has been a subject of debate for many years. One model suggests that the Silurian reefs that were common in western Ohio and contiguous areas formed a barrier that restricted flow of marine waters into the basins in which salt accumulated. The hot, arid climate promoted rapid evaporation of sea water, forming a dense brine that sank to the bottom of the basin and precipitated as halite or anhydrite as the solubility product of a particular mineral was exceeded. Normal marine waters periodically flowed into the basin to replenish the supply of salts. As an addition to this model, it has been suggested that salt may have been precipitated in the basins during times of lowered sea level, when the basins became even more restricted as evaporation lowered sea level. The flanking reefs or banks that isolated the basins became tidal flats. Seawater flowed into the lowered basin from the surrounding bank areas by subsurface circulation, which converted the carbonates on the basin margin into dolomites. Another model, known as the sabkha model, proposes that saline waters from restricted lagoons periodically inundated extensive tidal flats and deposited evaporite minerals.

Silurian rocks also have been an important target for oil and gas drilling for many years. Of particular importance has been the "Clinton" sandstone in eastern Ohio. Natural gas was discovered in the "Clinton" in 1887 in a well drilled in Fairfield County. By 1926, nearly 18,000 "Clinton" wells had been drilled in the eastern half of the state. There are 186 "Clinton" gas fields in the state, and 75,539 wells have been drilled to this target by the end of 1997. One of the incentives for drilling "Clinton" wells is the high success rate for these ventures. In 1997, for example, 276 "Clinton" wells were drilled and 242 (88 percent) were productive. Natural gas also has been produced in eastern Ohio from the Lockport Dolomite where reefs developed in these rocks have been productive targets.

SILURIAN LIFE

The Silurian of Ohio was a time of warm, shallow seas in which marine invertebrate life blossomed. The diverse faunas of the Ordovician expanded in the Silurian without significant appearances of new groups. The Silurian Period is sometimes referred to as the Age of Corals because these organisms built extensive reefs, which were a haven for other invertebrates. Late in the period, a momentous event occurred when land plants first appeared. Although they were small and probably had little immediate impact on the landscape, they were the harbingers of a new way of life for many groups of organisms that would conquer the land in later geologic periods. Jawless fishes, which include several groups collectively called agnathans, diversified during the Silurian, thus setting the stage for the rise of other vertebrates, including many varieties of jawed fishes and the first amphibians, in the succeeding Devonian Period.

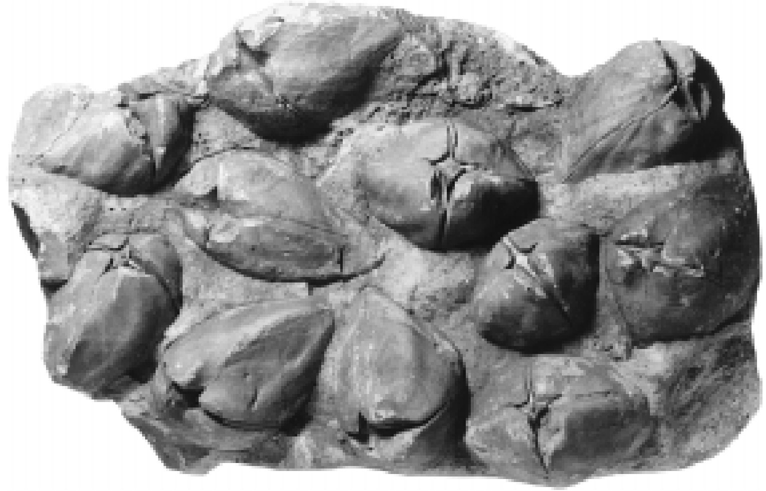
Ohio's record of Silurian life is not one that adequately reflects the real abundance and diversity of this period. Many Silurian units are dolomites in which recrystallization has destroyed most fossils. Some units, particularly those in the Salina Group, were deposited on tidal flats or in hypersaline waters in which few organisms could prosper. Despite these shortcomings, there are still many excellent Silurian fossils known from the state. A number of these species are described and illustrated in Division of Geological Survey Bulletin 70, *Fossils of Ohio*. Corals and echinoderms, particularly crinoids, are probably the two most abundant fossil groups in Silurian rocks in Ohio. Remains of these organisms were important contributors to rock volume in some units. It is estimated that the Brassfield Formation is made up mostly of echinoderm remains, although it is rare to find whole specimens. Another important reef-building group during the Silurian was the stromatoporoids, organisms of rather uncertain affinity that were shaped like heads of cabbage.

Some of the best-known Silurian fossils from Ohio include a very large pelecypod, *Megalomoidea canadensis* (formerly called *Megalomus*), and the brachiopods *Pentamerus* and *Trimerella*. These fossils are found mostly as internal molds. *Pentamerus* specimens sometimes occur in "nests," that is, clusters of specimens still in life position, and are popularly referred to as "turtle heads" or "fossil pig's feet." The Brassfield Formation is one of the most productive units for Silurian fossils in Ohio; however, many Silurian units locally have produced excellent fossils. Although Silurian dioramas typically are characterized by illustrations or models of eurypterid arthropods, these scorpionlike fossils are exceedingly rare in Ohio.

As with many human observations, perspective is critical. The fossil collector may perceive the Silurian of Ohio to be a monotonous sequence of poorly exposed and poorly fossiliferous rocks, completely eclipsed by the diversity, abundance, and preservation of fossils in the underlying Ordovician rocks and overlying Devonian rocks, but occasionally providing an exquisite trilobite or crinoid. The mineral collector perceives them as the host for exquisite specimens that rival those from anywhere in the world. From an economic perspective, these rocks rank as one of the most important in the state, providing an abundance of critical commodities that contribute to our well-being. To the tourist or casual observer, the cliffs, caves, and waterfalls developed in Silurian rocks present great beauty. All would agree, however, that Ohio would be diminished greatly if Silurian rocks were not present in the state.

ACKNOWLEDGMENTS

I thank Survey geologists Mac Swinford and Glenn Larsen for their perspectives on the Silurian and particularly Glenn's guidance through the maze of Silurian stratigraphy.



Underside of a slab of Silurian dolomite from the Dayton area containing multiple specimens of the brachiopod Pentamerus oblongus *in life position. University of Dayton collection (from Feldmann and Hackathorn, 1996).*

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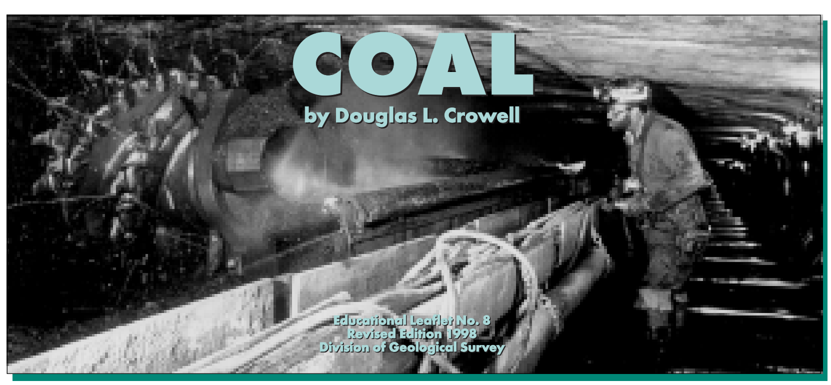
New Educational Leaflet on coal

The Survey has released a newly revised and expanded educational leaflet on coal and coal mining in Ohio. The leaflet covers the geology, formation, energy production, mining, cleaning, and uses of coal, and includes sections on abandoned underground mines and the Division's coal-research activities. A number of maps, diagrams, and photographs, many of them in color, highlight the informative text written by Survey coal geologist Douglas L. Crowell. Educational Leaflet No. 8, *Coal*, is available at no charge from the Division of Geological Survey, 4383 Fountain Square Drive, Columbus, OH 43224-1362, telephone 614-265-6576.



HANDS-ON EARTH SCIENCE

by Richard G. Hansgen
Bluffton College

LOCATING THE POSITION OF THE SETTING SUN

An excellent project for anyone interested in the Earth sciences is to record the position of the setting Sun over a period of several months. Of course, if you are a morning person, the rising Sun works just as well. You will be pleasantly surprised at your discoveries and will be challenged to offer suitable explanations. This project has the added benefit of being aesthetically pleasing, for what better way to end a hectic day than to watch a beautiful sunset. You say such times interfere with the evening news. So be it. The revolutions in Spain will have no end, but tonight's sunset happens only once.

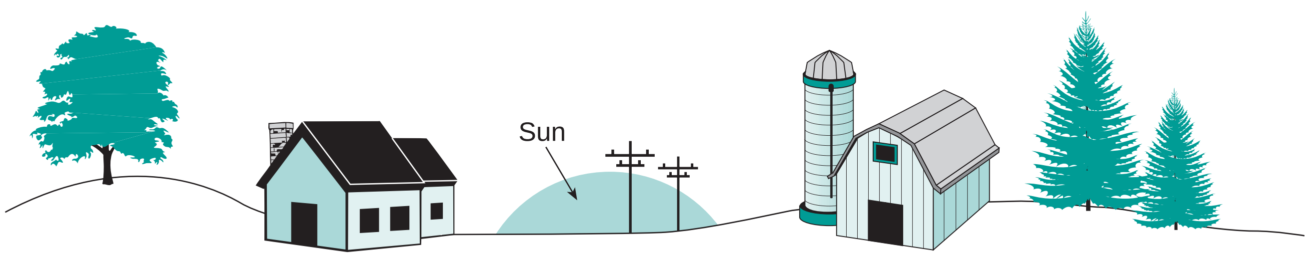
It is best to choose an observing spot where you have an unobstructed view of the horizon. If you live in a rural setting, you should have no problem finding such a site. If you live in town, then a park or a nearby ball field should suffice. However, if you want to remain near your house and do not have an unobstructed view, simply note where the Sun disappears behind the nearby buildings or trees. It is quite possible that your observations could be made by looking out one of the windows of your house. What is essential is that you observe the Sun just as it is disappearing from view and that you make each observation at precisely the same location. Clouds near the horizon are a bad omen for this project!

Looking directly at the Sun is harmful to your eyes, so only glance at the Sun when it is very near the horizon (or low and partially behind the trees) and even then only fleetingly. At that time, the light is coming through enough of our atmosphere that the rays should not be dangerous if your look is brief.

Check the local newspaper or television station for sunset (or sunrise) times. Arrive at your chosen site at least 15 minutes before the time for sunset. You will need a clipboard, sharp pencil, and paper. Make a sketch of the horizon in the vicinity of where the Sun seems to be heading. Include houses, trees, telephone poles, and any other obstacles. Now wait until the Sun is just ready to disappear on or near the horizon and indicate its position on your sketch (see example below). Also record the date and time.

Each clear evening, indicate the position of the setting sun on your original sketch. Or, if you prefer, make photocopies of your original sketch and record the Sun's position on a "clean" copy of your sketch each clear evening. You will find that you will have to extend your sketch of the horizon, including new features (such as houses and trees), as the weeks go by. If you are a photographer, simply shoot a picture of the setting Sun each evening. In either case, make sure you record the time and date of each observation. Maintain these observations for at least three months.

Having observed the Sun's changing position as it sets, you should now be able to answer these questions. Does the position of the setting Sun change from day to day? From week to week? Does the Sun appear to be moving north or south? Does the time of sunset change from day to day? From week to week? What would your observations indicate following a solstice? Following an equinox? And, now, for the most challenging question: how can you account for your observations?



Sketch of a horizon showing the position of the setting sun (modified from a drawing by Joy Gamble).

Ohio Geology

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