Ohio Geology

A Quarterly Publication of the Division of Geological Survey Fall 1994

CONCRETIONS: THE "LUDUS HELMONTII" OF THE OHIO SHALE

by Michael C. Hansen

Perhaps no other rocks found in Ohio generate so much public interest and curiosity than the large carbonate spheres, known as concretions, that weather out of the Devonian-age Ohio Shale. Along the outcrop belt of the Ohio Shale from Adams County on the Ohio River northward to Lake Erie, these orange-colored globes are a familiar sight as garden and yard ornaments, driveway markers, and repositories for bronze proclamations of public interest. Many of them reach 9 feet or more in diameter. Speculation on the origin of these giant concretions abounds, and they are commonly confused with crystalline glacial erratics.

The earliest detailed observations and speculations on the concretions of the Ohio Shale were made by Dr. John Locke in 1838 in Adams County. In the Second Annual Report of the First Geological Survey of Ohio, Locke described the concretions as ". . . the form of globes either perfect or a little flattened, and are singularly marked with parallels and meridians, like the lines of latitude and longitude on an 'artificial globe;' . . . . The equatorial part of this globe is a little raised, forming a kind of ring like that of Saturn." Locke speculated on the time of origin of these concretions, "The oblate spheroidal figure of some of these bodies always flattened on the top and the bottom, shows that the substance of the globe was somewhat soft and yielding at the time of the deposit or final setting of the slate, the layers of which are not interrupted by the globes but are bent or wrapped around them like blankets laid over them."

The fascination with and interest in the Ohio Shale concretions were certainly no less in Locke's day than today. Apparently, some contemporaries of Locke must have doubted the very existence of such huge and symmetrical concretions, if we correctly interpret the following comment from Dr. Locke: "I am aware that this extraordinary scene will probably excite the remark of such as can understand a subject better than those who have seen it, and are unwilling to admit any thing as true except that which has come under their own limited observation. Such persons will please to observe that I do not write romance for a geological report, nor give 'fancy sketches' for true sections of geological strata." Locke then used a Latin phrase to refer to the concretions, apparently comparing reports of them to the boasts of medieval explorers returning with fanciful tales: "The ludus helmontii have always been a curious subject to geologists."

Sketch of concretions in the Huron Member of the Ohio Shale, Adams County, by John Locke, 1838.

Ohio Shale concretions are primarily composed of carbonate (limestone or dolomite) rock and are enclosed within a dark-gray to black shale. In a 1975 Ohio Journal of Science paper, Barth likened them to "marbles pressed within the pages of a book,"

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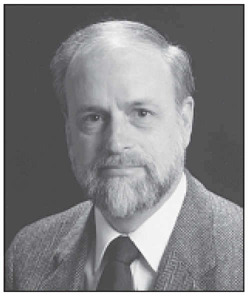

Thomas M. Berg, Division Chief and State Geologist

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From The State Geologist...

Thomas M. Berg

INTEGRATING THE DIVISION OF GEOLOGICAL SURVEY IN THE OHIO DEPARTMENT OF NATURAL RESOURCES

Most readers of *Ohio Geology* may not be aware that the Ohio Department of Natural Resources (ODNR) is subdivided into three "deputates," each headed by a Deputy Director. For more than $3\frac{1}{2}$ years under the current administration in Ohio, the Division of Geological Survey was assigned to the Deputate for Resource Management, headed by Deputy Director Sally T. Prouty. The Survey was assigned to that deputate along with the Division of Water and the Division of Soil and Water Conservation, two other divisions within ODNR that have a strong earth-science research orientation. Under Deputy Director Prouty, the Survey increased its educational outreach and became a departmental leader in applying total-quality-management concepts.

As part of a departmental reorganization in early 1994, the Division of Geological Survey was reassigned to the Deputate for Resource Protection, headed by Deputy Director Wayne R. Warren. This reassignment of the Survey places it with the Division of Reclamation, the Division of Oil and Gas, the Division of Engineering, and the Division of Real Estate and Land Management. The Survey interacts with every one of these divisions and offices. The Division of Reclamation and the Survey focus on mining issues in Ohio, both coal and industrial-mineral operations. The Geological Survey provides up-to-date geological information, identifies coal seams and aggregate resources, and maps mined-out areas. The Division of Oil and Gas and the Survey share responsibility for locating wells, assessing reserves of oil and gas, and answering inquiries relating to hydrocarbons in Ohio. The Geological Survey investigates and characterizes the subsurface geology of the state and maintains a comprehensive file of oil and gas well information. Plans are underway to digitize most of this information and incorporate it into client-accessible databases. The Survey interacts with the Division of Engineering and the Division of Real Estate and Land Management mostly with regard to Lake Erie and coastal issues in Ohio. The Survey is responsible for identifying the erosion-hazard area along Ohio's coastline and participates in crafting rules and regulations regarding construction in the erosion-hazard area.

The Ohio Geological Survey is pleased to be reassigned within the ODNR structure, but recognizes that it will continue to interact and be integrated with the total Department of Natural Resources family. This "cross-fertilization" among all the subdivisions of the Department has been a high priority of Director Frances S. Buchholzer. We are proud to be a part of that effort and look forward to even further integration of the Geological Survey within ODNR, with other state departments, and with Ohio's private sector.

WAYNE R. WARREN
DEPUTY DIRECTOR FOR RESOURCE PROTECTION
OHIO DEPARTMENT OF NATURAL RESOURCES

Wayne Warren was appointed Deputy Director for Resource Protection in the Department of Natural Resources by Director Frances S. Buchholzer in early 1991. Prior to that, Wayne served as Deputy Chief of the ODNR Office of Outdoor Recreation Services (1984-1991) and as Executive Director of the Lake Erie Office for the State of Ohio (1987-1990). From 1978 to 1984, he administered the State Lands Planning Section in ODNR. Wayne joined the Department in 1974 as a Staff Planner in the Office of Outdoor Recreation Services. Before beginning his now 20-year career with ODNR, Wayne worked for a year with Snell Environmental Group in Indianapolis, Indiana. He was awarded a Bachelor of Landscape Architecture degree from Ball State University (Muncie, Indiana) in 1974. He is a member of the Ohio Parks and Recreation Association and the National Recreation and Parks Association. Wayne has been appointed by the Governor to represent the State of Ohio on several organizations and commissions having to do with the Great Lakes.

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Concretion in the Huron Member of the Ohio Shale at Camp Mary Orton, Franklin County. The shale arches under and over this specimen. The calcite core has weathered away, leaving the dolomitic outer portion.

because the horizontally bedded shale bends around the concretion, both above and below. They range in diameter from a few inches to more than 9 feet, but most are less than 6 feet in diameter. Smaller concretions are nearly perfect spheres and resemble cannonballs, but larger ones tend to be flattened vertically and may have a funnel-shaped depression on the top and bottom. Concretions in the upper part of the Ohio Shale tend to be flattened and discoidal.

Most concretions have horizontal ribbing that represents layering of the surrounding shale before compaction. As Locke noted, the ribs in the central portion of the concretion are the most prominent. Vertical cracks commonly are filled with secondary minerals such as calcite or barite. These concretions are referred to as septaria.

The cores of larger concretions are typically calcite, which may surround an arthrodire fish bone or a fragment of fossil wood. The core is surrounded by fine-grained dolomite. The outer half inch or so of smaller concretions is commonly radially oriented pyrite. Freshly broken surfaces give off a fetid, sulfurous odor, attesting to the presence of altered organic matter.

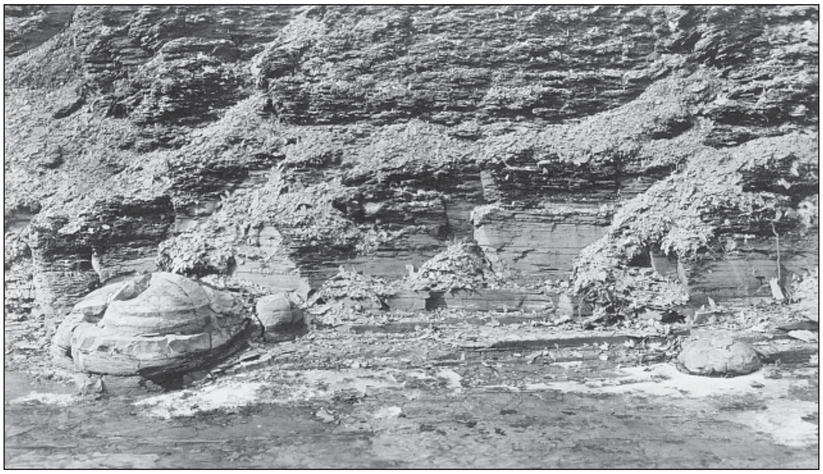
Large, spherical concretions are confined to the lower 50 feet or so of the Ohio Shale. High cliffs of Ohio Shale along such streams as Scioto Brush Creek in Adams County, Paint Creek in Ross County, Deer Creek in Pickaway County, the Olentangy River in Delaware and Franklin Counties, and the Huron River in Erie and Huron Counties have concretions embedded in the shale. The stream beds are littered with whole concretions as well as ones that have broken into large, angular fragments. The middle part of the Ohio Shale yields small (2-3 inches in diameter), ovoid, ironstone concretions that have a variety of fossils at their center. The upper part of the Ohio Shale has flattened, lenticular, carbonate concretions that commonly contain arthrodire bones; some contain exquisitely preserved remains, including soft tissue, of early sharks.

OTHER CONCRETIONS

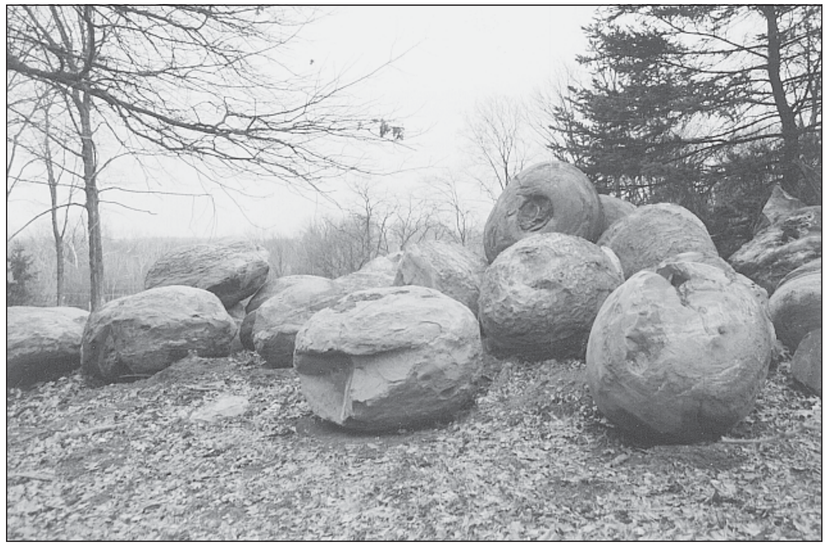
Dr. Ernest Carlson discusses the occurrence of concretions in a number of Ohio rock units in Division of Geological Survey Bulletin 69, *Minerals of Ohio*. None of these other units produces concretions as large or spectacular as those from the Ohio Shale, but some, particularly Pennsylvanian rocks, have interesting, mineral-filled septaria.

GEOLOGY OF THE OHIO SHALE

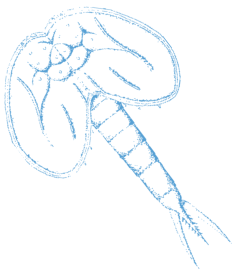
The Ohio Shale is a dark-gray to black, fissile, highly organic shale that weathers into small, brownish chips or flakes. The most extensive outcrop area includes 23 counties in central and northeastern Ohio, extending from the Ohio River northward to Lake Erie and then eastward along the lakeshore. A smaller outcrop is in west-central Ohio in Logan County and a small portion of Champaign County on the Bellefontaine Outlier (see *Ohio Geology*, Winter 1991). The Ohio Shale is the surface bedrock in seven counties in northwestern Ohio, but this area is relatively flat and covered by thick glacial drift, so there are few outcrops. All of eastern Ohio, east of the central outcrop belt, is underlain by a thickening wedge of Ohio Shale as the unit dips eastward into the Appalachian Basin



Concretions in the Huron Member of the Ohio Shale along Slate Run, Franklin County. Stratification planes, representing the original bedding, are clearly visible on the largest concretion.



Pile of large "Huron boulders" excavated during construction of a road for a housing development on the west side of Olentangy River Road, Columbus. Several broken concretions revealed black, porous arthrodire bones in their centers. One smaller concretion produced a lower jaw of Dinichthys herzeri (see Ohio Geology, Fall 1986). Note the funnel-shaped depression in the concretion at right center. Concretions are much in demand as landscaping ornaments, and smaller ones are quickly removed from such excavations. Photo by Preston Fettrow, Sr., 1986.

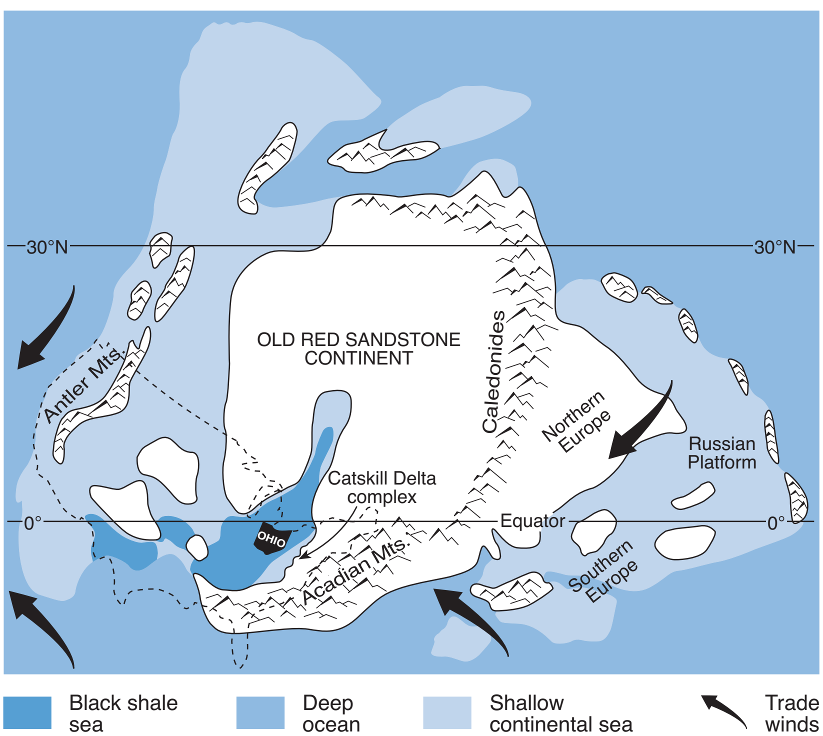


Echinocaris

at about 35 feet per mile.

Geologists have divided the Ohio Shale into three units. The lower unit is the Huron Shale Member, which averages about 410 feet in thickness. The lower part of the Huron contains the large, spherical concretions, which have been referred to as "Huron boulders."

The middle unit of the Ohio Shale is the Chagrin Shale Member; this gray shale is up to 1,200 feet thick in northeastern Ohio but thins rapidly to the south and west. In central and southern Ohio the Chagrin is recognizable as a thin, gray unit called the Three Lick Bed. In some areas of northeastern Ohio the Chagrin Shale Member is noted for small, elliptical, ironstone concretions that contain remains of fossils such as brachiopods, bivalves, cephalopods, conulariids, crinoids, and rare fishes. The most spectacular fossils are well-preserved crustaceans, of which eight species have been described. *Echinocaris* is the most common genus, and several species are known. Most of these specimens have been collected from Indian Point, at the confluence of the Grand River and Paine Creek in Lake County, and along Mill Creek just south of Ross Road, in Harpersfield Township, Ashtabula County. The small concretions weather out of the shale and lie in the stream bed.



Paleogeography of North America during the Late Devonian, at the time of deposition of the Ohio Shale. Ohio was in equatorial latitudes to the west of the Acadian Mountains. One speculation is that the mountains blocked the westerly trade winds, thus creating a rain shadow and a sediment-starved, stagnant sea in which black shale accumulated. Modified from Ettensohn and Baron (1981).

The uppermost unit of the Ohio Shale is the Cleveland Shale Member, which is very similar to the Huron Member but is only 20 to 60 feet thick on the outcrop. At least three zones of large, flattened concretions in the Cleveland Member have been observed along Big Creek and its tributaries in the Cleveland area.

The Ohio Shale accumulated in latest Devonian time, about 360 million years ago, along the western edge of the Catskill Delta. This delta complex was a great wedge of clastic sediments eroded from the rising Acadian Mountains, formed to the east by collision of northeastern North America with northern Europe. This continental mass is referred to as the Old Red Sandstone Continent, in reference to Devonian rocks of that name in Britain. Ohio was just south of the Equator at this time, and one theory suggests that the Acadian Mountains periodically blocked the westerly trade winds, forming a rain shadow on the western side. The relatively deep (some suggest 600 feet) sea was starved for sediment and became stagnant below a boundary layer known as a pycnocline. Although the upper waters in the sea were oxygenated, the bottom waters were foul, and black mud high in organic matter slowly accumulated. It was in this environment that the concretions formed.

ORIGIN OF CONCRETIONS

Speculations on the origin of the Ohio Shale concretions began with John Locke's observations in 1838 and continue to the present. The ideas on concretion development concentrate on the time of formation—did they form at the same time the shale was being deposited or did they form after deposition when the soft, black mud was being compressed? And why was concretion growth initiated at a particular site?

Locke, as quoted earlier, suggested that the concretions formed at the time of deposition of the shale but were not completely solid masses because many of them were compressed by the compaction of the shale. State Geologist John S. Newberry considered the concretions to have formed at the time of deposition of the shale and observed in 1873, "The layers of the shale are seen to be curved over and around these septaria; a fact which has been considered as proof that the laminae of the shale were deposited over them after they had obtained their present size and form. This appearance is, however, due entirely to the lose of volume in the shale, consequent upon vertical compression from overlying rocks. All such argillaceous strata shrink one-half or more when compressed from mud to rock. The solid concretions have yielded little or nothing to this compression, and hence the layers of shale are curved around them."

In a detailed study of the Ohio Shale concretions in 1957, H. Edward Clifton suggested that the concretions formed after deposition of the shale but before it had undergone complete compaction. Crystallization began at a nucleus and spread outward. Clifton called attention to the fact that replacement and secondary growth of crystals were important aspects of concretion development. He also suggested that the largest, somewhat flattened concretions achieved this configuration because water within the sediments tended to circulate in horizontal planes, thus favoring lateral growth until compaction proceeded to the point that mineral-bearing water was cut off.

Although many geologists who have studied these concretions have noted that crystallization appears to have begun around a nucleus of organic material, such as a fish bone, few seem to have speculated as to the chemical processes that would cause a large mass of carbonate to migrate to and accumulate around this nucleus. The most recent and comprehensive study of the Ohio Shale concretions was published in 1988 by the U.S. Geological Survey in a report by R. E. Criss, G. A. Cooke, and S. D. Day. These researchers suggested that the concretions began to form around decaying organic matter and initially may have been masses of low-density, organic, soapy matter known as adipocere. The concretions formed very near the sediment-water interface, where minerals filled in and cemented the void space of the sediment, which, before compaction, had between 81 and 94 percent pore space.

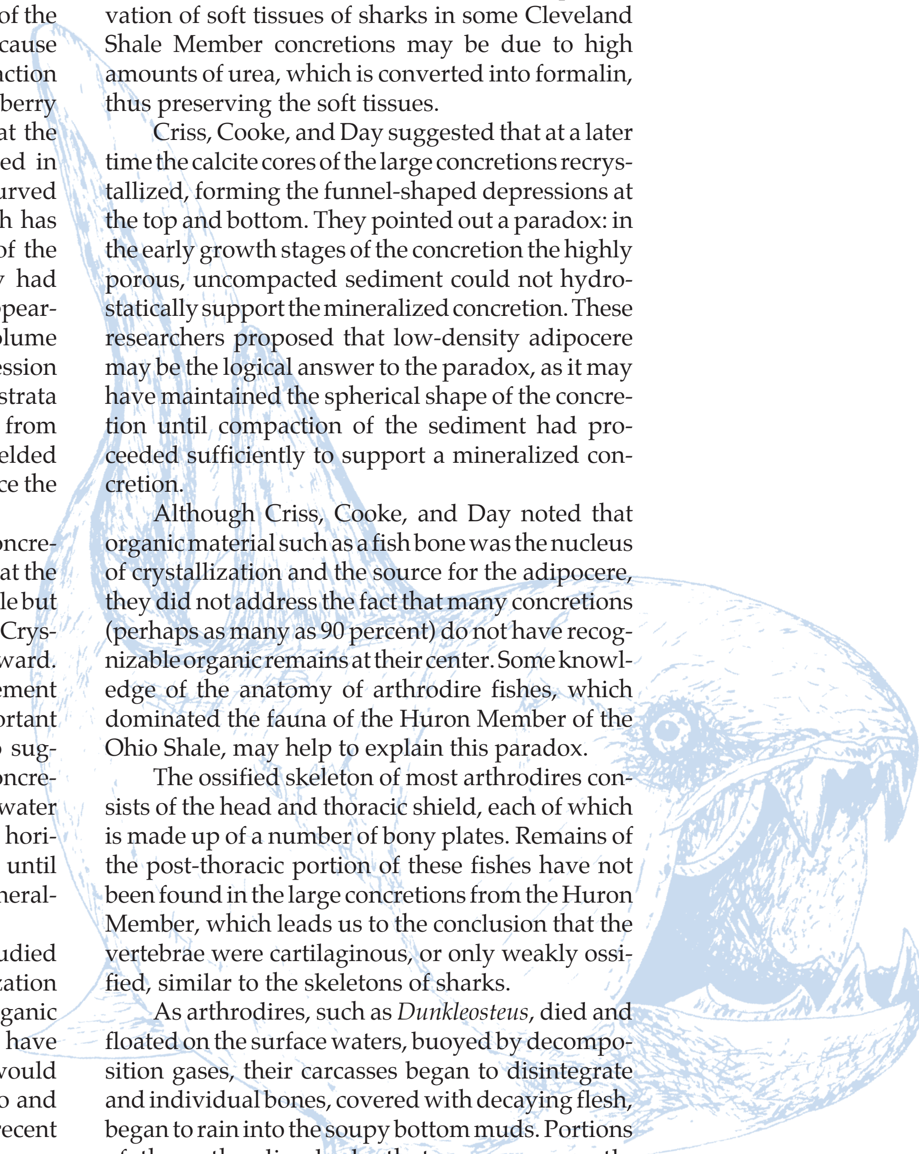
Criss, Cooke, and Day postulated that at an early stage in concretion formation the adipocere was replaced by calcite, which was later replaced by calcium- and iron-rich dolomite, except at the cores of larger concretions, where the calcite was not replaced. Dr. Michael E. Williams of the Cleveland Museum of Natural History points out that ammonia is the principal decay product from a dead fish in an oxygen-deficient environment. The ammonia creates a high pH halo around the decaying remains, which causes carbonate to precipitate. Williams further notes that the remarkable preservation of soft tissues of sharks in some Cleveland Shale Member concretions may be due to high amounts of urea, which is converted into formalin, thus preserving the soft tissues.

Criss, Cooke, and Day suggested that at a later time the calcite cores of the large concretions recrystallized, forming the funnel-shaped depressions at the top and bottom. They pointed out a paradox: in the early growth stages of the concretion the highly porous, uncompacted sediment could not hydrostatically support the mineralized concretion. These researchers proposed that low-density adipocere may be the logical answer to the paradox, as it may have maintained the spherical shape of the concretion until compaction of the sediment had proceeded sufficiently to support a mineralized concretion.

Although Criss, Cooke, and Day noted that organic material such as a fish bone was the nucleus of crystallization and the source for the adipocere, they did not address the fact that many concretions (perhaps as many as 90 percent) do not have recognizable organic remains at their center. Some knowledge of the anatomy of arthrodire fishes, which dominated the fauna of the Huron Member of the Ohio Shale, may help to explain this paradox.

The ossified skeleton of most arthrodires consists of the head and thoracic shield, each of which is made up of a number of bony plates. Remains of the post-thoracic portion of these fishes have not been found in the large concretions from the Huron Member, which leads us to the conclusion that the vertebrae were cartilaginous, or only weakly ossified, similar to the skeletons of sharks.

As arthrodires, such as *Dunkleosteus*, died and floated on the surface waters, buoyed by decomposition gases, their carcasses began to disintegrate and individual bones, covered with decaying flesh, began to rain into the soupy bottom muds. Portions of the arthrodire body that were apparently unmineralized, such as the entire body posterior to the thorax, fell into the bottom mud and generated an adipocere mass, which would eventually become a concretion. However, the lack of fossilizable hard parts in this mass would preclude the possibility of fossilization of recognizable organic remains, particularly after recrystallization and mineral replacement of the nucleus of the concretion.



Dunkleosteus

Yet another problem arises—why are many bones of arthrodires found in the Huron and Cleveland Members with no concretionary matter surrounding them? In some cases these bones have been reported from the same zones in which the concretions occur. Did the bones have so little flesh remaining when they settled into the bottom mud that no adipocere could form? Factors such as water depth, availability of carbonate in substrate waters, and perhaps other chemical and physical factors may have been operating during concretion formation. The occurrence of concretions in vertical and perhaps horizontal zones suggests that a multitude of conditions had to be just right for them to form.

Those wondrous "ludus helmontii" that so fascinated Dr. Locke more than 150 years ago still generate much interest. And we are still far from understanding their exact mode of formation and distribution.

ACKNOWLEDGMENTS

We thank Dr. William J. Hlavin of Bass Energy and Dr. Joseph T. Hannibal and Dr. Michael E. Williams of the Cleveland Museum of Natural History for information and discussions about Ohio Shale concretions.

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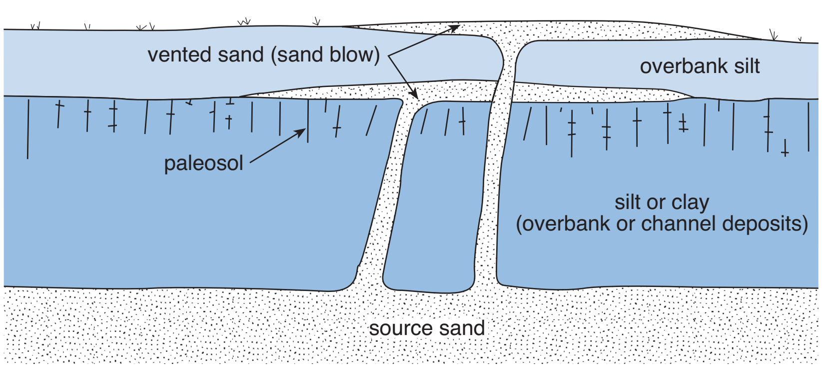
SEARCHING FOR ANCIENT EARTHQUAKES

In the last decade there has been an increasing awareness that seismic hazard in the eastern United States may be greater in some areas than the historic earthquake record would suggest. Long recurrence intervals for major events, measured in centuries or millenia, far exceed the 200-year historic record. There is a tendency for many people to be lulled into a false sense of security in areas that may be prone to periodic large, damaging earthquakes because the area may have never experienced such an earthquake in historic times.

We need only to think of the series of great magnitude 8 earthquakes in 1811-1812 in New Madrid, Missouri, to realize that if they had occurred a century or two earlier our written record of these events would probably consist of a brief notice of a light shock felt in New England. There would be little realization that this area was capable of producing the largest earthquakes ever recorded in the continental United States.



Generalized cross section of a stream bank showing two sets of vertical sand dikes and sand blows resulting from liquefaction of saturated sand by strong seismic shaking. Note that the dike on the right cuts through the sand blow generated by the dike on the left. This relationship indicates two separate seismic events. Modified from Obermeier and others (1993).

Intensive studies of the New Madrid seismic zone have raised the inevitable question—how often do such large earthquakes occur? In the absence of a written record, geologists turned to their book of the past, the record preserved in rocks and sediments. They soon began to realize that strong earthquakes cause some sediments to liquify into a fluidlike consistency and form dikes, sills, sand blows, and other ground-failure features. Thus was born the study of paleoseismicity and the search for earthquake-induced liquefaction features that could be dated by radiocarbon or archaeological associations and organized into a time sequence.

Typically, liquefaction is caused by upward propagation of shear waves from the bedrock into overlying unconsolidated sediments. Sand or gravelly sand that is saturated by a high water table and overlain by silt or clay is most susceptible to development of liquefaction features such as sand dikes. During an earthquake of sufficient intensity, the liquid sand-water mixture hydraulically fractures the overlying fine-grained materials. The sand-water mixture then typically protrudes up into the cap, forming a steeply dipping, tabular dike. In cross section, the dike may range from a few inches to a few feet in width. In plan view, the dike may extend for hundreds of feet.

Larger dikes tend to vent to the surface in the form of a sand blow, which may be a foot or two thick and more than 100 feet in diameter. In cross section the sand blows appear as horizontal layers of sand immediately overlying an ancient soil (paleosol). Later sedimentation may cover the surface sand deposit. Recurrent, strong earthquakes in an area may result in multiple sets of dikes and sand blows that exhibit a cross-cutting relationship. If each set of dikes can be dated, some prediction of recurrence intervals of large earthquakes can be made. In general, liquefaction features begin to appear during earthquakes of magnitude 5.5 or above. However, in the eastern United States these features seem to be associated with larger earthquakes, generally magnitude 6.0 or larger.

This past summer, Ohio was fortunate to have the services of Stephen F. Obermeier of the U.S. Geological Survey Branch of Earthquake and Landslide Hazards. He began a search for paleoliquefaction features that would indicate the occurrence of ancient great earthquakes in the state. Similar work by Obermeier and Patrick J. Munson of Indiana University in the Wabash Valley of Indiana and Illinois and other areas in this region indicated that at least seven strong earthquakes had occurred between about 20,000 years ago and 2,500 years ago. At least one of these events, about 6,100 years ago, is estimated to have had a magnitude on the order of 7.5.

Obermeier, accompanied by Ohio State University graduate student Erik Venteris, began his search in the western Ohio seismic zone, an area that has experienced at least 40 felt earthquakes since 1875 (see *Ohio Geology*, Summer 1993). The largest of these, on March 9, 1937, is estimated to have had a magnitude of about 5.5. The limited exposures of sediments in this relatively flat area are confined to stream banks and sand and gravel pits. Obermeier and Venteris canoed more than 100 miles of streams and found more than 25 miles of freshly eroded stream banks that could be searched for seismically induced dikes and sand blows. In the western Ohio seismic zone, they canoed portions of the Auglaize, Great Miami, Stillwater, and St. Mary's Rivers and Loramie Creek. Portions of the Scioto and Little Scioto Rivers in Marion County in north-central Ohio were examined, as were seven sand and gravel pits.

The good news, at least on a preliminary basis, is that Obermeier found no indisputable paleoliquefaction features in any of the outcrops he examined. He expresses some confidence that the western Ohio seismic zone has not experienced a very strong earthquake, above magnitude 7, in the last few thousand years. However, this evidence does not preclude the possibility that the area has had prehistoric earthquakes in the 6.0 to 6.5 range. If judgment can be drawn from the Charleston, Missouri, earthquake of 1895 (magnitude 6.5), liquefaction features only begin to appear at about this threshold magnitude and occur only in a very small epicentral area. Obermeier notes that large areas of western Ohio are unsuitable for development of liquefaction features such as dikes because of a lack of near-surface sand units and, therefore, would not exhibit evidence of strong prehistoric earthquakes, even if they did occur.

For the 1995 field season, Obermeier plans to examine stream exposures in northeastern Ohio in Lake and Geauga Counties. This area has experienced at least 20 felt earthquakes since 1836, including a magnitude 4.5 event in 1943 and a magnitude 5.0 event in 1986 (see *Ohio Geology*, Summer 1986). He also plans some additional investigations in western Ohio.

—Michael C. Hansen

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INALEIGH EISEN, 1944-1994

Inaleigh Eisen

It is with considerable sadness that we report the death of Inaleigh Eisen on September 23, 1994, after a difficult two-month struggle with cancer. Leigh had worked for the Survey since 1977, serving as a public inquiries assistant in the Survey's Publications Center, recently reorganized as the Geologic Records Center. Prior to coming to the Survey, she had worked for the Ohio Department of Taxation.

Leigh was striken with her fatal illness only a few months after returning to work following recuperation from a serious auto accident in November 1993. Leigh was a cheerful and friendly person and always helpful and courteous to customers and staff. She was both affable and reserved, not wishing to call attention to herself. Only a few of her very close friends at the Survey knew of her illness. Leigh did not want to be a worry or burden to others.

Leigh's role at the Survey was an important one as she made sure that mail orders for publications were processed quickly and that telephone or walk-in customers received the proper information or product to serve their needs. During her long career with the Division, she efficiently served many thousands of people. Leigh set a standard for quality public service. Survey staff admired her dedication and unselfishness. Many times she put in extra hours, commonly giving up her lunch hour, so that work could be completed on time or customers served more efficiently. Leigh's sense of humor stood out in her everyday contacts with both staff and the public.

Leigh is survived by her daughter Mychael, who reached her 16th birthday only a few days after her mother's death. We will miss Leigh both for her endearing personality and her significant contributions to the Division's mission.

HANDS-ON EARTH SCIENCE No. 3

by Sherry L. Weisgarber
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EVERYONE LOVES FOSSILS

What exactly are fossils? Fossils are the remains of past life. This definition includes anything that is a clue to past life, such as the bones of dinosaurs and mammoths, the tiny shells of one-celled animals, trails and footprints, worm burrows, leaves, tree trunks, seeds, and microscopic spores of fungi.

Fossils occur in sedimentary rocks such as limestone, shale, and sandstone. Because Ohio is covered with sedimentary rocks, fossil collecting is a popular hobby for many Ohioans.

How do fossils form? Some of the plants and animals that died in the geologic past were buried by sediments before they could decompose. After burial, the soft tissue of the organism slowly decomposed, but the harder parts of the plant or animal remained intact. The sediments eventually were hardened into rocks, preserving the harder parts of the organisms, such as bones, shells, teeth, leaves, and stems, that we find as fossils today.

Fossils are preserved in a variety of ways. The hard parts of some organisms are permeated by minerals in a process called *permineralization*. Petrified wood is an example of permineralization. Many plants are preserved as *compressions*. In this process, the remains of the organism are squeezed by the rocks that surround it until all of its liquids and gases are removed, leaving only a thin film on the surface of the rock. The hard parts of many Ohio fossils were dissolved by ground water moving through the sediment or rock and replaced with minerals in the water. This process is called *replacement*. In Ohio, common replacement minerals are pyrite and silica. Ground water also may dissolve the original material without replacing it with other minerals. If the sediment hardened into rock before the fossil was dissolved, the rock retains the imprint of the fossil, which is called a *mold*. A mold may later be filled with other sediment or minerals precipitated from ground water, making a *cast* of the fossil. A cast is a replica of the original fossil in a different material.

The following classic activity illustrates the concepts of molds and casts.

Each student will need the following materials:

- sea shell, twig, or other small object
- $^1/_4$ to $^1/_2$ cup plaster of paris
- $^1/_4$ to $^1/_2$ cup water
- petroleum jelly
- small plastic margarine dish
- paper cup
- plastic fork

Cover the small object, representing a dead organism, with a thin layer of petroleum jelly to keep it from sticking in the plaster of paris when it hardens. Put the plaster of paris into the margarine dish. Add water gradually to the plaster of paris, stirring gently with the fork until the plaster is thick and creamy. Gently tap the bottom of the dish onto the table to force out any air bubbles in the plaster. This layer represents the soft sediment that the organism fell into when it died. Let the plaster harden for about 1 minute so the object won't sink to the bottom of the container. Press the small, petroleum-covered object into the plaster and allow it to dry thoroughly, preferably overnight. Remove the object from the plaster. You now have a *mold* of your object. Leave the mold in the container and coat the entire surface of the dry plaster with a thin layer of petroleum jelly. Mix another batch of plaster of paris in the paper cup. Pour this mixture over the mold and allow it to dry. This layer represents the overlying sediments or the minerals precipitated from ground water that fill in the mold, making a *cast* of the original object. When the plaster is dry, separate the cast from the mold. It should separate easily along the layer of petroleum jelly. You now have a fossil cast and a fossil mold of your original object.

SOURCE: *Ohio Fossils*, ODNR, Division of Geological Survey, *Water, Stones, & Fossil Bones*, National Science Teachers Association, and *The Earth Science Book*, Dinah Zike.

NOTE: An Ohio Geology Crossword Puzzle is now available from the Survey. If you would like a copy, call Sherry at 614-265-6588.

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