GEOFACTS
OHIO GEOLOGICAL SURVEY • DEPARTMENT OF NATURAL RESOURCES

Ohio Shale Concretions

Perhaps no other rocks found in Ohio generate as much public interest and curiosity as the large carbonate spheres, known as *concretions*, that weather out of the Devonian-age Ohio Shale (figs. 1, 2A). 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. Some of them reach 3 meters (10 feet) or more in diameter.

Ohio Shale concretions are composed primarily of carbonate (limestone or dolomite) rock and are enclosed within a dark-gray to black shale. They range in diameter from 5 cm to 3 m (2 in to 10 ft), but most are less than 2 m (7 ft) in diameter. Smaller concretions are nearly perfect spheres, 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 disk shaped.

Most concretions have horizontal ribbing that represents layering of the surrounding shale before compaction. Vertical cracks are commonly filled with minerals such as calcite or barite. These concretions are referred to as *septaria*. The cores of larger concretions are typically calcite (fig. 2B), which may surround an *arthrodire* (a type of extinct armored fish) bone (fig. 3A) or a fragment of fossil wood (fig. 3B). The core is surrounded by fine-grained dolomite. The outer, thin layer of concretions is commonly pyrite (fig. 2A).

Large, spherical concretions are confined to the lower 15 meters (50 feet) of the Ohio Shale. High cliffs of Ohio Shale along streams, such 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. A variety of Ohio Shale concretions are exposed in Shale Hollow Park and Highbanks Metro Park north of Columbus in central Ohio. The middle part of the Ohio Shale yields small, 5–8-cm (2–3-in)-diameter, egg-shaped, ironstone concretions that have a variety of fossils at their centers. The upper part of the Ohio Shale (Cleveland Shale Member) has flattened, convex-shaped concretions, commonly containing arthrodire fish fossils. Some of these concretions contain exquisitely preserved remains, including the soft tissue of early sharks.

Geology of the Ohio Shale

The Ohio Shale is a an easily split, dark-gray to black, 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.

Figure 1. Well-rounded carbonate concretions in the Huron Member of the Ohio Shale found within Shale Hollow Park. Note the deformed layers of shale surrounding the concretions. Scale segments are 10 and 20 cm (4 and 8 in).

Figure 2. (A): Well-rounded concretion covered by a thin, grayish-brown pyrite layer. Scale segments are 20 cm (8 in). (B): A 1.2-m (4-ft)-diameter concretion with calcite crystals in the core. The core of a concretion in Ohio Shale is typically calcite with coarse crystals. Blue pen for scale.

Figure 3. (A): A concretion containing a fossilized lower jaw of *Dinichthys herzeri*, a Devonian-age placoderm (armored fish), with a blue pen for scale. (B): A 2-m (7-ft)-diameter concretion containing a Devonian-age plant fossil in the core; scale segments are 10 and 20 cm (4 and 8 in).

The Ohio Shale is divided into three units. The lower unit is the Huron Shale Member, which averages about 125 m (410 ft) in thickness. The lower part of the Huron contains large, spherical concretions (figs. 1, 2A).

The middle unit of the Ohio Shale is the Chagrin Shale Member; this gray shale is up to 365 m (1,200 ft) thick in northeastern Ohio but thins rapidly to the south and west. In some areas of northeastern Ohio, the Chagrin Shale Member is noted for small, elliptical, ironstone concretions that contain remains of brachiopods, crinoids, and mollusk fossils.

The uppermost unit of the Ohio Shale is the Cleveland Shale Member, which is very similar to the Huron Member but is only 6 to 18 m (20 to 60 ft) thick in 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 during the Late Devonian Period about 360 million years ago. During this time, Ohio was just south of the Equator. The relatively deep 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.

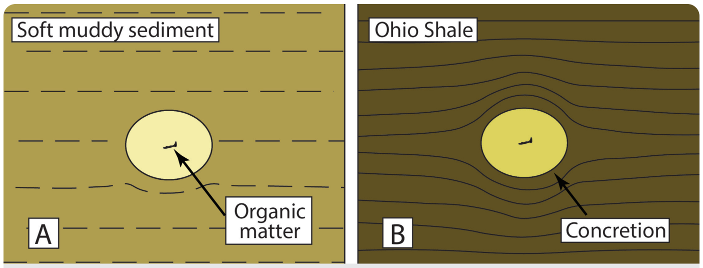

Figure 4. Development of concretions and deformation of the Ohio Shale around them. (A): Carbonate minerals form around organic matter in muddy sediment in sea floor. (B): Compaction and dewatering cause muddy sediment to become the Ohio Shale. Deformed layers around the concretion (fig. 1) indicate that the concretion was lithified and solid before compaction and dewatering of the shales. Concretions have been likened to "marbles pressed within the pages of a book" (fig. 4B) because the horizontally bedded shale bends around the concretion, both above and below (fig. 1).

Origin of concretions

The theories on concretion development focus primarily 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?

Past studies have suggested that concretion formation began very near the sediment-water interface, as localized chemical reactions occurred around decaying organic matter, such as a dead fish. In an oxygen-deficient environment, ammonia is the principal decay product. The ammonia creates a high-pH halo around the decaying remains, which initially may have been masses of low-density, organic, soapy matter known as *adipocere*. At an early stage in concretion formation, the adipocere was replaced by calcite as crystallization began at the nucleus and spread outward. Later, this calcite was replaced by calcium- and iron-rich dolomite, except at the cores of larger concretions, where the calcite was not replaced. Replacement and secondary growth of crystals were important aspects of concretion development. Concretions began to take on their signature shape after deposition of the shale but before the shale had undergone complete compaction (fig. 4).

Most researchers acknowledge that organic material such as a fish bone (fig. 3A) was the nucleus of crystallization, but many concretions do not have recognizable organic remains at the center. The ossified (bony) skeletons of most arthrodires consist only of the bony plates that comprised the head and thoracic shield. Remains of the post-thoracic portion of these fishes have not been found in the large concretions from the Huron Member, leading to the conclusion that the vertebrae of these animals were cartilaginous, or only weakly ossified, similar to the skeletons of sharks.

After larger arthrodires died, some individuals may have floated on the surface, buoyed by gases released during decomposition. As these large fish decomposed, their bodies broke apart and smaller pieces (such as individual bones) drifted down to the muddy sea bottom. Portions that were likely cartilaginous, such as the vertebral column or the tail, generated an adipocere mass that would eventually become a concretion. However, the lack of hard parts in this mass reduced the possibility of fossilization of recognizable organic remains.

Beyond the fish- or plant-specific organic factors that likely influenced concretion formation, environmental factors such as water depth, availability of carbonate in substrate waters, and other chemical and physical reactions also may have played a role in the formation of the concretions found within the Ohio Shale.

References & Further Reading

Barth, V.D., 1975, Formation of concretions occurring in the Ohio shales along the Olentangy River: Ohio Journal of Science, v. 75, no. 3, p. 162–163.

Carlson, E.H., 2015, Minerals of Ohio (2nd ed.): Columbus, Ohio Department of Natural Resources, Division of Geological Survey Bulletin 69, 304 p.

Clifton, H.E., 1957, The carbonate concretions of Ohio Shale: Ohio Journal of Science, v. 57, no. 2, p. 114–124.

Criss, R.E., Cooke, G.A., and Day, S.D., 1988, An organic origin for the carbonate concretions of the Ohio Shale: U.S. Geological Survey Bulletin 1836, 21 p.

Hansen, M.C., 1994, Concretions: the "ludus helmontii" of the Ohio Shale: Ohio Geology, Fall 1994, p. 1, 3–6.