



Layers of geode-bearing clayey dolomite, examined above by geologist Robert McKay, add great visual and educational interest to the Keokuk Water Works, both inside and outside of the plant. The geodes, Iowa's official "State Rock," are lined with quartz (chalcedony, upper left) and calcite on quartz (lower right).

descendant, the Mississippi River, flows past the front door, providing Keokuk and its residents with their drinking water supply.

The Keokuk Municipal Water Works recognizes its unique geography and geology. They have incorporated the bedrock, the bluffs, the valley, the river, and the lock and dam into their plant design. Inside the plant, the ancient geode-laced Mississippian strata form a striking visual counterpoint to the modern array of piping, tanks, valves, massive cones, catwalks, and computerized operations that organize and treat the river's water into a municipality's water supply.

Keokuk Water Works encourages public tours of their plant. They know these visits can increase the public's understanding not only of their local drinking water supply and its quality, but awareness of broader regional and state water supply issues as well. In this scenic setting, that awareness includes a unique reminder that we depend on and interact daily with geological resources and geological processes past and present.

* Lewis, Henry. 1967 (originally published in German in 1854). *The Valley of the Mississippi Illustrated*. Minnesota Historical Society, p. 219. Quote from J.N. Nicollet's 1843 *Report Intended to Illustrate a Map of the Hydrographical Basin of the Upper Mississippi River*. 26th Congress, 2nd session. Senate Documents, no. 237 – serial 380, p. 24, 26.



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Keokuk Water Works Its Geological Foundations



Keokuk Water Works, barely visible beyond Lock and Dam #19 on the far shore, is dwarfed by the broad expanse of the Mississippi River. Its width was scoured by the erosive action of glacial meltwaters that periodically flooded the valley over 9,000 years ago. Sweeping curves along the valley are defined by limestone bluffs of Mississippian age, a term of geologic time recognized worldwide and named for this segment of the Mississippi Valley between Keokuk and Burlington.

There is often more than meets the eye in a municipal water supply. This is especially true of Keokuk, Iowa, and its water works. Sandwiched between the Mississippi River's flow on one side and 345-million-year-old limestone bluffs on the other, the city's expanding state-of-the-art water plant is literally anchored to its geological foundations. With its special geologic setting and the city's interest in educating the community about its drinking water, Keokuk's Municipal Water Works has put out the welcome mat for visitors to its fascinating facility.

This Iowa stretch of the Mississippi River has attracted geological interest for over 150 years. The final sweeping curves in the state's eastern border between Burlington and Keokuk are formed

by bluffs of massive limestone, and the rapids at Keokuk were a noted obstacle to early exploration and travel by river. J.N. Nicollet writes, "In 1838 Congress ordered a survey of the rapids, which was entrusted to Captain R[obert] E. Lee of the corps of engineers. By his estimate, the length of the rapids is eleven miles, with a fall of twenty-four feet. Here the Mississippi tumbles over ledges of blue limestone which are at all times more or less covered with water and through which many crooked channels have been worn." *

These resistant bedrock ledges and bluffs are assigned to the Mississippian Subsystem, one of the basic divisions of geologic time recognized throughout the world. In fact, Mississippian-age strata were so-named in the geologic literature of



Mississippi River water is pumped through a network of pipes into massive cone-shaped clarifiers where sediment and dissolved minerals are removed from the swirling water. Keokuk's expanded, state-of-the-art water plant includes a 12-ft-high portion of the 345-million-year-old Mississippian limestone bluff along one entire interior wall of the 300-ft-long building.

the late 1800s for this Iowa segment of the Mississippi River valley. To geologists, these rock outcrops are the starting point for the definition of strata of this age.

The lime-rich sedimentary rocks actually had their origins 345-million years ago in shallow tropical seas that submerged the continent's interior, including Iowa. The rocks bear fossils of abundant marine organisms that inhabited these warm seas, an environment resembling the clear waters of the Florida Keys today. Lime sediments were precipi-

tated from seawater and also produced biologically as animals such as corals, crinoids, brachiopods, and snails built their skeletal shelters.

The Mississippi River itself appeared much later in time, likely originating with south-bound glaciers that periodically gripped the midcontinent in Arctic cold between 2.5 million and 10,000 years ago. Bedrock promontories, such as here at Keokuk, were left standing as the river gradually deepened its valley, especially during later chapters of Iowa's Ice Age history. Episodes of glacial

melting, particularly between 100,000 and 9,000 years ago, sent meltwater floods surging down the Mississippi, scouring the valley floor still deeper, and then partially back-filling its gorge with thick deposits of sand and gravel.

The most significant event in the river's modern history has been the construction and maintenance of a 9-foot navigation channel and its accompanying lock and dam system. Lock and Dam #19 is situated right outside the Keokuk Water Works, and its operation and accompanying river traffic add considerable interest for visitors.

The story of this place has further geologic aspects. In 1877, citizen William Stripe's concern for safe drinking water led him to found a private company known as the Keokuk Waterworks. Its purpose was to gather and treat Mississippi River water for distribution to citizens and industries of the prospering city. In 1938 the company was purchased by the City of Keokuk, and a new treatment building was constructed, with further improvements in subsequent decades. Then, in 1995, on the same piece of ground, an entirely new treatment plant was begun as a phased replacement of the older facilities.

The first important issue was location. The site on the Mississippi River still looked good over 100 years later because it already had functioning river-intake pipes and underground settling tanks that could be converted to clean water storage. In order to construct the new building on top of the 1979 settling tanks, engineers designed a pillar anchored into underlying bedrock to support the weight of a new 1.3 million-pound re-carbonation unit.

Construction at the existing site also entailed excavating into the steep limestone bluff to create more space. Contractors removed about 200,000 cubic feet of rock and cut a stair-step into the bluff so that massive cone-shaped water clarifiers and softeners would have a solid foundation. Phase I of

the new facility is complete, and includes a 14-million-gallon-per-day treatment process. With an eye to future expansion, the pipes and space are in place to add new filters and more water clarifying and softening cones as needed.

Excavation into the valley bluff exposed two Mississippian bedrock formations, the upper part of the Keokuk Limestone and the lower portion of the overlying Warsaw Formation, a more shaley interval. Both rock units, particularly the Warsaw, are widely known for the spectacular crystal-lined geodes that are embedded in the clayey dolomite.

Though geodes are known from many localities around the world, one of the most famous collecting regions occurs within a 35-mile radius of Keokuk. Rock collectors commonly refer to these specimens as "Keokuk geodes," and in 1967 the Iowa General Assembly declared the geode as the official "State Rock." These roughly spherical masses of silica-rich minerals easily separate from their host rock. The most prized specimens have hollow interiors lined with pointed crystals of quartz and other minerals. They can range in size from that of a walnut to a basketball.

The geode-laden rock bluff was so interesting that it was decided to incorporate a portion into the water plant's long west wall. About 9 feet of geode-bearing dolomite is exposed along the driveway outside the new plant (photo, next page), and the rock wall then continues some 300 feet along the entire length of the building's interior where the wall stands 12 feet high (photo, left).

Today, the Keokuk Water Works is situated against a limestone bluff significant in the history of the country's geological investigations, a bluff of sedimentary rock detailing a 345-million-year-old history of ancient seas and their inhabitants. The water works overlooks a geologically younger valley that was host to torrents of glacial meltwater floods just several thousand years ago, and whose modern