The Paleoecology of the Swatara Gap Fauna

by David Lehmann

Swatara Gap (in Lebanon County) is a popular and well-documented site for collecting Ordovician fossils (Figure 1). Here, the siltstones and mudstones of the Martinsburg Formation contain an abundant, diverse fossil fauna. Beautifully preserved, limonite-stained casts and molds of trilobites, brachiopods, mollusks, echinoderms, and other organisms attract fossil collectors from all over the United States.

Although the Reedsville Shale (a western correlative of the Martinsburg Formation) is fossiliferous, other Martinsburg rocks in the eastern part of the state typically contain very few fossils. This indicates that the sediments that formed the Martinsburg rocks at Swatara Gap were deposited in a different environment than the

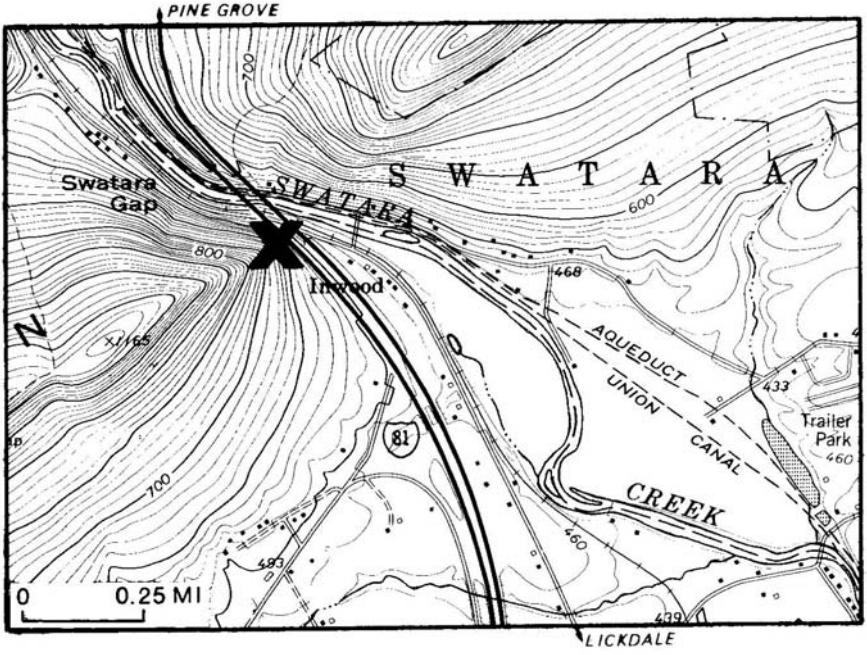


Figure 1. Location of the fossil-collecting site (x) at Swatara Gap.

sediments that formed other nearby Martinsburg rocks. Until now most geologists considered the Swatara Gap rocks to be the result of deep-sea deposition. Although most of the Martinsburg rocks seen at other eastern Pennsylvania localities are probably the result of deep-water deposition, a deep-sea environment cannot adequately account for the fossils and sediments seen in Swatara Gap rocks.

Why a Deep-Sea Explanation Does Not Work for Swatara Gap Rocks

Benthic (bottom-dwelling) fossils occurring in deep-water sediments may represent either transported or *in situ* assemblages. If the Swatara Gap fossils represent a transported assemblage, we would expect the shells to have become disarticulated, broken, and abraded as they bounced and rolled on the sea floor. These are typical characteristics of transported shells. Most of the fossils from Swatara Gap do not show any characteristics of transport, clearly indicating that these shells were not transported a great distance. On the contrary, many of the Swatara Gap organisms appear to have been buried in their life positions.

Because the Swatara Gap fossils represent an *in situ* fauna, sediments and sedimentary structures can be used to help us recognize the paleoenvironment. The Martinsburg rocks from Swatara Gap are extremely fine grained, much finer grained than nearby typical deep-sea Martinsburg deposits. In deep-water deposits, the grain size of sediments becomes increasingly coarser towards shore (Irwin, 1965). This means that if the Swatara Gap rocks result from deep-water deposition, they represent an even deeper environment than other nearby Martinsburg rocks. However, these other Martinsburg rocks lack benthic fossils, presumably because the water near the sea floor was too deep to contain enough oxygen to support life. Therefore, it seems unlikely that finer grained sediments of still deeper water could support an abundant benthic faunal assemblage.

Clues to Interpreting the Depositional Environment

The extremely fine grains in the Martinsburg rocks at Swatara Gap indicate that these sediments were deposited in a low-energy environment. The rocks contain abundant trace fossils, indicating a well-oxygenated sea floor. A few of the rocks contain herringbone cross-laminations. In herringbone cross-laminations, very thin laminae (or layers) of sediments are inclined in opposite directions. Herringbone cross-laminations form as the result of the bidirectional flow of incoming and outgoing tides.

This combination of sedimentary features, indicating a low-energy, well-oxygenated bottom and tidal-current influence, implies that the Swatara Gap sediments were deposited in a very shallow environment. Along very gently sloping coastlines, low-energy zones can exist shoreward of where waves break. Because waves have expended all of their kinetic energy, they do not strongly influence deposition in the shallow, low-energy zone.

The Ecology of the Fossil Organisms

Certain characteristics of trace fossils in the Swatara Gap rocks suggest that the sediments contained a large amount of water. Fine-grained sediments having high water content create a very soft sea floor. The Swatara Gap fauna was well suited for this soft substrate. The most abundant fossil organism, the blind trilobite *Cryptolithus bellulus* (Figure 2), burrowed in sediments.

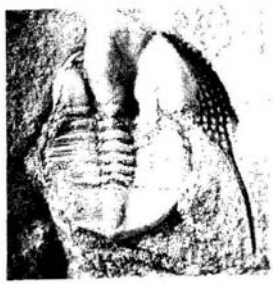


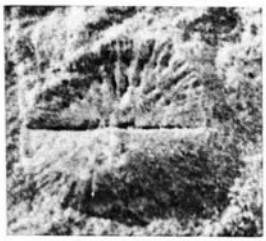
Figure 2. Fossil trilobite *Cryptolithus bellulus* Ulrich from Swatara Gap, x4.

Brachiopods, an abundant group of fossils in the Swatara Gap rocks, are represented by flat-shelled and very small varieties (Figure 3). Flat-shelled and small brachiopods have a low ratio of mass to surface area, which means that the weight of the brachiopods was distributed over a relatively large area. This prevented the brachiopods from sinking into the soft substrate in the same manner that snowshoes prevent a person from sinking in uncompacted snow. Some of the brachiopods (*Leptaena* and *Rafinesquina*) have wrinkled shells. These wrinkles, or rugae, may have helped to anchor the shell and keep it from sliding on the muddy substrate.

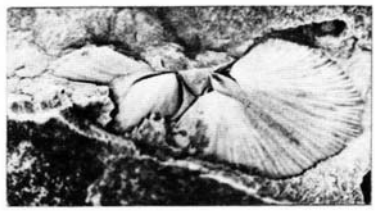
How Shallow is "Shallow"?

The Martinsburg sediments at Swatara Gap were apparently deposited slightly below and slightly above average low tide (subtidal and intertidal zones).

The subtidal deposits contain lenses and layers of fossiliferous siltstones and mudstones. Many of the subtidal organisms con-



A



B

Figure 3. Fossil brachiopods from Swatara Gap. A. *Sowerbyella plicatellus* (Ulrich), interiors of both valves, x8. The brachial valve is at the top of the photograph. B. *Onniella multisecta* (Meek), interiors of both a pedicle valve (left) and a brachial valve (right), x2.

sumed organic matter suspended in the water and buried in the sediments. Brachiopods consumed suspended nutrients close to the sea floor, whereas crinoids consumed suspended nutrients slightly higher off the floor. Some trilobites (*Isotelus* and *Gravicalymene*) scavenged the sea floor for food, whereas *Cryptolithus* and pelecypods consumed food in shallow deposits. Worms burrowed within the sediments, consuming organic matter, but also pushing nutrients up closer to the sediment-water interface. Nautiloids and eurypterids preyed upon these other organisms.

The lower intertidal environment is represented by mudstones and shales. Because this environment was located further from a high-energy source (waves), its sediments are slightly finer than the sediments of the subtidal environment. Organisms in an intertidal environment need mechanisms to avoid drying out during low tides. Not surprisingly, most of the fossil organisms in the intertidal deposits at Swatara Gap are burrowers, for instance, infaunal pelecypods and the inarticulate brachiopod *Pseudolingula*. Because these organisms could withdraw into burrows, they remained moist when topmost sediments dried.

The "Big Picture"

It may seem very unusual that this shallow-water Martinsburg deposit is geographically close to deep-water Martinsburg deposits. However, the rocks at Swatara Gap are younger than other nearby Martinsburg rocks. The older Martinsburg sediments were deposited in a young, deep sedimentary basin. Although the basin was subsiding, sediments filled it more quickly than it subsided. By the time

the Martinsburg sediments at Swatara Gap were deposited, the basin was filled nearly to sea level.

Furthermore, the rocks at Swatara Gap may not be in their original position. This region of the state is structurally complex, and the Swatara Gap rocks may be part of a large block that has been transported. However, geologists need a more complete understanding of the deep structures of eastern Pennsylvania before the complete structural history of the Swatara Gap rocks can be interpreted.

A Final Thought or Two

The ecology of an organism may be defined as its interactions with its environment and other organisms. Before we can understand the ecology of a particular organism, we must first be able to identify and interpret its environment. The sedimentary structures of the rocks at Swatara Gap indicate that the sediments were deposited in very shallow water.

Organisms are typically well suited for their environments; they have mechanisms for avoiding the dangers and maximizing the opportunities presented by their environments. The fossil fauna of the Swatara Gap rocks illustrates this principle. The muddy substrate and low energy were important physical parameters of the paleoenvironment, and the fossil organisms were well adapted for these parameters.

REFERENCE

Irwin, M. L. (1965), *General theory of epeiric clear water sedimentation,* AAPG Bulletin, v. 49, p. 445–459.

Article from Pennsylvania Geology, v. 19, no. 1, February 1988.