Late Ordovician Paleontology, Sedimentology and Stratigraphy in Ohio, Indiana and Kentucky

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INTRODUCTION

The Upper Ordovician rocks in the tri-state area around Cincinnati are among the most fossiliferous in the world. They contain extraordinary numbers of exquisitely preserved brachiopods, bryozoans, corals, echinoderms, trilobites, clams, snails, cephalopods, and numerous other smaller groups, some known only from this area. Cincinnatian fossils are displayed in virtually every natural history museum in the world, and the rocks which contain them are now internationally recognized type sections. Despite having been studied for over 150 years, though, Cincinnatian rocks and fossils still hold fundamental paleontological and sedimentological mysteries, and every year new discoveries are made. In the past few years the Upper Ordovician of the Cincinnati area has been the scene of a revolution in our concepts of Paleozoic communities and environments, fueled primarily by new techniques and ideas in paleobiology, sedimentology and sequence stratigraphy. This region, with its remarkable fossils and exposures, was the focus of a Keck Geology project in which students investigated fossils and sediments in the context of changing paradigms in historical geology and paleontology. For further information, along with additional links, e-mail addresses, updated data, color images and maps, please see our project website at: http://www.wooster.edu/geology/KeckOhio.html

THE ORDOVICIAN GEOLOGY OF OHIO, KENTUCKY AND INDIANA

Upper Ordovician rocks are exposed in a broad, gentle structural arch with its axis passing through Cincinnati. The most useful outcrops are roadcuts and creek banks beginning in the north near Richmond, Indiana, and Dayton, Ohio, and extending south across the Ohio River into the northern counties of Kentucky. Rock types are predominantly claystones and grain-supported limestones deposited on shallow marine ramps, typically between normal and storm wavebases. The carbonates are formed primarily of biogenic debris, with considerable early calcite cement precipitated from seawater and dissolving aragonite shells under "calcite sea" geochemical conditions (Palmer et al., 1988). The claystones are formed of clay-rich sediments eroded from mountains formed during the Taconic Orogeny to the east. Sedimentary structures are mostly common shallow-water features, including ripples, soft-sediment deformation, hardgrounds, imbricated fossils, and tempestites. Recent stratigraphic work by Holland (1993) and U-Pb zircon dating (Tucker and McKerrow, 1995) places the Cincinnatian within a second-order supersequence (the "Taconic") at approximately 454 to 443 Ma. Holland et al. (1997) and Miller et al. (1997) have established a hypothetical framework of storm cycles for the Cincinnatian.

FIELDWORK

Since all of the Cincinnatian outcrops are within a 3-6 hour drive from Wooster, the seven students and two faculty of the project took several three- and four-day trips from Wooster to complete the fieldwork, staying in inexpensive motels. Our field methods were primarily stratigraphic section measurement and description, along with sedimentological and paleontological sample collecting. When not in the field we were based in Wooster, where we used campus housing and food services while working in the geological laboratories and libraries.

LABORATORY AND LIBRARY WORK

The labwork was primarily preparing samples for later analysis. Several students made thin-sections using Wooster's Hilquist machine, and then examined them under Nikon petrographic microscopes. Many also made acetate peels. All students used the library heavily, starting with GeoRef computer database searches on their specific topics. We visited the libraries and geological facilities at Ohio State University (hosted by Dr. Scott Bair, chair of the department) and the Cincinnati Museum of Natural History (with Dr. Colin Sumrall, curator of the invertebrate fossil collection). Each student compiled a bibliography of relevant sources and wrote a report summarizing their work to date and what they intended to do at their home campuses. Students also wrote individual summaries of their projects for posting on the Web (see address above).

RECREATION

We visited Big Bone Lick State Park in Kentucky (which has marvelous Pleistocene fossils), Serpent Mound in southern Ohio (an archaeological site), the Cleveland Museum of Natural History (where we had a fascinating tour of the paleoanthropological facilities from Dr. Bruce Latimer), the Cleveland Museum of Art, and the Cleveland Botanical Gardens.

STUDENT PROJECTS

Bryn Clark (Colorado College): Bryn carefully examined an unusual sequence of deformed beds within the Fairview Formation near Maysville, Kentucky. The Upper Ordovician rocks of midcontinental North America are generally so flat and predictable that these ball-and-pillow structures within a typical sequence of limestones and claystones are very surprising. They have been described in the literature before (e.g., Pope et al., 1997), but Bryn was able to look at new exposures and to develop new ideas about the effects of early seafloor cementation on this deformation. Her task was to sort out the possible causes for these structures, primarily whether they were formed by contemporaneous seismic activities (seismites) or whether they are another type of soft-sediment deformation (following concepts in Mills, 1983). Bryn concludes in this volume and in her Symposium presentation that these Fairview structures probably are the result of seismic activity on this Late Ordovician ramp.

Dana Dettmers (Beloit College): Dana worked on a carbonate hardground south of Maysville, Kentucky, which was thought by contemporary authors (such as Cuffey, 1998) to be destroyed. Carbonate hardgrounds are carbonate seafloors which were lithified by carbonate cements while still exposed at the sediment-water interface (Wilson and Palmer, 1992). They thus show physical features of exposure, such as scouring and oxidation, as well as evidence of biological occupation by encrusters and borers. Dana's hardground crops out on a newly-widened highway, the construction of which seemed to have destroyed it. The surface was still there when we looked for it, though, and Dana was able to thoroughly sample and measure it. This hardground is unusual in the Ordovician because it was undercut by scouring, creating a series of cavities occupied by upside-down bryozoans and boring worms. It thus has a cryptic fauna similar to one described earlier from the Canadian Ordovician by Kobluk (1980). Dana has shown with her petrographic analysis that this hardground formed relatively rapidly during a minor sea level shallowing. The diagenetic origin of the early calcite cement may have been bacterial sulfate reduction. Dana's statistical analysis of the abundant borings shows that they were neither randomly spaced nor tightly clustered, meaning that the trace-making animals were probably not territorial or highly competitive, but still needed physical proximity, possibly for reproduction.

Woody Fischer (Colorado College): Woody worked on an esoteric form of fossil preservation little known in the USA but well studied in Europe: bioimmuration. Bioimmuration is a fossilization process by which soft-bodied or aragonitic-shelled organisms are enveloped by the calcitic skeletons of others, forming a kind of superbly-detailed external mold (Taylor, 1990). Bioimmurations were previously known only from the Mesozoic and Cenozoic, and most of those from Europe, but Wilson and others (1994) found numerous bioimmurations within the calcitic skeletons of bryozoans which overgrew aragonite shells during the Late Ordovician in the Cincinnati region. These are thus the oldest bioimmurations known, and they tell us much about ancient organisms not otherwise preserved. By looking in detail at these fossils, Woody was able to discern the ecological succession of Cincinnatian encrusters and borers, especially the differences between those on cryptic and exposed surfaces. He also has strong paleontological evidence for the very rapid dissolution of aragonite in this Ordovician "Calcite Sea". Woody's results and ideas, along with those of Jesse Lazzuri (see below) were presented as a poster at the 1999 annual meeting of the Geological Society of America (Lazzuri et al., 1999).

Matt Howard (Carleton College): Matt examined a sequence of rocks and fossils within the Grant Lake Formation in northern Kentucky. He worked very hard on four two-meter sections to test models of storm sedimentation (as in Kreisa, 1981) and shell-bed development (using observations of McFarland and others, 1999, and Li and Droser, 1999). Matt has strong petrographic and field support for his conclusion that while these limestones and claystones were influenced by storms during deposition, that was by no means the only mechanism to produce their characteristic composition and sequence. Matt can show that some sediments were deposited above wavebase and thus were easily reworked by storms, but other sediments accumulated below the influence of storms. He has evidence to question the prevailing orthodoxy that storms were the primary sedimentological mechanism in the Upper Ordovician of the Cincinnati region.

Jesse Lazzuri (Beloit College): Jesse studied borings and structures that look like borings ("pseudoborings") in Cincinnatian carbonate substrates. Borings are a type of trace fossil in which the animal has excavated a solid material, most commonly shells, rocks and hardgrounds (Warme, 1975). Jesse concentrated on borings and pseudoborings in brachiopod shells, bryozoan zoaria, and aragonitic mollusk shells, where they are commonly preserved as beautiful little casts. Jesse showed conclusively that the boring ichnofauna contains much more than the documented *Trypanites*, *Petroxestes* and *Ropalonaria*. A common new ichnogenus to the Cincinnatian, which may be *Palaeosabella*, has a curved hole which bends when it meets a change in substrate, such as the interface between a bryozoan encruster and its brachiopod substrate. Jesse also discovered some new details of the living reactions between bryozoans and the animals which bored into their skeletons. Her results, along with those of Woody (see above) were presented as a poster at the 1999 annual meeting of the Geological Society of America (Lazzuri et al., 1999). Jesse's work was also part of a paper at the North-Central section meeting of the Geological Society of America (Wilson and Lazzuri, 2000).

Michael Vanden Berg (Calvin College): Michael loved to explore, often leaping out of the van and quickly climbing to the top of our exposures. This enthusiasm paid off well when on our first day in Maysville, Kentucky, he discovered a new hardground high up on a seemingly endless roadcut of the Grant Lake Formation. He noticed the hardground because it contained absolutely gorgeous edrioasteroid and bryozoan encrusters. Michael did a classic analysis of this hardground, first by identifying the fauna (which included a rare edrioasteroid species) and then by completing a detailed petrographic analysis of the hardground and the rocks above and below it. He shows that the hardground is distinguished from the other limestone units by its preponderance of calcite spar over micrite in the matrix, which may mean that the hardground formed during a sea level change to shallower, higher energy waters, just like Dana's hardground (above). Another conclusion Michael makes is that the hardground was buried quickly in thick and partially coarse storm sediments, which prevented bioturbating organisms from destroying the delicate edrioasteroids below.

Laura Ward (Smith College): Laura is a sophomore who joined our project because of her interest in paleontology. She does not have a paper in this volume. Her project was an analysis of the paleoecology of the common Cincinnatian rugose coral *Grewingkia canadensis*, which is found abundantly in the Whitewater Formation of southeastern Indiana. She tested a model published by Elias and others (1990) that these solitary corals lived recumbently on a soft muddy substrate with their concave surfaces uppermost. Her primary method was to count and measure the borings and encrusters which infested the corals. Since many if not most of these borings and encrustations were produced during the life of the corals, their distribution should show that the concave surface (which faced upperwards in the model) is more fouled than the convex surface (which was embedded in the mud). Her data showed exactly that pattern.

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