Paleoecology and Paleoenvironment of an Upper Ordovician Hardground (Grant Lake Formation, Cincinnatian Series, Northern Kentucky)

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INTRODUCTION

Hardgrounds are synsedimentarily lithified carbonate seafloors that became hardened *in situ* by the precipitation of a carbonate cement in their primary pore space (Wilson and Palmer, 1992). The solidification of the sea floor provides opportunities for boring and encrusting fauna to colonize. Occasionally these hardground communities are buried quickly by fine-grained sediments and are preserved in extraordinary detail. These preserved hardgrounds provide detailed glimpses into the structure of the original hard substrate community (Wilson and Palmer, 1992).

A new Upper Ordovician hardground was discovered on State Route 3071 located west of Maysville, Kentucky. It was found in June of 1999 above the comformable boundary of the Fairview Formation and the Grant Lake Formation of the Cincinnatian Series. Preserved on the hardground are large encrusting bryozoans, which are bored in places, and a community of edrioasteroids. The rare edrioasteroids and large bryozoans provide a unique opportunity to study a seldom seen paleocommunity.

METHODS AND PROCEDURE

After the hardground was discovered, as much of it as possible was collected from the field and brought back to the lab for further analysis. The slabs of hardground were cleaned thoroughly using a stiff brush, water, and an ultrasonic cleaner. They were then reassembled and mapped so that faunal relationships could be studied. The individual edrioasteroid specimens were cleaned using a needle and dissecting microscope. Hydrogen peroxide was added to help in the removal of silt.

The next step was to identify the fossil taxa on the hardground. Identifications of edrioasteroids were made by comparison with literature and specimens from the Natural History Museum in Cincinnati. The edrioasteroids were then numbered, and diameters and substratum types were recorded. The large encrusting bryozoan was identified by making an acetate peel of a tangential cut and comparing it with literature. The hardground itself was compared with various other hardgrounds that are housed in the collections at The College of Wooster, Ohio.

In addition to collecting the hardground, a detailed stratigraphic column was constructed and samples were obtained from selected layers. Thin sections were made of these samples, as well as the hardground, for detailed petrological study under a petrographic microscope. A paleoenvironmental interpretation was then made by analyzing the thin sections and conducting point counts of the materials that make up the strata. All data were entered into a computerized spreadsheet for further analysis.

DESCRIPTION OF HARDGROUND AND ENCLOSING STRATIGRAPHY

The small stratigraphic section which contains this hardground is assigned to the Lower Bellevue Member of the Grant Lake Formation. According to Schumacher (1998 and 1999), the Bellevue contact occurs about 10 meters above the base of an interval of distinctive ball-and-pillow structures in the Upper Fairview Formation. These ball-and-pillow structures are easily seen about 14 meters below the hardground horizon (see Bryn Clark's paper on these ball-and-pillow structures in this volume).

Thin sections of the hardground reveal that it is a biosparite, a lithified layer of coarse bioclasts within a sparry cement. Its composition includes brachiopod shells and bryozoan pieces, combined with minor fragments of echinoderms and trilobites.

The hardground is a bed within a larger sequence of clay-rich, rubbly skeletal packstones and grainstones (Fig. 1), similar to Sumrall's (1999) Maysvillian hardground found 1.1 kilometers to the north on the same road. There are also thin, fine-grained sediment layers, including one layer 2-5 cm thick which covers the hardground. Point counts were also taken from thin sections of each coarse-grained layer. These point counts reveal that each layer is dominantly micritic cement, unlike the hardground layer which is dominantly sparry cement (Fig. 2).

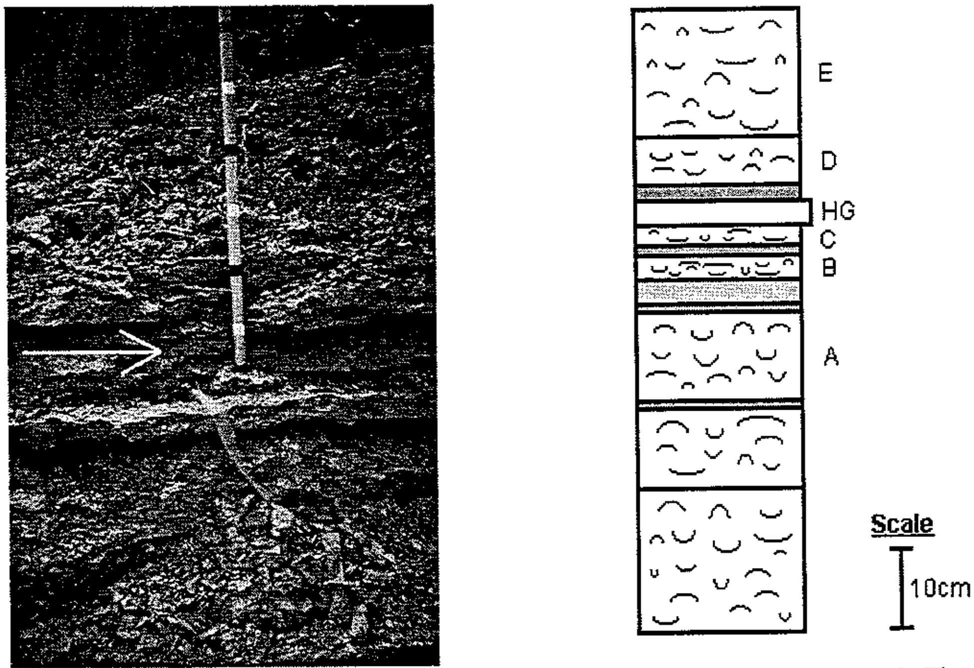

Figure 1 – Photographic and graphic stratigraphic section of the Upper Ordovician hardground. The arrow in the photograph points to the hardground layer.

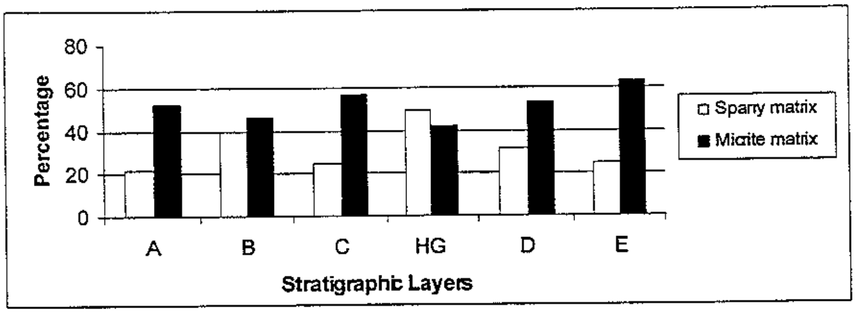

Figure 2 – Sparry matrix vs. micritic matrix based on thin section point counts (see stratigraphic section above for location of layers).

PALEOECOLOGY OF THE HARDGROUND

A hardground represents a unique sedimentary setting where many components of a paleocommunity are preserved *in situ*. Therefore, the study of hardgrounds can reveal fascinating things about the spatial relationships between ancient forms of life (Wilson and Palmer, 1992).

Preserved on this hardground are nine edrioasteroids belonging to three different taxa. There is one individual *Carneyella pilea,* which is a rather common species of edrioasteroid found in the Upper Ordovician. It is the only specimen that is entirely cemented to a bryozoan (Fig. 3); the remaining eight are cemented directly to the hardground with the exception of one, to be discussed later. There is also one individual of the fairly common *Isorophus cincinnatiensis*. Unfortunately this specimen is only represented by a few plates and a mold of its underside. The remaining seven are of the poorly known taxan, *Carneyella ulrichi.* Two complete specimens exhibit exquisite preservation. One specimen is half missing but the present half is also excellently preserved. In two specimens, only the peripheral rim was preserved and the remaining two are partially covered with sediment and are somewhat disarticulated. One of the best preserved specimens is half cemented to the hardground and half cemented to a bryozoan (Fig. 3). Before the discovery of this hardground horizon only one specimen of this edrioasteroid species was known. However, this species is no longer as rare. Sumeral's (1999) Maysvillian hardground found 1.1 kilometers to the north contains 107 specimens of *Carneyella ulrichi.*

The diameters of all the *Carneyella ulrichi* are similar, ranging from 16.7 mm to 23.5 mm. This suggests that they are all from the same generation. This is also seen in Meyer's (1990) study of two Upper Ordovician edrioasteroid beds. No juveniles are present on this hardground.

Figure 3 – *Carneyella ulrichi*, 21.3mm in diameter, left; *Carneyella pilea* attached to a bryozoan, 13.9mm in diameter, center; *Carneyella ulrichi*, 18.1mm in diameter, right.

In addition to the rare edrioasteroids, a large encrusting bryozoan covers about 20% of the hardground. By making a tangential cut and associated acetate peel of one of the bryozoan mounds, it was identified as *Stigmatella crenulata* (Fig. 4). The size of the bryozoan colony suggests that the hardground was exposed on the sea floor for an extended period of time.

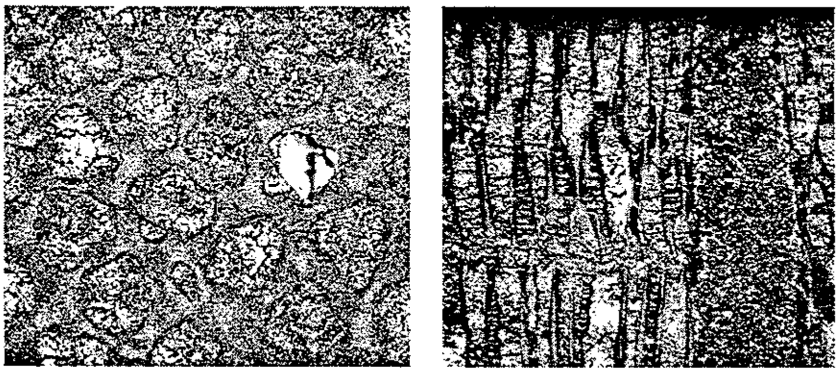

Figure 4 – Acetate peels of *Stigmatella crenulata*: tangential cut, left 50X; lateral cut, right 18X.

A third type of faunal element found on this hardground is borings. They are 2-3mm in diameter and are present on both the hardground and the bryozoans. Chimney structures are also present on one of the bryozoan mounds. Chimney structures are considered a type of pseudo-boring for they do not display cut walls. One hypothesis for the formation of these structures is that a soft-bodied creature landed on the bryozoan and the bryozoan grew up around it as a defense mechanism. This soft-bodied creature may have also emitted toxins which the bryozoan tried to defend against (see Jessica Lazzuri's paper on borings in this volume).

PALEOENVIRONMENT OF THE HARDGROUND

The coarseness of the hardground and the surrounding layers suggests a high energy environment. The filter-feeding creatures living on this hardened substrate would have thrived in these turbulent waters. The high energy, well-oxygenated waters would have delivered a constant supply of food to the hardground fauna (Wilson and Palmer, 1992). The types of creatures present on the hardground would need to be located in the photic zone to survive, therefore the hardground is presumed to have been in relatively shallow water. In addition, the relatively large size of the bryozoans present suggest that this hardground was exposed on the seafloor for an extended period of time.

One unique aspect of this particular hardground is that it includes no crinoid holdfasts. One explanation for this is that the energy in the water was too high for a stemmed echinoderm to survive. The fauna found on this hardground are all low-lying filter feeders with a large surface of attachment which would be suited perfectly for very high-energy waters.

The fauna located on the hardground is very well preserved; this suggests rapid burial by fine sediments. The entire hardground is covered by a 2-5 cm thick layer of fine-grained sediment which was most likely deposited by the first stages of a storm. The fine-grained sediment was then covered by a thick layer of shell hash which would have been deposited as the storm drew closer, or it could have been from an entirely different event.

In the case of the exceptional preservation of the edrioasteroids, studies of the rate of skeletal disarticulation after death in modern echinoderms such as crinoids (Meyer, 1971; Liddell, 1975; Meyer and Meyer, 1986) have shown that unless buried rapidly, echinoderm skeletons will disarticulate within days after death (Meyer, 1990). The occurrence of complete, multi-element fossil echinoderms is indicative of rapid burial or removal by other means from the normal cycle of post-modern degradation (Brett and Baird, 1986). Therefore, the edrioasteroids found on this hardground were either still alive when they were buried, which is most likely, or they were buried shortly after they died.

Bell (1976) noted that the greater the thickness of overlying fine sediment, the higher the preservational quality of edrioasteroids because bioturbating organisms were less likely to penetrate the overburden to disrupt them. This seems to be the case with this hardground. It is covered by 2-5 cm of fine sediment which would have buried the edrioasteroids gently, then on top of this protective layer is a thick sequence of shell pavements. These pavements would have prevented bioturbating organisms from reaching the edrioasteroids (Meyer, 1990). Meyer (1990) observed this in his Upper Ordovician (Maysvillian) Blue Rock edrioasteroid bed, found in Hamilton County, southern Ohio, which was also covered by a shell pavement.

REFERENCES CITED

Bell B.M., 1976, A Study of North American Edrioasteroidea: New York State Museum Memoir, v. 21, p. 1-447.

Brett, C.E., and Baird, G.L., 1986, Comparative taphonomy: a key to paleoenvironmental interpretation based on fossil preservation: Palaios, v. 1, p. 207-227.

Liddel, W.D., 1975, Recent crinoid biostratinomy: Geological Society of America, Abstracts With Programs, v. 7, p. 1169.

Meyer, D.L., 1971, Post-mortem disarticulation of recent crinoids and ophinroids under natural conditions: Geological Society of America, Abstracts With Programs, v. 3, p. 645.

Meyer, D.L., 1990, Population paleoecology and comparative taphonomy of two edrioasteroid (Echinodermata) pavements: Upper Ordovician of Kentucky and Ohio: Historical Biology, v. 4, p. 155-178.

Meyer, D.L., and Meyer, K.B., 1986, Biostratinomy of recent crinoids (Echinodermata) at Lizard Island, Great Barrier Reef, Australia: Palaios, v. 1, p. 294-301.

Schumacher, G.A., 1998, A new look at the Cincinnatian Series from a mapping perspective, *in* Davis, R.A., and Cuffey, R.J., eds., Sampling the Layer Cake That Isn't: The Stratigraphy and Paleontology of the Type-Cincinnatian: Ohio Division of Geological Survey, Guidebook No.13, p. 111-119.

Schumacher, G.A., 1999, Probable seismites in the Upper Ordovician Fairview Formation near Maysville, Kentucky, *in* Algeo, T.J., and Brett, C.E., eds., Sequence, Cycle and Event Stratigraphy of Upper Ordovician and Silurian Strata of the Cincinnati Arch Region: Field Trip Guidebook: Society for Sedimentary Geology, p. 112-116.

Sumrall, C.D., Brett, C.E., Work, P.T. and Meyer, D.L., 1999, Taphonomy and paleoecology of an edrioasteroid encrusted hardground in the lower Bellevue Formation at Maysville, Kentucky, *in* Algeo, T.J., and Brett, C.E., eds., Sequence, Cycle and Event Stratigraphy of Upper Ordovician and Silurian Strata of the Cincinnati Arch Region: Field Trip Guidebook: Society for Sedimentary Geology, p. 123-131.

Wilson, M.A., and Palmer, T.J., 1992, Hardgrounds and hardground faunas: University of Wales, Aberystwyth, Institute of Earth Studies Publications, v. 9, p. 1-133.