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Upper Ordovician hardgrounds – from localized surfaces to global biogeochemical events

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Upper Ordovician hardgrounds display a spectrum of complexity reflecting a range of local to global-scale processes. Hardgrounds are cemented seafloor surfaces typically marked by the presence of encrusting taxa and borings. Many hardgrounds show evidence for successive episodes of colonization by hard substrate specialists and are associated with localized evidence of seafloor erosion such as overhangs and reworked concretions. They commonly show trace amounts of pyrite and dolomite cements indicating an association with sulfate reduction. The most widespread hardgrounds are highly complex and unravelling their history provides insights into global biogeochemical events.

The Curdsville and Kirkfield hardgrounds in the Appalachian Basin (Kentucky and Ontario) represent relatively simple end members of the hardground spectrum. They covered 10s to 100s km^2 and formed relatively quickly during the early Katian. They display both planar to sub-planar and hummocky to topographically complex surfaces (cm-scale) and contain highly diverse encrusting echinoderm faunas. Study of these surfaces yields important insights into the evolutionary history of encrusting communities.

By contrast, the slightly younger hardground at the top of the Galena Group (Ka1) is a surface that is present throughout most of the Midcontinent Basin (>7.5 × 10^5 km^2). It is an example of a highly complex surface that was repeatedly modified by erosion and mineralization. Near the eastern margin of the basin in Indiana, the capping Galena hardground is pinnacled with cavity-filling sharpstone clasts, phosphate grains and bored crusts, iron ooids, and pyritic impregnated surfaces. It is onlapped by graptolitic shales of the Kope Formation (Fm) (Ka1) indicating an unconformity of approximately 1 m.y. To the west, in Illinois, the Kope Fm is erosionally truncated and the hardground is directly overlain by graptolitic shales of the Waynesville Fm (Ka3), where the unconformity expands to nearly 4 m.y. Toward Iowa, the hardground is onlapped by meters of phosphorite. Taken together, these observations reveal that the capping Galena Group hardground reflects a complicated history of repeated subaerial exposure, karsting, and marine flooding by a dysoxic to anoxic water mass with fluctuating redox conditions, similar to the age equivalent hardground at the base of the Fjäcka Shale in the Baltic Basin.

Thus, hardground studies provide important insights for resolving the temporal continuity of the Upper Ordovician rock record and unravelling processes that controlled carbonate precipitation and dissolution and the evolution of sea floor communities. Some simple hardgrounds may have formed through random exhumation of cemented sediments on the sea floor through the effects of storm scour. However, their clustering into certain portions of the Upper Ordovician suggests that processes that affected sea water chemistry may also be involved. The most complex surfaces reflect major environmental perturbations with large amplitude sea level oscillations and redox changes that in some cases generated rare-earth enriched phosphorites.

ABSTRACT

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