Hardgrounds and the Flood: the need for a re-evaluation

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Hardgrounds are claimed to be a challenge to Flood geology because of the long time alleged necessary for their formation. However, I show that this challenge is not valid because some hardgrounds have been misidentified, and that for others, the recycling of the constituents of antediluvian hardgrounds accounts for hardground cobbles, some 'in situ' fossils, as well as entire 'in situ' hardgrounds. Furthermore, when the reported geological evidence is stripped of its conventional hardground-related thinking, hardgrounds could have formed during the Flood by 'normal' geologic processes. The development of hardgrounds in time and space needs more research within creationist geoscience and to be properly reviewed and formalised.

Hardgrounds, those purported ancient lithified seafloor horizons[1] (figure 1), are found throughout most of the Phanerozoic sedimentary record, and are perceived to be a challenge to Flood geology. This is because of the long time alleged necessary for their formation, including the time required for the faunal 'communities' to establish, and the time for the surface to harden.[2] This work explains hardgrounds in a Flood context, and is a sequel to the July 2004 field study of Ordovician hardgrounds.[3] Additional fieldwork was completed at the Caesar Creek site (figures 2 and 3) in August 2005 by a team that included this author and Dr Whitmore.

In all geologic interpretation there is an element of subjective inference. For example, a 'Were you there?' (Job 38:4) mode of thinking is exhibited by two bryozoan researchers,[4] who comment:

> 'In the narrowest sense, all paleoecologic studies are suspect because they involve inferences from skeletal morphologies and sedimentary structures rather than direct environmental observation, measurement or experiment. Consequently, the difficulties inherent in paleoecologic studies often yield caveats, but they are not likely to deter paleontologists from their efforts to decipher the paleoenvironments of the geologic record.'

Most hardground studies also seem to blur the line between interpretation and observation, leaving little room for alternative interpretations even within uniformitarianism, let alone beyond it. Investigations of ancient hardgrounds confessedly 'depend heavily on actualistic comparisons with hardgrounds from recent environments, particularly those of the Persian Gulf'.[5] This means that hardgrounds are 'read into' the sedimentary record in part because they are expected to be there, and non-hardground interpretations are implicitly discouraged. Moreover, much thinking surrounding ancient hardgrounds suffers from overgeneralization,[6] and the possibility of fortuitous coincidences[7] of inferred hardground phenomena is usually overlooked.

Ironically, hardgrounds pose no less a time challenge to uniformitarianism than to diluvialism (interpretations based on the Genesis Flood):

> 'It cannot be postulated, however, that these complex hardgrounds were exposed at the seafloor for geologically significant periods, despite the presence of hiatuses which must amount to several million years. Each hardground contains a distinct assemblage of borings and other biological erosion and displays evidence of physical abrasion. It is difficult to envisage how the characteristics of earlier surfaces would be preserved if they were exposed to physical and biological erosion at the seafloor for extended periods.'[8]

The focus, from a creationist perspective, should be on the processes that created hardgrounds during the Flood year itself. These include actual *in situ* hardgrounds formed in a matter of months during lulls in Flood action, as well as 'hardgrounds' that are actually the accumulations of allochthonous organisms. The development of post-Flood hardgrounds is also an issue that needs to be fully considered. Although not otherwise considered in this paper, the encrusting and/or boring of siliclastic rocks,[9] termed rockgrounds, also needs further analysis.

Rethinking hardground phenomena in general

The student of hardgrounds is struck by their spatial and temporal variability. Both boring-only hardgrounds,[10,11] and those that lack borings exist.[12,13] Often, borings predominate statistically on topographic high spots while encrustings predominate on topographic low spots.[14] In other hardgrounds, no such dichotomy exists.[15] Encrusting faunal content, when present at all, can differ considerably from hardground to hardground even within the same geologic period.[16,17] Surficial hardground topography varies greatly, ranging from highly-convoluted surfaces, as shown in hardground #4 in figure 2, to extremely smooth ones.[18]

Hardgrounds also vary greatly in complexity as can be seen by comparing figures 1 and 2. While some hardgrounds

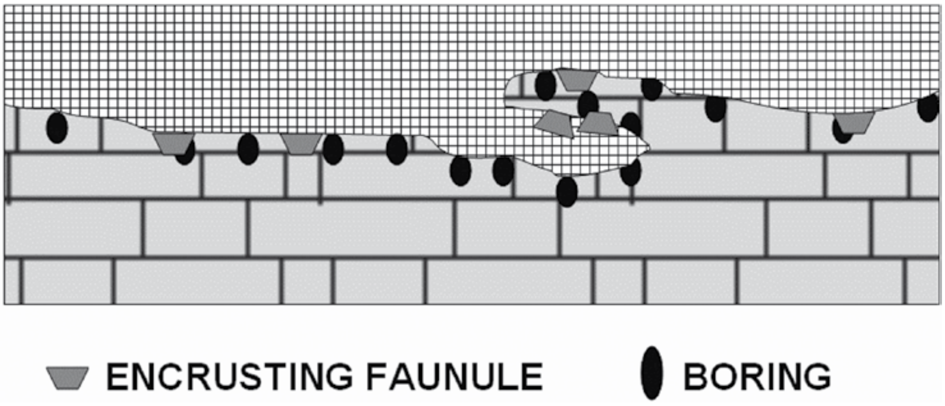

Figure 1. A schematized simple hardground in profile. It includes an overhang with cavity-dwelling (cryptobiontic) fauna and a sharp lithologic difference (facies change) above the hardground.

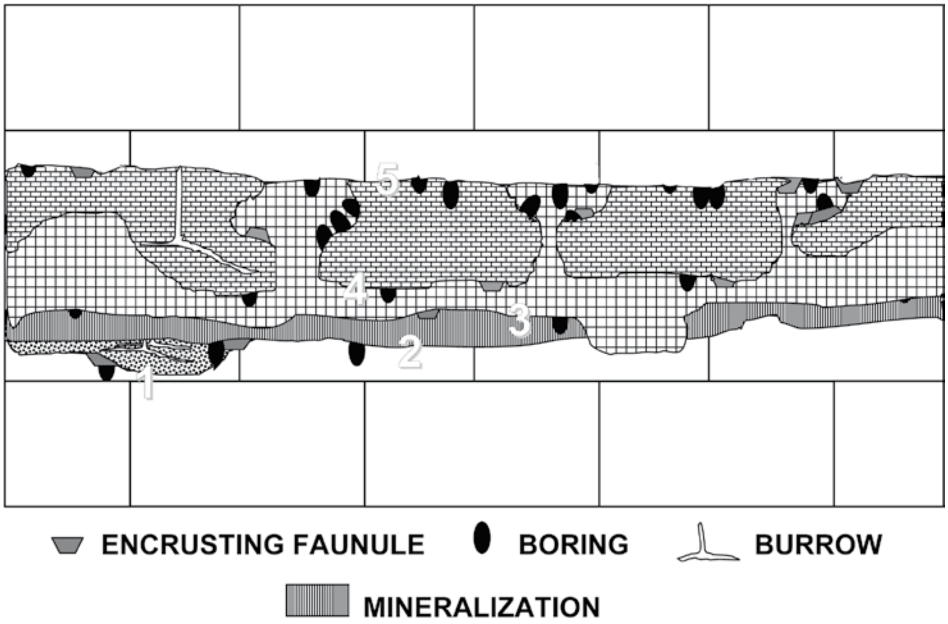

Figure 2. A schematization of a composite hardground,[89] with repeated deposition, lithification, encrustation, boring, erosion and mineralization. There are five superposed hardground surfaces shown, each one prominently delineated by an erosionally-truncated set of borings and encrusters.

can supposedly be traced long distances, others peter out over tens to hundreds of meters.[19] Out of 36 European Jurassic hardgrounds surveyed,[20] only one-third is described as having a rich fauna of body fossils,[21] and only about 30% of inferred shallow-shelf ones are mineralized.[22] Composite hardgrounds such as that shown in figure 2 are 'rather limited' in frequency, at least in the English Cretaceous.[23] Hardground cobbles that show multiple generations of boring and encrusting are relatively uncommon,[24] at least in the Jurassic of India. The degree or even reality of ecological succession encountered on hardground clasts and '*in situ*' hardground surfaces is debatable.[25]

As for the cryptobiontic (cavity-dwelling, sometimes called coelobiontic) hardground faunas that sometimes are found in the crevices of overhangs (see figures 1 and 2), there is only a weak polarization of upper and under-ledge faunas in Ordovician hardgrounds compared with those of the Jurassic.[26] Most overhangs lack coelobionts, and when they do occur, the colonization of the undersides can be partial.[27] Only 13 of the 36 aforementioned surveyed Jurassic hardgrounds have cavities, and only some of their encrusting faunules exhibit polarization, which, to the extent it is real, points to the encrusters growing on the underside of a hardground ledge being somewhat different from those that grow on the upper side of the hardground surface.[28]

Cryptobiontic faunas are admittedly difficult to diagnose:

> 'No single criterion, not even downward oriented skeletal growth, is definitive on its own of a coelobiontic habitat.'[29]

Instead, a coincidence of clearly-defined cavities and upside-down organisms and borings is utilized. However, once one recognizes the fact that only a vanishingly tiny fraction of Phanerozoic sedimentary rock contains cryptobionts as deduced from two or more ostensibly independent lines of evidence, fortuitous coincidences[8] of supposedly-diagnostic cryptobiontic features assume major importance. One cannot help but wonder how many so-called overhangs and cryptobiontic faunas are misinterpretations of other phenomena.[30]

Potential alternatives to ancient hardground lithification

All inferences of Phanerozoic hardgrounds rest on the premise that the surface in question was lithified at the time of inferred boring and/or inferred encrustation. Criteria for this diagnosis are not agreed.[31] The conventionally-believed submarine cementation of alleged ancient seafloors is acknowledged to rely on circumstantial and negative evidence[32] (and that within the narrow scope of uniformitarianism) that, moreover, is not unique to any specific microenvironment.[33]

With regard to the commonly-mentioned ‘sculpted’ hardground surfaces,[34] once pre-hardground geologic interpretations allowed for firm, but not lithified, surfaces being sufficiently stiff for the generation of the ‘sculpted’ surfaces during erosion.[35] In view of the fact that a large range of substrate stiffnesses are known to exist between compacted lime mud and fully-lithified material,[36] one must ask if hard objects such as fossils, bioclasts or large carbonate grains found truncated flush with inferred hardground surfaces *necessarily* required a lithified, as opposed to firm, matrix in order to be cleanly cut by erosion. The flush truncation of the inferred hardground surface and its embedded fossils is thought to imply an equality of hardness of all constituents at the erosional surface.[37] This premise should be tested experimentally, not assumed.[38] Flume experiments need to be conducted involving the rapid flow of water along carbonate surfaces of varying degrees of lithification, and in which objects of various hardnesses are embedded.

Just as soft-sediment ichnofossils can be misdiagnosed inorganic or body-fossils,[39] so also can hardground ones, specifically borings.[40] In fact, a precedent exists for questioning the boring and even organic origin of some ostensible *Trypanites*.[41] Otherwise, the existence of distinctive and unique, sharp-edged, tapering, tube-shaped rohrenkarren[42] (the product of condensation corrosion within air pockets in carbonates) is problematic. The product of condensation corrosion within air pockets in carbonates disproves the common contention[43] that inorganic structures, in contradistinction to biogenic ones, necessarily lack a self-consistent geometry. Under the high-pressure and short-duration conditions of the Flood, many rohrenkarren could potentially have formed that fit the dimensions of *Trypanites*,[44] and this would be most applicable to encruster-rare or *Trypanites*-only hardgrounds.[45] Extending potential abiotic processes, one must ask if the diverse manifestations of apparent encrustation of *Trypanites* by bryozoan colonies[46] could ever have a mechanical rather than a biological origin.[47]

Figure 3. A *Petroxestes*-bearing hardground from the Cincinnatian (Ordovician) of Ohio, USA, occurring on top of a storm-deposited decimeter-thick limestone-shale couplet. The subjacent thin shale layer had been eroded away, and a brachiopod coquina occurs on top of the subjacent couplet.

Burrows in soft sediment are almost always constructed much more rapidly than borings in lithified sediment. So how many burrowed horizons have been mistaken for bored ones? At least some *Petroxestes,* as shown in figure 3 are probably burrows rather than borings, as they have lips of material at their margins, proving that the carbonate material was soft at the time of their construction.[48] Following accepted burrow-boring distinctions, the lithified state of many inferred ancient hardgrounds is impossible to prove.[49] Furthermore, it is now acknowledged that sharp margins of ichnofossils do not necessarily imply the lithified state of the penecontemporaneous surface.[50] Moroever, any straightforward dichotomy between burrowing and boring activities is contradicted by the fact that some organisms can switch from burrowing to boring as they proceed downward.[51] Hence the same modern organism can excavate a similar burrow and boring structure.[52] One must ask if the clean truncation of hard objects such as large carbonate grains, intraclasts or fossils at the holes’ margins necessarily proves that the entire holed limestone layer was lithified at the time of the excavation of the holes or if the hardness of the object itself is a sufficient explanation for this observation.[53]

Ironically, one of the criteria claimed to discriminate burrows from borings implies that some *Trypanites*, notably those that hole bryozoans, as shown in figure 4, are actually burrows and not borings. Only burrows are supposed to show changes in direction that imply the tracemaker’s avoidance of a hard obstruction.[54] Yet there is an intriguing *Trypanites* that holes a bryozoan and then turns 90° to avoid a subjacent intraclast.[55] Perhaps the tracemaker probed for a weak spot[56] in the bryozoan’s skeleton, and then burrowed rather than bored through it.

We now turn our attention to alleged obligate hard-surface encrusting organisms. Assuming that they are actually *in situ* and self-cemented to the substrate, how can one be certain that fossil encrusters necessarily required a hard substrate? Smith[57] raises cautions about inferences of the habits of extinct bryozoans that rest on comparison with their modern counterparts, and warns that interpretations are

Figure 4. A hardground from the Cincinnatian (Ordovician) of Ohio, USA, that includes an encrusting bryozoan riddled with the boring *Trypanites* (US penny is 19 mm diameter).

especially tenuous for the Paleozoic fauna. Parenthetically, the recommended practice of using multiple criteria to justify interpretations does not consider the problem of fortuitous coincidences,[8] leading to at least an element of reinforced circular reasoning.[58] Interestingly, Hageman *et al.*[59] refuse to include the type of substrate as a formal bryozoan character class because:

> 'First, it is not a morphological characteristic and therefore invites circularity in ecological interpretations. Secondly, this character can usually only be determined with confidence by direct observation from live material.'

Some 'Were you there?' (Job 38:4) thinking is evident here!

Let us move beyond hardground cementation to the subject of mineralization. Are mineralizations that are found on many hardground surfaces *necessarily* limited to previously lithified surfaces, subaqueous conditions and long periods of time? The ferruginous crusts found in certain hardgrounds have an origin from nonphotosynthetic bacteria.[60] By contrast bacterial precipitation of iron and manganese accounts for other hardground mineralization.[61] To put this in perspective, our understanding of the bacterial role in mineralization is in its infancy.[62] Finally, considering the fact that some iron-stained silicified hardground rinds formed diagenetically,[63] one must ask if there is any firm line between synsedimentary and diagenetic processes.

'Instant' hardgrounds

Some hardgrounds could have formed during the Flood year itself by 'normal' processes. Initial lithification of hardground crusts, at least those typical of oolitic hardgrounds, is known to take *a few months or less*.[64] The rapidity of ancient hardground lithification is acknowledged to be indicated by the preservation of ephemeral features such as preserved ripple marks[65] and soft-sediment burrows.[66] To the extent that modern encrusting bryozoans are any guide, extinct encrusters needed little time to overgrow appreciable areas of carbonate surfaces during the Flood year. *Steginoporella* can grow laterally up to 11 cm annually,[67] while some smaller bryozoans have quoted growth rates of up to 0.5 cm per day[68] (sic), at least for brief periods of time. A community consisting of numerous epibionts that overgrow each other (on plastic bottles, in the cited instance) formed in only 10 months.[69] Moreover, successive encrustation that exhibits faunal polarity reminiscent of that which occurs around inferred hardground overhangs has developed in a matter of several months on experimental substrates.[70]

Let us consider some modern rates of boring that occur in a variety of carbonates, beginning with boring echinoids. *Echinus* can bore at least 1 cm deep in limestone per year and even deeper into granite in one year[71] while *Eucidaris* can bore even faster over brief periods of time.[72] Some members of the boring clam *Penitella*[73] and the boring bivalve *Lithophaga*[74] can bore up to 3–5 cm deep into carbonate rock in one year, and comparable rates sometimes hold for the boring sponge *Cliona*,[75] which has otherwise been known to bore an astonishing 2–8 cm in less than 220 days![76] Otherwise, *Lithophaga*, a known borer of inferred ancient hardgrounds,[77] can produce a visible mark on a shell, and presumably other relatively soft limestone, in a matter of days.[78] Other borers can hole shells at a rate of 0.2–0.5 mm/day.[79] It appears that boring rates generally tend to be atypically high at the commencement of boring upon a surface,[80] and to increase when the environment is disturbed[81,82] or when the boring organism is injured.[83] All have obvious relevance to Flood conditions.

In situations where encrusting organisms overgrow boreholes, it is unclear whether the boring and the overgrowth must necessarily occur successively. A modern sponge was observed overgrowing some boring bivalves, yet the latter were still alive one year later.[84] Based on the results of field experiments in the modern reef environment, Davies and Hutchings[85] doubt the conventional premise that encrusting organisms necessarily inhibit or smother nearby borers.

In general, the biology of bioerosional processes is not well understood.[86] Moreover, the entire foregoing discussion is necessarily limited, as very few boring organisms have been studied for individual 'borehole-drilling' rate.[87] Finally, we must remember that the extant biosphere is an impoverished remnant of the antediluvian biosphere. In all likelihood, the world at the time of the Flood included organisms that could bore faster, and do so under more adverse conditions, than any extant carbonate borer.

Interestingly, some hardgrounds contain a profusion of small and narrow *Trypanites* recognizably indicative of time constraints on the boring action.[88] I would argue that hardgrounds should be systematically surveyed and catalogued for the frequency of such occurrences.

Conclusions

Conventional hardground-related thinking is so profoundly steeped in uniformitarianism that it takes a great deal of mental effort to free oneself from these mind-squeezing boxes. There are too many unsubstantiated premises behind conventional hardground thinking, and much paleoecological 'folk wisdom' has already been proven incorrect. Clearly identifying hardgrounds within the Phanerozoic sedimentary rock is a rather subjective task, given the lack of clear criteria to define them and the large variability observed in the criteria used. The traditional long-age assumption that hardgrounds were lithified at the time of the supposed borring and/or encrusting is found wanting. There is insufficient evidence to assume that lithification is a necessary requirement for producing hardground features, there is evidence that suggests at least some supposed 'borings' were either inorganically produced or sediment burrowings. The assumptions that lithification, boring and encrusting themselves require long periods to occur are problematic as well. There are many examples where all three of these are contradicted in several instances. Therefore, actualistic interpretations of hardgrounds fail to rule out diluvial explanations, but there remain many unsolved puzzles associated with hardgrounds. Thus, far from being an insuperable obstacle to Flood Geology, one must recognize the existence of a wide-open field of research initiatives that could reconcile Phanerozoic hardgrounds with the Universal Deluge.

References

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6. If a structure (X) contains features believed to compel a hardground interpretation, other structure (X)'s, though lacking these features, are nevertheless summarily attributed to hardground origins.
7. For instance, the co-occurrence of (A) with (B) is taken as support for a hardground interpretation. But the vast numbers of instances where (A) and (B) each occur alone in the Phanerozoic sedimentary record is not factored. Nor is group probability taken into account. For example, a group of fossils fortuitously deposited mostly in life orientation is very unlikely when considered in isolation. However, encountering an occasional suite of fossils deposited in apparent life orientation may not be so unlikely when one also factors the existence of large numbers of fossil assemblages whose members are not in life orientation.
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