Sediment bioturbation experiments and the actual rock record

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The bioturbation of sediments by trace makers is often perceived by naturalists as a process requiring extensive periods of time. Little experimental work has been conducted to either support or refute such a concept. However, recent laboratory analysis indicates that the bioturbation of marine sediments can occur within short periods of time.

Bioturbation experiments

Marine worms, bivalves (clams), arthropods (shrimp and crabs), and echinoderms (sea urchins and brittle stars) are just some of the many animals that live on or in marine sediments (figures 1 and 2). The study of traces created in sediment is identified as ichnology (Gk *ichnos* = trace).[1]

Recently, an investigation was conducted to determine the rate that select bivalves, arthropods, and echinoderms could bioturbate marine sediments. The animals were collected from tidal flats and shallow subtidal sediments from the Ogeechee estuary, Georgia (U.S.A).[2] They were placed into glass aquaria filled with alternating layers of sand and heavy minerals with each layer being approximately 5 to 10 mm thick.[2] Examination of the rate of bioturbation occurred at 1, 6, 24, 72 and 144 hour intervals by collecting X-ray images of the aquaria sidewalls.[2]

Experiment results

The results of the study indicate that:

> "… ten filter-feeding individuals could take as long as 115 yr to churn a 1 m^2 plot of sediment, by indexing the measured burrowing rates to realistic animal population densities. Ten such mobile deposit feeders as irregular echinoderms could bioturbate the same sediment in just 42 days. Under maximum population densities modeled, the animals could bioturbate the sediment plot in 61 min. Given the reported results, qualitative interpretation of the rock record is possible: highly burrowed examples of the *Skolithos* Ichnofacies reflect high population densities and at least seasonal time spans. Highly burrowed examples of the *Cruziana* Ichnofacies may represent moderate population densities and short time spans."[3]

Figure 1. Filter-feeding organisms have penetrated the quartz sands creating vertical to subvertical burrows. The displaced sand now lies adjacent to the opening of the burrow. The vertical nature and spacing of these tubes would limit the extent of bioturbation. Only through a large population of organisms would the horizontal sedimentary fabric be completely removed. Diameter of the larger sand piles is approximately 10 cm. These particular traces would fall into the *Skolithos* Ichnofacies. This setting is a modern subtidal lagoon located in St. Andrews State Park, Panama City Beach, Florida.

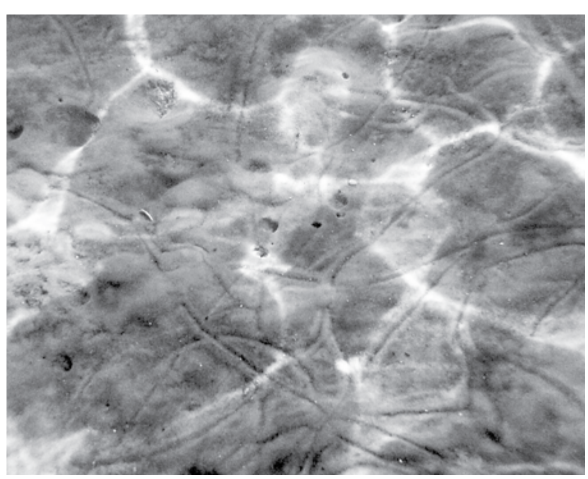

Figure 2. Mobile deposit feeders have left a trail on top of the quartz sand as they plowed through the sediments looking for food. These types of trace makers moving through the sediment substrate would rapidly bioturbate the sands and destroy any laminations in the sediments. These traces would fall into the *Cruziana* Ichnofacies. The width of view is approximately 60 cm. The setting is a modern subtidal lagoon located in St. Andrews State Park, Panama City Beach, Florida.

It should be noted that the filter-feeding animals are interpreted to occur in the *Skolithos* Ichnofacies (figure 3) while the mobile deposit feeders would be found in the *Cruziana* Ichnofacies (figure 4). The benthic environment for each of these ichnofacies is defined as:

"*Skolithos* Ichnofacies (shifting substrates)—Lower littoral to infralittoral, moderate to relatively high-energy conditions most typical. Associated with slightly muddy to clean, well-sorted, shifting sediments subject to abrupt erosion or deposition. Higher energy increases physical reworking and obliterates biogenic sedimentary structures, leaving a preserved record of physical stratification. Generally corresponds to the beach foreshore and shoreface; but numerous other settings of comparable energy levels also may be represented, such as some estuarine point bars, tidal deltas, and deep-sea fans.

"Cruziana Ichnofacies (shifting to stable substrates)—In shallow

marine settings, typically includes infralittoral to shallow circalittoral substrates below minimum but not maximum wave base, to somewhat quieter conditions offshore; moderate to relatively low energy; well-sorted silts and sands, to interbedded muddy and clean sands, moderately to intensely bioturbated; negligible to appreciable (though not necessarily rapid) sedimentation. A very common type of depositional environment, including not only shelves and epeiric embayments but also littoral to sub-littoral parts of certain estuaries, bays, lagoons, and tidal flats."[4]

Implications for the rock record

If we are consistent in applying the uniformitarian philosophy to the rock record then we should expect a high level of bioturbation for almost all of the sediments deposited in a former marine setting, especially if that environment existed with little to no change for thousands to millions of years. Counter to that conceptualization, some diluvialists have predicted that we should expect little sediment bioturbation due to the high-energy conditions associated with the Genesis Flood.[5] Within this diluvial interpretation it could be postulated that the rapid deposition of sediments, one atop another, would leave little time for trace makers to move in and stir them. However, neither perspective is consistent with the actual rock record (figure 5).

The presence or absence of trace fossils and bioturbated sediments is dependent on many different factors including trace maker population density, sediment firmness, salinity, pH, food and oxygen. Also, the behavior of trace makers facing abnormal environmental stress should be considered. For example, Woodmorappe[6] proposed a unique idea suggesting that rapid bioturbation could occur concurrently in several vertical tiers if the stressed ichnofauna were protected from sediment compaction and provided an aerobic environment. Many different factors would go into determining if this occurred or if the traces were rapidly produced as individual layers. There are many reasons why sediments may or may not have been bioturbated within a proposed diluvial setting and the site-specific paleoenvironmental factors should be identified.

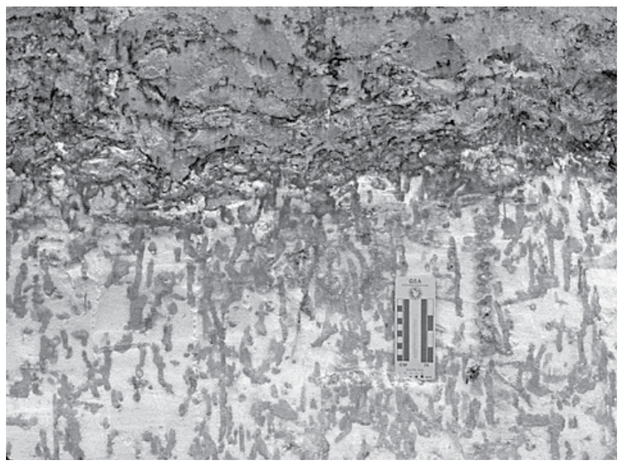

Figure 3. *Skolithos* traces dominate this exposure of the Meridian Sand from Campbell Mountain, Alabama. Note the vertical to subvertical traces in the sand filled by gray clay. Conditions were optimum for trace maker activity and the amount of time necessary to create these traces could be measured in months, not years or decades. Sediment deposition during this portion of the Flood was low enough to allow the bioturbation of the sediments and the destruction of any preexisting sedimentary fabric. Scale in inches and centimeters.

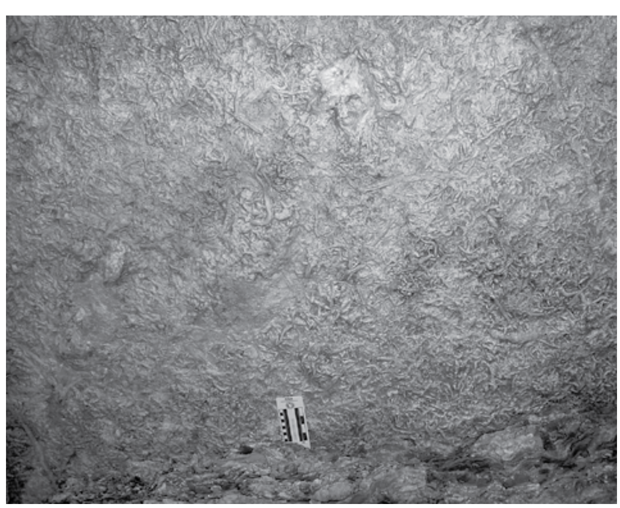

Figure 4. This image shows *Cruziana* traces created as casts on the base of a sandstone layer.[7] This type of sediment stirring activity would rapidly destroy any preexisting sedimentary fabric. This outcrop is located alongside Lookout Mountain, Georgia (USA). Scale in inches and centimeters.

Conclusions

Recent laboratory experiments document that the bioturbation of marine sediments can occur over a short period of time depending on the type and population density of trace makers. For uniformitarians, the lack of any stirred sediment requires that they appeal to punctuated catastrophic events. Such events do not eliminate their reliance on deep time assumptions—the vertical rock record should exhibit layers of intense bioturbation interrupted by nonbioturbated sedimentary events followed by intense bioturbation. However, this is not typically found in the actual rock record.

As diluvialists, we can use trace fossils to help define the probable geologic conditions in which the traces were created relative to the Flood setting. Knowing the differences in the rate of bioturbation between the *Skolithos* and *Cruziana* ichnofacies allows diluvialists to possibly estimate the time period in which these traces were formed. Where no bioturbation has occurred, we need to determine the factors that prevented trace makers from stirring those sediments.

The importance of this new experimental work cannot be overemphasized as the challenge to explaining highly bioturbated sediments no longer requires deep time—it depends on the availability and types of trace makers.

Figure 5. Sidewall along Providence Canyon, Georgia (USA). Uniformitarians assert that these sands were deposited in a mixed-energy barrier island setting cut by tidal inlets.[8] Some of the canyon sidewalls display a few sub-vertical *Ophiomorpha* traces but many more do not. This sidewall exhibits no evidence of any bioturbation where it would be expected within the hypothesized uniformitarian setting. The cross-bedding displayed in the sands indicates this was a high-energy depositional environment. While some trace makers were present in this energetic setting, they had little opportunity to bioturbate the sediments due to rapid deposition and the reworking of the sediments during the later stages of the Flood. Scale in 15-cm divisions.

A large population of filter-feeding or mobile sediment-feeding animals could easily bioturbate marine sediments within the short time frames of the global Flood of Genesis. The lack of any bioturbation should direct us to other important considerations why sediment stirring did not occur.

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Colorado Plateau sandstones derived from the Appalachians?

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Provenance studies have become rather popular lately.[1] In these studies, the types of grains or rocks within a formation are analyzed, and the original outcrop location "upcurrent" is determined. This in turn can provide the minimum transport distance, and the path of the particle is reinforced by paleocurrent indicators in the sedimentary rock. These indicators are typically abundant in sandstones and conglomerates.

Long distance spread of resistant rocks from mountains

Creationists have employed provenance studies in tracing the long distance transport of rocks to determine the paleo flow regime and transport distance. For instance, powerful currents in the northern Rockies region of the United States eroded and transported quartzite rocks both east and west: up to 1,300 km to the east and about 640 km to the west.[2–6] During transport, the power of the current can be estimated by the rounding of these extremely resistant rocks and by percussion marks that have indented many of them. A similar phenomenon has been observed in northern Arizona, where quartzite and other igneous rocks were spread a modest distance east and northeast from their source across the area of the Mogollon Rim.[7] And it is not restricted to the western United States; resistant rocks have spread up to 1,000 km east, south and west from sources in the Appalachian Mountains and a fair distance north of the Alaska Range in southern Alaska.[8,9]

The ubiquitous distribution of such gravel beds, the distance of transport from the nearest source upcurrent, the location of the source across present day mountain ranges or continental