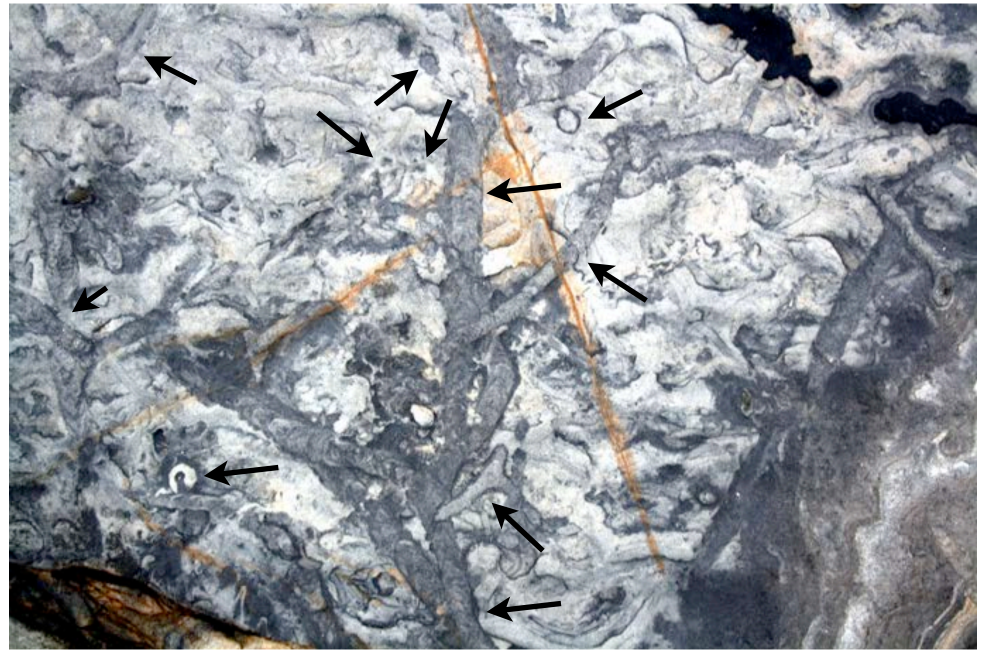
TRACE FOSSILS IN THE CARMELO FORMATION

Some outcrops of the Carmelo Formation at Point Lobos bear a stunning array of fossils. Visitors who expect to find shells or bones, however, will be disappointed. The fossils that abound in these rocks are trace fossils, a physical record in the rock left by an animal's activities. Whereas body fossils are the remains or partial remains of an organism, trace fossils record the passage of an organism over or through the sediment, the chambers in which they dwelt, or their feeding activities.

Body fossils and trace fossils provide very different kinds of interpretive information Whereas paleontologists commonly can identify the animal represented by a body fossil, the identity of the animal that made a trace fossil characteristically is impossible. On one hand, very different animals can make similar traces; on the other a single animal may be capable of making very different traces. Body fossils are commonly used to establish the age of a sedimentary rock. Because many organisms thrive in specific habitats, body fossils can contribute to the reconstruction of ancient depositional environments..

Trace fossils, in contrast, have limited value in age assessment, and few are indicative of a specific depositional setting. They can, however, provide information that body fossils can't, such as the physical nature of the sea floor, rates of sediment accumulation, and the character of physical processes that prevailed at the time of deposition.

Body fossils are vanishingly scarce at Point Lobos, but finer-grained sections of the Carmelo Formation, particularly at Weston Beach, display a myriad of trace fossils.



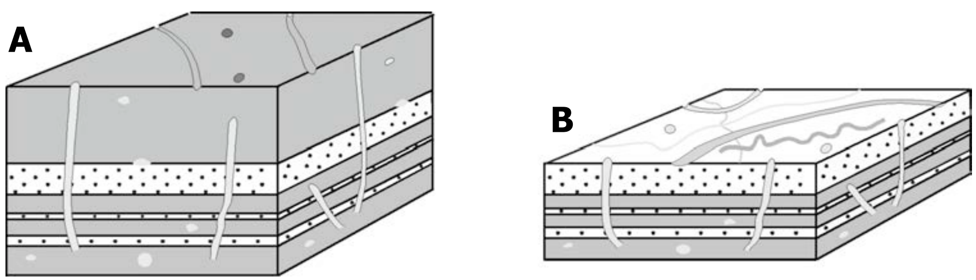
Display of many different trace fossils (arrows) in the surface of a thin, fine-grained sandstone bed at Weston Beach (many others on the surface are unmarked).

Trace fossils result from specific behavioral activities. Some simply mark the passage of an organism over or through the sediment. Others result from dwelling chambers: tubes or burrows occupied by their maker. Feeding by an organism produces a third type; these trace fossils are likely to be among the more complex. Some traces combine activities, such as simultaneous transit and feeding. They have been given scientific names as if they were actual organisms, and this is how they are known and communicated among geologists. The names cited in the following paragraphs are the equivalent to genus names for actual organisms.

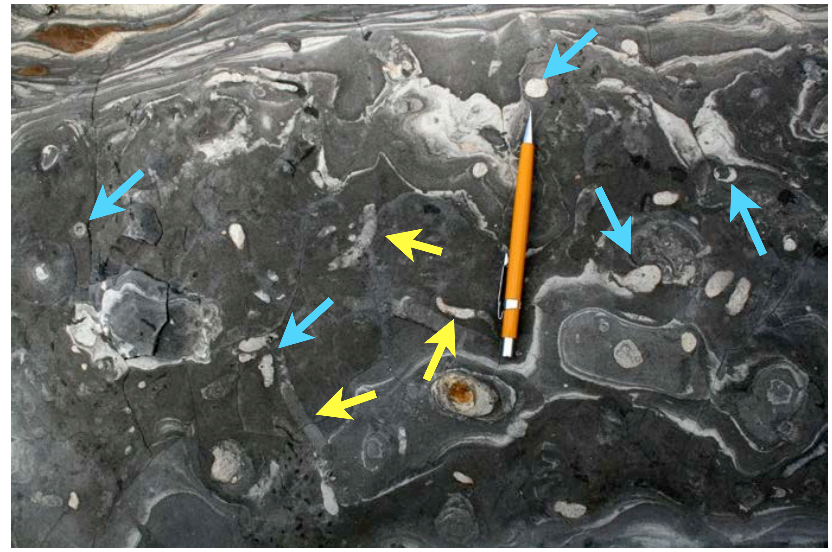
In contrast to organisms themselves, which have a specific unvarying definitive character, trace fossils do not. A single named trace may display lots of variability.

Trace fossils are typically viewed on a 2-dimensional surface, a bedding plane or a cross sectional exposure through the bedding. The traces themselves, however, are, for the most part, three-dimensional features that form in the sand and mud of the sea floor. Compaction of the mud, as the sediment turns to rock, distorts and flattens many of the traces. The rocks of the Carmelo Formation were subsequently uplifted, exposed, and partly eroded, and on these eroded surfaces that the traces at Point Lobos appear. In the sedimentary rock exposures, we typically see the trace in one of two views, and the same trace can be manifested quite differently depending on the orientation of the surface of exposure. One is in a cross-section through the rock, the other is on exposed bedding plane surfaces.

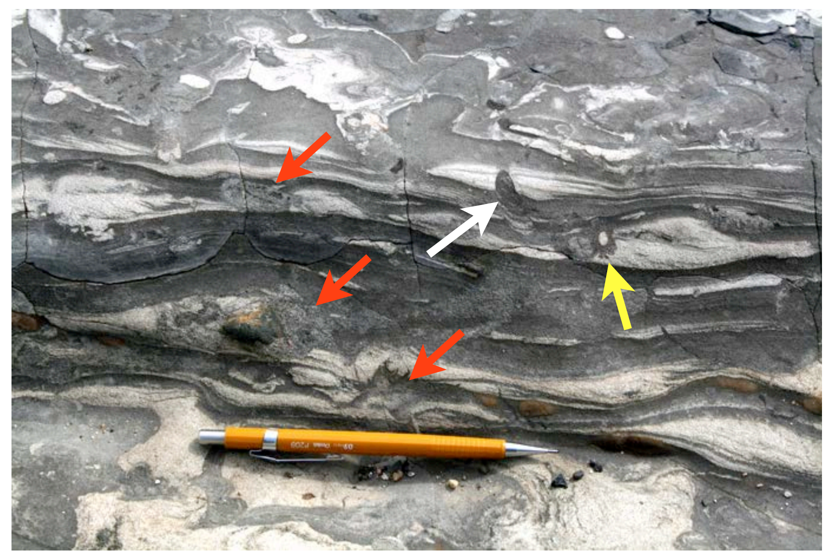
The two views show different aspects of the traces. Vertical tubes (cylinders) appear on bedding plane exposures as circles or ellipses filled with sand or mud, and horizontal burrows appear as wide lines across the surface (Fig.2). Cross-sectional views (perpendicular to bedding) (Fig 3) show vertical tubes as lines and horizontal tubes as circles or ellipses. They also show where the passage of an organism through the sediment disrupted the stratification.



A. Cartoon of sea-floor sand and mud containing numerous tracks and burrows. B. Same block of sediment after compaction, lithification, and erosion down to the top of a sandstone bed. Note the different aspect of traces in the bedding-plan and cross-section views.



Trace fossils on a bedding plane surface include cross-sections of vertical or inclined sand-filled burrows (blue arrows), and horizontal filled tubes (yellow arrows).



Trace fossils exposed on a bedding cross-section include cross-sections of vertical or inclined sand-filled burrows (white arrow), horizontal filled tubes (yellow arrow), and disrupted strata where an animal passed through the sediment disrupting the layering (red arrows).

Distinctive trace fossils in the Carmelo Formation

Much of the evidence for life on and below the ancient Carmelo sea floor occurs in the form of disrupted stratification and obscure patterns in the rock ("bioturbation") made by the organisms some 50 million years ago. Several traces, however, common and distinctive distinctive .

Large sand-filled tubes (Thallasinoides or Planolites) are common traces in the Carmelo; they represent open dwellings in the mud that later became filled with sand. Most are horizontal (parallel to bedding), or nearly so. Commonly the tubes are branched, indicating that the burrows were part of a complex network. Burrowing shrimp and crabs make similar burrows in the sediment today.

Some tubes have an internal structure that looks like a stacked set of the letter "U" within the burrow. These are made as the animal packs sand and mud into the burrow behind it; the "U" opens in the direction the animal was moving.

Horizontal network of sand-filled tubes seen on a bedding plane surface at Weston Beach (Thalasinoides). The circular feature just off back end of the pen is a cross-section of a vertical burrow.

Sand-filled tubes on a bedding plane surface at Weston Beach (Thalasinoides or Planolites). Note that two of the burros display branching, as well as "U" shaped structure in the filling

Pellet-lined tubes (Ophiomorpha) are common traces in the Carmelo, where they can be vertical, horizontal , or inclined. Many have an internal structure that looks like a stacked set of the letter "U" within the burrow. These are made as the animal packs sand and mud into the burrow behind it; the "U" opens in the direction the animal was moving. Lining burrow walls with pellets is done today by ghost shrimp on the East Coast to keep the sand from collapsing into the burrow. A similar, deepwater shrimp may have made these burrows.

Horizontal burrow lined with mud pellets, on sandstone bed surface.

Tiny white branching traces (Chondrites) These small traces are very common, particularly in the darker mudstone layers. They appear as small white flecks, that, if examined closely, can be seen to be branch. They are the only burrow that is lined by calcium carbonate (calcite), the principle mineral in oyster shells and chalk. The organism that produces the burrows is unknown, but they are common in deep-water mudstones of many ages all around the world. It is generally thought that they are produced in environments low in oxygen, which is consistent with their occurrence in darker mudstones within the Carmelo Formation. These are dark because they have a high content of organic matter, the decay of which tends to exhaust the oxygen in the mud beneath the seafloor, where the trace forms**.**

Tiny, calcium carbonate-lined. branching tubes created by an unknown organism.

Clusters of **Little mud-filled blebs** (Phycosiphon?) are common in fine-grained thin-bedded sandstones in the Carmelo Formation. The small circular or oval blebs of mud appear to be cross-sections of steeply inclined mud-filled traces. The few elongate blebs of mud within the clusters are probably nearly horizontal slices through a trace.

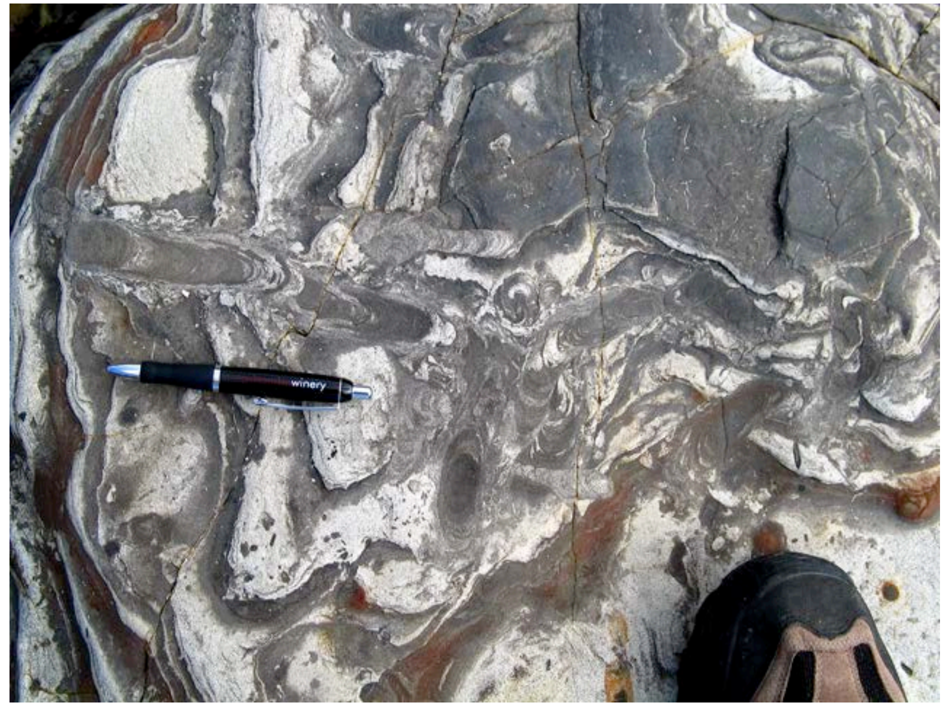
On close inspection, the mud blebs are enclosed by subtle halos of sandstone lighter in color than the rest of the rock. This trace may represent the feeding pattern of a small polychaete or other worm that extracted and ingested clay-size particles from the sand and passed them through its gut, producing a small dark sinuous tube Each cluster may represent the feeding area of a single worm.

Cluster of mud “blebs” in fine-grained sandstone at Weston Beach. Halos of lighter-colored sandstone are barely visible.

Cluster of mud “blebs” in darker fine-grained sandstone. Sand enclosing the traces is distinctly lighter-colored, presumably as a result of the extraction and ingestion of clay-sized sediment.

Large “passageways” through muddy sediment
(Scolicia?)

Muddier intervals of the Carmel Formation are likely to contain a distinctive trace that seems to have been made by an animal pushing its way through the mud. Up to 3 inches across, the traces are characterized by a central core in which a marked back-filling pattern occurs. As with the sand filled tubes, the “C”s or “U”s open in the direction toward which the animal was moving. Similar traces have been attributed to burrowing sea urchins (“heart urchins”), but the maker of this burrow in the Carmelo Formation remains unknown. In some places it pushed other, smaller traces aside in its transit through the mud, a relationship that tells us that it was a later activity suggests that the small traces had already formed in the sediment when the larger organism passed through. The small white traces may have formed somewhat closer to the sediment-water interface and were disrupted by a deeper-burrowing, larger organism that passed through the mud, pushing them aside and back-filling the burrow with mud that lacked little burrows.



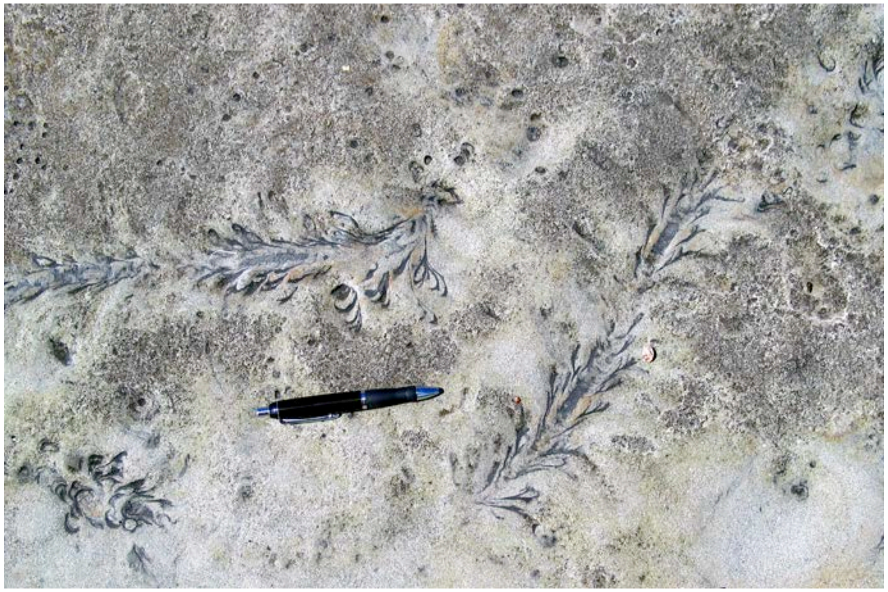
A relatively large organisms transited through and and sand beneath the sea floor, leaving the traces denoted by arrows. The generating organism is unknown. The maker of the trace above the pen was moving to the left. Many other traces exist on this surface.

The transit of the creature that formed the large burrow off the end of the pencil clearly postdates the generation of the little white burrows which it pushed aside as it moved through the mud. Another large sand-filled burrow is exposed in the upper right quadrant of the photo.

Hillichnus, a feathery, enigmatic trace fossil

Perhaps the most striking trace fossil at Point Lobos is a large complex form that has been named Hillichnus lobosensis. Herold first described the trace in 1934 as a fossil seaweed because of its resemblance to certain local kelp (such as feather boa kelp). Fossilized seaweed, however, should be carbonaceous and two-dimensional (like a pressed leaf). Although it does superficially resemble seaweed, the feature is three-dimensional, crosses bedding surfaces, and that the dark component is the mud, not carbon.

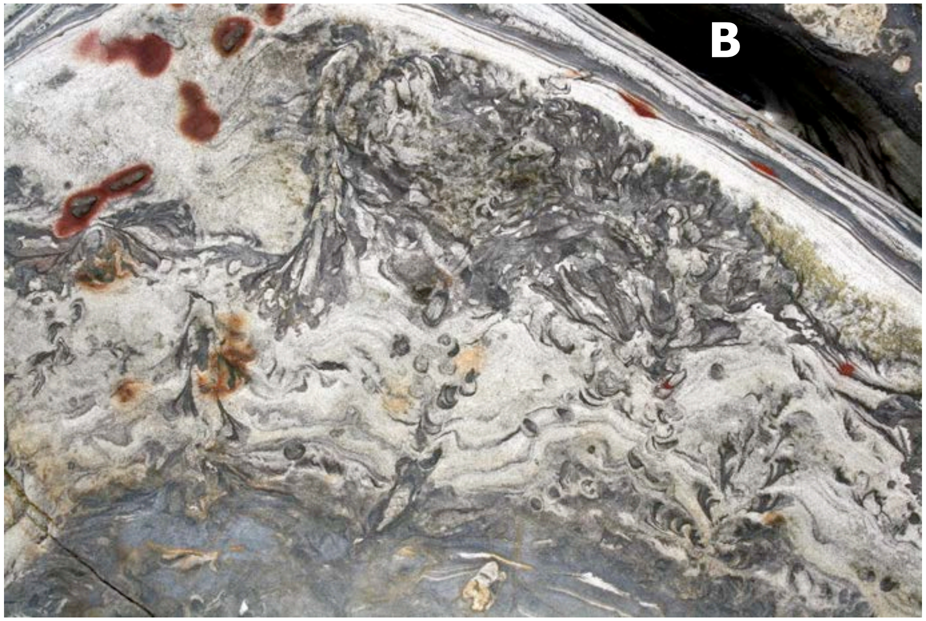
The trace has many manifestations, depending in large part on orientation of the surface on which it is exposed and the level of the section through the trace. which makes it particularly interesting, but hard to visualize in its entirety.

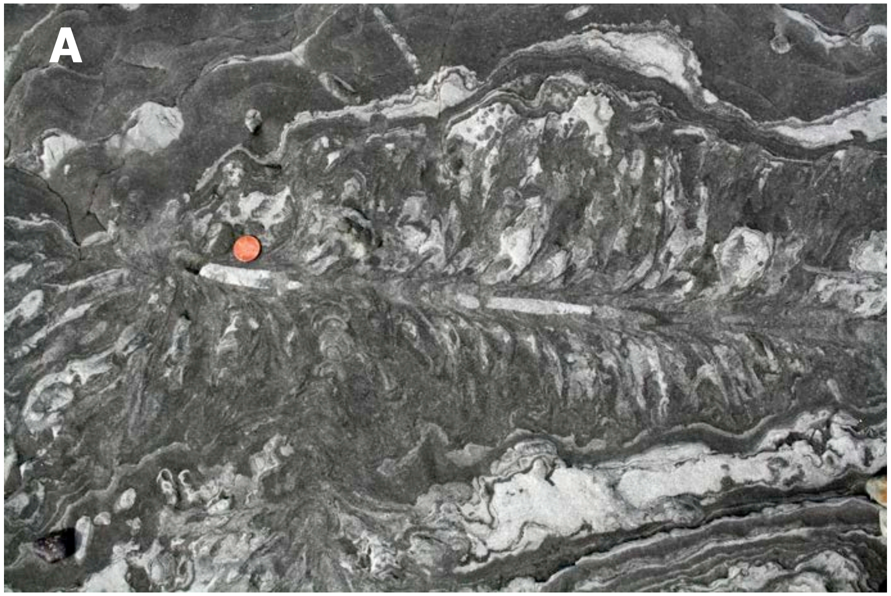


Hillichnus, as seen on bedding plane surfaces of Carmelo sandstones

Hillichnus exposed on three surfaces of either different composition or different lithologies A. muddy surface parallel to bedding. The trace is wide and has a central sand-filled core. B. Sloping sand surface with numerous Hillichnus traces. C. Surface perpendicular to a graded sandstone bed.   Burrows in a graded bed demonstrate that the trace formed in the sediment below the sediment-water interface. It is difficult to reconcile the traces depicted in "C" with the feeding activity of a bivalve.

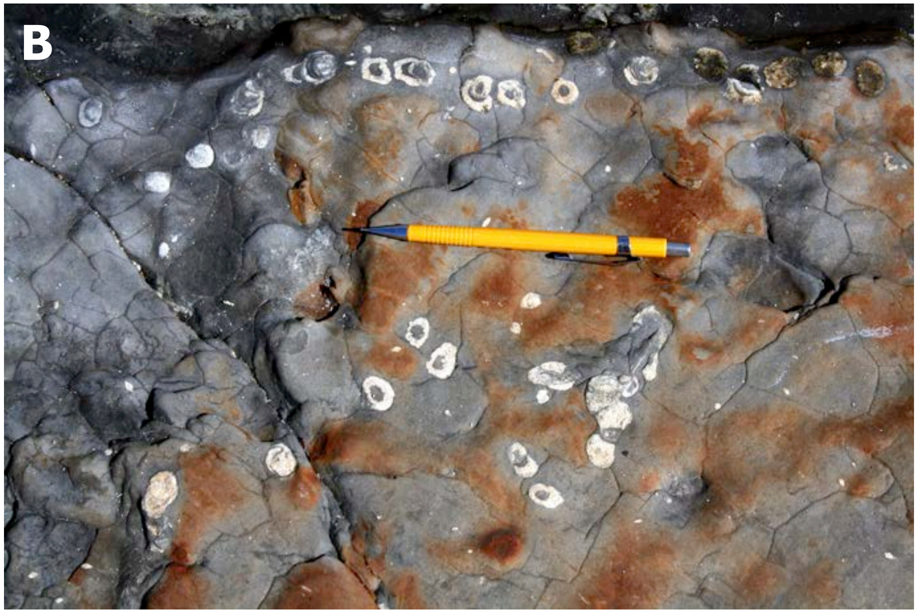
Hillichnus exposed on three surfaces of either different composition or different lithologies A. muddy surface parallel to bedding. The trace is wide and has a central sand-filled core. B. Sloping sand surface with numerous Hillichnus traces. C. Surface perpendicular to a graded sandstone bed.   Burrows in a graded bed demonstrate that the trace formed in the sediment below the sediment-water interface. It is difficult to reconcile the traces depicted in "C" with the feeding activity of a bivalve.





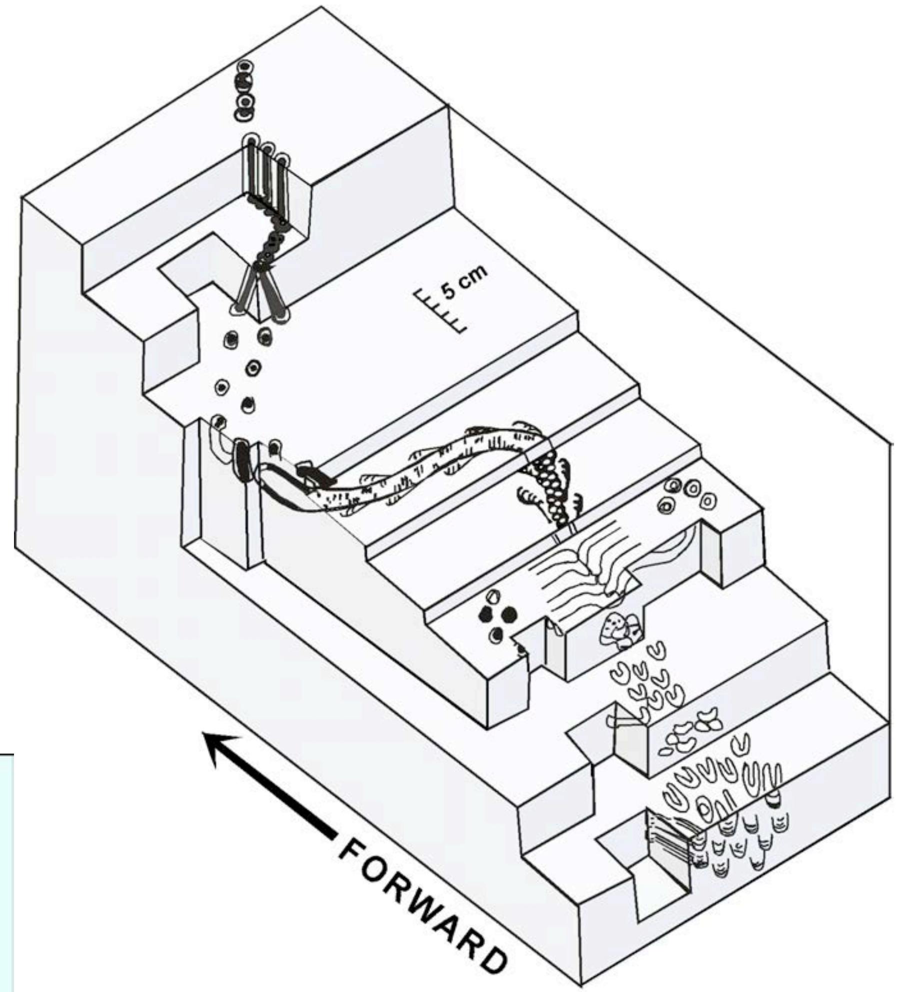
Other manifestations of Hillichnus in the Carmelo Fomation at Weston Beach A. Vertical section through sandstone above the trace. Some of the upward-extending mud "lines" may be paired or a represent a section through an upward extending tube cored with sane and lined with mud, perhaps similar to those in the center of figure "B" on the previous page.

B and C: Cross-sections through aligned (and apparently random) vertical tubes rimmed with sand and cored with mud. Tubes in "C" record movement to the right as are those in the uppe rorw in "B". These features have been considered part of the Hillichnus trace (HIll, 1981, Bromley et al., 2003), although a connection between the two is difficult to find.

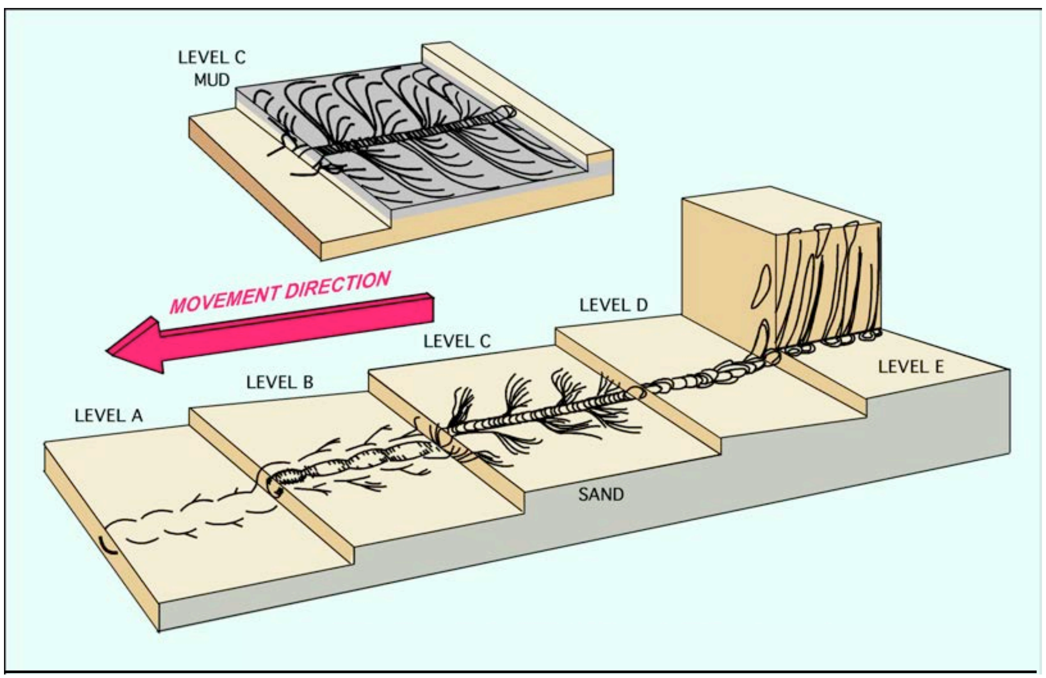


Hill (1981) provided the first attempt to reconstruct the trace. He pointed out that its numerous manifestations were not the result of different organisms, but were parts of a complex three-dimensional feeding pattern of a single organism

Bromley et al, (2003) named the trace "HIllichnus lobosensis", and suggested that if was produced by a substratal deposit-feeding bivalve. Their 3-dimensional model does not show the lower tier of traces depicted in the Hill model, and, in contrast to the Hill model, depicts movement of the trace-maker away from the direction in which the lateral "frills" or "feathers" open.



HIll's (1981) 3-dimensional reconstruction of the complex trace.



Three-dimensional model of the trace Hillichnus lobosensis by Bromley et al. (2003)


Multiple Hillichnus traces on a sandstone surface, Weston Beach. Trace above pen appears to be transiting in the direction pen is pointing.

Bromley et al. (2003) are probably correct in deducing that the structure was produced by the feeding of a subsurface animal. Hill arrived at the same conclusion in 1981; he believed the organism was feeding on organic matter contained in the mudstone layers. The trace locally disrupts the sand at the base of turbidite beds 6-10 inches thick. These beds almost certainly amassed their full thickness in one rapid depositional event. The disturbance of sand at their base indicates that the organism that formed them passed through after the entire bed accumulated.

Curiously, Hillichnus and Scolicia (the large passage ways through muddy sediment) seem to be mutually exclusive, never both occurring in the same set of strata. This may reflect a preference on the part of the organisms responsible for the traces for specific types of sea bed material. Scolicia seems not to occur where sand layers are thicker than about 2 inches and Hillichnus seems only to occur if such beds exist.

For all its prevalence at Point Lobos, Hillichnus is globally a very rare trace fossil. It has been reported from rocks of similar or slightly older ages at a few places along the central and northern California coast, including Point Reyes. A similar trace fossil, was described in a lower Cretaceous shallow marine sandstone in Argentina (Pazos and Fernandez, 2010). Although strikingly similar in one photograph, the Argentine example differs in a number of ways from the traces at Point Lobos, and it may represent the feeding trace of a totally different organism.

Summary

Trace fossils are a prominent feature in most of the finer sandstone and mudstone of the Carmelo Formation. They generally are absent in mudstone or fine-grained sandstone interbeds within a conglomeratic succession. The traces record a prolific fauna living on and beneath the floor of the ancient submarine canyon. For the most part, we have little idea of the identity, or even the nature, of the organisms that made the traces.

References

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Ed Clifton
September, 2013