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Gallery of Geology

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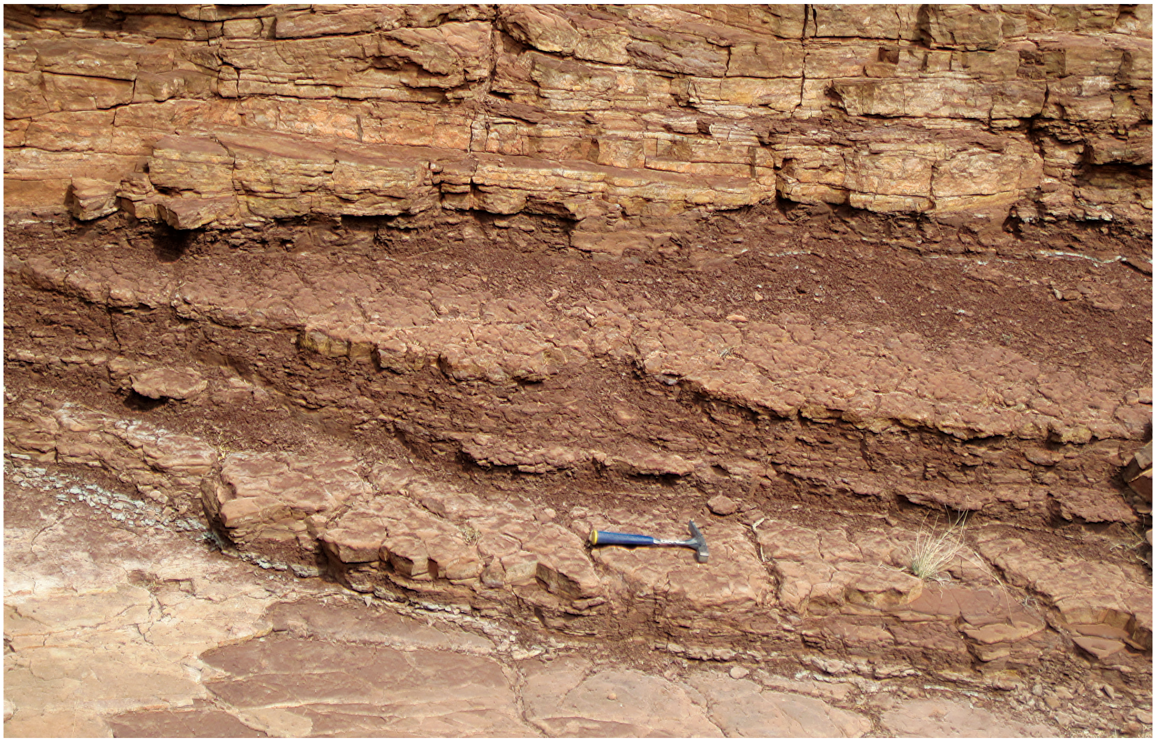

Figure 1. Overview of Astropolithon locality northeast of Socorro. The rock hammer is lying on the bed covered with Astropolithon.

Across much of New Mexico, the lower Permian (Wolfcampian-Leonardian) Abo Formation contains a significant record of continental plant fossils (DiMichele et al., 2013), vertebrate body fossils (Berman et al., 2015), and red-bed (*Scoyenia* ichnofacies) trace fossils representing both vertebrate and invertebrate producers (Hunt and Lucas, 2015).

Most unusual is recent discovery in the Abo Formation of Astropolithon, an inorganic sedimentary structure (pseudofossil) considered to have been formed within a cohesive microbial matground. This very rare and highly localized occurrence was discovered in 2012 by William DiMichele of the U. S. National Museum at a location near Mesa del Yeso, northeast of Socorro. The Astropolithon specimens are preserved in concave epirelief in the uppermost Abo Formation on top of a 15-cm-thick bed of massive, very fine grained sandstone about 7 m below the base of the overlying Arroyo de Alamillo Formation of the Yeso Group. Below the Astropolithon bed is a 0.3-m-thick bed of ripple-laminated sandstone with walchian conifer remains, and above is a 1.3-m-thick bed of ripple laminated sandstone with tetrapod footprints (*Batrachichnus, Dromopus*) near its base. These sandstone beds are intercalated with red mudrock, and, stratigraphically higher, the base of the overlying Yeso Group is marked by two thin dolomite beds.

The Abo deposits at the Astropolithon locality are characteristic Abo overbank mudrock and unchannelized sheetflow deposits of sand that produced thin, tabular sandstone beds with ripple lamination. However, this floodplain was beginning to feel the effects of a marine transgression advancing from the south at about the beginning of Yeso time. This marine transgression likely affected the climate and the salinity of the landscape, and these effects may account, at least in part, for the occurrence of Astropolithon.

The Astropolithon consist of a central area that is partially domed in appearance and surrounded by two or three concentric rings that show multiple radial lineations. The central area displays a wrinkled surface texture on the domed portion. The concentric rings outwardly rise in a stepwise fashion towards the uppermost bedding plane. These rings variably show outwardly directed, and sometimes branched, radial lineation. The bedding surface beyond the periphery of the outer ring shows in places relatively large reticulate "elephant skin" texture, as well as wrinkles. We confidently identify these unusual structures as Astropolithon, which is an inorganic sedimentary structure (pseudofossil).

Astropolithon hindii was first described by the prominent nineteenth century Canadian geologist and pioneering ichnologist Sir John William Dawson (1820–1899). He initially considered these structures, which he found

Figure 2. Closer view of the Astrolpolithon bed from above. Note: numerous, circular Astropolithon above the rock hammer. Rock hammer is 28 cm long.

in the Cambrian-Ordovician of Nova Scotia, Canada, to be organic, plant-like "fucoids" with radiating fronds (Dawson, 1878). He later reinterpreted Astropolithon as the mouths of large burrows with outwardly radiating trails, although he also thought that it might represent an organism (Dawson, 1890). In either interpretation, Dawson regarded Astropolithon as a fossil, so the Latin name he gave it was italicized.

Pickerill and Harris (1979) and Pickerill (1984) restudied the original material and determined that Astropolithon hindii is not a biogenically produced trace fossil, but instead is a sedimentary pseudofossil (sand volcano) produced on bedding planes by fluidization processes. Thus, Astropolithon is either a sediment volcano formed by the expulsion of water from sediment through different agencies such as slumping, rapid sedimentation or agitation (Reineck and Singh, 1980; Gerdes, 2007) or it is a ruptured gas dome that resulted from microbial mat decay (Pflüger, 1999; Ericksson et al., 2007). As an inorganic structure, Astropolithon is now regarded as a pseudofossil, so the name is no longer italicized.

We cut transverse sections through several of the Abo Formation specimens to determine that penetrative vertical shafts are not present. This demonstrates that the Abo specimens were not persistent sand volcanoes, but were more likely short-lived structures produced by fluidization or degassing processes (Hagadorn and Miller, 2011). The stepwise concentric ring structures seen in some of the Abo specimens may have resulted from the sequential expulsion ("multiple burps") of sediment outward from the central area. However, the concentric ring structures seen on most specimens might also have been formed by the sequential retraction of highly cohesive, expelled sediment that fell back towards the depressed central area.

Astropolithon is thought to form only within cohesive host sediments such as microbially bound sand (Seilacher and Goldring, 1996; Gerdes, 2007).

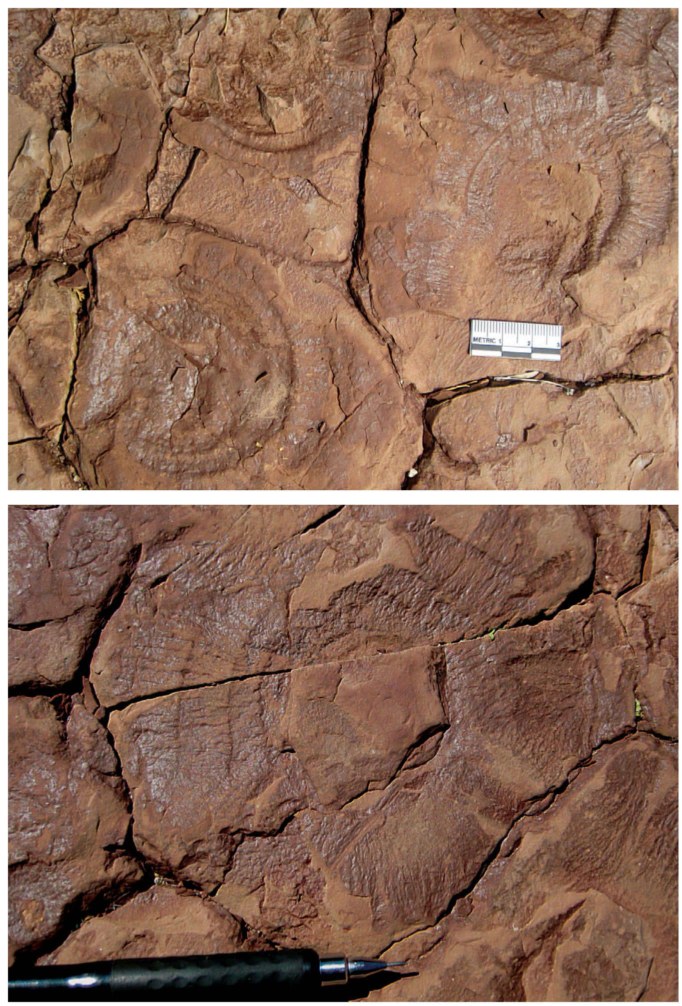

Figure 3. Views of selected Astropolithon in the Abo Formation. Note: structure of concentric rings with radial lineation and wrinkled clay drape.

Indeed, there are indications on the Abo slab surfaces that a microbial matground was present when the Abo Formation specimens were formed. These indications include examples of "elephant skin" texture, which is considered to reflect the growth structures of microbial mats (Porada and Bouougri, 2007).

Matground structures were notably common prior to the Cambrian agronomic revolution (Seilacher and Pflüger, 1994) but were limited thereafter to generally inhospitable habitats (Pflüger, 1999). Characteristic sedimentary structures appear in modern biomat habitats, but their preservation potential is very low (Pflüger, 1999). Interestingly, many of the Astropolithon from the Abo Formation show a clay drape, which may have quickly covered the already cohesive matground surfaces in which they formed. This clay drape might have helped stabilize and preserve the unusual multi-tiered morphology seen in the Astropolithon.

The Astropolithon documented here are readily interpreted as sedimentary structures mediated by a matground. They are microbially induced sedimentary structures (MISS) sensu Noffke et al. (2001), but can also be called pseudofossils or synsedimentary structures (Seilacher, 2007). The matground structures from the Abo Formation show elephant skin texture and "Kinneyia"-like wrinkles. Like Astropolithon, Kinneyia was a Latin name long ago applied to structures thought to be fossil. However, also like Astropolithon, Kinneyia has more recently been regarded as inorganic wrinkles in sediment, so the name is no longer italicized. However, both Astropolithon and Kinneyia are sedimentary structures that have been influenced (or controlled to some extent) by microbial films (MISS—microbially induced sedimentary structures). Therefore, Stimson et al. (2017) have very recently argued that such structures should be considered trace fossils and thus have italicized Latin names. Because this bold, recent proposal remains to be discussed at length, we simply follow the consensus view here that Astropolithon and Kinneyia are informal names applied to different kinds of MISS.

The mechanism of formation of the Abo Formation Astropolithon is reasonably that posited by Seilacher (2007) and Seilacher et al. (2002): (1) the microbial mat formed a seal above underlying siltstone/very fine-grained sandstone; (2) when fluid or gas escaped from the underlying layer, the mat was domed upward; and (3) it then radially cracked and collapsed. This happened without a central tube for liquid/gas release (as in a true "sand volcano") or any deformation of the siltstone/very fine-grained sandstone layer. It took place in a floodplain setting, so the conditions to allow the matground to form must have been present and localized, possibly influenced by the beginning of a marine transgression that signaled the onset of Yeso Group deposition.

Astropolithon is an exceedingly rare structure in the geological record (Pflüger, 1999), and this is particularly true for post-Cambrian occurrences. Given the rarity of Astropolithon in the Phanerozoic record, the conditions under which the Abo Formation specimens were created must have been extremely unusual.

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