4(d). Mat-decay features

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Destructive features created by physical processes, such as mat chips, shrinkage cracks, and rolled up mat fragments, are the focus of Chapter 4(c). The suite of structures in this section are hypothesized to result from the decay of organic material, often mat-derived, buried underneath mat surfaces. Of particular interest are features resulting from the escape of gases or fluids produced by decay of buried organic matter beneath cohesive biofilms. These structures include:

1) Radial gas or fluid escape structures, sometimes called '*Astropolithon'*;
2) Gas or fluid escape structures without radial forms.

The decay released gases or fluids that escaped through the upper mat surface, creating distinctive structures termed 'gas domes' (see also Chapter 6(c)). Some of these structures have radial morphologies and were first described as animal trace fossils and named *Astropolithon hindii* (Dawson, 1878). '*Astropolithon*' was later reinterpreted as an escape structure (Pickerill and Harris, 1979) (Fig. 4(d)-1). Other gas or fluid escape structures lack the radial morphology of '*Astropolithon*' and consist of conical mounds that are roughly circular in shape (Figs. 4(d)-2, -3).

The structures discussed and figured here should not be confused with the structures commonly termed 'sand volcanoes', which are purely physical structures that occur commonly in impure sands along the high water line of the lower supratidal zone. They are temporary in nature, and only form during the rising flood. Sand volcanoes form from gas pressure that is pushed upward by flood water in the sediment. This gas has the same composition as the atmosphere. In contrast, 'gas domes' are thought to form in the presence of microbial mats when decaying microbial mat mass underneath the topmost microbial mat generates upward-rising gas pressure. These gases are typically richer in methane, CO_2, CO, H_2, and H_2S than the atmosphere (e.g., Gerdes et al., 2000; Noffke et al., 1996, 1997a, 1997b, 2000, 2001a, 2001b, 2003; Draganits and Noffke, 2004).

Radial gas or fluid escape structures: Fig. 4(d)-1A to -1F

<u>Name of structure:</u> Radial gas or fluid escape structures.

<u>Other terms used</u>: '*Astropolithon*', 'gas domes'.

<u>Age range:</u> Cambrian ('*Astropolithon*' was considered a Cambrian index trace fossil; Pickerill and Harris, 1979).

<u>Description of structure:</u> Roughly circular conical mound with a central or subcentral depression, or aperture, and radiating structures than can appear as ridges or grooves. The radial structures extend from the central depression to the edge of the mound and

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range from straight and continuous to sinuous and bifurcating. The mound is a surface expression of a vertical inverted-cone structure that extends downward into the sedimentary layers and contains a core linked to the central depression. The edges of the mound are typically indistinct as they grade into the surrounding sediment.

Associated sedimentary structures: (1) sand stromatolites; (2) thinly bedded laminated quartz arenites; (3) oscillation ripples.

Environment: Intertidal.

Ideas on genesis: These structures are interpreted as resulting from the escape of pressurized gas or fluid through a cohesive microbial mat surface. The gas or fluid was produced during the decay of buried mat material. As decay progressed, the gas or fluid pressure underneath the mat increased to the point of rupture when the trapped gas or fluid erupted through the mat surface, depositing a conical mound of sediment on the seafloor. The central depression in these mounds is the zone through which the gas or fluid and sediment flowed. Once the pressure was released, this central zone collapsed and created the depression. The radial structures were likely zones through which the sediment flowed as it spilled onto the seafloor, as they can occasionally extend beyond the margin of the mound itself (Pickerill and Harris, 1979).

Non-radial gas or fluid escape structures: Fig. 4(d)-2A to –2F; Fig. 4(d)-3A, –3B

Name of structure: Non-radial gas or fluid escape structures.

Other terms used: ‘Gas domes’.

Age range: Neoproterozoic-Cambrian.

Description of structure: Roughly circular conical mound with a central or subcentral depression or aperture. Unlike in ‘*Astropolithon*’, there are no radial structures visible on the surface of the mound, although internal radial structures have been noted in some forms (Pickerill and Harris, 1979). In these structures, the mound is also a surface expression of a vertical inverted-cone structure that extends downward into the sedimentary layers and contains a core linked to the central depression. The edges of the mound are typically indistinct as they grade into the surrounding sediment, although they may be overgrown by microbial structures such as sand stromatolites.

Associated sedimentary structures: (1) sand stromatolites; (2) oscillation ripples (see also Chapter 7(a); (3) combined flow ripples; (4) thinly bedded laminated to ripple cross-laminated quartz arenites.

Environment: Supratidal to intertidal.

Ideas on genesis: These structures are also interpreted as resulting from the escape of pressurized gas or fluid through a cohesive microbial mat surface. The gas or fluid was produced during the decay of buried mat material. As decay progressed, the gas or fluid pressure underneath the mat increased to the point of rupture when the trapped gas or fluid erupted through the mat surface, depositing a conical mound of sediment on the seafloor. The central depression in these mounds is the zone through which the gas or fluid and sediment flowed. Once the pressure was released, this central zone collapsed and created the depression. The mounds may later be flattened by overlying layers, or overtop adjacent primary surface structures such as ripples. These features lack the radial structures found in '*Astropolithon'*, perhaps because the sediment flowed out of the rupture in a more uniform manner, or because the mounded sediment has buried such fractures.

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Figures: Chapter 4(d):

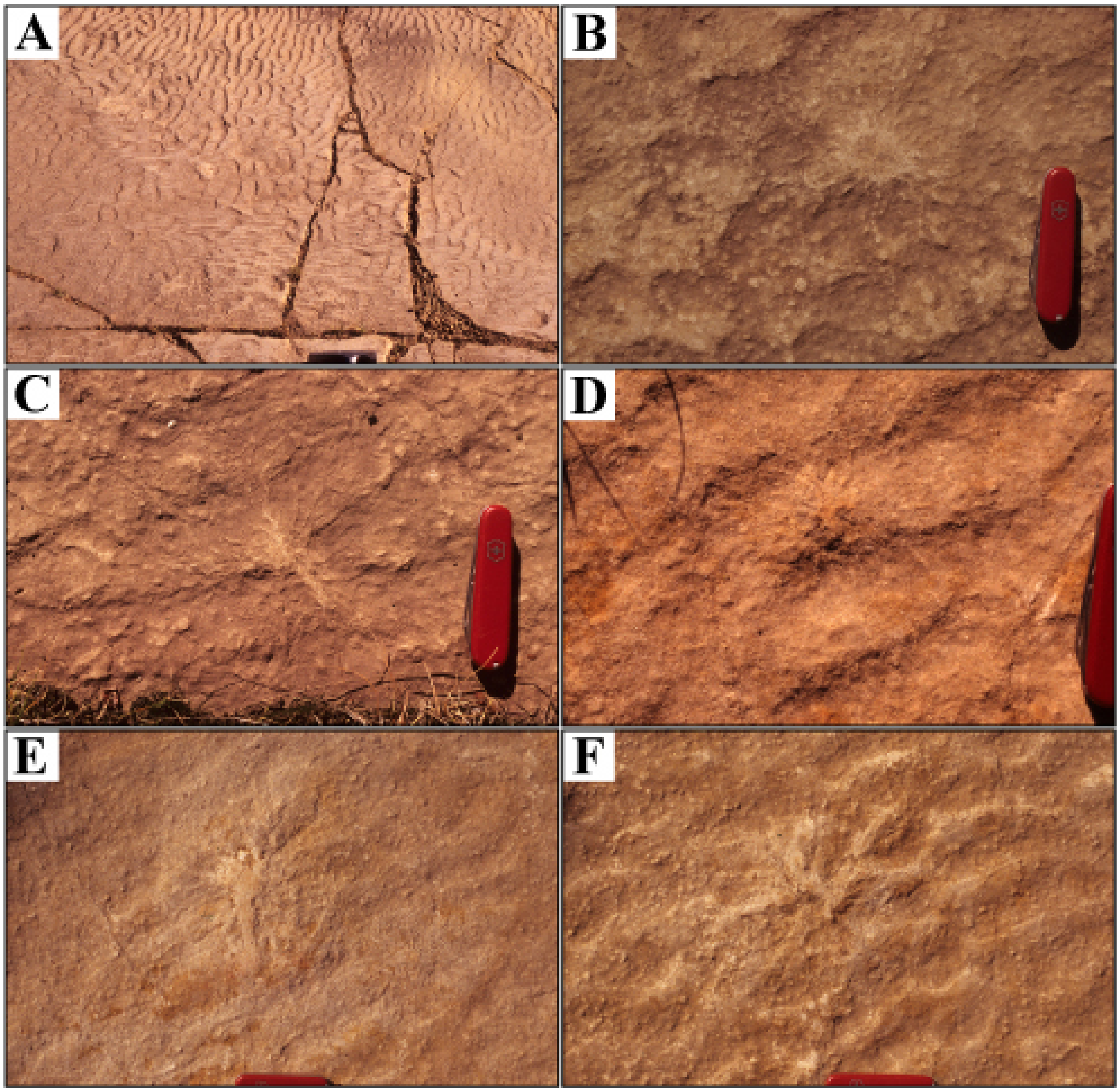

Fig. 4(d)-1: Radial gas or fluid escape structures (‘*Astropolithon*’) in quartz arenites, Late Cambrian Elk Mound Group, Wisconsin:

All images are from a ripple-marked bed surface (partially illustrated in A), which exhibits evidence of oscillation ripple washouts from tidal retreat, as well as ridge and runnels. Surface is characterized by small sand stromatolites (raised pustules in B-F, and at lower left in A), and is underlain and overlain by thinly bedded laminated quartz arenites. Locations of several of the escape structures on this surface are arrowed. B-D illustrate the typical raised boss with radiating cracks, thought to form when gas or fluid pressure from underlying layer(s) arches overlying sediment upward, cracking it. Radiating cracks are often filled with sand, either from below, or from surface transported grains. When minimal sand is ejected from below, the raised boss and cracks are the only evidence for gas/fluid escape. Stringers of ejected sediment are sometimes visible in the downcurrent direction (E) and overlap small sand stromatolites (E, F), but can be cross-cut by surface trails, such as the *Helminthoidichnites* in E. Together, these features demonstrate the presence of a microbially bound cohesive sandy surface layer that was arched upward and cracked prior to deposition of the overlying layer. Hammer head in A is 17.5 cm long, knife in B-F is 8.3 cm long.

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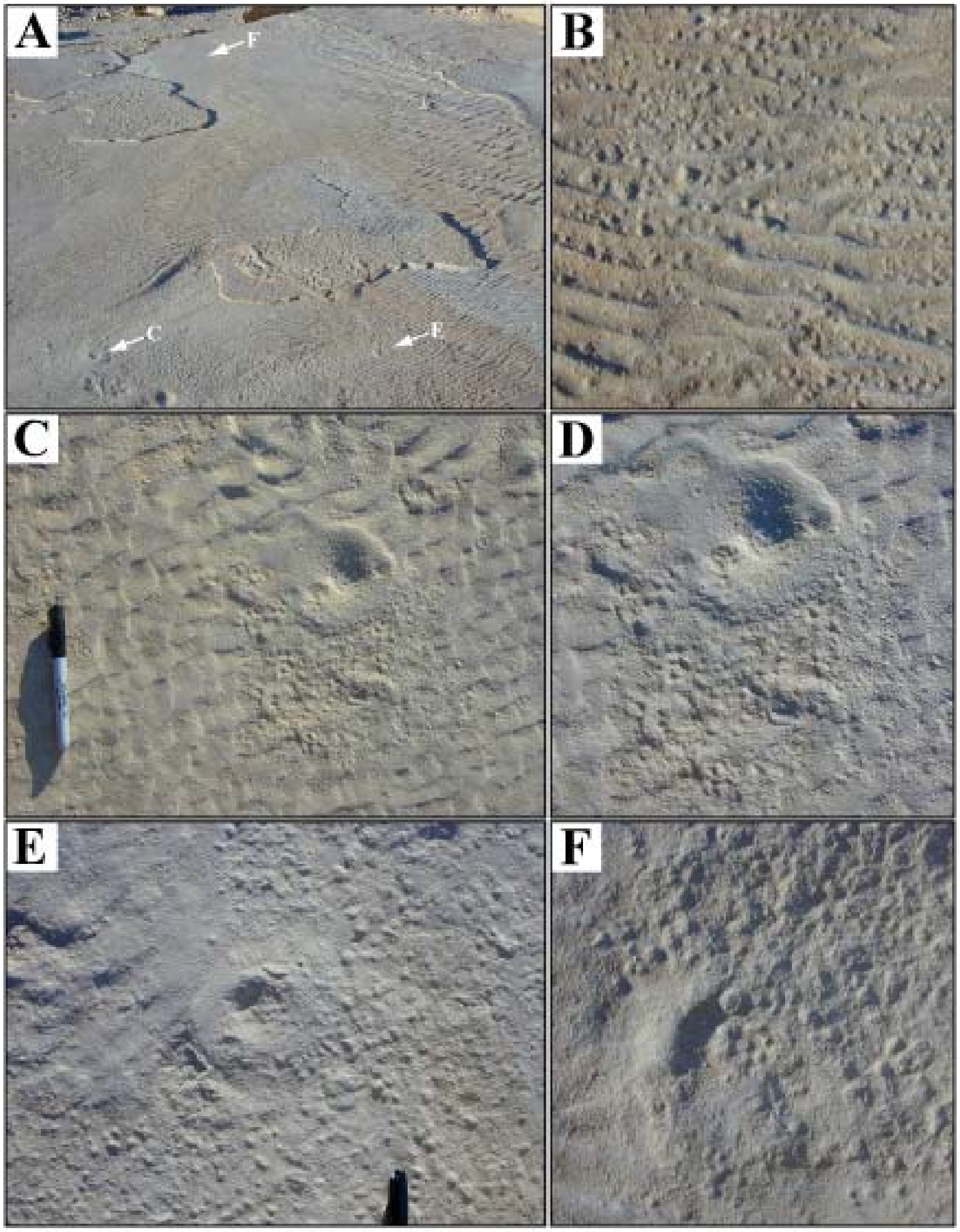

Fig. 4(d)-2: Gas or fluid escape structures in quartz arenites, Late Cambrian Elk Mound Group, Wisconsin:

All images are from the oscillation- and combined flow-ripple marked bed surface in A, which is characterized by patchy ripples, swaley topography, and is underlain and overlain by thinly bedded laminated to ripple cross-laminated quartz arenites. Three of the escape structures on this surface are arrowed. Sand stromatolites (B) that also occur in non-rippled patches (A, C, D, F), are often over-run by oscillation ripples. B is from lower right corner of surface in A. D is a close-up of C, and bears the hallmark central depression characterized by a raised but flattened mound of adjacent sediment, which

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overlaps adjacent ripple crests and is in turn overlain by the margin of a cluster of sand stromatolites. E illustrates more asymmetric sediment expulsion, and overlap of this sediment mound by non-clustered sand stromatolites. F is similar to D, but only a portion of the central cavity and marginal sediment mound remain. Together, these features demonstrate the presence of microbially bound surfaces before, during,
and after ripple formation, and that gas or fluid-driven evulsion of sand occurred after ripple formation but before the final episode of microbial sealing. Width of field of view in A: 2.5 m, B: 25 cm; F: 17 cm; pen is 13 mm wide.

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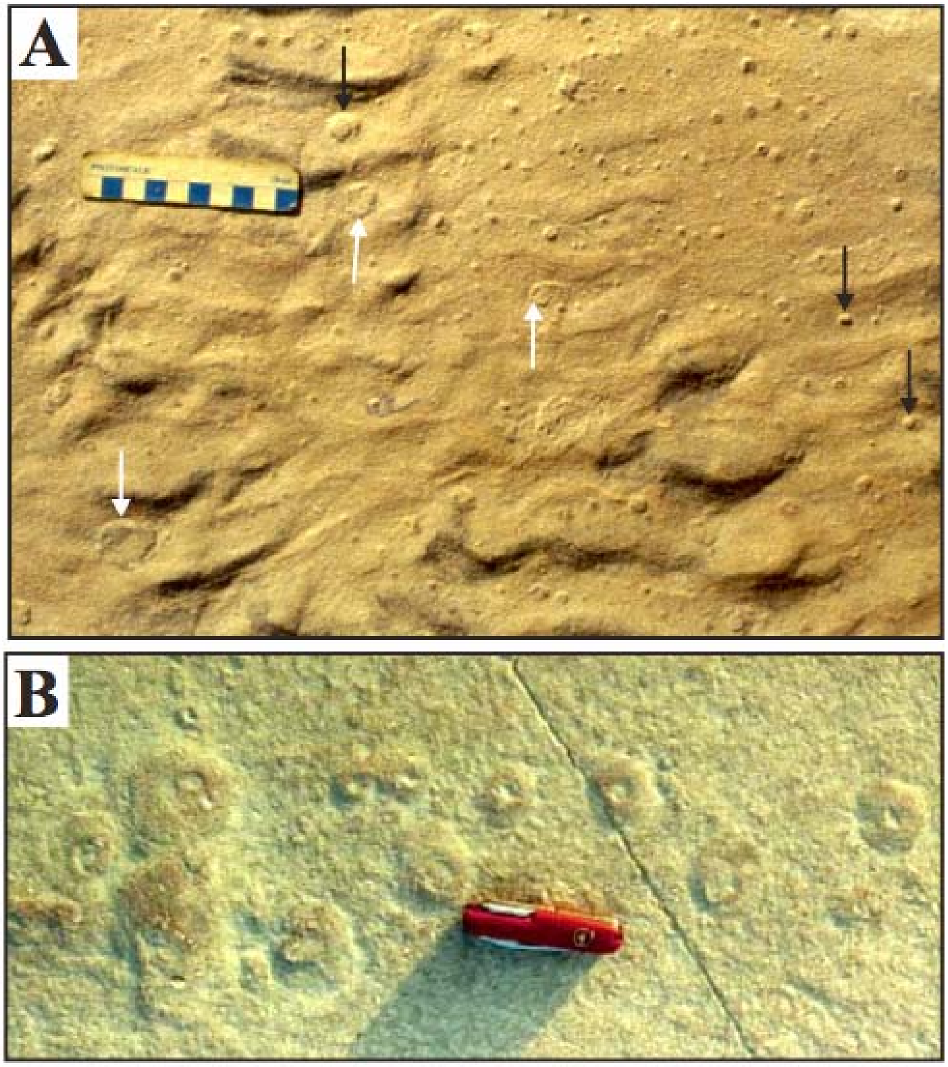

Fig. 4(d)-3: Mat decay features from the Neoproterozoic of India:

(A) Small bulges (black arrows) on a sandstone bed surface in the intertidal-supratidal 0.6 Ga-old Sonia Sandstone, Jodhpur Group, Rajasthan, India. Note association with minute gas domes with craters at their centres (white arrows). (B) Bulges with craters at their centres in the same Sonia Sandstone. Gas entrapped under a mat and filling of the space thus created underneath the mat by sand, created the bulges. On the other hand, the gas domes formed where the upcoming gas could rupture through the mat cover. Decay of mat at its base presumably generated the gas pressure.

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