

8(b). Disruption of mats by seismic events

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This series of photographs documents structures in quartz arenites of the Nepean Formation (Cambro-Ordovician) in Ottawa, Canada, attributed to the influence of biofilms during sedimentation and subsequent seismically related deformation (Donaldson and Hilowle, 2002; Donaldson et al., 2002b, 2005a and b; Donaldson and Chiarenzelli, 2004). Similar structures have been seen in the stratigraphically equivalent Potsdam Sandstone in northern New York State (USA), so these structures are likely widespread throughout the region. The rocks depicted are texturally and compositionally mature quartz arenites (95% to 98.2% SiO₂, total whole rock analyses). They are virtually devoid of fine detrital material other than illite; framework grains consist of well-rounded quartz grains, traces of chert and feldspar, and <2% heavy minerals. The detrital grains are cemented primarily with epitaxial overgrowths of quartz, and up to 5% carbonate in recessively weathered layers. Laminations and primary structures are accentuated by darker colouration of the beds containing carbonate cement, which has facilitated the accumulation of modern organic matter. No original cyanobacterial matter has been detected; in fact, the beds inferred to represent sand layers originally bound by microbial mats are almost universally free of carbonate cement, appear white on both fresh and weathered surfaces, and have been essentially unaffected by weathering.

These quartz arenites often display both the original biofilm growth forms, as well as subsequent modifications of primary mat morphologies. Most of the photographs represent features whose mechanical behaviour is inconsistent with consolidated and/or unconsolidated sand, thus requiring the influence of biofilms in their formation. Primary growth forms include low-relief stromatolitic domes and wrinkled, crinkly, or knobby textured bedding surfaces, often superimposed on non-biogenic sedimentological features (Fig. 8(b)-1). Modified biofilm morphologies include desiccation cracks (i.e., sand cracks), roll-ups, rip-ups, flip-over folds, erosional truncations, and the foundering and reorientation of stromatolitic heads (Fig. 8(b)-2). Evidence of evaporitic conditions during deposition is provided by the close association with pseudomorphs after gypsum.

Among the most intriguing findings is the disruption of a distinct half-metre-thick stratigraphic interval, presumably by palaeoseismic events. In this zone low-amplitude, decimetre-scale, domal stromatolites, composed of rounded quartz grains have sunk or foundered into underlying unconsolidated layers (Fig. 8(b)-3). This implies that the stromatolites were at least semi-consolidated to behave as coherent blocks during disruption. The glacially polished outcrop displays numerous, random cross-sections through the stromatolites which show a variety of internal features emphasized by slight variation in the ratio of quartz to carbonate cement. These striking outcrops convincingly document the influence of organic mats on sedimentation, and during their subsequent seismically activated deformation, in a shallow marine depositional environment.

Figures

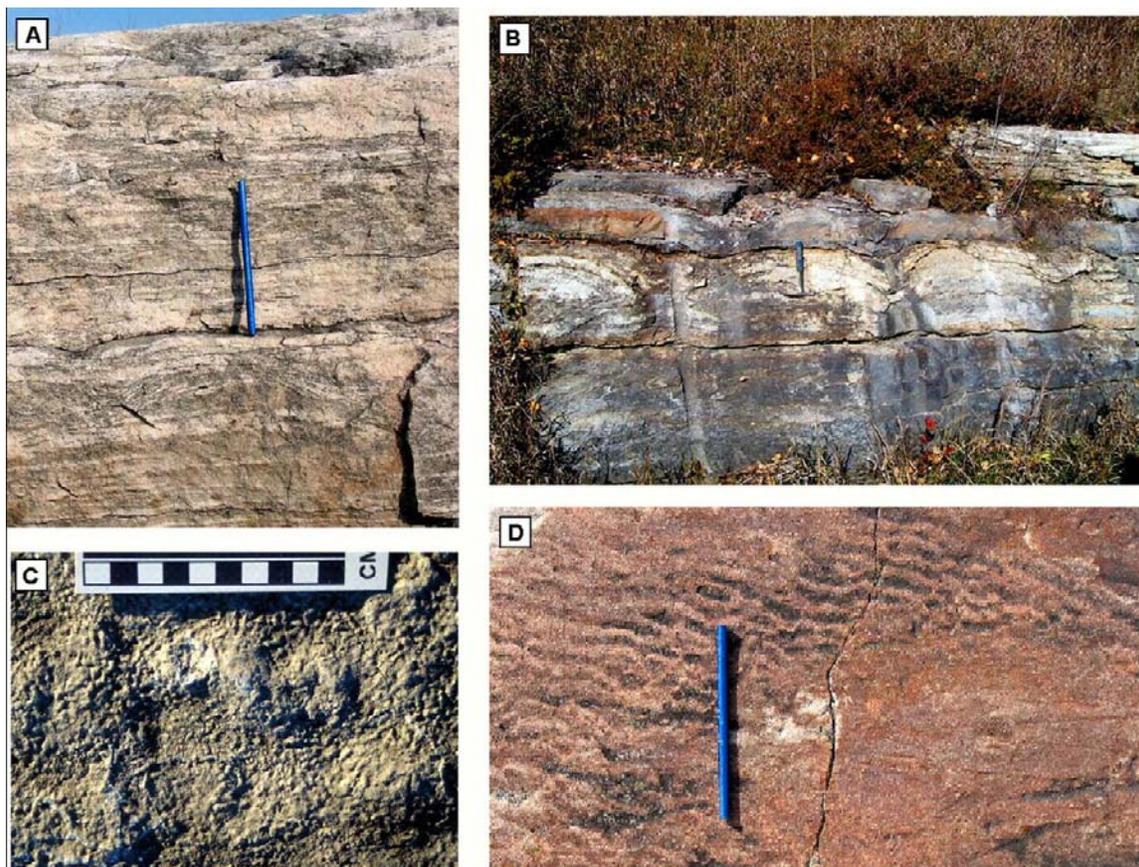


Figure 8(b)-1: Primary structures.

(A) Biofilm structures, Nepean Formation, Canada. The crinkly and discontinuous laminations above and below the truncated gently domed stromatolite (immediately below the blue bar – 15 cm) are interpreted as biomat layers, some of which were folded or torn up during storm events. (B) Low-amplitude, laterally-linked stromatolites from the Potsdam Sandstone, along Highway 12 just east of Chippewa Bay, New York, approximately >85 km due south of Ottawa. The host rock is a medium-grained, quartz cemented, quartz arenite. Geological pick for scale. (C) Top view of stromatolite outcrop in A displaying low amplitude, domal stromatolites ornamented with a knobby surface. This bedding plane morphology is inferred to mimic an original biomat developed in a shallow subtidal environment. (D) Iron oxide stained wrinkle structures capping a bed of medium-grained quartz arenite. Such “microripple”-like patterns are inferred to have been formed under the influence of a continuous biofilm that coated the original unindurated sand in a shallow marine setting. The smooth surface to the right of the scale bar (15 cm) has been modified by glacial polishing.



Figure 8(b)-2: Reworking of biofilms.

(A) Sand ridges lining the concave underside of a lamination within an overturned domal stromatolite, as seen on the upper bedding surface of the chaotic zone described in Figures 8(b)-3A to -3D. The reticulate ridges are inferred to represent infills in desiccation cracks within a subsequently degraded biomat layer. (B) Quartz arenite showing folding in biofilm-bound sand sheets intricately folded by storm events in a shallow marine setting. The length of the pocket knife is 9 cm. (C) Roll-up structures in quartz arenites of the Nepean Formation, inferred to have developed in a supratidal environment. The long axis of the large roll-up at left is 10 cm.

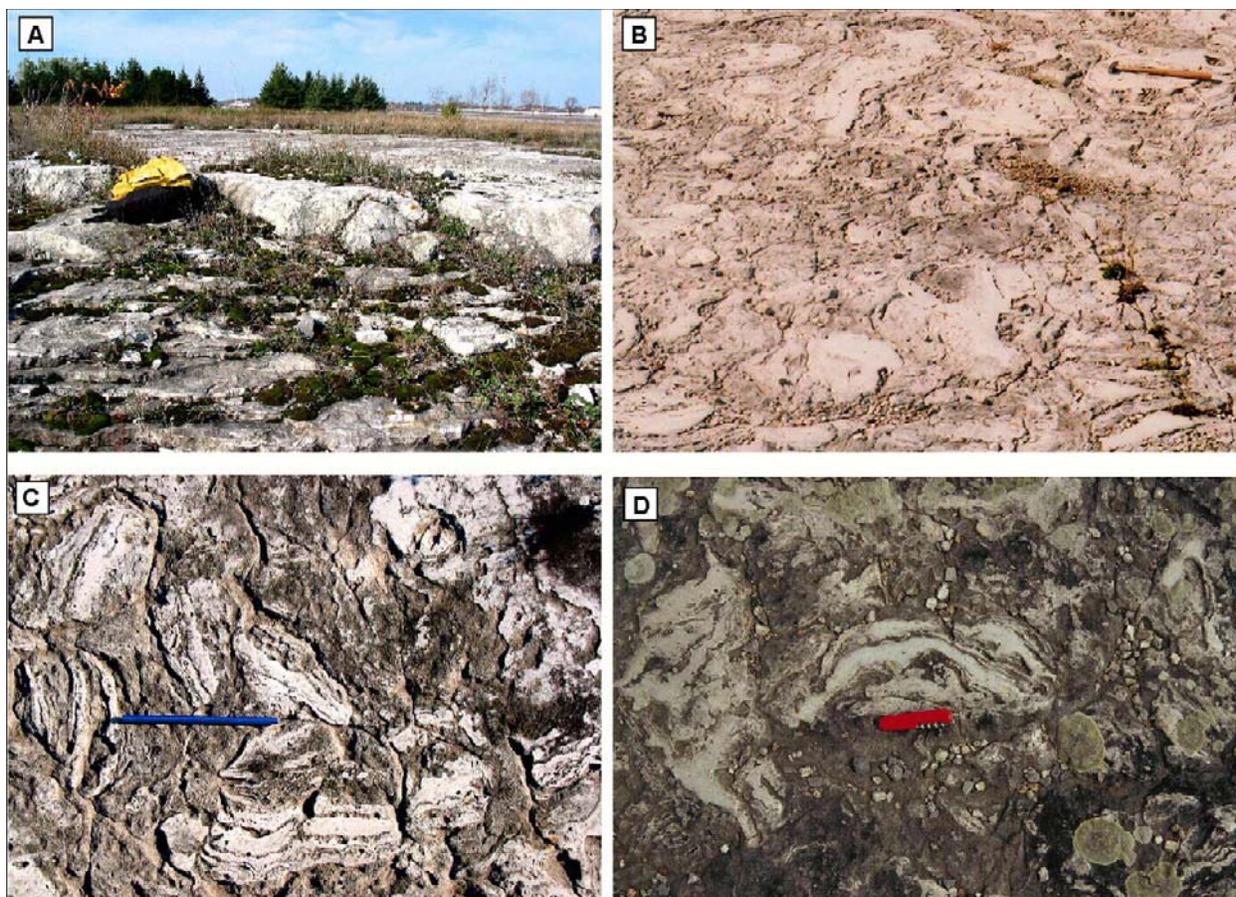


Figure 8(b)-3: Palaeoseismic mat disruption features.

(A) Outcrop photograph of glacially polished Nepean quartz arenites along Highway 417, near Kanata, western Ottawa. Note the thin centimetre-scale horizontal bedding in the foreground. An approximately half-metre thick “chaotic” zone, which begins at the base of the backpack, is shown in detail in photographs C to D. (B) Beddingparallel surface showing extent of disruption in the chaotic zone. Note size of the disrupted blocks. Hammer for scale. (C and D) Close-up views of glacially polished surface of the chaotic zone in which silicified biomats and stromatolites have foundered, during a palaeoseismic event. The chaotic zone has been traced for several kilometres to another location and in both places is composed of rotated, decimetre-scale blocks that must have been coherent (penecontemporaneously cemented) at the time of disruption above the still-unconsolidated sand. Layering is accentuated by zones of calcite cementation. In some blocks, pointed terminations of pseudomorphs after gypsum are apparent (D, in domal stromatolite above right end of the knife). The blue scale-bar is 15 cm long and the pocket-knife is 9 cm.

References

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