7(i). Ripple patches in the Cretaceous Dakota Sandstone near Denver, Colorado, a classical locality for microbially bound tidal sand flats

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The Dakota Sandstone marks the Early Cretaceous transgression onto the North American craton in Colorado, and forms prominent NS trending hogback ridges just west of Denver, Colorado. Deposition in a tidal setting is inferred from the presence of dinosaur tracks, root casts and branches of mangroves, channels filled with muddy sediments and mud clasts, and ripples modified by flowing water during emergence (McKenzie, 1972).

Mckenzie (1972) noticed unusual rippled patches on otherwise non-rippled bedding planes of the Dakota Sandstone (Fig. 7(i)-1), and tentatively interpreted them as due to microbial mat stabilization of the surface. He felt, however, that the energy regime in a tidal flat setting would not allow partial erosion of mat-bound surfaces. H.-E. Reineck was able to match the morphology of these ripple patches closely to modern examples from intertidal sandflats of the island of Mellum in the North Sea, firmly establishing the microbial mat-related origin of these rippled patches in the Dakota Sandstone (Reineck, 1979). Since then the microbial mats of Mellum have figured prominently in many other studies of microbial mats on sandy substrates (e.g., Gerdes and Krumbein, 1987; Noffke and Krumbein, 1999; Draganits and Noffke, 2004).

Colonization by microbial mats renders sandy surfaces substantially more resistant to erosion (Neumann et al., 1970; Yallop et al., 1994; Paterson, 1997), but erosion and reworking will commence once currents are sufficiently strong. In Phanerozoic mats, like those of the Dakota Sandstone, erosion will typically start at those places where the mat has previously been weakened, for example by grazing or by burrow perforations. The bound nature of the sand surface leads upon erosion to sedimentary features that are distinctively different from what we would expect from erosion of a non-cohesive substrate. On modern tidal sand flats, local erosion of the mat-bound surface exposes underlying sand to wave and current action and leads to rippled patches in an otherwise smooth surface (Reineck, 1979; Gerdes et al., 1985). More extensive erosion can also lead to erosional remnants (equivalent to a mesa or inselberg) of a mat-bound surface that are surrounded by rippled sand (Gerdes and Krumbein, 1987).

Figure 7(i)-2 shows examples of ripple patches from the Dakota Sandstone that are probably among the closest match to mat-erosive ripple patches in modern settings, such as at Mellum. Figure 7(i)-2A, -2B and -2C show variously magnified views of what is interpreted as erosive ripple patches on a microbially bound sand surface. The way in which the rippled surfaces and their ripple crests blend into the edges of the smooth surface surrounding the ripple patches (Fig 7(i)-2B, -2C) is a good indication that the

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rippled erosive “pockets” formed after the flat non-rippled surface (Reineck, 1979). From a distance (Fig. 7(i)-2A) the outcrop first gives the appearance that the rippled surfaces may belong to a lower-lying bedding plane and have been revealed because pieces of the upper layer weathered out. Such a mode of origin, however, would give rise to sharp steps between upper and lower layers (Fig 7(i)-2D). Thus, the smooth transition between ripple patches and the surrounding surface is a key observation that indicates that the ripple patches were eroded into an originally mat-bound surface.

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Figures and Captions: Chapter 7(i)

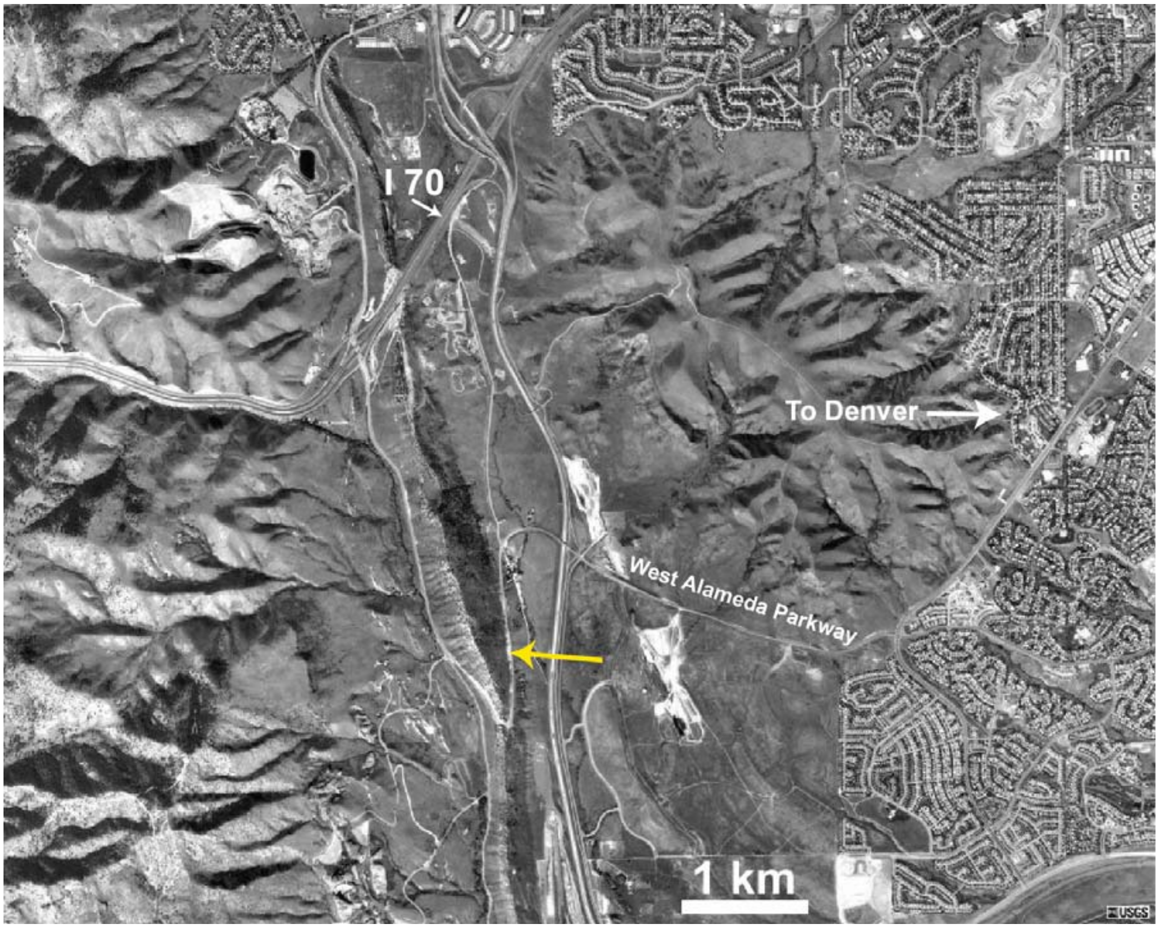

Figure 7(i)-1: Location of outcrop pictured in Fig. 7(i)-2:

The outcrop is located on the east side of the Dakota hogback along West Alameda Parkway (yellow arrow). It is easily reached by heading south from interstate I-70. The outcrop coordinates are 39^{o} 40’ 48” N and 105^{o} 11’ 32” W.

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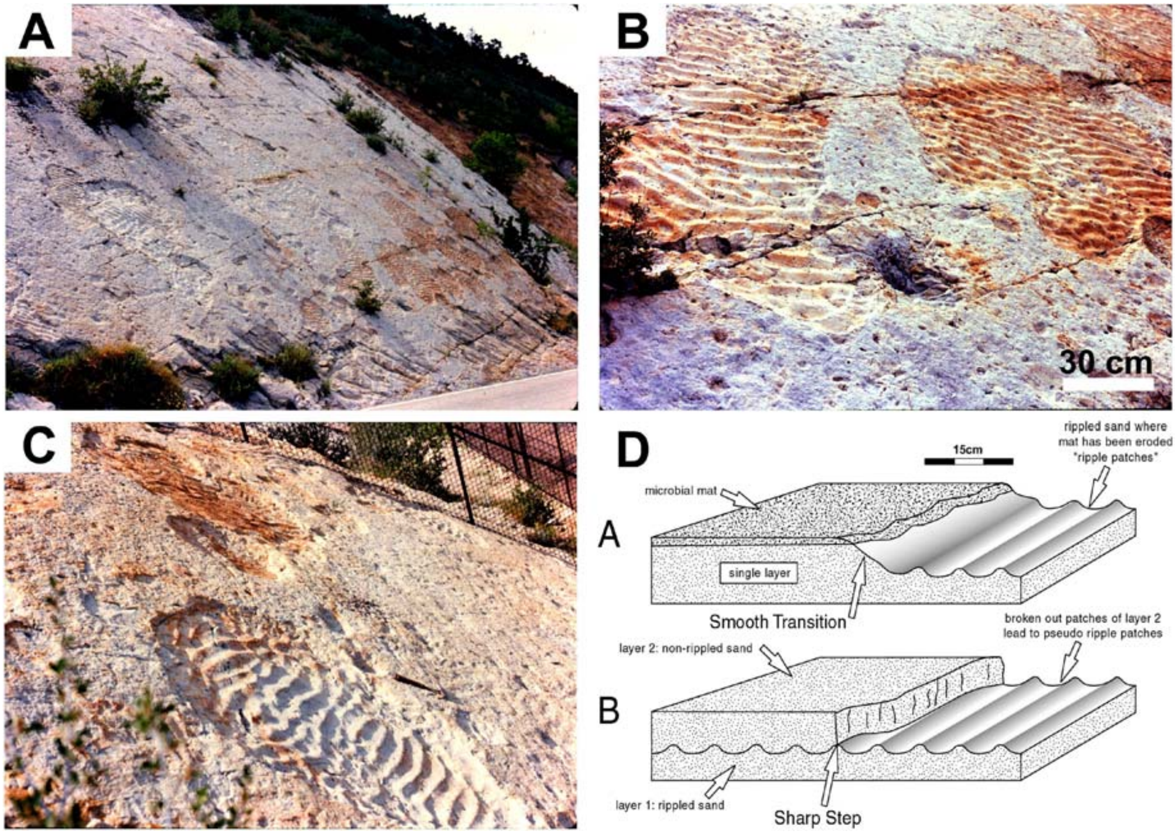

Fig 7(i)-2: Upper third of the Dakota Sandstone west of Denver, showing ripple patches:

(A) Road cut in the Dakota Sandstone along West Alameda Parkway, Denver, Colorado, USA. Sandstone beds dip steeply to the right and ripple patches are clearly visible. On the right side of the image ripple patches are accentuated by reddish brown colouration (probably a result of pre-roadcut outcrop weathering). Ripple patches measure from some decimetres to as much as two metres across. (B) Close-up of ripple patches from (A). Note symmetrical nature of ripples, straight ripple crests, and tuning-fork splits of ripple crests. Collectively these features indicate a wave action origin (Reineck and Singh, 1980). Spacing of ripple crests is approximately ten centimetres. (C) Oblique close-up of another ripple patch from (A). Shows smooth transition between ripples in the erosive “pocket” and the surrounding non-rippled surface. This smooth transition has also been documented from modern counterparts (Reineck, 1979). Hammer (32 cm long) for scale. (D) Sketch that illustrates the morphological difference between erosive ripple patches and rippled layers that are seen because pieces of an overlying layer broke out during weathering and erosion. The smooth transition between the purported mat surface and the rippled sand surface in the erosive patch indicates that the rippled surface formed later than the presumably mat-bound flat surface. A sharp break between non-rippled surface and ripple patch strongly suggests that the lower rippled layer is older than the non-rippled surface.

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