Eolian and Subaqueous Sedimentary Structures of the Devils Island Sandstone Sand Island, Wisconsin (U. S. A.)

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Abstract

The Devils Island Sandstone, Northern Wisconsin, U. S. A., is a supermature quartz arenite (99% quartz). The depositional environments of rift sediments like the Devils Island Sandstone are not well understood. This study describes sedimentary structures in a ~5 m thick interval of outcrop observed on Sand Island, Wisconsin. The observed sedimentary structures are dune-scale sets of eolian cross-strata, mm pinstripe-lamination, grain flows, adhesion structures, subaqueous ripples, a pustular algal mat, m-scale trough cross-stratification, pinstriped intraclasts, and soft sediment deformation. The studied interval within the Devils Island Sandstone is dominated by eolian strata, but exhibits at least one subaqueous stratigraphic layer. These two types of deposits are interpreted to represent a depositional environment in a barchan dune field subject to occasional flooding and reworking by ephemeral braided streams. The aqueous environments, called wadis, formed under the influence of possibly complex climatic factors operating across a range of timescales, likely including fluctuations in rainfall, atmospheric moisture, and water table elevation.

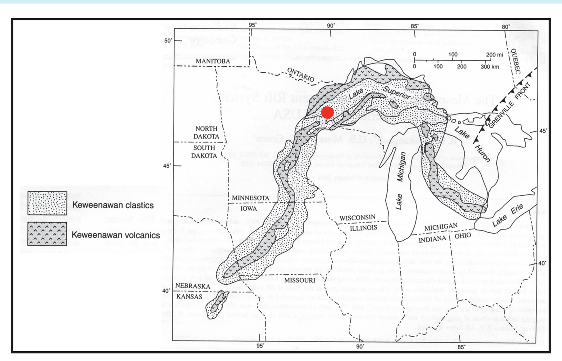

Figure 1. Geologic map of the Mid-Continent Rift System, showing the distribution of volcanic and sedimentary rock broadly. Study area is designated with a red circle. Modified from Ojakangas et al. (2001).

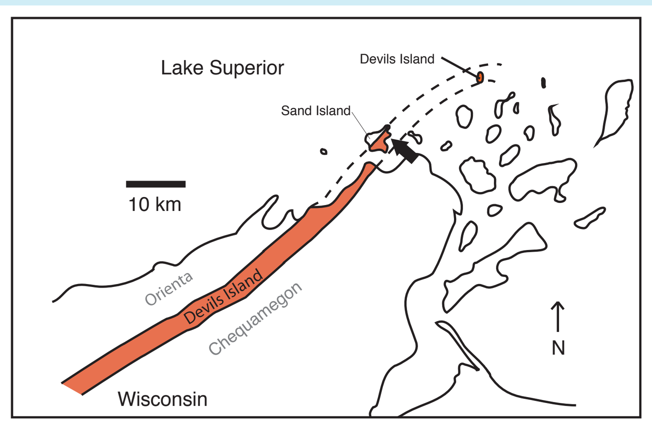

Figure 2. The narrow belt of Devils Island Sandstone outcrop is shaded in orange. Black arrow points to study area. Modified from Adamson (1997).

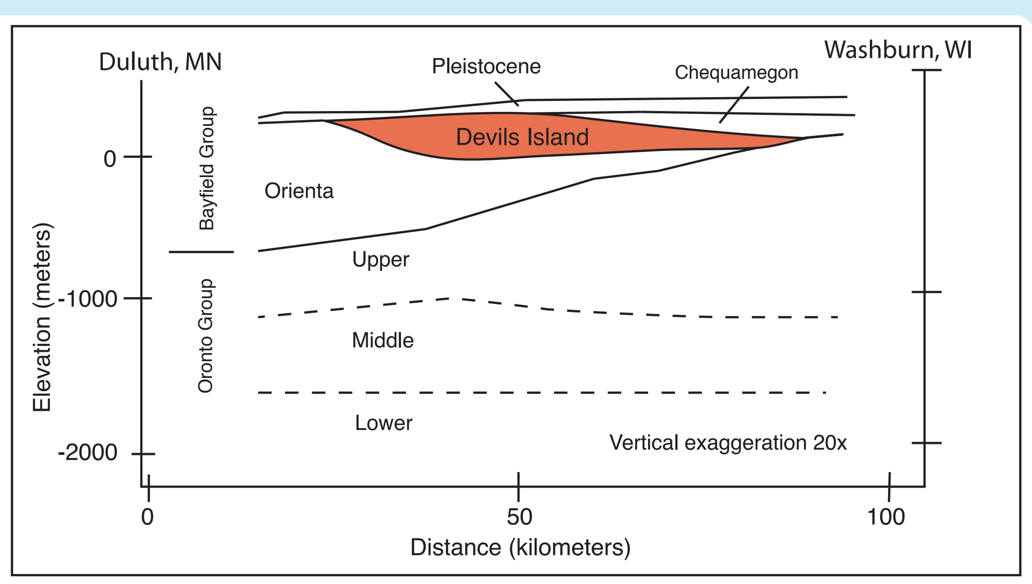

Figure 3. Regional stratigraphy of the Bayfield and Oronto Groups along an East-West transect from Duluth, MN to Washburn, WI. Adapted from Morey and Ojakangas (1982).

Geologic Setting

Alternating basalts and rhyolites were extruded during the ~1,100 Ma formation of the Mid-Continent Rift, and the Oronto Group and Bayfield Group sandstones were subsequently deposited in a subsiding axial basin (Fig. 1; Ojakangas et al., 2001; Cannon, 2005). The Bayfield Group is divided, in ascending order, into the Orienta Sandstone, Devils Island Sandstone, and Chequamegan Sandstone (Fig. 3; Morey and Ojakangas, 1982). The Devils Island Sandstone has been subject to various paleoenvironmental interpretations, including lacustrine, fluvial, and braided stream deposits (Johnson et al., 2001; Galston et al., 2008; Ojakangas and Morey, 1982).

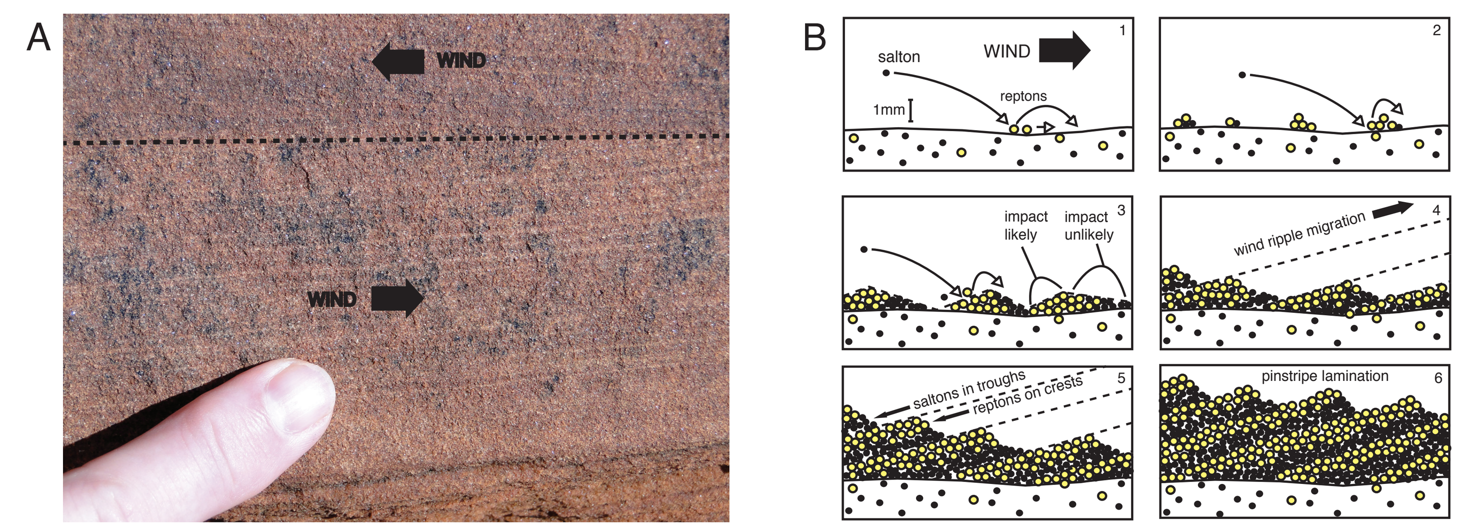

Figure 4. Photograph A is eolian pinstripe lamination with finger for scale. Note two different wind directions are preserved in this rock. B depicts the process of forming pinstripe lamination through climbing wind ripple migration. In time 1, small airborne grains impact larger grains, forming microtopography in time 2. In 3 grains start to organize into ripples due to fewer impacts on lee surfaces. In time 4 and 5, wind ripples migrate downwind, small grains tending to deposit in ripple troughs while large grains deposit on crests. 6 is the pinstripe lamination left behind wind ripples (compare to bottom section of A, where wind blew left to right).

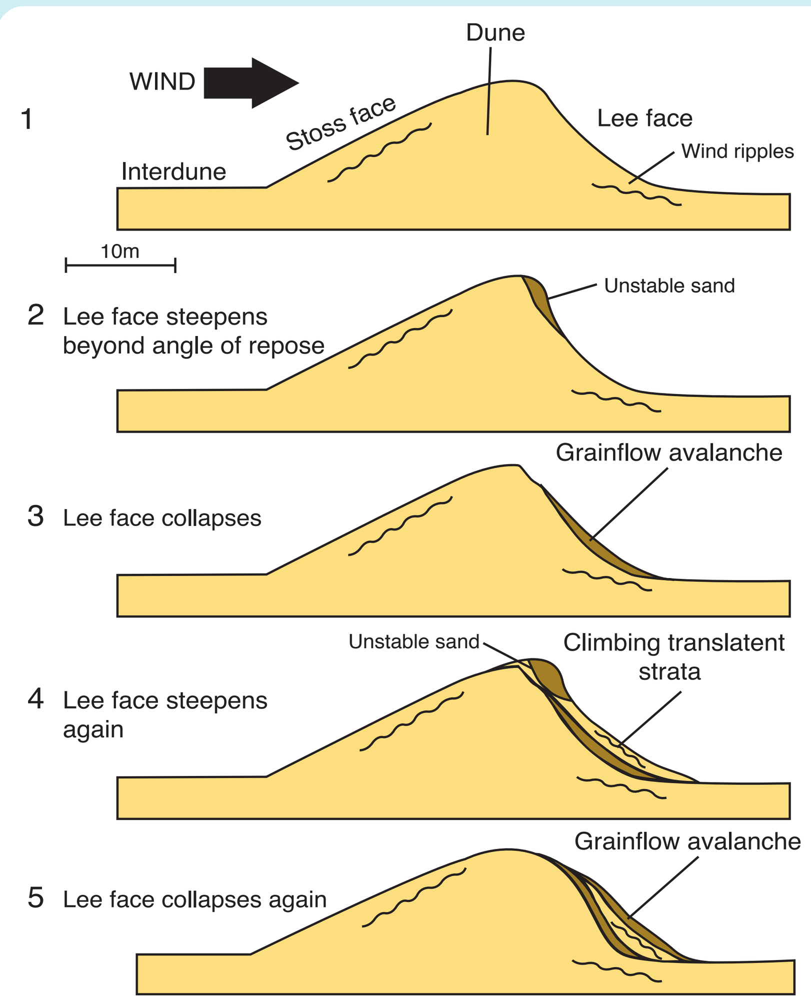

Figure 5. Cartoon illustrating the deposition of unstratified sand wedges. In panel 2 the lee face of the dune steepens past the angle of repose. The sand near the top of the lee is unstable and prone to avalanching. Panel 3 shows the resultant grainflow in darker brown. In panel 4 downwind dune migration and steepening of the lee face continue as climbing translatent strata are deposited over the unstratified grainflow. Panel 5 shows another grainflow avalanche, and depicts the interbedded tongues of unstratified sand (brown) and pinstripe lamination (tan) deposited by Devils Island Formation dunes.

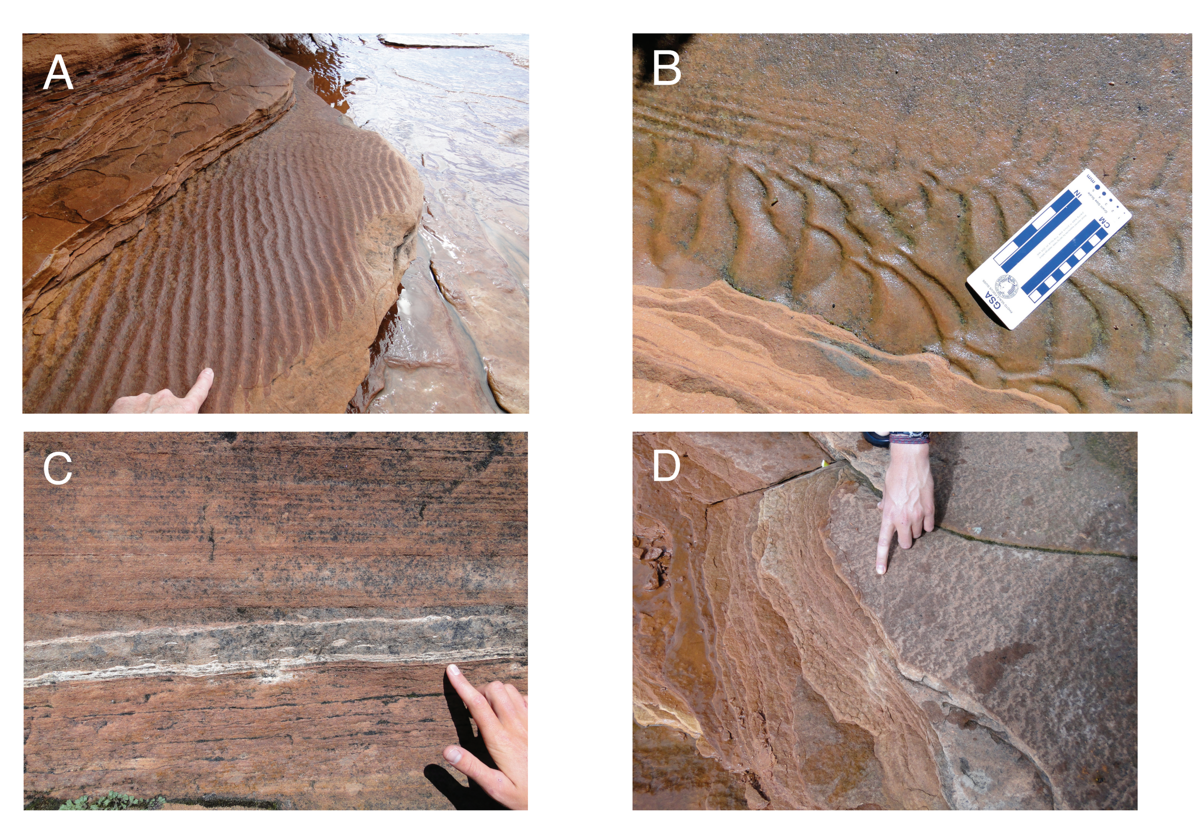

Figure 6. A shows wave ripples. B shows current-modified or current ripples with multiple flow directions. C shows Facies 2, the intraclast bearing channel deposit. D shows adhesion structures with hand for scale.

Discussion of the Paleoenvironment

Eolian subcritically climbing translatent strata, grainflow deposits, and adhesion structures make up most of the study area outcrop, so the majority of Devils Island Sandstone deposition must have occurred in dry to damp conditions. The remainder of the study area consists of subaqueous features such as wave and current ripples, intraclasts, and trough cross-stratification. These were deposited in ephemeral ponds, pools, and stream channels that formed in interdune areas when water was introduced to the system.

The amount of water present determined depositional processes, and could have fluctuated on multiple timescales due to the complex interplay of many factors. Water in the Devils Island system could have varied depending on rainfall events, fog or atmospheric moisture, fluctuations in the water table, seasonal variance in precipitation, annual weather changes (el Niño), or long term climatic changes.

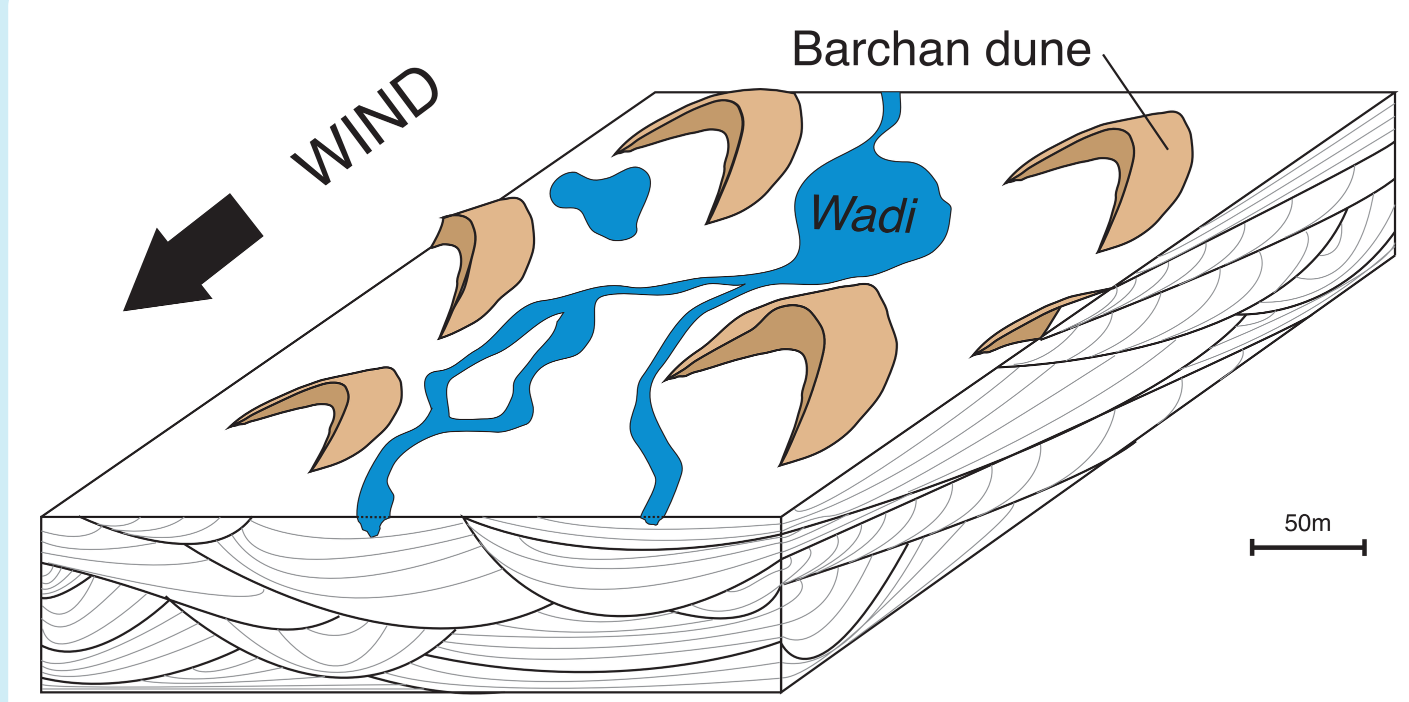

Figure 7. 3-D block diagram of the Devils Island Sandstone paleoenvironment. A series of barchan dunes is migrating downwind, leaving behind Facies 1 eolian sets visible in cross section. Occasionally, wadis (illustrated here in blue) flow through the interdune area, forming the subaqueous features of Facies 2 in stream or pond environments.

Conclusions

The observed sedimentary structures indicate eolian dune and interdune deposits interbedded with ephemeral braided stream sediments (Fig. 7). The Devils Island barchan dune field was occasionally inundated by wadis and ephemeral pools that formed under the influence of variable timescale fluctuations in rainfall, atmospheric moisture, and water table height.

Acknowledgements

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