Discussion of “Palaeoclimatic significance of co-occurring wind- and water-induced sedimentary structures in the last-interglacial coastal deposits from Bermuda and the Bahamas”
(Kindler and Strasser, 2000, Sedimentary Geology, 131, 1–7)

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Abstract

Kindler and Strasser [Sediment. Geol. 131 (2000) 1] have identified sedimentary structures of possible aeolian origin within the chevron ridges of north Eleuthera, thereby proposing that they are migrating parabolic dunes formed by wind rather than the impact of giant waves, as postulated by Hearty et al. [Quat. Res. 50 (1998) 309]. However, the abundance of beach fenestrae and the conspicuous absence of foreset bedding throughout the chevron structures invalidate their conclusions. In addition, enormous “megaboulders” situated between the two Kindler and Strasser (2000) study sites in north Eleuthera confirm the occurrence of giant waves at the end of marine isotope substage (MIS) 5e, and argue strongly the same genesis for the chevron ridges and runup deposits. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Kindler and Strasser (2000) have identified sedimentary structures of presumed aeolian origin within the water-laid deposits of chevron-shaped landforms in the Bahamas, as described by Hearty et al. (1998).

These structures, which they categorize as “subcritically climbing translatent stratification” or “SCTS” (Hunter, 1977), may be wind-generated, thus indicating that the wind was blowing during the formation of the chevron ridges. On the basis of SCTS identification at three sites (one in Bermuda; two in Eleuthera, Bahamas), they state that the chevron ridges must be wind-deposited parabolic dunes rather than wave-deposited beach ridges.

In order for Kindler and Strasser (2000) to support a wind origin of the chevron ridges, serious revisions of known dune-forming processes and palaeoclimate
are required: existing climatic gradients must be inverted; Saharan droughts are interspersed with Amazonian downpours; a process of “rainwater-induced fenestrae” is invented to explain the abundance of hydrogenic structures in the chevrons; dunes must climb hillsides while drenched in sediment slurries; and coastal carbonate parabolic dunes must migrate where they never did before or since.

2. Microscopic vision

2.1. STCS

At best, the SCTS structures Kindler and Strasser (2000) describe are polygenetic; therefore, ancient environments of deposition should be interpreted with caution. Kindler and Strasser emphasize that the fine laminations, interbedded with fenestrae-rich zones, must be exclusively of wind origin. Beaches (and chevron ridges and wave runup deposits) composed of fine sand also produce finely laminated, inversely graded bedding (Fig. 1A). Further, dunes composed of very coarse sand form thick, tabular, slab-like aeolian laminations of centimeter to decimeter scale under high-energy conditions, such as those at found at The Cliffs on north Eleuthera (Fig. 1B). Therefore, the scale of laminations is not an adequate criterion with which to distinguish the origin of beds created either by the migration of ripples, or the swash of waves.

2.2. Migrating parabolic and climbing dunes

2.2.1. The present is not the key to the past

Kindler and Strasser (2000) create migrating parabolic dunes in a region where none existed before or since MIS 5e. There are no migrating parabolic dunes composed of carbonate sand in the Bahamas (even in the arid and windy southern islands) or anywhere else in the Caribbean, despite abundant sediment sources and perpetually strong trade winds. The coastal parabolic dunes reported by Pye (1993) are siliciclastic. Coastal carbonate dunes exhibit radical differences in their “behaviour” when compared to siliciclastic dunes, mainly due to their predisposition for rapid cementation. Coastal carbonate dunes may accrete or expand, but they do not migrate. Migrating carbonate dunes are found only in the most extreme, driest interior regions of the world (McKee and Ward, 1983).

2.2.2. An unclear palaeoclimatic picture

To allow for migrating parabolic dunes and to explain the presence of SCTS wind laminations, Kindler and Strasser (2000) invoke a dramatic increase in the aridity of the northern Bahamas, in essence reversing the current climatic regime. They then envision “wave splashing or heavy rainfall” that floods the migrating(?) dunes in order to form the beach fenestrae.

Based on a cm-scale sequence of alternating fine laminations and beach fenestrae (e.g., Fig. 7 of Hearty et al., 1998), which are generally formed by the flooding of dry sand by sheets of water in the
intertidal zone (Dunham, 1970), they paint a palaeo-climatic picture of bizarre weather, frequently oscillating between drought and downpours. One would imagine that extreme aridity and the absence of vegetation would be prerequisites for coastal carbonate dunes to migrate 3–10 km across the lowland Bahama Islands over a 500–5000-year period, as they propose. Yet, considering the torrential downpours required to explain the interbedded rain-induced “beach bubbles” in subaerially exposed carbonate sediments in a subtropical climate, it seems certain that vegetation would grow, and cementation would occur with remarkable speed by meteoric diagenesis (Dravis, 1996), thus preventing dune migration.

2.2.3. Where are the foreset beds?

If migratory, parabolic dunes should reveal predominantly foreset beds in cross-section (Hunter, 1977). These steeply inclined strata express the mechanism of grain migration like the angular motion of a forward-moving tank tread. Dune migration occurs as a result of the wind erosion and downwind movement of the topset beds (including SCTS), deposition of the foreset beds near the angle of repose, and the advance of the foreset beds over the bottomset beds (Fig. 2A).

Unlike parabolic dunes, the internal structure of chevron ridges shows a vertical and, in some cases, slightly seaward growth vector by marine progradation (Fig. 2B) generated by the upward accretion of low-angle fenestrae-filled tabular bedding. Foreset bedding of any size or significance is largely absent from chevron ridges or runup deposits. Thus, it is difficult to invoke parabolic dune migration when the most fundamental diagnostic evidence of migration is missing from the picture.

2.2.4. Wave runup vs. climbing dunes

In areas of older built-up shore-parallel ridges, deposits consisting of fenestrae-filled, seaward-dipping tabular beds with lenses of pebbles, plant morphs, and landsnails rise to over +25 m (Hearty et al., 1998). Deep planar scour surfaces, like that in Blackwatch Pass, Bermuda (Kindler and Strasser’s (2000) Fig. 3; 50 cm above geologist’s head), and Old Land, Great Exuma (Figs. 7 and 8 in Hearty et al., 1998) truncate older aeolian deposits, while water flow and ripup structures are preserved among fenestrae-rich bedding above the scour surfaces.

Kindler and Strasser (2000) propose that these deposits are climbing aeolian dunes, which create many problems of interpretation. First, predominantly seaward-dipping tabular beds at and above +25 m are filled with cm-scale interbeds of fenestrae that bear a striking resemblance to those on modern beaches (Fig. 3A and B). In order to produce fenestrae, the dry sediments must be flooded by sheets of water. Sheet flow on seaward slopes would imply by the law of gravity that significant down slope transport of sediments should occur. Is it then possible for dry sand to climb the hillside by the wind while being swept down slope by torrents of water?

Second, climbing dunes supplied by the beach are, by their nature, depositional. It seems improbable that a depositional process such as climbing dunes could so deeply and evenly scar the hillside, leaving no foreset beds but only bubble-filled beds as evidence of
their passing. Kindler and Strasser (2000) argue that “runup deposits...compare well with swash-ramp characteristics, but also evoke climbing (aeolian) dunes”. To “evoke” a similarity is not to prove a causal link.

3. Rain-induced fenestrae (or RIF)

Kindler (1991) and Bain and Kindler (1994) introduced the possibility that fenestrae in the chevron ridges could be produced by the action of heavy downpours on dune surfaces. Kindler and Strasser (2000) reiterate this “hypothesis without data” to support parabolic dune migration, and to negate the wave-generation of chevron ridges. Their apparent logic is that if rainfall can produce fenestrae, then chevron ridges must have been formed by wind.

Previous researchers have attributed beach fenestrae (“beach bubbles, keystone vugs, birdseyes”) to the flooding action of waves over dry sand (e.g., Dunham, 1970; Shinn, 1983). Additional problems with the RIF hypothesis include the following.

(1) If rainfall was indeed an important process in the fabrication of fenestrae in dunes, as proposed by Bain and Kindler (1994), then one would expect to find RIF at high elevations in all sides of all dunes of all ages, since one can safely assume that heavy rainfall occurred with annual regularity in the Bahamas. Preserved rain-induced fenestrae have never been described in modern sand dunes, nor unequivocally linked to heavy natural downpours. In contrast, abundant beach fenestrae can be exposed in any swash zone of almost any sandy beach simply by digging a hole.

In north Eleuthera, middle Pleistocene deposits with beach fenestrae, mentioned by Kindler and Strasser (2000), are directly tied to a +20-m sea level at the end of MIS 11 (Hearty et al., 1999), and not to rainfall. The abundance of fenestrae associated with these and coeval deposits at lower levels are relicts of turbulent seas and washovers that occurred during the...
retreat of the sea from MIS 11 highstand. The fossil examples of interpreted rain-induced fenestrae in coastal dune sites identified by Kindler and Strasser in Mallorca and Australia stand an equally great chance of being generated by large waves.

(2) We reject as invalid Bain and Kindler’s (1994) supportive experimentation performed to test the rainfall hypothesis. Applying 40 l (buckets) of glue-saturated water on the top of dune sand more closely resembles wave flooding rather than rainfall.

We conclude that the RIF hypothesis is at best an obscure and remote process that cannot be documented by geological data, or by direct observation in modern environments.

4. Geological evidence unified by one process

Hearty et al. (1998) and Hearty (1997) have presented several clear lines of evidence demonstrating that the Bahamas were struck by giant waves near the end of the last interglaciation. The effect of the impact of these waves was felt in different ways along the changing topography of the coastlines. At tidal passes or gaps in the coastal dunes, waves surged several kilometers landward, leaving chevron-shaped ridges constructed within by aggradational and progradational bedding and abundant beach fenestrae. On coastlines with a developed coastal ridge, waves ran up to over +40-m elevation, leaving typical swash

Fig. 5. Tormey’s (1999) frequency plots of measured MIS 5e aeolian, chevron, and beach bedding characteristics comparing: (A) percent of fenestrae beds; (B) average inclination of bedding; and (C) bedding plane frequency. The data prove an unambiguous positive correlation of chevron bedding with beach bedding, and no correlation of chevron bedding with aeolian bedding.
bedding filled with beach fenestrae, evidence of scour, and pebble and rubble zones. On clifed coastlines, the impact of giant waves tore lose megaclasts, heaving them onto and over 20-m-high ridges, and up to 0.5-km inland. The boulders (Fig. 4) deposited by giant waves at the end of MIS 5e are located within 4–10 km between both of Kindler and Strasser’s (2000) study sites in Eleuthera.

The deposition of giant boulders by waves (Hearty, 1997) at the end of MIS 5e is one of several key arguments used by Hearty et al. (1998) to establish a causal link among the variety of late MIS 5e landforms. Unfortunately, Kindler and Strasser (2000) avoided this essential element of the discussion. The occurrence of SCTS, if indeed wind-formed laminations, might suggest that the wind was blowing before, during, and/or after the impact of the waves. Megaboulder 2 (Fig. 4), a 600-ton boulder situated at the crest of a 20-m cliff (Hearty, 1997), overlies late MIS 5e deposits that contain storm-deposited, fenestrae-rich washover and finely laminated bedding, perhaps SCTS. Thus, does the presence of SCTS, by its association with Boulder 2, imply that Boulder 2 and several other neighboring 100s to 1000-ton boulders were also deposited by wind?

In a recent study by Tormey (1999), an analysis was made of the sedimentary structures of typical beach and dune deposits in north Eleuthera. The results were then compared to the sedimentary structures of chevron ridge deposits at two sites in north Eleuthera (EAJ and ELI). The study indicated unequivocally that bedding in the chevrons is most similar to typical beach deposits at Boiling Hole (Kindler and Hearty, 1995). In categories of percentage of fenestral beds, inclination of bedding, and bedding plane frequency (Fig. 5), chevron deposits were unanimously tied to wave-generated swash-zone bedding rather than with aeolian bedforms (Tormey, 1999; Tormey et al., 1999).

5. Summary and conclusions

Kindler and Strasser (2000) have assembled a random and unrelated collection of scenarios to independently explain each of the selected features associated with chevrons, while disregarding other crucial elements. They argue that the chevron ridges were not formed by waves on the basis of: (1) sedimentary structures (SCTS) of uncertain, or polygenetic origin; (2) migrating parabolic dunes, which are not known in carbonate sediments on any tropical coastlines of the world today; (3) rain-induced fenestrae, which were apparently not induced in any Holocene dune deposits in the Bahamas or elsewhere; (4) inverted climatic gradients; and (5) a palaeoclimate which alternated between extreme aridity and torrential downpours.

Along the Atlantic-margin Bahama Islands, a remarkable array of geomorphic and geologic features was generated, not by wind, but by giant waves that spilled across lowland platforms to form V-shaped chevron ridges, ran up on older coastal dunes, and catapulted 1000-ton boulders over clifed coastlines. The megaboulders alone provide indisputable evidence of the wave impact. In addition, while remaining faithful to the Law of Parsimony, the ample evidence surrounding the chevron ridges and runup deposits provides an equally powerful argument for the occurrence of giant waves at the end of MIS 5e.

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