SHORT COMMUNICATION

CRESCENTIC DUNES AT SCHIERMONNIKOOG, THE NETHERLANDS

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Received 23 July 1996; Revised 4 February 1997; Accepted 4 March 1997

ABSTRACT

This paper describes the appearance and maintenance of crescentic dunes in high wind speed conditions on a frozen beach at Schiermonnikoog, The Netherlands. The dunes were crescentic forms with horns. They were barchanoidal in plan view, but had reverse morphologies to typical barchans: the highest and steepest slopes were upwind and led to long low slopes downwind. Slipfaces were absent. It is hypothesized that such crescentic dunes may be a stable aerodynamic form under high to very high (*c*.15–20 m s^{-1}) flow conditions. © 1997 by John Wiley & Sons, Ltd.

Earth surf. process. landforms, **22,** 785–788 (1997)
No. of figures: 2 No. of tables: 0 No. of refs: 10
KEY WORDS: crescentic dunes; barchans; dune morphology; sand transport

INTRODUCTION

Cooke *et al*. (1993) define a barchan as 'a crescentic dune isolated on a firm coherent basement such as sabkha, pediment or desert pavement' (p. 371). The dunes are typically crescentic in shape, terminating downwind with horns or wings. A slipface is usually formed around the downwind edge of the dune. The term has been variously spelt barcan, barchane, barkan and barkhan (Glenn, 1979).

Barchans have been observed to develop in virtually all latitudes and in most coastal and desert regions (e.g. Beadnell, 1910; Bagnold, 1941; Walker and Matsukura, 1979). They may arise virtually spontaneously from the bed, evolve from dome dunes (e.g. Hastings, 1994), or from other proto-dune forms (Kokurek *et al*., 1992), and they may evolve into linear and transverse dunes (Bagnold, 1941; Tsoar, 1984).

In this paper we briefly describe the existence and maintenance (a day at least) of some unusual crescentic dunes on a frozen beach at Schiermonnikoog in The Netherlands. These crescentic dunes displayed a markedly aerodynamic shape, and had a plan view similar to that of barchans, but their morphology was the *reverse* of that for typical barchans.

THE ENVIRONMENT

Schiermonnikoog is the northeasternmost barrier island in The Netherlands, located at latitude 53·5° and longitude 5·9°. The beach is modally dissipative, wide and flat (gradient 1:500). The spring tidal range is 2 m. Mean sand grain size is 2·54ϕ and sorting is 0·21ϕ, which is very well sorted (Arens, 1994).

The winter of 1996 was very cold in The Netherlands. Low temperatures below freezing accompanied by winds from easterly directions had prevailed for the previous weeks in the region. The nearshore and surfzone of the adjacent North Sea was frozen and ice push ridges were present along the intertidal area. Normal tide and wave activity was suppressed. The beach was very wide (approximately 600 m) and frozen. The surface was covered with coarse granules and shell debris, across which fine sand was in motion.

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CCC 0197-9337/97/080785–04 $17.50

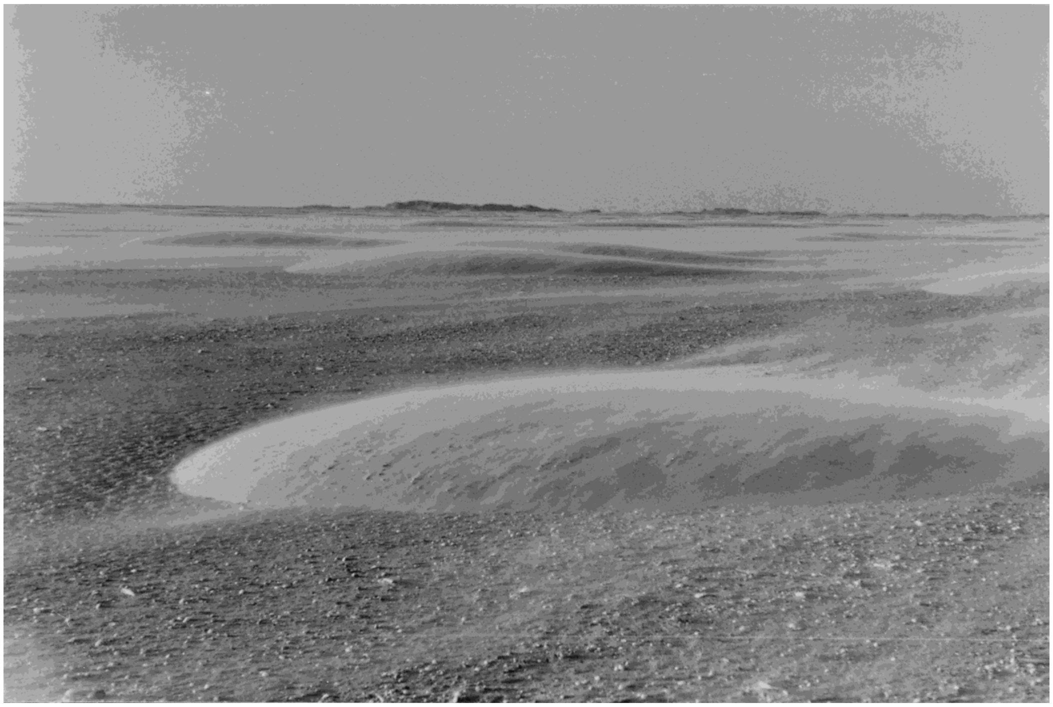

Figure 1. Oblique view of the upwind portion of a crescentic dune migrating across a frozen beach. Note the strongly streamlined asymmetric form

Figure 2. Oblique view of a crescentic dune illustrating the crescentic barchanoidal plan shape, steep asymmetric windward slope, low, long leeward slope, straight-crested normal ripples, and dune horns

On the day of observation, 25 January 1996, a forecast force 8 easterly gale was blowing directly alongshore. Wind speeds at ground level were visually estimated at 15 to 18 m s^{-1} based on observations of sand transport and the wind streamlining of vegetation. The measured temperature at 1 m height was –10°C.

MORPHOLOGY AND DYNAMICS OF THE CRESCENTIC DUNES

Hundreds of crescentic dunes, and a few sinuous transverse dunes and barchans, were distributed across the wide beach. Most of the crescentic dunes were relatively small, being, on average, 3 m wide across the outside edges of the horns, and 3 to 5 m long on the downwind axis from upwind toe to tips of horns. All were less than 1 m high and most ranged from 0·3 to 0·6 m high at the highest portion.

Dune morphology was highly asymmetric. The upwind margin formed the highest part of the dune, displaying a convex form rising rapidly from the beach base level and reaching a maximum dune height within a metre downwind on the larger dunes (Figure 1), and within 20 to 50 cm downwind on the smaller dunes (Figure 2). The convex form decreased in height downwind to a leading edge which was relatively straight and normal to the wind direction.

No slipfaces were present and none could be seen to be forming. The dunes had well developed horns (or wings) but these were very thin and narrowed to fine apexes. The dunes displayed somewhat similar morphologies to the 'wind ripple proto-dunes' described by Kocurek *et al*. (1992), although their dunes were less asymmetric than these.

Of particular interest was the orientation and presence of ripples (Figure 2). As Figure 2 indicates, the ripples were straight-crested and normal to the direction of wind flow. They were very slightly slanted inwards on some horns (see the right-hand horn in figure 3), but this was less common. Typical barchans have ripples which tend to follow the contours of the dune somewhat more closely. In addition, fully developed barchans do not have ripples on the slipface or generally along the inside slopes of the horns.

The crescentic dunes were rapidly migrating downwind, maintaining their shapes and ripple orientations. Because the environmental conditions were severe, we were only able to periodically monitor the dunes for three hours. During this time we saw no evidence of change towards a more typical barchan shape.

FORMATION AND MAINTENANCE

The crescentic dunes may have initially been transformed from typical barchans, which are a common feature in winter time on the wide beaches of the Wadden Islands (Arens, 1994). Typical barchans in these environments only form during dry, easterly winds, with usually less extreme wind speeds, up to 12 m s^{-1}. Those conditions generally occur in winter time during periods of high pressure. Possibly the crescentic dunes are modified by erosion of partially or completely frozen former barchans. There were eroding, degraded and frozen dune forms on the upper part of the beach in places. However, none of the bodies of any of the few crescentic dunes we examined had cores or frozen upwind slopes.

Alternatively, the crescentic dunes may have developed as dome dunes (or as proto-dome dunes) and have been in a transitional stage between dome and barchan as described by Hastings (1994) and Kocurek *et al*. (1992). Observations of the evolution of domes to barchans in Namibia indicates that dome dunes tend to extend or elongate downwind, forming an asymmetric dune morphology characterized by a short, higher convex upwind slope and a long, slightly convex downwind slope. The highest segment of the dome dune gradually migrates downwind as the dune evolves from an asymmetric (upwind) domal morphology towards an asymmetric (downwind) barchanoidal morphology with attendant slipface.

However, while the crescentic dunes may have been evolving towards the classic barchan form, we saw little evidence of this in the field, and the dunes were able to maintain their morphology during migration. This may have been due to the high speed flow conditions prevailing at the time. The crescentic dunes were describing a fundamental wing shape with a higher, curved leading edge and a long, smooth, trailing leeslope on which there was no flow separation (as indicated by the ripples presence and orientation). The dunes had features in common with many other streamlined landforms including drumlins, yardangs and mid-channel islands, but these latter features tend to be formed in materials with non-mobile beds, or where obstructions occur or the channel morphology changes.

The crescentic dune morphology seen here would be the expected streamlined form in conditions where the bed is not easily erodible or mobile. The evolution to a typical barchan form takes place because the bed is erodible and flow deceleration and eventual separation occur, leading to the formation of a slipface. Perhaps under such strong flow conditions the crescentic dune form seen at Schiermonnikoog is acting like an aerofoil, which is the smoothest form aerodynamically and can be maintained as long as wind speeds remain high. Because of the high wind speed, grain trajectories are probably much longer than under moderate conditions; the dimensions of a potential slipface are small compared to the distance over which a grain is transported and deposited (cf. Anderson, 1988). In other words, the adaptation length for sand transport is so large that no slipface can be formed or maintained. The result is that the trajectory length of most grains is long, and they easily pass the region that a slipface may form within. The steep upwind dune slope is a stable, but erosional form. Because of the high wind speed and surrounding frozen surface conditions, the wind flow on the beach is unsaturated. When the flow passes the dune form, transport suddenly increases because of the presence of a loose sand bed and thus the upwind part of the slope is eroded, while the actual form is maintained.

ACKNOWLEDGEMENTS

Patrick Hesp gratefully acknowledges the support of the Department of Geography and Soil Science at the University of Amsterdam. We thank Kathleen Hastings, Michael Osborne and Anne-Frédérique Deiller for their company in the field, Dr John McArthur (Massey University), Dr John van Boxel (University of Amsterdam), Dr Tom Spencer (Cambridge University) and an anonymous referee for their critiques of this paper. We particularly wish to thank Cor Visser and Melle Blom of the Rijkwaterstaat for saving us from frostbite and hypothermia.

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