Barchan Dunes: Walvis Bay and on the Skeleton Coast

17

Abstract
Barchans are mobile crescentic dunes that form transverse to the wind. Barchans have a range of forms from slim to pudgy and are found in areas with limited sand supply and narrowly bimodal winds. Near Walvis Bay there are particularly good examples, formed by winds coming from the south west. Long term studies, using air photographs, show that these dunes can move at rates of some metres per year. Large sand ripples are also found on some of the coastal dunes between Walvis Bay and Swakopmund.

Barchans are individual mobile dunes of crescentic shape, the two horns of which face in the direction of dune movement. Sand avalanching takes place on their lee sides. They are generally regarded as occurring in areas of limited sand supply, on planar surfaces, with a low precipitation (usually less than 100 mm per annum) and vegetation cover, and where winds are narrowly bimodal in direction (with a directional index that is normally around 0.7–0.9). At a global scale they are quantitatively of limited significance—less than 1 % of all dune sand on Earth is contained within them—but they can be locally dominant, as is the case in some parts of the coastal Namib Desert. They are variable in size, ranging in height from a few metres to over 500 m in the case of megabarchanoids (Bishop 2010).

Bourke and Goudie (2009) compared the shapes of barchans in the Namib and on Mars and developed the following classification scheme:

Classic symmetrical barchans—slim. The simplest form of barchan is the classic individual crescentic feature. Some of these are elegantly slim as shown by examples on the rocky plains to the south and east of Lüderitz and Elizabeth Bay (Fig. 17.1). They also appear to be rather angular in plan. They display a wide range of sizes, with some having widths as great as 500–600 m, and some being only a few tens of metres in width. The slim symmetrical type of barchans is a feature of areas with unidirectional winds and with low sand influx and high values for shear velocity (Parteli et al. 2007).

Classic symmetrical barchans—pudgy and fat. Some simple crescentic forms possess a larger area in relation to their width than the examples given above. The horns are relatively small in relation to the total mass of the dune and may be nearly absent. Such dunes have shapes reminiscent of kidneys, broad beans and pectens. Fat dunes occur in areas where there is a substantial sand influx and lower shear velocities (Parteli et al. 2007). Many of the world's barchans described in the literature appear to be fat rather than slim, and this is the shape of many of the barchans in the Kuiseb delta area (Barnes, 2001).

Classic symmetrical barchans—large, fat and unstable. Some barchans are large features, which may be termed mega-barchans. Over 500 m in width, they often have secondary features on their flanks, which may be indicative of instability. They may also shed small barchans onto the desert plains downwind. This appears to be an example of what Elbelrhiti et al. (2005) describe as 'surface-wave-induced instability'. They argue that dune collisions and changes in wind direction destabilize larger dunes and generate surface waves on their lee flanks. The resulting surface waves propagate at a higher speed than the dunes themselves, producing a series of small, new born barchans by breaking the horns of large dunes. This type of barchans can be seen near the Walvis Bay salt works.

Classic symmetrical barchans composed of smaller barchans. In southern Namibia a single classic barchan form some 400 m across and 700 m long that is predominantly

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Fig. 17.1 Google Earth image of slim barchans near Elizabeth Bay. Scale bar 0.5 km. (© 2012 Google Image, Digital Globe)

made up of a cluster of smaller barchans exists. It may be an extreme an example of a proto-megabarchan (Cooke et al. 1993, p. 327).

Barchans developing into linear dunes. Following on from the classic model of Bagnold (1941) it is evident that some simple crescentic forms are deformed into linear (seif) features when they move into areas with changing wind regimes. Linear ridges some km long can develop downwind from the original barchans, creating a tadpole shape. Good examples of this can be found in northern Namibia along the Skeleton Coast (Fig. 17.2).

Barchan dunes developing into transverse ridges. There are many examples of classic individual barchans merging together with their neighbours to form ridges transverse to the formative winds. The original barchanoid and linguoid elements are clearly visible. It is generally believed that sand availability is a crucial control, and that with greater sand supply transverse dune ridges rather than individual isolated barchans will occur (see below).

Barchan convoys developing into linear ridges. Some intriguing linear dune ridges appear to be formed by convoys of approximately equally sized barchans. Wang et al. (2004) proposed this style of barchans merging in their model of complex linear dune formation.

Another type seems to have formed downwind of major nebkha fields. These develop from sand that has accumulated around bushes, rather than through the normal style of evolution from a non-anchored sand pile.

Moving barchans dunes can encroach upon houses, railways, roads and other types of infrastructure (Fig. 17.3). In the vicinity of Walvis Bay there are migrating barchan dunes that are so mobile that they can pose problems for roads, the railway and houses. They are driven primarily by winds coming from the south west (Fig. 17.4). These migrating dunes are of the classic symmetrical—large, fat and unstable type (Fig. 17.5). Good examples can be seen near the Radio Station and also at the Salt Works to the south of the Walvis Bay lagoon. The barchans near the Radio Station, illustrated in Figs. 17.6 and 17.7, have changed form with changes in wind regime and through time. Thus in July 2004, some of the barchans have plainly been moulded by northeasterly winds, as their arms face to the south west, whereas in September 2010 they point in the opposite direction. By 2010, the five dunes being shed from the westerly arm have disappeared, while those being shed from the easterly arm have migrated northwards and have developed a classic form.

The Salt Works barchans have a mean height of around 8 m, though some are nearly 20 m in height. The movement history of these latter dunes has been described over a period of some decades by Slattery (1990) and Barnes (2001) (Fig. 17.8). Slattery (1990) found a mean annual rate of movement of 13.5 m. Barnes, on the other hand, found that rates varied from decade to decade and year to year, ranging from just 4.2 m per annum between 1976 and 1988, to 56.1 m per annum between 1997 and 1999. She related these differences to changes in wind velocities during the period of observations.

One of the reasons why the Walvis Bay barchans are of particular interest is because unlike inland dunes they have

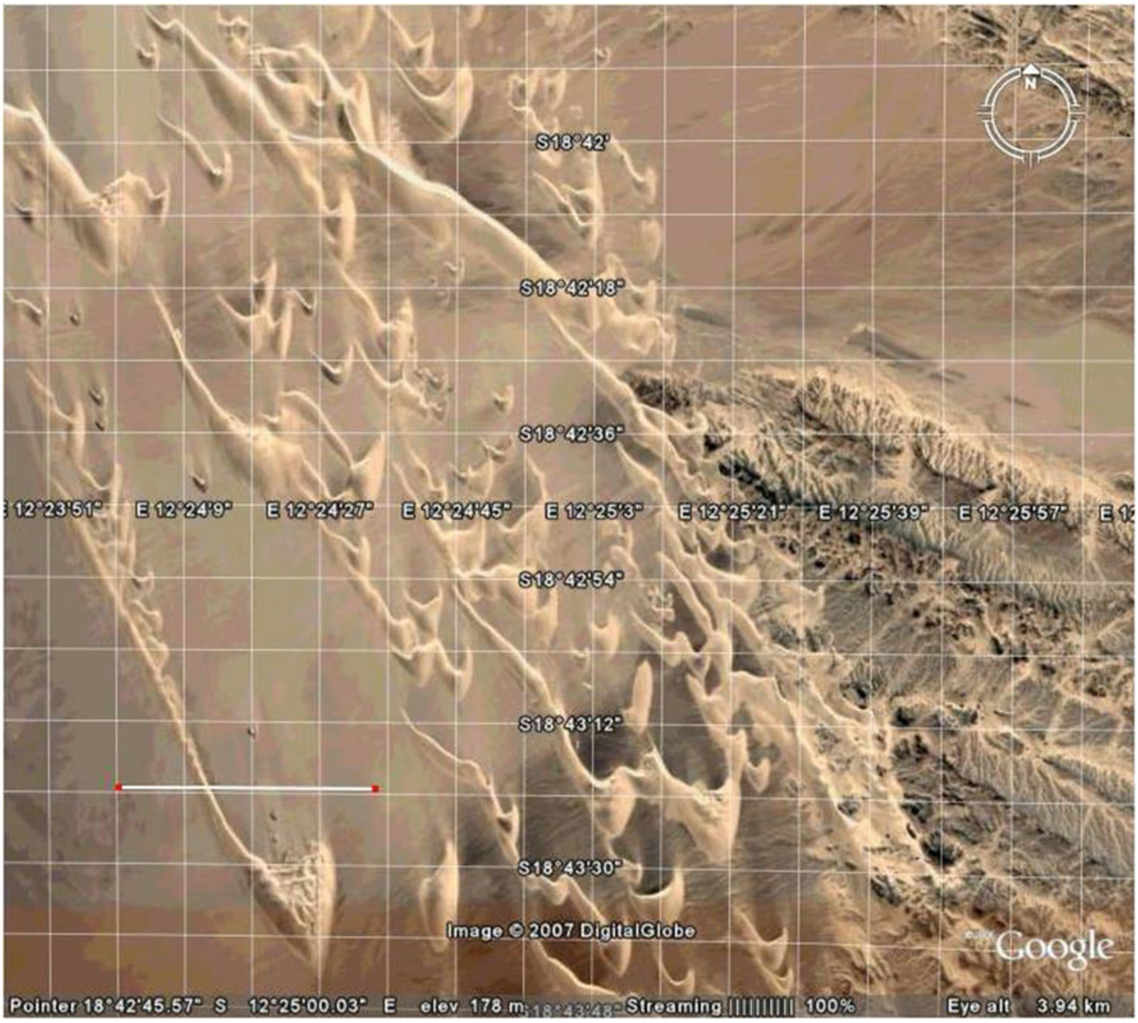

Fig. 17.2 Google Earth image of barchans elongating into linear dunes on the Skeleton Coast. Scale bar 1,000 m. (© 2007 Digital Globe)

Fig. 17.3 Dune encroaching upon the abandoned mining town of Kolmanskop, southern Namib

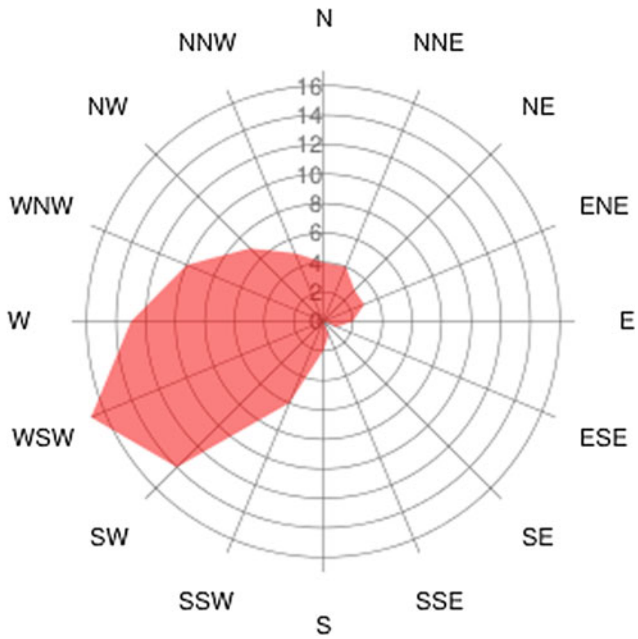

Fig. 17.4 Wind rose for Walvis Bay Airport for the whole year (http://www.windfinder.com/windstats/windstatistic_walvis_bay_airport.htm) (accessed 30th January 2014)

an appreciable salt content (Besler 1981) and are frequently wetted by fog, and this affects sand movement and some of the micro-forms developed upon them, including slab avalanches. They have recently been studied as a possible analogue for dunes on Mars.

Between Walvis Bay and Swakopmund the narrow coastal dune range is composed of a variety of dune types, but many of them are ridges that run transverse to the south westerly winds. On their seaward side there are large areas, visible from the main coastal road, where there are exceptionally large sand ripples, which are also perpendicular to the south westerly winds. Wind ripples are the smallest of aeolian bedforms and are present on almost all sand surfaces except those undergoing very rapid deposition. They generally trend perpendicular to the sand-transporting winds, although on sloping surfaces where the downwind component of grain movement is supplemented by gravity, they may be slightly flow oblique. Typically they have a wavelength of 13–300 mm and an amplitude of 0.6–14 mm. Like dunes, ripples have gentle windward slopes (in general between 8 and 13°) and rather steeper lee slopes (up to 30°). However, the large ripples of the coastal tract, many with a wavelength of c 3 m, are called granule ripples (Fryberger

Fig. 17.5 Barchans near Walvis Bay, 2011. These are the same ones as shown on the Google Earth Images. The large dune from which the smaller dunes have been shed is in the background

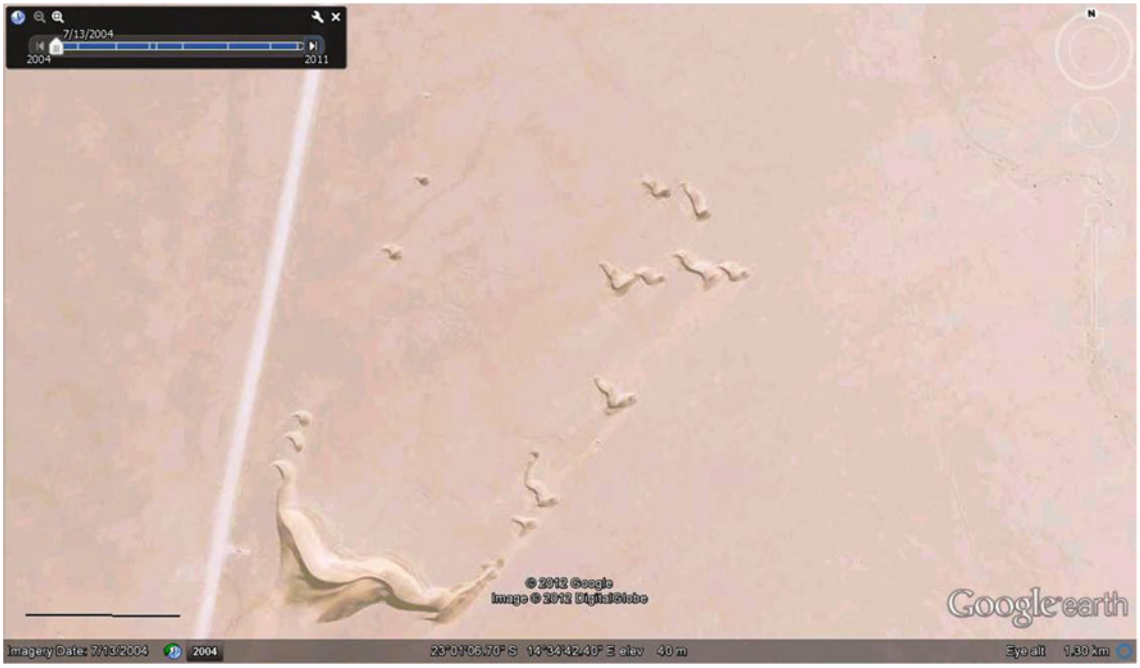

Fig. 17.6 Google Earth image of Walvis Bay barchans, July, 2004. Scale bar 200 m. (© 2012 Google Image, Digital Globe)

Fig. 17.7 Google Earth image of Walvis Bay barchans, September 2010. Scale bar 200 m. (© 2012 Google Image, GeoEye)

et al. 1992). These are 'aeolian bedforms comprised of a sandy core that is covered by a surface layer of granules, particles that are typically 1–2 mm in diameter' (Zimbelman et al. 2009). They tend to be significantly larger than wind ripples formed in well-sorted fine sand. They are also known as gravel ripples or megaripples (Isenberg et al. 2011).

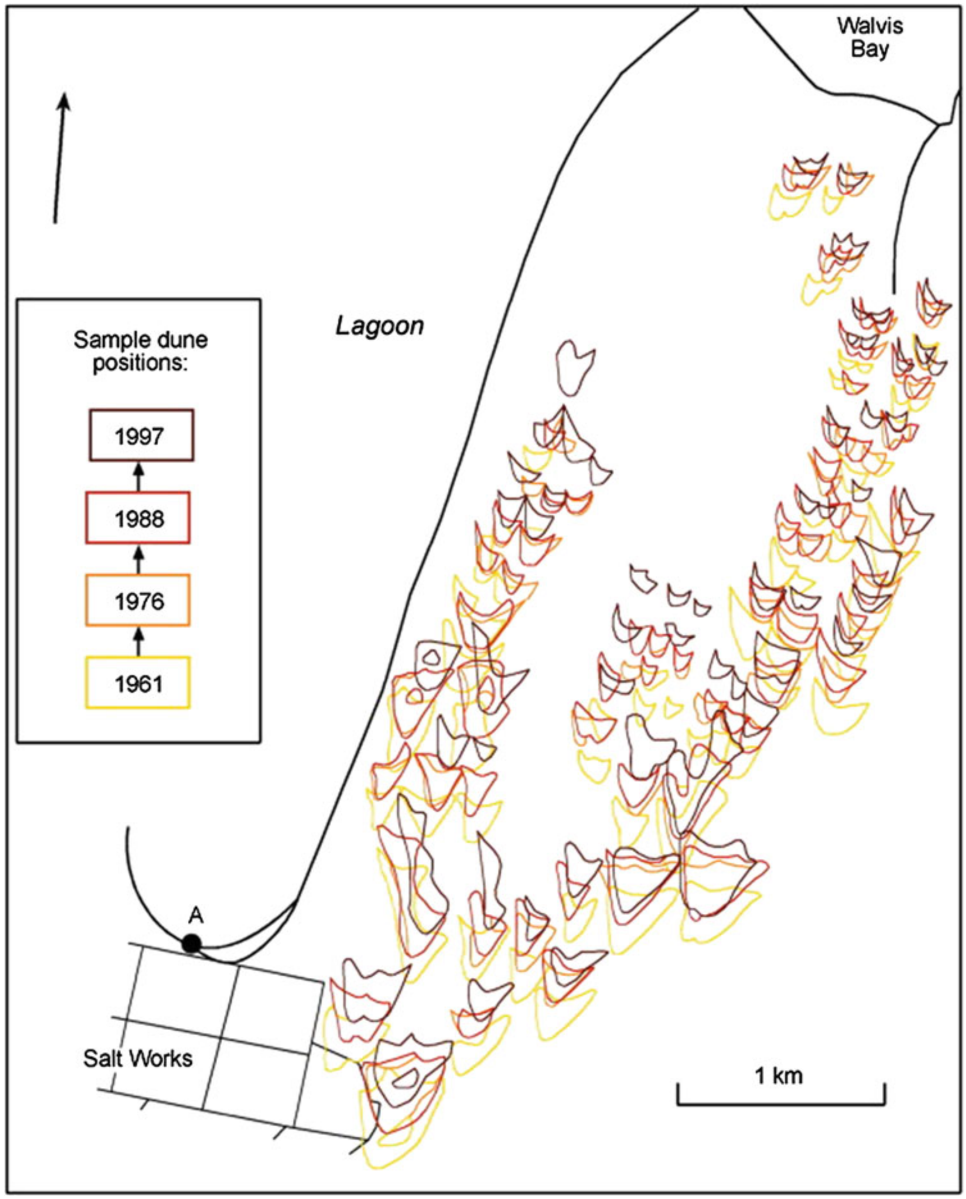

Fig. 17.8 The Walvis Bay barchans from 1961–1997 (modified after Barnes 2001, in Livingstone, 2013, Fig. 6)

References

Bagnold RA (1941) The physics of blown sand and Desert Dunes. Methuen, London

Barnes J (2001) Barchan dunes on the Kuiseb River delta, Namibia. S Afr Geogr J 83:283–292

Besler H (1981) Surface structures on Namib dunes caused by moisture. Namib und Meer 9:11–17

Bishop MA (2010) Nearest neighbour analysis of mega-barchanoid dunes, Ar Rub' al Khali, sand sea: The application of geographical indices to the understanding of dune field self-organization, maturity and environmental change. Geomorphology 120:186–194

Bourke MC, Goudie AS (2009) Varieties of barchan form in the Namib Desert and on Mars. Aeolian Res 1:45–54

Cooke RU, Warren A, Goudie A (1993) Desert geomorphology. UCL Press, London

Elbelrhiti H, Claudin P, Andreotti B (2005) Field evidence for surface-wave-induced instability of sand dunes. Nature 437:720–723

Fryberger SG, Hesp P, Hastings K (1992) Aeolian granule ripple deposits, Namibia. Sedimentology 39:319–331

Isenberg O, Yizhaq H, Tsoar H, Wenkart R, Karnieli A, Kok JF, Katra I (2011) Megaripple flattening due to strong winds. Geomorphology 131:69–84

Parteli EJR, Durán O, Herrmann HJ (2007) Minimal size of a barchan dune. Phys Rev E 75: article no. 011301

Slattery MJ (1990) Barchan migration on the Kuiseb River Delta, Namibia. S Afr Geogr J 72:5–10

Wang X, Dong Z, Zhang J, Qu J (2004) Formation of the complex linear dunes in the central Taklimakan Sand Sea, China. Earth Surf Proc Land 29:677–686

Zimbelman JR, Irwin RP, Williams SH, Bunch F, Valdez A, Stevens S (2009) The rate of granule ripple movement on Earth and Mars. Icarus 203:71–76