Chapter 17
Namib Sand Sea: Large Dunes in an Ancient Desert

Andrew Goudie

Abstract The Namib Desert on the west coast of southern Africa is a very dry desert which is believed to be of considerable antiquity. It is underlain by a fossilized sand sea called the Tsondab Sandstone Formation. Modern dunes include barchans and transverse ridges at the coast and large linear and star dunes further inland. The sand, which is derived from the coast, rivers such as the Orange, and from weathering of bedrock, becomes progressively redder as one moves inland.

Keywords Barchans • linear dunes • Namib • star dunes

17.1 Introduction

Dunes are one of the world's most fascinating and aesthetically pleasing landform types. As Ralph Bagnold remarked in his classic 'Physics of Blown Sand and Desert Dunes' (Bagnold 1941: xxi):

> Here, instead of finding chaos and disorder, the observer never fails to be amazed by a simplicity of form, an exactitude of repetition and a geometric order unknown in nature on a scale larger than that of crystalline structure. In places vast accumulations of sand weighing millions of tons move inexorably, in regular formation, over the surface of the country, growing, retaining their shape, even breeding, in a manner which, by its grotesque imitation of life, is vaguely disturbing to an imaginative mind. Elsewhere the dunes are cut to another pattern – lined up in parallel ranges, peak following peak in regular succession like the teeth of a monstrous saw for scores, even hundreds of miles, without a break and without a change in direction, over a landscape so flat that their formation cannot be influenced by any local geographical features.

The development of these two types of dune, the rapidly moving mass and the linear ridge, are especially well-developed in the Namib as is another type, the star dune. Small mound-like dunes (shrub and coppice dunes) also accumulate around clumps of vegetation such as Nara melon plants (*Acanthosicyos horrida*).

Under strong wind conditions, sand grains are transported across desert surfaces. When the wind velocity exceeds the threshold velocity that is required to initiate sand grain movement, the grains begin to roll along the ground, but after a short distance this gives rise to a bounding or jumping action called saltation. Grains are taken up a small distance into the airstream and then fall back to the ground in a fairly flat trajectory. The descending grains dislodge further particles and thereby the process of saltation is maintained across country. Dunes form because saltating grains tend to accumulate preferentially on sand-covered areas rather than on adjoining sand-free surfaces. This seems to result from the check to a strong wind through intensified sand movement over a sand surface and from the lower rate of sand movement where saltating grains 'splash' into loose sand compared with firm ground. This means that a small sand accumulation gets bigger and turns into a dune. The precise form of such a dune will depend on such factors as the wind regime, the degree of vegetation cover, the amount of sand available, and the size of the grains involved.

17.2 The Environment

The Namib is one of the world's driest, oldest and most beautiful deserts. It extends for more than 2,000 km along the Atlantic coast of southern Africa from the Olifants River in South Africa itself to the Carunjamba River in Angola. On its inland side it is bounded by the Great Escarpment which forms the western edge of the

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interior plateau and basin of southern Africa. Thus it forms a rather narrow strip some 120–200 km wide. Being on the west (and lee) side of the continent, in a zone of subsiding anticyclonic air, and bounded by the cool Benguela current offshore, the Namib is hyper-arid. Rainfall at the Namibian coastal resort of Swakopmund averages a mere 10–20 mm per annum, but increases towards the base of the Great Escarpment, where it may exceed 200 mm. The coastal Namib is also a foggy desert with fog on over 100 days in the year in the area around Swakopmund. This precipitates appreciable amounts of moisture (~34 mm/year at Swakopmund). Nonetheless, the vegetation cover is very sparse, and this means that desert winds are able to sweep unhindered across the surface, and to shape available sediments into a variety of sand dune types (Fig. 17.1). The desert has a number of sand seas (*ergs*) in which these dunes occur – in southern Angola is the Curosa-Bahia dos Tigres sand sea, in northern Namibia are the Cunene and Skeleton Coast sand seas, while in the south is the largest of them all – the Namib Sand Sea itself. Much of it is incorporated into the Namib Naukluft National Park.

17.3 The Birth of the Desert

The existence of arid conditions in the Namib must have been controlled to a considerable extent by seafloor spreading leading to the opening up of the seaways of the Southern Ocean as Africa and South America split apart in the late Jurassic and early Cretaceous around 130 million years ago. In addition, the movement of Antarctica to the South Pole, and the resulting initiation of the offshore, cold Benguela Current (Goudie and Eckardt 1999) were important. The precise date of the birth of this aridity in the Namib has, however, been a matter of some controversy though its great antiquity in comparison with many of the world's deserts seems clear. Ward et al. (1983) said (p. 182) that 'A review of the Late-Mesozoic-Cenozoic geology leads us to conclude that the Namib tract, which dates back to the Cretaceous, has not experienced climates significantly more humid than semi-arid for any length of time during the last 80 million years.' The cemented Tsondab Sandstone erg in the southern Namib dates from at least the Lower Miocene, and overlies wind-sculptured Late Proterozoic rocks (Senut et al. 1994).

The Tsondab Sandstone Formation is indeed a truly remarkable phenomenon. It is a red brown rock, up to 220 m thick, which underlies great tracts of the modern Namib Sand Sea and beyond (Ward 1988). Large parts of the Tsondab Sandstone are dune materials (Kocurek et al. 1999), though there are also materials that must have been laid down in salt lakes and in ephemeral rivers. The aeolian deposits appear to have formed under a similar wind regime to that of the present. They also contain the fossilized tracks of termites

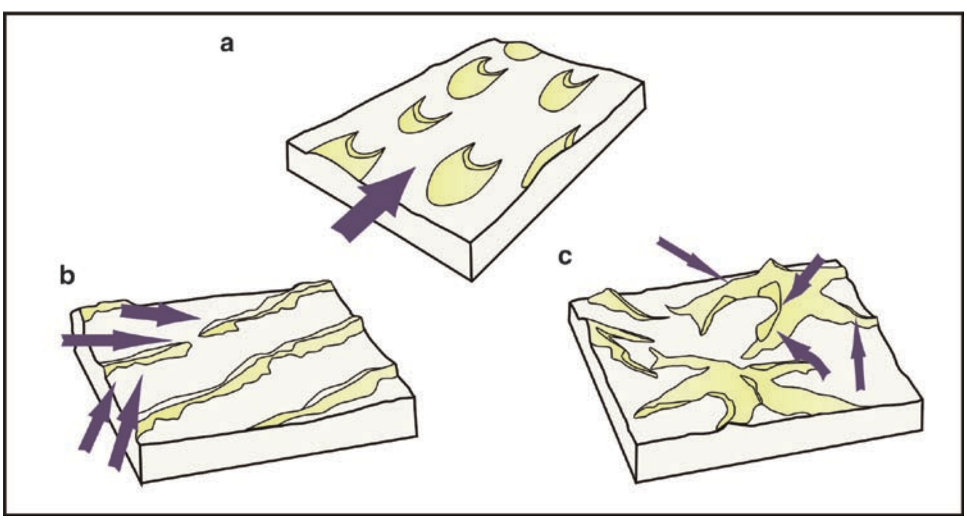

Fig. 17.1 The shape of three types of dune and the wind roses of the winds that have moulded them: (**a**) barchans, (**b**) linear dunes, (**c**) star dunes

and golden moles that live in the Namib today, together with lithified ostrich eggs.

17.4 The Modern Sand Sea

Overlying the Tsondab Sandstone Formation between Lüderitz and the Kuiseb River is the modern Namib Sand Sea (Lancaster 1989), an erg that covers some 34,000 km^2 (Fig. 17.2). At the coast crescentic dunes are dominant, including highly mobile barchans (Slattery 1990; Barnes 2001) (Fig. 17.3). Their horns point in the direction of movement, they have steep slopes (~32°) on their lee sides and gentler slopes (2–10°) on their windward (stoss) sides, they have an ellipsoidal shape in plan view, and have formed in response to the strong unidirectional (SSW) wind regimes that are prevalent in the coastal zone. These can be seen inland from Walvis Bay and in the vicinity of Lüderitz, where they often cross the railway and the main road respectively. They have encroached on the old mining town on Kolmanskop (Fig. 17.4). The barchan dunes of the Kuiseb Delta near Walvis Bay have average rates of movement of 12.4–14.6 m/year. Their mean height is about 8 m and the distance between their horns averages c 155 m. Where there is a large sand supply, the barchans sometimes coalesce to create transverse ridges. Elsewhere they may have the form of mega-barchans, with small features developed on a much larger crescentic base.

The heart of the sand sea is dominated by linear dunes (Fig. 17.5) that are associated with more bi-directional wind regimes (SSW–SW and NE–E). The

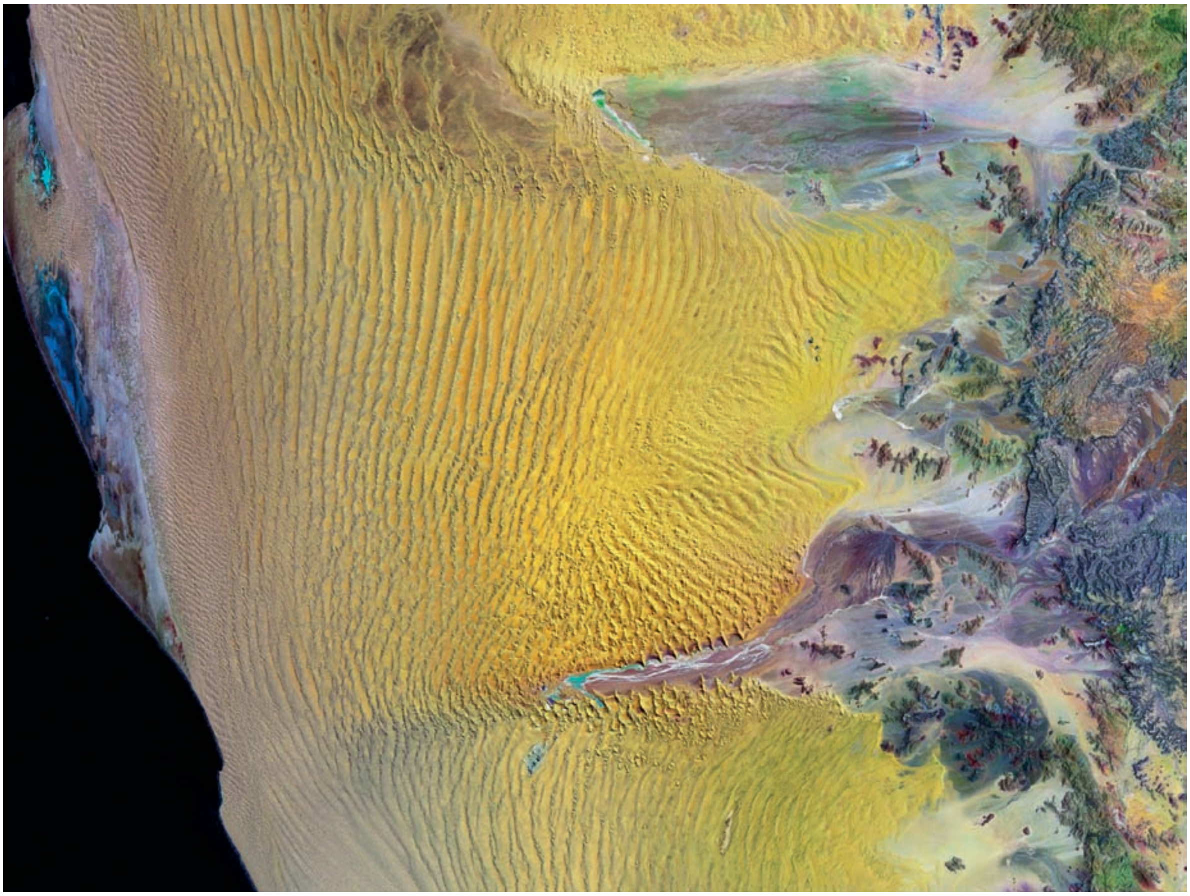

Fig. 17.2 Landsat 7 image of the central Namib Sand Sea, with the Atlantic Ocean to the west and the Great Escarpment to the east. Two ephemeral rivers occasionally flow into the eastern margin of the sand sea producing the Tsondab vlei (in the north) and the Sossus Vlei (in the middle) (Courtesy NASA)

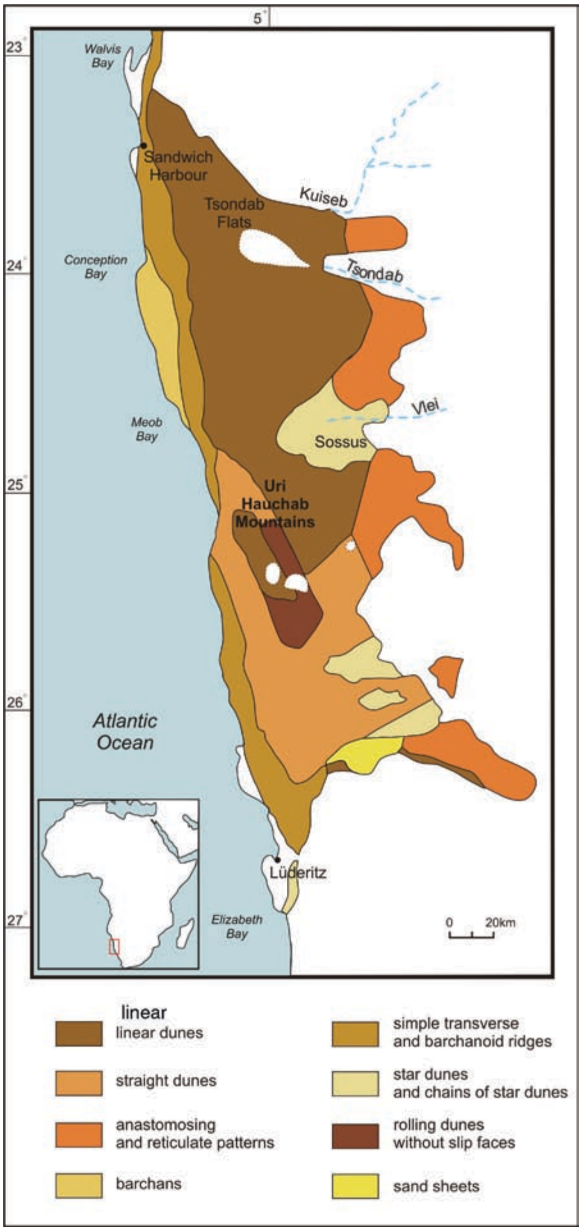

Fig. 17.3 Map of the main types of dunes in the Namib Sand Sea (Based on the work of N. Lancaster)

former winds blow inland from the South Atlantic Ocean and the latter sweep down the Great Escarpment from the interior. The dominant annual sand movement appears to be from the south. The spacing of the linear dunes varies through the sand sea. It is greatest in the central regions at 1,800–2,500 m, whereas in the southern parts these dunes are generally spaced at 1,500–2,000 m. The dunes are mostly between 6,000 and 900 m wide and between 50 and 150 m high. They are the dominant dune form in the sand sea. Changes in their form and the nature of wind flow over them over more than two decades have been described by Livingstone (2003). He found that the crests of the dunes move laterally back and forth in response to seasonal switching of wind direction, but return at the end of the year's cycle to their position at the beginning. This, says Livingstone, suggests that the dune is an equilibrium response to the wind regime and that there is no evidence of any lateral shifting of the dune. However, recent studies using Optically Stimulated Luminescence dating and ground Penetrating Radar (Bristow et al. 2007) have suggested that a few hundreds of metres of lateral migration have taken place in the last few thousands of years.

Star dunes, characterized by their pyramidal morphology and radiating sinuous arms, are associated with complex, multidirectional wind regimes (SW–WSW, NE–E and N) that occur along the sand sea's eastern margin, close to the Great Escarpment. The dunes are highest and most widely spaced in the central and some northern parts of the erg, with progressively lower and more closely spaced dunes towards the margins. Some of the star dunes, including those in proximity to the much visited Sossus Vlei, are well over 150 m high, and some may reach heights of 200–300 m, making them some of the largest dunes in the world, only exceeded perhaps by those of China's Badain Jaran Desert.

The sharply defined northern margin of the sand sea is formed by the Kuiseb River, for although this is only ephemeral, it flows sufficiently often and powerfully to prevent the dunes, driven by winds from the south, from moving further north, except in the immediate coastal fringe between Walvis Bay and Swakopmund. Further south, rivers deriving their flow from the mountains of the interior, such as the Tsauchab and the Tsondab Vleis, have entered the dune field and deposited light-coloured, horizontally laminated silts, but at the present time they do not have the power to reach the Atlantic. When conditions may have been moister in the past, these rivers may have extended further into the sand sea than they do today, depositing lake sediments (Teller and Lancaster 1986).

The sources for the sand that make up the sand sea are probably varied and could include eroded material from the older Tsondab Sandstone Formation (Besler and Marker 1979), weathering of extensive areas of

Fig. 17.4 Sand encroaching on the mining town of Kolmanskop, east of Luderitz (Photo A. Goudie)

Fig. 17.5 Linear dunes at Gobabeb in the north of the sand sea (Photo A. Goudie)

Fig. 17.6 Large linear dunes overlooking Sossus Vlei (Photo A. Goudie)

granites and Karoo sandstones, deflation of sand from river beds, and derivation from the Atlantic shoreline. Lancaster and Ollier (1983) believe that much of the sand may have been supplied by the Orange River to the coastal zone and then been blown inland.

The colour of the dune sand of the Namib shows clear spatial trends. In coastal areas dominated by crescentic dunes the sand is yellowish brown to light yellowish brown, whereas in eastern areas it becomes a very striking yellowish red, a shade that would not disgrace a ripe apricot (Fig. 17.6). Four main hypotheses have been suggested to account for the reddening of dunes as one progresses inland (Walden et al. 1996; Walden and White 1997). The first of these is that the increasing age of the sands inland allows greater time for weathering processes to develop the iron (haematite) coatings around quartz grains. The second is that in areas of active sand transport and high energy winds near the coast, coatings may be lost or fail to develop. The third is that different sand source materials occur in the coastal zone compared with inland. Finally, it may be that a regional climatic gradient with warmer and wetter conditions inland provides a control on the rates of weathering processes which generate the haematite coatings. On the basis of detailed analyses, Walden and White (1997) suggest that different sand source materials play a major role, but that so also do age and environmental gradients.

17.5 Conclusions

The dunes of the Namib Sand Sea are not only an example of the main forms of dunes that occur in the world's deserts, nor are they only some of the world's largest and most colourful. They are also home to a diverse and intriguing variety of animal life which has evolved remarkable adaptations to the aridity, stark temperature contrasts and instability of the dunes.

The Author

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