21 Linear Dunes of the Kalahari

Abstract

The Kalahari of eastern and northern Namibia has many linear sand dunes, some of which have tuning-fork junctions. In the north they run from east to west, while in the south west they generally run from northwest to southeast. Many of these dunes are currently inactive and may be the product of formerly drier conditions. In the southwest of the Kalahari they occur in an area where the rainfall is less than 250 mm per annum whereas in the northern areas the present rainfall well exceeds 1,000 mm. Those in the southwest have mobile crests in dry, windy years. In recent years a number of studies have been undertaken on the ages of the Kalahari dunes using thermoluminescence (TL) or optically stimulated luminescence (OSL) dating techniques. These have shown that there have been a number of phases of dune accumulation over at least the last 186,000 years and that the dunes of the south west Kalahari have been partially active during both the Late Pleistocene and the Holocene. The chapter discusses the various models that have been proposed to account for the formation of linear dunes.

21.1 Introduction

The dunes of the Kalahari are notable for a variety of reasons: they cover a vast area, most of them are inactive, few are very spectacular, most are linear dunes (Fig. 21.1), and many of those have particularly well developed 'tuning-fork junctions' (Fig. 21.2). They are composed of the famous, generally red and ocherous Kalahari Sand, which is dominantly quartzose and for the most part derived from local sources, including accumulated weathering products derived from Karoo and other rocks (Thomas and Shaw 1991, Sect. 3.4.1).

The dunes extend from the Upington region on the Orange River in South Africa far northwards into Angola, Zambia, Zimbabwe and the Congo (Fig. 21.3). They form a great anticlockwise wheelround not unlike the pattern of dunes found over Australia (Goudie 1970). Those in southeast Namibia trend more or less from northwest to southeast, though to the east of the Karas Mountains there is a small area where the dunes run from west to east. Those in northeastern Namibia run more or less from east to west. In the southwest of the Kalahari they occur in an area where the rainfall is less than 250 mm per annum whereas in the northern areas the present rainfall well exceeds 1,000 mm. Those in the southwest have mobile crests in dry, windy years, but over the rest of the Kalahari most of the dunes now appear to be stabilized by vegetation. The great bulk of the dunes, eighty five percent in the southwest (Fryberger and Goudie 1981), are linear types and this dominance is again reminiscent of Australia. The linear dunes, especially in the southwest, have 'tuning-fork' junctions that have a similar morphometry to dendritic stream systems (Goudie 1969) and which are seldom as well developed in other sand seas, except perhaps those of the Simpson Desert in Australia.

21.2 Origin of Linear Dunes

What are linear dunes and how do they form? The first point to make is that linear dunes, or *seifs*, are straightish ridges with slip faces on both sides that run more or less parallel to the resultant wind trend. Linear dunes are also sometimes called sand ridges or longitudinal dunes, but linear dune is now the preferred term, partly because it has no genetic connotations. They often develop a sharp crest which explains why they are called *seif* (a sword) in Arabic. They may also display a meandering tendency (Parteli et al. 2007).

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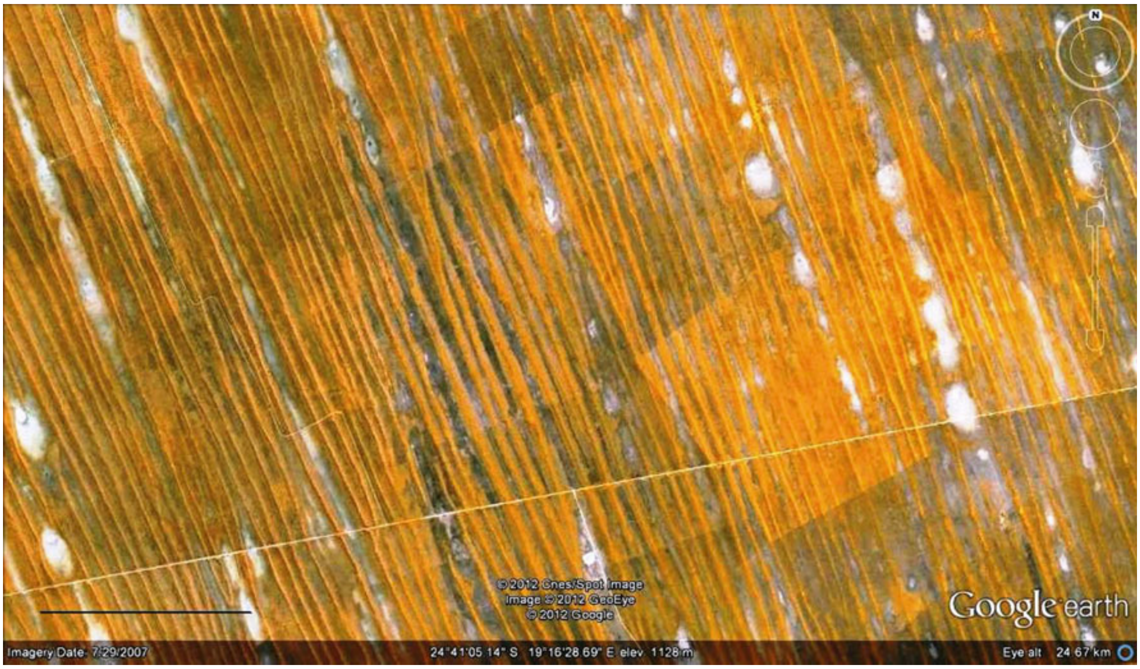

Fig. 21.1 Google Earth image of parallel linear dunes in the south west Kalahari. Scale bar 5 km (© 2012CNES/Spot Image, GeoEye, Google)

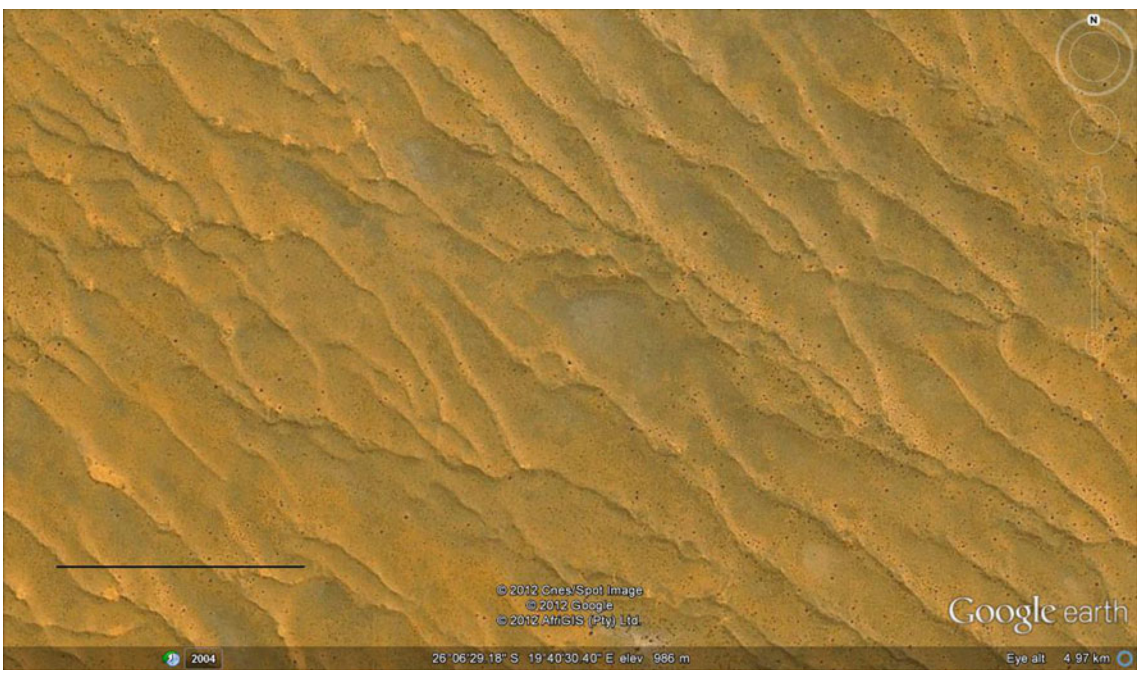

Fig. 21.2 Google Earth image of dunes with tuning-fork junctions in the south west Kalahari. Scale bar 1 km (© 2012 CNES/Spot Image, Google, AfriGIS (Pty) Ltd.)

They occur in loose sand in areas where there is seasonal or diurnal change in wind direction (Fig. 21.4)—i.e. a bimodal wind regime and where sand supply is relatively high (Parteli et al. 2009). They can also occur in areas with a more unimodal wind regime if the sand is locally stabilised by vegetation, sediment cohesion (due to the presence of salt, moisture or mud) or topographic shelter (Rubin and Hesp 2009).

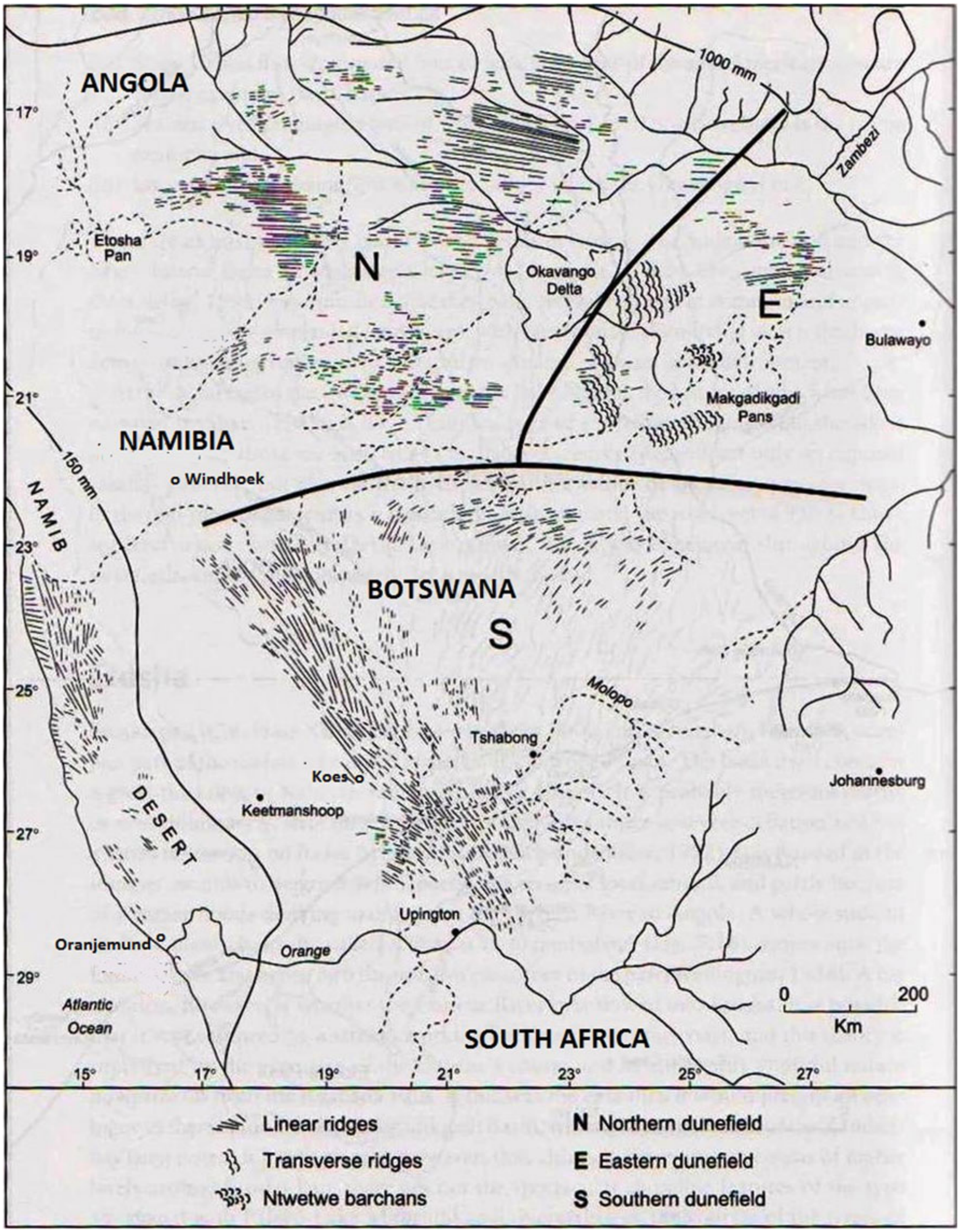

Fig. 21.3 The dunefields of the Mega-Kalahari. The 150 and 1,000 mm isohyets are shown

Some linear dunes may be modest in height (ten to twenty metres) and spacing (a few hundreds of metres) but others can be considerably larger, with heights in excess of 150 m, and a spacing of one or two kilometres. Examples of the former are the dunes of Australia and the Kalahari, whereas examples of the latter are the dunes of the central Namib (Chap. 18) or those of the Rub Al' Khali. The larger linear dunes are often described as complex or compound forms and may have multiple sub-dunes superimposed on a large plinth or draa. In general, as linear dunes get higher so they become more widely spaced (Lancaster 1995, p. 63).

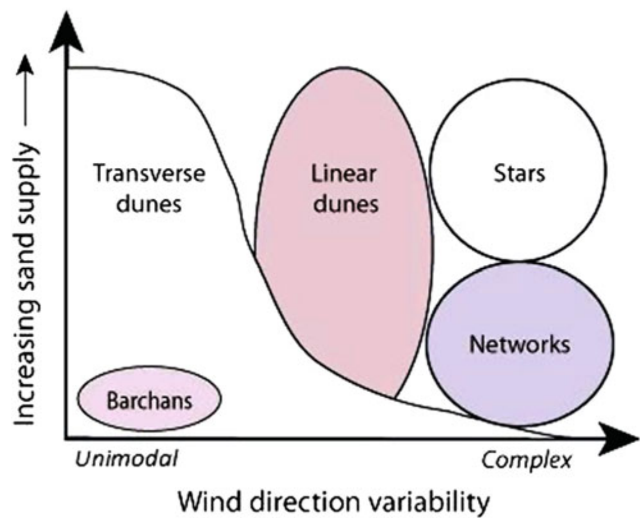

Fig. 21.4 The relationships between major dune types, availability of sand, and wind directional variability (after ideas of Wasson and Hyde, 1983)

There is a great range in the size and morphology of linear dunes, and this suggests that it would be an error to expect to be able to explain them by any one simple model. Some linear dune fields show a whole range of morphologies, and this is the case, for example, with the south west Kalahari (Bullard et al. 1995; Bullard and Nash 1998). The presence of river channels may modify the patterns of linear dunes as is the case with the valley-marginal dunes in that area (Bullard and Nash 2000) (Fig. 21.5). They may do this by modifying wind flow and by providing a local source of sand supply from their dry beds.

One early theory for linear dunes was that they were moulded by *thermally-generated helical roll vortices* (Bagnold 1953). These vortices, sometimes known as Langmuir circulation, are created by shearing in the boundary layer of the atmosphere. Bagnold suggested, speculatively, that paired, horizontal roll vortices, whose axes are parallel to the dominant wind direction, might sweep sand out of interdune troughs and onto sand ridges where currents would meet and ascend. In this model the wind pattern would create the dune and the dune spacing would represent the width of a pair of vortices. Roll vortices do exist, but a number of arguments have been developed that suggest that this model is not of general applicability (Livingstone 1988). First, there is little coincidence in the lateral spacing of linear dunes and the measured sizes of roll vortices. The latter are generally much greater. Secondly, roll vortices display measured transverse velocities well below that required to move sand. Thirdly, the model requires that winds blow parallel to the dune trend, an event which occurs rarely in many linear dune fields.

Bagnold (1941) had also argued that linear dunes could form from barchan dunes that became deformed as they moved into a regime which had less unimodal winds. This may happen in local situations, but scarcely seems a model that can apply, for example, in Australia, or, indeed the Kalahari, where linear dunes are near ubiquitous but barchans are almost absent. Verstappen (1968) suggested

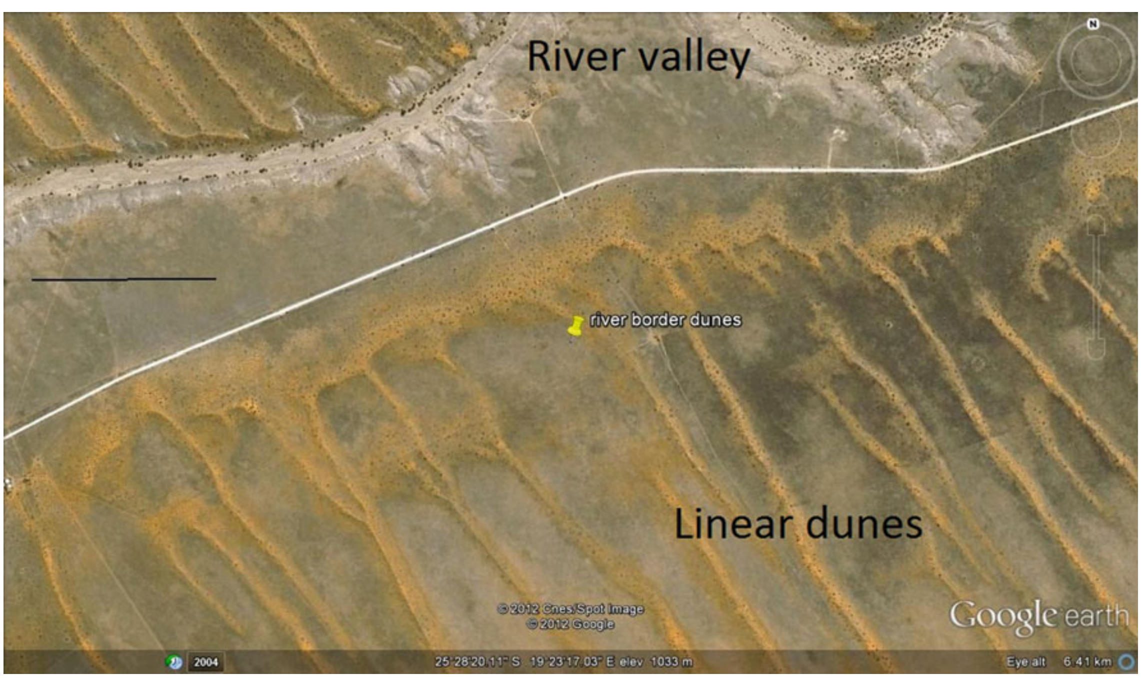

Fig. 21.5 Google Earth image of river bordering dunes in the Kalahari. Scale bar is 1 km. The river valley runs on the north side of the road (© 2012CNES/Spot Image, Google)

that in the Thar Desert of India linear dunes could arise from the progressive elongation of parabolic dunes. This model may again have local applicability, but many linear dunes occur in areas where parabolic dunes are absent, which is the case in most of the Namib.

Modern models, based on field measurement of wind directions and velocities, relate linear dune development to the effects of bimodal wind regimes. Notable here are the studies of Livingstone in the Namib Sand Sea (1989, 1993). He showed that the crest of the linear dunes migrated laterally in response to seasonally bimodal wind regimes, but that net sand transport was along the dunes.

Assuming that linear dunes result from the operation of bimodal wind regimes, there are two different ways in which they may develop. On the one hand there is the downwind extension model which envisages that linear dunes extend longitudinally by progradation along their length. They are fed by sediment from upwind and the dunes become progressively younger downwind. Telfer (2011) found evidence for this in the southwest Kalahari, by dating a linear dune extending into a pan.

21.3 The Age of Kalahari Linear Dunes

In recent years a number of studies have been undertaken on the ages of the Kalahari dunes using thermoluminescence or optically stimulated luminescence dating techniques. They have demonstrated that there have been a number of phases of dune accumulation (Thomas et al. 2000; Stone and Thomas 2008) over at least the last 186,000 years and that the dunes of the south west Kalahari have been partially active during both the Late Pleistocene and the Holocene (Blümel et al. 1998).

In future decades, with global warming, it has been postulated that many of the linear dunes of the Mega-Kalahari will become much more active in response to a reduced vegetation cover resulting from lower precipitation and greater moisture loss through evapotranspiration (Thomas et al. 2005).

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