NAMIB UND MEER 1981 Band 9
Gesellschaft für Wissenschaftliche Entwicklung und Museum,
Swakopmund, Südwestafrika/Namibia

Surface Structures on Namib Dunes caused by Moisture

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1. Normal surface structures: ripplemarks

The normal surface pattern on dunes and blown sands in general consists of ripples. Their size and spacing is varying according to the velocity of the wind and the mean grain size: stronger winds and coarser sands giving the larger features.

The largest ripples in the Namib dunefield are found near Grillenberg (the old German Diamond Camp) where the heights reach 30 cm. According to K. W. Glennie (1970) this is already the minimum dune height. In this case, however, the ripple character is evident from the fact that the crest region consists of slightly coarser grains than the lower parts. In dunes on the contrary the crest sands are usually finer than the basal sands. (For explanation of ripple formation see R. A. Bagnold 1935 and also H. Besler 1972a.) In accordance with the size of these ripples the mean diameter of the pure quartz grains is 1–2 mm. How strong the modelling winds must have been can be concluded from the fact that the crest sands near Gobabeb with a mean grain size of 0,15 mm are only transported by winds >20 km/h (H. Besler 1975).

Although even on windy days the ripples seem to be stationary, they move downwind at a rate specific for the wind speed and the grain size. But as the ripple pattern migrates on the whole and the distance between two individual ripplemarks is always the same, this movement is not necessarily observed. Measurements at the northern fringe of the Great Eastern Erg in the Tunesian Sahara have shown that already average wind velocities of 4,35 m/sec (=15,66 km/h) cause a ripple migration of 6,8 mm/min (H. Besler 1977). The mean grain size of these sands, however, is smaller than those of the crest sands of the interior Namib dunefield (0,13 mm and 0,23 mm).

2. Surface patterns caused by moisture

a) Latent moisture

In addition to these surface structures caused by wind alone, a variety of other patterns could be observed on the Namib dunes in 1976 because of their high moisture content. The abnormally high precipitation in 1975 and 1976 (more than 500% of the average year) supplied enough water for storage within the great dunes. The moisture content of dune sand near Gobabeb for example being 1,4% (related to wet sand) was raised to 2,2% after only 5 mm precipitation on the 24.1.1976. The field capacity of the sand was measured at 18,5% (measurements by M. Robinson, Gobabeb).

Experiments (H. Besler 1977) and observations have shown that after a rain the surface sands are soaked completely and that this moisture is penetrating downwards very slowly because of the typical structure of dune sands (layers) and their missing capillarity (H. Löwy 1953: "schleichende Bewegung"). On the other hand this lack of capillarity prevents the evaporation out of the water lenses in dunes especially when the upper layers are dry again. In this case a dune thoroughly wet inside may look completely dry from the outside. Only where a dune overlies a less porous substratum will the downward movement of water result in a wet fringe around the dune base. Here the water pressure may make up for the loss by evaporation. In 1976 these dark wet lines were very common around Namib dunes.

b) Moisture and wind

The latent moisture of dune sands only becomes apparent if there is wind erosion or deflation. If the dry surface sand is blown away and the wet interior of a dune is exposed, two facts become obvious:

1. A dune is not homogenous but consists of a multitude of thin sand layers (Fig. 1). At a first glance these layers differ only in colour. The colour, however, is caused by the slightly different mineral composition of each layer which results from sorting of grains according to their specific weight (for example from quartz (light) to mica (dark) to garnet (dark heavier)) and their roundness (sand grains are not rounded by wind but round grains are transported faster and farther), and according to the wind velocity at a given time. The colour of individual layers

Fig. 1: Different sand layers in a 40 m high wet barchan dune in the Kuiseb Delta, exposed by wind deflation. (Note the wavy pattern which results from hollows in the surface caused by wind eddies.) Photo: H. Besler, 22.4.1976.

may also be caused by the different moisture content which is higher in fine grained sands. Alternating layers of coarse and fine sands also indicate changing wind velocities.

2. The character and the shape of these layers reveal the history of a dune (Fig. 2). While the wind speed during the formation of a dune is recorded in the grain size and mineral content of the various layers, the direction of the prevailing winds appears in the downward inclination of these layers. Usually the dipping is at an angle of 10–20° upwind and >30° downwind. If the strike of layers shows a curvature on the surface the most convex part gives approximately the upwind direction during formation. Shifting winds are clearly recorded by the changing structures of curves. In fig. 2 for example the observer is looking WNW. During the formation of the layers exposed as curved lines the wind was shifting around southerly directions.

Fig. 2: Strike of curved sand layers on the upwind slope of a 40 m high barchan dune in the Kuiseb Delta. (Note the changing curves indicating shifting winds around south during barchan formation.) Photo: H. Besler, 22.4.1976, looking WNW.

3. As long as the surface sands are drying quickly enough to supply loose material for wind erosion, the whole surface will be lowered by deflation. Wind erosion, however, becomes linear if it is cutting down into harder surfaces. A small-scale example are the parallel wind flutes or grooves on rocks. In the Namib they are very common in marble at Swartbank, in quartzite near Rooibank (H. Besler 1972b), in calcretes almost everywhere within the dunefield, and in granite, gneiss and gabbro especially in the southern Namib (near Lüderitz).

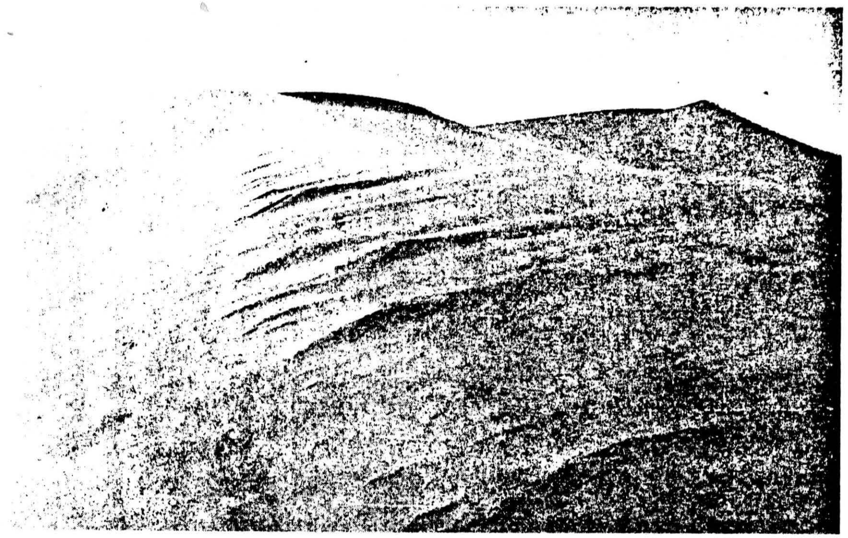

Fig. 3: Study dune south of Swartbank with yardang-like features on the upper part of the eastern slope during strong NE wind. (Note the smoking crest in the right background.) Photo: H. Besler, 26.4.1976, looking SE.

Fig. 4: Detail of study dune with single "yardang", covered by a mixture of organic matter and sand on the upwind part. (The scale is 20 cm.) Photo: H. Besler, 26.4.1976, looking S.

A large-scale example are the yardangs (A. Gabriel 1964), "elongated forms with rounded upwind faces and long downwind projections" (R. U. Cooke & A. Warren 1973), the remnants of wind-eroded sediments. Proper yardangs have not been found in the Namib. The formation of small-scale yardang-like features, however, was observed on a study dune near Swartbank in 1976 (Fig. 3 and 4). On the 18.4. the north-pointing dune had a dry surface (10 cm) and a distinct slip face to the east. One week later (26.4.) during a strong NE wind the slip face was reversed to the west and on the eastern side the moist interior was exposed. Parallel to the wind direction small ridges had developed: approximately 30–40 cm high in the upwind part, downwind lower and on the whole up to 2 m long. The upwind surface of these yardang-like features was covered by a mixture of organic matter (dead grasses and sand (fig. 4)) whereas the lower parts between the ridges showed no grass accumulation.

c) Moisture and salt

Surface structures on dunes become more complex if the sand contains salts. First hygroscopic salts may increase the moisture content of sands and therefore cause a faster display of the patterns already described. The sands of the coastal dunes in the Namib contain a variety of salts: carbonates, chlorides, nitrates, but mostly sulphates. After calcium (gypsum!), magnesium is the commonest cation and most probably responsible for the hygroscopic character (H. Besler 1972b). On the other hand, evaporation from wet salty material results in a typical, puffy, cauliflower-like surface structure (fig. 5). At the same time these surface parts are darker because of the higher moisture content.

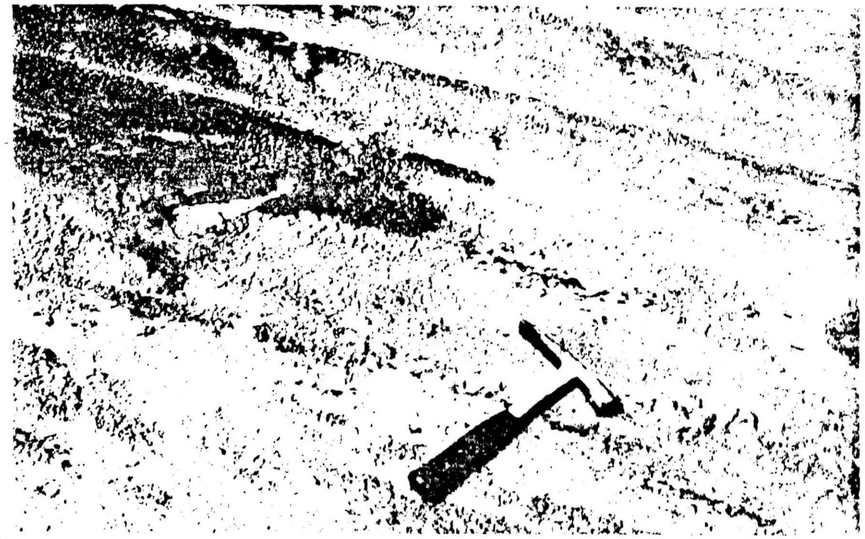

Fig. 5: Dark puffy patches on the western slope of the study dune farther south, caused by high salt content and moisture. (Note the remnants of layered structure.) Photo: H. Besler, 18.4.1976.

A rare phenomenon on dunes are adhesion ripples which are common in the brackish coastal part of the Kuiseb Delta (P. J. C. Nagtegaal 1973). In 1976 they were observed near the crest of a 110 m high dune south of Swartbank (fig. 6)! Adhesion-ripples are round or elongated pimples which grow vertically around capillaries (exceptional!) because here blown sand is trapped by the wet surface. The salt content seems to support the formation of capillaries. The observed adhesion-ripples were almost 10 cm high which is exceptional compared with the coastal features described by Nagtegaal (up to 6 cm high).

All the mentioned phenomena like: adhesion-ripples, dark puffy patches, yardang-like features, curved lines, and layered surfaces are — if showing on dunes — evidence for an exceptional high moisture content of the sands. These conditions make the Namib dunes especially interesting for investigations into the history of dune formation, dune migration and palaeowind regimes.

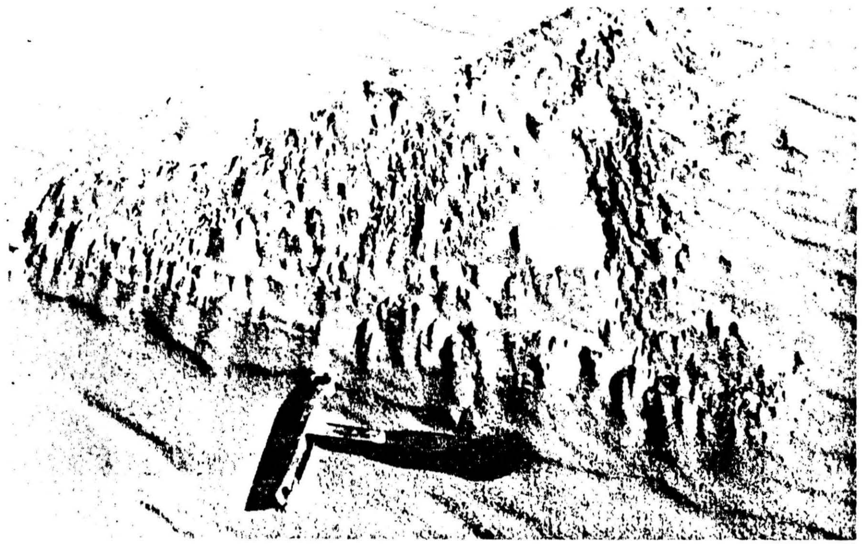

Fig. 6: Adhesion-ripples near the crest of the highest part of the study dune farther south (110 m), caused by trapping of blown sand on the wet surface around capillaries. Photo: H. Besler, 18.4.1976.

ZUSAMMENFASSUNG

Feuchte-Muster auf Namib-Dünen

Mit dem Wind wandernde Rippelmarken bilden die typische Oberflächenstruktur trockener äolischer Sande. Bei starker Durchfeuchtung entstehen jedoch Muster auf den Dünen, die deren Aufbau und Zusammensetzung, die beteiligten Winde und den Salzgehalt der Sande verraten.

Wird das feuchte Innere durch Deflation freigelegt, so erkennt man den vielschichtigen Aufbau aus unterschiedlichen Sanden (Fig. 1). Wechselnde Kurvenstrukturen lassen die Richtungen der am Dünenaufbau beteiligten Winde erkennen (Fig. 2). Durch Winderosion (linear) entsteht ein yardang-artiges Kleinrelief auf den Dünen (Fig. 3 und 4). Sind außerdem Salze in den Sanden enthalten, so bilden sich bei Verdunstung der Feuchtigkeit Gekröse- oder Blumenkohlstrukturen (Fig. 5). Ein seltenes Phänomen sind Adhäsions-Rippeln, die um — in trockenen salzfreien Sanden nicht vorhandene — senkrechte Kapillarröhren entstehen (Fig. 6).

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