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Using the response diagram to recognise zones of aeolian activity: a note on evidence from a Namib dune

Ian Livingstone*

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A recent study by Besler (1983) discussed the validity of Friedman's (1961) diagram in distinguishing zones of aeolian activity using grain size parameters. Surface movement data from a complex linear dune in the Namib Desert indicate that Besler's interpretation of the response diagram must be questioned.

Introduction

It would naturally be of considerable value to be able to distinguish the processes at work in a sedimentary environment from the grain size frequency distribution of the sediments. In considering aeolian landforms, Besler (1983) attempted to show that Friedman's diagram (Friedman, 1961) enables differentiation between sediments which are mobile, those which are stable and those which are residuals or lag deposits, by plotting mean grain size against the standard deviation of the distribution. Besler suggests that the zone marked by Friedman as the zone of 'overlap' between aeolian and fluvial sands can be redesignated a zone of 'aeolian stability' when considering sands which are known to be from dunes.

Some doubt, however, must be expressed about Besler's proposed modification of Friedman's diagram. For instance, in his study of a simple linear dune in the Negev Desert, Tsoar (1978) reported sand from an active dune crest with a mean grain size of 1·87 phi and a standard deviation of 0·42 phi, which therefore lies in the zone of 'aeolian stability'. Vincent (1985) too has shown that truly aeolian sands which are currently active can fall into Besler's zone of 'aeolian stability', largely, he suggests, as a result of the method of calculation of the values for the parameters. Vincent ensured that his sands were from active zones on dunes by considering samples taken from the lee of advancing barchans, and noted that the sands taken from the barchans are bimodal but that this is hidden when grain size parameters are calculated using the formulae of Folk & Ward (1957). Vincent proposed that the grain size distributions found on barchans are mixtures of two component modes: one a highly mobile, finer mode lying in the zone marked 'aeolian' on Friedman's diagram, and the other a less mobile mode lying in the zone of stability representing the coarser grains moved as the traction load. Vincent also reported that grains coarser than 1·49 phi, the limit suggested by Friedman for aeolian transport, can in fact be moved by the process of bedload creep in high magnitude, low frequency events.

Both Besler and Vincent used indirect indications of the dynamics of dunes when assigning them to zones of 'mobility' or 'stability', and Besler's belief that Friedman's zone of 'overlap' is a zone of 'stability' when applied solely to aeolian dunes is based, in part, on

* School of Environmental Studies, Gloucestershire College of Arts and Technology, Oxstalls Lane, Gloucester GL2 9HW, England.

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her conviction that Namib dunes are in general stabilised (Besler, 1983, p. 292). As part of a wider study of the dynamics of a complex linear dune in the Namib Desert (Livingstone, 1985), data have been collected that concern both dune surface change and grain size characteristics. This enables examination of the validity of the Friedman diagram using a quantitative measure of sand mobility.

Method

The study dune lies at the northern edge of the Namib sand sea in Namibia, southern Africa. It is aligned roughly north–south and, at the study site, it is approximately 350 m wide and 50 m high.

This part of the Namib Desert is subjected to a multidirectional, seasonal wind regime so that, broadly speaking, the dunes are attacked by low to moderate force winds from the southwest and the northwest in summer, and high energy easterly winds in winter. Under their influence the crest of the dune moves laterally back and forth on an annual cycle with an amplitude of about 14 m.

Measurements of surface change were made on a weekly basis over a 2-year period between October 1980 and October 1982 using a grid of 58 steel posts sited on a cross-section of the dune (Fig. 1*a*). From these results it has been possible to calculate 'average weekly surface change', a measure of dune mobility, and compare this with grain size parameters. Twelve samples for grain size analysis were taken from 25 points related to the grid of steel posts, a total of 300 samples in all.

Average weekly surface change is a measure of the mobility of the dune surface rather than of the mobility of individual sand grains, often expressed as bulk transport. It is possible to envisage a situation in which a large volume of sand is moved but there is negligible erosion or deposition of the dune surface. This distinction between bulk transport and surface change is sometimes overlooked and the two are usually considered synonymous. Here, surface change is used as a measure of aeolian activity and this is plotted in Fig. 1*b*.

Figures 1*c* and 1*d* show the patterns of grain size distribution across the dune profile. There is a clear, progressive fining from dune base to crest and this fining is matched by improved sorting of the size frequency distribution. The study dune is considered atypical when compared with other dunes in this region, in that finer, better sorted sand is found on a ridge of secondary, barchanoid features on the east flank around posts T, U and V than on the main crest of the dune. This does not invalidate the use of results from this dune in the present study.

Discussion

The information on surface change and grain size parameters provides empirical, quantitative field evidence against which the validity of Friedman's response diagram can be tested, particularly as interpreted by Besler. Figure 2 shows how the sand samples are distributed on the Friedman diagram, while Fig. 3 plots the mean grain size against average weekly surface change. These diagrams show that all the samples lie in Friedman's zones marked 'aeolian' and 'overlap', and this trend is confirmed by 180 samples taken from four neighbouring dunes (Livingstone, 1985). The results show that the finer, better sorted sands around the dune crest are associated with a zone of considerable aeolian activity. Conversely, coarser, more poorly sorted sands are found at the base of the dune located in zones of more limited surface change.

From these data, though, there appears to be little justification for dividing the distribution. The zones marked on Besler's diagrams as zones of 'aeolian mobility' and 'aeolian

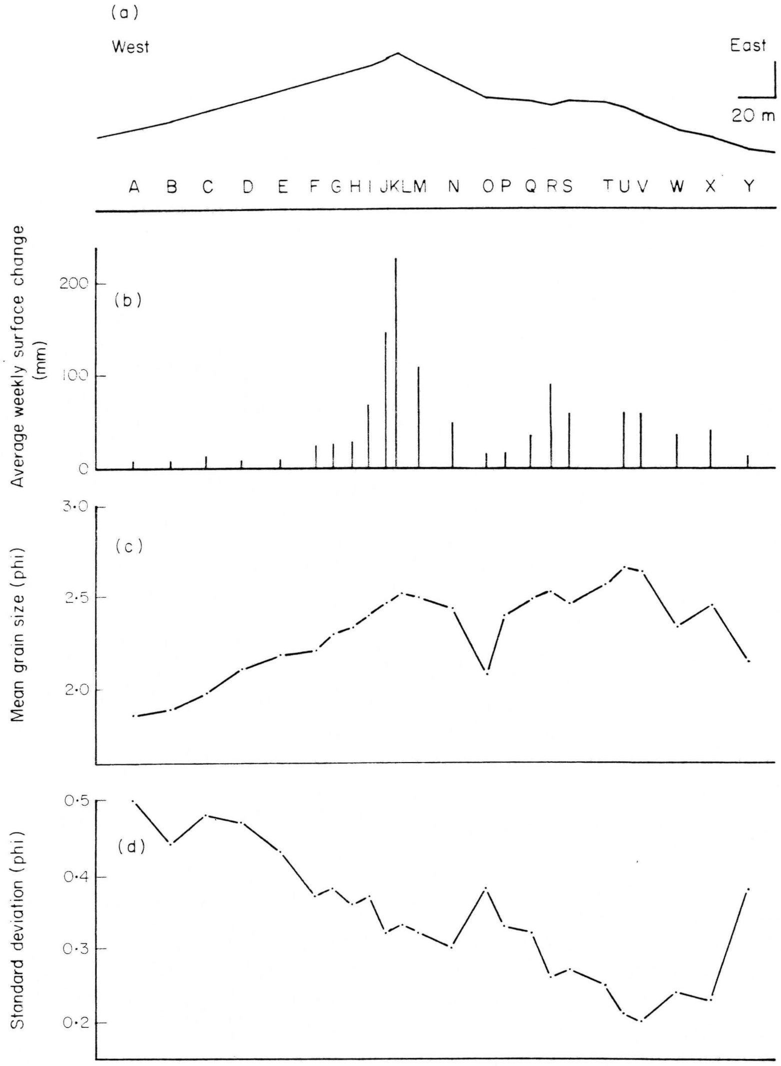

Figure 1. (*a*) Cross profile of the study dune showing the location of sampling points denoted by letters A–Y; (*b*) variation of average weekly surface change (mm) across the dune; (*c*) variation of mean grain size (phi) across the dune; (*d*) variation of the standard deviation of the grain size frequency distribution across the dune.

stability' would appear to be more accurately labelled 'greater aeolian activity' and 'less aeolian activity'. While the inference from Besler's interpretation of the Friedman diagram is that there is a discrete difference between activity in the two zones, we find that this change is progressive and that activity does indeed occur in sands in Friedman's zone of 'overlap'. Figure 1*b* shows that a typical linear dune in the Namib sand sea is far from stabilised as Besler has suggested.

Besler's division of dune sand into 'mobile' and 'stable' enables her, she believes, to recognise sands currently immobilised by a cover of vegetation, which would become active in time of devegetation by desertification. In other words, Besler believes that only

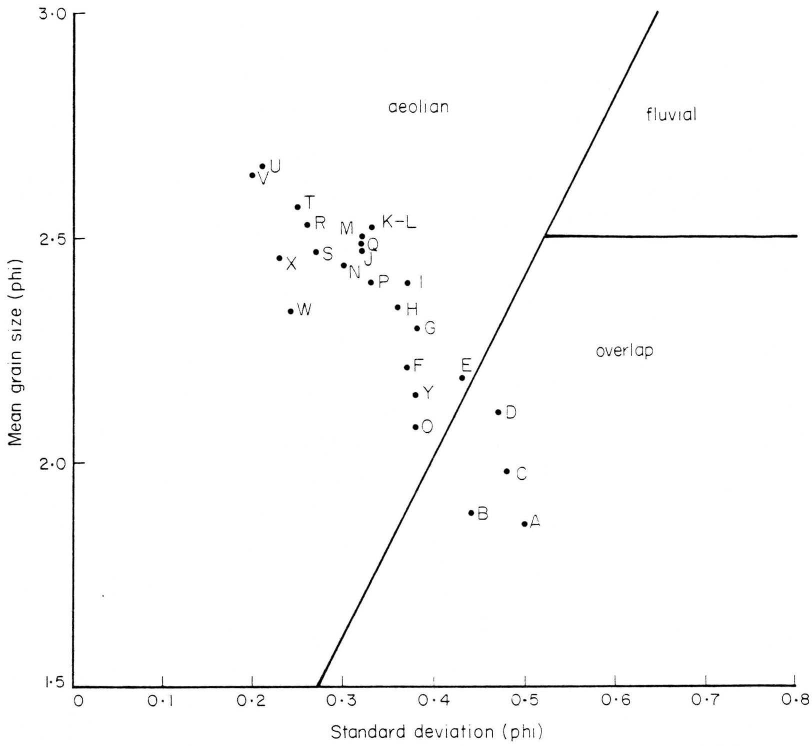

Figure 2. The position of the samples from the study dune on the Friedman diagram.

sands which already have a size frequency distribution which would place them in the zone of 'aeolian mobility', would be susceptible to future entrainment.

There are two reasons for arguing that this might not be the case. First, we have shown that, at least on one dune in the Namib Desert, sands which are currently mobile can be found to have grain size characteristics which place them in the zone of 'overlap' on Friedman's diagram, and have been labelled 'stable' by Besler. Second, it is surely not the case that fluids only entrain particles from sediments if the sediment already has the same size frequency distribution as the final deposit. From any given source of sediment, the process will selectively remove certain size fractions, thus determining the nature of the deposit, and it is on this basis that we hope to recognise sedimentary environments from grain size distributions. The nature of the source sediment will, of course, affect the frequency distribution of the final deposit, and certain source sands may be predisposed to aeolian transport. However, provided that sand of a size which can be moved by the wind is available, and is not protected by a lag of much larger grains, that sand will be remobilised. This explains the apparently anomalous size of sand from the Negev dune cited above.

The implication of Besler's argument is that grain size frequency distribution is not only a response to a process but controls it. While there may well be size limits outside which it is impossible for a process to entrain sand, it would be turning the mechanism on its head to suggest that the lower flanks of the dune are less active because coarser sand is found there. In fact, grain size responds to a differential spatial pattern of near-surface wind speed across the dune profile, and the sand is sorted according to this dynamic pattern (Livingstone, 1985).

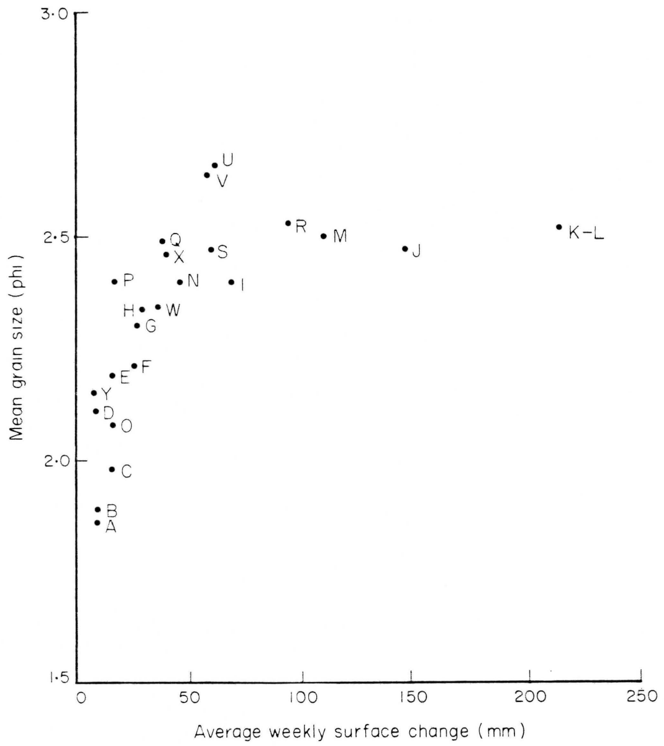

Figure 3. The relationship between average weekly surface change (mm) and mean grain size (phi) for points on the study dune.

Conclusion

It appears from this study of a single linear dune in the Namib Desert that Besler's (1983) division of dune sands into 'mobile' and 'stable' cannot be supported by empirical evidence of surface movement and grain size parameters. While sands from more active zones of the dune are indeed finer and better sorted than sands from less active zones, there is no reason to divide the distribution into two discrete populations. Instead, we should return to Friedman's version of the diagram so that, when dune sands are considered, both the zones marked 'aeolian' and marked 'overlap' can be thought of as zones of aeolian mobility.

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