THE RESPONSE DIAGRAM: A POSSIBILITY TO PREDICT SAND MOVEMENT

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Summary

A diagram to distinguish between sands according to their depositional environment (aeolian or fluvial), empirically developed by Friedman, is interpreted in a new way and developed farther.

The new diagram allows the additional distinction between aeolian mobility, aeolian stability and aeolian residuals which means between the actual response of sandy deposits to present-day winds, concerning saltation processes. This "response diagram" is tested with a large number of sand samples (393) from the Namib, the Kalahari, the Rub' al Khali, the western and the eastern Sahara. It seems to be valid for all types of sandy deposits and dunes with the exception of barchans which have no typical grain size characteristics.

As the diagram considers the response of sand grains to aeolian activity in a certain grain size distribution, it might also supply information whether a sandy deposit stabilized by vegetation would be mobilized by winds in the case of desertification or not.

This contribution is a short version of a more substantial paper published in the Supplement 45 to the Annals of Geomorphology. But as this short paper was submitted to the Symposium and accepted, the following is meant to complete this volume.

In 1961 G. M. Friedman published several empirically developed diagrams for the distinction between dune, beach and river sands from their textural characteristics. In a particular diagram to distinguish between dune and river sands he used the grain size parameters sorting (So) and mean grain size (Mz) on the X- and Y-axis respectively (calculated after Folk & Ward 1957). The sand samples considered in this diagram were grouped according to their depositional environment which in each case

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was known. By drawing a line between the groups the diagram could be devided into a section of dune sands and a section of river sands. But there was also a large section of overlap.

The Friedman diagram also offers the inverse possibility of finding the mode of deposit for a particular sand by entering its textural characteristics. Therefore is was applied to sands sampled during research on the formation and dynamics of the Namib dunefield (Besler 1980). Evidently aeolian and fluvial test sands proved the validity of the diagram for the Namib environment. But unfortunately all other sands were concentrated in the section of overlap, and no conclusion was possible. This was a suprising result as all 74 Namib sands were sampled form clearly discernible dunes.

In 1978 investigations on dunes and small ergs were carried out during the Tanezrouft Expedition of the Geographisches Institut, Universität Stuttgart (Besler 1984). Again the parameters mean grain size and sorting of sampled sands were entered into the Friedman diagram (Fig. 1). This time the sands in the diagram were clearly divided into seperate provinces of depositional environment which were well in accordance with the investigated dune types and dune topography.

1. Dune sands sampled at the margins of the Great Eastern and the Great Western Erg without any exception are grouped in the dune sand section. Included are some highly mobile sands from man-made or afreg dunes. Repeated investigations (Besler 1977, 1985) provide evidence that all dunes are actually mobile. Most of them belong to the transverse aklê type which is characteristic for seasonally changing winds from nearly opposite directions in a marginal position to ergs. The samples were taken from crests, bases, windward slopes and slip faces. The sampling locality within one dune makes no difference in the diagram.

2. Dune sands sampled in small isolated ergs in the Algerian Sahara (Egatalis at the Tropic of Cancer and Maatallah east of Timimoun) are grouped around the dividing line between the section of dune sand and the section of overlap. According to their topography the investigated dunes in both ergs belong to the longitudinal sief type. According to investigations (Besler 1984) the lower parts of these dunes are sta-

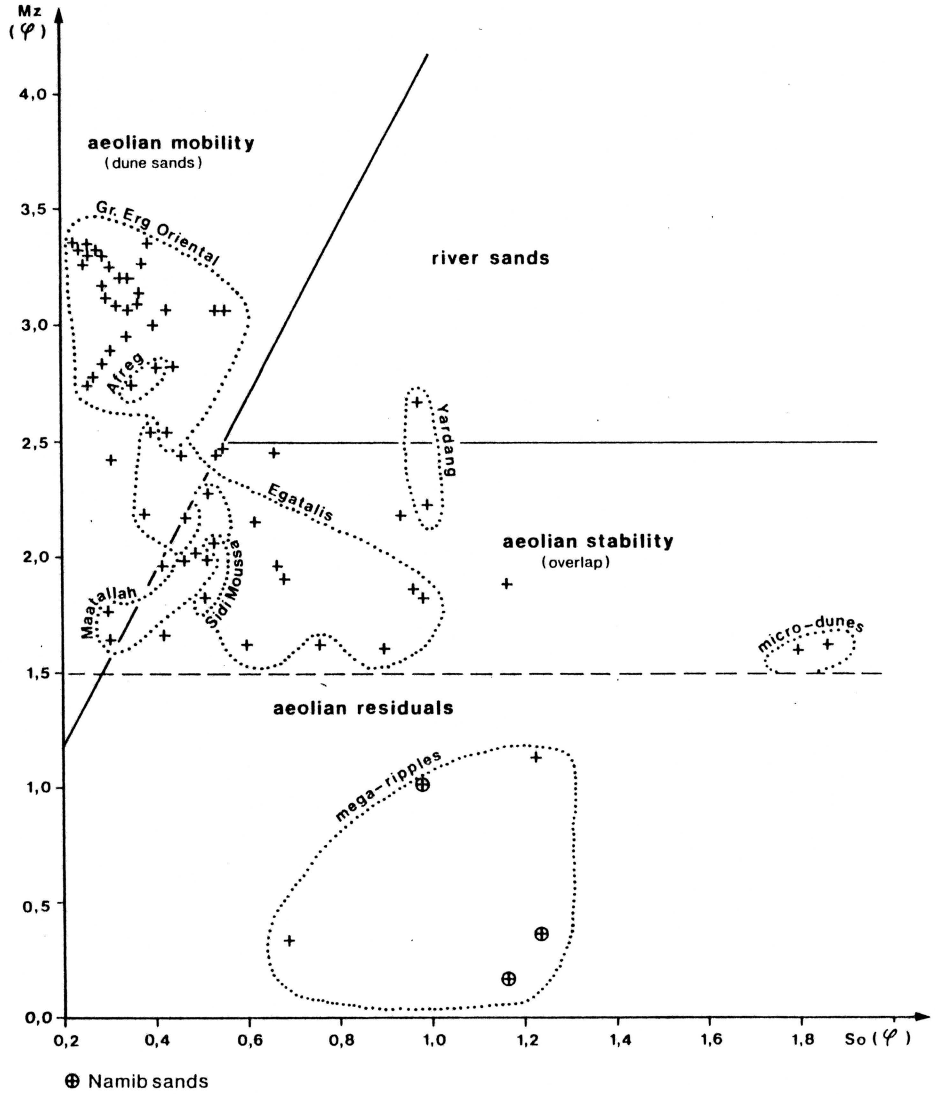

Fig. 1: The key diagram form Besler 1983: the Friedman diagram applied to West-Saharan sands showing the response of deposits to aeolian activity.

ble, but the crests are shifting with the wind. Exactly these relations between stable and mobile parts within one dune are reflected in the diagramm. Sands from bases and flanks are grouped in the section of overlap, only the few sands from crests and actual slip faces are concentrated in the section of dune sands. Obviously the threshold line allows the division between mobile and stable aeolian sands.

3. An expection is provided by the barchan dunes of the small Erg Sidi Moussa near In Salah. Although the shape of a barchan is already an aerodynamic expression of its mobility, these sands fall into the section of overlap. The diagram is not valid for barchan sands. (This is later corroborated by barchan samples form various deserts.)

4. Some other types of sand in the diagram are of interest: samples taken from mega-ripples and from micro dunes. Both features were investigated thoroughly and show textural and structural as well as genetic differences although they look alike (Besler 1984). Microdunes - like normal transverse dunes - possess a leeward dipping stratification and their sands show a unimodal frequency distribution of grain size. Mega-ripples, on the other hand, have no bedding planes and consist of sands with a bimodal frequency distribution. They are lag material or an aeolian residual, and in the diagram form a subsection within the section of stable sands.

First Conclusions

The original Friedman diagram allows the distinction between dune and river sands, that means according to their depositional environment. But there is a large section of overlap. The new interpretation of the diagram allows the additional distinction between aeolian mobility, aeolian stability and aeolian residuals, that means according to the different response of sands to wind action. Threrefore the diagram is called the response diagram. It seems to provide a possibility to predict sand movement.

When this new interpretation is used for the diagram of Namib samples mentioned earlier, the position of sands in the diagram is well in ac-

cordance with the results of ground control and air photo interpretation. All samples are dune-base sands, and the Namib dunes in general are stabilized. Even most of the crest sands (81) of Namib dunes fall into the section of aeolian stability. This is corroborated by the fact that in 1976 crest shapes and crestal dune pits still were displaying the same pattern as on air photos taken in 1968/69. Some 20 samples falling into the section of mobility can be explained by a special aerodynamic situation. Twelve sands are representing marginal dunes on the rim of the sandstone plateau underlying the dunefield. The remaining eigth sands were sampled from dunes much higher than the surrounding dunes (15 - 80 m difference). Thus the response diagram seems to be highly sensitive to the local equilibrium between wind and sand which is reflected in the grain size parameters. Eighty seven other sands sampled from various localities within the Namib dunefield except from dune bases and crests corroborate these results.

Finally the response diagram was applied to sands from other deserts: four sands from the northern Kalahari sampled in 1977, eleven sands from the Rub' al Khali sampled in 1980 (Besler 1982) and forty four sands from the Libyan Desert in Egypt sampled in 1982. Especially interesting are the sands from the northern Kalahari as all of them were vegetated. One of the samples falls into the fluvial section. This sand was taken from a small grass island in the Ntwetwe Pan, the western part of the great Makgadikgadi Pan in Botswana. By inspection this sandy island was found to be a water deposit and not a vegetated barchan dune as suggested by Grove (1969). The sand is more fine-grained than normal dune sand with the main bulk in the fraction 0.063 - 0.125 mm. One sample falls into the section of aeolian mobility. This sand was collected from a sand ridge near the Gubatsa Hills in northern Botswana. The Gubatsa sand ridge is bordering the Mababe Depression to the north and is supposed to be the shore line of a former lake in that depression (Grey & Cooke 1977). Today the ridge is completely covered by tropical deciduous woodland. But where tracks are crossing, the extremly loose sand makes driving difficult. The frequency distribution of grain size shows a strong maximum in the fraction 0.125 - 0.25 mm, the actual blown-sand fraction. Without vegetation this sand surely would be mobile. Of the two samples in the section of aeolian stability one sample represents a vegetated barchan dune northwest of the Ntwetwe Pan and as a barchan sample is the usual exception

The other sample was taken from a low grass-covered sand undulation north-west fo the pan. The topography here is similar to a zibar pattern. Contrary to the Gubatsa sand ridge the sandy undulation without vegetation most probably would be a stable deposit. The frequency distribution shows a low maximum in the fraction 0.125 - 0.25 mm and a distinct tail of coarser grains.

The sand samples from Botswana show that one has to distinguish between textural aeolian stability and stability caused by vegetation. The response diagram, of course, considers textural characteristics and the response of grains to aeolian activity. Therefore the diagram may also provide the information whether a vegetated sandy deposit in case of desertification would be mobilized by winds or not. - The sands from the Rub' al Khali and the Libyan Desert where detailed investigations were carried through, corroborate the results.

Conclusions

The present equilibrium between sand and wind materializes in the grain size distribution of sands. This distribution is responsible for the textural characteristics which - as parameters mean grain size and sorting - are used in the response diagram. This diagram, therefore, can indicate whether a given sand is mobile or stable in response to aeolian activity. As long as the sand texture ist not much altered by diagenetic processes, the diagram seems to be also applicable to sandy deposits fixed by vegetation. This by now seems to be corroborated by investigations in the Sudan (H. Mensching, priv. communication).

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