MISCELLANEA GEOGRAPHICA
WARSZAWA 2004 Vol. 11

Mariusz Potocki
Department of Antarctic Biology, Polish Academy of Sciences, Ustrzycka 10, 02-141 Warszawa, Poland, e-mail: mariuszpotocki@go2.pl

Piotr Angiel

CHANGE OF GRAIN SIZE PARAMETERS OF SEDIMENTS AS A RESULT OF WIND ACTIVITY. BARCHANS JARANGIYN ELS IN GOBI, MONGOLIA

Abstract. Research conducted on the Jarangiyn els field on the Gobi desert in Mongolia took place during the transformation of barchans resulting from the changes in wind direction. The investigation undertaken by the authors had as its goal the evaluation of the changes in the morphology of the forms, extended by the interpretation of the grain size parameters distribution in the longitudinal profiles of the dunes. The results indicate that the processes of barchan transformation are recorded in grain size parameters.

Keywords: barchans, dune transformation, grain size parameters.

INTRODUCTION

There are many examples of research on changes in the morphology of barchans resulting from the reversal of the wind direction by 180°. This phenomenon is known and observed in regions, where two opposite wind directions prevail. The transformation of the barchans is very distinctly marked in their morphology, and if the phenomenon persists for a sufficiently long time, a reversal of the form occurs.

Seasonal changes of the wind direction can be observed, a.o., near Douz (Tunisia). As a result, the morphology of the dunes in this region changes. This is manifested by the creation, within the crests of the dunes, of secondary forms with direction of the winward side opposite with respect to the direction of the original form (Mycielska-Dowgiałło et al., 1997, 1998). Research from the region of Douz did not, however, include the change of grain size parameter in the profiles of the transformed dunes, but only the distribution of the grain size parameter on the slopes of the forms typical for barchans.

Not much has been written about the issue of the distribution of the grain size parameters in longitudinal profiles of the dunes and there is a lack of studies dealing with the changes resulting from the transformation of the forms.

THE REGION UNDER INVESTIGATION *

The dune field Jarangiyn els (Fig. 1) is situated in the intermontane basin in the Gobi Tien-Shan. Orogenic movements, leading to the folding of the mountain complex (at the turn of the Palaeozoic and Mesozoic) were linked with the Gobi-Tien-Shan uplift (Kalicki, Prokop, 1995, after Timofeyev, 1986). In a later period denudation occurred in the region. The current relief is the result of the neotectonic movements at the turn of the Pliocene and Pleistocene. Rejuvenation of the relief became marked in the creation of pedestal mountain ridges in the early phases of development (Altay and Gobi Tien-Shan) divided by basins (Kalicki, Prokop, 1995, after Timofeyev, 1986).

The mean annual air temperature recorded in the region under investigation is around 9°C (the mean monthly temperature in July is +26°C and in January, −12°C). The annual sum of precipitation is small and equal to around 20 – 50 millimetres, with 80% in the summer half-year (Kalicki, Prokop, 1995).

The dune field Jarangiyn els (Fig. 1) is situated between two mountain ridges of latitudinal direction. In this part of Asia, winds from the northwestern and southwestern directions dominate; the latitudinal position of the mountain ridges changes these directions to westernly. This is the main direction of dune-forming winds in this region.

METHODS OF RESEARCH

Measurements and sampling began before the sand storm (Form 3.1). During the weakening of the storm the next barchan was investigated (Form 3.2), and on the next day, when the strong wind ceased, the next dune (Form 3.3). The measurements included the length and the angle of inclination of the windward and leeward slopes, as well as the height of the form. The results were used to construct longitudinal profiles of the dunes.

Sediment samples underwent laboratory analysis. The analysis consisted in sieve analyses of dune sediments from different parts of the profiles. This allowed for the plotting of the grain size curves, which make additional interpretations possible. Such curves are used in calculations of the basic grain size parameters determined by the Folk – Ward formulae (1957). Three of them seem the most valuable for the later genetic conclusions. They are: mean grain diameter (Mz), standard deviation (δ_1) and skewness (Sk_1).

Grain size parameters make it possible to obtaine valuable information concerning the character of the sediments and the environmental conditions, in which the deposition of sediments occurred. The mean grain diameter (Mz)

* Observations were conducted during the expedition of the Scientific Association of the Students of the Department of Geography, Warsaw University, to Mongolia.

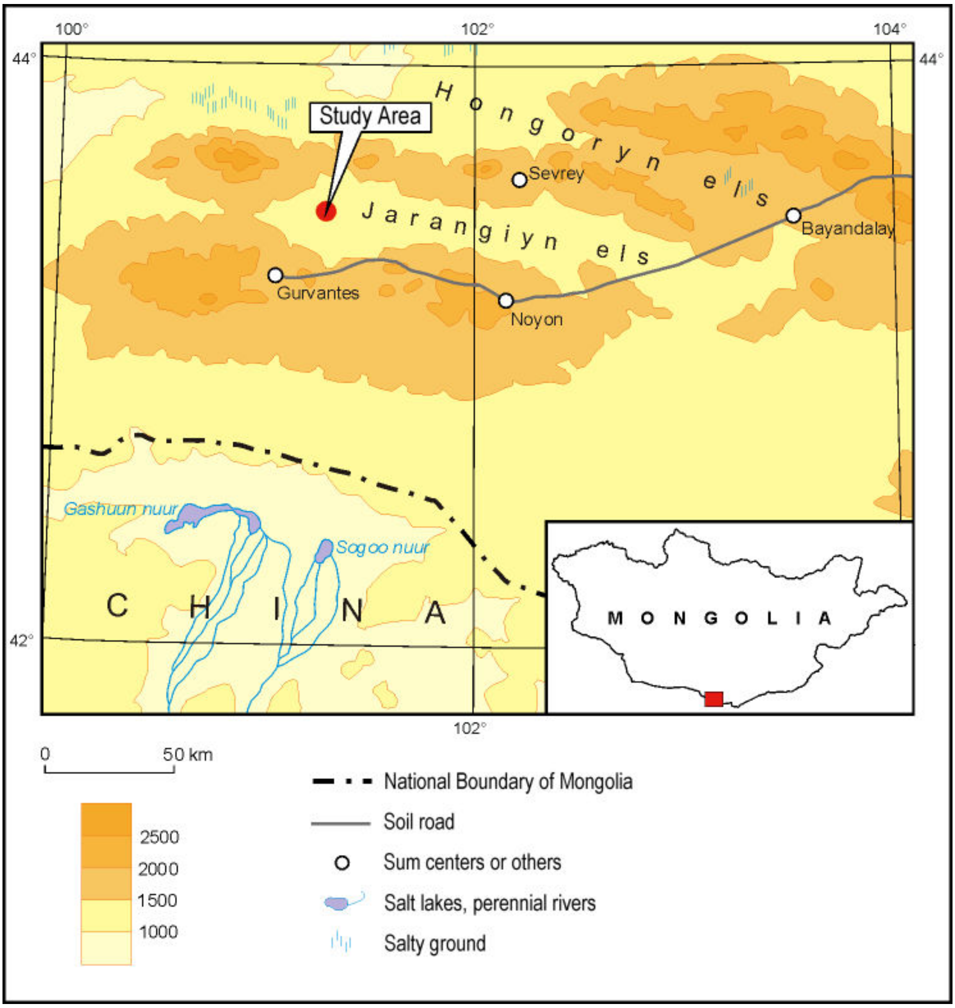

Fig. 1. Location of the region under investigation.

indicates the strength of the transporting environment: the larger the strength, the greater grains could be transported (decreasing parameter Mz). The standard deviation (δ_1) is an parameter measuring sediment sorting; it describes the changeability and dynamics of transport: the smaller the value of the standard deviation, the better the sediment sorting. The skewness (Sk_1) allows for the estimation of the strength of the transporting environment. Positive value of Sk_1 indicates that in the given sample, a finer fraction dominates over the fraction with maximal frequency, while a negative one, the domination of the coarse-grain fraction over the fraction with maximal frequency (Mycielska-Dowgiałło, 1995). In aeolian sediments positive value of the Sk parameter is associated with the deposition of the grains transported in the suspention. The negative value of Sk means that the saltation of the already deposited sediment occurs or else that the transporting medium has large strength.

RESULTS OF THE RESEARCH

A distinct asymmetry of the form marks the longitudinal profile of a typical barchan. The windward slope is long, more sloping, with the inclination between a few and around 15 degrees. The leeward slope, on the other hand, is steeper, with the inclination reaching the value of the natural angle of repose of dry sand (25 to 34 degrees). The border between the proximal and distal parts of the dune is a sharp edge.

The profile of the barchan (3.1: Fig. 2) before a sand storm confirms the regular features mentioned above. The creation of the dune in Fig. 3.1 was connected with the westerly wind. Its slopes have the inclination typical for the classical barchan arising in situations when the dune-forming winds maintain the same direction. The only part whose profile has a different shape is the crest zone of the dune. A slight displacement of the edge towards the west as well as its build-up on the windward slope created before the sand storm, can be seen here.

The distribution of the Mz parameter in the leeward slope shows that the average diameter of grains increases downslope (Fig. 2). This results from the characteristic features of the sediment transport on the steep distal slope. The sediment moves downwards avalanche-like, causing the coarsest grains to roll down farthest, due to their greater inertia. The distribution of the value of the standard deviation on this slope shows that sorting decreases in the same direction. This is due to the supply of the material moving avalanche-like down the slope and to the deposition of the grains in the suspension created as a result of the breaking off from the crest of the dune of a sediment-transporting air stream during a strong wind (Fig. 3). This is also connected with the transport of the sand at the feet of the slope by a reverse circulation cell created on the leeward slope of the dune (Walker, Nickling, 2002). The action of this cell can be felt at the distance of four to ten times the height of the dune (counting from its highest point) (Fig. 3).

On the windward slope of the dune the diameter of the grains tends to decrease towards the top of the form. This is typical for a long windward slope (around 100 metres in length). During the upward transport of the sediment finer fraction enrich the sediment, while coarser fractions accumulate in the lower parts of the slope (Fig. 2). This is caused by the sorting effect of the wind during the transport. Similar tendencies in the distribution of the grain size parameters, both on the windward and on the leeward slopes, occur in barchans of similar size situated near Kharga in Egypt. Such regularities have not been observed in the case of dunes of smaller size (near Douz in Tunisia) (Mycielska-Dowgiałło et al., 1998).

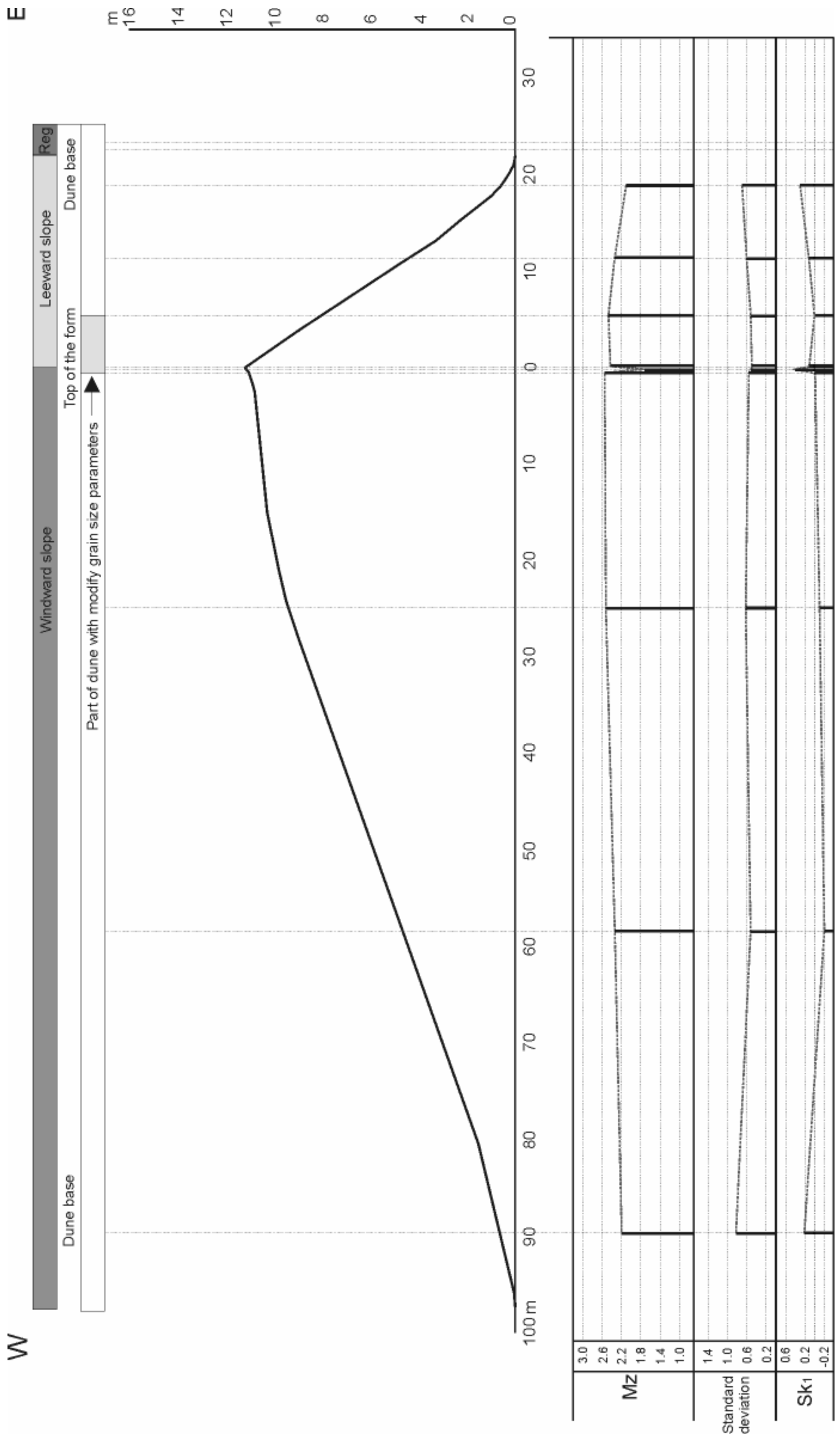

Fig. 2. Distribution of grain size parameters in the longitudinal profile of the dune 3.1.

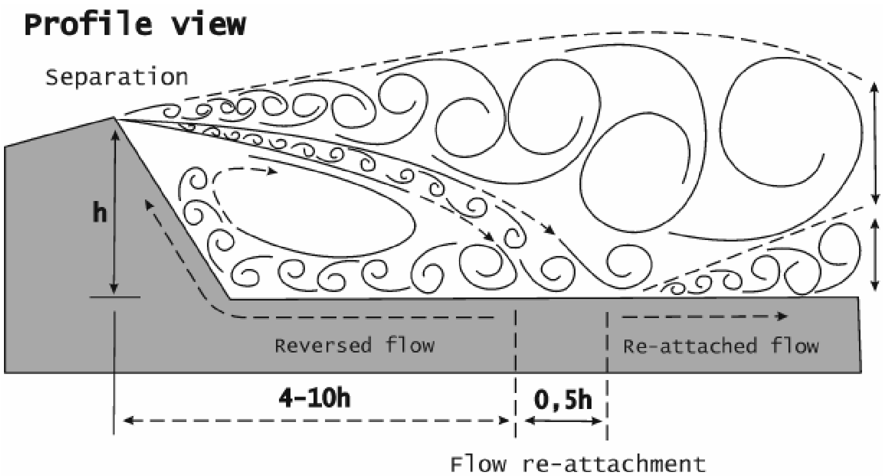

Fig. 3. Diagram of the action of a reverse circulation cell on the leeward slope of the dune (Walker, Nickling, 2002).

The crest part of the dune 3.1 (Fig. 2) is an evidence for its transformation caused by the wind from the east, opposite to that which created the whole form. The wind created a small (around 30 cm in height) mound on the crest of the dune. The transformation of the crest part of the dune profile has also a record in the sediment. On the former leeward slope, in its upper segment, a very small increase of the grain diameter towards the top occurs (from 2.48 phi in the upper part of the slope to 2.43 phi at the top). This tendency is opposite to that observed on the remaining part of the slope. This is an evidence of the great strength of the wind, within the top of the form, transporting the material upslope on the former leeward slope.

The profile of the next form (3.2, Fig. 4) was formed during a strong wind connected with a dust storm coming from the west (on 9. August 2002) (Photo 1). During the dust storm the speed of the displacement of the dune crest towards the former windward slope was measured. During the strongest wind, lasting two and a half hours (with speed reaching 20 metres per second), the top moved by 43 centimetres towards the west. Afterwards Form 3.2 was measured and samples of sediments were taken. On the next day the distance of the displacement of the top of the dune 3.2 was measured again. The displacement was equal to 47 centimetres towards the west. During the whole storm the top moved therefore by 90 cm westwards. In the longitudinal profile of the form the changed shape of the hilltop can be clearly seen (Fig. 4). The angle of inclination in its upper, crest part of the leeward slope decreased, the slope became more sloping (inclination 19 degrees), and the crest moved in the direction of the new eastern wind. On the western part of the crest a new leeward slope was created, with the angle of inclination approaching the customary angle of repose, progressing along the hilltop of the original windward slope (Photo 2). The summary length of the

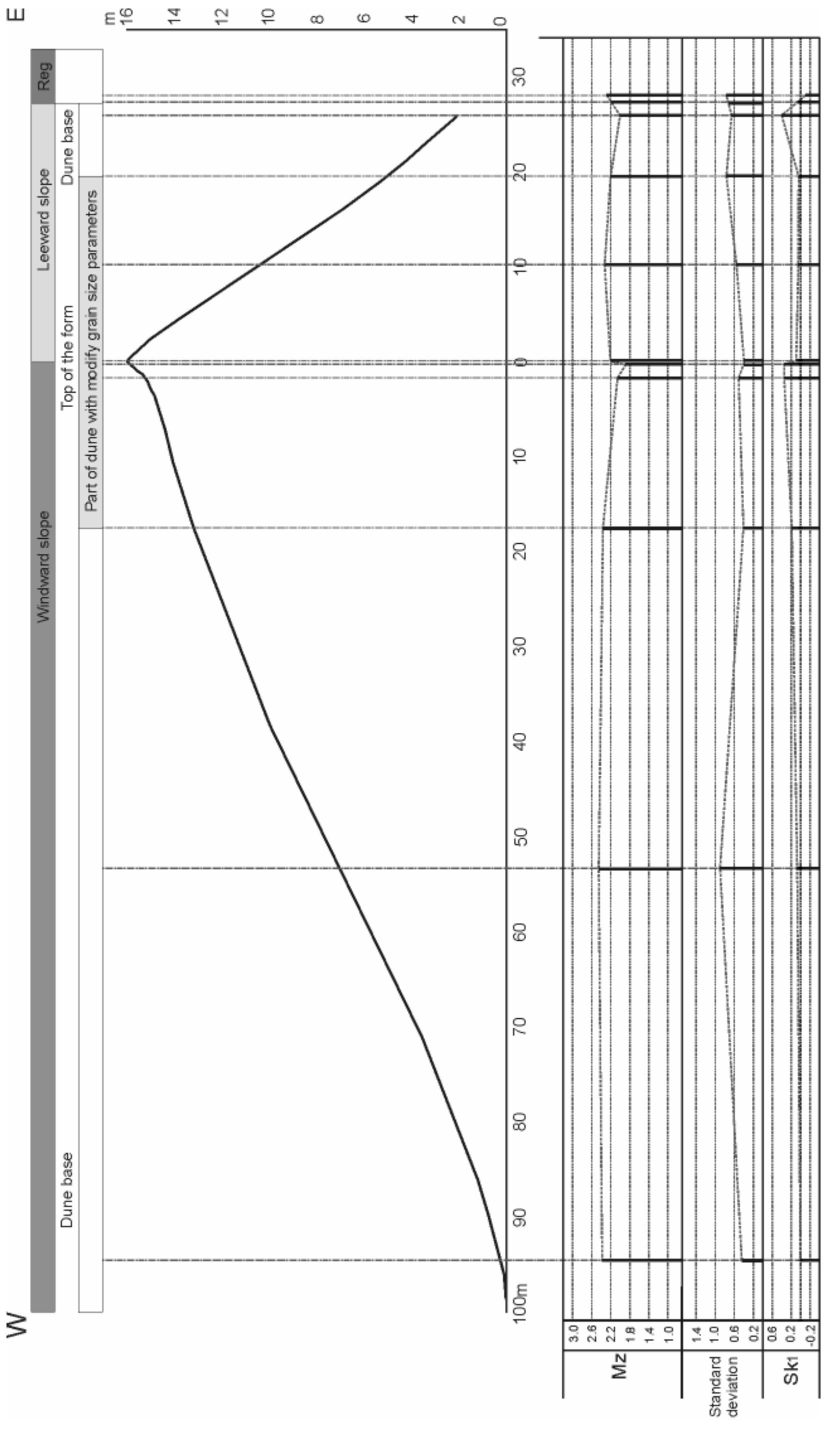

Fig. 4. Distribution of the grain size parameters in the longitudinal profile of the dune 3.2.

built-up slopes is equal to around 12 metres and the height of the built-up top, to 1.2 metres above the surface of the former upwind slope.

The change of profile of the barchan 3.2, and in particular the build-up on the hilltop, is reflected in the characteristics of the sediments in the upper part of the windward slope being transformed (Fig. 4). This zone is much wider than in the case of the dune 3.1. The transformation of the leeward slope, however, didn't last long enough for the transformation to be completed. This is evidenced by the tendency of change of the grain size parameters. The majority of grains don't change in the same way on the entire western slope. In its upper part the diameter of the grains increases from 2.34 phi to 2.21 phi in the region of the new crest. In the lower part the tendency of the grain diameter to increase towards the base of the slope persists. This tendency is similar to that observed on the non-transformed segment of the slope of the dune 3.1 (Fig. 2).

When the wind calmed down, morphological measurements of the third form (3.3, Fig. 5) were made and samples were taken. A comparison of the profiles of the first and the currently described dunes shows a significant difference in the form of the slopes (Fig. 2 and Fig. 5): A distinct remodelling of the slopes took place (Photo 2). The profile of the former windward slope is clearly changed: it became concave and its inclination angle increased, reaching in its upper part the value of the customary angle of repose (up to 33 degrees). Thos means that this slope had become transformed into a leeward slope. The summary length of the newly built windward and leeward slopes is around 22 metres and the height of the built-up top is 1.9 metres above the former windward slope.

The grain size parameters suggest, that the circulation cell created behind the new top influenced its upper part. Where the air stream descends directly from behind the crest, the coarsest grains are precipitated from the suspension (the value of Mz decreases). The stream divides into two parts, one of which forms a reverse circulation cell with a weaker carrying force, thus capable of transporting finer material. This transport takes place upslope toward the crest. The other part of the divided stream descends, and the sediment becomes enriched by finer fractions as well (the value of Mz increases).

Compared with Form 3.2 (Fig. 4) the transformation of the western slope (the former leeward slope) has an even greater scope. This is evidenced by the tendency of the grain size to increase towards the top of the form (from 2.4 phi at the base of the slope to 1.68 phi at the top). In the case of dune 3.3 (Fig. 5) this regularity is marked along the entire former leeward slope. In the profiles of barchans created by the wind from one dominating direction a characteristic feature of the leeward slope is the creation of a reverse circulation cell (Walker, Nickling 2002). In the case of dune 3.3 the record of the reverse circulation cell in the grain size parameters (together with a significant change of the dune's profile) is a very good argument confirming a distinct transformation of this barchan.

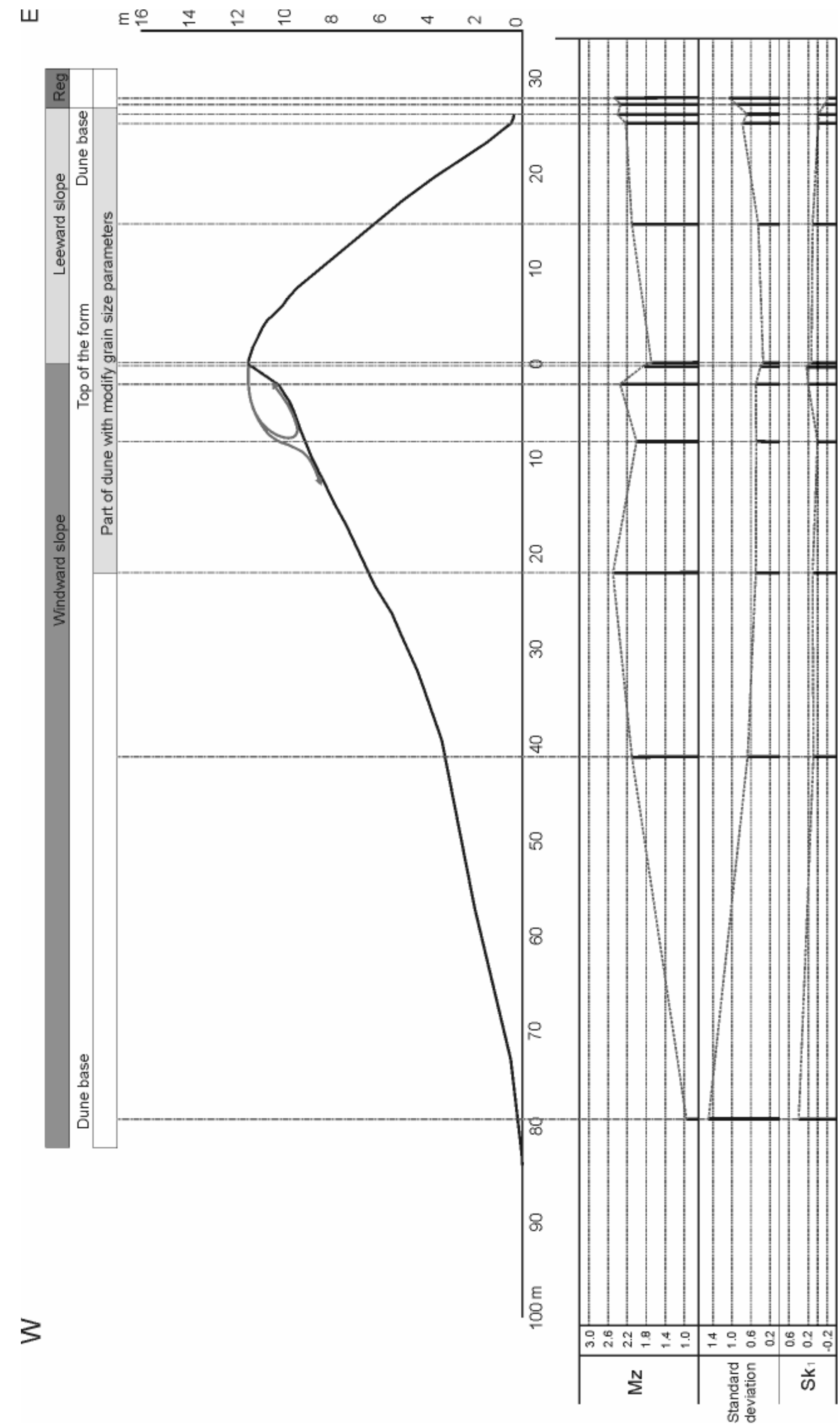

Fig. 5. Distribution of the grain size parameters in the longitudinal profile of the dune 3.3.

Photo 1. Transformation of the crest of barchan 3.2 during a dust storm.

Photo 2. Change of barchan hilltop: clearly visible build-up of the form.

Photo 3. Barchan after a dust storm: clearly visible change of the shape of the form.

CONCLUSIONS

The effects of a dust storm from the direction opposite to the dune-forming one caused very distinct changes in the morphology of barchans. The effect of a strong eastern wind lasted for only around ten to twenty hours. The result was a significant change of the profiles of the barchans. In the top parts of the dunes the build-up of the slopes in the direction opposite to the original one occurred. The process of the transformation of the dunes became obvious in the tendency to the change of the values of the grain size parameters for particular slopes. A comparison of the tendency for a dune transformed in a small degree (3.1: Fig. 2) with a dune after a dust storm (3.3: Fig. 5) shows, that the change in the direction of the displacement of the barchan is clearly recorded in the sediments. A great interpretational significance of the grain size parameters is evidenced by the fact that the circulation during the wind from the opposite direction can be reconstructed. Based on the tendency of the mean diameter of grains to change and on the standard deviation in the dune's profile, a reverse circulation cell behind the newly created leeward slope of the dune 3.3 (Fig. 5) was distinguished.

REFERENCES

Folk R.L., Ward W., 1957, Brazos River bar: A study in the significance of grain size parameters, *J. Sed. Petrol.*, 27.

Kalicki T., Prokop P., 1995, Warunki występowania i skutki ekstremalnych wezbrań w Zaałtajskiej Gobi [Conditions for Occurrence and Effects of Extreme Floods in Trans-Altai Gobi; in Polish], *Przegląd Geofizyczny*, vol. LXVII (1–2).

Mycielska-Dowgiałło E., 1995, Wybrane cechy teksturalne osadów i ich wartość interpretacyjna [Selected Textural Features of Sediments and Their Intepretation Value; in Polish], [in:] *Badania osadów czwartorzędowych. Wybrane metody i interpretacja wyników* [Research on Quaternary Sediments. Selected Methods and Interpretation of the Results; in Polish], ed. by E. Mycielska-Dowgiałło and J. Rutkowski. WGiSR UW, Warszawa.

Mycielska-Dowgiałło E., Dłużewski M., Pękalska A., Smolska E., Szwarczewski P., Woronko B., 1997, Development of dunes in southern Tunisia as an effect of the process of desertification. Preliminary study, *Acta Universitatis Carolinae. Geographica. Supplementum*, PAG.

Mycielska-Dowgiałło E., Dłużewski M., Pękalska A., Smolska E., Szwarczewski P., Woronko B., 1998, Rozwój wydm na wybranych obszarach Sahary jako efekt pustynnienia [Development of Dunes in Selected Regions of Sahara as an Effect of Desertification; in Polish], [in:] *Współczesne procesy eoliczne* [Contemporary Aeolian Processes; in Polish], ed. by T. Szczypek, J. Wach. WNoZ UŚ, SGP, Sosnowiec.

Walker I.J., Nickling W.G., 2002, Dynamics of secondary airflow and sediment transport over and in the lee of transverse dunes, *Progress in Physical Geography*, 26 (1), 47 – 75.

English translation: Małgorzata Mikulska