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Contemporary aeolian landforms and deposits in the Ural river basin (south Russia)

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Abstract

This paper presents main features of environment conditions of the steppe zone in southern Russia in Orenburg Region. These features make a background where contemporary aeolian landforms of psammosteppes are discussed. Mechanical features of dune sediments (grain size distribution and sand abrasion) are also discussed and compared to the substratum sediments. The observations included the Irtek river valley and the interfluve area of the Ilek and Khobda rivers.

Key words: aeolian landforms, aeolian sands, Ural river basin, southern Russia

1. Introduction

The area of the European part of southern Russia is situated in the steppe landscape zone (Fig. 1A), which, at least in the south-western Ural foothills, is divided into four distinctive natural subzones (Geograficheskiy atlas... 1999). From the south, these subzones are as follow: meadow steppe, grass-feather grass steppe, fescue-feather grass steppe and wormwood-grass steppe (Fig. 1B). A part of these areas is still covered by natural vegetation, but most of them have been, from the 19th century through the whole 20th century, more or less changed into agricultural land and used as pastures for cattle, sheep and goats (Chibilyov et al., 2004a). This caused destruction of vegetation and soil cover and, in case of sandy soils, development of contemporary aeolian processes. For that reason there are in many areas of southern Russia psammosteppes, which are areas of blown sands partly preserved by psammophilous vegetation (Chibilyov et al., 2004a, 2004b, in press). In these areas, a specific deflation relief develops at present. A general classification of forms occurring here is given by Ryabukha (2003), but only little is known about features of individual contemporary aeolian forms (Chibilyov et al., 2004a). There is no information on features of contemporary aeolian sands and their relation to substratum sediments. The aim of this paper is to describe features of contemporary aeolian relief and to determine basic parameters of grain size distribution and degree of abrasion of aeolian sands and substratum sands. The fieldwork was carried out in two sites located in the southern part of Orenburg Region (Fig. 1).

2. Methods

Investigations were carried out using the field method of geomorphological mapping, whereas mechanical features of aeolian sands and substratum material were investigated using laboratory methods. They included determination of grain size distribution using classical sieves and also determination of the degree of grain (diameter 1.0–0.8 mm) abrasion using two methods: mechanical graniformametry method by Krygowski (1964) and modified morphoscope method by Cailleux (1942). Direct results of analyses were calculated using simple statistical methods. In case of grain size analysis, mean diameter Mz and coefficient of sorting degree σ were calculated according to formulas by Folk and Ward (1957); in case of Krygowski's method, abrasion coefficient Wo and content of grains of γ type (round), β type (semi round) and α type (angular) according to the formula suggested by the author of this method were determined; in case of Cailleux's method, content of grains of RM type (round opaque), EL type (round polished), EM type (semi round) and NU type (angular) was determined.

3. Climate and vegetation of the investigated area

Investigations were carried out in two sites. The first one (I) is located in the lower course of the Irtek river close to its confluence with the Ural river (about 150 km west of Orenburg). The second site (II) is located on the asymmetric interfluve of the Ilek and Khobda rivers, about 100 km south of Orenburg (Fig. 1).

Dry continental climate with severe winters, hot summers, small amount of precipitation (280–320 mm) and intensive evaporation prevails there. Mean annual air temperature is +4.1 °C, mean July air temperature is 22.0 °C (maximum temperature is 42.0 °C) and mean January temperature is –14.5 °C (minimum temperature: –44.0 °C). The absolute annual temperature amplitude is therefore 86.0 °C (Chibilyov et al., 2004a). In the neighbourhood of the Irtek valley, eastern winds predominate in winter, whereas in summer north-western winds are predominant (Chibilyov et al., 2004b). In the area between the Ilek and Khobda rivers, south-western winds predominate (Chibilyov et al., 2004a). The velocity of winds is the highest in winter and spring (10–15 m/s). Also in summer south winds carrying dry air occur quite frequently and their velocity in gusts reaches 20 m/s.

The Irtek area is situated in the zone of typical fescue-feather grass steppe (*Festusca* sp. – *Stipa* sp.) and the interfluve of the Ilek and Khobda rivers is situated in the zone of wormwood-grass steppe (Fig. 1B).

The sands of the Irtek valley are covered in large areas by three vegetation formations: forest-steppe with predomination of *Populus tremula*, feather-grass steppe with large contribution of *Stipa pennata* and psammosteppes, where *Leymus racemosus* – *Festuca valesiaca* community predominates (Chibilyov et al., 2004b).

The sandy areas of the interfluve of the Ilek and Khobda rivers are also partially covered by forest-steppes, more common wormwood-grass steppes and psammostep-

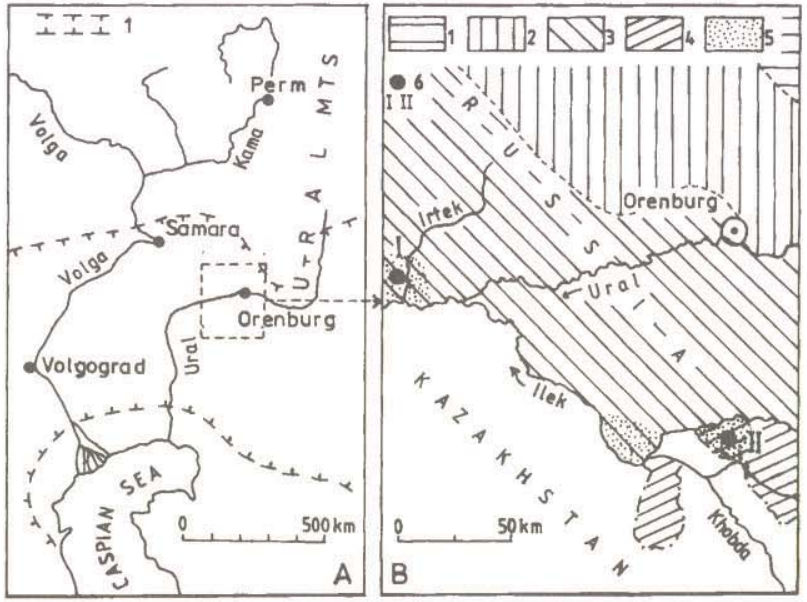


Fig. 1 **A** – location of the investigated area on the background of steppe belt (**1**) and (**B**) on the background of main types of steppes of southern Russia (according to: Geograficheskiy atlas... 1999): **1** – meadow steppes, **2** – grass-feather grass steppe, **3** – fescue-feather grass steppe, **4** – wormwood-grass steppe, **5** – psammosteppes, **6** – the investigated area (**I** – the Irtek valley, **II** – the Ilek and Khobda interfluve)

pes. In the psammosteppes, *Artemisia arenaria – Euphorbia seguieriana* community predominates in three variants: with *Calamagrostis epigejos*, with *Stipa pennata* and with *Leymus racemosus* (Chibilyov et al., 2004a, Chibilyov et al., in press).

4. Contemporary aeolian relief

4.1. The Irtek valley

The overbank terrace in the lower course of the Irtek river is built of Pleistocene lacustrine-fluvial grey-yellow sandy sediments and sandy-silty sediments. This material was considerably blown up and different accumulation and deflation landforms developed there. Densely located, not very high (4–8 m) and oval dune hills of soft shapes predominate in the landscape. They are divided by deflation basins of different size and shapes (Photo 1).

At present this area is covered by rare psammophilous grass vegetation. However, the excessive pasturage of cattle, sheep and goats caused in many places destruction of vegetation cover and repeated blowing of sands by strong winds. The aeolian relief which develops there at present has a typical deflation character because different dune forms which were developed earlier are now blown by winds. Among different elements of the relief deflation plains, basins and ditches predominate as well as

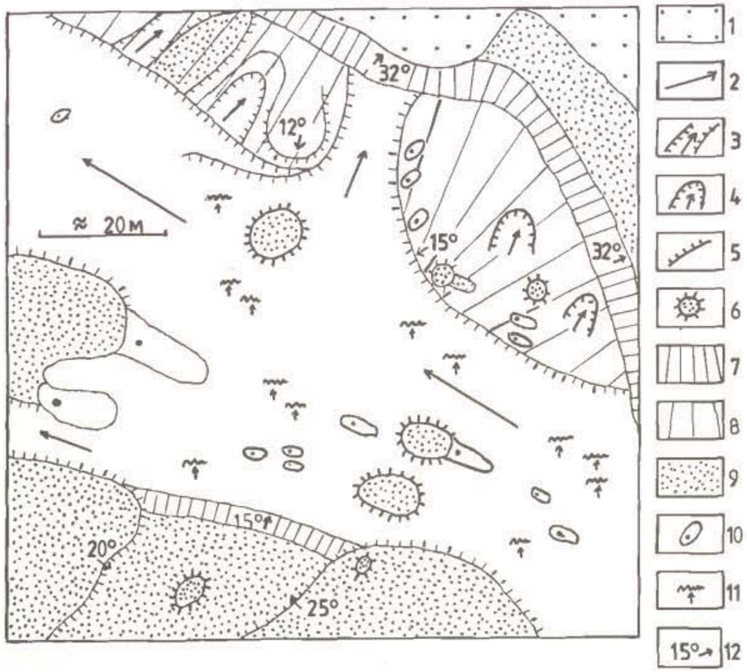


Fig. 2 Geomorphological sketch of the selected site in the Irtek valley: **1** – alluvial plain, **2** – deflation plane, **3** – deflation ditche, **4** – deflation basin, **5** – deflation undercut, **6** – deflation remnants, **7** – proximal slope of dune, **8** – distal slope of dune, **9** – aeolian cover, **10** – sand shadows of nebkha type, **11** – arrangement of ripplemarks on the day of observation (June 2003), **12** – angle and direction of slope inclination

Photo 1 Aeolian relief in the Irtek valley – general view (photo by T. Szczypek)

Photo 2 Blown dune sands in the Irtek valley (photo by T. Szczypek)

deflation remnants of different sizes and shapes (Fig. 2, Photo 2). Old dunes are represented here by remnants of typical distal slopes (proximal slopes were in fact completely destroyed). The effects of aeolian accumulation are usually less visible. They are present in form of small covers of blown sands of sandy hillocks, which develop in the shade of tufts of grass vegetation.

4.2. The interfluve of the Ilek and Khobda

In the interfluve of the Ilek and Khobda, older surface sediments are also represented by lacustrine-fluvial sediments of Apsheron – middle Quaternary age and also by sandy eluvia of Albian and Cenomanian sandstones (Chibilyov et al., 2004a). At the turn of Pleistocene and Holocene, these sediments and especially sandy eluvia of Cretaceous sandstones were blown up, similarly to sands of the Irtek valley, and different dune landforms developed. They are not so densely distributed and so well developed as they are in the Irtek valley. Relatively flat or slightly undulated surfaces predominate.

At present this area is also covered by relatively rare grass vegetation of psammosteppes and excessive agriculture and pasturage caused blowing of the substratum material. Modern aeolian relief of this area has a typical deflation character. Older dune forms have been almost completely destroyed and their place was taken by predominating deflation planes and other deflation forms (Fig. 3). The depth of concave forms may reach 4–5 m. Forms of modern aeolian accumulation play only an insignificant role in the morphology of this area. These are relatively small sandy covers often blown by winds and sandy hillocks with vegetation tufts.

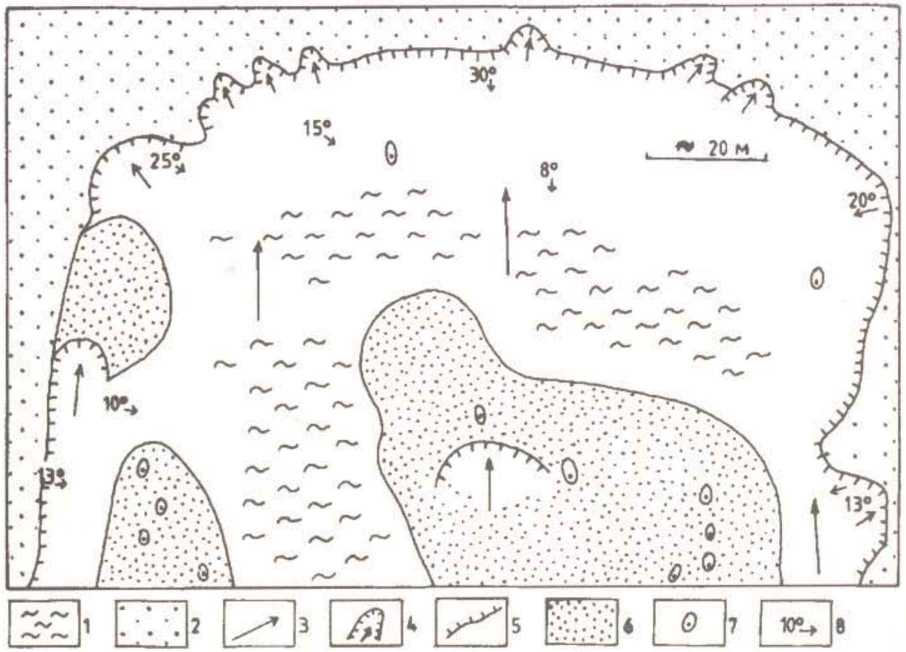


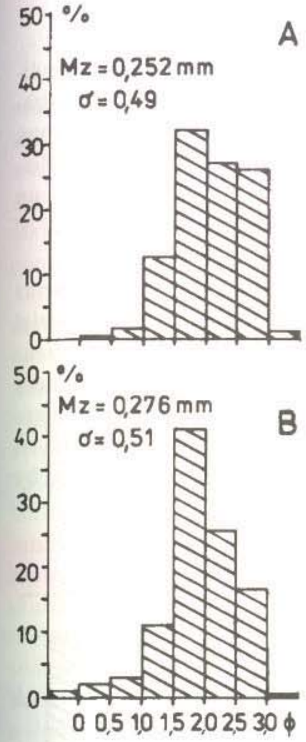
Fig. 3 Geomorphological sketch of the selected site in the Ilek and Khobda interfluve: **1** – cover of clayey waste-mantle of sandstones, **2** – eluvial plane, **3** – deflation plane, **4** – deflation basin, **5** – deflation undercuts, **6** – aeolian cover sands, **7** – sandy hillocks of nebkha type, **8** – angle and direction of slope inclination

5. Features of aeolian sands on the background of the substratum

5.1. The Irtek valley

In terms of granulometric composition, the aeolian sands and substratum sediments are typical medium-grain sediments, but they differ from each other in terms of the content of admixture fractions, especially coarse-grain fraction. Fluvial sediments show mean diameter Mz = 0.252 mm, and aeolian sands show mean diameter Mz = 0.276 mm (Fig. 4). Substratum sediments contain 1.1% of coarse-grain sands (> 0.5 mm), whereas blown sands contain 5.5% of this fraction. Substratum sediments contain also 1.1% of silty deposit (< 0.1 mm) and dune sands contain 0.6% of this fraction. Sorting degree of both sediments is similar: $\sigma = 0.56$ for substratum sediments and $\sigma = 0.51$ for aeolian sands, however there is a distinctive trend of sorting improvement in aeolian sands.

There are small differences in terms of quartz grain abrasion. Taking into account the results of analyses with application of mechanical method by Krygowski (1964), in both cases there is an insignificant content (2.1–2.2%) of round grains of γ type and there is predomination of angular grains of α type (76–77%). Slightly smaller content of α grains and also slightly larger content of semiround grains of β type in aeolian sands

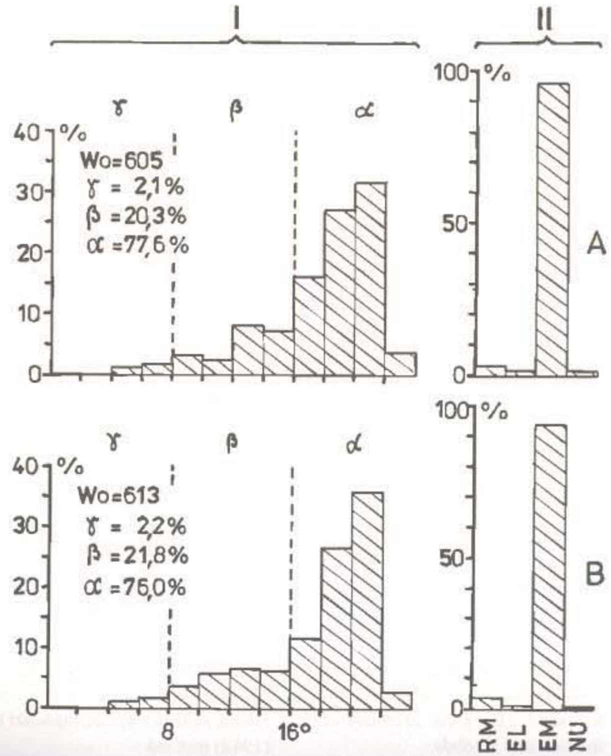


as compared to substratum sediments causes that the value of abrasion coefficient Wo for dune sands is 613 and for terrace sands 605 (Fig. 5I).

Similar small differences are confirmed by the results of morphoscopic method by Cailleux (1942). They show that aeolian sands of the studied area contain 4.0% of round opaque grains, 0.6% of angular grains and 94.3% of transitional grains. In case of terrace sands these values are 2.7%, 1.2% and 95.7% respectively (Fig. 5II).

◄ *Fig. 4* Grain size distribution of fluvial sediments (**A**) and aeolian sands (**B**) in the Irtek valley

▼ *Fig. 5* Degree of quartz grains abrasion of fluvial sediments: (**A**) and aeolian sands (**B**) in the Irtek valley determined from: **I** – Krygowski's (1964) method and **II** – Cailleux (1942) method



Both eluvial sands of substratum and aeolian sands represent medium-grain sediments. They contain however a clearly different content of admixture fraction: substratum sediments contain 0.9% of material >0.5 mm and 0.9% of silty material <0.1 mm, whereas aeolian sands contain 8.3% and 2.0% respectively. Therefore the mean diameter for eluvial sediments Mz = 0.233 mm, whereas for dune sands Mz = 0.281 mm (Fig. 6). Sorting degree of both sediments is medium, but aeolian sands show trend of sorting deterioration ($\sigma = 0.68$) as compared to eluvial material ($\sigma = 0.49$).

Also in terms of material abrasion, there are clear differences between the sediments studied. Taking into account Krygowski's (1964) mechanical method, eluvial material contains 8.0% of round grains of γ type and 36.7% of coarse grains of α type, whereas aeolian sands contain 9.7% γ grains and 40.2% of α grains. Simultaneously, substratum sediments contain 55.3% of grains with medium abrasion (β) and aeolian sands contain only 50.2% of such grains. Therefore the value of abrasion index Wo for eluvial material is 986 and for aeolian sands 968 (Fig. 7I). Similar differences are revealed by the results of analysis with application of Cailleux (1942) method (Fig. 7II).

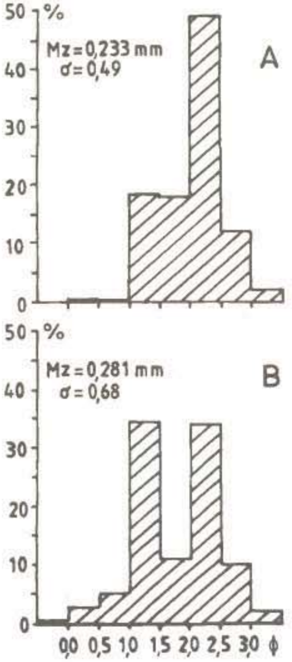


Fig. 6 Grain size distribution of alluvial sediments (**A**) and aeolian sands (**B**) in the interfluve of the Ilek and Khobda

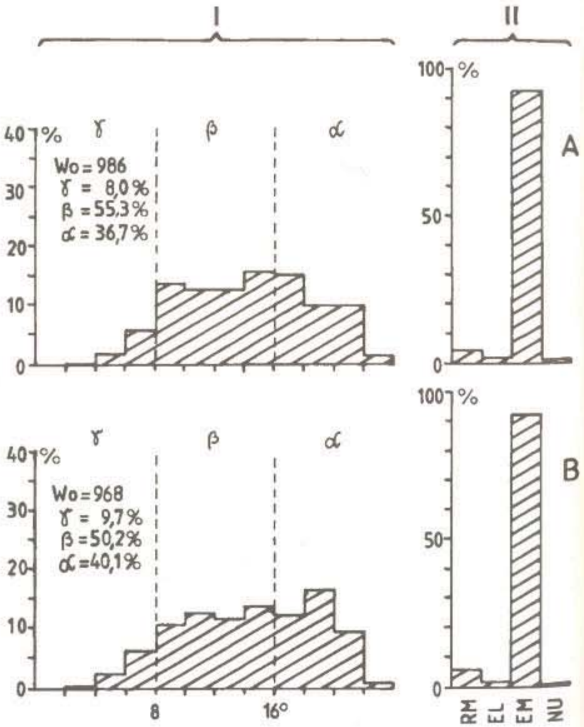


Fig. 7 Degree of quartz grains abrasion of alluvial sediments (**A**) and aeolian sands (**B**) in the interfluve of the Ilek and Khobda determined from: **I** – Krygowski's (1964) method and **II** – Cailleux (1942) method

Wind, as a relief-forming and segregating factor, played a differentiated role in the area of the Irtek valley and in the interfluve area of the Ilek and Khobda. Because of the fact that different dominating wind directions (NW, E, S and SW) occurred in these areas, univocal and simple for classification dunes could not develop. Instead, united dunes of complex shapes developed. At present, due to deterioration of vegetation and steppe soils by excessive pasturage and ploughing, wind forms here a typical and common deflation relief.

The aeolian factor quite clearly changed grain size distribution of the sediments: dune sands are slightly coarser than substratum sediments and sorting degree of these sediments does not change or shows trend of deterioration. The aeolian factor did not influence however the character of abrasion of blown sands. Dune sands in the Irtek valley do not have abrasion typical for aeolian sediments (Wo value about 600; content of γ grains typical for wind environment is only 2%; content of α grains as much as 75%), and they are only slightly better rounded then terrace sands. This may result from both short distance of material migration and short time of wind influence on transported sandy material. In the interfluve of the Ilek and Khobda, dune sands show features of blown sands (value of Wo over 900; content of γ grains typical for wind environment is about 10% and simultaneously content of transitional β grains about 50%; content of α grains only 40%), but the degree of their transformation as compared to substratum sediments is still very small. This results from the fact that eluvial sediments must have been earlier transported by wind (not necessarily producing dune forms) and also from a short renewed transport of contemporary dune sands in aeolian environment.

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WSPÓŁCZESNA RZEŹBA I OSADY EOLICZNE W DORZECZU RZEKI URAL W POŁUDNIOWEJ ROSJI

Streszczenie

Praca przedstawia główne cechy warunków środowiskowych stepowej strefy południowej Rosji w obwodzie orenburskim (rys. 1), a na tym tle – charakterystykę współczesnej rzeźby eolicznej psammostepów oraz mechaniczne cechy utworów wydmowych (uziarnienie i stopień obróbki piasków) w porównaniu z materiałem podłoża. Obserwacje objęły dolinę rzeki Irtek oraz obszar międzyrzecza Ileka i Chobdy.

Wiatr, jako czynnik rzeźbotwórczy i segregujący, odegrał na badanych obszarach doliny Irteka oraz międzyrzecza Ileka i Chobdy zróżnicowaną rolę. Pod wpływem odmiennych dominujących jego kierunków (NW, E, S i SW) nie mogły rozwinąć się jednoznaczne i proste do zaklasyfikowania typy wydm, powstały natomiast wydmy łączące się ze sobą, o skomplikowanych zarysach (fot. 1). Współcześnie, wskutek niszczenia roślinności i gleb stepowych przez nadmierny wypas oraz orkę, wiatr tworzy tu charakterystyczną i wszechobecną rzeźbę deflacyjną (rys. 2, 3; fot. 2).

Czynnik eoliczny dość wyraźnie zmienił uziarnienie osadów: piaski wydmowe są nieco grubsze od piasków podłoża, a stopień wysortowania osadów nie uległ zmianie lub wykazuje tendencję do pogarszania się (rys. 4, 6). Czynnik eoliczny nie wpłynął natomiast na charakter obróbki piasków przewianych. Piaski wydmowe w dolinie Irteka nie mają obróbki typowej dla środowiska eolicznego (wartość Wo rzędu tylko 600; zawartość typowych dla środowiska wiatrowego ziaren typu γ rzędu zaledwie 2 %; zawartość ziaren typu α – rzędu aż 75 %) i są tylko bardzo nieznacznie lepiej obtoczone w porównaniu z piaskami terasowymi (rys. 5). Może to wynikać zarówno z krótkiej drogi przemieszczania materiału, jak i z krótkiego czasu oddziaływania wiatru na transportowany materiał piaszczysty. Na międzyrzeczu Ileka i Chobdy piaski wydmowe mają już znamiona osadów przewianych (wartość Wo ponad 900; zawartość typowych dla środowiska wiatrowego ziaren typu γ rzędu 10 % i jednocześnie udział ziaren pośrednich typu β rzędu 50 %; zawartość ziaren typu α – rzędu już tylko 40 %), ale stopień ich przeobrażenia w stosunku do utworów wyjściowych jest nadal minimalny (rys. 7). Wynika to z faktu, że osady eluwialne musiały już wcześniej być przenoszone przez wiatr (niekoniecznie tworząc typowe formy eoliczne) oraz z krótkiego ponownego transportu współczesnych piasków wydmowych w środowisku eolicznym.