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The granulometric properties of contemporary aeolian sands in a taiga-steppe area of Eastern Siberia

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Abstract: The grain size distribution and quartz grain (1.0–0.8 mm) abrasion degree for the contemporary aeolian sands occurring in a zone of taiga and steppe in the neighbourhood of Lake Baikal, in Eastern Siberia, is compared with similar features in other aeolian sediments. Five sites in a taiga zone, one in a forest-steppe zone and one in a steppe zone have been investigated. Whereas the morpho-forming influence of the wind is obvious in the area investigated, the role of the wind is important only in respect of grain size distribution and is not an important factor in determining in quartz grain abrasion size.

Key words: Eastern Siberia, modern aeolian processes, aeolian landforms, aeolian sands

Introduction

Aeolian sands in Eastern Siberia area form part of genetically quite different sand-gravel deposits, some of which are widespread. Such areas have local names – „tukulans", „kuytuns" or „badars" (Preobrazhenski, 1961; Pavlov, 1981; Krendelev, Nasyrova, 1985 and others) and may usually occur on the floors of large faulted depressions. Other sandy areas are smaller and these reflect particular local lithological conditions. Thanks to it, the aeolian sands in the area above-mentioned seem to be rather popular, although they usually occupy relatively small areas. Whatever they originate, the aeolian sands are now covered by taiga vegetation (dark and light taiga – Baikal, 1993). Seasonally, these areas are affected by powerful, usually undirectional, winds, especially in early Spring and Autumn (Vyrkin, 1986; Lubtsova, 1994). Whereas these deposits are widespread, such mechanical properties as: grain size distribution and quartz grain abrasion, are almost completely unknown. Further, very little is known about the sources of these sediments. The purpose of the research described here was to determine the influence of aeolian processes in the study area by analysing selected aeolian sands and by a review of the literature concerning such sediments. Most of the study sites lie in the Baikal rift zone; in the Tunka Basin on the western margin of Baikal; on the western shore of Olkhon Island on Baikal and on the shores of the Bratsk Reservoir on the River Angara. The following sites of aeolian sands have been investigated: of taiga – I – Rassvet on Bratsk Reservoir, II – Great Khuzhir on Olkhon, III – Sandy Bay, IV – the terrace of the Irkut River, V – the slope of Mt Khayrkhan in the Tunka Basin, vegetated by forest-steppe: VI – the valley of the Tunka in the Tunka Basin and of steppe: VII – the Seven Pines area on Olkhon (Fig. 1).

The area analysed is characterised by very strong continental climatic conditions with large mean temperatures variations between Summer and Winter, reaching an amplitude 30–40° or more; the precipitation is also very low here, the annual sums fluctuating between 200 mm on Olkhon and 450–500 mm in the Tunka Basin (Baikal, 1993; Szczypek, 1995).

Anemological conditions

The anemological conditions in the area investigated are very variable. In this study it is necessary to know the directions of prevailing winds as well as the annual distribution of days with very strong winds, i.e. blowing

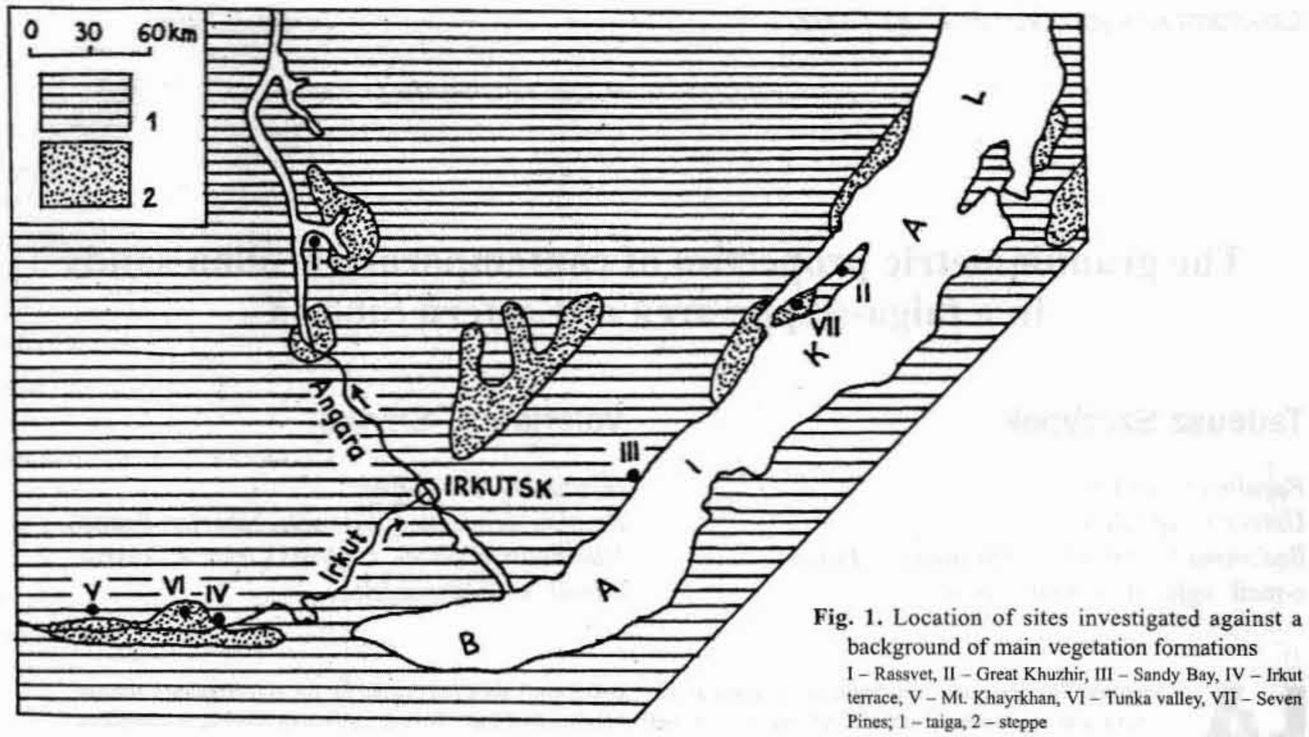

Fig. 1. Location of sites investigated against a background of main vegetation formations
I – Rassvet, II – Great Khuzhir, III – Sandy Bay, IV – Irkut terrace, V – Mt. Khayrkhan, VI – Tunka valley, VII – Seven Pines; 1 – taiga, 2 – steppe

with velocities > 15 m×s[-1] (*Spravochnik po klimatu...*, 1967). In this respect, the shores of Baikal and Olkhon fundamentally differ from the Tunka Basin. On Olkhon, westerly and north-westerly winds clearly predominate although northerly winds are also important; a similar wind regime is observed in Sandy Bay (Szczypek, Wach, 1992). By contrast, in the western part of the Tunka Basin, westerly winds overwhelmingly predominate, but in the eastern part – easterly ones with a certain influence of morpho-forming westerly winds (Fig. 2A). In the comparatively short section of the Angara valley in the neighbourhood of the Bratsk Reservoir the situation is

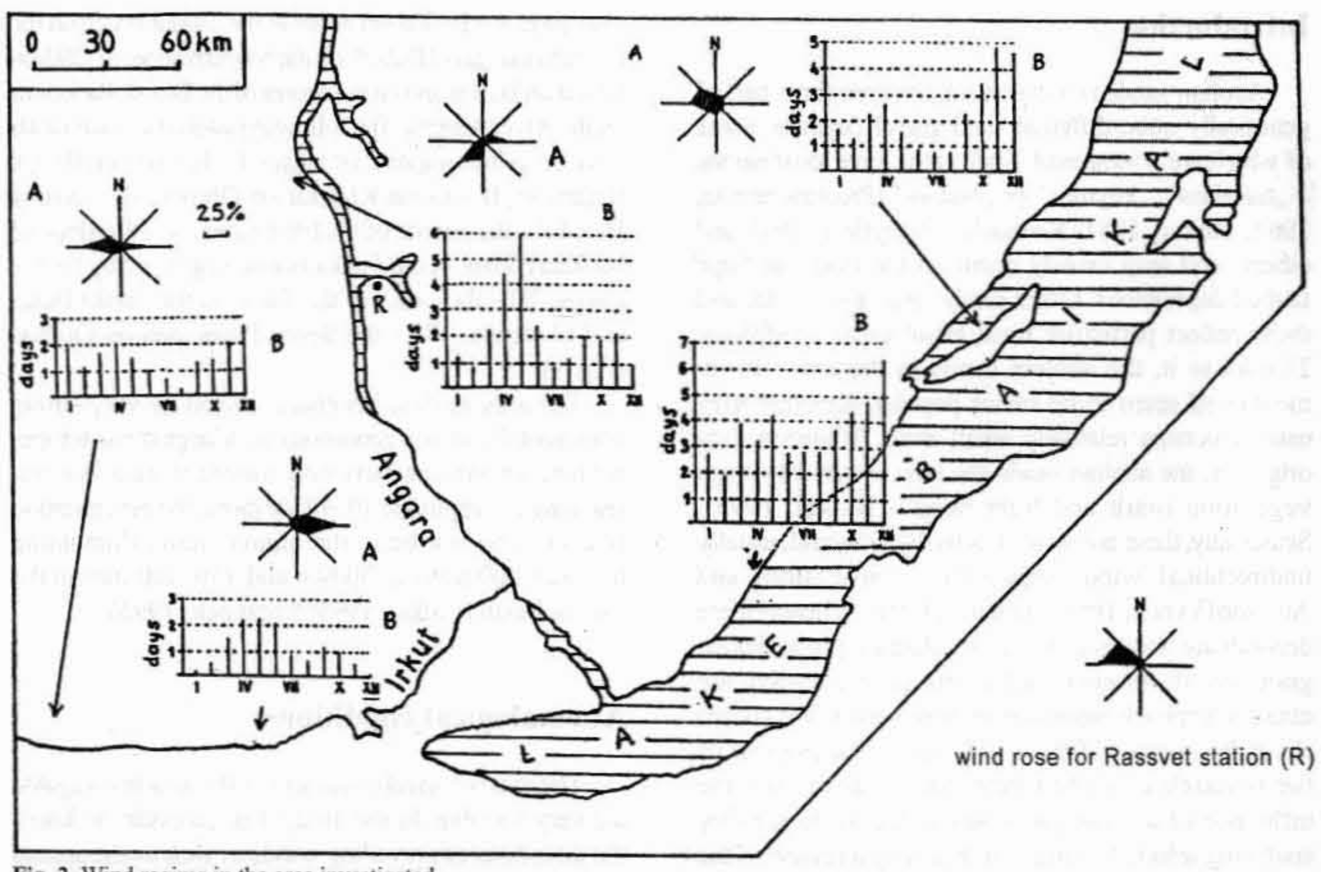

Fig. 2. Wind regime in the area investigated
A – wind roses, B – mean days number with winds > 15 m . s[-1]

more complicated, because, in the vicinity of Balagansk, the south-westerly and southerly winds alternate with an easterly air flow. Further, in the neighbourhood of the Rassvet Station, westerly and north-westerly winds prevail (Ovchinnikov, 1998). With regard to the average number of days with strong winds per year, Olkhon has 27 such days (mostly in Autumn and in the beginning of Winter, and least of all, in Summer); Sandy Bay has 43 (these being fairly evenly distributed through the year); although it is also possible to distinguish an Autumn and early Winter air flow as well as one in Spring. In the Tunka Basin there are significantly fewer (the western part has 18, similarly with a seasonal distribution; the eastern part has only 13, the Spring and early Summer air flows predominating. As at Olkhon and in the Angara valley, the mean number of days with strong winds is 26, but here Spring air flows are strongest, the minimum flows are in Summer and Winter (Fig. 2B). The significantly larger number of days with strong winds at Baikal is presumably a result of the intensive local atmospheric circulation over this lake and its neighbourhood. Normally there are large differences in atmospheric pressure between these areas (Galaziy, 1987 and others). The same is probably true for the Bratsk Reservoir.

Characteristics of aeolian sands

Research methods

Laboratory analyses of these deposits included:

a) standard grain size distribution, following which the mean grain size diameter Mz and sorting degree of deposits – σ have been calculated (Folk and Ward, 1957);

b) quartz grains (1.0–0.8 mm) abrasion degree, applying (1) the mechanical method by Krygowski (1964) – from this the abrasion coefficient Wo, the content of well-rounded grains of γ type, medium-rounded grains of β type and angular grains of α type have been calculated, and (2) morphoscopy by Cailleux (1942) – from this the content of mat-rounded grains of RM type, polished rounded grains EL, intermediate EM and angular NU have been calculated.

Taiga sites

Rassvet

• *Main geomorphological features.* Holocene wind-blown aeolian sands occur along the shores of Bratsk Reservoir, on the margins of or only partly overlapping the area of taiga (Owczinnikow, 1996; Ovchinnikov, 1998). They lie at 400 m a.s.l. or more. The source deposits are dry lake sands and unconsolidated river deposits. The aeolian forms in the study area appear to be produced by abrasion processes which occur in the reservoir, especially at times of fluctuating water level, when widespread sandy deposits become uncovered and dry out (Owczinnikow, 1996; Ovchinnikov, 1998).

Owing to the intensive influence of westerly and north-westerly winds, those sandy deposits which are uncovered at times of low water level become blown clear of the reservoir shores. Thick aeolian covers have thereby been created on the beach, whereas at the edge of the reservoir, irregular dunes are present, which gradually migrate towards the south-east (Fig. 3).

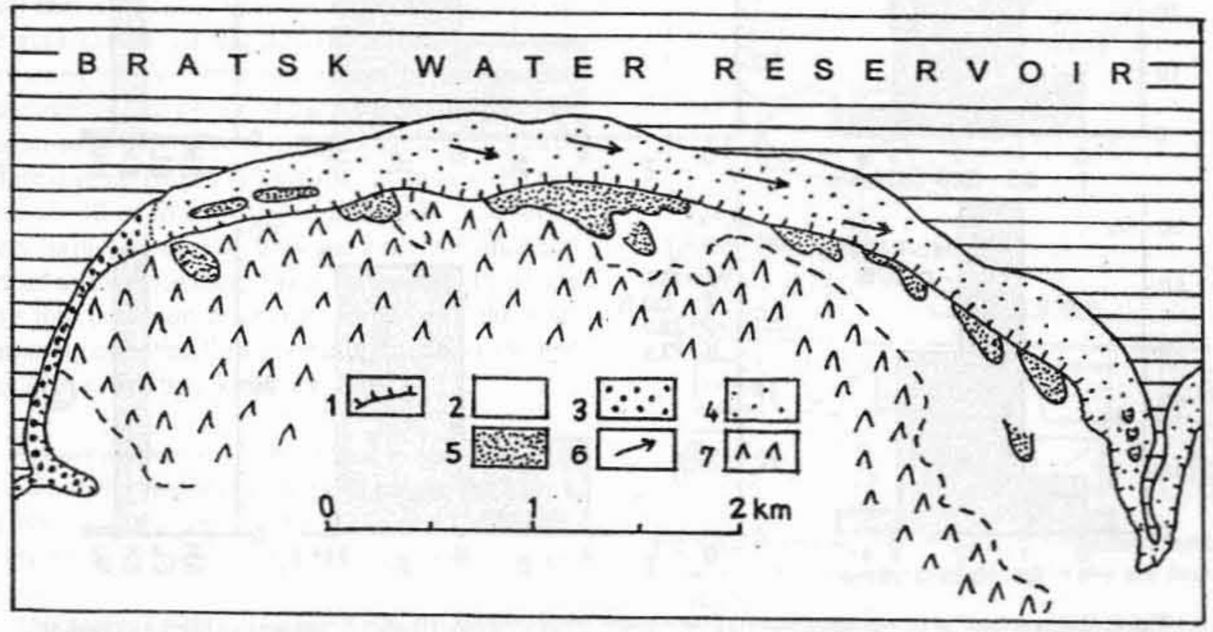

Fig. 3. Morphological sketch-map of aeolian landforms in the neighbourhood of Rassvet (after Ovchinnikov, 1998)
1 – edge of reservoir shore in 1996, 2 – alluvial-deluvial deposits, 3 – lacustrine pebble-deposits, 4 – lacustrine sandy deposits, 5 – aeolian sands (mostly dunes and covers), 6 – direction of deflation processes, 7 – forest

• *Properties of the deposits*. The river /bank/-sands are characterised by having significant fine fraction. On average, they contain 4.6% of coarse grains (0.5 mm) and 38.4% of silt/clay particles (<0.125 mm). Therefore mean grain diameter in these weakly sorted deposits ($s = 1.05$) is relatively small and the Mz is 0.137 mm (0.100–0.210 mm).

The beach deposits are clearly well-washed and, therefore, more coarsely-grained. The 0.5 mm fraction is 10.6% on average and silt/clay particles, 4.7%. So, these deposits are better sorted ($\sigma = 0.66$) and they have a mean grain diameter $Mz = 0.282$ mm (0.155–0.451 mm).

The aeolian sands here are characterised by an even larger coarse fraction. Their mean grain diameter $Mz = 0.326$ mm (0.188–0.807 mm): the average content of material >0.5 mm is 12.7% (2.5–61.5%) and the finest – 3.9% (0.3–11.0%). These deposits are less well sorted than these of the beach – $\sigma = 0.77$ (Ovchinnikov, 1998) (Fig. 4 I).

With respect to the quartz grains abrasion, the fluvial deposits are characterised by a mean value of abrasion coefficient $Wo = 628$: they are devoid of grains of γ type, but they contain 73.5% of angular grains of α type. Morphoscopy shows that they also contain only 0.8% of grains of RM type and 2.0% – NU. EM grains are dominant – 96.0%.

The beach sands are characterised by the similar abrasion degree – $Wo = 621$, the share of grains of γ type is 0%, α – 73.8%, RM – 1%, NU – 2.9%; EM – 93.9%.

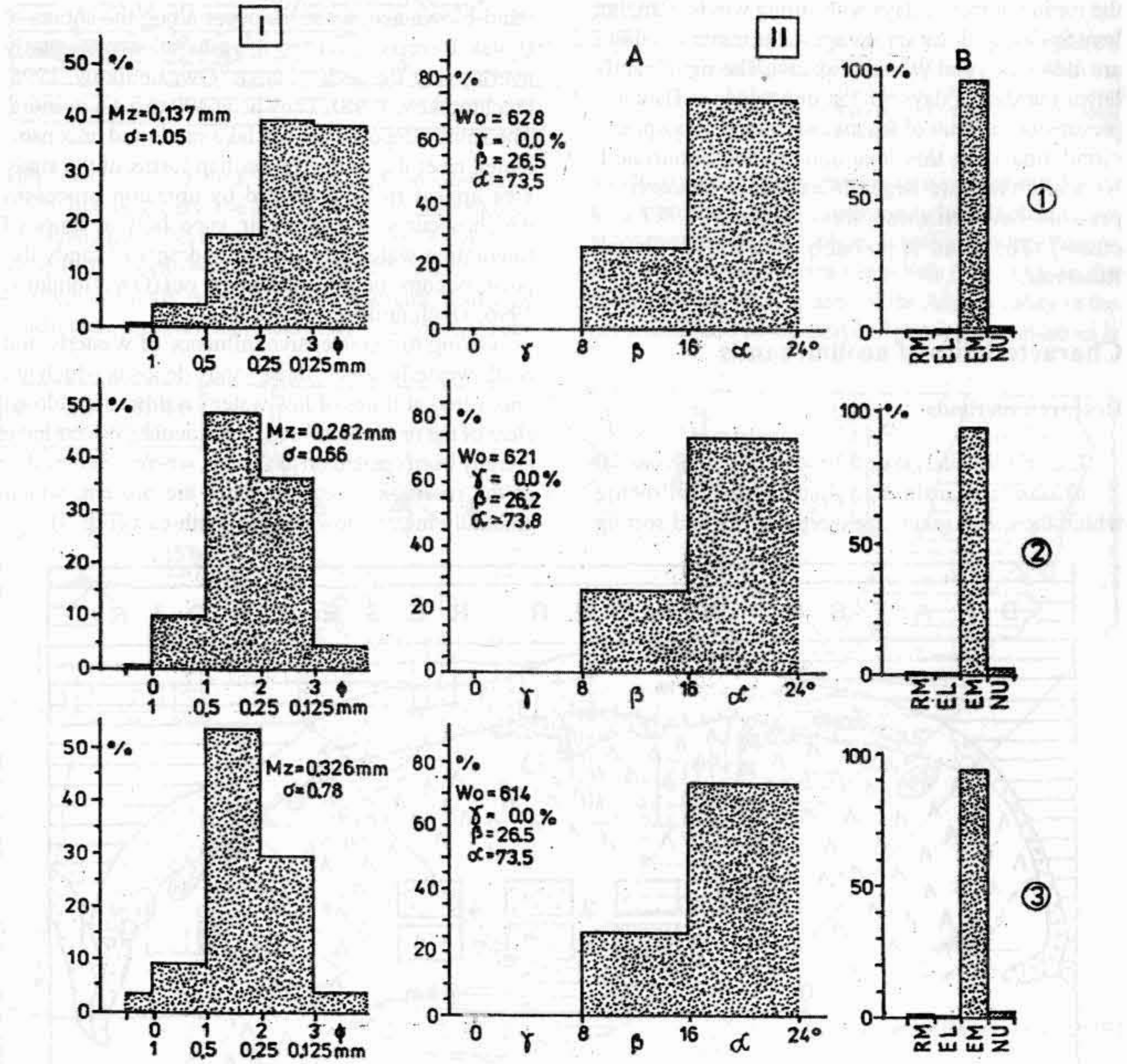

Fig. 4. Histograms of grain size distribution (I) and quartz grain abrasion (II) after Krygowski's (1964) mechanical method (A) and morphoscope Cailleux's (1942) method (B) in the neighbourhood of Rassvet

1 – river sands, 2 – beach deposits, 3 – aeolian sands; Wo – abrasion coefficient, γ – well rounded grains, β – medium rounded grains, α – angular, unabraded grains; RM – mat rounded grains, EL – polished rounded grains, EM – intermediate grains, NU – unabraded grains

With respect to the abrasion degree, the wind-blown sands do not differ from the source material. The Wo value amounts to 614 (497–673): they contain 0% of grain of γ type; α – 73.5% (61.2–81.1%), RM – 1.8%, NU – 2.7% and EM – 94.3% (Ovchinnikov, 1998) (Fig. 4 II).

Great Khuzhir

• *Main geomorphological features*. The taiga ranges on Olkhon are located in the north-eastern part of the island. Widespread areas of aeolian sands occur there and they are almost completely covered by east-Siberian light pine-larch taiga with *Rhododendron dahuricus* in the undergrowth (Wika, Snytko, Szczypek, 1997). In some places, large areas of that taiga have been damaged by uncontrolled deforestation which has caused the mobilisation of the aeolian sands. Their source is the beach deposits of Baikal, following erosion of the local Neogene deposits (Afagonov, 1975, 1990; Taisaev, 1982).

The relief is very similar across Olkhon. The main geomorphological features of this area are typified by the Great Khuzhir range, which is located in the middle of the island. This lies at the height of c. about 456 m a.s.l. at the Baikal shore to about 470 m a.s.l. The contemporary aeolian relief is formed under the influence of northerly winds.

The main feature of mobile sand relief is the occurrence of a formerly well-developed, but now less distinct blown complex dune form, generally arcuate and, in some places – even parabolic (Fig. 5). Aeolian cover sands are forming around it. The thickness of aeolian sands, which lie on granitoid or granitoid regolith, ranges from several centimetres on the beach scarp to at least 12–13 m in the dune culminations. In the area discussed the deflation forms with the prevailing depressions and planes of the genesis above-mentioned decide of the contemporary face of aeolian sands. They are of different age and they have different sizes, from 5–10 m to 30–50 m in width and from 20–30 m to 100–150 m in length. In front of every form, a clear mobile tongue built from material carried away from them has been created. There are only few deflation remnants. In general, the contemporary deflation forms occur in a multi-horizontal way (Wika, Snytko, Szczypek, 1997).

• *Sand properties*. These relate to material sampled from the neighbouring taiga range; the beach, the Neogene, the granitoid regolith and the aeolian sands have all been sampled (Szczypek, Snytko, 1998).

The beach sands are rather coarse-grained: their mean value $Mz = 0.563$ mm and they contain 66.3% coarse grains and 0.2% silt/clay particles. Therefore, they are moderately sorted ($\sigma = 0.45$). The Neogene deposits are slightly finer, because the value of $Mz = 0.403$ mm; they are composed of 30.1% coarse grains and 3.5% of the finest particles. They are also sorted to a moderate degree, although less well so than the beach sands ($\sigma = 0.89$). The granitoid regolith (missing the coarsest parts) is coarse-grained: 69.2% of grains are >0.5 mm in diameter there are no silt/clay particles, so the value of $Mz = 2.250$ mm. The sorting is poor ($\sigma = 2.12$).

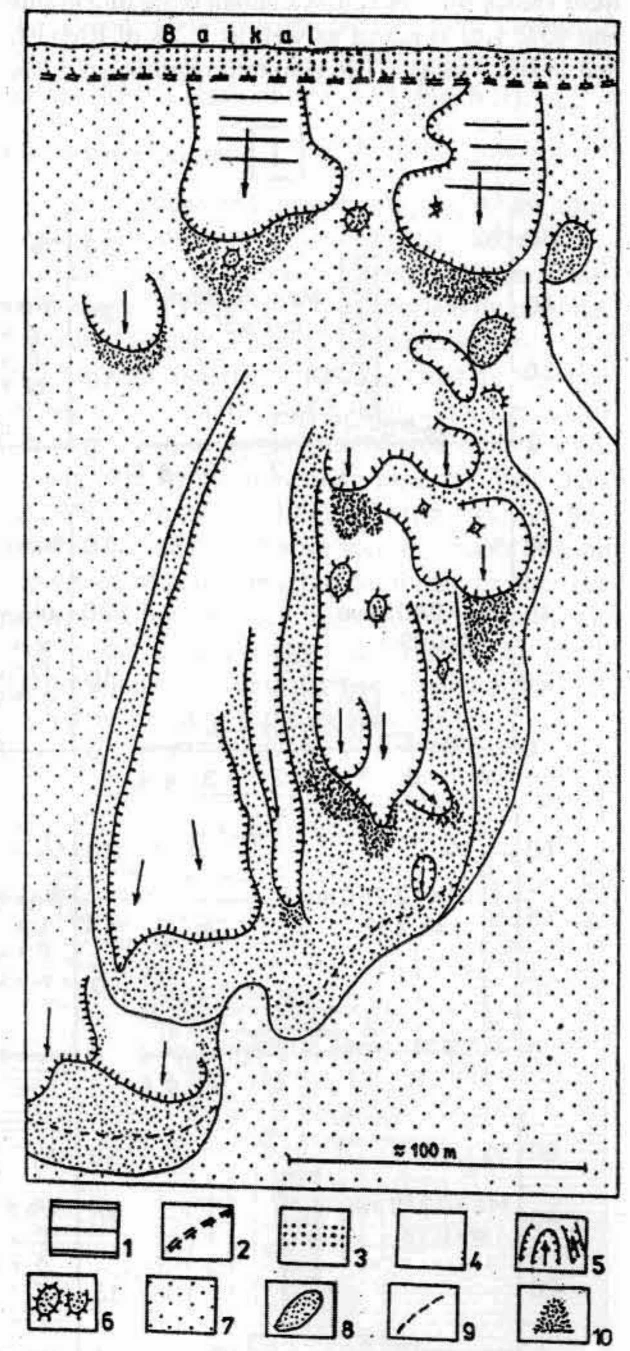

Fig. 5. Geomorphological sketch-map of drifted sands in the taiga area of Great Khuzhir (after Wika, Snytko and Szczypek, 1997)

1 – outcrops of crystalline rocks, 2 – sandy cliff near knickpoint of crystalline substratum, 3 – sandy beach of Lake Baikal, 4 – deflation plains, 5 – deflation knickpoints, basins and ditches, 6 – deflation remnants, 7 – aeolian cover sands, 8 – dunes, 9 – crest lines, 10 – modern aeolian covers

The aeolian sands are clearly finer: they are characterised by a mean value of Mz = 0.363 mm (0.310–0.966 mm), the coarse grains fraction is 12.1% (1.7–84.9%), whereas silt/clay particles – 0.7% (0.2–1.9%). They are moderately sorted (δ = 0.78) (Fig. 6 I).

With regard to the quartz grain abrasion properties, these sediments show no marked differences. On average, the beach sands contain 6.8% of γ grains, 67.8% of α grains, 3.2% of RM+EL and 29.5% of NU. The value of Wo is 720. The Neogene deposits have values Wo = 861, they contain 6.5% of γ grains and 45.2% of α grains as well as 3.2% of RM+EL and 11.0% – of NU. The granitoid regolith has 6.2% of γ grains and 48.9% of α grains and a Wo = 858. They also contain 2.6% grains of RM+EL type and 7.8% – of NU grains.

The aeolian sands are characterised by a mean value Wo = 722 (599–908), on average they contain 3.6% (1.8–6.5%) of γ grains and 62.7% (39.0–77.6%) of α grains. They also comprise 4.8% (1.2–12.5%) of RM+EL grains and 15.7% (6.3–35.7%) of angular grains of NU type (Fig. 6II).

Sandy Bay

• *Main geomorphological features.* The bay is nearly semi-circular, with a diameter of 1 km. From the west and the east it is surrounded by two high rocky capes, built from hard varieties of granitoid, but the coast is mostly composed of lacustrine sands. Away from the shore, the terrain gradually and gently rises into high mountains, built of softer granitoid rocks, which easily undergo mechanical weathering. Their outcrop is covered by a thick regolith. In the middle, and especially in the eastern parts of the area, near the bay, the morphological effects of northerly and westerly wind destruction are striking. In places, the root system of larches, have been uncovered to a depth of 2.5 m, in others, especially in the east, a widespread deflation field, formed within the regolith deposits is present. The sands from this field have been directly blown to Baikal and also to the slopes and ridge of the granitoid bank (Szczypek, Wach, 1992; Wika *et al.*, 1999) (Fig. 7). Aeolian sands occur here at a height of about 460–500 m a.s.l.

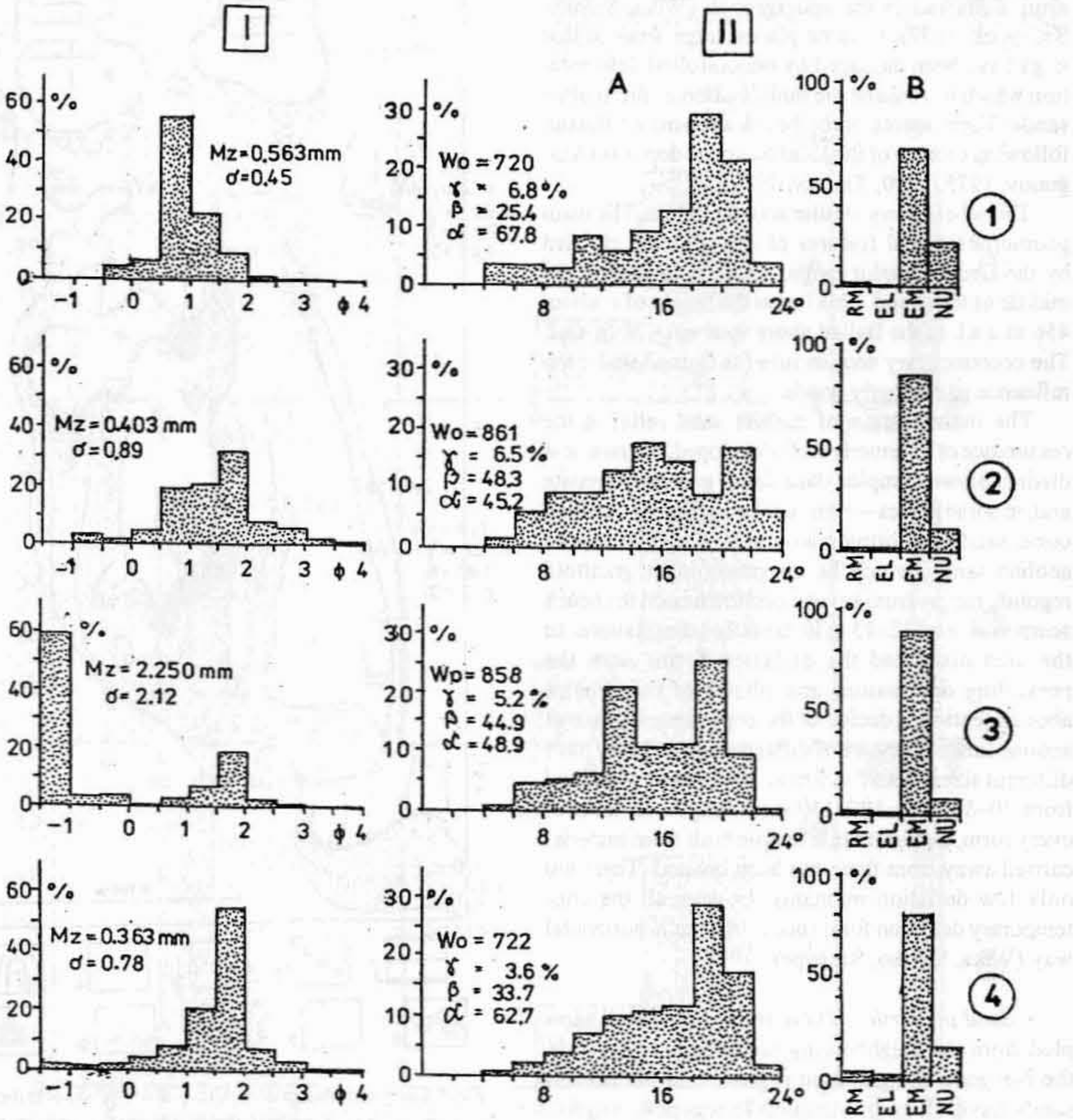

Fig. 6. Histograms of grain size distribution (I) and quartz grain abrasion (II) after Krygowski's (1964) mechanical method (A) and morphoscope Cailleux's (1942) method (B) in taiga area on Olkhon Island (after Szczypek and Snytko, 1998)

1 – beach sands, 2 – Neogene deposits; 3 – granitoid regolith, 4 – aeolian sands; other explanations – see Fig. 4

• *Sand properties.* The regolith of granitoid rocks (the source material) is characterised by a large, coarse granulation (Mz = 0.847 mm). 89.4% of the grains are coarse and only 1.7%, silt/clay. It is well sorted (δ = 0.39). The wind-blown material at the deflation field is only slightly finer (mean value of Mz = 0.642 mm) (0.525–0.707 mm). On average, it contains 67.3% (54.9–74.3%) of coarse fraction and 1.9% of silt/clay (1.0–2.6%). It is thus moderately sorted (σ = 0.73 mm). The sands blown onto the ridge are characterised by significantly smaller sizes: Mz = = 0.289 mm, and they contain 7.5% of coarse grains and 1.3%, silt/clay. In sum, this material is better sorted than the blown sands but less well so than the regolith (Fig. 8 I).

The source material for the aeolian deposits is characterised by a value of Wo = 124. They do not contain grains of g type, but 95.0% of the grains are of a type. No RM or EL grains were observed. The content of NU grains is 95.5%. Blown sands are characterised by a mean Wo = 184 (163–207). The content of a grains is 93.7% (93.0–94.5%) and there is an absence of g grains. They comprise 94.2% of NU grains; no rounded grains were observed (RM+EL). The drifted sands are characterised by Wo value of 156; the a grains content is 92.0% (lack of g); NU grains – 89.5% (lack of RM+EL) (Fig. 8 II).

The Irkut river terrace

• *Mean geomorphological features.* At the Irkut meadow terrace, at the height of below 720 m a.s.l., Late Pleistocene river deposits comprise dunes of different size and shape. They are overlain by irregular deposits of aeolian sands. The dunes are usually covered by taiga, but the covers are fixed by a sparse herbaceous vegetation with individual bushes of willow, as well as by patches of wind-blown sand, brought here by the prevailing easterly winds (Ivanov, 1966; Szczypek, 1993; Martyanowa, Snytko, Szczypek, 1998). In this respect, the dunes give an impression of being longitudinal forms, i.e. they are widespread but not very high. To the south of this dune occurs aeolian cover, which is pitted by small, flat deflation basins (Fig. 9). In the south this area is limited by the edge of the meadow terrace.

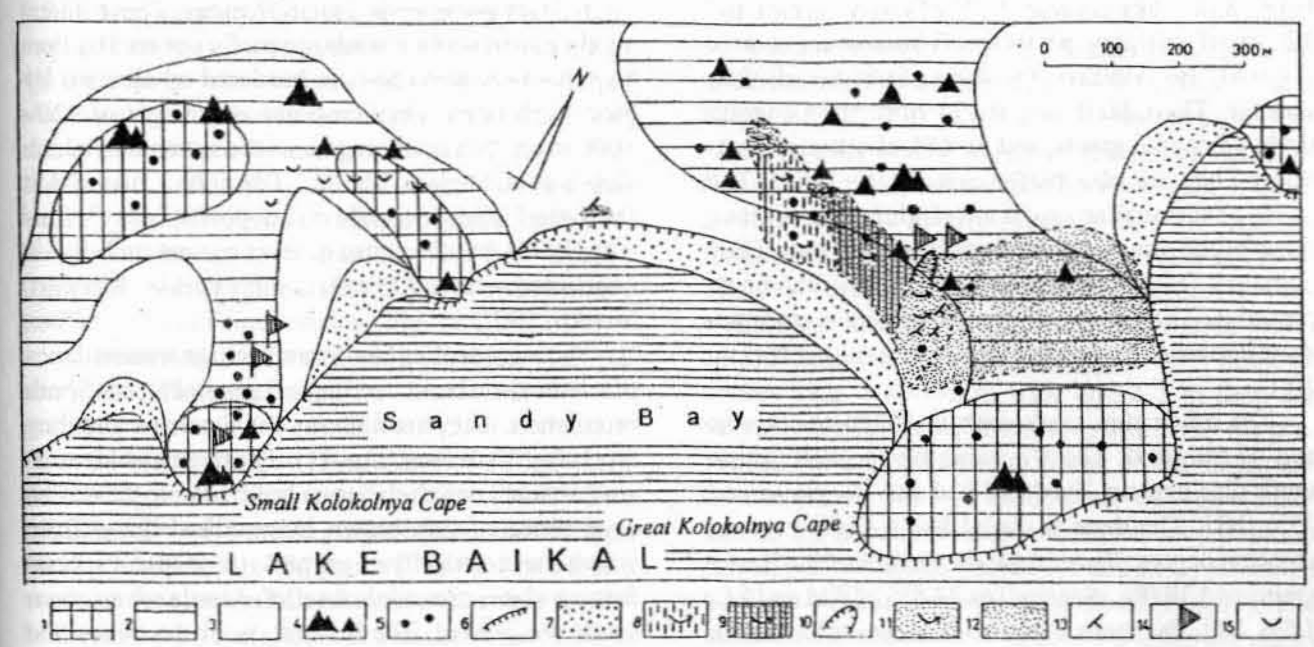

Fig. 7. Geomorphological sketch-map of the Sandy Bay area (after Wika *et al.*, 1999)

1 – ridges formed of hard granitoids, 2 – gentle mountain slopes formed of soft granitoids, 3 – main granitoids remnants, 4 – cliff, 5 – beach, 6 – Aeolian accumulation cover, 7 – aeolian cover with deflation relief features, 8 – advancing trees, 9 – trees with root systems exposed due to denudation, 10 – deflation basins, 11 – modern blown sand cover, 12 – aeolian cover sands, 13 – „walking" trees, 14 – wind-shape trees, 15 – forms of sheet wash

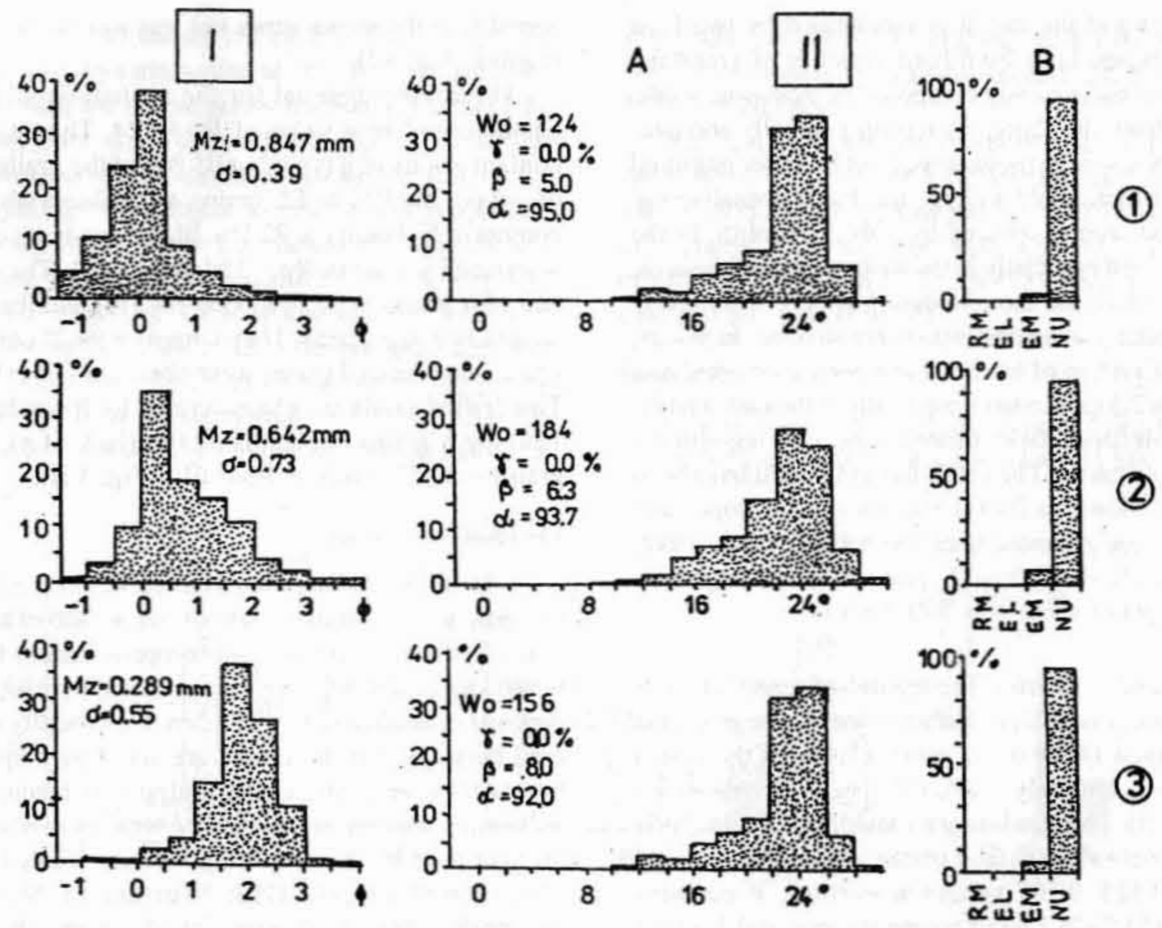

Fig. 8. Histograms of grain size distribution (I) and quartz grain abrasion (II) after Krygowski's (1964) mechanical method (A) and morphoscope Cailleux's (1942) method (B) on Sandy Bay (after Szczypek and Wach, 1992)
1 – granitoid regolith, 2 – drifted sands on deflation field; 3 – aeolian cover sands; other explanations – see Fig. 4

• *Sand properties*. The source river sands of the Irkut terrace are fine-grained. The *Mz* value is 0.140 mm. They contain 0.7% of coarse grains and 12.3% of silt/clay particles. The sorting degree $\delta = 0.61$. By contrast, the dune sands are slightly coarser. Their *Mz* being 0.174 mm: they contain 0.6% of coarse grains and 20.0% of silt/clay particles. They are also better sorted ($\sigma = 0.50$). The sands of the aeolian cover are slightly coarser than these of the dunes, where the $Mz = 0.206$ mm. They contain 0.5% of coarse grains and 6.7% of the finest particles. The sorting of these deposits is intermediate between these of the dune and river sands (Fig. 10 I).

The substratum sands contain 16.0% of γ grains and 42.5% of α. The *Wo* value being 1018. These sands also contain 19.0% of RM and EL grains and 13%, NU. The dune material has a slightly better abrasion degree: $Wo = 1044$; they contain 18.5% of γ grains and 38.0%, α as well as 24.5% of RM and EL, 8.5%, NU. The sands of the aeolian covers have even better abrasion, the value $Wo = 1082$; the content of γ grains is 21.7%, α, 40.8%. They comprise 30.3% of RM and EL particles and 5.7% – NU grains (Fig. 10 II).

Mt Khayrkhan slope

• *Main geomorphological features*. These intensively blown aeolian sands are partly covered by herbaceous vegetation and are bordered on all sizes by pine-larch taiga. They crop out at a height of 920–1000 m a.s.l. on southern side of this mountain, which slopes at an angle of 18–22°. The source material is the Late-Pleistocene alluvial deposits here (Ufimtsev, 1998), but the cause of their current mobility is connected with religious reason (Vyrkin, Kuzmin, Snytko, 1991).

The main aeolian landforms here are arcuate dunes of asymmetric cross-section and general North-South orientation. They are not very high, narrow and they are 100–150 m long (Fig. 11). The deflation areas as well as small deflation basins occur among them. The occurrence of flat, blown longitudinal dune, from which the arcuate dunes are parasitic is also a special feature of this area aeolian relief. Also, aeolian cover sands are present. The orientation of the dunes and the spatial distribution of the remaining forms indicate that they were formed by westerly wind flow; as suggested by reference to the wind rose in this part of Tunka Basin (Martyanova, Snytko, Szczypek, 1998).

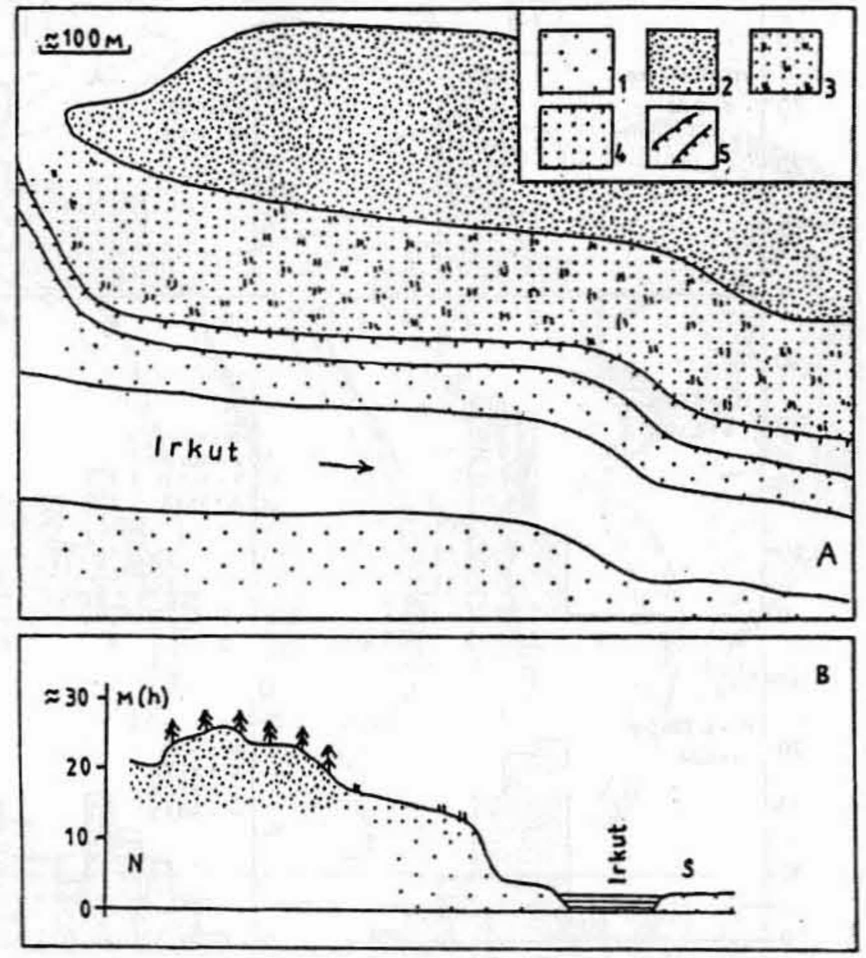

Fig. 9. Geomorphological sketch-map (A) and cross-section (B) through the drifted sands on Irkut river terrace (after Martyanova, Snytko and Szczypek, 1998)
1 – flood-plain, 2 – dune, 3 – partly stabilized sandy aeolian cover, 4 – drifted sandy aeolian cover, 5 – scarp of flood-plain

• *Sand properties*. The source alluvial sands are characterised by a large fine fraction (mean grain diameter *Mz* 0.120 mm) and moderate sorting (σ – 0.91). They contain 1.8% of coarse grains (>0.5 mm) and up to 45.8% of silt/clay particles (<0.12 mm) (Fig. 4). By contrast, the aeolian sands on Mt Khayrkhan slope are more than twice as coarse; on average they contain 18.0% of coarse grains and 4.2% – fine fraction; the *Mz* value is 0.297 mm. They are also better sorted ($\delta = 0.68$). In certain samples analysed, these sands have a mean grain diameter $Mz = 0.213$–0.406 mm; they contain 1.9%–47.9% of coarse grains and 2.9–5.5% of fine fraction (Fig. 12 I).

Considering the quartz grain abrasion (1.0–0.8 mm), the substratum deposits contain 16.1% of γ grains as well as 56.6%, α: the coefficient of abrasion $Wo = 844$ (according to the method of Krygowski). According to the method of Cailleux (1942) they contain 4.2% of rounded grains of RM and EL type and 3.2% of angular NU grains (Fig. 4). The aeolian sands on the slope of Mt. Khayrkhan are very similar to these of the substratum. The mean value of *Wo* is 882 (ranges 675–1130). The mean content of γ grains is 8.4% (2.2–24.8%) and α, 44.2% (9.9–61.1%), but 8.3% of the grains are RM and EL types; NU, 2.2% (Fig. 12 II).

Forest-steppe site

Tunka river valley

• *Main geomorphological features*. Slightly sinuous outcrops of aeolian cover sands, located at a height of 720–730 m a.s.l. predominate here. The Late-Pleistocene river sands are the source sediment (Ufimtsev, 1998), but the modern derivation of these aeolian deposits clearly relates to the 18th-century forest cutting for the defensive purposes (Larin, 1991). The cover sands are partly fixed by herbaceous vegetation and individual willow bushes. Rather widespread deflation basins, which are several hundred metres long, 100–150 m wide and 2–3 m deep are very widespread here. These have formed by the prevailing easterly winds. The floors of the basins are not completely flat – on the contrary they are characterised by numerous small deflation-accumulation forms, partly fixed by vegetation and partly modelled by the subsiding westerly wind flows (Fig. 13). The basic forms within these basins are deflation plains with occasional basins. Also there are small areas of fixed aeolian sands together with small deflation remnants, small sand shadows and modern, mobile aeolian sands (Martyanova, Snytko, Szczypek, 1998).

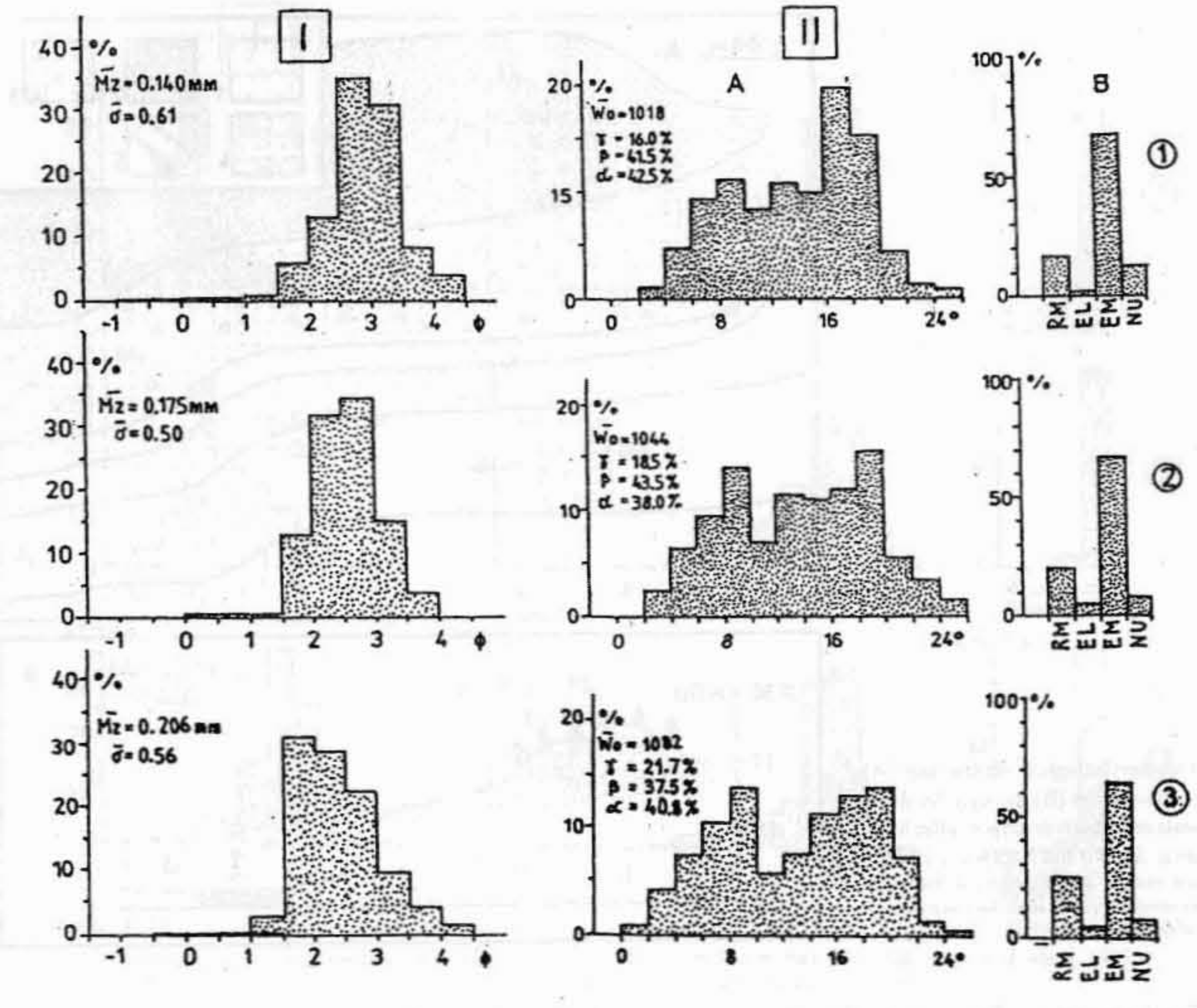

Fig. 10. Histograms of grain size distribution (I) and quartz grain abrasion (II) after Krygowski's (1964) mechanical method (A) and morphoscope Cailleux's (1942) method (B) on Irkut river terrace (after Martyanova, Snytko and Szczypek, 1998)

1 – substratum deposits, 2 – dune sands; 3 – sands of aeolian covers; other explanations – see Fig. 4

• *Sand properties*. The alluvial deposits of the substratum are here generally coarser than these at the Mt Khayrkhan site. On average, they contain 1.2% of coarse grains and 12.4% of silt/clay particles and the *Mz* value = 0.233 mm. They are moderately well sorted (σ= 0.64). Aeolian sands, which have been formed from their blowing out are characterised by being coarser, being 16.6–49.9% (on average 31.4%). The silt/clay fraction is 5.2–10.7% (on average 7.2%). The *Mz* values range within limits 0.308–0.438 mm (on average, 0.359 mm), and the sorting σ= 0.79–0.96 (on average, 0.87) (Fig. 14 I).

The substratum sands abrasion degree *Wo* is 603; they contain 1.6% of γ grains and 73,3%, α. They also contain 4.5% of rounded grains of RM and EL type and 4.5% of angular grains of NU. The aeolian sands abrasion degree *Wo* = 618 (559–709); γ type grains comprise 1.4% on average (0.0–5.0%), α, 69.5% (58.5–79.5%), RM+EL, 4.9% (3.5–6.0%), and NU, 2.8% (1.6–3.9%) (Fig. 14 II).

Steppe site

Seven Pines

• *Main geomorphological features*. The steppe ranges on Olkhon are located in the south-western part of the island. The Seven Pines range includes the western slope of Mt. Khaday, which is covered by rare low-gramineous steppe vegetation. Rather thick (from several to tens of cm) discontinuous aeolian cover occurs here, and it spreads from the level of Baikal lake (about 455 m a.s.l.) to 666 m a.s.l. (Mt. Khaday summit). These sands lie on a coarse-grained granitoid regolith or directly on the granitoid outcrops. They have been transported from the lake shore by very strong north-westerly winds (sarma).

The primary elements of aeolian relief here are the numerous irregular deflation basins, which are present in the aeolian cover. In the upper part of slope, they are wide (10–200 m), but short (from several to

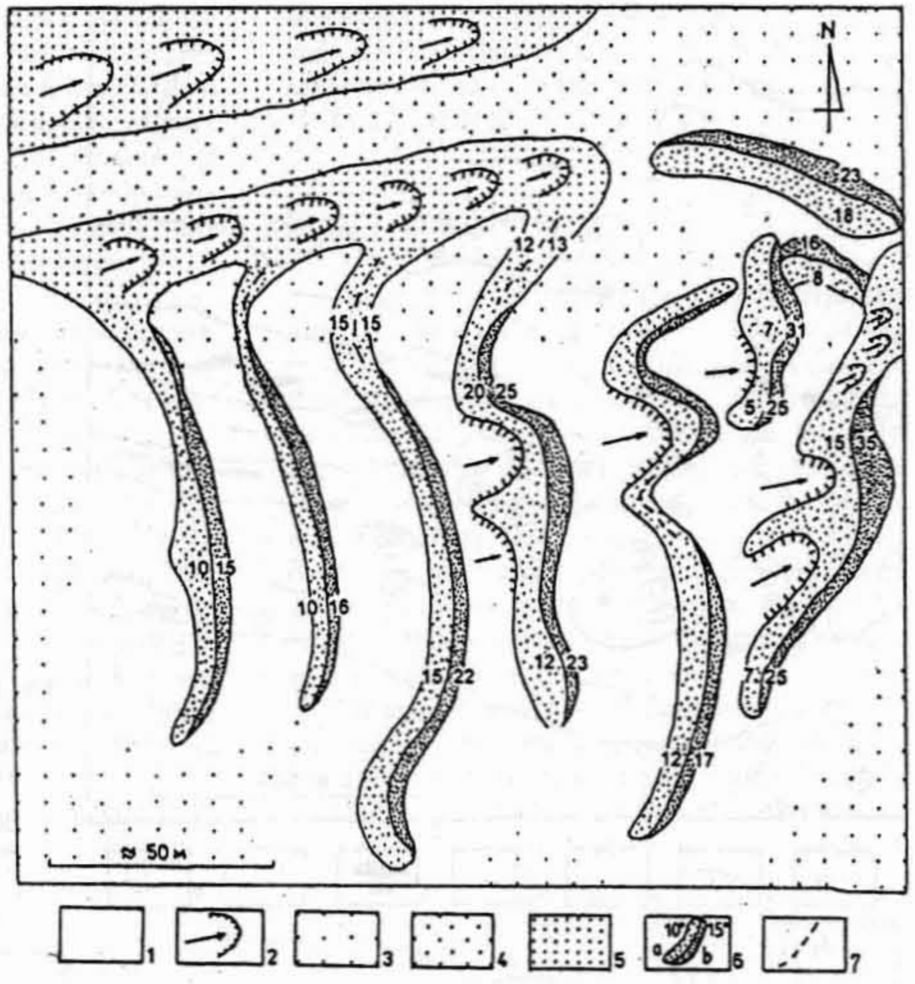

Fig. 11. Geomorphological sketch-map of drifted sands on the Mt. Khayrkhan slope (after Martyanova, Snytko and Szczypek, 1998)

1 – deflation plain, 2 – deflation basins, 3 – aeolian cover sands, 4 – aeolian „terrace", 5 – longitudinal dune banks, 6 – transverse arch dunes: a – windward slope, b – leeward slope (with values of slope inclination), 7 – crest lines on symmetric slopes

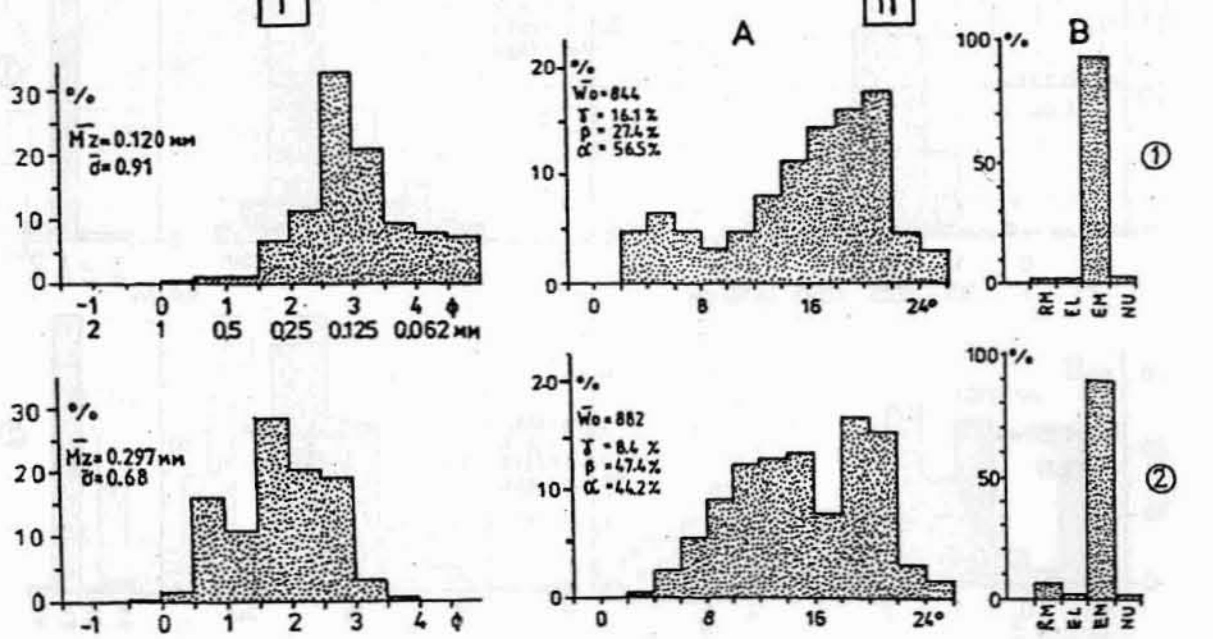

Fig. 12. Histograms of grain size distribution (I) and quartz grain abrasion (II) after Krygowski's (1964) mechanical method (A) and morphoscope Cailleux's (1942) method (B) on Mt. Khayrkhan slope

1 – substratum deposits, 2 – aeolian sands; other explanations – see Fig. 4

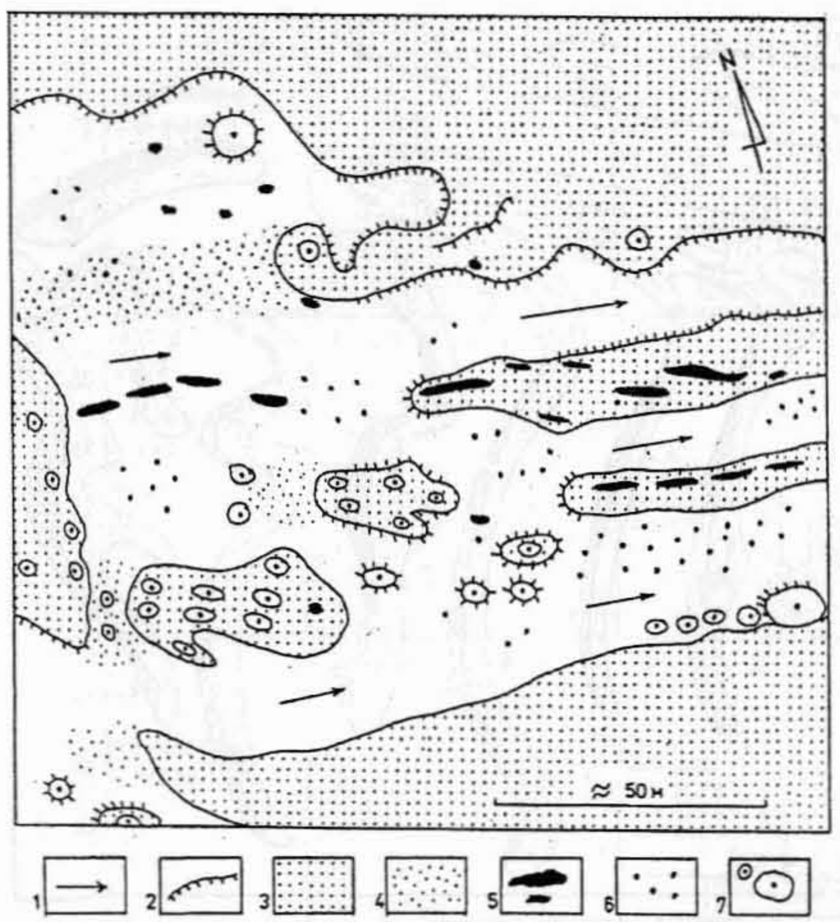

Fig. 13. Geomorphological sketch-map of drifted sands in the forest-steppe area in the Tunka river valley (after Martyanova, Snytko and Szczypek, 1998)
1 – deflation plain, 2 – deflation basins, 3 – aeolian cover sands (stabilized by herbaceous plants), 4 – mobile aeolian covers, 5 – initial dune forms, 6 – sand-shadows of nebkha type, 7 – small convex sandy surface stabilized by single willow bushes

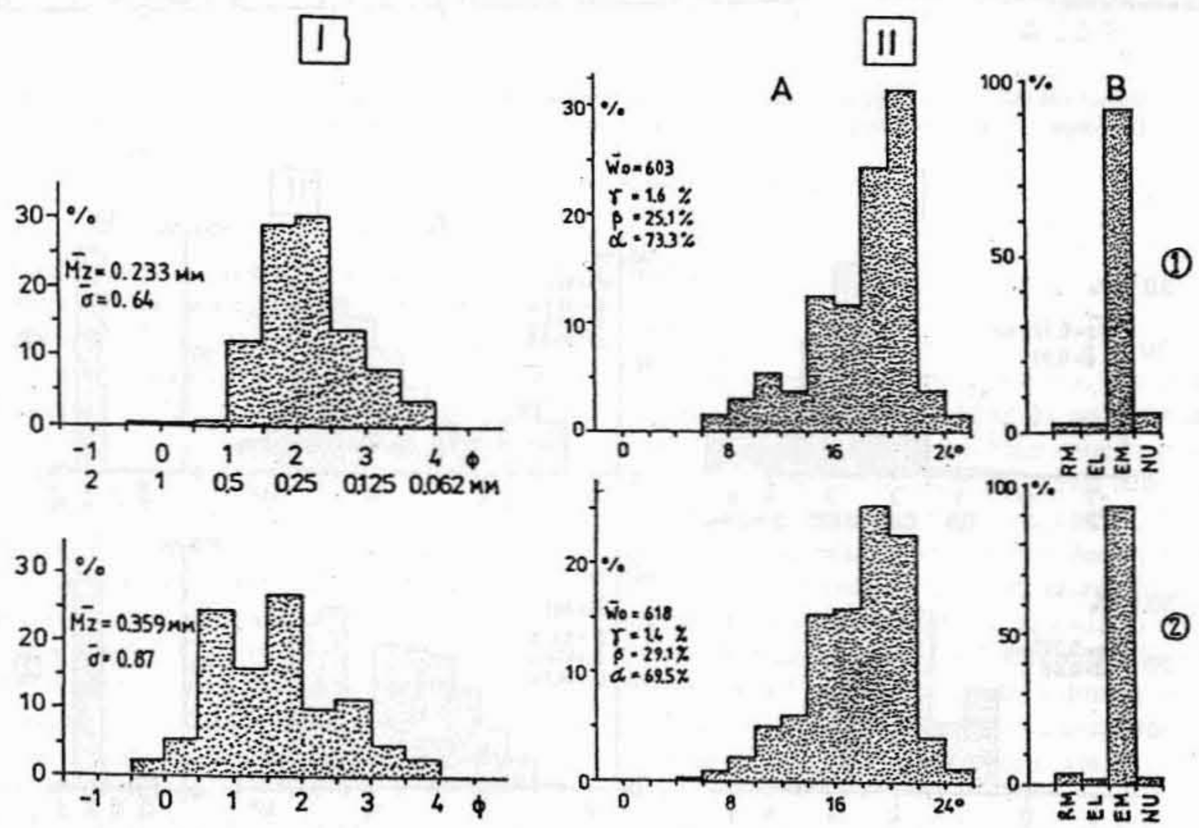

Fig. 14. Histograms of grain size distribution (I) and quartz grain abrasion (II) after Krygowski's (1964) mechanical method (A) and morphoscope Cailleux's (1942) method (B) in forest-steppe area in the Tunka river valley (after Martyanova, Snytko and Szczypek, 1998)
1 – substratum deposits, 2 – aeolian sands; other explanations – see Fig. 4

20–30 m). Numerous sandy shadows behind the clump of low grass occur at these forms bottoms. In the middle part of the slope, there are fewer deflation basins, but they are very large, in the upper part there are very few of these forms (Fig. 15). Outcrops of granitoid rocks at the surface were observed in many places on the floors of the basins as well as in other parts of the slopes (Wika, Snytko, Szczypek, 1997).

• *Sand properties*. The source material at this site, i.e. beach sand and the granitoid regolith has not been investigated, because it is identical to that of the taiga site.

The aeolian sands here are exceptionally coarse-grained: mean value of Mz = 0.923 mm: on average they contain 82% of material of fraction above 0.5 mm and only 0.6% of particles below 0.12 mm. They have a relatively poor sorting (Fig. 16 I). From the foot to the head of the slope a progressive fining of material was observed: from Mz = 1.125 mm through 1.014 mm to 0.629 mm. The sorting gradually improves in the same direction (from σ = 1.25 trough 0.99 to 0.80).

The average degree of mechanical abrasion in the deposits discussed is Wo = 866. The average content of γ grains = 7.4% and α = 54.3%, RM+EL = 6.3% and NU, 10.6%. Spatial changes in the abrasion degree are irregular and inconsiderable (Szczypek, Snytko, 1988) (Fig. 16 II).

Final remarks

The aeolian sands analysed in this part of Eastern Siberia occur at different elevations: from about 400 m to about 1000 m a.s.l. They are frequently distributed beyond the limits of their source materials. This effect is widespread on Olkhon and in Sandy Bay, and notably so on Mt. Khayrhan in the Tunka Basin, here sands have been transported to the highest elevations. They create sandy covers and variable dune forms. Contemporary aeolian activity in this area is in every case linked to anthropogenic effects. The initiation of the remobilisation of these sands appears to be as little ago as 200–300 years.

The aeolian relief has a deflationary character in the majority of the sites investigated, but the constructional process of wind activity is also widespread (with the exception of the Rassvet site). The older aeolian accumulation forms (probably dating from the end of

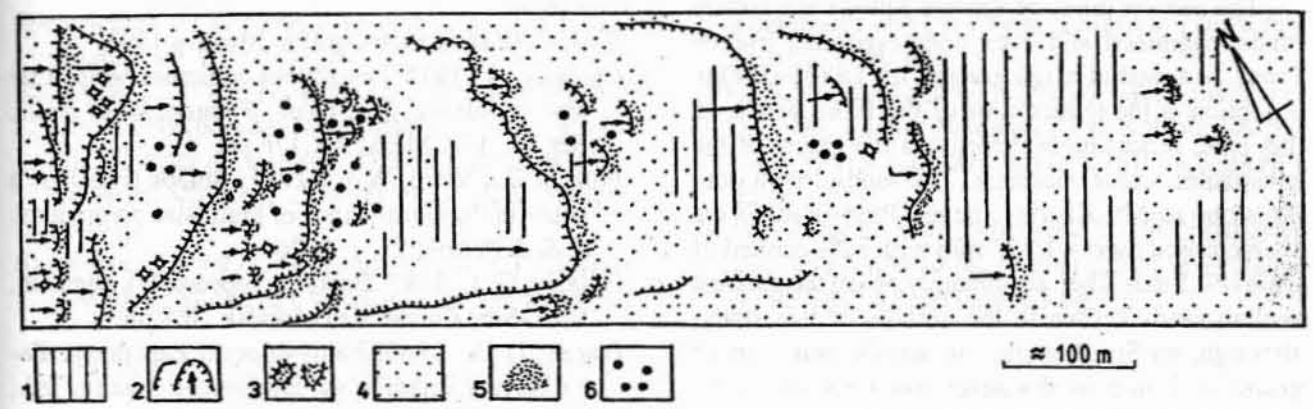

Fig. 15. Geomorphological sketch-map of drifted sands in the steppe area of Seven Pines (after Wika, Snytko and Szczypek, 1997)
1 – outcrops of crystalline rocks, 2 – deflation knickpoints and basins, 3 – deflation remnants, 4 – aeolian cover sands, 5 – modern aeolian covers, 6 – sand-shadows of nebkha type

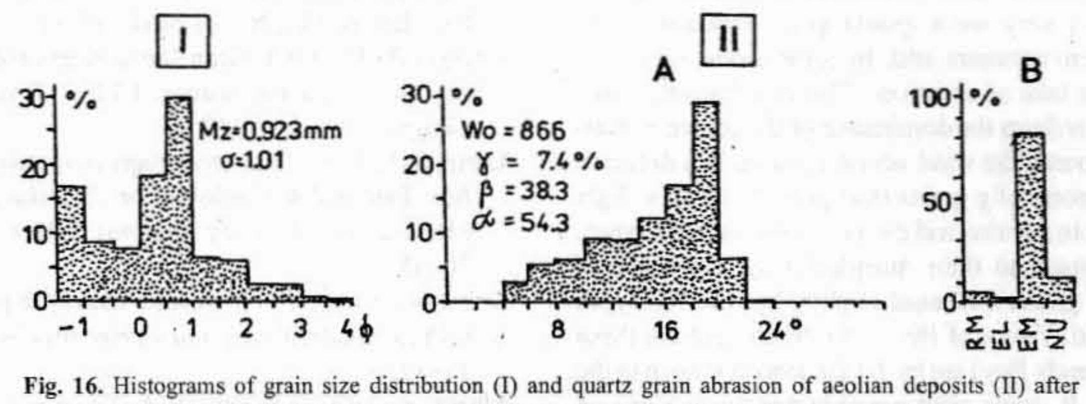

Fig. 16. Histograms of grain size distribution (I) and quartz grain abrasion of aeolian deposits (II) after Krygowski's (1964) mechanical method (A) and morphoscope Cailleux's (1942) method (B) in steppe area of Seven Pines (after Szczypek and Snytko, 1998). Explanations – see Fig. 4.

the Late Vistulian (Würm) and the beginning of the Holocene – Ivanov, 1966 and others) have frequently been degraded.

Apart from the evidence for renewal morphogenetic activity, the wind in the study area has influenced the granulometric properties of these sands features to a pronounced degree. Data presented in the earlier part of this elaboration clearly indicate that the aeolian factor has usually controlled the increase in coarse granulation in wind-blown sands in relation to the substratum, a lag process whereby the finest particles were ablated and the coarser ones remain. However in Sandy Bay and in taiga ranges on Olkhon an increase in the size of the fraction was observed; this has resulted from the morphological location of the covers and longer transport. The coarse granulation of aeolian sands in the steppe range of Seven Pines are clearly derived from the regolith as the probable source material for these first-mentioned, but it may also result from the influence of very strong winds of sarma type. The field of Seven Pines is located on the opposite side of the Sarma river valley mouth, where very strong winds originate. In general the sand is less well sorted than the source material, an aeolian effect, but, in some cases, the converse is true.

The aeolian sands of Eastern Siberia are usually medium-grained and even coarse-grained (Seven Pines and partial taiga ranges on Olkhon). One exception is the terrace area of the Irkut, which, in this case, relates more directly to the nature of the substratum source sediment. The sands blown onto the slope of Mt. Khaday (Seven Pines Range) are characterised by $\sigma = 1.125$ mm with 82% content of grains >0.5 mm. They are certainly one of the coarsest aeolian sands known to the authors of this study, although, on Spitsbergen, the aeolian transport of grains >12 mm in diameter has been observed (Szczypek, 1982) and in the Antarctic even as much as 40 mm (Miagkov, 1979). But no widespread aeolian covers were created there.

The aeolian sands of Eastern Siberia are characterised by very weak quartz grain abrasion in the aeolian environment and, in some cases, there is a complete lack of abrasion. This is a feature, which strongly reflects the dominance of the source material. In general, the wind action resulted in a decrease in the content of *g* grains (morphoselection), a slight decrease in *a* grains and their conversion into *b* types. With respect to their morphoscopy, the share of RM+EL grains increased slightly but the NU types decreased. Values of *Wo* = 159, as observed in these sands (Sandy Bay) are by far the lowest known to the Authors. It seems quite possible that this is a unique feature not previously described. On the margin, it was observed that the values of *Wo* for the granitoid regolith in Sandy Bay and for the analogous regolith in the taiga range on Olkhon are very different, about 120 and about 860. This is presumably a reflection of great differences in the source material. Certainly, the degree of wind influence on both kinds of regolith is minimal in both cases.

Therefore, the aeolian sands of the Eastern Siberia study area are essentially raw, unmodified deposits, differing from the substratum source rocks only in respect of their mechanical composition and hardly all in terms of the mechanical quartz grain abrasion. This indicates that the effect of aeolian deflation, transport and deposition had hardly any effect on the sand particles. In view of the short transport distance involved perhaps this is not surprising.

References

Afagonov, B. P., 1975: Rasprostranenie i prognoz fiziko-geograficheskikh processov v Baikalskoi vpadinie. *In*: *Dinamika Baikalskoi vpadiny*. Sib. Otd. Izd. Nauka, Novosibirsk: 59–138.

Afagonov, B. P., 1990: Ekzolitodinamika Baikalskoi riftovoi zony. Sib. Otd. Izd. Nauka, Novosibirsk: 176 pp.

Baikal. Atlas. Roskartografia, Moskva 1993.

Cailleux, A., 1942: Les actions éoliennes périglaciaires en Europe. *Soc. Géol., France. Mém. Nouv.* Sér. 21, 1–2. Mém., 46: 176 pp.

Folk, R. L., Ward, W. C., 1957: Brazos river bar: a study in the significance of grain size parameters. *J. Sed. Petrol.*, 21, 1: 3–26.

Galaziy, G. I., 1987: Baikal v voprosakh i otvetakh. Vost.-Sib. Knizhn. Izd., Irkutsk: 368 pp.

Ivanov, D. A., 1966: Eolovye peski Zapadnogo Zabaikalya i Pribaikalya. Buriatskoe knizhn. izd., Ulan-Ude: 230 pp.

Krendelev, F. P., Nasyrova, R. A., 1985: Sovremennye dolinnye obrazovania Charskoy kotloviny. *In*: *Udokan (prirodnye resursy i ikh osvoenie)*. Sib. Otd. Izd. Nauka, Novosibirsk: 53–82.

Krygowski B., 1964: Graniformametria mechaniczna, teoria, zastosowanie. PTPN. *Prace Kom. Geogr.-Geol.*, 2, 4: 112 pp.

Larin, S. I., 1991: Osnovnye etapy osvoenia landshaftov Tunkinskikh kotlovin. *In*: *Istoriko-geograficheskie issledovania Yuzhnoi Sibiri*. Irkutsk: 70–85.

Lubstova, E. M., 1994: Ocenka eolovykh processov v Predbaikale. *Geografia i prirodnye resursy*, 4: 71–77.

Martyanova, G. N., Snytko, V. A., Szczypek, T., 1998: Priznaki sovremennykh eolovykh processov v Tunkinskikh kotlovinakh (yugo-zapadnoe Pribaikale). IG SB RAS, Irkutsk: 56 pp.

Miagkov, S. M., 1979: Geomorfologicheskie processy v oazisakh Antarktidy – na primere oazisa Mak-Merdo. *Geomorfologia*, 3. Moskva: 3–12.

Ovchinnikov G. I., 1998: Nekotorye zakonomernosti raspredelenia nanosov na osushennykh otmelakh i beregovykh sklonakh Bratskogo vodokhranilishcha pod vlianem vetrovykh i volnovykh faktorov. *In*: T. Szczypek, J. Wach *(Eds.)*. *Współczesne procesy eoliczne*. WNoZ UŚ, SGP, Sosnowiec: 61–72.

Owczinnikow, G. I., 1996: Rozwój współczesnych procesów eolicznych nad Zbiornikiem Brackim i ich rola w kształtowaniu strefy brzegowej. *In*: T. Szczypek, J. M. Waga *(Eds.)*. *Współczesne oraz kopalne zjawiska i formy eoliczne. Wybrane zagadnienia*. WNoZ UŚ, PK CKKRW, SGP, Sosnowiec: 102–110.

Pavlov, P. D., 1981: Geograficheskoe rasprostranenie eolovykh peskov v Tsentralnoy Yakutii. *In*: M. N. Milkheev *(Ed.)*. *Eolovye obrazovania Tsentralnoy Yakutii*. Izd. Inst. merzlotovedenia, Yakutsk: 18–30.

Preobrazhenskiy V. S., 1961: Barkhany i gidrolakkolity Charskoy kotloviny. *Priroda*, 5: 93– 95.

Spravochnik po klimatu SSSR, vyp. 22, ch. III. Leningrad, 1967.

Szczypek T., 1982: Działalność eoliczna w rejonie Zatoki Gås (południowy Spitsbergen). *In*: M. Pulina, T. Szczypek *(Eds.)*. *Wyprawy polarne Uniwersytetu Śląskiego 1977–1980, I*. UŚ, Katowice: 87–108.

Szczypek, T., 1993: Wybrane cechy teksturalne piasków eolicznych w dolinie środkowego Irkuta (wschodnia Syberia). *In*: Geographia. Studia et Dissertationes. Vol. 17. UŚ, Katowice: 45–58.

Szczypek T., 1995: Bajkał. Szkic o przyrodzie. WNoZ UŚ, Sosnowiec: 96 pp.

Szczypek T., Snytko V. A., 1998: Main granulometric properties of modern aeolian sands on Olkhon Island on Lake Baikal. In: T. Szczypek, J. Wach *(Eds.)*. *Współczesne procesy eoliczne*. WNoZ UŚ, SGP, Sosnowiec: 73–86.

Szczypek T., Wach J., 1992: Efekty działalności wiatru nad bajkalską Zatoką Piaszczystą – buchta Pieszczanaja. *In*: Geographia. Studia et Dissertationes. Vol. 16. Wyd. UŚ, Katowice: 103–116.

Taisaev T. T., 1982: Eolovye processy v Priolkhonie i na o. Olkhon (zapadnoe Pribaikale). *Doklady AN SSSR*, 265, 4: 948–951.

Ufimtsev G. F., 1998: Współczesne zjawiska eoliczne na obszarze Przedbajkala. *In*: T. Szczypek, J. Wach *(Eds.)*. *Współczesne procesy eoliczne*. WNoZ UŚ, SGP, Sosnowiec: 91–93.

Vyrkin V. B., 1986: Sovremennoe eolovoe rel'efoobrazovanie v Barguzinskoy kotlovine. *Geografia i prirodnye resursy*, 2: 71–77.

Vyrkin V. B., Kuzmin V. A., Snytko V. A., 1991: Obshchnost i razlichia nekotorykh chert prirody Tunkinskoi vetvi kotlovin. *Geografia i prirodnye resursy*, 4: 61–68.

Wika S., Martyanova G. N., Snytko V. A., Szczypek T., 1999: *Bukhta Peschanaya na Baikale – razvevaemye peski i ikh okruzhenie*. IG SB RAS, Irkutsk: 60 pp.

Wika S., Snytko V. A., Szczypek T., 1997: *Landshafty podvizhnykh peskov ostrova Olkhon na Baikale*. IG SB RAS, Irkutsk: 63 pp.