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МОРФОСКОПИЯ КВАРЦЕВЫХ ЗЕРЕН ИЗ ОТЛОЖЕНИЙ ГРИВНЫХ ТОЛЩ ТОБОЛ-ИШИМСКОГО МЕЖДУРЕЧЬЯ

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В работе приведены результаты морфоскопии кварцевых зерен с целью реконструкции условий осадконакопления и особенностей формирования гривной толщи в разрезе “Кареглазова” (юго-западная часть Западно-Сибирской равнины). С помощью растрового электронного микроскопа (РЭМ) изучены кварцевые зерна фракции среднего песка (0.25–0.5 мм) из 19 образцов. В гранулометрическом отношении грива сложена преимущественно мелким низкосортированным песком с большой долей глинистой и алевритовой компоненты. Выявлены четыре типа зерен, различных по морфологии и комплексу текстур поверхности, которые демонстрируют следы переноса и накопления в различных средах. Коэффициент окатанности частиц фракции среднего песка (по А.В. Хабакову) варьирует по разрезу от 54 до 65%. Преобладают угловато-окатанные зерна кварца (до 57%), доля хорошо окатанных зерен в среднем составляет 39%. Многие кварцевые зерна несут следы постседиментационных преобразований в виде кремневой пленки осажденных коллоидов, скоплений аморфного кремнезема различной интенсивности, следов травления ранее сформированных текстур. Коренными источниками для отложений гривы, по всей видимости, служат аллювиально-озерные отложения различного возраста, распространенные в районе исследований. Микроморфология поверхности большей части кварцевых зерен несет следы эоловой обработки и наложения эоловых текстур поверхности (мелкоямчатый микрорельеф) на рельеф поверхности зерен с чертами аквального происхождения (V-образные микроуглубления, серпообразные желобки, гладкая глянцевая поверхность). Встречаемость специфических эоловых текстур поверхности в основном только на выпуклых участках кварцевых зерен и наличие криогенных текстур поверхности свидетельствуют об аккумулятивном формировании грив и преобладании преимущественно местного (ближнего) переноса вещества в холодных и аридных условиях перигляциального климата. Верхняя часть разреза гривной толщи, вероятно, формировалась в условиях относительно умеренного гумидного климата, когда была возможной миграция коллоидных растворов.

Ключевые слова: гривно-ложбинный рельеф, Западная Сибирь, морфоскопия песчаных зерен, растровая микроскопия, эоловые процессы, криогенез, покровные отложения

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1. INTRODUCTION

In the southern part of Western Siberia and Northern Kazakhstan, primarily in the northern part of the Ishim-Tobol and Ishim-Irtysh interfluves, as well as in the Barabinsk and Kulunda lowlands, special ridge (crest)-hollow relief is widespread (Volkov et al., 1969). Despite the large amount of geological and geomorphological data, still there is no consensus about this crest relief origin. It is considered to be the result of fluvio-glacial processes (Zemtsov, 1959; Orlov, 1959), interaction of tectonics with frost-breaking fracturing, flat flush and solifluction (Alter, 1960), gravitational processes (Fialkov, 1964), permafrost inversion (Tarnogradskii, 1966), complex of subaerial processes (Nikolaev, 1963; Martynov, 1966 et al.), injection folding, deep and clay tectonics of the sedimentary cover (Generalov, 1981; Generalov, 1982; Kuzin, 2002), shear tectonic deformations (Maksimov, 1995), fluvial disasters (Grossvald, 1999).

The most popular are the aeolian and aquatic hypotheses. Proponents of the aeolian hypothesis associate the origin of the ridges with aeolian accumulation during the periods of aridization and climate warming (Volkov et al., 1969) or vice versa, aridization and cooling (Zykina et al., 2012; Alekseeva et al., 2016; Larin et al., 2020; Larin et al., 2020a; Larin et al., 2021). The aeolian hypothesis in general is supported by the association of the ridge (crest)-hollow relief with the cover of loess-like deposits, the correctness of the alternation of ridges with inter-ridge depressions, the consistency of the size and orientation of ridges, their cigar-like shape (Volkov et al., 1969). Particular importance in the aeolian approach is the crests orientation, since it does not follow the ancient relief, but is superimposed with unconformity on it. Also, the recent hydrographic system does not correlate with the placement of crests, it either slits the crests systems, or adapts to them. Proponents of the aquatic hypothesis consider them to be the result of the fluvial erosion-accumulative processes activity with increased watering of the territory and the participation of the latest tectonic movements (Gorodetskaya, 1972). Data obtained by A.A. Velichko and co-authors (2007) allow considering the oriented crest relief of Western Siberia and the related loess-like cover with its paleocryogenic relics to be the key climatic morphotypes of Late Glacial arid landscapes similar to cold deserts or semi-deserts. The age of crests strata within the southern plains of Western Siberia and Northern Kazakhstan is determined within the maximum of the Late Pleistocene cold snap and the end of the Late Glacial period (Volkov et al., 1969). That's why the clarification of the origin and age of crests and their loess-like cover is of great importance for the reconstruction of the landscape development in the southern parts of Western Siberia.

Recent field and laboratory multi-proxy studies of the crest material within the Tobol-Ishim interfluve (55°–57°N) carried out by the authors have made it possible to identify the main stages of crest formation, paragenetic relationships with overlayering deposits and paleocryogenic layers (Alekseeva et al., 2016; Larin et al., 2020; Larin et al., 2020a; Larin et al., 2020b; Larin et al., 2021). The particle size distribution analysis, mineralogical (cryogenic contrast ratio according to V.N. Konishchev and V.V. Rogov (2005), geochemical proxies and major element indices, as well as morphology of quartz sand grains were used as the main indicators of the sediment's origin for the crest strata formation. Crest sections are composed mainly of horizontal and sub-horizontal laminated fine clayey sands. The composition of crests loose deposits, with a specific layering that is sharply different from the underlying rocks, allowed to suppose their aeolian-accumulative origin (Volkov et al., 1969).

In general, in the structure of the upper part of the Cenozoic sedimentary cover terrigenous facially variable and complexly stratified Paleogene and Neogene deposits of lacustrine and alluvial origin of some regional stratigraphic horizons of Western Siberia take part. Quaternary lacustrine-alluvial and eluvial-deluvial deposits are widespread within the interfluvial plains. Alluvial sediments of different ages compose the river terraces and Holocene floodplains of the main rivers – Tobol and Ishim – and their tributaries (Volkov et al., 1969; Volkova et al., 2016).

The aim of this paper is to study the micromorphology of quartz grains from the sedimentary sequence of a typical crest within the forest-steppe area of the Ishim River region in order to reconstruct the depositional environments of its formation.

2. MATERIALS AND METHODS

The micromorphology of quartz sand grains as a part of complex mineralogical analysis includes the study of shape and surface features which bear signatures of sediment properties and origin. Each genetic type of grains has its specific set of surface microtextures (Krinsley et al., 2011; Mahaney, 2002).

This paper presents the results of a micromorphology study of the quartz grains collected from a crest section located near the Kareglazova Village, in the northern part of the Ishim Plain, on the left bank of the Ishim River, near the mouth of its left tributary, the Kiternya River.

The study area belongs to the forest-steppe zone of the West Siberian Lowland. It is located on the surface of the second flat and flat-wavy terrace of the Ishim River, complicated by large ridges (crests), hollows and depressions. The Ishim River has a well-developed valley cut into the depth of about 40 m, with a wide floodplain (Larin, 2016).

The crests form combinations of parallel relief forms, with 3–10 m high, up to 5–7 km long and up to 0.2–1.5 km wide. The steepness of the slopes is 3°–60°. Crests are most often elongated from northeast to southwest. Their top surfaces are flat-convex, complicated be depressions. There are sometimes terraced areas on the slopes. The crest shape is straight, sometimes slightly curved, in some cases their south-western ends widen or split. The inter-ridge depressions are flat-bottomed valley-like hollows, with lakes, swamps and solonetz in the lowest part. Sometimes they are crossed by bridges 2–3 m high, connecting neighboring crests (Larin, 2016). The soil cover of the district is diverse. In the south-western part of the district on ridges there are leached chernozems.

The selection of this particular crest section for the research was due to its typical appearance for this area. In addition, the presence of a deep quarry made it possible to carry out a detailed study of the lithological and stratigraphic features of the section and to make the necessary sampling for analytical studies.

In order to reconstruct the sedimentary history and depositional environments of the crest deposits formation the quarry wall has been studied on the east-north-eastern part of the crest, about 500 m to the west of the Kareglazova Village and about 1.8 km to the

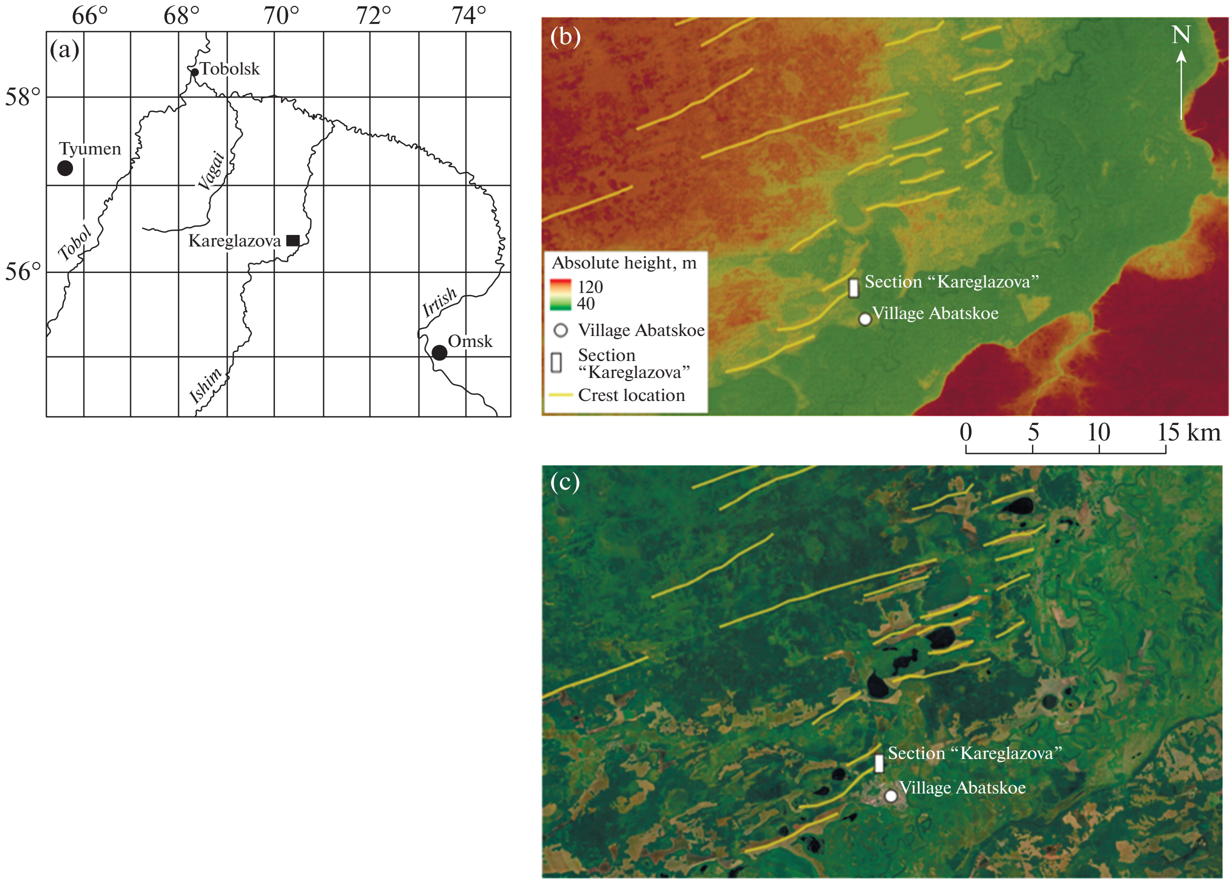

Fig. 1. Location of studied section of crest deposits near the Kareglazova Village: (a) – on the Tobol-Ishim interfluve, within the Ishim River valley, (b) – on DEM based on SRTM data, (c) – on a Google Earth satellite image.

Рис. 1. Местоположение изученного разреза отложений гривы вблизи дер. Кареглазова: (а) – в пределах Тобол-Ишимского междуречья, в долине р. Ишим, (b) – на ЦМР, составленной по данным SRTM, (c) – на космоснимке Google Earth.

north of the Abatskoe Village (Abatskiy district, Tyumen region, Russian Federation) (56°18′29.1″ N, 70°26′49.4″ E) (fig. 1). The absolute altitude of the sample site is 77 m. The relative height of the quarry wall above its bottom is 12.0 m (fig. 2, a). 19 samples were taken evenly from the section. The sampling step of 60 cm was chosen due to the peculiarities of the section stratigraphy and the required representativeness.

The particle size analysis of the deposits done by pipette method showed that the crest is composed mainly of fine low-sorted sand with a large input of clay and silt components (fig. 2, b–c). The structure of the geological section is the following (from top to bottom) (fig. 2, d):

Layer 1. 0.0–0.3 m. Modern soil, locally with traces of anthropogenic impact.

Layer 2. 0.3–3.1(3.3) m. Silty-argillaceous sand, whitish brown, very dense in the upper part of the section (at 0.3–2.8(3.0) m), loess-like, fissured, with vertical fracturing and inclusions of carbonates in the form of streaks and beans with up to 1–3–5 cm in size, strongly weathered (at 0.3–0.5 m). The bottom contact is defused.

Layer 3. 3.1(3.3)–12.1(12.5) m. Fine-grained sand, grey, horizontally- and wavy laminated. In places there are thin (0.5–2 cm) and long (1–2 m) lenses of, greywacke-quartz fine-grained sand, unrounded. The layer represents the consecutive change from top to bottom of silty-clayey sand, strongly clayey sand, silty-strongly clayeysand, clayeysand. Towards the edge of the crest, an inclination of layers is about 6°.

For the sample taken from 7.20–7.25 m depth optically stimulated luminescent data was obtained which showed an age of 26 ± 2 kyr BP (the laboratory of VSEGEI, St. Petersburg, Russian Federation; RGI–0712). The dating was carried out using a quartz fraction of 180–250 μm with a standard measurement error (1σ) on the automated TL/OSL dating system RISO TL/OSL Reader DA-20 C/D using a low-background gamma-ray spectrometer based on a CANBERRA BE3825 pure germanium crystal.

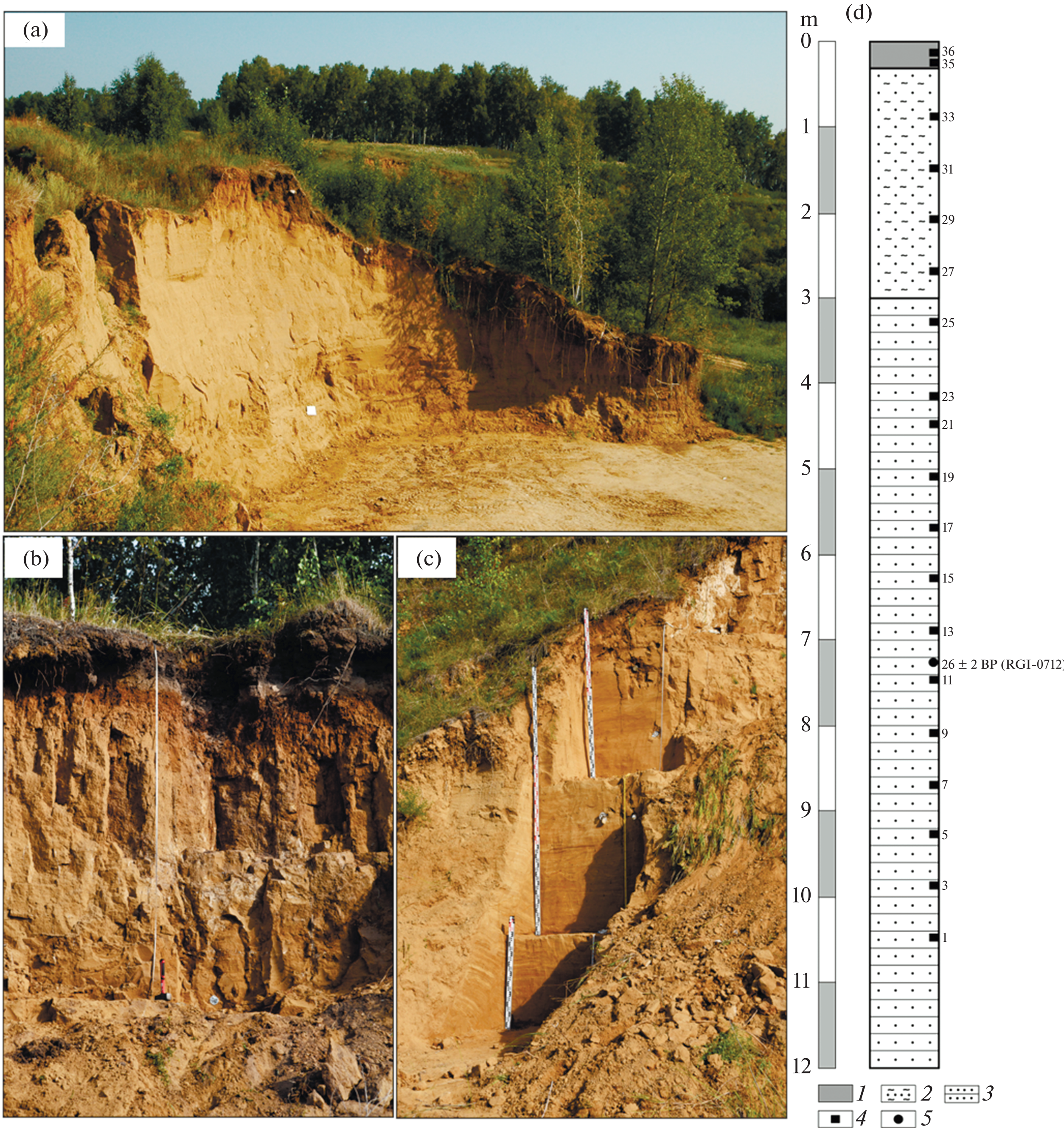

Fig. 2. The studied section of the crest located near the Kareglazova Village: (a) – the general view of the quarry wall exposed to the south-southeast; (b) – the upper part of the section; (c) – the middle and the bottom parts of the section (all photos by S.I. Larin, August 2016); (d) – section structure (*1–3* – lithological layers (see description in the text), *4* – sample number, *5* – position of the OSL-date).

Рис. 2. Изученный разрез отложений гривы, расположенный вблизи дер. Кареглазова.

Стенки карьера ЮЮВ экспозиции: (a) – общий вид стенки карьера, (b) – верхняя часть разреза, (c) – средняя и нижняя части разреза (фото С.И. Ларина, август 2016 г.), (d) – строение разреза (*1–3* – литологические слои (см. описание в тексте), *4* – номер образца, *5* – положение ОСЛ-даты).

The micromorphology of quartz grains – their shape and surface microtextures – were studied for the fraction of medium (0.25–0.50 mm) sand (Alekseeva, 2003; Alekseeva et al., 2004 et al.). The scanning electron microscope was used (SEM, model TESCAN VEGA 3 LMU at an accelerating high voltage of 15–30 keV) in the Secondary electron image and Backscattered electron image modes and in high vacuum. Quartz grains were observed with magnification from 300–500 times for whole grains to 1.500–

2.000 times for grain fragments and individual surface elements. The sample preparation was carried out according to the previously tested technique based on the world practice (Alekseeva, 2003; Alekseeva, 2004; Vos et al., 2014 et al.). The samples were covered with gold as conductive material. In each sample, 25 randomly selected quartz grains were selected (Krinsley et al., 2011; Vos et al., 2014 et al.); the chemical composition of which was later verified using a microanalyzer. For each grain, its shape was described and surface textures of mechanical and chemical origin were recorded. The roundness of quartz grains was evaluated visually, on a five-point scale. For each sample, the roundness ratio characterizing the average roundness of grains in a sample was calculated using the formula proposed by A.V. Khabakov (1946). When describing the grain, three groups of features were evaluated: 1) general morphological features – the shape and manifestation of the grain surface relief; 2) surface textures developed as a result of mechanical action on grains (conchoidal fractures, steps, fracture plates, scratches and grooves, V-shaped pits, upturned plates, etc.); 3) surface textures of a chemical origin (traces of etching, irregular solution-precipitation surface, adhering particles, silica and other films, etc.) (Alekseeva, 2003). The combination of the quartz sand grain surface textures, based on the ideas of various researchers (Mahaney, 2002; Alekseeva, 2005; Krinsley et al., 2011; Vos et al., 2014), was used to determine their origin.

3. RESULTS AND DISCUSSION

Semi-rounded quartz grains with a mixed shape of boundaries prevail (fig. 3, a). According to A.V. Khabakov (1946) they belong to II roundness class. An average frequency of their occurrence along the section is 57%. Rounded quartz grains (III–IV class of roundness) present on average 39%, and their share increases in the lower part of the section. Angular particles (0–I class of roundness) are quite rare, found not even in every sample (0–12%, 3% on average) and almost never found in the lower part of the section. Correspondingly, the roundness ratio of grains is rather high (54–65%), averaging 60% for the section.

The 0.25–0.50 mm fraction of the studied samples from the Kareglazova section contains four main types of quartz grains with different morphology and complexes of surface textures, which bear signs of transportation and accumulation in various environments.

The first group combines angular grains of the I (rare of the II) roundness class, with sharp or slightly rounded edges and corners (fig. 3, b–c). The surface of particles is a combination of conchoidal fractures of various sizes, arcuate and straight steps, depressions and fracture plates. Such combination is characteristic for either the products of bedrock weathering or a result of glacial treatment (Mahaney, 2002; Alekseeva, 2004; Alekseeva, 2005; Krinsley et al., 2011). Since the study area was not under the Quaternary glaciation, the eluvial nature of this type of grains is more likely.

The second group of grains is represented by semi-rounded particles (II roundness class), as well as rounded particles (III–IV roundness classes). The grain surfaces largely bear traces of inheritance from the original (eluvial) shape in the form of conchoidal fractures, ledges, and depressions of various morphology. At the same time, there are surface textures such as V-shaped pits, straight scratches and curved grooves (fig. 3, d–e). The glossy, generally smoothed surface and a specific combination of surface textures indicate the influence of the aquatic environment (Mahaney, 2002; Alekseeva, 2004; Krinsley et al., 2011; Vos et al., 2014). The irregular size and small depth of V-shaped pits, as well as their low density on the quartz grains surfaces (often only on the convex parts of the grains) indicate rather river transfer or modifications in the coastal area of the lake. More rounded grains (III, rarely IV roundness class) to a lesser extent retained the original surface features formed during weathering processes. They demonstrate a high density of textures associated with processing in the aquatic environment, which can occur over the entire visible surface of the grain.

The third grain group combines semi-rounded quartz particles (II roundness class), as well as rounded grains (III–IV roundness class) and rarely angular grains (I roundness class). The grain surfaces represent a combination of fracture plates and conchoidal fractures (fig. 3, f–g). However, there are mechanically upturned plates (finely pitted microrelief) and meandering ridges on the convex parts of the grains, on edges and corners. This is regarded as a result of aeolian processing (Mahaney, 2002; Alekseeva, 2005; Krinsley et al., 2011; Vos et al., 2014). The main factor participating in the formation of the surface of this group of sand grains is the mechanical corrasion in the wind flow. For well-rounded grains, the area of the visible surface transformed by traces of aeolian processing is higher due to the smoothing of conchoidal fractures and other original irregularities on the surfaces of sand particles.

The fourth group of quartz grains bears traces of combined processing in aquatic and aeolian environments (fig. 3, h–i). Here, one can also distinguish the category of angular-rounded (semi-rounded) grains, on the surface of which specific textures are present only in the convex parts of the grains, and the category of rounded grains that have undergone more intensive processing, with a predominance of upturned plates. Mostly the upturned plates and meandering ridges produced by aeolian processing are re-imposed on the V-shaped pits and curved grooves, traditionally considered an attribute of particles that have experienced transport in the aquatic environment of different degree (Alekseeva, 2004; Alekseeva, 2005).

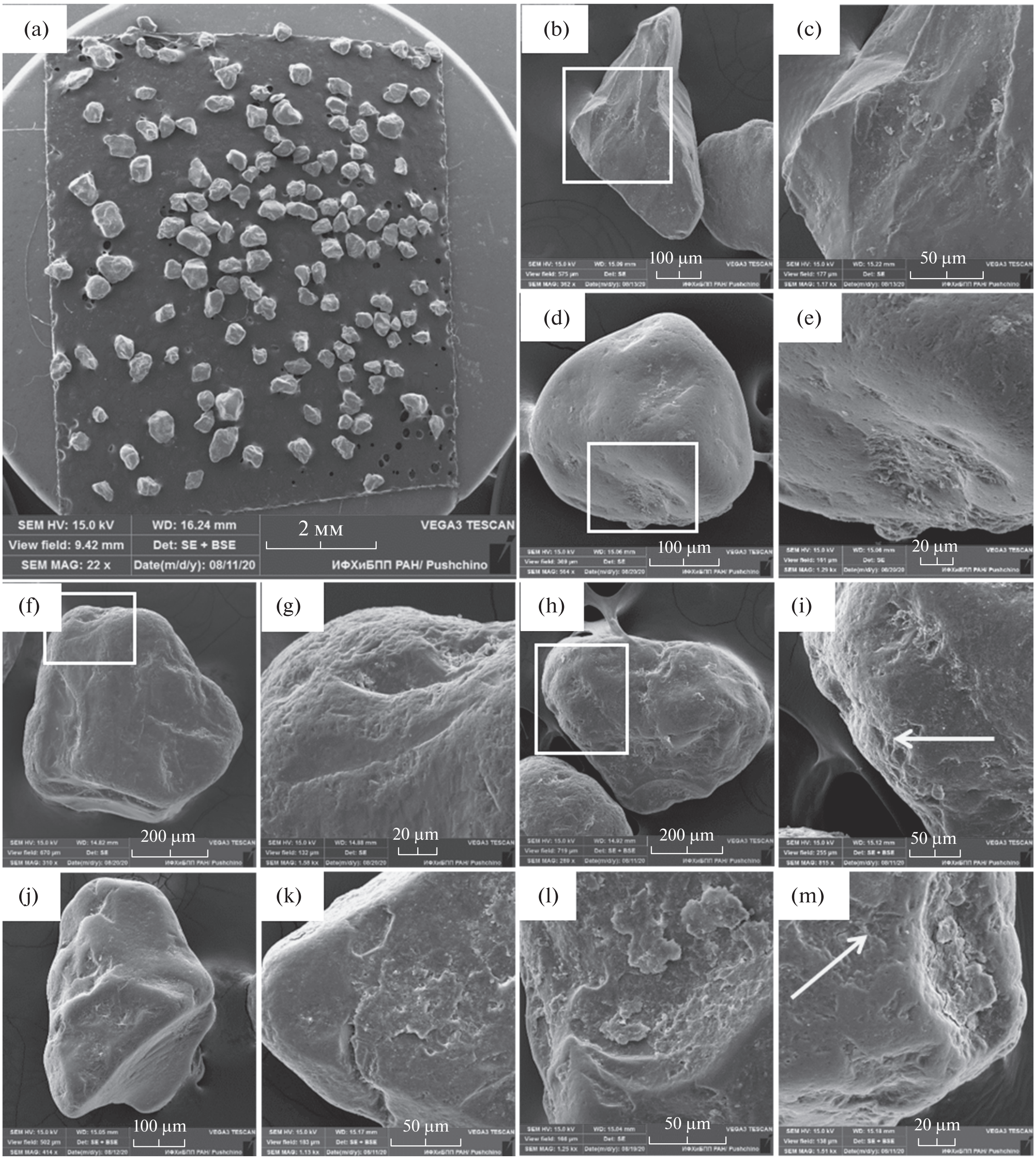

Fig. 3. Micromorphology of quartz grains of the 0.25–0.5 mm fraction out of the deposits of crest section near the Kareglazova Village: (a) – the combination of quartz sand grains of various shapes (×22; sample No. 21); (b) – angular elongated grain from eluvial group, with angular shape and I roundness class, without any significant traces of flow transportation; there is a superimposed fracture, presumably of a cryogenic nature, in the upper right part of the grain (×362; sample No. 31); (c) – enlarged fragment of grain *b*, showing a series of fractures and straight steps of different sizes, with sharp edges; surface is complicated by silica film, adhering particles are observed in depressions (×1170); (d) – rounded grain (IV roundness class), with clear features of transformation in aquatic environments (×564; sample No. 36); (e) – an enlarged fragment of grain *d* with numerous V-shaped pits on a generally smooth surface; at the bottom of the depression, an accumulation of silica precipitation products is noted; surface textures smoothed with silica deposition film (×1290); (f) – semi-angular grain (II roundness class), with traces of aeolian processing; in the lower part of the photograph there is a cryogenic cleavage that splits off a grain fragment (×310; sample No. 36); (g) – enlarged fragment of grain *f*: the entire visible convex surface of the grain is covered with upturned plates, except for the adjacent cleavage walls (×1580); (h) – semi-rounded grain (II roundness class), with traces of water and aeolian processing (×289; sample No. 21); (i) – a fragment of the surface of grain *h*: a combination of curved grooves and V-shaped pits with upturned plates on the convex grain edge; surface textures smoothed with silica deposition film (×815); (j) – a cleavage of cryogenic nature, splitting a grain (III roundness class) into several parts; despite its superimposed nature, the cleavage does not look very

The proportion of quartz grains of the selected morphogenetic groups showed that angular grains of an eluvial origin are rare with their average content of 3% (fig. 4). There are no grains of this type in the lower part of the section. The proportion of grains of the second group, to some extent indicating aquatic environment such as river flow or the coastal part of the lake, averages 13%, reaching 20–28% in the upper part of the section. Angular and rounded grains with traces of aeolian transfer make up a significant part of sand particles (46% on average over the section). There is also a significant variation in the proportion of particles with mixed surface textures produced by water and aeolian transport: from 4–8 to 52–64% (on average 38% over the section).

Thus, with a minor content of eluvial grains without traces of any flow processing and grains with aquatic processing, the vast majority of quartz grains from the deposits of the Kareglazova section are particles that have been transformed to a greater or lesser extent during the aeolian transportation. The content of such particles ranges from 68–72% to 88–96% (average for the section 84%), in rare cases decreasing to 48%. At the same time, it should be noted that traces of aeolian reworking rarely occupy large areas on the visible grain surfaces, often appearing only on the most convex areas of grains against the background of significant surfaces occupied by either eluvial or aquatic textures. This may indicate that the aeolian transformation was of either relatively short duration or weak.

Vast majority of grains from studied samples bear traces of post-sedimentary transformations. Textures of chemical dissolution and silica precipitation may significantly change the original appearance of grains. The most common surface feature is the amorphous silica films, enveloping the grain surfaces, leveling the surface relief and largely masking the primary elements of grain surface (fig. 3, l). The amount of quartz grains with a silica film is 76–96%, sometimes reaching up to 100% (89% on average). Post-sedimentary changes include also the traces of etching of previously formed textures, such as deeper elaboration of V-shaped pits, grooves, and scratches, as well as areas of the grain surface "eaten away" by dissolution (fig. 3, m). The active development of post-sedimentary processes significantly changing the appearance of the surface morphology of sand grains and greatly smoothing primary surface textures, is resulted in low content of angular, non-rounded, quartz grains (I roundness class). The wide demonstration of such surface textures like traces of silica dissolution and precipitation indicates a rather high chemical activity of the environment in which the crests deposits are located connected with humidity and the impact of reactive soil humic acids.

Additionally, quartz grains demonstrate specific surface textures reflecting the cryogenic weathering, which lead to grain splitting and the formation of cleavage, grooves, and striations (Konishchev et al., 2005; Kurchatova et al., 2020) (fig. 3, j–k). The typical features of grain morphology which indicate the cryogenic eluvium are cleavages of four main types: conchoidal fracture, which is the most common wedge-shaped cleavage, splitting of well-rounded particles into fragments, and cleavage associated with cavities inside particles (Kurchatova et al., 2020). In most cases these superimposed cleavages are not absolutely "fresh"; their surfaces have undergone subsequent post-sedimentary changes in the form of slight deposition of amorphous silica. The content of grains with cryogenic surface textures in the studied section varies greatly, averaging 50% in the uppermost part of the

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"fresh" due to the silica film (×414; sample No. 23); (k) – splitting crack in the crystal structure leading to disintegration of particles during cryogenic weathering (×1130; sample No. 21); (l) – the surface of a grain is strongly transformed by the processes of silica precipitation (×1250; sample No. 17); (m) – grain with traces of post-sedimentary transformations in the form of surface etching elements (×1510; sample No. 21).

Рис. 3. Морфоскопия кварцевых зерен фракции 0.25–0.5 мм из отложений разреза Кареглазова: (a) – ансамбль частиц кварца различной формы (×22; обр. № 21); (b) – угловатое вытянутое зерно из элювиальной группы (I класс окатанности), без видимых следов потоковой транспортировки; в правой верхней части зерна – наложенный скол предположительно криогенного характера (×362; обр. № 31); (c) – увеличенный фрагмент зерна *b*, демонстрирующий серию сколов и линейных структур различного размера, с острыми краями; поверхность зерна покрыта пленкой кремнезема, в понижениях наблюдаются прилипшие частицы (×1170); (d) – окатанное зерно (IV класс), значительно преобразованное в водных обстановках (×564; обр. № 36); (e) – увеличенный фрагмент зерна *d* с многочисленными V-образными микроуглублениями на в целом гладкой поверхности; в днище скола отмечается скопление продуктов осаждения кремнезема; текстуры поверхности сглажены пленкой осаждения кремнезема (×1290); (f) – угловато-окатанное зерно (II класс), преобразованное в условиях эолового переноса; в нижней части снимка – скол криогенного характера, отщепляющий фрагмент зерна (×310; обр. № 36); (g) – увеличенный фрагмент зерна *f*: вся видимая выпуклая поверхность зерна покрыта мелкоямчатым микрорельефом, кроме стенок прилегающих сколов (×1580); (h) – полуокатанное зерно (II класс) со следами водной и эоловой обработки (×289; обр. № 21); (i) – фрагмент поверхности зерна *h*: комбинация серпообразных желобков и V-образных микроуглублений с мелкоямчатым микрорельефом на ребре; текстуры поверхности сглажены пленкой осаждения кремнезема (×815); (j) – скол криогенного характера, раскалывающий зерно (III класс окатанности) на несколько частей; несмотря на свой наложенный характер, скол не выглядит "свежим" из-за пленки осаждения кремнезема (×414; обр. № 23); (k) – трещина расщепления в структуре кристалла, ведущая к дезинтеграции частиц в ходе криогенного выветривания (×1130; обр. № 21); (l) – поверхность зерна, сильно преобразованная процессами осаждения кремнезема (×1250; обр. № 17); (m) – зерно со следами диагенетических преобразований в виде элементов травления поверхности (×1510; обр. № 21).

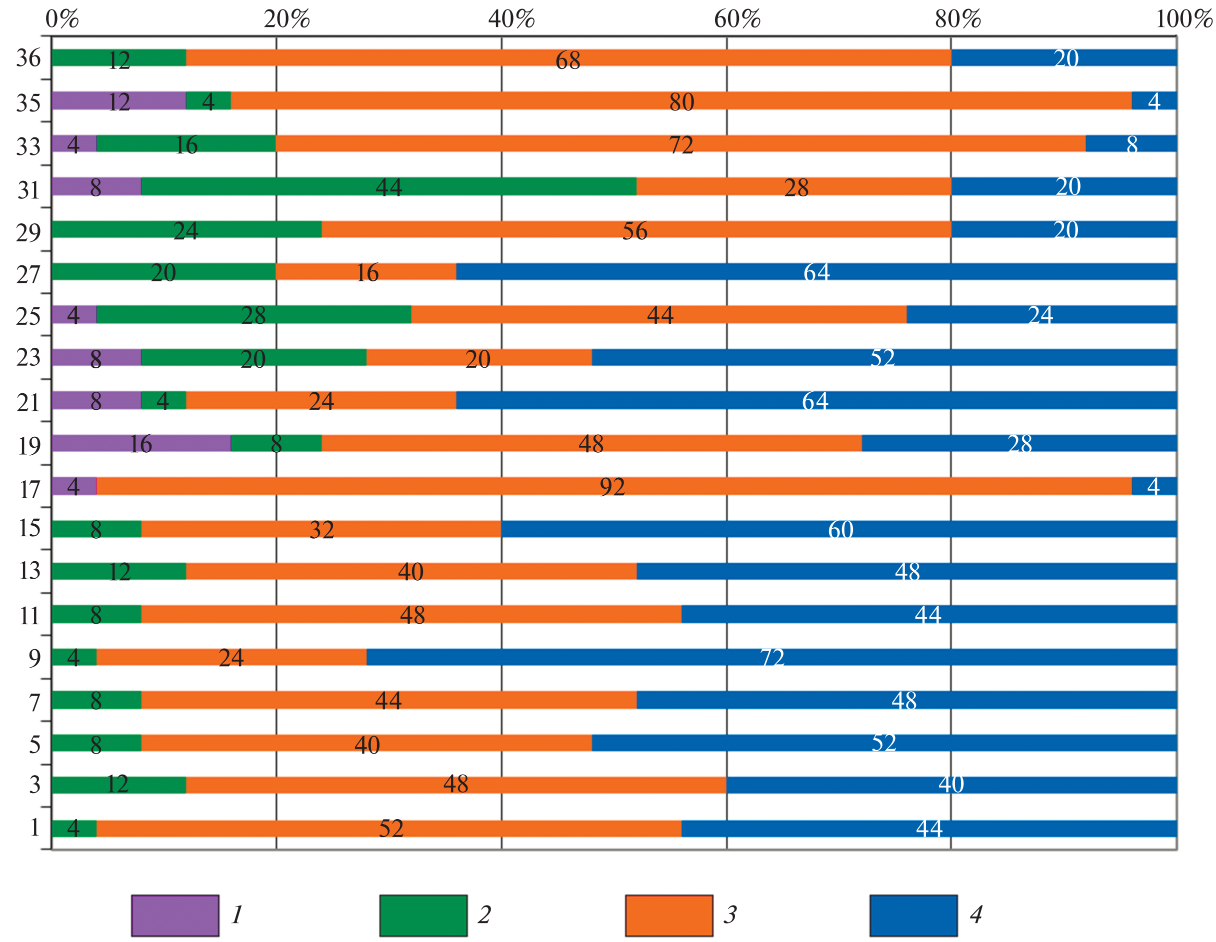

Fig. 4. Ratio of quartz grains of various morphogenetic groups in samples of Kareglazova section.
Morphogenetic groups: 1 – eluvial ones, without any significant traces of flow transportation, *2* – ones with features of transformation in aquatic environments, *3* – ones with traces of aeolian processing, *4* – ones with traces of water and aeolian processing.
Рис. 4. Соотношение кварцевых зерен различных морфогенетических групп в образцах из разреза Кареглазова.
Морфогенетические группы: 1 – элювиальные, без видимых следов потокового переноса, *2* – преобразованные в водных средах, *3* – преобразованные при эоловом переносе, *4* – со следами водной и ветровой обработки.

section, then noticeably decreases to 4(8)–24(28)% in the lower parts.

4. CONCLUSIONS

The study of quartz grains micromorphology from the sediments of the Kareglazova section showed that the primary sources for the crest's formation are, apparently, the bedrock deposits of alluvial-lacustrine origin, exposed at the base of the crest strata, as well as overlaying from above sediments brought by wind. The absence of buried soil at the base of the aeolian cover, the nature of its lower boundary, as well as the structure of the upper part of the bedrocks indicate a denudation cut of the underlying rocks. A similar conclusion was reached by (Zykina et al., 2012), who noted that the cover deposits in the south of Western Siberia were predominantly an ancient entrained aeolian sediment formed under cryoarid conditions during the second half of the Sartan stage of glaciation.

Correspondingly parallel crests within Western Siberia represent ancient continental, predominantly accumulative aeolian ridges, longitudinally elongated to the prevailing westerly winds. Similar ridges of West Siberia were formed at the mentioned time in many other regions of the Earth (Pozdnyakov et al., 2020).

In light of the above the crest near the Kareglazova village is a typical aeolian-accumulative formation, similar to others stretching from south-west to north-east on the left bank of the Ishim River valley north of the town of Ishim. In addition to the crests oriented in the direction of the prevailing winds (longitudinal), there are also cross ridges formed as a result of local wind blowing of loose material from the hollows.

With a transverse crest's location, the accumulation of material occurred on the eastern or south-eastern lakeshores outside the negative deflationary landform, when it was blown out by the western wind. Later, with the climate humidification, these negative landforms were flooded by water, and lakes or vast wetland depressions were formed, often drained by small local rivers. One of these is the left tributary of the Ishim River, the Kiterna River, near the mouth of which the crest under study (section Kareglazova) is located.

Generally clear predominance of quartz grains with traces of aeolian processing (mainly only in convex areas of quartz grains) and the presence of cryogenic surface textures indicate that the crest strata is an accumulative body developed during local wind blowing of the local (alluvial-lacustrine) deposits in cold and arid periglacial conditions.

Quartz Grains Surface Texture of the Crest Relief Deposits of the Tobol-Ishim Interfluves

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The paper presents the results of quartz grains surface textures study in order to reconstruct the sedimentary history and deposition environments of the crest strata formation in the Kareglazova section (southern part of the West Siberian Plain, Russian Federation). Using a scanning electron microscope (SEM), quartz grains of the medium sand fraction (0.25–0.5 mm) from 19 samples were studied. The crest is composed mainly of fine low-sorted sand with a large proportion of clay and silt components. The studied samples from the Kareglazova section contains four main types of quartz grains with different morphology and complexes of surface textures, which bear signs of transportation and accumulation in various environments. The roundness ratio of grains of the medium sand fraction (according to A.V. Khabakov) varies across the section from 54 to 65%. Semi-rounded quartz grains predominate (up to 57%), the share of well-rounded grains averages 39%. Vast majority of grains bear traces of post-sedimentary transformations, which are expressed in the presence of amorphous silica films and traces of etching of previously formed textures. Alluvial-lacustrine sediments of different age, common in the study area, are likely to be the primary sources for the crest deposits. The quartz grains surface features have traces of eolian processing and overlay of aeolian surface textures (upturned plates) on the surface textures typical for subaqueous environments (V-shaped pits, curved grooves, smooth surface). The occurrence of specific aeolian surface textures mainly on convex areas of quartz grains and the presence of cryogenic processing traces indicate the accumulative nature of crest with the predominance of local terrigenous provenances in cold and arid conditions of the periglacial climate. The upper part of the crest section was probably formed in a relatively moderate humid climate, when the migration of colloidal solutions was possible.

Keywords: ridge (crest)-hollow relief, Western Siberia, quartz grains surface textures, SEM, aeolian processes, cryogenic processes, cover deposits

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