GEOMORPHOLOGY AND PALEOGEOGRAPHY

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UDC 551.345(571)

*FIRST DISCOVERED PERMAFROST TRACES IN KURGAN REGION**

SUMMARY. According to fund materials and space images, for the first time the development areas of paleocryogenic structures have been defined and mapped in the south-west of the West Siberian Plain. The article studies the pseudomorphosis of the second lam ice of the last cryolithogenesis stage in the Kurgan region.

KEY WORDS. Paleogeocryogensis, Pleistocene, Holocene, paleothermokarst, stratigraphy, paleoclimate, ridges and troughs relief, radiocarbon age.

In sections of the quaternary deposits of the southern regions of Western Siberia and Northern Kazakhstan the permafrost traces have been known for a long time. One of the first assumptions of its prominent role in the formation of the lake basins in the south of Western Siberia was expressed by G.I. Tanfilyev [1]. Later, similar views were advanced by other authors [2], [3].

These views were based on the discoveries of various paleopermafrost traces, including buried polygonal frost cracks, hollow and depression landforms of the permafrost subsidence genesis with traces of cryoturbation, wedge structures, diagnosed as pseudomorphs of icy veins [4-17]. The few finds of permafrost traces do not allow determining the southern boundary of the ancient permafrost distribution in the south of Western Siberia and Northern Kazakhstan. Therefore, A.G. Kostyaev [17], allowing the reduction of the average annual temperature during the Pleistocene glaciation by 6-70, defines the southern boundary of the permafrost at 51-52 north latitude, and according to F.A. Kaplyansky's calculations [15], this boundary did not run further than 50 north latitude during the late Pleistocene glaciation.

A.A. Velichko in his works [18], [19] states that in the late Pleistocene period the southern permafrost boundary shifted southwards for 2,000 km on the average

* The study was supported by the RFBR grant 11-05-01173-a. The authors thank V.P. Kotenev for help with the field work.

and within the study area there was a zone of continuous permafrost up to 200-400 m, and the temperature of the rocks was from — 3 to -5°C. To the south of 50 north latitude to 47-48 north latitude there was a lane of discontinuous and insular permafrost. In one of the major works on the geology and paleogeography of the Pliocene-Quaternary period of the southwest part of Western Siberia [20] the role of ancient permafrost in the formation of cover loess deposits and relief is refuted, although some obvious signs of permafrost (frost wedges) in cuts of first overfloodplain terraces are noted. V.S. Volkova [21] writes that the southern boundary of the cryolithozone during the Sartan glaciation was located in Kazakhstan. Therefore, of great importance for the reconstruction of paleogeographic conditions of the late Pleistocene and Holocene period are the new finds of long-term permafrost traces in the southwest of the West Siberian Plain which are provided with less paleocryogenic information, in comparison with the southeastern part.

To determine the development area of paleocryogenic structures according to the published data and the results of the interpretation of satellite images (SI) Google Earch, we attempted to map the presumable traces of relict cryogenic microrelief (RCM) within the Tobol-Ishym and Ishym-Irtysh interfluves. At SI with coordinates from 57°12'53" to 53°55'78" north latitude and from 62°56'92" to 73°56'92" 20'18" east longitude numerous areas of macropolygonal, lenear-polygonal and micropoligonal (fine-mesh) terrain can be singled out. The degree of its markedness and safety in the south of the Tyumen region, in the Kurgan and Omsk regions and in Northern Kazakhstan (the area length of about 4 in latitude and 11 in longitude) differs greatly. The traces of such relief, in our interpretation the RCM, are clearly seen in SI, shot in autumn or late spring, on the spots taken up by ploughlands. There is a clearly visible patchy block-poly relief, polygons mostly square. The location of such areas, identified in the Kurgan region, is shown in Table 1.

In the southern part of the Kurgan region on the left shore of Lake Gorkoe the RCM traces are presented by large-block polygonal terrains. The size of the base block unit is about 80 m according to the dimensional scale of the image. In SI clearly visible are light central parts of the blocks and interconnect reductions of darker colors, which are modelled by linear erosion and take the form of erosion gullies while approaching the slope. Their adaptation to the blocks shape is quite noticeable. Sometimes they bend, following the shape of the block. The RCM traces are visible within the area of Lake Krutali. On the southern and south-eastern shore of Lake Krutali in SI (a piece of fresh plough land) the structure is seen in the form of large blocks, their shape similar to a square (Fig. 1). The block size is about 80-95 m. On the whole, the pattern of block-hollow relief bears "chessboard" character and looks like roll-like relief. The width of the interridge hollows makes about 1/3 of the block sizes. Since Lake Krutali is located on a late pleistocene drain valley, this site, owing to its hypsometric position, could freeze through due to the remoistening in the late Pleistocene period. Therefore, it may be assumed that the expansive depression, a part of which occupies the modern Lake Krutali, is an ancient alasy.

Table 1

The location of some sites of the presumable RCM depicted in SI within the Kurgan region

Location	Form of expression of RCM in SI*	Shooting date	Coordinates **		Sea level m.
			(NL) latitude	(EL) longitude	
The Makushinsky district, lake terrace on the eastern shore of Lake Baskoe	BP*. Large blocks	05.06.2005	55^{0}50’12”	67^{0}28’54”	128
The Makushinsky district, to the East of Lake Baskoe	BP. Hexagonal blocks of different size	05.06.2005	55^{0}04’20”	67^{0}32’75”	139
The Petukhovo district, to the NW and SE of Lake B.Gusinnoe	BP. Square large blocks	05.06.2005	54^{0}59’46”	67^{0}27’29”	138
The Belozersk district, to the North of Nizhnetobolnoye	BP. Square blocks	05.11.2010	55^{0}13’45”	65^{0}06’54”	74
The Ketovsk district, to the N.E. of Lake Krutali	BP. Large square blocks	05.11.2010	55^{0}17’16”	65^{0}00’24”	78
The Tchelinnyi district, left shore of Lake Maloye Gorkoe	BP. Large isometric blocks	06.11.2005	54^{0}25’31”	64^{0}16’43”	101
The Tchelinnyi district, the left shore of Lake Gorkoe	BP. Large square blocks	06.11.2005	54^{0}25’10”	64^{0}18’50”	82
The Ketovsky district, the NE shore of Lake Krutali	BP. Large isometric and square blocks	05.11.2010	55^{0}17’52”	65^{0}48’55”	76
The Ketovsky district, the NW shore of Lake Krutali	BP. and LB*. large isometric, square and extended linearly	05.11.2010	55^{0}17’58”	65^{0}04’28”	77
The Ketovsky district, the S and SE shores of Lake Krutali	BP. Large square blocks	05.11.2011	55^{0}13’95”	65^{0}03’57”	134
The Petukhovsky district, to the south of Petukhovo	BP. poorly expressed, isometric blocks	09.07.2003	55^{0}01’44”	67^{0}56’96”	135

Note: *BP — block and polygonal, LB — linear- block relief;
** the coordinates are given on the average, for a site occupying a certain space.

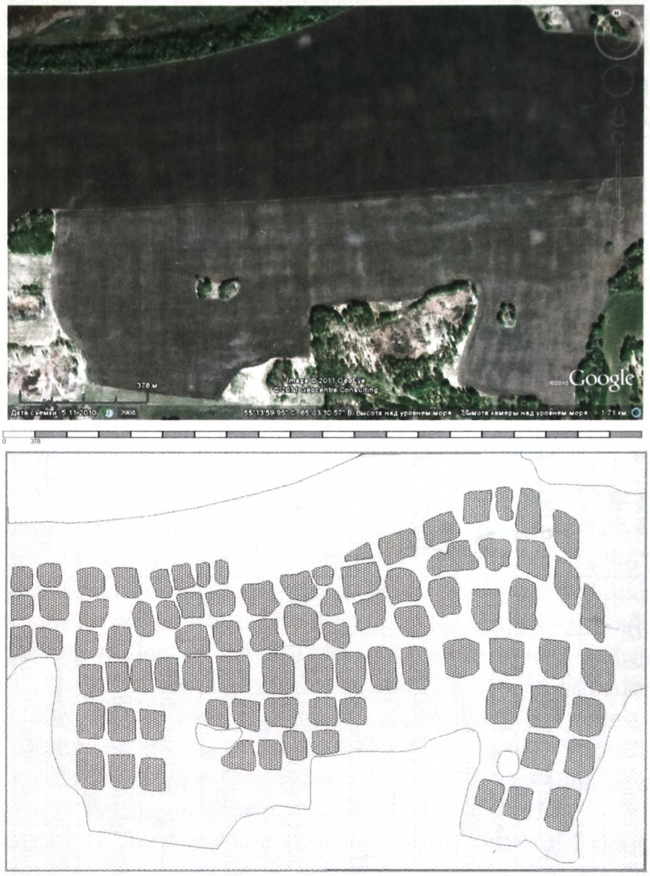

Fig. 1. Block-macropoligonalic relict permafrost terrain. The southern and south-eastern shores of Lake Krutali (the Ketovsky disirict of the Kurgan region)

In the SI of the north-eastern shore of Lake Krutali on arable land the RCM traces are expressed as well. They are presented by large-block relief: there are blocks around 40-90 m in size and dividing them interblock depressions of about 40 m in width, which stretch in the north-west direction along the lake terrace. The block contours are sometimes isometric. This relief can be considered linear-block. A very interesting and important feature of the microrelief structure of this site is the presence of modern lakes input in interblock depressions. This shows a direct link between the block-polygonal relief and the location of modern lakes, apparently, inheriting thermokarst depressions. The morphology of these lakes does not differ in their appearance from many other lake baths in this area, which allows us to employ this fact to a larger territory and to confirm numerous earlier expressed views on the thermokarst genesis of many lakes in the south of Western Siberia.

On the north-western shore of Lake Krutali, in SI, on the area of fresh arable land with dark colour there are loosely structured light spots. As well as in the north-eastern, south-eastern and southern shores of the lake, block-polygonal relief is noted here. Most of the square or isometric blocks are up to 60-70 m in size. The analysis of the data at our disposal shows that the size and shape of the block-acts are different depending on the area and, probably, the degree of the moisture extent of the area in the past. For example, on the left shore terrace of Lake Gorkoe, block-polygonal relief is clearly expressed. The blocks are represented in SI by isometric spots and, compared to the area of Lake Krutali, are much larger, with a base of about 120-180 m long. They are divided by depressions, green in SI. The edge depressions open towards Lake Gorkoye in the form of small "trailing" valleys which do not block the lake flood plain.

It should be noted that in some SI the river network "adjustments" are clearly seen peculiarities of a block polygonal terrain. In SI it is highlighted as light tree-like belts. Clearly visible are riverbed knee-bends, rounding blocks and inheriting interblock hollows. Minor tributary valleys also fall into the mainstream by interblock hollows, knee-bending, according to the shape of the block and interblock hollow, correlating to it. The upper parts of the watersheds are surfaces with a honeycomb relief, in the form of blocks with dark central parts separated by light bands at the edges. The blocks form is square, trapezoidal, in some cases, hexagonal or irregularly shaped.

It can be assumed that within that territory of the Ishym plain in the late Pleistocene, long-term permafrost was widespread. It is understood that the information obtained only from satellite images is not enough, that required proofs of the compliance identified by the SI traces of RCM on the ground and in the cuts of natural and artificial (quarry) outcrops.

In 2011, during the field work most of the sites with presumable RCM expressions were examined. At the test site break (5-6 m) of the left-bank terrace of the Ick river (55°37'04" N and 65°02'18" E, about 1.5 km from the village Stariy Prosvet) only the upper part of the cliff (2-2.5 m) is exposed, below the modern soil (0,1 m) interlayer grained sand (silt) of a light fawn color (0.5-1.1 m) opens. It is underlain by a brown loam, dense, highly sandy (probably floodplain alluvium of the Ick river) with 1.1 m thickness. Cryogenic traces were not found in the outcrop. The total amount of about 25 sandpits of different depths within the Ketovskiy and Petuhovskiy administrative areas of the Kurgan region were explored, four of them — acting. The open pits reveal a horizontal loam of interbedded brownish-gray and yellowish-gray sand. In the sand bands the bedding is horizontal and lenticular-horizontal; the genesis is presumably of lake character. Sometimes sections are topped with fine-grained white sand (0.5-1 m) of aeolian origin. Sometimes steep pit clearing could open sands and underlying loam. Traces of cryogenesis were found in an abandoned pit on the south-eastern outskirts of Galishovo (the Ketovsky area of the Kurgan region). The east wall of the pit (absolute height of 76 m, 55°11'12" N and 64°59'58" E) opens wedge structure (Fig. 2).

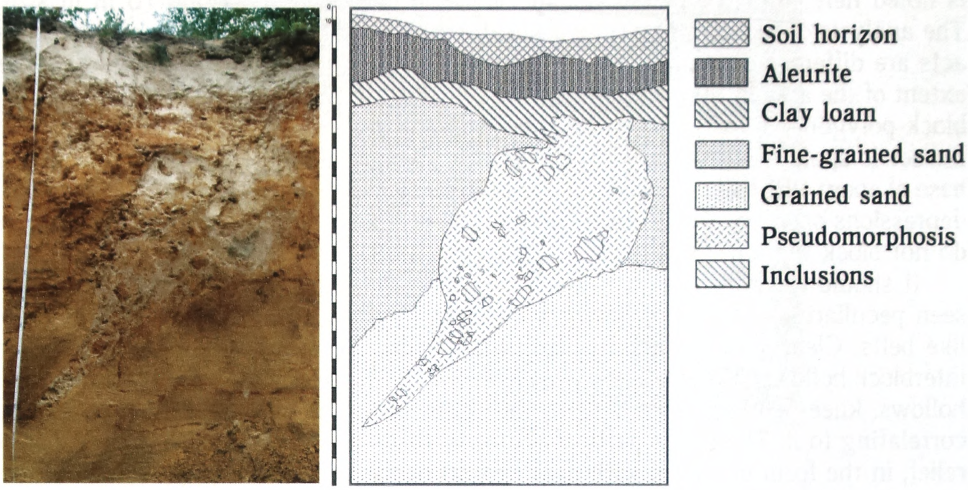

Fig. 2. A groundwater vein on the pit wall near Galishovo (the Ketovsky district of the Kurgan region). Photo by S.I. Larin

The wedge has clear boundaries and sharply narrows down to the base. It begins at the depth of 0.45-0.55 m from the surface. To the depth of 1.39 m it has the form of a boiler, then, to the depth of 1.89 m — the form of a tapered wedge. The wedge is filled with whitish silt interspersed with grayish-brown fragments of various sizes and shapes, from square to oval, elongated, isometric. The sizes of these inclusions reach 0.8 meters, thus creating a brecciated texture. The structure of the cut (from top to bottom):

1. Silt, whitish and gray-whitish, powdery, granular, fine. These sediments in this region are composed of aeolian landforms. Observations within the limits of the pit show that its true thickness is unlikely to exceed 1 m. The lower boundary on the wall of the cut is sharp. On the surface the layer is covered with turf.
2. Loam (from the depth of 0,44-0,54 m), rusty-brown nonlamellated, small-fragmented, sandy, very thick (thickness of about 0.2 m). The lower boundary is flat. In the wedge structure the lower boundary reduces to 0.7-0.8 m.
3. Sand, ocher-yellow, fine-grained (0.8-1 m) with very little horizontal stratification and 3-5 sand bands of rusty-brown ferruginous, thick clay.
4. Light yellow sand, grained, quartz, with horizontal stratification, with the apparent thickness of up to 1.5 m.

The cut is situated in the Tobol River valley within 12-13 km from its bed and opens the top of the alluvial deposits of the first terrace above the floodplain of the Tobol, so its age can be defined as Late Pleistocene-Holocene [20]. Based on the stratigraphy, the sands of Layer 4 are of the river bed character, and Layers 2 and 3 are floodplain facies of the roof terrace. The wedge-shaped structure lies in Layers 3 and 4. It begins in Layer 3 at 15-30 cm below its roof, but thin veins penetrate the top of Layer 3, Layer 2 connects the vein with Layer 1. The basic pseudomorph lies at the reconstructable depth (if the layer thickness is 1 — 1 m) of 1.2-1.5 m and penetrates to the depth of 1.89 m. To the depth of 1.39 m the vein has the shape of a boiler and is filled mostly with sand of Layer 3, less — with the silt of Layer 1. Below it has a shape of a vein with the slope of 50-70 degrees and is filled with silt of Layer 1 and the ortstein fragments of Layer 3.

In its form, fill, and mode of occurrence the wedge structure is interpreted as primarily ground (ground-ice?) vein, which developed in the area of a seasonally thawed layer with its bottom penetrating into the zone of permafrost.

The discovery of this cryogenic structure is of great interest because in this part of the south-west of the West Siberian Plain tapered cryostructures have been observed in the literature [5] far eastwards. Judging by the pseudomorph form, during the formation of the wedge-shaped structure the permafrost surface was at the depth of 1.7-1.8 m from the day surface, and thawing and vein turning into a pseudomorph occurred after the accumulation of aeolian silt of Layer 1, that is more likely in the post-glacial period. To the south of Lake Krutali, 5-6 km north-north-east of the investigated cut, according to SI on the fresh arable land there was frequent spotting, but it was impossible to check whether it was associated with the polygonal network.

To detect the traces of the polygonal network and details of the cut structure along the south wall of the pit, a 16-meter-long clearing was carried out. The stratigraphy of this part of the cut is similar to that described above. The upper part (Layer 1) is presented by gray siltstone with a clear lower boundary (with thickness of 0.4m). Below there is Layer 2 of a dense brown clayey sand with thickness of about 0.7 meters. Its lower boundary forms "pockets" on the wall of the cut which are filled with silt from the upper layer, or with clayey sand. The distance among the pockets filled with silt, is respectively 4.4 m, 3.7 m and 3.5 m, and the depth is 1.4-1.6 m, which allows suggesting the presence of signs of a polygonal network. Below lies Layer 3 of fine-grained, yellow-brown, ferruginous, stained ocher sand and layers of yellow, thick sand with weak horizontal stratification, with density of about 0.8-1 m. Along the wall of the section in this layer there are 3-4 brown and grayish-brown dense sand and clay layers, which bend, change their thickness and angle. At some places of the layer vertical or subvertical wedge cracks, filled with sand grayish- brown clay, are visible. At Layer 3 base there is a tight clay interlayer of sand, similar to filling cracks. Some narrow vertical cracks filled with whitish silt stand out against the background. Separate cracks penetrate to the base of Layer 3 and penetrate to the depth of 2 m into Layer 4, made up of yellow horizontally layered, fine quartz sand, with visible thickness of about 2 m.

The general appearance of the section suggests that multiple strains of Layer 3 are of paleocryogenic character. The narrow cracks are probably shrinkage cracks, or a later stage of freezing in comparison to the pseudomorph described above.

The above-stated data are the first findings of possible traces of the ancient permafrost in this region, so their further study will certainly lead to a more detailed reconstruction of the final stage conditions of the the cryomorphogenesis.

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