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Geocryological Aspects of Landscape Formation in River Valleys of Kolyma River Upper Reaches

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Abstract: The study shows particular features of geocryological condition formation in transverse sections of river valleys with bottom land taliks. The influence of fine-grained mineral biogenic sediments accumulation on drainage and overall landscape appearance formation is assessed. The research contains results of geocryological research on key areas of modern ancient (pleistocene) cryogenic processes development which determine the development of icy permafrost sediments, respectively, pingos and large re-wedge ice. We determined features and some patterns of soil-plant complex development along with the deterioration of ecogeocryological conditions, fall of temperature and seasonal thawing of soil in and outside the area affected by taliks.

Key words: Permafrost, geomorphology, age of quaternary sediments, geocryological, cryogenic processes

INTRODUCTION

Powerful technogenic "pressure" on highly vulnerable landscapes of Northern valleys causes their instability under the influence of natural (e.g., shift and deepening of watercourse channels) and anthropogenic (e.g., placer development, agromeliorative and hydropower construction) factors. Because of that in the assessment of stability and rational use of river valley landscapes under permafrost conditions an important place is left to the study of cryogenesis influence on landscapes formation.

However, despite the huge amount of work on the development of placer gold deposits in the pool valleys of Kolyma river headwaters, cryolite structure, permafrost processes, underground ice and iciness of quaternary sediments are currently poorly studied (Uhov and Basisistyiy, 2013; Uhov, 2008). Valley landscapes have been studied mostly for providing stability of natural-technological systems and environmental protection (Uhov and Samohvalov, 2010). Thus, on the areas of development the influence of cryogenic factors on them was has been studied for preventing negative processes, e.g., on mountain gold mining polygons, construction sites, bottom land pool of water-power plant, reclamation construction (Uhov, 2013, 2014). Research results of active layer soil show the essential influence of its gleying on the reduction of their water conductivity due to abrupt reduction of filtration coefficient, more than an order of magnitude and at the same time reduction of active layer power (Uhov, 2007). Based on the foregoing we believe that natural tendency of drainage deterioration from channel to foot of the river valley slope, the "trigger" role is left to the soil gleying.

Goal of the research: Study the features and overall tendencies of landscapes formation in river valleys of mountain permafrost areas. To achieve this goal we have been studying lithological structure in river valleys, hydrothermal mode, soil freezing-thawing dynamics, vegetation regarding geomorphological location and age of quaternary sediments.

MATERIALS AND METHODS

The research is done according to the engineering research materials on the areas of reclamation systems construction and ecological expertise of construction and monitoring project of Ust-Srednekanskaya water-power plant bottom land pool.

Severe climatic conditions (average annual temperature below minus 10°C) cause the development of permafrosts, with power up to 500-600 m under mount massives and up to 150-200 m in river valleys, interrupted only under channels, formation under river floodplains (Uhov and Basisistyiy, 2013; Uhov, 2008). In the basement of quaternary sediments of valley bottom central parts lie gravels, usually 2-3 m deep and above

fine-grained sands, less often sandy loam, floodplain slope part of deluvial origins. Slope formations consist of sandy loams, loam, silt, silty sands with various organic contents and coarse fractions. On areas with weak drainage on the surface of two-layer thickness the third, peat horizon is forming, usually no >1.5-2.0 m thick.

It is known that quaternary sediments in valleys of Kolyma river upper reaches are classified by age into modern (holocene, age<10-12 thousand years) and pleistocene, mostly sartan ice sediments (Uhov and Basisistyiy, 2013; Uhov, 2008).

Lithogenic base analysis shows the decisive role of geomorphological location in some cases, and age in other cases. It is known that halocene alluvium has formed under climatic conditions close to modern ones, that is why frost cracking does not lead to the formation of re-wedge ice (Uhov and Basisistyiy, 2013; Uhov, 2008). Such conditions are common for valley bottoms of Kolyma river and Buyundy within the largest in the Russian North-East Seimchano-Buyundin cavity.

At the same time ancient sediments of pleistocene, most often of sartan glaciation have formed under severe climatic conditions, that is why they are characterized by high iciness and contain large ice cores sized >1.5-2.5 m, extending even to coarse soils. Because of high iciness of ancient sediments modern thermokarst and thermal erosion processes influenced the reduction of their power and extension areas. Due to that, they preserved only on limited areas, e.g., in the bottom of the Taskan river valley or in the buried state, e.g., floodplain terraces of Orotukan river valley (near Sporniy village).

Materials of field work and research of floodplain aerial photographs of Kolyma River upper reaches valleys show the significant difference of their vegetation, micro-relief and respectively geocryological in the transverse and longitudinal profile are different.

RESULTS AND DISCUSSION

On the example of two key segments of large watercourse valleys let us consider some features and overall tendencies of cryolite structure formation of soil landscape complex and their appearance. The first one is located in the segment of Kolyma river, near Verkhniy Seimchan village, the second one-Taskan river (near the confluence of Osshibite creek). On the first segment the sediments are formed by modern geological processes and moved to permafrost state in holocene and on the second-pleistocene.

The segment of Kolyma river valley that is being considered is located in the vast, elongated in the latitudinal direction (up to 80-90 km) Seimchano-Buyundin cavity. There the floodplains and the corresponding taliks are broader with size up to hundreds, less often thousands meters than outside the cavity. At the same time the riverbed strongly meanders, there are many islands and as a result of channel shift on the floodplain terraces remain chains of extended oxbow lakes.

Through ecological and geocryological research on floodplain talik of key segments of Kolyma River valley we determined the influence of fine-grained floodplain sediments accumulation on hydrothermal mode of trees edificators root zone (chosenia, poplar, willow tree, larch). According to particle size distribution grained floodplain sediments correspond to fine-grained and silty sands with filtration coefficient 0.5-1.5 m/day, so they can be classified by this parameter as poorly permeable. Due to that along with accumulation of floodplain sediments and increase of surface level above mean water, temperature and permafrost thawing rates go down, the depth of seasonal freezing goes up till permafrost alluvium lenses formation on a high floodplain, e.g. in the segment of Seimchano-Buyundin cavity, near Verkhniy Seimchan village (Fig. 1). Here, because of the common tendency of stable deepening and right shift of Kolyma riverbed, on its left bank, along with the receding riverbed and reduced role of alluvial processes, heating influence of river talik, followed by drainage worsening and strengthening cryogenesis, in forming the soil and plant complex, that is, the landscapes appearance.

Soil complex thermal mode analysis of Kolyma river valley landscapes confirms the previously identified pattern of thermal mode worsening along with drainage weakening (Fig. 2). For the considered Kolyma river profile we note the decreasing territory drainage and soil temperature when moving away from Kolyma river bed.

The island part surface of floodplain talik is characterized by plenty ridges and troughs with fairly steep slopes. It is to be noted that island highlands (high floodplain) of the considered key segment are characterized by the maximum power of fine-grained floodplain sediments (up to 2.5-4.5 m). In these places, unlike the middle floodplain, which is covered with azonal deciduous willow-poplar-chosenia tree stands (*Chosenia arbutifolia*, *Salix boganidensis*, *S. shwerinii*, *S. rorida*, *Populus suaveolens*), their gradual replacement by larch

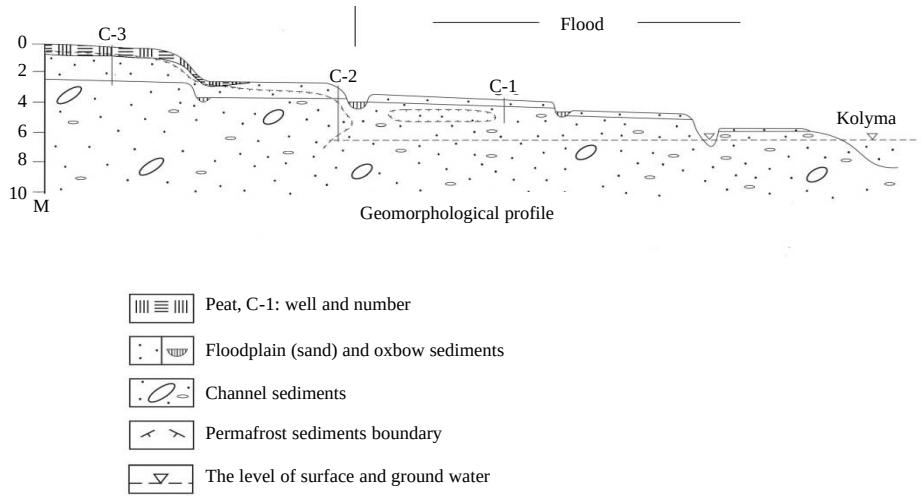

Fig. 1: Schematic permafrost geomorphological profile of Kolyma river valley near Verkhniy Seimchan village; 1: peat, C-1: well and number; 2: floodplain (sand) and oxbow sediments; 3: channel sediments; 4: permafrost sediments boundary; 5: the level of surface and ground water; 6: floodplain; 7: Kolyma River

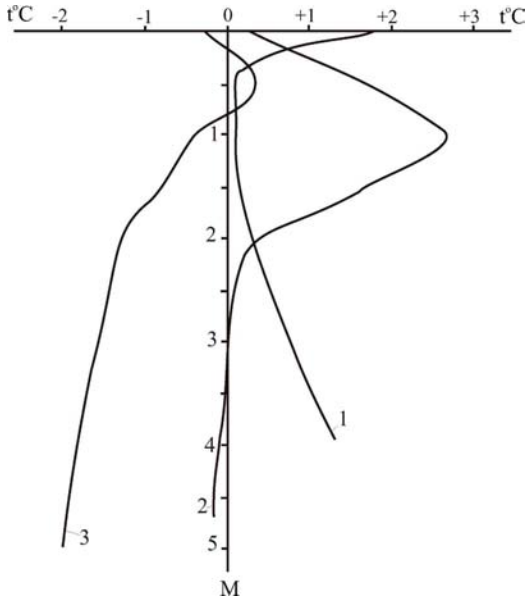

Fig. 2: Typical plots of solids temperature, measured in wells after the warm period (1: high floodplain, 2: old floodplain, 3: terrace above the floodplain)

and birch is typical (*Betula platyphylla*, *Larix cajanderi*) with shrub-motley grass-cereal lower tier. Here, depending on the year weather conditions and river level mode (height and the passage of the flood time), flights and permafrost alluvium are formed in the form of lenses with little power (up to 1.4-1.8 m).

Outside the field of riverbed meandering, that coincides with the floodplain talik boundary, the emergence of specific elements is typical in active layer soil formation. Soil processes are classified as alluvial, so called, old-floodplain type. Due to that in the more drained field near talik highly productive deciduous forests grow which are spread only at a high altitude when humidity is high. Here because of the weakening influence of alluvial processes, relief is a combination of ridges, flat watersheds separated by drain troughs with lake fragments. In low areas of the considered territory with stable soil waterlogging soil gleying and peat accumulation is typical. The depth of seasonal thawing is usually 0.8-1.4 m and it increases in troughs up to 3-4 m. Permafrost solids temperature, measured at 10 m depth is minus 0.1-0.9 °C.

On the first terrace above the floodplain the territory drainage weakening is followed by an active peat accumulation (power 1.0-1.5 m, less often more) and permafrost solids temperature reduction up to minus 2-3°C. Processes of peat accumulation and drift of the dispersed soil material of diluvial and diluvial-proluvial genesis from the slopes that surround valley, cause smoothing and leveling of fluvial landforms. Here, almost everywhere grow moisture-loving, mostly sphagnum mosses, sedge-cotton grass tussocks, bushes. Peat is underlay by mineral sand and sandy loam soil, characterized by high gleying rate, therefore low water permeability. The power of seasonal-thawing layer varies from 0.35 m (beneath the sphagnum mosses) up to

0.5-0.6 m in the places where shrub-sedge-cotton grass grow. Such conditions are favorable for the development of some cryogenic process types and icy permafrost soil formation. The greatest development here got mounds with ice-saturated soil cores of migration type. The height of mounds is up to 0.8-1.2 m, plan dimension up to 14-20 m.

The second key site is located on the valley segment near the confluence of Osshibite creek. Taskan river valley, left large inflow of Kolyma river, is characterized by significant asymmetry and lack of a clear floodplain boundary. The riverbed is pressed to the left and tall original bank, whereas the right bank part of the valley bottom is a flat marshy plain with individual outcrops of bedrock (Mesozoic sand-clay shale). Due to comparatively little power of Quaternary sediments the taliks, covered with deciduous willow-poplar-chosenia wood are developed on islands and zones adjacent to the channel, usually no >100-120 m wide. On the territory adjacent to talik with the background of shallow gravel, <0.5-0.6 m, the larch forest grows in fragments.

Outside the larch forest there is a comparatively drained zone covered mostly with bushes, and further along the channel goes the shrub-tussock swamp. With comparatively close gravel bedding (up to 0.6-0.8 m), in fine-grained sediments frost polygons are developed with the size 25-30 m, bounded by steep grooves.

Outside the modern frost cracking residual ancient wedge textures can be traced in Pleistocene permafrost alluvium. It is to be noted that along with territory waterlogging the size of polygons is reduced to 8-12 m, along the frost cracks wide flat rollers emerge. All in all, it is typical for wetlands, despite the fact that gravel bedding is comparatively close to surface (usually no >2.4-3.2 m), to mostly have ice cores 2-5 m wide and of weird shape. It is to be noted that on the territories adjacent to drained zone the ice cores lie right beneath the active layer. On this territory thermokarst ravines form upon underground melted ice, and at their intersection they have a rounded shape. The depth of thermokarst ravines is usually not >0.7-0.9 m. At the site located further away from the riverbed, the upper part of mines lie deeper than the seasonal thawing border, that is why thermokarst relief shapes are not typical here.

CONCLUSION

Cryolithological analysis of the river valley cross-section shows that soil-ice structures have the most complex structure. So, their lower parts shaped as ice wedges penetrate gravel up to and >3 m deep, whereas the upper ones-abruptly expand in dispersed soil by several times, acquiring a lenticular cross-sectional shape. Often in soil mines, above the ice body edges, the lenses of small pebbles and gravel can be traced. They often extend up to day surface, making the soil layer structure more complex.

Thus, on the example of the two key sites of modern and icy pleistocene sediments development of river valleys when moving away from the riverbed in and outside the floodplain talik successive change of permafrost conditions can be traced that control the main landscape elements including surface micro-relief, structure and tate of active layer soil, landscape vegetation.

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