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FROZEN-GROUND AND FACIAL ANALYSIS OF PLEISTOCENE DEPOSITS AND PALEOGEOGRAPHY OF CENTRAL YAKUTIA

The area visited by the participants of the Symposium displalys two landscapes: the terrain on the right side of the Aldan has the alluvial-glacia topo g raphy with lakes and dome-like morainic hills; on the left hand side of the river there is a typically alluvial plain with several geomorphological levels (6 to 11 have been distinguished) which present 3 groups of terraces: low, middle and upper ones.

Detailed descriptions of the terraces, their stratigraphy and paleogeographical reconstruction based on the geological and paleontological data can be found in the papers of LUNGERSGAUZEN (1957, 1961), SOLOVIEV (1959), VANGENGEJM (1961), GITERMAN (1969), BOYARSKAYA and MALAEVA (1967), RUSANOV (1968). In the present work, the Quaternary deposits of Central Yakutia are considered from the geocryologic point of view. The author's main aim was to determine the beginning of deep freezing of the earth crust and elucidate when, in what turn and under which conditions the transition of these sediments into the stage of permafrost took place.

The reconstruction of the history of permafrost formation is one of the most important problems in Yakutia. It cannot be solved through usual climatical reconstructions based on the floral and faunal remains. The nature of sedimentation in the presence of permafrost, regardless of the age of deposits, may be elicited only on the basis of cryogenic phenomena originated syngenetically with the deposits.

Studies on the Pleistocene, and especially Holocene deposits which froze syngenetically, proved that their types and facies (colluvial, of flood-plain terraces, of oxbows, etc.) are of different cryogenic structure while passing into permafrost stage. Formation of variously shaped and situated ice lenses and thin layers, either ground- or ice veins, depends on the origin of the deposits, i. e. on the mode of their accumulation (KATASONOV, 1962). Good knowledge of cryogenic phenomena and recognition of those originated in the course of accumulation of the deposits require the determination of genetic types and facies of the permafrost deposits by means of the frozen ground-and facial analysis.

The main indicators of syngenetically freezing deposits are leading cryogenic structures which had been formed due to a high permafrost table (fig. 1).

1. Subaerial deposits (flood plain-, slope-, and deltaic terraces) are characterized by the stratified and striated cryogenic texture (fig. 1: B, C). It is formed when the active layer freezes from the bottom, i. e. from the top of permafrost.

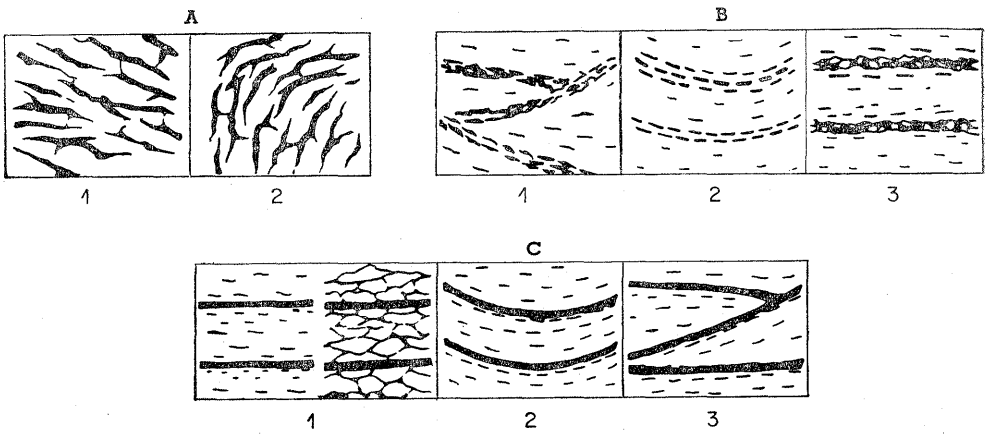

Fig. 1. Leading cryogenetic types of structure in syngenetically frozen deposits

A — latticelike structure (originating during the freezing of aqueous deposits): 1. oblique, 2. vertical; B — striated structure (originating during the freezing of active layer from the bottom): 1. undulate, 2. flexed inward, 3. horizontal; C — stratified structure: 1. horizontal, 2. flexed inward, 3. undulate

The pattern of permafrost top is reflected by ice-intercalations and streaks which are horizontal, bent or undulate.

2. Subaqueous sediments (oxbow-, lacustrine-, and others), which before being frozen had not undergone any diagenetical changes, display a latticelike cryogenic structure. Its vertical and oblique pattern indicates that freezing proceeded from the side of closed taliks which testifies to the presence of permafrost (fig. 1: A). The deposits that remained unfrozen for a long time and before freezing were strongly consolidated, are usually dissected by lithogenic fissures. They do not display any stratified, striated or latticelike cryogenic structure.

Syngenetic freezing of the deposits is proved by a weak consolidation of ground, which becomes loose while melting, and by the development of ground veins in alluvial sediments containing small amount of ice as well as by the ice veins in peaty-muddy grounds. The most reliable indicators of syngenesis are ice veins with irregular contact lines and thin ice layers adhered to them.

PROFILES OF MAMONTOVA GORA AND OF OTHER PLACES ON THE ALDAN LOWLAND

Five terraces have been distinguished in the vicinity of Mamontova Gora (310 km from the Aldan mouth). The highest, 80—90 m terrace, is built of sands: in the bottom part of Neogene in age and in the upper part — of Low-Pleistocene sands. No syngenetic cryogenic forms are present.

The geologic profile of 50 m terrace (fig. 2) shows that the terrace base built of the Neogene sands is overlain by two series of deposits. On the bottom the Mid-Quaternary sands reveal some horizons of pebbles (1.5—2.5 m) and interlayers of clays and peats. In the upper part there is 10—15 m horizon of slope-, lacustrine-, and inundational-terrace silts. Traces of syngenetic freezing are visible in the whole section. Aqueous and subaerial deposits show cryogenic structure characterized by stratification, striation, oblique and vertical reticulate texture. Ice- and ground veins which occur on various levels are associated with corresponding alluvial facies.

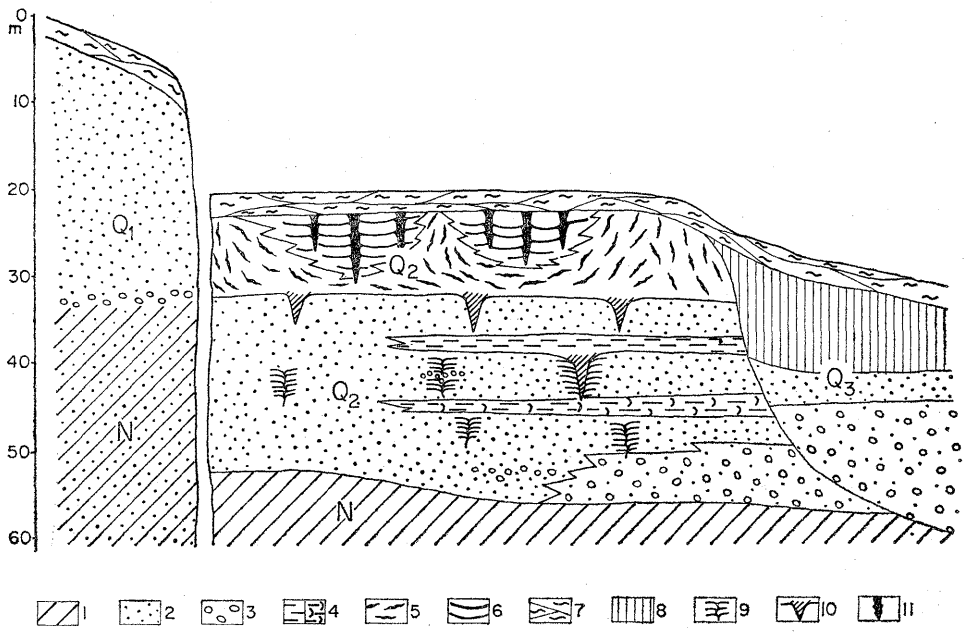

Fig. 2. Geological profile of the 50-m terrace at Mamontova Gora

1. sands with remains of warm-loving vegetation; 2. sands with remains of Pleistocene flora and fauna; 3. pebbles; 4. clayey and peaty silts (boggy flood-plain facies); 5. aqueous deposits (clays) with latticelike cryogenic structure; 6. stratified peaty silts; 7. loess-like silts with undulate and striated structure (slope); 8. clayey sands and silts, structure not examined; 9. ground veins of a "sag" type; 10. ground veins of infilling; 11. ice veins

Some ground veins of a "sag" type often occur in the fine-grained sands (near-bed shoales) on the depth of 20—30 m; they sometimes enter into the pebble horizon. The origin of these veins cannot be explained by convection processes, but they developed due to the formation of frost fissures in sands. Such fissures can be seen now in Central Yakutia. In the upper part of the section in the river-bed alluvia, there occur large, 1—1.5 m wide and 3—4 m long, veins filled with clayey silts containing fragments of twigs and some pebbles. The veins are genetically associated with deposits of the swampy flood plain facies. The present author believes that they are primary veins with mineral infilling (see the writer's paper in *Biul. Perygl.*, no 23, p. 81).

The upper part of the 50-m terrace (fig. 2) is built of dark-blue clays containing shells of mollusks (*Stagnicola*, *Rodix* and others) as well as ice lenses — schlieren, that give oblique and vertical cryogenic latticelike structure of deposits (pl. 1). In this section the clays are often replaced by peaty silts with tiny vein ice. The silts appear as separate "massifs" surrounded from the bottom and sides by aqueous deposits. The thickness of these deposits is some 35—40 m as seen in the section at Rossypna, Kuranakh, Tettigi, and Čujskaya Gora (fig. 3; sites 5, 4, 3, and 2 respectively). Southwards, on the left bank of the Aldan, the dark-blue

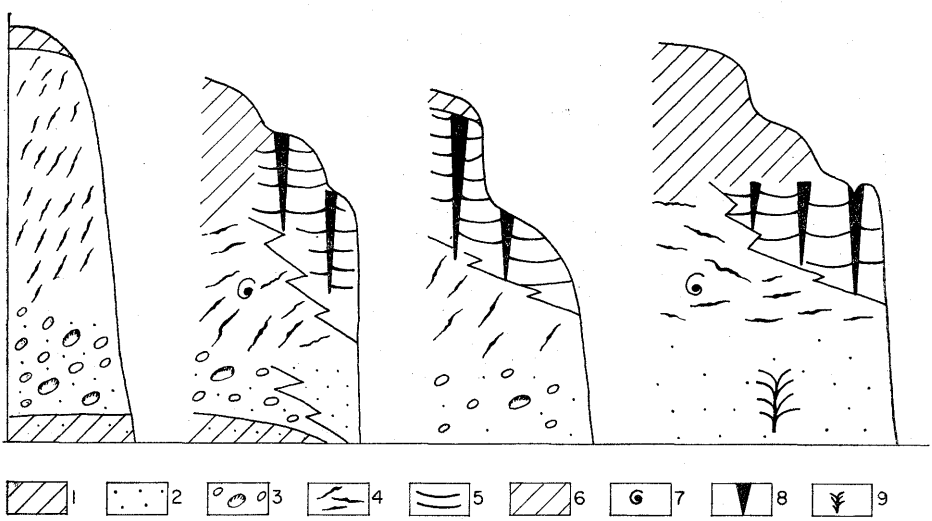

Fig. 3. Profiles of the Aldan Lowland at Čujskaya Gora, Tettigi, Kuranakh, Rossypna (see the map in *Biul. Perygl.*, no 23, p. 82: sites 2, 3, 4, and 5 respectively)

1. Neogene sands; 2. sands with Pleistocene flora or fauna; 3. pebbles with small stones; 4. aqueous deposits (clays) with oblique cryogenic structure; 5. stratified peaty silts; 6. silts, structure not examined; 7. mollusks shells; 8. ice veins; 9. ground veins of a "sag" type

clay give way to peaty silts, which provides evidence for gradual transition of the glaciofluvial series into alluvial ones, whereas towards the Verkhoyansk Mts. the clays contain more and more pebbles and small stones and pass into a moraine (fig. 4).

The uppermost part exposed in the section of 50-m terrace consists of a series of loess-like silts with grass remains *in situ*. The wavy and striated cryogenic structure (pl. 2) clearly indicates that the silts were deposited on slopes where shallow seasonal thawing took place. Analogous slope silts of various age cover also other supra-inundational terraces. They are 0.8—3 m in thickness.

The deposits of the lower, Upper-Quaternary terraces have been examined in the region of Mamontova Gora (20—30 m), in the depression of the river Tumara (fig. 4), and in the section at Krest—Khaldžaj. The lower, river-bed horizon of these terraces is seldom visible: the upper one is built mainly of peaty silts of flood-plain facie which underwent a syngenetic freezing (ice veins, etc.). The deposits of shallow water basins play a minor role. The conditions of development of cryogenic phenomena in Holocene deposits were discussed (see: *Biul. Perygl.*, no 23, p. 81).

On the basis of the frozen-ground and facial analysis of the Quaternary deposits it may be stated that the continuous existence of permafrost is the most characteristic of paleogeography of Central Yakutia. The alluvial sands and silts as well as deposits of shallow water basins underwent the syngenetic freezing as far back as in Mid-Pleistocene time. Then, the typical cryogenic texture, and ice- and ground veins were formed. The periglacial conditions were very severe and deep freezing of the earth crust must have started relatively early.

Formation of glaciers in the presence of permafrost is another peculiarity of the paleogeography of Yakutia. In Pleistocene time it gave rise to the specific landscape, uncommon in the history of the Earth, characterized by plains of lacustrine origin with high permafrost table. The frequent occurrence of aqueous deposits called by the present author flood-glacial (KATASONOV, 1963) is therefore of great importance. The complex and irregular occurrence of the lacustrine and peaty-muddy facies within these deposits as well as their relations with the alluvial and moraine deposits provide a reliable testimony that they originated in the course of glaciation, on the plain with a large number of lakes lying far southwards of the Verkhoyansk Mts.

The deposits of shallow (0.5—2 m) braided and often drying up water basins, which occupied vast areas, were frozen syngenetically mainly from the bottom and sides. On the surfaces separating the water basins there accumulated peaty silts, whose successive layers passed into stage of permanent freezing. The ice veins were also gradually growing.

The third peculiarity of the paleogeography of Yakutia is the stability and orientation of changes in the geological—permafrost conditions. There were no remarkable climatic changes in Yakutia during the Middle and Upper Pleistocene.

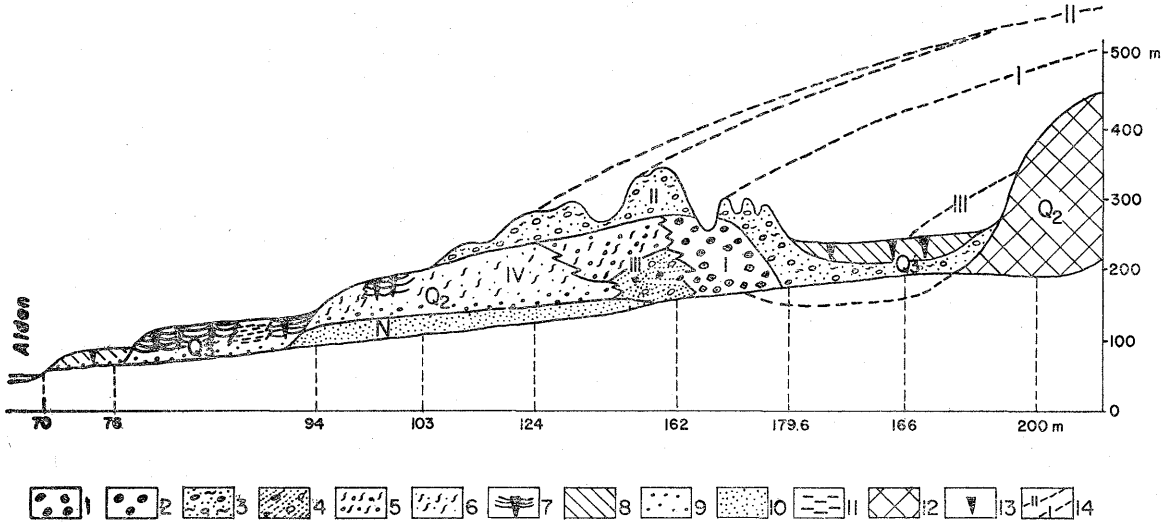

Fig. 4. Geological profile of the Aldan right-bank area (along the river Tumara)

Roman figures: I — moraines of the advancing glacier, II — moraine of the retreating glacier, III — glaciofluvial deposits, IV — flood-glacial deposits

1. weathered stones and pebbles; 2. morainic boulders; 3. clayey sands and sands with admixture of clays and pebbles; 4. stratified sands with stones and pebbles; 5. silty-clayey sands with chaotically distributed pebbles and stones, oblique structure; 6. silts and clayey sands, latticelike structure; 7. stratified peaty silts; 8. loess-like silts; 9. pebbles; 10. sands; 11. lacustrine deposits; 12. Mesozoic sandstones; 13. ice veins; 14. glacier limit in the initial stage (I), maximum stage (II), during recession (III)

General deterioration which began when climate was humid enough initiated the development of mountain glaciers and caused formation of swamps on the nearly whole terrain.

As mentioned above, the deposits of shallow water basins prevail in the series of the Mid-Quaternary formations, whereas within the Upper-Pleistocene ones such deposits play a minor role. In that period the Yakutian glaciers must have shrunk and the boggy terrains diminished. However, there were not such climatic changes as to cause thawing of permafrost, as some authors believe. In Central Yakutia, which at present is a dry area, the permanently frozen deposits with syngenetic cryogenic phenomena are continuously formed.

The scientists who have determined the succession of cold and warm periods in Yakutia, sometimes point to the formation of pseudomorphoses caused by melting of ice veins as main argument. But this is not conclusive. The development of ground veins in former periods as well as at present is controlled by the local frozen ground-and facial differences in conditions under which the deposits originated. Thawing of the deposits of the stratified and striated cryogenic texture with large contents of ice would have led to more essential changes in their structure. There have not been noticed any of such changes in the sections examined. Thus, the opinion which was expressed 10 years ago that the peculiarity of the glacial epoch in Northern Siberia consisted in the fact that the interglacial periods were cold and periglacial conditions did not differ from the glacial ones, can be also true for Central Yakutia. In other words, during the Pleistocene in Northern and Eastern Siberia permafrost existed permanently; the mountain glaciation which started and ended under severe climatic conditions did not display clear paleoclimatic differentiation.

Translated by Z. Apanańska

References

ALEKSEEV, M. N., 1961 — Stratigrafiya kontinentalnykh neogenovykh i četvertičnykh otloženij Vilujskoj vpadiny i doliny nižnego tečeniyar. Leny (Stratigraphy of terrestrial Neogene and Quaternary deposits in the Viluj depression and the valley of the Lower Lena). *Trudy Geog. Inst. Akad. Nauk SSSR*, vyp. 51.

BOYARSKAYA, T. D., MALAEVA, E. M., 1967 — Razvitie rastitelnosti Sibiri i Dalnego Vostoka v četvertičnom periode (Development of vegetation in Siberia and the Far East during the Quaternary). Moscow.

GITERMAN, R. E., 1963 — Etapy razvitiya četvertičnoj rastitelnosti Yakutii i ikh značenie dla stratigrafii (Stages of development of the Quaternary vegetation in Yakutia and their meaning for stratigraphy). *Trudy Geol. Inst.*, vyp. 78.

KATASONOV, E. M., 1962 — Kriogennye tekstury, ledyanye i zemlyanye žily kak genetičeskie priznaki mnogoletnemerzlykh četvertičnykh otloženij (Cryogenic structures, ice— and ground veins

as genetic features of permanently frozen Quaternary sediments). *In*: Voprosy kriologii pri izučenii četvertičnykh otloženij; Moscow.

KATASONOV, E. M., 1963 — Merzlotno-facialnyj analiz četvertičnykh otloženij nižnej časti bassejna r. Tumary (Frozen ground-and-facial analysis of Quaternary deposits of the lower part of the drainage-basin of the Tumara). *In*: Usloviya i osobennosti razvitiya merzlyhk tolšč v Sibiri i na Severo—Vostoke; ed. Akad. Nauk SSSR.

LUNGERSGAUZEN, G. F., 1957 — Stratigrafiya četvertičnykh otloženij vostočnoj časti Sibirskoj platformy (Stratigraphy of Quaternary deposits of the eastern Siberian platforme). *In*: Trudy Mezved. Soveščˇ. po razrabotke unificirov. stratigr. skhem Sibiri; Leningrad.

RAVSKIJ, E. N., ALEKSEEV, M. N., *et al.*, 1960 — Četvertičnyj period v Vostočnoj Sibiri (The Quternary period in Eastern Siberia). *In*: Khronologiya i klimaty četv. perioda; ed. Akad. Nauk SSSR.

RUSANOV, B. S., 1968 — Biostratigrafiya kajnozojskikh otloženij Yužnoj Yakutii (Biostratigraphy of Cenozoic deposits of Southern Yakutia). Ed. Nauka, Moscow.

SOLOVIEV, P. A., 1959 — Kriolitozona severnoj časti Leno—Amginskogo meždurečya (Cryolithozone of the northern part of the interfluve between the Lena and Amga). Akad. Nauk SSSR, Moscow.

VANGENGEJM, Z. A., 1961 — Paleontologičeskoe obosnovanie stratigrafii antropogenovykh otloženij Severa Vostočnoj Sibiri (Paleontological fundaments of the stratigraphy of anthropogenic sediments of Northeast Siberia). *Trudy Geol. Inst.*, vyp. 48.

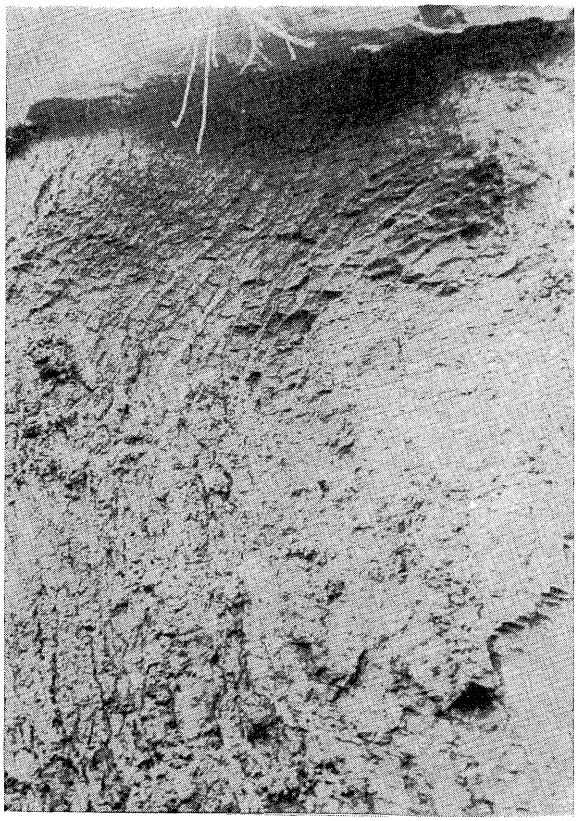

Photo by E. M. Katasonov

Photo 1. Latticelike vertical structure in syngenetically frozen lacustrine deposits. Section in the 50-m terrace in Mamontova Gora

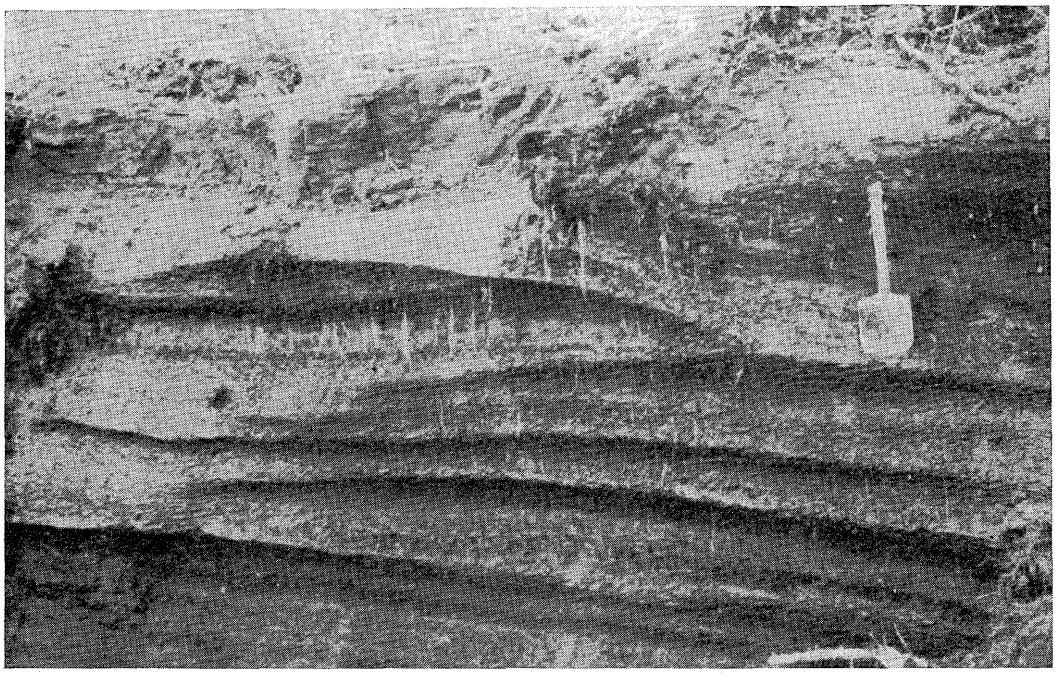

Photo by E. M. Katasonov

Photo 2. Undulate striated structure of slope deposits. Section in the 50-m terrace in Mamontova Gora