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DIAGENETIC GROUND VEINS IN THE PRESENT-DAY ALLUVIUM OF THE LOWER OMOLOJ RIVER-BASIN

Diagenesis of sedimentary rocks and, in particular, the convexion instability of grounds are phenomena of a general nature. This is obviously confirmed by the development of diagenetic structures in the recent alluvial deposits of the Lower Omoloj river basin, in a region of very severe climate and widespread permafrost. This fact was to the present writer the cause of a great though pleasant surprise.

Wedge structures were found by the author in the deposits of an inundation terrace of the Markoj-Yurege stream, one of the lesser right-bank tributaries of the Omoloj river. Over a considerable part of its lenght, this stream intersects the frozen, sandy lacustrine deposits of the alluvial plain whose age is upper-middle Quaternary (Würmian), The absolute height of the plain varies 80—100 m. In the sector discussed, that lies in its upper part, the stream runs along a narrow valley with an inundation terrace and two, partly preserved supra-inundation ones.

The inundation terrace forms a smooth or slightly undulating surface raised some 1.5—2.5 m above river level; its width varies 80—100 m and increases gradually towards the valley sides. With the change in elevation above river level, the inundation terrace changes its character and the composition of its constituent deposits.

The parts of the valley bottom bordering closely on the river bed are totally free of vegetation and built of pebbles, gravels and sands often forming small gently sloping near-bed ridges. The upper inundation terrace (up to 2.5 m) is slightly inclined towards the near-slope valley parts. Its surface is flat, thouroughly saturated, in some places even boggy. To a depth of 0.7—1.2 m it is built of strongly peated fine sands and clays of the flood facies; these sediments are underlain by river-facies deposits composed of sands, gravels and pebbles. The top of permafrost lies at a depth of 0.25—0.45 m. The surface of the upper inundation terrace is characterised by a well-marked polygonal microrelief clearly connected with ice-veins (which were found under similar conditions in other stream valleys). The furrows above these ice-veins have some 0.2—0.4 m in width and are often disturbed by thermokarst processes. In size the polygons range from 8—10 m to 12—18 m and are predominantly hexagonal in shape. Therefore, the polygonal structures with primary mineral filling occurring close by the ice-veins on the lower inundation terrace are most interesting.

The lower terrace exhibits intermediate features. It has an even surface 1.5—2.0 m in height, overgrown with shrubs, dry mosses and low birch thickets. Isolated hill-like elevations occurring on its surface usually bear relatively large groups of larch trees and juniper shrubs. The permafrost top lies at a depth varying here from 0.5—0.6 to 0.8—1.1 m.

The composition of the lower terrace is exposed in an undercut river bank. At the top rest deposits of the inundation facies, some 0.2—0.5 m in thickness, containing in their downward part some grey dust and fine, non-stratified clayey sands including silts interbedded with a few bands of pure, fine- and medium grained quartz sand. Upward, these intervening bands pass into dark-colored clayey sands and silts as well as light fine- and medium grained sands, with a frequent predominance of the latter. The contact of these sediments with the underlying river deposits is sometimes well-defined and sometimes only marked by a gradual difference in the material.

In the vertical profile, the river deposits exhibit a somewhat complicated pattern of interbedding while in the horizontal cast sandy strata merge into gravels and pebbles. Concentrations of the latter appear mostly in the upper part of the river-facies deposits. Their downward part, which is predominantly sandy, exhibits lenses of oxbow deposits, bluish-grey in color, indistinctly stratified silts and dusty sands with lenses of organic remains. The bedding pattern of the river deposits varies widely, from horizontal to oblique, diagonal and undulating.

The surface of the lower inundation terrace shows a characteristic polygonal microrelief pattern consisting of feebly outlined polygons, commonly penta- or hexagonal in shape and ranging from 5 to 12 m in diameter. The polygons are quite flat; in the cross-cut

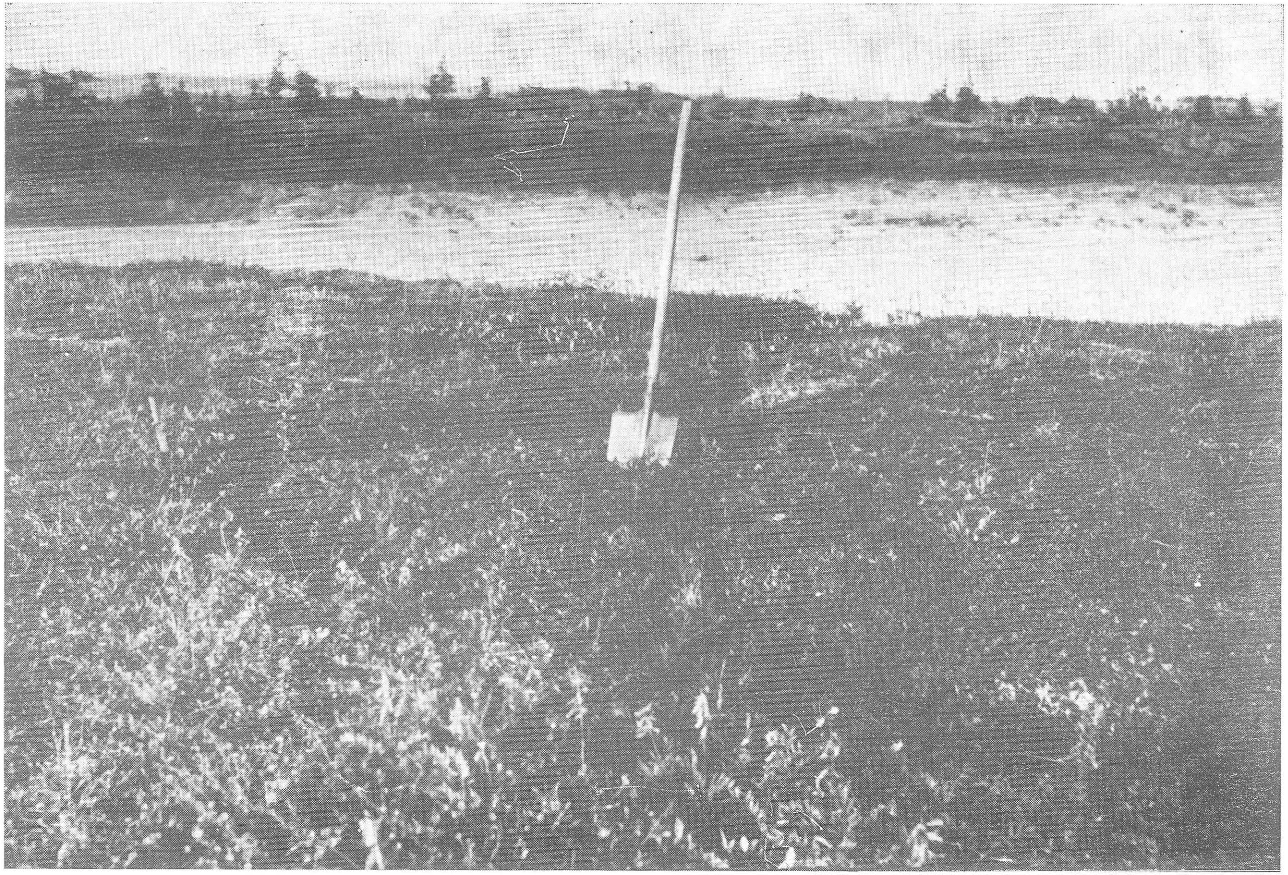
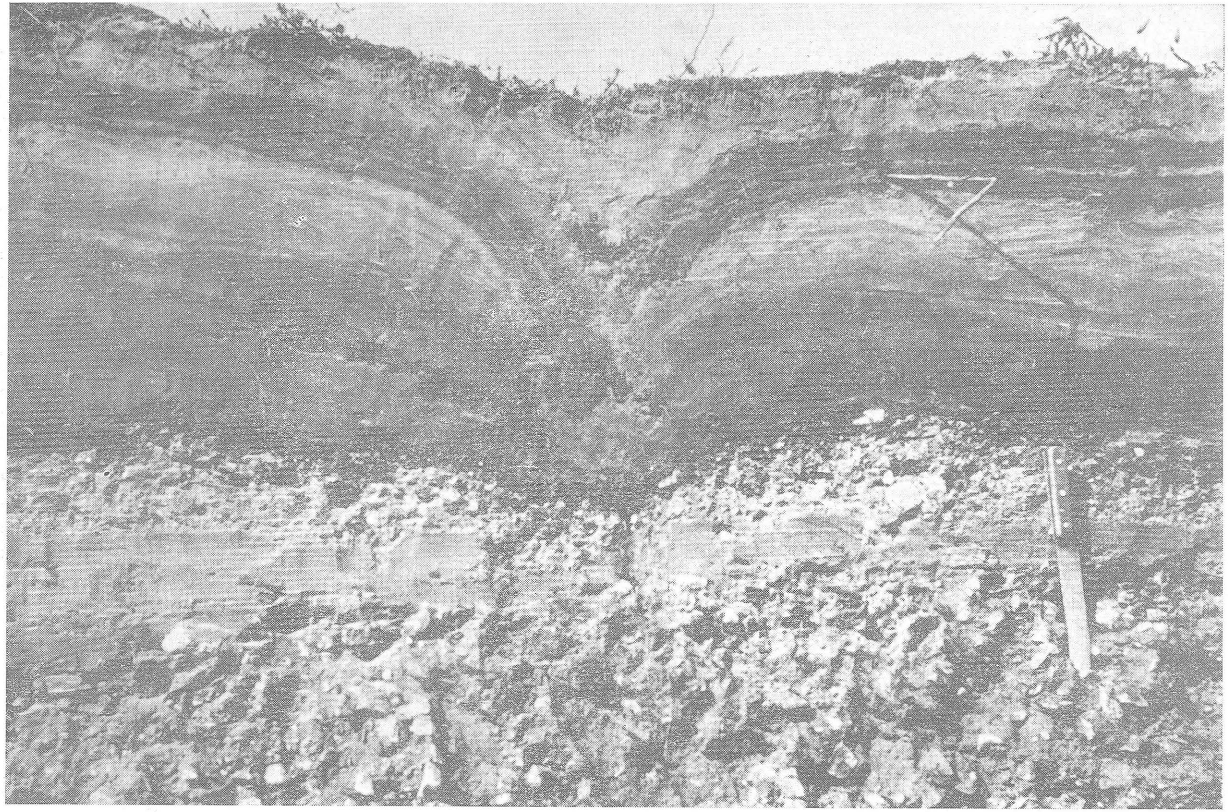


Photo by the author

Pl. 1. Bordering polygonal furrow on the surface of the inundation terrace of the Markoj—Yurege stream



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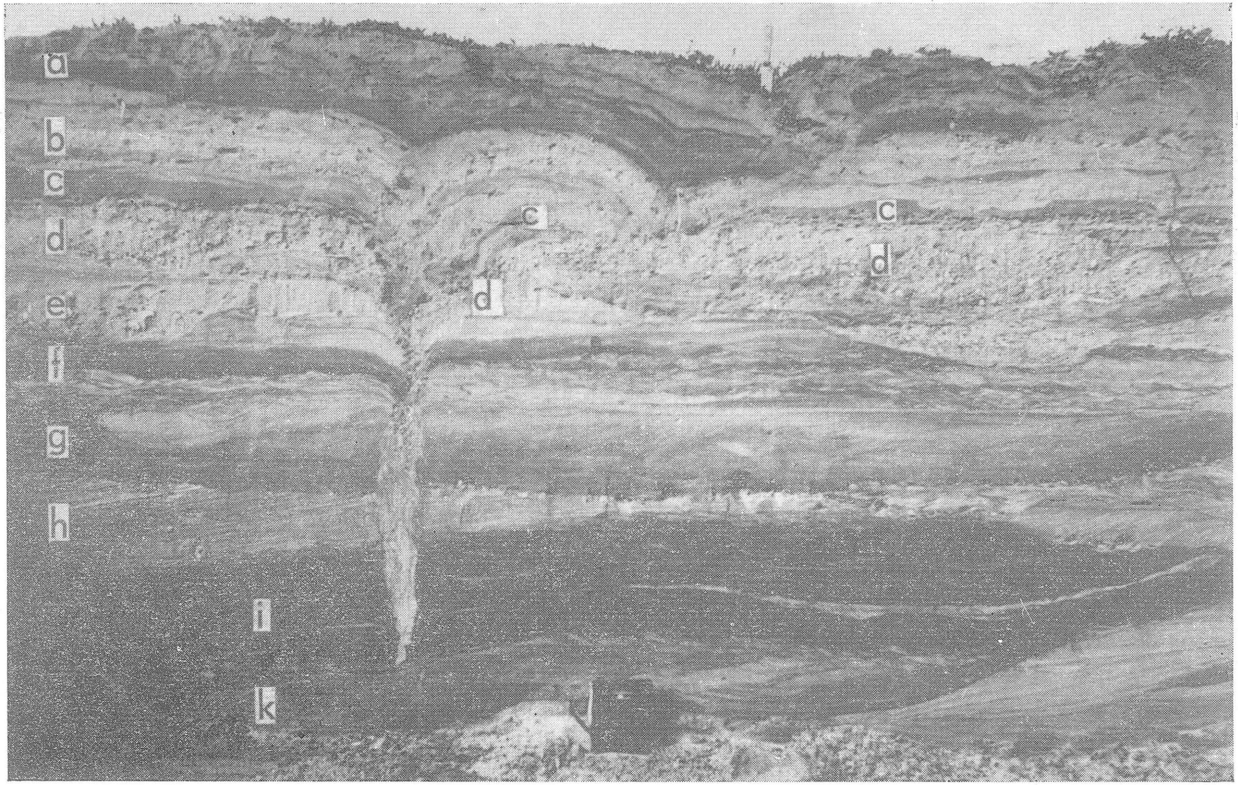
Pl. 2. Ground vein in deposits of the alluvial flood facies of the low inundation terrace



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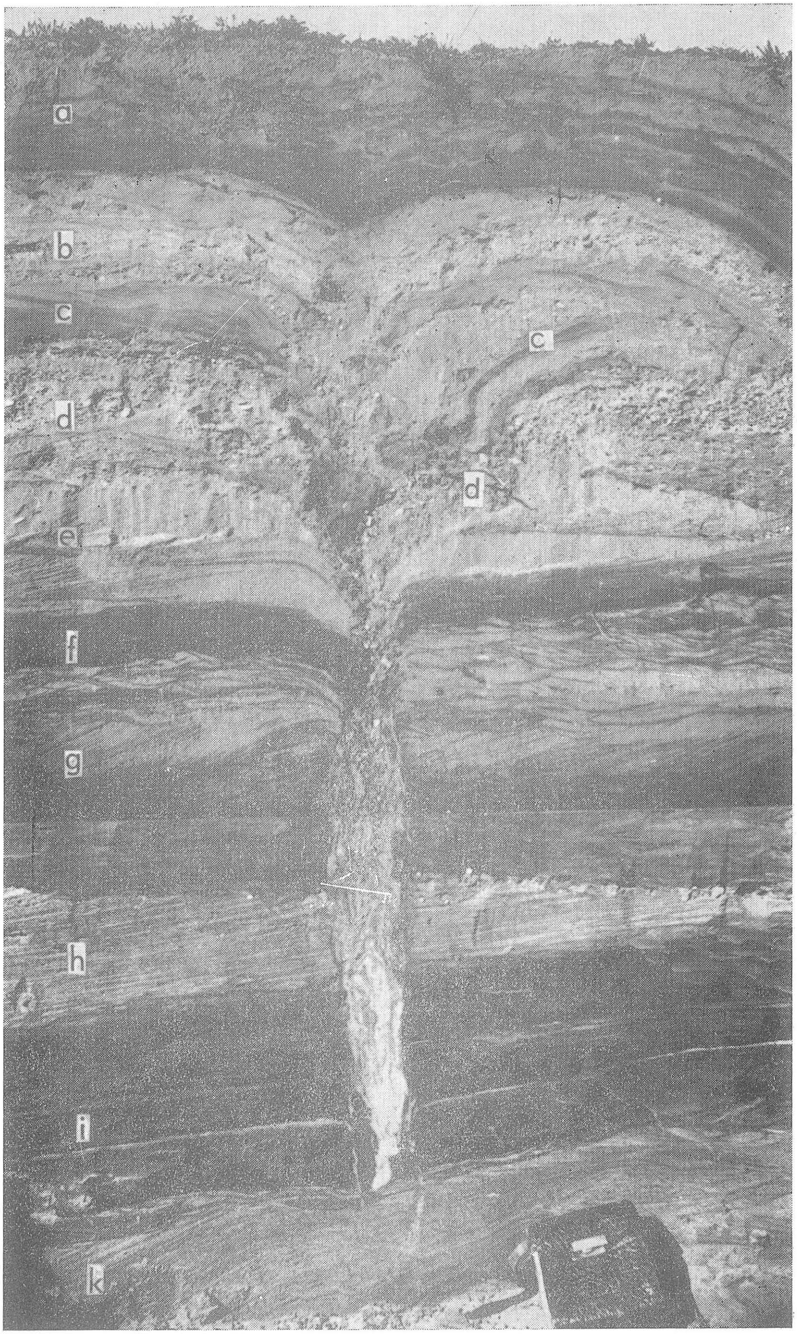
Pl. 3. Disturbances in the alluvial deposits of the flood and fluvial facies of the low innudation terrace

a — dusty-silty sand thinly interbedded with well-washed fine- and medium grained sand, horizontal and lense-like bedding; b — fine- and medium grained sand with inlaid gravel, horizontal and undulating bedding; c — dusty-silts, including fine sand, cross-bedded; c_1 — dusty and fine-grained sand with single gravels, horizontal and cross bedding; d — gravels and small pebbles including variously grained sands; e — fine- and medium grained sands, diagonal bedding; f — dusty fine-grained sand, bedding pattern obliterated; g — fine- and medium grained sand with single gravels, diagonal and cross bedded; h — fine- and medium grained sand including gravel, gently oblique bedding; i — dusty, homogeneous indistinctly bedded sandy silt with lenses of organic remains; k — coarse- and medium grained sands, diagonal bedding



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Pl. 4. Ground vein — well-developed form of subsidence by convexion (detail of Pl. 3)

Explanation as in Pl. 3

they exhibit a normal horizontal sedimentary pattern of flood deposits. An outstanding feature, revealing the presence of a polygonal form are shallow, feebly outlined trough—furrows, some 0.1—0.15 m (up to 0.25 m) in depth and 0.25—0.40 m in width, which are additionally marked by a denser shrub growing along their borders (Pl. 1). The furrows vary in direction which shows a curved line with frequent knick points. Small but deep funnel-like depressions appear at the points where the furrows intercross. The above mentioned polygonal pattern does not cover the whole surface. In some parts of the area, polygons occur in coherent groups but gradually, towards the river bed they soon become shallower and finally disappear altogether.

An intervening furrow between polygons in the exposure of the undercut and completely thawed steep bank of the inundation terrace was investigated.

The first ground vein corresponding with the 0.15 m wide and 0.1 m deep furrow which is very feebly outlined on the terrace surface is shown in Pl. 2. In depth, (from the furrow bottom) the vein has 0.45 m while its width at 0.15 m depth attains 0.36 m. This vein is marked by a gentle downward bend of the top layer of the portion of the inundation deposits that consist of dark silts underlain by medium- and fine grained light sands which pass into the subjacent dark silty-clayey sands. The component layers of the structure as well as those bordering on them show plastic disturbances at their lower level and even a partial intermixture of material at the very tip of the vein. The fine and medium grained sand of the upper layer, as well as of the other layers, is highly loosened at the center of the structure, forming a well defined openwork structure. This fact may be attributable to subsequent processes of suffusion within the furrow. An important detail of the profile is the bending of the bottom part of the inundation deposits at the end of the vein and their gradual up-turn outside the structure.

The natural assumption that the structure in question is frost-caused, must be discarded, for several facts plainly disprove that origin. These are: a complete absence of signs of ground cracking in the zone of the vein (clearly visible in the subjoined Pl. 2), the negligible depth of the structure (frost wedges have at least 1.0 m), and the plastic character of the disturbances.

The origin of the structure may be satisfactorily accounted for by invoking the leading role of diagenetic (convexion) processes. In all likelihood the deposits of the inundation terrace which was repeatedly flooded year after year and subsequently saturated with water, became liable to convexional instability of the ground. Bands of silty sands and the underlying light sands of the upper series, being heavier began to sink into the less compact dusty sand.

Such a slow plastic collapse affords a reasonable explanation of the downward bend of the layers, the disturbances according to the line of contact of the various sediments, the clearly compensatory character of the disturbances involving the deposits at the base of the structure and the quiet course of the boundary between the inundation terrace- and the fluvial deposits below the ground vein. This is a result of downward pressure. The formation of a vein-like depression in the terrace surface is obviously a result of subsidence of the layers. The shape of the structure — collapse by convexion at the borders — corresponds to the ratio of viscosity of the cooperating layers according to the theory of convexional instability, for in the upward segment of the layer it is larger than in the downward one.

Inverted density was largely promoted by the conformity of the upper permafrost limit — which, in the case under discussion, extends during the moister months of the year at a depth of 0.40—0.50 m — with the base of the sedimentary series of the flood facies. Permafrost facilitated a rapid downflow of the meltwaters and by forming a sound impervious horizon kept for a long time the lower parts of the flood-facies sediments (pulverulent sands) in a state of saturation facilitating thereby the development of convexional movements which, however, failed to affect the underlying closely packed pebbles.

The degree of viscosity of the recent inundation sediments which is on the whole rather negligible, becomes still lesser in a condition of oversaturation. In the case in question, the deposits belong to the active zone of permafrost in a polar region, where owing to the defficiency of electroliths in the soil solutions as well as to the general inhibition of chemical weathering and of a number of various processes, grounds show, as well-known, a particular lack of stability. The time of origin of the convexional structures coincided, therefore, with that of the intensive accumulation of alluvials.

Interesting structures were exposed in the terrace sediments, adjoining another polygonal furrow (Pl. 3). Unlike the former ground vein, these forms fail to show any connection with the furrow on the surface of the terrace extending on their right hand side (marked by knife) and exhibiting merely intrasedimentary disturbances within the terrace deposits. The properties of the structure shown in Pl. 3, especially the consistent course of the line of disturbances throughout the contacts of various layers — which is very well-defined in the instance in question — as well as the complete absence of any traces of frost-caused cracking — allow of the assumption that these disturbances are also due to convexion.

The present writer holds that these forms presumably developed in the following manner. Deformations occurred at the boundary between the layer of dark, pulverulent terrace sands (a) and the upper segment of medium- and fine grained fluvial sands with interbedded gravels (b) — on the one hand — and the dark dusty sands (c) passing into dusty fine grained sands (c_1) — on the other. Disturbances in this particular zone did not develop accidentally for both on the right and the left side of the structure these sediments are underlain by a rather thick gravel-and-pebble series (d) while between the structures the gravel layer visibly decreases (d_1).

Subsidence within the structure on its left hand side penetrated deeper downward by involving into the movement the underlying beds: it thus became transformed into a large vein up to 1.5 m in length. But with increasing seepage of material from the adjoining site of subsidence on the right hand side, the upper segment of the structure began to show a well-marked asymmetry. Along its right border, the layers of material entered more deeply, encroaching as it were upon the left border of the vein and thereby contributing to a steepened arrangement of the layers.

Morphologically, the ground vein consists of three different segments (Pl. 4). Its broadest upper part from where the material migrated is funnel-like in shape and arose as a result of the closing up of layers on both sides. These layers were included into the structure in unequal proportions, owing to the variety of the material (the heavier, less compact gravels and pebbles having sunk deepest) and the aforementioned effect of subsidence on the right hand side.

The segment in the middle of the structure (more or less at the level of the dark pulverulent fine-grained sand bed — "e") forms a narrow gorge resulting from a disruption of the gravel and pebble layer whose components intruded earlier than those of the other layers.

In the downward segment of the vein, the material accumulates; in those places where the intruding ground draws in the material of the surrounding layers it is mixed up into "boisterous" oblique and horizontal bedding. Evidence of such "drawing into" of the material is clearly provided by the bordering contours of this segment. One side shows a large quantity of tiny irregular infiltrations and small lenses of intrusions along the vein borders, and on the other — partly isolated patches of horizontally bedded sediments that have sunk deep into the vein. The absence of severe disturbances at the contact of the vein with the adjoining layers is plainly accounted for by that "drawing in" of material from the upper parts of the layers surrounding the structure and by the quality of their grain-size gradation (loose, variously grained sands).

Worthy of note are the discontinuous thread-like striae running from the base of the vein; like the vein itself they exhibit a filling consisting of pure fine- and medium grained sand. Those striae cut not only through the lower part (f) of the sandy silt but penetrate — tapering gradually — the layer of loose medium- and coarse grained sands (g). The intervening distance between them corresponds exactly with the width of the structure itself and the striae mark, as it were, the outlines of the places involved subsequently in the process of deposition. They constitute the initial stage of certain specific wedge-like diagenetic forms which are very common in the loose rocks of periglacial Europe as well as in those of present-day regions of severe climate.

Unlike the vein previously described, the form in question surpasses the average thickness of the active zone of the inundation terrace. It however, fully corresponds with the thickness of the active layer throughout the total area (mean depth of the active zone — 1.8—2.2 m) a fact which shows the prompt response of convexion processes to any local changes within the permafrost.

There are reasons to assume, that the development of the ground vein is still in progress. Two of the other veins have achieved their development, inhibited as it was by unfavourable lithologic conditions.

As concerns the formation of the furrow on the surface of the inundation terrace, it should be noted that this effect was here called forth by subsidence of the terrace sands and silty sands of the upward part owing to intrusion of material from above into the subjacent layers; both these forms belong, however, to the same type of disturbances. Transformation of the subsidence fissure into a steep-sided furrow was activated by suffusion and erosion.

The wedge-like structures in question being connected with a micropolygonal pattern are, therefore, diagenetic (produced by convexion) forms developed within the active zone of permafrost. In loose sediments, veins are formed as a result of lithologic differentiation of the various layers on which the chief properties of the veins, their depth in particular, are dependant.

Under favourable conditions such structures may exactly mark the thickness of the active zone and, therefore, be taken as paleogeographic indicators. Similar forms were studied by the writer in the inundation terrace sediments of other streams in the area in question, as well as in those of the first and the second supra-inundation terraces.

Fairly common as it is, the occurrence of diagenetic processes under such seemingly unfavourable conditions as those provided by the permafrost cemented sea-shore plains of the north-eastern part of the Eurasiatic continent, clearly indicates their widespread and leading significance in the formation of structural peculiarities in any one kind of loose sediments, whatever their composition, age or origin.

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References

Artyushkov, E. V., 1965 — Obrazovanie konvektivnykh deformacij v slabolitificirovannykh osadochnykh porodakh (Development of convexion disturbances in sligtly lithificated deposits). *Izv. Akad. Nauk SSSR, ser. geol.*, no. 12.

Danilova, N. S., 1963 — Pervichno-gruntovye zhily v chetvertichnykh otlozheniyakh r. Viluya (Primary ground-veins in Quaternary deposits of the Viluj river). In: *Merzlye chetvertichnye otlozheniya Yakutii*, Moscow.

Fedorovich, B. A., 1962 — Merzlotnye obrazovaniya v stepyakh i pustynyakh Evrazii (Periglacial phenomena of the Eurasiatic steppes and deserts). *Trudy Kom. po izucheniyu Chetvertichnogo Perioda, Akad. Nauk SSSR*, t. 19.

Katasonov, E. M., 1962 — Kriogennye tekstury, ledyanye i zemlyanye zhily kak geneticheskie priznaki mnogoletnemerzlykh chetvertichnykh otlozhenij (Cryogenic structures, ice- and ground veins as genetic indicators of Quaternary permafrost). In: *Voprosy kriologii pri izuchenii chetvertichnykh otlozhenij*, Moscow.

Katasonova, E. R., 1963 — Sovremennye mnogoletnemerzlye otlozheniya i ikh bolee drevnie analogi v severo-vostochnoj chasti Yano—Vilyujskogo mezhdurechya (Present-day perennially frozen deposits and their ancient analogues in the north-eastern part of the Yana—Vilyuj interfluve). In: *Usloviya i osobennosti razvitiya merzlykh tolshch v Sibiri i na Severo-Vostoke*, Moscow.

Kindle, E. M., 1917 — Deformation of unconsolidated beds in Nova Scotia and southern Ontario. *Bull. Geol. Soc. America*, vol. 28.

Kostyaev, A. G., 1965 — O priznakakh razlichiya merzlotnykh i konvektivnykh (diageneticheskikh) struktur v chetvertichnykh otlozheniyakh (On the possibility of identification of frost-caused and convectional (diagenetic) structures in Quaternary deposits). In: *Podzemnyj led*, vyp. 2; Moscow.

Kostyaev, A. G., 1966 — O nekotorykh obshchikh voprosakh razvitiya konvektivnykh struktur v chetvertichnykh otlozheniyakh (On some general problems of the development of convectional structures in Quaternary deposits). In: *Geologiya kajnozoya severa evropejskoj chasti SSSR*, Moscow.

Lavrushin, Yu. A., 1961 — Tipy chetvertichnogo alluviya nizhnego Yeniseya (The types of Quaternary alluvial sediments of the lower Yenisey). *Trudy Geol. Inst. Akad. Nauk SSSR*, vyp. 47; Moscow.

Lazarenko, A. A., 1964 — Litologiya alluviya ravninnykh rek gumidnoj zony (na primere Dnepra, Desny i Oki) (The lithology of alluvial sediments of the lowland rivers of the humid zone — as exemplified by the Dneper, the Desna and the Oka). *Trudy Geol. Inst. Akad. Nauk SSSR*, vyp. 120; Moscow.

McKee, E., 1939 — Some types of bedding in the Colorado river delta. *Jour. Geol.*, vol. 47.

Popov, A. I., 1962 — O psevdomerzlotnykh obrazovaniyakh (On pseudoperiglacial phenomena). *Vestnik Moskovskogo Univ., ser. geog.*, no. 3.

Stewart, H. B., 1956 — Contorted sediments in modern coastal lagoon explained by laboratory experiments. *Bull. Am. Ass. Petrol. Geol.*, vol. 40.

Svensson, H., 1962a — Ice-wedge in fossil tundra polygons on the Varanger peninsula. *Svensk. Geog. Arsb.*, årg. 38.

Svensson, H., 1962b — Note on a type of patterned ground on the Varanger peninsula, Norway. *Geografiska Annaler*, vol. 44.

Thorarinsson, S., 1964 — Additional notes on patterned ground in Iceland with a particular reference to ice-wedge polygons. *Biuletyn Peryglacjalny*, no. 14.

Vinogradov, B. V., 1959 — Poligonalnaya kompleksnost pochv i rastitelnosti v landshaftakh sukhoj stepi Severnogo Kazakhstana (Interrelations between patterned grounds and vegetation in the dry steppe of Northern Kazakhstan). *Izv. Akad. Nauk SSSR, ser. geog.*, no. 1.