*I. D. Danilov**
Moscow

SUBAQUEOUS PSEUDOMORPHOSES IN PLEISTOCENE DEPOSITS

Wedge-shaped rock saggings occur at various depths in the series of the Pleistocene alluvial, shallow lacustrine and coastal marine deposits. They constitute one or several stages down the section of the deposits, the structure of the saggings being frequently multistaged, too.

The development of wedge-shaped saggings is generally attributed to the melting-out of ice veins under subaerial conditions, and to the filling of the hollow spaces formed thereby with a mineral or a peat substratum (pseudomorphosis). Some authors explain the formation of pseudomorphoses by ice vein thawing under conditions of a reccurrently flooded second plain (Kaplina, Romanovsky, 1960), or at the bottom of floodplain thermokarst lakes (Lavrušin, 1960).

The presence of several stages of buried pseudomorphoses is commonly assumed to be a result of interruptions in the accumulation of sediments, during which occurred freezing-up of the deposits, development of ice veins, their subsequent melting-out and filling with ground. As a rule, the improving climatic conditions of a general or a local nature are recognized to be the cause of vein ice melting and thawing of the deposits enclosing. On the basis of the presence of buried wedge–shaped pseudomorphosis saggings in the melted-out ice veins, conclusions are drawn as to the climatic fluctuations in the Pleistocene, that are compared with those of the glacial and interglacial epochs, and attempts are made to detect a rhythm in the recent tectonic movements.

A genetic facies analysis of the deposits enclosing pseudomorphoses shows that in most cases they were formed without any interruptions in sedimentation, and are genetically unified rock series of the same age. Material of a subaerial origin (peat, soil formations) is often absent in the pseudomorphoses and is neither found in the pseudomorphosis tops. The spore

* Department of Cryolithology and Glaciology, Faculty of Geography, University of Moscow.

and pollen spectra of the deposits surrounding and overlapping the pseudomorphoses do not reveal any noticeable changes in the landscape conditions that might provide indication of considerable variations of the climate. The above mentioned facts gave A. G. Kostyaev (1965) reason to deny any relation of the majority of wedge-like deformations in sedimentary rock to the melting-out of ice in polygonal-veins.

Studies of the Pleistocene deposits in the north of Western Siberia and in the Pečora lowland have shown that the formation of wedge-shaped sagging in the stratified alluvial and shallow basin deposits was preconditioned by the melting-out of polygonal vein ice, but took place during the process of sedimentogenesis, i.e., was not related to interruptions in sedimentation or to changes of the paleoclimatic conditions.

Wedge-shaped saggings are found in the frozen alluvial bedded sand, with ice veins situated along their continuations (Pl. 1). The sagging presented in Pl. 1 has a typical wedge shape with a widened, funnelled upper part (0.6 to 0.8 m in cross-section) and a narrow, elongated lower part (0.1 to 0.2 m in width). The intensively deformed layers of the enclosing rock are drawn into the widened part of the saggings from the side walls. The alluvium strata near the contact with the wedge in its upper part rise steeply upwards and then run abruptly downwards being drawn into the sagging's body. The enclosing layers are not deformed at the contacts with the lower narrow part of the wedge. The wedge-shaped sagging is 3.5 m long, and the ice vein located along its continuation is 0.1 m or 0.2 m in width and about 2.0 m in extent. The vein consists of a number of small, normally oriented elementary ice veinlets.

Thus, a direct relation of the wedge-shaped sagging buried in the alluvial deposits to the melting-out of vein ice is ascertained, and affords reasons to regard the sagging as a pseudomorphosis.

The alluvial deposits of the river terrace with pseudomorphoses are in a frozen state; high content of ice is characteristic of them, especially in the lower and middle parts of the section (up to 60% or 80%). At some distance from the pseudomorphosis under consideration, the alluvial sand is pierced through by a system of vertical ice veins from the base of the active layer whose thickness does not exceed 1.0 m down to a depth of 6 to 8 m from the surface. The position in the section and the dimensions of the ice veins correspond to the bedding conditions and to the dimensions of the pseudomorphosis, including the ice vein situated at its continuation. This is still another evidence of the relation existing between the development of wedge--shaped saggings and the melting-out of polygonal-vein ice.

The joint presence in one section of pseudomorphoses and ice veins, similar in dimensions and bedding conditions, indicates that the melting-out of ice veins was preconditioned by local causes, rather than by general climatic ones. In all probability, the processes of selective thermokarst were the causes predetermining the improvement of the geothermal ground regime at local sites. The ice-content of the deposits surrounding the pseudomorphoses is much lower (10 to 20%) than that around the ice veins (60 to 80%). If the formation of pseudomorphoses were brought about by the improving climatic conditions of a general or a local nature, then the entire system of polygonal-veined ice would have thawed out, as would have the icy rock series of a corresponding thickness.

Pseudomorphoses, just like ice veins, are in a buried condition. They dissect the horizontally and obliquely stratified sand of the channel facies and the first floodplain facies of alluvium, and are overlain by indistinctly stratified loamy deposits of the second bottom. The floodplain loam does not intrude into the pseudomorphosis body, its base only slightly subsides over it, forming a trough-like synclinal fold that flattens out up the section. Hence the pseudomorphosis originated in the course of alluvial sedimentation, prior to or at the very beginning of the floodplain loam formation.

The buried pseudomorphoses are situated at different depths in the series of alluvial deposits, which allows of some general speculations on the conditions of formation of pseudomorphoses. Rather significant are, despite their small dimensions, the buried ice vein and the pseudomorphosis lying directly above it in the stratified alluvial sand (Fig. 1). The thin ice vein 0.1 m wide and 2.0 m long dissects the obliquely and undulatedly bedded fine-grained sand. The sagging above the ice vein is composed of fine-grained sand of the interlayer situated directly above. Medium-grained obliquely stratified sand lying above the pseudomorphosis dissects the rock seams containing the sagging and the ice vein. The fine-and medium-grained sand with different stratification forms a unified series of channel and low-floodplain alluvial deposits constituting the lower part of the river terrace section.

The vein ice appeared in the course of alluvial sedimentation which was accompanied by simultaneous freezing-up at the stage of the scroll meander ot the low floodplain. As a result of the shifting of the meandering river channel, the sediments deposited earlier and frozen were partly washed out. Together with them, the upper part of the ice vein was washed out too. The rock below the wash-out contact thawed down to an insignificant depth owing to which a small sagging originated. The thawing-out of the rock was of limited extension, since the outwash of the previously accumulated sediments took place, most likely, during the spring flooding, when the temperature of the water in the river was low, and the denuded sediments were quickly buried under the new ones.

As it is known, a river channel shifts repeatedly in the process of alluvial

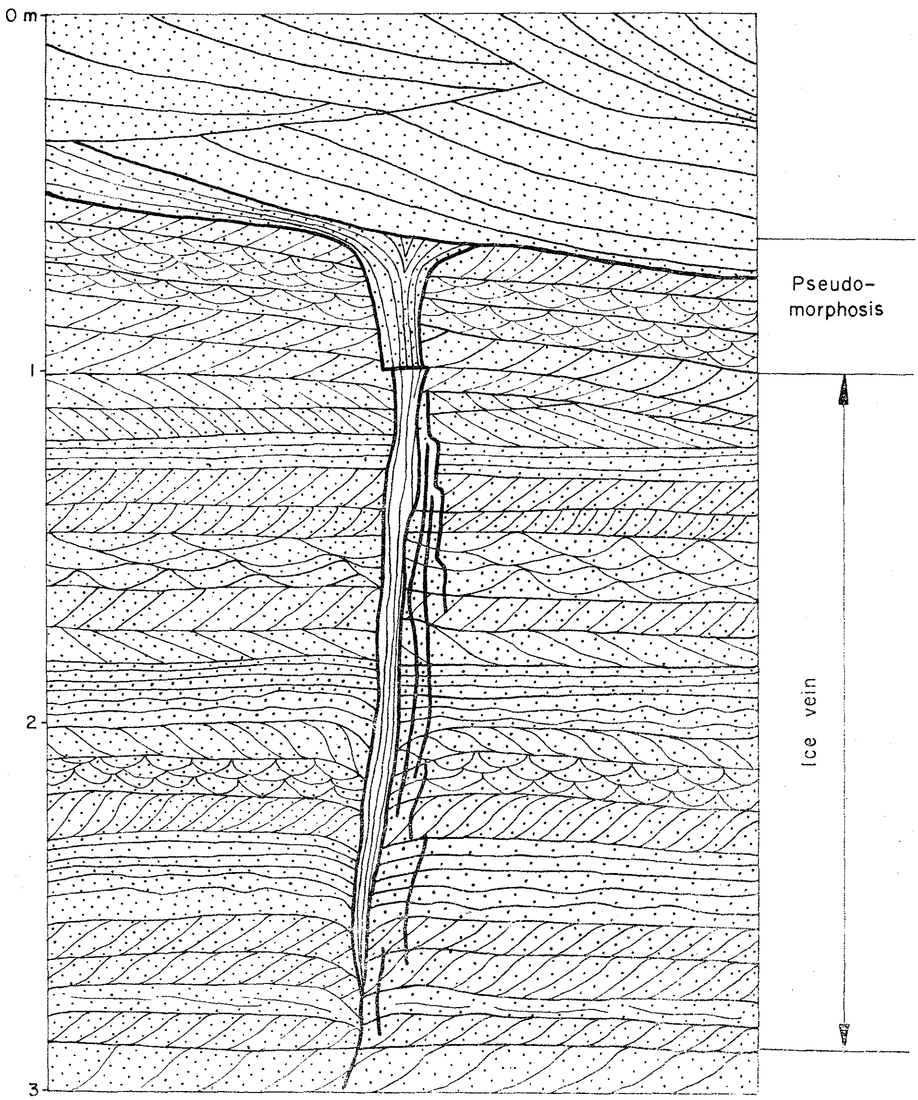

Fig. 1. Ice vein with a pseudomorphosis above, buried in stratified alluvial sand

sedimentation. Under conditions of a tectonic downwarping of the area, made up for by alluvial sedimentation, pseudomorphoses can be located at various depths in the series of alluvial deposits. The dimensions of buried pseudomorphoses are determined by the depth of the outwash of previously accumulated sediments. In the channel facies whose accumulation was accompanied by the most intensive outwash of the previous series of sediments, small narrow pseudomorphoses (Pl. 2) are formed along the lower, thin portions of the ice veins that survived the outwash.

During the terminal periods of alluvial sedimentation, outwash of the earlier accumulated sediments occurs rarely and feebly at the stages of the first and second floodplains. Owing to this, large pseudomorphoses commensurable with the dimensions of the primary ice veins develop in the floodplain facies of alluvium in the upper parts of the alluvial sites.

In connection with the above mentioned views, it is important to note that ice veins are present in the recent alluvial sand of the low floodplains, shoals and islands in the river channels on the Gydan peninsula and in the Taimyr lowland. The existent ice veins whose growth is still developing reach 0.5 m to 1.0 m in width and 2 m to 3 m in vertical length.

Thus the formation of pseudomorphoses takes place in the course of continuous alluvial sedimentation under rigorous climatic conditions and with permafrost presence. It is an integral part of the alluvial cryolithogenesis.

A similar process of pseudomorphosis formation can be found in the shallow coastal basin sediments (wadden, laida, estuary, and lacustrine sediments), if their accumulation is accompanied by freezing. With the increase of basin depth, the previously frozen sediments thaw out and pseudomorphoses develop along the ice veins. A recurrent, rhythmic change in the basin depth, insignificant as it might be, preconditions the origin of several stages of buried pseudomorphoses, or a multistage structure of the latter.

An increase in basin depth under conditions of cold polar climate and low temperature of the bottom water does not always bring about the melting-out of the ice veins which persist in a buried state. This permits to observe the buried ice veins, and to venture certain conjectures concerning the mode of formation of pseudomorphoses. A system of buried ice veins in the Pleistocene coastal marine sediments of wadden origin has been studied in the Lower Yenisey area (Pl. 3). The ice veins lie in rhythmically stratified silty sandy loam with aggraded peat interlayers which are overlain by the deeper-water rock of aleurite clayey composition. The vertical extent of the ice veins ranges 4 m to 5 m, with a width of 1.2 m. Apparently, the pseudomorphoses would have been of similar dimensions if the melting-out of the ice veins had occurred. Sandy loam with peat interlayers passes gradually into the overlying deep-water aleurite clayey sediments without any traces of interruptions in sedimentation. Both the layers constitute a single continuous series of sediments. If, with increasing depth of the basin, the ice veins had melted out and pseudomorphoses had developed in them, they would have lain in a unified, uninterrupted series of sedimentation. At the same time, it might be assumed that in most cases not ice veins do pass into a buried state with increasing depth of the basin, but rather pseudomorphoses along them.

Pseudomorphoses are present in rhythmically bedded lagoon estuarine shallow deposits commonly occurring in the north of Western Siberia. The deposits contain a complex of fresh-water and brackish-water diatoms, as well as isolated Foraminifera, which is an indication of sediment accumulation on the bottom of a freshenned, or recurrently salinized, basin.

Apart from pseudomorphoses of a usual shape, wedge-like bodies of a peculiar torch-like form (Pl. 4) occur in the rhythmically bedded brackish--water deposits. The enclosing rock layers sort of creep down into the wedge--like sagging only from one side. On the opposite side, the rocks represented by horizontal interbedding of fine-grained sand and aleurite maintain their regular, primary sedimental stratification. The development of pseudomorphoses of such shape in a unified continuous series of sediments could take place only under subaqueous conditions.

The rock layers enclosing the pseudomorphoses were accumulated in a shoaling reservoir. At the stage of recurrently drained shallow water, freezing-through of the deposits started with formation of polygonal-vein ice. The subsequent increase of the basin depth, insignificant as it was, resulted in the ice veins melting out and the bottom moisture-saturated sediments sliding down into the cavity formed in conformity with the stratification gradient. It is possible that the melting-out of ice took place during the initial events. The torch-like shape of the pseudomorphoses and the absence of a break in the accumulation of the rhythmic, horizontally stratified deposits that enclose and overlie the pseudomorphoses cannot be explained by any other reason but that of having been under conditions of a basin bottom.

The types of pseudomorphoses considered above, whose formation took place under subaqueous conditions on basin bottoms in the course of continuous sedimentation, are widerspread in the Pleistocene deposits of the plains in northern Eurasia. They are an indication of the rigorous climatic conditions in the period of deposit formation and of the simultaneity of sedimentation and congelation. The process of formation of subaqueous pseudomorphoses can be regarded as a characteristic process of lithogenesis of the shallow basin and alluvial deposits in the zone of occurrence of perennially frozen rock, i.e., as a peculiar process of cryolithogenesis.

Thus the fact of the presence of pseudomorphoses in deposits of aqueous origin affords evidence of the former frozen state of the rocks. But the origin of subaqueous pseudomorphoses is not associated with any improvement of the climatic conditions and with a degradation of permafrost either partial or complete.

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