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THE SCHEME OF CORRELATION OF POLYGONAL WEDGE STRUCTURES

Polygonal wedge structures resulting from frost fissuring represent various forms of ground wedges, ice-wedges, ice-wedge casts and series of forms that have no definite terms. They are of great importance for Quaternary geology of periglacial regions, paleogeography and stratigraphy. Enormous literature is devoted to the description and interpretation of different categories of these structures. The variety of polygonal wedge structures, their relation to deposits different in composition and facies, their formation under different frost-thermal conditions — all these need good systematics based on the genetic background. Such systematics is necessary for further investigations and to define wedge structures precisely for tasks of paleogeography and Quaternary geology. We should emphasize that prof. JAN DYLIK has devoted much attention to the problem of nature and systematics of polygonal wedge structures. The present writer's paper on polygonal wedge structures published in *Biuletyn Peryglacjalny* (ROMANOVSKIJ, 1973) had been carried out after having it consulted with this scientist.

It is well known, that polygonal wedge structures both recent (active) and fossil (inactive) have a lot of variety of form and size, have different texture of wedge bodies, and are developed in soils of various genesis and texture. Therefore their systematics should be based on the development conditions, i.e. on the character of frost-fissure infilling, the position of fissures (wedge structures) in relation to seasonally freezing, seasonally thawing and permafrost horizons; besides, the transformation of internal substance in fissures and wedge structures due to seasonal and perennial thaw should be taken into consideration. Such a method of approach allows to determine the features that are typical of different categories of polygonal wedge structures, resulting from frost fissures, to determine signs of every group, and what is of most importance, to determine the natural conditions necessary for their development.

In this paper merely the basic scheme of systematics of polygonal wedge-structures is considered. All polygonal wedge structures may be subdivided into two large groups: of primary and secondary origin. The primary structures develop as a result of repeated processes, icluding formation of frost-fissures, their filling with ice or mineral matter and further alternation of the infilling substance. The

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secondary structures develop in the result of thawing of primary structures and of enclosed frozen ground.

In the formation of primary structures there are two main types of infilling: (1) infilling with water that freezes in fissures and transforms into congelation ice producing elementary ice veins, and (2) infilling with aeolian sand and fine gravel.

Water, filling the frost-fissures, can contain different quantity of mineral and organic admixture. Sublimation ice can be accumulated in the open frost-fissures. The fissure can be partly filled with mineral particles collapsing from the walls. All these sources of infilling material, however, play a secondary role as associated processes in fissure infilling by congelation ice or dry sand.

When frost-fissure, filled with congelation ice, is present in seasonally thawing layer (STL) or seasonally freezing layer (SFL), an elementary ice vein thaws in summer and as a result open fissure occurs and adjacent mineral soil fills the void. This repeating process leads to the formation of primordial wedges or ground part of wedge structures, occurring above ice wedge in STL (ROMANOVSKIJ, BOYARSKIJ, 1966; ROMANOVSKIJ, 1972, 1973). The formation of primary ground wedges is associated with washing in of aleurites and humus particles, sometimes with deformation of ground layers and with upheaving of stones in the result of seasonal freeze.

Frost-fissures, penetrating below STL into permafrost, being infilled by repeated processes are transformed into ice wedges (secondary vein ice).

Multiple infilling of frost-fissures with dry sand and fine gravel leads to the formation of sand wedges (original sand wedges of PÉWÉ, 1959).

Filling of fissures with water transforming into congelation ice takes place under conditions of excessive or high moistening of surface ground, when in spring, even for a short time, meltwater of floods overflows the surface. This occurs widely in the taiga zone, in Subarctica and Arctica. The climate as a whole can be different — from excessively wet to arid, continental. Fissure filling with dry aeolian sand results from limited surface moistening, activity of aeolian processes and sources of gravel-pebble materials. Such type of infilling and origin of sand wedges always occur in regions of dry continental climate. Temporal changes in the degree of ground moisture provoke differentiation in fissure infilling: once the fissure may be filled either with aeolian pure sand, sometimes with intrusions of sublimation ice, or with congelation ice only. As a result sand-ice wedges are being formed in permafrost (they are known in American literature as "composite wedges"), while in STL and SFL sand wedges develop with characteristic downward bending of layers in adjacent deposits which is an evidence of repeated collapse of the material into the void after elementary ice veins.

Sand-ice and ice-sand infillings of frost-fissures have a transitional character between ice and sand types and are characteristic of dry continental climate with periodical changing of ground moisture. In Antarctica there are continuous series from original sand wedges through sand-ice wedges to ice wedges, which reflect the change in surface moistening and soil moisture in STL, and hence — the freezing-facial condition of frost-fissure infilling (BERG, BLACK, 1966).

It is not excluded that, in the regions where intensive aeolian processes are absent (especially blasting of sand) and climate is arid enough with thin snow cover disappearing by evaporation, the frost-fissures are filled with sublimation ice in spring. Under such conditions formation of congelation ice is either absent or occurs only in some years. Polygonal wedge-structures originating due to filling of fissures with sublimation ice are insufficiently known for their limited spread and for their similarity in shape to the structures which were formed due to infilling with congelation ice when number of crack cycles was rather small.

Thus, the character of fissure infilling is controlled by ground surface moisture, i.e. the moisture control is of great importance for the formation of different categories of polygonal wedge-structures. The surface moistening influences not only the peculiarities of fissure infilling but also the soil moisture in STL and SFL.

In rough estimation we can consider that infilling of fissures with water takes place when the types of seasonal thawing and freezing according to soil moisture (according to classification of V. A. KUDRYAVCEV, *in*: DOSTOVALOV, KUDRYAVCEV, 1967) are regarded as low and average. In the first case the soil moisture in STL (w) exceeds 2/3 ($w_f - w_n$), and in the second — it varies from 2/3 ($w_f - w_f$) to 1/3 ($w_f - w_n$), where w_f is the moisture equal to the full soil moisture capacity, w_n is the non-frozen moisture.

Infilling of fissures with sand takes place if seasonal thawing is of a high type, i.e. $w = <1/3$ ($w_f - w_n$). The formation of sand-ice wedges is accompanied (from our view-point) by the change in soil moisture in STL (SFL) and by transition of seasonal thawing (freezing) types according to moisture from high to low and *vice versa*. However, the problem of changes of soil moisture in STL during sand-ice infilling of fissures needs further investigations. It has already been shown that the peculiarities of frost-fissure development are defined by thermal conditions in permafrost (ROMANOVSKIJ, 1970; 1972; 1973). According to the present writer's opinion, it is obvious that the position of frost fissures (filled with such or other material), occurring in STL and SFL and in permafrost as well as under similar facial conditions, changes according to lowering of rock temperature at the base of its oscillation that depends on permafrost (geocryogenic) zonation. When t_{an} is near 0°C frost-fissures are situated in STL and SFL; and when t_{an} is below 0°C they begin to penetrate into permafrost. Further, with lowering t_{an} and reduced thickness of STL a greater part of fissure is in permafrost, while the minor part in thawed layer. We should point out that the frost fissures penetrating from seasonally thawed layer into permafrost occur in the deposits of different composition and moisture (ice content), i.e. in Quaternary deposits of various facies which freeze at different t_{an}. But the general regularity always remains. This produces the polygonal-wedge structures arranged in zonal (frost-thermal) complexes. If frost fissures are filled with congelation ice a zonal complex of primordial soil wedges — ice wedges — develops. This complex is videly developed in Europe and Asia and in North America in grounds of different composition and ice-content but until now it is insufficiently investigated. An attempt at generalization of the available material is shown in a scheme (fig. 1) which gives the peculiarities of transition of primordial soil wedges into ice wedges, depending on t_{an} for the ground of different composition and moisture (ice-content) in STL. The scheme is elaborated only for structures occurring under continental, moderate and high continental conditions of seasonal thawing (V. A. KUDRYAVCEV).

Zonal (frost-thermal) complexes are represented by polygonal wedge-structures, developed due to primary infilling and secondary fissure infilling of sand-and-ice. However, these complexes as yet are insufficiently known. Primordial sand and sand-ice wedges, occurring in Antarctica, under very rigorous permafrost conditions

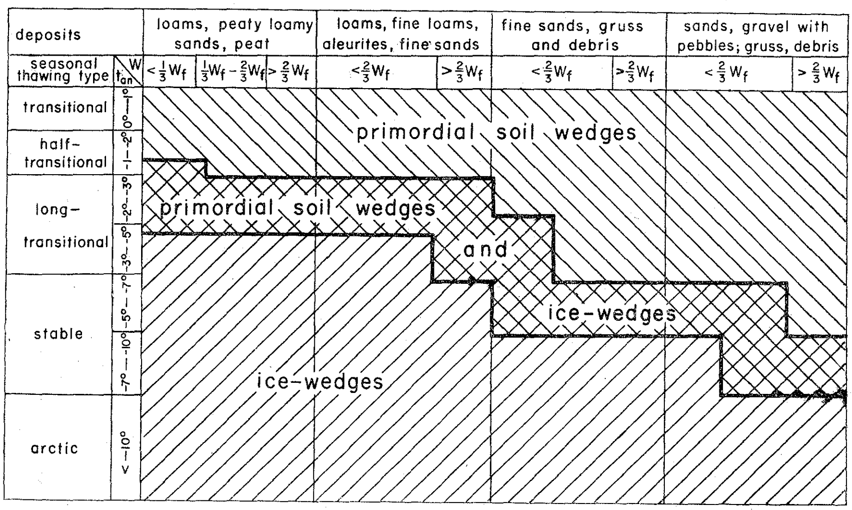

Fig. 1. The scheme of correlation between primordial soil wedges and ice wedges in the deposits of different texture and moisture in STL depending on soil t_{an}

The scheme is made for continental and high-continental types of STL (by V. A. KUDRYAVCEV); w_f — full moisture minus unfrozen' water

do not occur as zonal complexes. In eastern Siberia where the climate in general is dry and continental, the terrains of limited ground moisture occur but only sporadically. They are restricted mainly to sandy areas of different origin: to fluvioglacial sands of Northern Transbaikal, to aeolian forms (tukulans) on the alluvial sediments of river terraces of Central Yakutia, to alluvial sands of the Lena delta and marine sands of the Bunge Land. Wedge structures are well studied only in the tukulan forms (KATASONOVA, 1963; 1972). According to the present writer's opinion this type of wedges is connected with wide range of temperature oscillations, and were formed when sand-ice filled frost-fissures. Likewise, the analysis of fossil sand wedges characteristic of the periglacial Würmian zone of Europe confirms that the development of primary sand-wedges and sand-ice wedges was rather considerable, and that these structures show zonal (frost-thermal) distribution. These facts indicate that the investigations of zonal and facial peculiarities of such wedges are of great paleo-permafrost significance.

Thus on the one hand the character of infilling of frost-fissures depends on the moistening conditions of ground, i.e. there is a "moistening control" on the fissure infilling and on development of wedge structures. On the other hand, the position of frost fissures in relation to STL (SFL) and to permafrost is controlled by thermal regime in ground in the zone of annual oscillations of temperatures and, above all, of t_{an}.

The scheme of correlation of polygonal wedge-structures made by the present writer is based on the "moistening" and "temperature" control on the development and infilling material. In the scheme the wedges are subdivided into the primary structures, and the secondary structures developed due to thawing of the first type forms containing ground ice. Among the primary structures there are not distinguished zonal complexes of polygonal wedge-structures the fissures of which were filled with ice as a result of sublimation; these structures are not investigated well enough, their distribution is limited, and they are similar in the appearance to fissures filled with congelation ice. By their position they should be placed between zonal complex of wedges with water (congelation ice) and ice-sand infilling of frost-fissures.

The secondary types of polygonal wedge-structures contain ice-wedge casts, the distinctive signs of which have already been described in many papers (Kaplina, Romanovskij, 1960; Romanovskij, 1972; 1973), and sand-ice wedge casts or composite wedge casts. The latter have transitional character between ice-wedge casts and original sand wedges developing in deposits of low ice-content and with unchanged primary features while thawing. The degree of changes of sand-ice wedges while thawing depends on the ice content: if the ice content of enclosed sediments and in wedges is low, the wedges lose only the texture peculiarities. If the ice-content is high the structures show characteristics of ice-wedge casts and have additional features — intrusions of aeolian sand.

It should be noted that the original sand-wedges and sand-ice wedges with low ice-content underwent considerable changes while thawing but this is not taken into consideration in the scheme. The changes result from subsidence of the latter forms, from solifluction and other processes evolved during permafrost degradation. In some sections of periglacial rhythmically bedded slope deposits that the present writer has investigated in Poland, original sand wedge casts (or composite wedge casts) occur as bi-partial forms. The upper part of wedges is dislocated down the slope (often fossil slope) at a distance of some cm to 1—1.5 m. Numerous fossil original sand wedges and sand-ice wedges and ice wedge casts, contorted and removed are known, evidently, as a result of enclosed soil shifts while thawing (Black, 1964; 1965; Goździk, 1973, etc.). Many of them occur together with various miniature forms of convection nature (Goździk, 1973).According to the present writer's interpretation they appear while the upper, heavily saturated with ice, permafrost horizons thaw. After the opinion of F. A. Kaplyanskaya and V. D. Tarnogradskij (1974) such disturbances represent cryoturbations originating mainly due to heaving and shifting processes during thawing of STL.

In the suggested "scheme of correlation" the place and taxonomy of the known categories of wedge structures are defined in a new aspect. As it is evidenced the wide distributed in Europe and Asia and well investigated primordial soil wedges

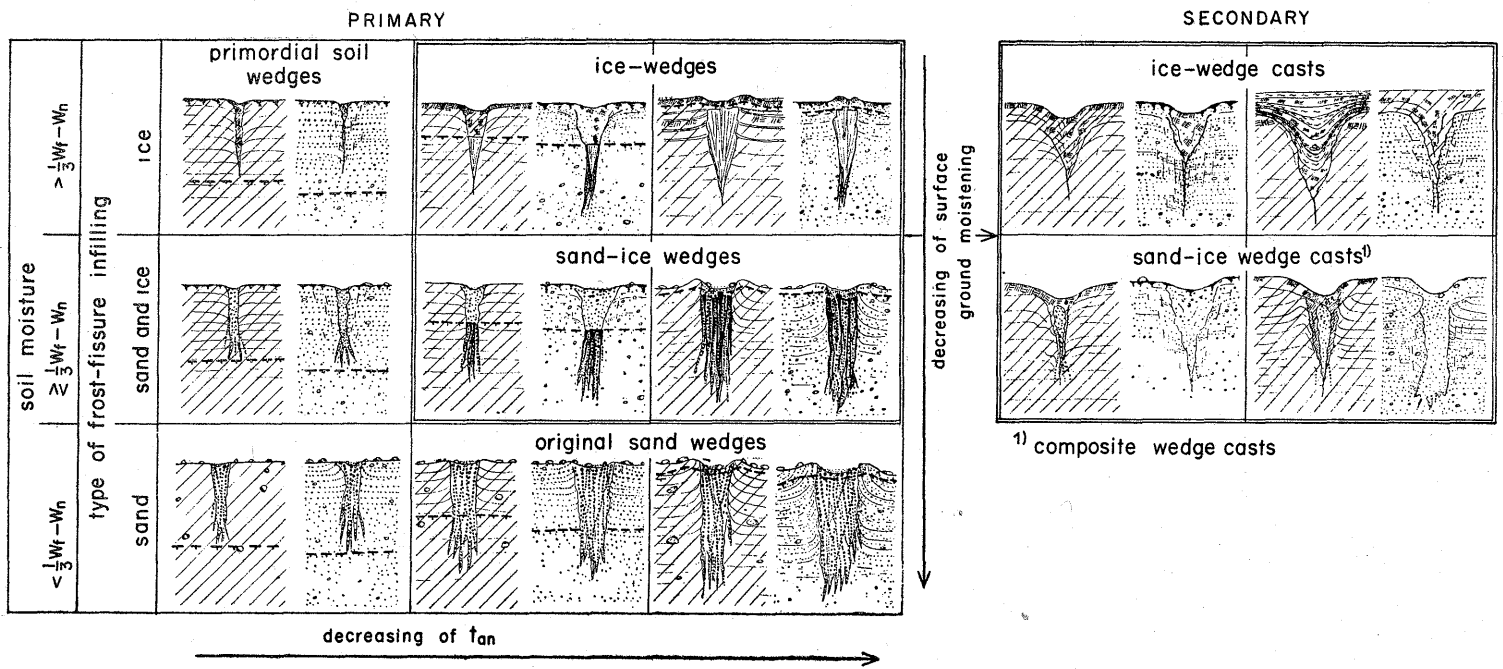

Fig. 2. The basic scheme of correlation of polygonal wedge-structures

cannot be united with original sand wedges in one group. The latter occur in zonal (frost-thermal) complex and develop by "dry sedimentation" of sand in frost-fissures. Primordial soil wedges present high-temperature forms of frost-regime complex of structures and develop by infilling of frost-fissures with water (congelation ice). The isomorphism phenomenon is widely developed within the polygonal wedge structures belonging to various categories. Some structures, belonging to different types, have a very similar form and size and show similar characteristics. Mostly they may be referred to the under-developed structures formed in a short period. For example, primordial soil wedges, "high temperature" variety of original sand ice wedges and small wedge casts developed in sands, may have a similar appearance. At the contact the adjacent sand layers are bent downwards and there may occur some debris accumulations, subsidence of the material, etc. These structures are usually united into the wedge group called by E. M. KATASONOV (1962; 1973) "sag" veins. However, both the character of infilling and the frost-regime conditions during the formation of wedge structures, regarded as "sag" veins, may be defferent. They are also of palaeo-permafrost significance. The same may be said of similar forms, called by E. M. KATASONOV "wedges of infilling". These wedges and small ice-soil wedges developed in sands are very similar to each other in appearance, and present initial stage of development. Such an isomorphism of wedge structures is a result of similar processes operating during their development. Further investigations should be undertaken to subdivide these structures due to their (mineralogical, geochemical, structural, etc.) characteristics.

The suggested systematics of the polygonal wedge-structures can be used in subdivision of epigenetic structures, developed after sedimentation of enclosed deposits, as well as of syngenetic structures originated contemporaneously with sedimentation. The latter forms undergo some influences which affect their characteristics, their forms, and their length, in comparison with epigenetic structures and therefore they are indicators of their origin contemporaneously with the sedimentation of the adjacent deposits.

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