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WEDGE- AND FOLD-LIKE DIAGENETIC DISTURBANCES IN QUATERNARY SEDIMENTS AND THEIR PALEOGEOGRAPHIC SIGNIFICANCE

The problem concerning the origin of wedge- and fold-like disturbances in Quaternary sediments has from the very beginning been intimately associated with that of the periglacial environmental zone in the foreland of the European glaciers. The recognition of certain phenomena as characteristic of this zone and the introduction of the term *periglacial* have exercised a decisive influence upon the formation and the development of the concept of a geologic and paleogeographic periglacial zone.

The views on the origin of fold-like disturbances evolved under the influence of controversies between two alternative hypoheses concerning the origin of structural soils to which these disturbances were originally attributed. Those hypotheses were: (1) that of thermal convexion (*Brodel-Böden*) advocated by Gripp (1926) and (2) that of frost-heaving advanced by Bahr (1932), *et al.* In the middle 30th, under the influence of Mortensen's (1932) and Steche's (1933) criticism of Gripp's theory, a large number of investigators passed over to the camp of the partisans of the frost-heaving hypothesis. The terms *cryoturbation* and *cryoturbate sediments* (Edelman, Florschütz, Jeswiet, 1936) settled the triumph of this conception. In those years, Dewers (1934) alone set forth the idea that certain fold-like deformations (ground-pockets) may have been produced by gravity and convexion.

A particular importance, for a correct definition of the paleogeographic nature of the conditions prevailing in the periglacial zone, was attributed to ice-wedges. The exclusively frost-caused character of wedges was advocated — following Kessler — by Soergel (1936), Selzer (1936), Gallwitz (1937) *et al.*, i.e. practically all the investigators of Quaternary sediments. The Soviet workers (Popov, Danilova) recognized a new type of structures, namely the so-called „wedges with primary mineral infilling". Such views are necessarily connected with the idea of very severe climatic conditions and wide-spread permafrost in periglacial Europe. This view gained wide acceptance (objections were raised only by A. Penck). The attempt towards critical approach to the problem of wedges undertaken by Gusev (1958) failed to achieve any tangible results.

That interpretation was chiefly inspired by the three following reasons: (1) the likelihood of a considerable fall of temperature in the Pleistocene, throughout vast areas bordering from the South on the ice sheets, (2) the striking similarity of ice-wedges to present-day ice- and ground-veins, (3) the impossibility to take any well-defined position in face of the still unsatisfactory explanation of certain problems of ground knowledge which can alone afford a basis for well-documented conclusions. The scarcity of data concerning present-day processes in cold climate- and permafrost areas as well as the lack of examples of „ice-wedges" and „cryoturbation" were also largely responsible for these misconceptions. Such forms were generally identified much later and moreover in areas which to-day are neither subjected to permafrost nor to cold climate; these forms were mostly studied in pre-Quaternary sediments.

In pre-Quaternary formations (from pre-Cambrian to Tertiary) wedge-like structures are rather common. They are usually referred to as „clastic (neptunistic) dikes", sometimes also as injections of one rock into others. Both the surrounding and the component material of these structures may be widely heterogeneous, ranging from limestones to pebbles. The materials vary also in size. In the present paper, small forms alone will be discussed i.e. such as are comparable with those occurring in Quaternary sediments and have been called forth by desiccation, subsidence and interpenetration of rocks.

Wedge-like dikes in compact formations have been described by various writers (Petrascheck, 1935; Eardley, 1938; Colacichi, 1939; Price, Lucke, 1942; Bronguleev, 1947; Schwarzbach, 1950; Shrok, 1950). Wedge-like forms resulting from intrusion of overlying rocks into underlying ones, which are practically indiscernible from typical „ice-wedges" developed in Quaternary sediments, were likewise discussed in a number of works (Keilhack, 1931; Lotze, 1932; Smith, Rast, 1958; Pavlov, 1946; Popov, 1962; von Bülow, 1964).

In pre-Quaternary sediments, the number of folded or ball-like deformations of the „involution" or „cryoturbate" type is indeed overwhelming. They are usually referred to as convectional laminations (or convolutions) and disturbances caused by sub-aqueous downcreep. Convolutions are particularly common in flysch (Richter, 1952; Vassoevich, 1953; Kuenen, 1953; Kopstein, 1954; Ten Haaf, 1956; Wood, Smith, 1958). Nonetheless, convolutions may occur as well in rocks of another lithologic compositions — from coarse sands and gravels to clays — and widely differing in age — from pre-Cambrian to Pleistocene (Beets, 1946; Shrok, 1950; Konyukhov, 1951; Belostockij, 1955; Dott, Howard, 1962; Einsele, 1963; von Bülow, 1964).

Wedge-like and folded structures, similar to those encountered today, are also found in the Quaternary sediments of many southern regions: the South of France and other Mediterrenian areas such as Morocco, Greece, Cyprus, Galilea (Tricart, 1956; Johnsson, 1960; Markov, 1961; de Vaumas, 1964), the western Black Sea coast (Morariu, Savu, 1964), the Near East — Antiliban, the Sinai peninsula (Kaiser, 1960; de Vaumas, 1964), the desert and semi-desert areas of Asia Minor, Central Asia and North America (Dobrovolskij, 1961; Fedorovich, 1962; Knechtel, 1952), the subtropical coastal parts of China (Yan Huan-jen, Yan Sen-youan, 1957). Such deformations are also common under present-day conditions also: in inundational terraces, river deltas, in southern regions (Mc Kee, 1939; Vinogradov, 1959; Kostyaev, 1964, 1965; Lazarenko, 1964), in proluvial submountain planins (e.g. in Turkmenia — Vinogradov, 1955), in lagoons and liman coasts, also in the Mexican Pacific coast (Kindle, 1917; Steward, 1956; Doskach, 1962; Einsele, 1963), in lake- and see bottoms (Gorsline, Emery, 1959; Shepard, Einsele, 1962; Maev, 1961, 1964).

1961 marked a decisive turning point in the current views concerning those formations. The works of A. I. Popov (1962, *et al.*) and A. G. Kostyaev (1962, *et al.*) have shown the vast spread of diagenetic polygonal wedge- and fold-like deformations in various Quaternary sediments, periglacial ones too. At the same time E. V. Artyushkov (1963, *et al.*) elaborated on a physical basis a theory concerning the formation of polygonal structures, which he called „theory of convectional instability". During the following years, a new system of concepts was almost fully worked out concerning all the geologic, paleogeographic and physical aspects — revealed by the initial stage of that theory.

These hypotheses were tested and confirmed by laboratory experiments (Dżułyński, 1963; Dżułyński, Walton, 1963). A group of geographers from the University of Cracow (Butrym, Cegła, Dżułyński, Nakonieczny, 1964) holds views similar to those advocated by those Soviet workers who regard diagenetic deformations as the most significant type of periglacial deformations. The importance of load-caused disturbances was also emphasized by Jahn and Czerwiński (1965) who, at the same time, underline the contribution of frost-caused impulses to the formation of such disturbances.

As results from the above considerations, the problem of the origin of various deformations in Quaternary sediments calls for a revision of the views held hitherto on this question. Such a revision does not however imply any negation of the existence of frost-caused deformations, having similar appearance.

A discussion of the particular examples of ground deformation in Quaternary sediments ought to be preceded by a brief description of the major diagenetic processes in loose sedimentary rocks. The difference between frost-caused and diagenetic structures will thus become easily discernible.

The chief morpho-creative diagenetic processes in loose rocks are: convectional instability of the ground, syneresis and dilatation.

CONVECTIONAL INSTABILITY OF THE GROUND

This phenomenon was first recognized and thoroughly tested on a physical basis by E. A. Artyushkov (1963a, b, 1964, 1965). It is a vigorous and widespread process which is responsible for horizontal disturbances in the sedimentary pattern and for the formation of various structures; it is due to the unsettled balance — in the Earth's field of gravity — of a layer of heavier material overlying a lighter one. Instability in homogeneous, horizontally bedded material leads to the formation of tri-, tetra- or hexagonal patterns which — in the vertical section — have the appearance of prisms.

In the course of the process of instability, 4 successive stages can be distinguished; each of them is characterized by a particular set of forms. During the initial stage, gently outlined sinusoidal deformations appear at the contact of the layers, and do not yet exhibit any polygonal patterns in the plane. At the next stage.

depending on the degree of viscosity of the ground, well-defined polygonal structures become visible as a result of subsidence along the borders i.e. the collapse of the overlying material associated with the formation of ground wedges or veins and subsidence at the center in the form of a drop. During the third stage, the material is displaced farther downward and the polygons acquire their ultimate shape. The fourth stage brings a complete upthrust of the lighter rocks and a cessation of all movement. Ground movements are inhibited by the process of lithification of the deposits, generally during the first or the second stage of unsettled balance, sometimes though rarely during stage III, and exceptionally during stage IV.

Artyushkov holds that the following relations afford the prerequisite conditions for the development of unsettled balance in sedimentary rocks: (1) $\gamma_1 > \gamma_2$ (γ_1 — the volume weight of the overlying sediments, γ_2 — the volume weight of the underlying ones), (2) $\Delta\gamma \cdot \Delta h \geqslant \tau_0 \max$ ($\tau_0 \max$ being the maximum relation value of the limit of fluidity of both rocks, $\Delta\gamma$ — the difference in volume weight between the over- and the underlying bed, Δh — the mean value of fluctuations of the separating boundary throughout the whole extension of disturbances. Tangible data provide evidence of a very common occurrence in nature of both these conditions. Most favourable to the development of an unsettled balance are the conditions prevailing during the period of accumulation of sediments and the initial phase of diagenesis in a subaqueous environment. Unsettled balance is likewise possible in a subaerial environment (upheaving, tyxotrophy, consolidation of grounds). It may develop in colloidal grounds as well as in pure sands, or in coarse-grained material including sands and silts. The primary polygonal forms vary in dimensions from several cm to hundreds of meters. If the viscosity of the ground is of 10^9—10^{15} poise, the time required for the development of unsettled balance may range — according to Artyushkov — from a few days to some tens of millenia.

SYNERESIS

Apart from plastic intrusions of material, there exist also various diagenetic forms which are solely associated with fissures (0.5 to 10 and more meters in length). The zone of disturbance, in the sediments bordering on the structures, is insignificant. The filling material is derived from the overlying and the adjacent layers. Some fissures and structures formed as a result of side-pressure, are often concealed.

Such forms owe their existence to processes of syneresis i.e. to subsidence and consolidation of feebly cemented deposits as a result of transformation of their structure and greater cohesion between the individual particles. Differential stresses in a homogeneous ground mass afford the conditions required for the formation of a polygonal network pattern in the vertical cut and in the plane. Such polygons range in size from a few decimeters to tens of meters. Syneresis under subaerial and subtropical conditions operates alike.

Syneresis is strongly reminiscent of another significant and wholly subaerial diagenetic process, which is that of desiccation. In size, however, polygons produced by desiccation are much smaller. Many experts, including A. I. Popov (1958, 1959, *et al.)* and B. N. Dostovalov (1961) have emphasized the relevant morphogenetic role of desiccation fissures.

Syneretic fissures are naturally very widespread. Forms of that type were discussed by S. S. Shulc (1964) who holds that diagenetic fissuring of sedimentary rocks is a general phenomenon occurring throughout the whole Earth's globe. Noteworthy is also the role of fissures of structural splitting which are usually polygonal in igneous and eruptive rocks. Each rock type is characterized by a distinct type of polygonal pattern. Tetragons are typical of granites, regular small hexagons — of tuffs, etc. Such polygonal fissures ultimately reach the zone of egzogenic processes and gradually evolve into ground veins.

DILATATION

Dilatation is due to a loosening of the coarse-grained material as a result of displacement of particles i.e. of the increasing volume and the ensuing modification of form and reversely. The significance of that phenomenon consists in the fact that in comparatively coarse-grained sediments owing to the intimate cohesion of the particles and the absence of intervening hydrate layers, the production of plastic deformations requires a larger increase of volume than that which is needed to tear apart one level of stress. Sands and grounds with a sand-like grain-size gradation are therefore — under the pressure of even an insignificant load — liable to disturbances in the form of cracks rather than of plastic flowage. The process is also responsible for the production of wedge-like fissures bordered by a zone of cracks below the base of convexion movement and a whole level of convectional disturbances.

Dilatation may produce fissures independant of convexion, which are in many respects similar to syneretic structures.

A correct distinction between frost-caused and diagenetic structures is clearly of vital importance for both the geology and the paleogeography of the Quaternary. The criteria concerning pseudomorphoses of ground veins — those major paleogeographic indicators — have been widely discussed in the literature (S o e r g e l, 1936; G a l l w i t z, 1949; K a i s e r, 1958; J o h n s s o n, 1959; K a p l i n a, R o m a n o v s k i, 1960; D y l i k, 1963). Considering, however, that those discussions were largely based on out-dated views on the genesis of polygonal structures, most of those criteria call for a revision and a more precise understanding. A particular role in that respect ought to be ascribed to the pseudomorphoses occurring to-day in permafrost regions (K a t a s o n o v a, 1965, S k r y l n i k, 1965). On the ground of investigations of this problem from a new point of view, pseudomorphoses and diagenetic (convectional) wedges may be said to show the following major properties.

Pseudomorphoses, just like ice veins, ought to have a sharp-tipped wedge-like shape and their vertical dimensions must be much larger than the horizontal ones; convectional structures usually show a reverse pattern. In the cross section, pseudomorphoses attain their absolute downward limit at ca. 1 m (exceptionally 0.3—0.5 m); convectional veins acquire significant dimensions. In pseudomorphoses, the relation of the structure's lenght to the spacing of the particular structures varies widely, while in convenctional veins that interdependance is constant. The contact between a pseudomorphosis and its surrounding is feebly marked, often dubious; the contact of a convectional form — inter-sedimentary borders — is usually perfectly defined. Fissure fillings are generally chaotic or include horizontally bedded sedimentary portions; the structure of convectional veins is either monolithic or reproduces the outline of the form. In the majority of cases, the layers bordering on pseudomorphoses dip downward; the adjoining layers of numerous convectional wedges, are upturned. At the center of polygons and below pseudomorphoses (wedges), the layers remain undisturbed; in the case of convectional forms, disturbance of the layers is a rule. Disturbances of a "cryoturbation" or "involution" type, which are never encountered in the vicinity of ice-wedges, are commonly associated with convectional forms. In the presence of pseudomorphoses, it should be ascertained whether there are any traces of an active layer or at least some evidence of its erosional truncation; if there are none, the structures ought to be regarded as convectional. The above considerations show that the conditions, both geologic and geomorphic of pseudomorphoses are more reduced than those of convectional structures.

Initial frost wedges, as judged from their present-day forms, have generally the appearance of narrow fissures (D e m e n t e v, 1946; P a t a l e y e v, 1955; W a s h b u r n, S m i t h, G o d d a r d, 1963; and others). In the light of the above description they totally differ from convectional structures. Relevant items, for a correct distinction between frost-caused and syneretic (rarely dilatational) fissures are: the presence of traces of an active layer, the compositon of the ground, the morphologic properties of the terrain, etc.; nonetheless, the problem still requires further studies. At the present state of knowledge concerning this question, the origin of a large group of wedge-like disturbances cannot yet be satisfactorily accounted for, although it includes such structures which ought to be regarded as frost-caused.

As concerns fold disturbances, their origin can be only convectional, although frost processes may have had a share in their formation. The origin of such disturbances of the ground resulting from tension in the course of upfreezing has not, however, been yet demonstrated either by theoretical speculations, field observations, or experiments.

Basing on the features discerned in frost-caused and diagenetic wedge-like structures, the present writer has studied these types of disturbances in various periglacial regions of Europe, in particular in the Low Rhine sandy-gravelly alluvials and in the interfluves of West Germany which are built of sands, loess-like sandy silts, pebbles, silts, etc. (D e w e r s, 1934; S t e e g e r, 1944; S t e u s l o f f, 1952; K a i s e r, 1958) in the sandy clayey formations of North- and North-East France (P a t t e, 1941), in the central East German plains composed of gravels and pebbles (G a l l w i t z, 1949; V i e t e, 1953), in the loesses of Central and Eastern Europe (S o e r g el, 1936; S e l z e r, 1936; G a l l w i t z, 1937; M o j s k i, 1961, Pécsi, 1963), in the sandy and boulder-clayey deposits of the interfluve areas of East Poland (Jahn, 1957), in the deposits of various age and composition occurring in Hungary (Pécsi, 1963), in both the old and the young alluvial sediments of Czechoslovakia (Sekyra, 1960; Ksandr, 1962). Further, such structures occurring in non-periglacial zones — e.g. in the old alluvials of SW France (Bastin, Cailleux, 1941) were also taken into consideration. Examples of typically periglacial disturbances are illustrated by Fig. 1 and Pl. 1.

A whole range of specific properties such as: adjustment of disturbances to the interlayer boundary, their morphology, the deformation of deposits in polygons, the presence of typically convectional involutions close by the wedges, the occurrence within them and in their neighbourhood of deposits identical in lithology and facies, as well as other features suggest that these forms are essentially diagenetic (predominantly convectional). In the present writer's opinion, therefore, the wedge structures described by J. Dylik, K. Kaiser, R. W. Galloway and other workers, though they may be justly regarded as frost-caused are primary (seasonal) ground-wedges rather than pseudomorphoses of ice-veins.

The present writer has studied numerous convectional and convexion-dilatational forms in the marine deposits of the coastal facies in the Shapkin river region (tributary of the Lower Pechora) which — according to S. L. Troickij — were developed in the sublittoral zone of accumulation of clays in a moderately cold sea without any evidence of contribution by river streams. Analysis of the microfauna seems to confirm this view (G. N. Nedejshev).

Wedge- and fold-like deformations as well as irregular disturbances are developed within all the horizons: at the contact of unstratified silts and sands, in packets of variously laminated sands, silts etc. and in the underlying diagonally bedded sands. Wedges form polygonal networks and vary in length from 0.5 do 3—4 m and more. They fall into two major types: convectional intrusions of unstratified silts into sands (upper part in Pl. 2) and fissure-like convexion-dilatational forms in the downward part of the profile (P. 3). Just as numerous are fold-like disturbances in the form of small synclines and anticlines (*Brodelböden*), of diapir and irregular intrusions of one layer into the other. A whole number of features such as: the morphology of the structures, the

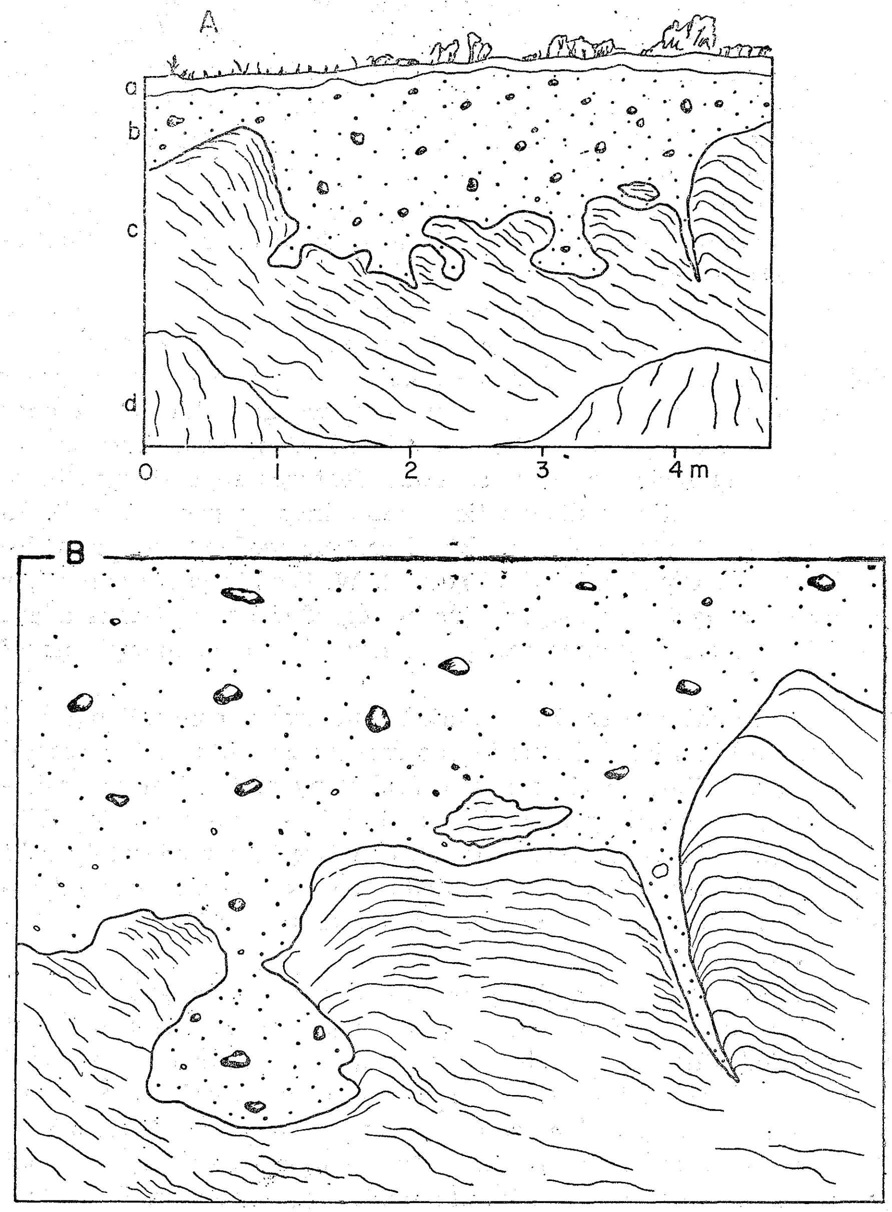
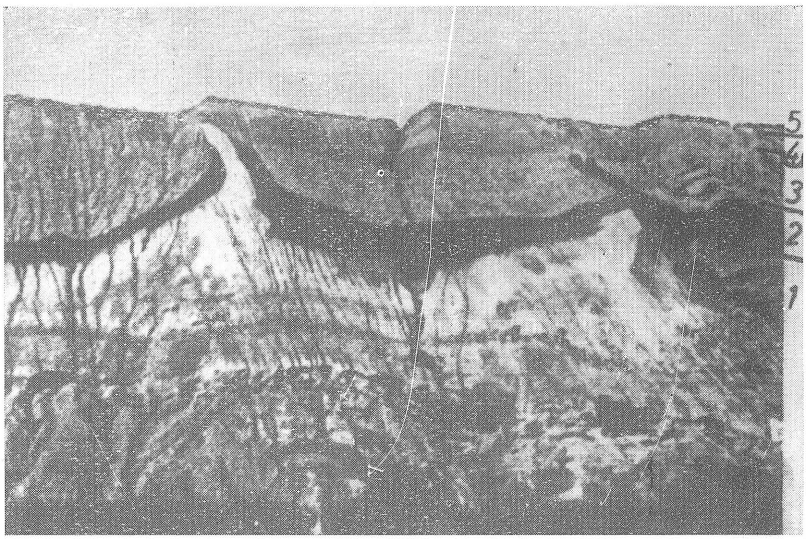


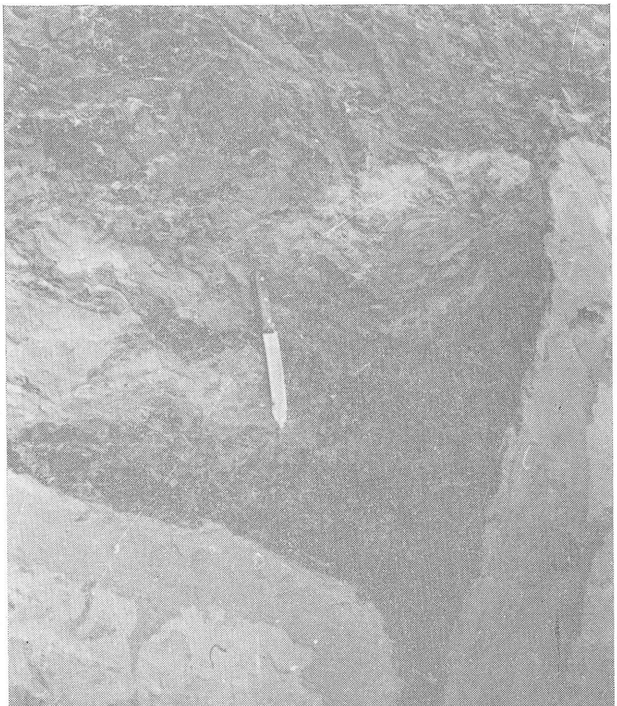
Fig. 1. Border subsidence caused by convexion — pocket-like and wedge structures at the contact of morainal clayey sands and stratified sands. Section Lehe—Georgswert near Wiefelstede, Lower Saxony (after F. Dewers, 1934): A — general view, B — fragment

a. podzolic soil; b. sandy boulder clay; c. stratified coarse sands and gravels; d. obscured



after K. Kaiser, 1958

Pl. 1. Large deformations caused by convexion, near Duran, Lower Rhine
1. Tertiary quartzitic sands; 2. lignite; 3. pebbles of main terrace; 4. loess-like silts (loess); 5. soil



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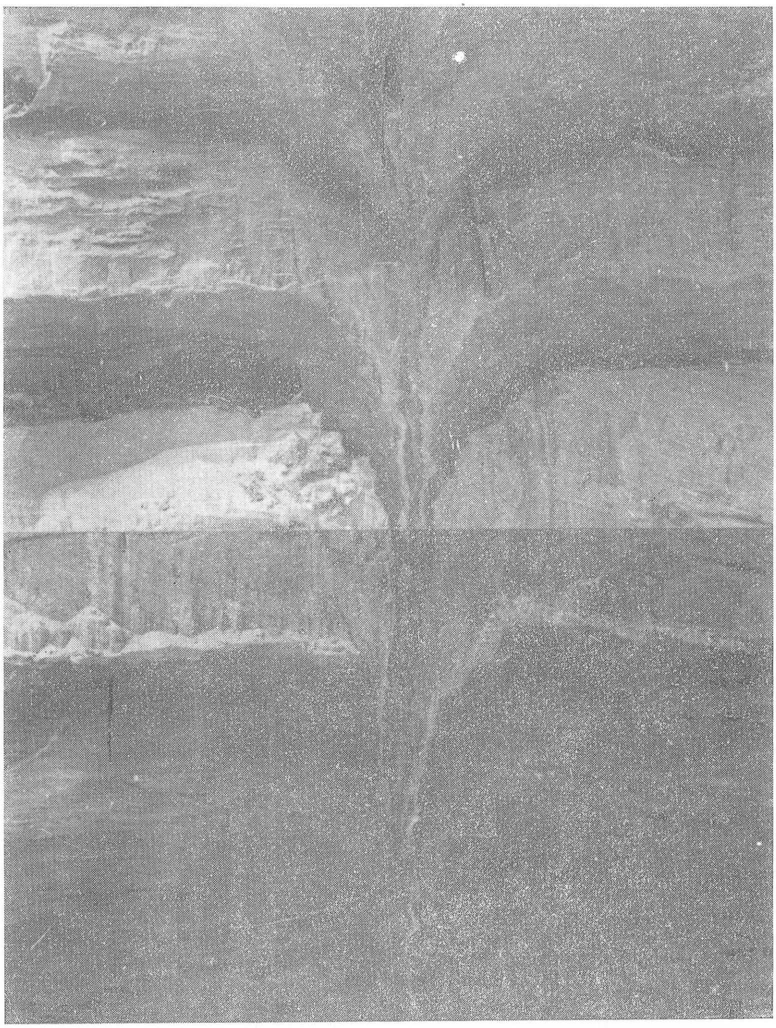
Pl. 2. Convectional structure of the border type at the contact of boulder clay and fine sands. Littoral marine sediments in the Shapkin river valley (lower Pechora river basin)



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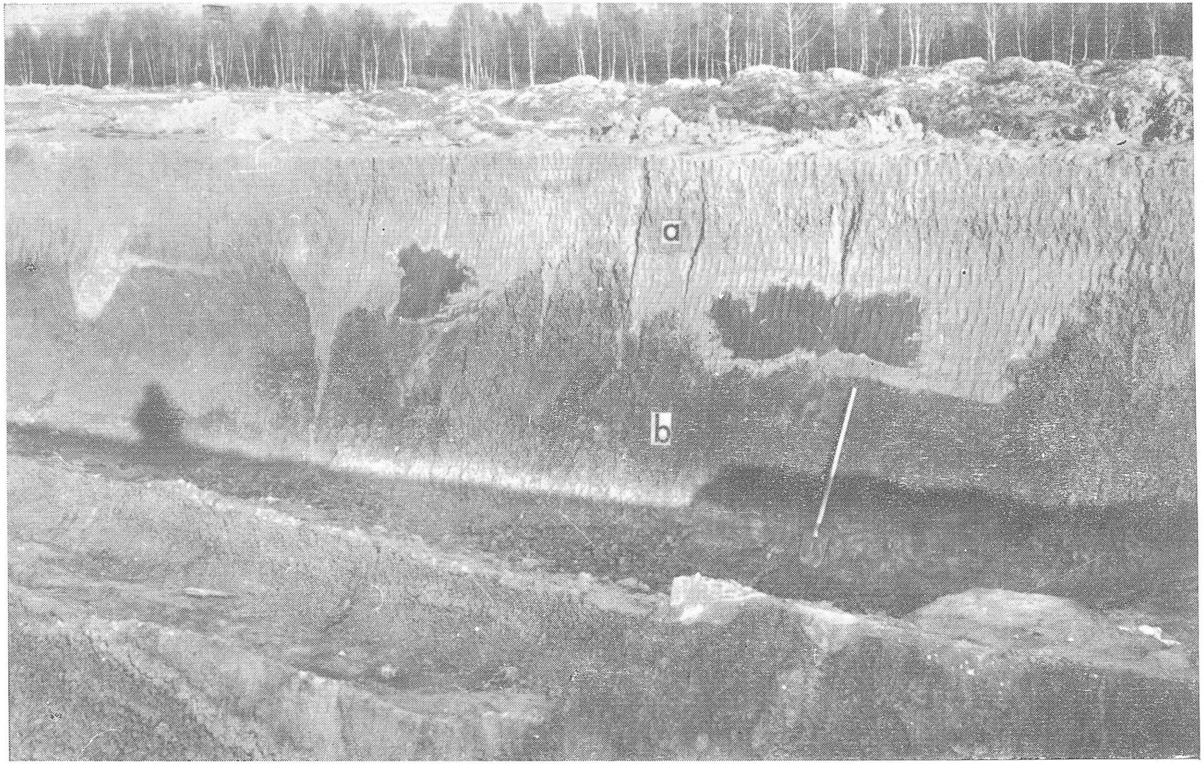
Pl. 3. Convexion-dilatational fissure in littoral sediments: dusty fine sands. Shapkin valley



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Pl. 4. Characteristic convectional and convexion-dilatational forms in the brick-kiln at Sidorovsk, SE of Moscow
a. pale yellow loess-like covering silts (loess); b. unstratified greenish-brown coarse silt

adjustment of their forms to the compactness of the deposits — according to the theory of instable balance — the absence of any evidence of invasion by continental climatic conditions — tend to suggest a diagenetic origin of these structures. The identity of their major features with those of other deformations, including also periglacial ones, seems to justify some broad generalisations.

On the ground of the criteria presented above, the present writer discusses the origin of the polygonal-block pattern occurring in the Bolshezemelskaya Tundra and in other regions of the Russian plain. The pattern is formed by a polygonal system of mounds —blocks (averaging 50—100 m in dimensions) and the intervening depressions (10—30 m in width) built in their top portions of loess-like and lacustrine silts. In the cross-cut, the inter-block depressions are found to coincide with wedge- and tongue-like intrusions of the covering sediments into the underlying silts and sands, which have up to several mts in thickness. There are also some smaller blocks which fail to influence the relief pattern.

Nowadays, the majority of workers regards the Bolshezemelskaya tundra as marine and glacial-marine (P o p o v, 1961, and others). Some questions however remain controversial as e.g. that concerning the origin of the covering silts. The present writer holds that the loess deposits of the Russian Plain are predominantly water-laid. The Bolshezemelskaya tundra is of lagoonal and lagoon-lacustrine origin, while the formations occurring farther subsequent weathering and pedogenic processes. The block relief waters. The loessy nature of the sediments provides evidence of subsequent wearthering and pedogenic processes. The block relief of the largest part of the Russian Plain is — in the present writer's opinion — convectional, rather than due to frost-cracking and was developed in mobile, moist grounds as a result of well-marked differences in the material. Various, frost-caused processes have, however, largely influenced its modelling.

One of the numerous sections studied by the present writer exhibiting the diagenetic structures of the near Moscow region may be presented as example, namely a cross-cut through the interfluve plain NE of Moscow (fig. 2). The passage from sinusoidal to wedge-like forms characteristic of convectional structures is here readily discernible. No less typical, from the point of view of origin is Pl. 4 which displays convectional deformations at the contact of covering and morainic silts.

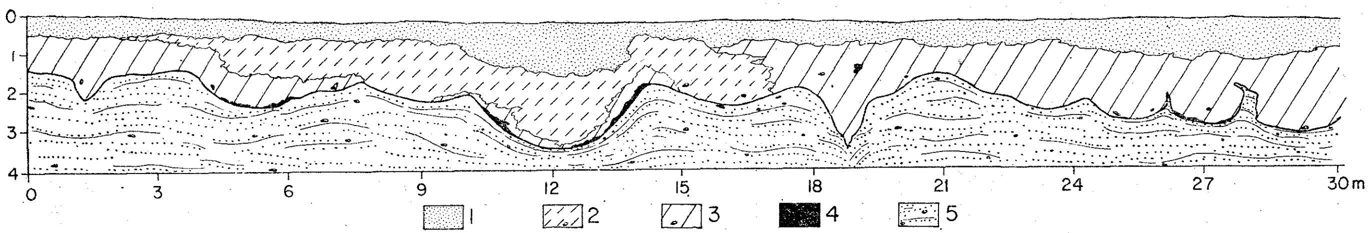

Fig. 2. Wedge-like and sinusoidal structures in the interfluve area, SE of Moscow, Zagoryanskaya, on the Northern Railway Road

1. ferruginous fine sand, non-stratified; 2. sandy silt including a few pebbles; 3. heavy silt with a few pebbles and small stones; 4. brownish-black organic matter; 5. ferruginous, horizontally stratified variously grained sand with single pebbles and gravels

Diagenetic processes are, however, by no means confined to loose sediments. As results from the data obtained, these processes, convectional instable balance in particular, have contributed also to ice-vein formation.

As concerns the role of instable balance it may manifest itself in two different manners. One of them consists in the formation of low-centered polygons (subsidence at the center) in loose, thawing grounds; polygon „anticlines" provide suitable sites for ice-vein development, in the course of progressive upfreezing. Such examples were recognized by the writer on the inundational terrace at the outlet of the Yana river. The second manifestation of instable balance consists in a very slow and essentially convectional outpressing of ice from the vein, due to the surrounding heavier ground; evidence of that process is provided by a very abrupt upturn of the layers, even by their overthrow at the contact with veins. As a result, a depression was formed in the polygon center together with the deformations which are well-known from many examples and due to a gentle upheaving of the overlying beds by the tops of larger ice-veins.

From the analysis of individual structures in totally different regions of the periglacial zone und on the background of the present state of knowledge concerning this question, it may be assumed that the nature of a periglacial region, i.e. the structural properties of its constituent deposits are practically defined by its diagenetic deformations. Frost wedges, ground (seasonal) wedges in particular, and may be also relatively small ice-wedges are likewise significant under periglacial conditions.

Because of the difficulty at the present state of knowledge of tracing the southern limit of permafrost on the evidence of its remnants within the deposits, we must forcibly try to find out some additional criteria, unrelated with periglacial phenomena within the ground. The maximum value of the mean annual cooling of temperature in the Pleistocene, corresponding to the value at which a fairly enduring underground glaciation (= permafrost) is formed (ca 3°) may be used to that purpose. If the reasoning of A. Penck (1938) and C. Emiliani (1955, 1958) be adopted as correct (cooling ca 8°) almost the whole of periglacial Europe (except mountains rising more than 800—1000 m), the major part of the SW area adjoining the ice-sheet and the southern part of the Russian Plain were free of permafrost. If this were the case, the southern permafrost border would coincide with the present-day course of the izotherm 5° (fig. 3). Many workers, however, assume a severer cooling down to 10—12°. In that case, permafrost must have been spread over the major part of the plains of periglacial Europe — from the Sub-Caspian lowland in the East to the La Manche strait in the West. The final solution of this problem will largely depend on whether any relevant post-cryogenic structures — pseudomorphoses of ice-veins — are going to be identified in periglacial regions on the basis of some new criteria.

A significant feature of the old (fossil) periglacial zone is the periglacial accumulation cycle of deposits dependantly on the outflow or the stagnation of waters at the time of ice-sheet melting from the moment when the ice-sheet front came to a standstill, till the beginning of its rapid retreat. The width of the periglacial zone would be thus determined by that of the belt of sediments laid during a given period and would shift in the trail of the ice-sheet. Accumulation of large water masses in the front of the ice-sheet was due to its presence, for large ice-masses induce an izostatic depression of the earth-crust, comprising not only the ice-covered areas but the adjoining „periglacial" ones as well (Artyushkov, 1966, and others). Within permafrost areas a periglacial climatic zone can be distinguished as a region of insignificant width, controlled by cold and dry winds blowing from the ice-sheet. If the indirect influence of the ice-sheet upon this zone be taken into account, it may be extended to comprise a vast expanse of terrain. The periglacial zones of ice-sheets, occurring under varying conditions, may differ from each other in a geologic and climatic respect (for example the present-day glaciers in the Antarctic or in Greenland, and the Pleistocene one of Europe or North America).

In the European periglacial zone, the remarkably numerous occurrence of wedge- and fold-like disturbances is a result of particularly suitable conditions promoting the development of convexion and other processes. Those favourable conditions were provided by a large variety of rocks of a totally different lithologic composition and a remarkable degree of saturation, sometimes even oversaturation with water. The deformations and the sediments within which they were developed constitute a sedimentary-dynamic periglacial formation of flood-lacustrine origin. Loess covers and the structures within them, belong to its signifi-

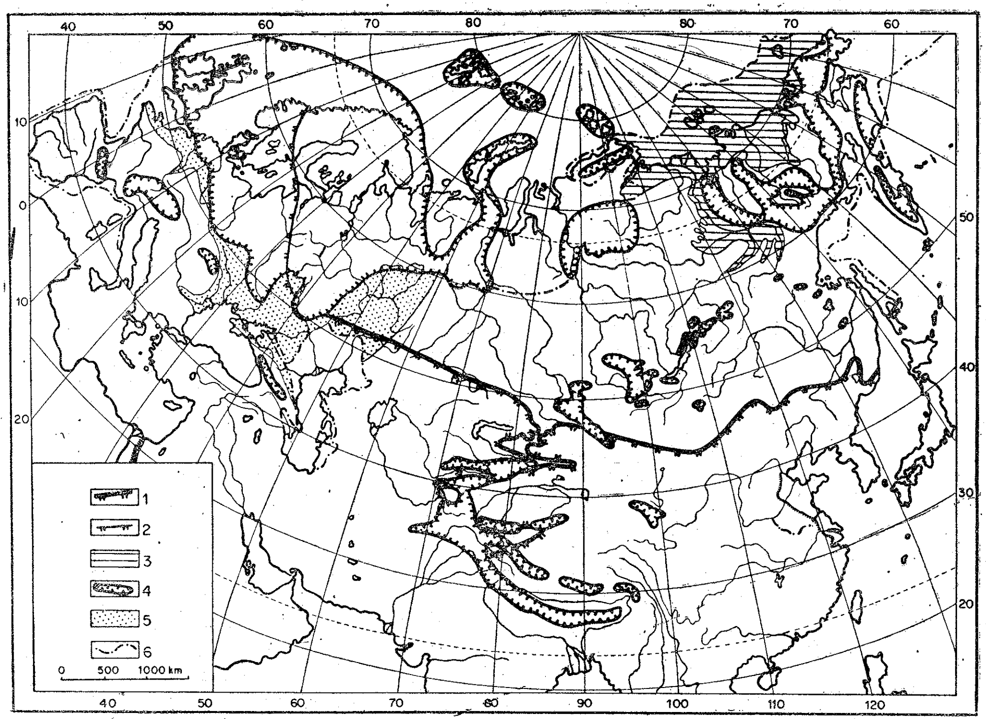

Fig. 3. Distribution of subterrenian glaciation (= permafrost) in Eurasia during the Pleistocene maximum cooling

1. southern limit of permafrost; 2. southern limit of permafrost during ice-sheet recession; 3. area of accumulation with syngenetic freezing of deposits and development of large fissureice; 4. glaciers; 5. zone of periglacial loess deposits; 6. sea-shore line

cant components. The formation is, at the same time, also one of a climatic nature.

Since the time of Tutkovskij, Łoziński and A. P. Pavlov loesses are unanimously regarded as a typically periglacial formation. Considering all its basic characteristics, the continental loess of the periglacial zone plains may safely be considered as water-laid. This interpretation of the origin of loess prevails amongst the Soviet scholars (Berg, 1947; Gerasimov, Markov, 1939; Krasnov, 1944; Spiridonov, 1948; Yakovlev, 1954; Sokolovskij, 1958; Polyakov, 1960; Lukashev, 1961; Shulc, *et al.*, 1963; Bondarchuk, 1965; Markov, Lazukov, Nikolaev, 1965; and others). This view is supported by the very existence of convectional disturbances within loess formations and at the contact between them and other deposits (boulder clay, glacifluvial sands, etc.). Apart from water-laid loesses, however, some are also eluvial, eluvio-colluvial and eolian.

Periglacial conditions induced intensiwe loess accumulation on interfluves as well as in valleys. On interfluves, loess covers were the predominant type of sediment. They were a result of deposition of fine, dusty particles in extensive, shallow basins and deltas. Apart from loess, uplands exhibit also other periglacial formations such as sands, muds etc. Intensive accumulation took place likewise in valleys where thick layers of flood-water sediments (Goreckij, 1958) and periglacial alluvials were deposited (Lavrushin, 1963).

In regions at higher altitudes which were not invaded by glacial melt-waters, eluvial and colluvial-solifluxion processes were at work. Soil horizons subsequently converted to fossil soil horizons were developed on elevations and periodically dry places.

Rapid accumulation of water-saturated deposits consisting of various lithologic components was the major but by no means the sole factor of development of wedge- and fold-like deformations. Of predominant importance in that respect was seasonal upfreezing manifested by dynamic impulses by which those disturbances were called forth or increased.

In the periglacial zone the conditions under which these disturbances occurred, varied widely. Such disturbances were often developed beneath the bottoms of water basins and were thus of entirely sub-aqueous origin. Together with a general decrease of water depth in the basin, the bottom formations were subjected to seasonal upfreezing. In those places where convectional movement had already been induced, it was intensified by frost-caused impulses, while in those which were in a condition of pseudo-balance on the verge of its loss, movement began within the sediments.

Diagenetic processes within the ground did not cease entirely with the complete drying up of one or another area; in such cases thermal oscillations played, naturally, an important role. Intervals in accumulation on generally loess-covered interfluves and in valleys are marked by soil horizons, often connected with systems of narrow fissures — due either to desiccation or frost. With recurrent inundation, the soil horizons rapidly acquired a condition which made them liable to displacement and were affected by convectional movements which were largely promoted by a considerable difference in density between loess or any other rock and humus-bearing strata (the top layers with deformations usually consist of loess, sand etc. while the underlying one is a soil-bed). Disturbances affecting fossil soil developed in loess and other sediments, are of that nature.

A multitude of horizons, displaying wedge- and fold-like disturbances in periglacial deposits, are basically of a diagenetic and diagenetic-frost-caused nature and are fully syngenetic with the accumulation of these sediments. Consequently, most of them bear the imprint of the severe climatic conditions of a periglacial zone. Frost-caused ground veins were, no doubt, also commonly developed in the periglacial zone, since the existence of fine-grained material and of a severe climate provided suitable conditions.

Leaving aside the question of diagenetic disturbances under subaerial conditions, there is no valid reason for directly correlating these disturbances with the active permafrost layer of periglacial areas. Nor, is there any foundation for identifying the fold-like and irregular structures found in thin beds with such microforms from the present-day polar and Arctic regions as stone polygons or spotted tundra, which are often likewise of a frost-caused convectional nature. The correctness of this statement is clearly supported by an obvious difference between both these form-types, the one namely that periglacial deformations are distincly bedded while structural grounds are not. Apart from the essential primary differences between deposits displaying various types of disturbances (sedimentary bedding in one case and non-stratified eluvials and deposits in another), they may be additionally accounted for by the fact that the former are undoubtedly structures due to convectional instability in its various stages, while the latter are an effect of stationary convexion. There are two reasons for which frost-caused-convectional disturbances in Quaternary sediments were not converted into stationary forms. First of all, the accelerated rate of accumulation tended to fossilize these disturbances and secondly the frost-caused impulses as compared with those of the polar and Arctic regions of to-day were of lesser intensity.

All these facts provide evidence of a wide diversity and of the imparalleled character of the geologic and climatic events of the Pleistocene in Europe, which events have no analogues under the present-day conditions but are clearly recorded in the deposits and structures of the periglacial zone.

In consequence, the present writer proposes that the term *periglacial* be used with greater caution and reduced to its primary (narrow and strict) meaning which is to designate the totality of processes and phenomena occurring on the peripheries of the large ancient ice-sheets, the specific sedimentary processes in particular which operated around the ice-sheet margins as well as various diagenetic and frost-caused-diagenetic phenomena within the ground. Periglacial conditions include moreover such phenomena as climate, especially in the zone of diffusion of air masses from the ice-sheet, glacial forms, vegetation, etc. The processes and phenomena known from the terrains bordering on the present-day glaciers of Greenland and the Antarctic should be likewise defined as periglacial (recent) in spite of the fact that periglacial zone of to-day, as regards the whole set of its characteristics, differs in many respects from the old (fossil) one of both Europe and North America.

Ethymologically correct, the term has thus the advantage of underlining the specific character of the near-glacier regions.

Apart from the periglacial lithologic formations there are still other ones that are likely to develop diagentic sub-aqueous phenomena of a dynamic nature, namely Quaternary marine and glacio-marine sediments. Such is the glacio-marine sedimentary dynamic formation extending in the north-east part of the Russian Plain and in western Siberia. Rapid accumulation — on a very uneven sea bottom — of various sediments, usually liable to disturbances, afforded suitable conditions for their development in a glacio-marine environment.

In present-day regions with either permafrost or frost-controlled morpholithogeny, relief-productive processes vary in their development, dependantly on the geomorphic trend of relief evolution. Therefore, three separate zones have been distinguished, which are: that of accumulation, that of relative balance and that of denudation (P o p o v, 1958). Best-defined are the frost-caused processes in areas of accumulation with syngenetic upfreezing of deposits and formation of large ice-veins, that are closely related with the formations within which they occur. It should be noted, that numerous epigenetic ice-veins and, though less numerous ground ice-veins likewise do most commonly occur in the fine--grained material of low-lying areas of accumulation. Areas of well-balanced processes of accumulation and denudation exhibit ground veins and various kinds of structural grounds such as isles of spotted tundra, stone polygons etc. Microstructures (stone polygons) and their slope correlates are characteristic of areas with a predominance of denudation. While ice-, ground-ice and ground veins are invariably frost-caused, the origin of structural grounds requires discussion and elucidation.

It is well-known, that the set of forms, generally referred to as structural grounds is quite remarkably wide-spread. As subaerial forms, they occur on interfluves, in river-valleys, on the shores of drying-out lakes in Arctic and polar regions and also in altitudinal areas. As subaqueous forms they are found in coastal regions (Greenland etc.), at the bottoms of deep non-freezing lakes (in the Alps, Antarctica, Khibiny Mts.) and in caves. Structural grounds occur in high as well as in low geographical latitudes. Moreover, their typical morphologic pattern is — no matter under what conditions they occur — remarkably enduring.

The problem of structural grounds is one that dates back at least a several decades. In the course of those years many various hypotheses were set forth — more than twenty, in fact, to mention the most important contributions only (W a s h b u r n, 1958). Since any discussion on the subject requires both abundant factual data and a voluminous literature, the present writer will — considering the scope and the subject-matter of this paper — restrict his treatment of the question to a brief presentation of his personal views, derived from both field material and the literature of the subject. These views are on the whole consistent with those expressed earlier by H. M o r t e n s e n (1932) and S ö r e n s e n (1935).

Already the widely varying conditions under which structural grounds are likely to occur and the persistence of their essential morphologic features indicate that the mechanism of their formation is aclimatic by nature. In the present writer's opinion this mechanism is primarily due to ground convexion by gravity, according to the law of convectional instability which invariably induces the formation of a polygonal network throughout vast areas. Alone, the essentially universal and aclimatic nature of the process is capable to account for the existence of identical forms in deep-lake and sea bottoms as well as on tundra surfaces. It should be noted that the distribution of subaerial structural grounds throughout the whole earth-globe is largely controlled by zonal climatic factors.

The investigations of C. T r o l l (1944) conducted during many years have shown that the zone of structural soils strictly coincides with that of solifluxion, i.e. one of a water-saturated (fluid) condition of the ground. Since the latter is one of the basic conditions of development of convectional instability, that conicidence is rather astounding. According to T r o l l the lowermost limit of that solifluxion zone of which permafrost forms a most important component part runs from the Pole to the Equator and from the Ocean shores to the central parts of continents. Its highest altitudinal situation lies within the arid subtropical belt (as e.g. in the Central Tibet at altitudes of more than 5500 m) to descend farther towards more humid equatorial regions (in the East-African mountains at 4000—4500 m).

A zone of structural soils may, therefore, be regarded as a climatically controlled zone fully saturated with water and particularly liable to ground movements promoting the formation of gravitational convexion and solifluxion. In the northern part of this zone — in Arctic and polar regions — the prerequisite dispositions are provided by a whole set of conditions, first of all by the presence of permafrost and a seasonal migration of water within the active layer. Relevant evidence of the development of convectional movements in the subsurficial ground layer of these regions is that of the zonally conditioned processes, leading to the production of instable stratification within the active layer. As a result of frost-heaving of rock fragments, the heavier material (stones) accumulates on the surface, while moisture and fluidity increase in the underlying horizons at the boundary of the impervious layer, in the form of either permafrost table or solid rock. Frost-caused impulses during seasonal or diurnal oscillations of the temperature, contributed largely to the initiation and development of these movements within the ground. Unlike in the case of convectional structures in sediments, the influence of a frozen soil and the absence of accumulation cause the active structural grounds to appear in the form of stabilized convexion, where each ground particle (except large stones) inside the polygon is uninterruptedly (during a lengthy period) involved in a circular movement.

Such forms — either sorted or non-sorted — are essentially frost-caused-convectional. Under different conditions, wherever the necessary degree of moisture depends on other climatic factors and on the reduced development of frost-caused processes, structural grounds must be considered as chiefly convectional forms, akin to typically subaqueous polygonal grounds.

Apart from convectional processes, desiccation which is a diagenetic process largely contributes to the formation of various micro-relief forms, polygonal ones in particular (P o p o v, 1959). There is no need of stressing the fact that climate — especially freezing and thawing — is not directly responsible for the development of structural soils.

On account of specific, relief-productive processes, the present--day regions of severe climate may be defined as a zone of climatically controlled polygonal structures and solifluxion. Ice- and ground veins (in areas of accummulation), initial ground- and ground ice veins (in areas of relatively balanced accumulation and denudation) and frost-produced diagenetic forms like stone polygons, earth islands etc., when occurring in permafrost regions constitute such a group of climatically controlled forms, due solely to frost. In non-permafrost regions such as high mountains, where the influence of temperature and consequently that of frost-caused processes is of lesser significance, there is a predominant occurrence of diagenetic (convexion) and frost-diagenetic structural grounds.

In the Pleistocene, the zone of severe climate, that of permafrost in particular, considerably expanded its reach in Eastern Eurasia. Considering the degree of climatic fluctuations which was here lesser than in the West and the warming influence of the West Siberian sea-basin, a mean annual cooling of temperature of 6—7° as compared with that of to-day, should be assumed for this area. At the same time, the limit of subterrenian glaciation (permafrost) ran through north Kazakhstan along the 51—52° N. lat., turning distinctly southward in the river-basin of the upper Irtysh, from where a large lobe branched off to comprise the mountainous area of Central Asia. In Eastern Siberia and the Far East, the degree of lowered temperature was still lesser — some 5°C only. The extension of the Pleistocene subterrenian glaciation was, as compared with that of to-day, lesser in Eastern than in Western Siberia.

Most peculiar forms are the polygonal systems consisting of large ice-veins (some 30—40 m deep and 6—8 m in width). They occur in the vast accumulational lowlands of central Eastern Siberia and in the much more extensive areas of its northern part. Ice-veins and syngenetically freezing sands, silts and peats containing ground ice were formed under conditions of long-lasting tectonic depression, compensated by a constant accumulation of new deposits. This fact accounts as well for the large dimensions of the ice-veins as for the impressive thickness of the ice-bearing sediments. The significant width of the East Siberian Pleistocene ice-veins provides evidence of the existence in this area of a very severe climate during the formation of these veins, for the size of the diagenetic voids which largely contribute to the frontal growth of vein-ice masses depends on the degree of thermal oscillations within the active layer (P o p o v, 1965).

It may be said in a general manner that in East Eurasia the climatic conditions and the main trend of relief-forming processes — frost-caused ones in particular — did not appreciably differ in the Pleistocene from those observed to-day. In contrast, the western part of Eurasia underwent certain qualitative modifications of its climatic and geologic environment.

Worthy of note is that the limit of subterrenian glaciation constitutes a barrier for frost-caused processes alone. For, diagenetic processes can easily transgress it. Therefore, in the Pleistocene zone of frost-caused morpholithogeny apart from frost-caused processes, purely diagenetic ones as well as frost-diagenetic impulses during the accumulation of deposits were of no less importance for they led to the production of polygonal structures and relief-forms under subaqueous and subaerial conditions.

From the above considerations it may be safely inferred that such diagenetic processes as convexion, instability of grounds, syneresis and dilatation in loose, feebly cemented sediments play a role which is by no means insignificant. The first two of these processes contribute to the development of polygonal networks and of wedge-like disturbances throughout vast areas in a subaqueous or subaerial environment.

Among these processes instability of grounds appears as one of particular importance. The physiographic conditions under which it manifests itself are widely diversified. From the geologic and paleogeographic point of view, 3 major types of instability can be distinguished, according to the degree to which climatic (frost) processes contribute to its development:

(1) Instability as a simple function of gravitational differences resulting from accumulation under subaqueous or subaerial conditions without any influence on the part of climate. This type of instability is proper to nearly all the pre-Quaternary sediments, the marine and glacio-marine Quaternary deposits as well as to certain periglacial formations developed in relatively deep waters.

(2) Instability resulting from accumulation during partial innundation or complete drying of the surface, strongly influenced by climate in the form of frost-dynamic impulses during seasonal or diurnal oscillations across the freezing point. This type of instability was characteristic of vast continental areas of the northern hemisphere towards the close of the Tertiary (Pliocene) and may be also of extensive parts of the earth-globe in other pre-Pleistocene cold periods, such as the Permian-Carboniferous of Australia and South Africa, etc. It was most vigorously marked during the Pleistocene in the periglacial zone of the European ice-sheets and — though on stretches of lesser extension — in that of permafrost morpholithogeny in eastern Eurasia.

(3) Instability occurring under subaerial conditions without any accumulation of deposits but under the direct action of such climatic factors as: the presence of permafrost, frost-heaving of rock fragments and intensive upheaving during seasonal ground freezing. This kind of instability is, first of all, typical of the active layer of permafrost of a large portion of both the Pleistocene and the present-day zone of frost-caused morpholithogeny as well as of both the recent and the ancient periglacial zone in high geographic latidudes: in Greenland and in the Antarctic. A variety of instability which passes into the one mentioned above is that occurring in etiher permafrost-free areas or at very profound depths

and where frost-caused impulses are very weak. This variety is characteristic of tropical and subtropical high-mountain regions as well as of the bottoms and the shores of drying mountain lakes and of caves.

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References

Afanasyev, B. L., 1961 — Neotektonika Pechorskogo ugolnogo bassejna i prilegayushchikh rajonov Severnogo Priuralya (New tectonics in the Pechora coal field and adjacent areas of the Northern Ural). in: Materialy po geologii i poleznym iskopaemym severo-vostoka Evropejskoj chasti SSSR; Moskva.

Anderson, J. G., 1906 — Solifluction, a component of subaerial denudation. *Jour. Geol.*, vol. 14.

Artyushkov, E. V., 1965 — Obrazovanie konvektivnykh deformacij v slabolitificirovanykh osadochnykh porodakh (Development of convexion disturbances in slight lithified deposits). *Izv. Akad. Nauk SSSR, ser. geol.*, 12.

Artyushkov, E. V., 1966a — O kharaktere izmeneniya vyazkosti verkhnej mantii s glubinoj (On viscosity changes of deposits depending on their depth). *Fizika zemli*, no. 8.

Artyushkov, E. V., 1966b — On the isostatic equilibrium of the Earth's crust. *Ann. Acad. Sci. Fennicae*. A. 3, 90, 455.

Bahr, A., 1932 — Frostgestauchte Böden im westlichen Schleswig-Holstein. *Ztschr. Deutsch. Geol. Ges.*, Bd. 84

Baranov, I. Y., 1958 — Reliktovy termokarst v Predbajkale (The relict thermokarst in Fore-Baikal region). *Materialy k osnovam ucheniya o merzlykh zonakh zemnoj kory*, vyp. 4; Moskva.

Baranov, I. R., 1962 — Kriometamorfizm gornykh porod i yego znachenie dla paleogeografii chetvertichnogo perioda (Cryometamorphosis of the rocks and its significance for paleogeography of the Quaternary). in: Voprosy kriologii pri izuchenii chetvertichnykh otlokzenij; Moskva.

Bardin, V. I., 1965 — Gory centralnoj chasti Zemli Korolevy Mod (The mountains of the central part of the Queen Maud Land, Eastern Antarctida). Izdat. Nauka, Moskva.

Bastin, A., Cailleux, A., 1941 — Action du vent et du gel au Quaternaire dans la région bordelaise. *Bull. Soc. Géol. France, 5-me sér.*, t. 11.

Baulin, V. V., Shmelev, L. M., 1962 — O sledakh drevnikh kriogennykh processov v verkhneplejstocenovykh otlozheniakh nizhnego techeniya r. Obi (On the traces of cryogenic processes in late-Pleistocene deposits of the lower Ob river). in: Vorpsy kriologii pri izuchenii chetvertichnykh otlozhenij; Moskva.

Beets, C., 1946 — Miocene submarine disturbances of strata in Northern Italy. *Jour Geol.*, vol. 54.

Belopukhova, E. B., 1960 — Zemlyanye zhily v alasnykh kotlovinakh v Verkhne-Vilujskom rajone Yakuckoj SSR (Ground veins in alas depressions in the Upper Viluj area, Yakuck territory). *Trudy Sev.-vost. Otd. Inst. Merzlot. im. Obrucheva*, vyp. 2; Yakuck.

Belostockij, I. I., 1955 — Nekotorye primery deformacij osadkov v period ikh otlozheniya (Some examples of disturbances of deposits during their accumulation). *Biul. Mosk. Obshch. Ispyt. Prirody, otd. geol.*, t. 30.

Berg, L. S., 1947 — Less kak produkt vyvetrivaniya i pochvoobrazovaniya (Loess as the product of weathering and soil formation). in: Klimat i zhizn, gl. IX; Moskva.

Bigot, M., 1936 — Bibliographie analitique des travaux sur les plages suspendues et les dépôts de solifluxion dans le Massif armoricain et les îles anglo-normandais. *Rev. Géogr. Phys. Géol. Dyn.*, t. 9.

Black, R. F., 1954 — Permafrost. A review. *Bull. Geol. Soc. Amer.*, vol. 65.

Born, A., 1929 — Über atektonische Faltung bei Kimberley, S. A. U. *Ztschr. Deutsch. Geol. Ges.*, Bd. 81.

Bronguleev, V. V., 1951 — Melkaya skladchatost platformy, opyt strukturnogo analiza (Small folds in platform areas, an attempt to analize of structure). Moskva.

Butrym, J., Cegła, J., Dżułyński, S., Nakonieczny S., 1964 — New interpretation of „periglacial structures". *Folia Quaternaria*, 17: Cracow.

Büdel, J., 1944 — Die morphologischen Wirkungen des Eiszeitklimas im gletcherfreien Gebiet. *Geol. Rundschau*, Bd. 34.

Büdel, J., 1953 — Die periglazial-morphologischen Wirkungen des Eiszeitklimas auf der ganzen Erde. *Erdkunde*, Bd. 7.

Büdel, J., 1960 — Die Gliederung der Würmkaltzeit. *Würzburger geogr. Arbeiten*, H. 8.

Bülow, W. von, 1964a — Ein Taschen- und Tropfenboden von Grebs (SW-Mecklenburg). *Geologie*, Jhg. 13.

Bülow, W. von, 1964b — Der Tropfenboden von Rüterberg (SW-Mecklenburg). *Geologie*, Jhg. 13.

Cailleux, A., 1942 — Les actions éoliennes périglaciaires en Europe. *Mém. Soc. Géol. France, N.S.*, t. 21.

Cailleux, A., 1948 — Carte des actions périglaciaires quaternaires en France. *Bull. Serv. Cartes Géol. France*. t. 47, no. 225.

Cejtlin, S. M., 1964 — Sopostavlenie chetvertichnykh otlozhenij lednikovoj i vnelednikovoj zon Centralnoj Sibiri, bassejn Nizhnej Tunguski (The comparison of Quaternary deposits occurring in glacial and non-glacial zones of Central Siberia, the Lower Tunguska basin). *Trudy Geol. Inst. Akad. Nauk SSSR*, vyp. 100.

Chigir, V. G., 1962 — Formy reliefa, obuslovlennye merzlotnymi processami, na ostrovakh Krasnoflotskikh, Severnaya Zemlya (The land-forms caused by periglacial processes, Krasnoflotskie Islands, Severnaya Zemlya). in: Voprosy geograficheskogo merzlotovedeniya i periglacialnoj morfologii; Moskva.

Colacichi, R., 1959 — Dichi sedimentari del Flysh oligo-minovenico della Secilia Nord-orientale. *Ecl. Geol. Helv.*, vol. 51.

Corte, A. E., 1963 — Relationship between four ground patterns, structure of the active layer, and type and distribution of ice in the permafrost. *Biuletyn Peryglacjalny*, no. 12.

Danilov, I. D., 1962 — O genezise tolshchi serykh valunnykh suglinkov Vorkutskogo rajona (On the origin of grey boulder clays in the Vorkuta region). in: Voprosy geograficheskogo merzlotovedeniya i periglacjalnoj morfologii; Moskva.

Danilov, I. D., 1964 — Diageneticheskie narusheniya sloistosti v morskikh chetvertichnykh otlozheniyakh Bolshemelskoj tundry. (The diagenetic disturbances of layers in the Quaternary marine deposits of the Bolshezemelska tundra). in: Problemy paleogeografii i morfogenezisa v polarnykh stranakh i vyskogore; Moskva.

Danilova, N. S., 1956 — Gruntovye zhily i ikh proiskhozhdenie (Ground veins and their origin). *Materialy k osnovam ucheniya o merzlykh zonakh zemnoj kory*, vyp. 3; Moskva.

Danilova, N. S., 1963 — Pervichno-gruntovye zhily v chetvertichnykh otlozheniyakh r. Vilyuya (Ground veins in the Quaternary deposits of the Vilyuj river). in: Merzlye chetvertichnye otlozheniya Yakutii; Moskva.

Danilova, N. S., 1965 — Osobennosti formirovaniya sovremennykh merzlykh otlozhenij v delte Leny (Specific features of the formation of present permafrost deposits in the Lena delta). *Izv. Akad. Nauk SSSR, ser. geogr.*, no. 5.

Dementev, A. I.,1946 — Morozobojnye treshchiny v rajonakh vechnoj merzloty (Frost fissures in permafrost areas). *Merzlotovedenie*, t. 1.

Dewers, F., 1934 — Kritische Betrachtungen zur Frage der Beschaffenheit und Entstehung der Taschenböden. *Abhandl. u. Vorträge Bremer Wiss. Ges.*, Jhg. 8/9.

Dobrovolskij, V. V., 1961 — O prirode tak nazyvaemykh „merzlotnykh klinev" Kazakhskogo melkosopochnika (On the nature of so called "frost wedges" in the hilly region of Kazakhstan). *Biul. Mosk. Obshch. Ispyt. Prirody, otd. geol.*, t. 36.

Doskach, A. G., 1962 — O psevdoperiglacialnykh yavleniyakh (Pseudoperiglacial phenomena). in: Voprosy kriologii pri izuchenii chetvertichnykh otlozhenij; Moskva.

Dostovalov, B. N., 1952 — O fizicheskich usloviyakh obrazovaniya morozobojnykh treshchin i razvitiya treshchinnykh ldov v rykhlykh merzlykh porodakh (Physical conditions of the origin of frost fissures and of the development of fissure ice in loose rocks). *Issledovaniya vechnoj merzloty v Yakuckoj respublike*, vyp. 3; Yakuck.

Dostovalov, B. N., 1961 — Issledovaniya morozobojnogo i diageneticheskogo rastreskivaniya porod (The study of frost- and diagenetic cracking in rocks). *Merzlotnye issledovaniya*, vyp. 2; Moskva.

Dott, R. H., Howard, J. K., 1962 — Convolute lamination in non-graded sequences. *Jour. Geol.*, vol. 70.

Dücker, A., 1933a — Frostschub und Frosthebung. *Zentralblatt Mineral., Geol., Paläont.*, Abt. B: Geol. u. Paläont., Jhg. 1933.

Dücker, A., 1933b — Die Windkanter des norddeutschen Diluviums in ihren Beziehungen zu periglazialen Erscheinungen und zum Decksand. *Jhb. Preuss. Geol. Landesanstalt.*

Dylik, J., 1956 — Coup d'oeil sur la Pologne périglaciaire. *Biuletyn Peryglacjalny*, no. 4.

Dylik, J., 1964 — Periglacial investigations and their significance for paleogeography. *Rev. Polish Acad. Sci.*, nr 1.

Dylik, J., 1965 — Right and wrong in sceptical views on the problem of periglacial phenomena revealed in Pleistocene deposits. *Bull. Soc. Sci. Lettr. de Łódź*, vol. 16, no. 8.

Dżułyński, S., 1963 — Polygonal structures in experiments and their bearing upon some periglacial phenomena. *Bull. Acad. Polonaise Sci., sér, géol., géogr.*, vol. 11.

Dżułyński, S., 1965 — New data on experimental production of sedimentary structures. *Jour. Sediment Petrol.*, vol. 35.

Dżułyński, S., Walton, E. K., 1963 — Experimental production of sole markings. *Trans. Edinburgh Geol. Soc.*, vol. 19.

Eardley, A. J., 1938 — Sediments of Great Salt Lake, Utah. *Bull. Am. Assoc. Petrol. Geologists*, vol. 22.

Edelman, C. H., Florshütz, F., Jeswiet, J., 1936 — Über spätpleistozäne und frühholzäne kryoturbate Ablagerungen in den östlichen Niederlanden. *Verhandl. Geol. Mijnb. Genoot. Nederlanden Kolonien, Geol. ser.*, Deel 11.

Einsele, G., 1963 — „Convolute bedding" und ähnliche Sedimentsrukturen im rheinischen Oberdevon und anderen Ablagerungen. *N. Jhb. Geol. Paläont.*, Bd. 116.

Emery, K. O., 1950 — Contorted pleistocene strata at Newport beach, California. *Jour. Sediment. Petrol.*, vol. 20.

Fairbridge, R. W., 1946 — Submarine slumping and location of oil bodies. *Bull. Am. Assoc. Petrol. Geologists*, vol. 30.

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

Flohn, H., 1963 — Zur meteorologischen Interpretation der pleistozänen Klimaschwankungen. *Eiszeitalter u. Gegenwart*, Bd. 14.

Frödin, J., 1912 — Beobachtungen über den Einfluss der Pflanzendecke auf die Bodentemperatur. *Lunds Univ. Arsskrift*, N.F., Bd. 7, no. 9.

Galloway, R. W., 1961 — Ice wedges and involutions in Scotland. *Biuletyn Peryglacjalny*, no. 10.

Gallwitz, H., 1937 — Fliesserde und Frostspalten als Zeitmarken im Löss bei Dresden. *Geol. Rundschau*, Bd. 28.

Gallwitz, H., 1949 — Eiskeile und glaziale Sedimentation. *Geologica*, Bd. 2.

Gerasimov, I. P., Markov, K. K., 1939 — Chetvertichnaya geologiya (Quaternary geology). Moskva.

Gorsline, D. S., Emery, K. O., 1959 — Turbidity-current deposits in San Pedro and Santa Monica basins of southern California. *Bull. Geol. Soc. Am.*, vol. 70.

Goreckij, G. I., 1958 — O periglacialnoj formacji (On periglacial formation). *Biul. Kom. po izuch. chetvert. perioda Akad. Nauk SSSR*, t. 22.

Goreckij, G. I., 1961 — Geneticheskie tipy i raznovidnosti otlozhenij periglacialnoj formacii (Genetic types and varieties of periglacial deposits). in: Materialy po genezisu i litologii chetvertichnykh otlozhenij; Minsk,

Gorelov, S. K., 1962 — O sledakh periglacialnykh obrazovanij na yugo--vostoke Russkoj ravniny (The traces of periglacial phenomena in the south-eastern part of the Russian plain). in: Voprosy kriologii pri izuchenii chetvertichnykh otlozhenii; Moskva.

Gorkova, I. M., 1957 — Glinistye porody i ikh prochnost v svete sovremennykh predstavlenij koloidalnoj khimii (Clayey grounds and their stability in the light of chemical studies of colloids). *Trudy. Labor. gidrogeol. problem Akad. Nauk SSSR*, t. 15.

Gorkova, I. M., Dushkina, N. A., Ryabicheva, K. N., 1959 — Strukturno-mekhanicheskie svojstva ilov Chernogo morya i ikh izmenenie v processe diageneza (Textural and structural properties of clays of the Black Sea and their changes due to diagenetic processes). *Trudy Labor. gidrogeol. problem Akad. Nauk SSSR*, t. 22.

Govorukhin, V. S., 1960 — Pyatnistye tundry i plikativnye pochvy Severa (The spotted tundra and contorted soils in the North). *Zemlevedenie*, nov. ser., t. 5.

Gravis, G. F., 1962 — Ledyanye zhily v delyuvialno-soliflyukcionnykh otlozheniyakh (Ice-veins in solifluxion deposits). *Voprosy geografii Yakutii*, vyp. 2; Yakutsk.

Greensmith, J. T., 1956 — Sedimentary structures in the Uper Carboniferous of north and central Derbyshire, England. *Jour. Sedim. Petrol.*, vol. 26.

Grigorev, N. F., 1962 — Formirovanie reliefa i merzlykh gornykh porod poberezhya Vostochnoj Antarktidy (The formation of land-forms and of permafrost in coastal area of Eastern Antarctica). Moskva.

Gripp, K., 1924 — Über fossile Abtragungsformen im Diluvium Nordwestdeutschlands. *Zentralblatt Miner., Geol. Paläont.*, Abt. B; Geol. u. Paläont.

Gripp, K., 1926 — Über Frost- und Strukturboden in Spitzbergen. *Ztschr. Ges. f. Erdkunde zu Berlin.*

Gripp, K., 1930 — Gletscher und Bodenfrost, rezente und diluviale. *Geol. Rundschau*, Bd. 21.

Gripp, K., Mortensen, H., 1931 — War der Boden in den eisfreien Gebieten um das diluviale Inlandeis gefroren? *Pet. Geogr, Mit.*, Jhg 77.

Grishchenko, M. N., 1959 — O mnogoyarusnosti iskopaemykh sledov merzloty v chetvertichnoj tolshche bassejna verkhnego Dona i stratigraficheskom polozhenii ikh (On the multiple horizons of fossil traces of permafrost in Quaternary sediments in the upper Don basin and on their stratigraphic position). *Bul. Obshch. Estestv. pri Voronezh. Univ.* t. 11.

Gusev, A. I., 1958 — Ob iskopaemykh „sledakh" merzloty i „ledyanykh" klinyakh v chetvertichnykh otlozheniyakh (On fossil „traces" of permafrost and on „ice" wedges in Quaternary deposits). *Geol. Sbor. Lvov. Geol. Obshch.*, no. 5.

Halicki, B., 1960 — Sur la différente genèse des déformations structurales des sédiments dans un milieu hydroplastique. *Biuletyn Peryglacjalny*, no. 7.

Högbom, B., 1914 — Über die geologische Bedeutung des Frostes. *Bull. Geol. Inst. Univ. Upsala*, vol. 12.

Holland, G. H., 1960 — Load cast terminology and origin of convolute bedding: some comment. *Bull. Geol. Soc. Am.*, vol. 71.

Jahn, A., 1951 — Cryoturbate phenomena of the contemporary and of the Pleistocene periglacial zone. *Acta Geol. Polonica*, vol. 2.

Jahn, A., Czerwiński, J., 1965 — The role of impulses in the process of periglacial soil structure formation. *Acta Univ. Vratislav.*, no. 44.

Johnsson, G., 1959 — True and false ice-wedges in Southern Sweden. *Geogr. Annaler*, vol. 41.

Johnsson, G., 1960 — Cryoturbation at Zaragosa, northern Spain. *Ztschr. f. Geomorph.*, Bd. 4.

Kachurin, S. P., 1960 — Poligonalnye formy reliefa Severa (Polygonal land-forms of the North). *Trudy Inst. Merzlotovedeniya Akad. Nauk SSSR*, t. 16.

Kagner, M. N., 1959 — K voprosu o narusheniyakh v zaleganii lentochnykh glin i prichinakh ikh vozniknoveniya (On the origin and disturbances of varved clays layers). *Vestnik Mosk. Univ., ser. biol., pochvoved, geol., geogr.*, no. 1.

Kaiser, K., 1958 — Wirkungen des pleistozänen Bodenfrostes in den Sedimenten der Niederrheinischen Bucht. *Eiszeitalter u. Gegenwart*, Bd. 9.

Kaiser, K., 1960 — Klimazeugen des periglazialen Dauerfrostbodens in Mittel- und Westeuropa. *Eiszeitalter u. Gegenwart*, Bd. 11.

Kaplina, T. N., Romanovskij, N. N., 1960 — O psevdomorfozakh po poligonalno-zhilnomu ldu (Pseudomorphoses of the polygonal-veined ice). In: Periglyacialnye yavleniya na territorii SSSR; Moskva.

Katasonov, E. M., 1958 — Ledyanye zhily i prichiny izgibaniya sloev v merzlykh chetvertichnykh otlozheniyakh (Ice-veins and causes of disturbances of layers in Quaternary deposits). *Materialy k osnovam ucheniya o merzlykh zonakh zemnoj kory*, vyp. 4; Moskva.

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

Katasonova, E. G., 1963 — Sovremennye mnogoletnemerzlye otlozheniya i ikh bolee drevnie analogi v severo-vostochnoj chasti Leno-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 Sibirii i na Severo--Vostoke; Moskva.

Keilhack, K., 1931 — Über „atektonische Faltung" (Stiche) in der Trias des Harzvorlandes und über einen merkwürdigen Fall von Hakenschlagen. *Ztschr. Deutsch. Geol. Ges.*, Bd. 83.

Keller, J., 1954 — Drucktexturen in eiszeitlichen Sedimenten. *Eiszeitalter u. Gegenwart*, Bd. 4/5.

Kelling, G., Walton, E. K., 1957 — Load-cast structures. *Geol. Magazine*, vol. 94.

Khomichevskaya, L. S., 1960 — Ob ostatochnom zhilno-poligonalnom reliefie Dalnego Vostoka (Remnant fissure-polygonal relief of the Far East). *Trudy Inst. Merzlotovedeniya Akad. Nauk SSSR*, t. 16.

Khruckij, S. F., 1964 — Relikty treshchinno-poligonalnykh ldov v nizhnej chasti doliny r. Obi (Relict fissure-polygonal ice in the lower Ob valley). In: Problemy paleogeografii i morfogeneza v polyarnykh stranakh i vysokogore; Moskva.

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

Knechtel, M. M., 1952 — Pimpled plains of eastern Oklahoma. *Bull. Geol. Soc. Am.*, vol. 63.

Konishchev, V. N., 1964 — Pokrovnye lessovidnye obrazovaniya yugo-vostochnoy chasti Bolshezemelskoj tundry (Loess-like covering deposits of the south-eastern Bolshezemelskaya tundra). In: Problemy paleogeografii i morfogeneza v polyarnykh stranakh i vysokogore; Moskva.

Konovalov, A. A., 1965 — K voprosu o dinamike podzemnogo oledeneniya — vechnoj merzloty (On the dynamics of underground glaciation — permafrost). *Podzemnyj led;* vyp. 1, Moskva.

Konyukhov. I. A., 1951 — Podvodnye opolzni v produktivnoj tolshche Apsheronskogo poluostrova (Subaqueous slumping in the coal bearing beds of Apsheron peninsula). *Geol. Sbor.*, vyp. 1; Moskva.

Kostyaev, A. G., 1963 — Otlozheniya pokrovnogo kompleksa i blochnyj relief vostochnoj chasti Bolshezemelskoj tundry (Covering deposits and polygonal block relief of the eastern Bolshezemelskaya tundra). In: Kajnozojskij pokrov Bolshezemelskoj tundry; Moskva.

Kostyaev, A. G., 1964 — O proiskhozhdenii klinovidnykh i skladchatykh deformacij sloev v chetvertichnykh otlozheniyakh (On the origin of wedge- and fold-like deformations in Quaternary deposits). In: Problema paleogeografii i morfogeneza v polyarnykh stranakh i vysokogore; Moskva.

Kostyaev, A. G., 1965a — Problema genezisa periglacialnykh lessov v svete proiskhozhdeniya gruntovykh klinev (The problem of the genesis of periglacial loess in the light of the origin of ground wedges). *Vest. Mosk. Univ., ser. geogr.*, no. 5.

Kostyaev, A. G., 1965b — O yuzhnoj granice podzemnogo oledeneniya i periglacialnoj zone v chetvertichnyj period (On the southern boundary of underground glaciation and on the periglacial zone in the Quaternary period). *Podzemnyj led*, vyp. 2; Moskva.

Kostyaev, A. G., 1965c — O priznakah razlichiya merzlotnykh i konvektivnykh — diageneticheskikh — struktur v chetvertichnykh otlozheniyakh (Distinguishing of the features of periglacial and convection — diagenetic — structures in the Quaternary deposits). *Podzemnyj led*, vyp. 2; Moskva.

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

Köppen, W., Wegener, A., 1924 — Die Klimate der geologischen Vorzeit. Berlin.

Krasnov, I. I., 1944 — Chetvertichnye otlozheniya Molotovskoj i Sverdlovskoj oblastej (The Quaternary deposits in the Molotov and Sverdlovsk regions). In: Geologiya SSSR, t. 12: Ural; Moskva—Leningrad.

Kriger, N. I., Kopylova, V. P., 1964 — O plejstocenovykh „moroznykh" i „aridnykh" klinyakh v Pribalkhashe (On the Pleistocene „frost" and „arid" wedges in the area adjacent to Lake Balkhash). *Bul. Kom. po izuch. chetvert. perioda Akad. Nauk SSSR*, no. 29.

Krygowski, B., 1962 — Rola glacitektoniki w rozwoju niżowej rzeźby Polski zachodniej (summary: The part played by glacitectonics in the development of the lowland relief of western Poland). *Czasopismo Geogr.*, t. 33.

Krylkov, Y. V., 1957 — Periglacialnye otlozheniya v oblasti bassejna r. Kamy (Periglacial deposits in the Kama river basin). Tezisy dokl. Vses. mezhduved. soveshch. po izuch. chetvert. perioda: Russkaya ravnina; Moskva.

Ksandr, J., 1962 — Über die glaziale und periglaziale Problematik in der Tschechoslovakei. *Biuletyn Peryglacjalny*, no. 11.

Kudryavcev, V. A., 1954 — Temperatura verkhnikh gorizontov vechnomerzloj tolshchi v predelakh SSSR (Temperature of the upper horizons of permafrost within the USSR territory). Moskva.

Kuenen, Ph. H., 1953 — Significant features of gradded bedding. *Bull. Am. Assoc. Petrol. Geologists*, vol. 37.

Kuenen, Ph. H., 1958 — Experiments in geology. *Trans. Geol. Soc. Glasgow*, vol. 23.

Lang, W. B., 1943 — Gigantic drying cracks in Animas valley, New Mexico. *Science*, vol. 98.

Lavrushin, Y. A., 1960 — O proiskhozhdenii tak nazyvaemykh „merzlotnykh struktur oblekaniya" v chetvertichnykh otlozheniyakh i ikh stratigraficheskom znachenii (The origin of the „enveloping permafrost structures" in Quaternary deposits and their stratigraphical importance). In: Periglacialnye yavleniya na territorii SSSR; Moskva.

Lavrushin, Y. A., 1963 — Allyuvij ravninnykh rek subarkticheskogo poyasa i periglyacialnykh oblastej materikovykh oledenenij (Alluvial sediments of lowland rivers of the subarctic zone and of the Pleistocene periglacial areas). *Trudy Geol. Inst. Akad. Nauk SSSR*, vyp. 87.

Lazarenko. A. A., 1964 — Litologiya allyuviya 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.

Leckwijck, W. van, Macar, P., 1960 — Les structures périglaciaires antérieures au Würm en Belgique. Le périglaciaire prewürmien. Liège 9 au 12 juin, 1959. *Coll. Intern., Univ., vol. 17. Biuletyn Peryglacialny*, no. 9.

Leffigwell, E., 1915 — Ground-ice wedges, the dominant form of ground ice on the North Coast of Alaska. *Jour. Geol.*, vol. 23.

Litvinov, A. Y., 1962 — Sledy drevnykh kriogennykh processov i yavlenij v okrestnostyakh g. Krasnoyarska (The traces of past cryogenic processes and phenomena in the vicinity of Krasnoyarsk). *Trudy Inst. Merzlotovedeniya*, t. 18.

Lotze, F., 1932 — Über Schuchtaufrichtungen an Klüften. *Ztschr. Deutsch. Geol. Ges.*, Bd. 84.

Łoziński, W., 1909 — Über die mechanische Verwitterung der Sandsteine im gemässigten Klima. *Bull. Intern. Acad. Sci. Cracovie.*

Łoziński, W., 1910 — Die periglaziale Fazies der mechanischen Verwitterung. *C. R. XI Congr. Geol. Intern. Stockholm*, vol. 1, 2.

Łoziński, W., 1934 — Palsenfelder und periglaziale Bodenbildung. *N. Jhb. Min., Geol., Paläont.*, Bd. 71, Abt. B.

Macar, P., Antun, P., 1950 — Pseudo-nodules et glisement sous-aquatique dans l'Emsien inférieur de l'Ouesling. *Ann. Soc. Géol. Belgique*, vol. 73.

Maev, E. G., 1961 — O proyavlenii konsedimentacionnoj skladchatosti na dne Yuzhnogo Kaspiya (On the occurrence of folds synchronous with bottom sediments of the southern part of the Caspian Sea). *Doklady Akad. Nauk SSSR*, t. 137.

Maev, E. G., 1964 — Podvodnye opolzni i otlozheniya suspenzionnykh potokov na dne Yuzhnogo Kaspiya (Subaqueous slumping and sediments of the suspended currents on the bottom of southern part of the Caspian Sea). *Okeanologiya*, t. 4, vyp. 2.

Makowska, A., 1961 — Excursion in southern part of the Warsaw Basin: Baniocha. In: The Warsaw Basin, *Guide-book of excursions in the vicinity of Warsaw, VIth INQUA Congress.*

Maksimovich, G. A., Gorbunova, K. A., 1955 — Merzlotnye bugry v Molotovskoj oblasti (Frost-caused mounds in the Molotov region). *Priroda*, no 4.

Malaurie, J., 1949 — Sur des sols structuraux sous-marins de la côte Ouest du Groenland. *C. R. Acad. Sci.*, t. 228; Paris.

Markov, K. K., 1956 — Nature du milieu géographique des régions périglaciaires à la lumière des données paléobotaniques. *Biuletyn Peryglacjalny*, no 3.

Markov, K. K., 1958 — Sovremennaya Antarktida — drevnelednikovaya oblast severnogo polushariya (Present-day Antarctica — a counterpart of the Northern Hemisphere past glaciation). *Nauchn. Doklady Wysshej Szkoly, geol.-geog. nauki*, vyp. 1.

Markov, K. K., 1959 — Periglyacial Antarktidy (Periglaciation of Antarctica). *Biul. Sov. Antarkt. Eksped.*, no. 9.

Markov, K. K., 1961 — Problemy paleogeografii antropogena Marokko (Some problems of paleogeography of the Anthropogene of Morocco). *Biul. Kom. po izuch. chetvert. perioda*, no. 26.

Markov, K. K., 1965 — Tipy stratorajonov, glavnejshie cherty ikh razvitiya v chetvertichnom periode — gipoteza (Types of physical regions — principal features of their Quaternary development, a hypothesis). In: Chetvertichnyj period i jego istoria, Moskva.

Markov, K. K., Bodina, E. L., 1961 — Karta periglacialnykh obrazovanij Antarktidy (The map of periglacial phenomena of Antarctica). In: Antarktika; *Doklady Mezhduved. Kom. po izuch. Antarktiki za 1960.* Moskva.

Markov, K. K., Lazukov, G. I., Nikolaev, V. A., 1965 — Chetvertichnyj period, lednikovyj period — antropogenovyj period (The Quaternary period). Moskva; t.. 1—2.

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

Mead, W. J., 1925 — The geologic role of dilatancy. *Jour. Geol.*, vol. 33.

Michel, J. P., 1965 — Microtectonique périglaciaire quaternaire dans les formations sédimentaires du Bassin parisien. *Cahiers géol.*, No. 77—78.

Mishunina, Z. A., 1960 — Nekotorye tipy gravitacionnykh deformacij v terrigennom flishe (Some types of deformations due to gravity in the terrigenous flysch). *Geol. Sbornik*, vyp. 5, *Trudy VNIGRI*, vyp. 163.

Mojski, J. E., 1961 — Stratigraphy of the loesses. Cryogenic structures within loesses. Amount of fossil soils within loesses (Hrubieszów-Nieledev). In: *Guide-book of Excursion E: The Lublin Upland, VIth INQUA Congress.*

Molodykh, I. I. 1958 — Ob iskopaemykh sledakh merzloty v Priangare (On the fossil traces of permafrost along the Angara valley). *Trudy Vostochno-Sibirskogo fil. Akad. Nauk SSSR*, vyp. 15.

Morariu, T., Savu, A., 1964 — Quelques problèmes du modelé périglaciaire en Roumanie. *Bull. Assoc. Géogr. Fr.*, No. 322—323.

Mortensen, H., 1932 — Über die physikalische Möglichkeit der „Brodel" -Hypothese. *Centralblatt Min., Geol. u. Paläont.*, Abt. B: Geol. u. Paläont.

Mortensen, H., 1957 — Temperaturgradient und Eiszeitklima am Beispiel der pleistozänen Schneegrenzdepression in den Rand- und Subtropen. *Ztschr. f. Geomorph., N. F.*, Bd. 1.

Moskvitin, A. I., 1940 — „Ledyanye" klinya — klinovidnye treshchiny i ikh stratigraficheskoe znachenie („Ice" wedges — wegde-like fissures and their stratigraphic significance). *Biul. Mosk. Obshch. Ispyt. Prirody, otdel geol.*, t. 18.

Moskvitin, A. I., 1946 — Odincovskij interglacial i polozhenie moskovskogo oledeneniya sredi drugikh oledenenij Evropy (The Odintsovo Interglacial and position of the Moscow glaciation among the other glaciations of Europe). *Biul. Mosk. Obshch. Ispyt. Prirody, otdel geol.*, t. 21.

Moskvitin, A. I., 1958 — Chetvertichnye otlozheniya i istoriya formirovaniya doliny r. Volgi v ee srednem techenii (Quaternary deposits and formation of the Volga valley in its middle course). *Trudy Geol. Inst. Akad. Nauk SSSR*, vyp. 12.

Moskvitin, A. I., 1962 — Plejstocen Nizhnego Povolzhiya (The Pleistocene of the Lower Volga region). Moskva.

Nagtegaal, P. J. C., 1963 — Convolute lamination, metadepositional ruptures and slumping in an exposure near Pobla de Segur (Spain). *Geol. en Mijnbouw*, vol. 42.

Natland, M., L., Kuenen, P. H., 1951 — Sedimentary history of the Ventura Basin, California, and the action of turbidity currents. *Soc. Econ. Pal., Miner., Spec. publ.*, no 2.

Nazarenko, D. P., 1957 — O merzlotnykh smyatiyakh, klinovidnykh treshchinakh, glyaciodislokaciyakh i drugikh marginalnykh obrazovaniyakh v oblasti dneprovskogo lednikovogo yazyka (Frost disturbances, wedgelike fissures, glacial dislocations and other marginal features in the area of the Dneper ice-lobe). *Uchenye zap. Kharkovskogo Univ.*, t. 93.

Newsom, J. F., 1903 — Clastic dikes. *Bull. Geol. Soc. Am.*, vol. 14.

Novoselskaya, N. B., 1961 — Sledy sushchestvovaniya mnogoletnemerzlykh gornykh porod v predelakh Evropejskoj chasti SSSR, vne oblasti ikh sovremennogo rasprostraneniya (Traces of perennially frozen grounds within the territory of the European part of the U.S.S.R.). *Trudy Inst. Merzlotovedeniya Akad. Nauk SSSR*, t. 17.

Olchowik-Kolasińska, J., 1955 — Struktury kongeliflukcyjne w okolicach Łodzi (summary: Congeliflual structures in the region of Łódź). *Biuletyn Peryglacjalny*, no. 2.

Pataleev, A. P., 1955 — Morozobojnyje treshchiny v gruntakh (Frost fissures in grounds). *Priroda*, no. 12.

Patte, E., 1941 — Eocène et quaternaire soliflués de Pontpoint (Oise). Remarques général sur la solifluction. *Bull. Soc. Géol. France*, t. 11.

Pavlov, A. P., 1946 — Geologicheskij ocherk okrestnoj Moskvy (An outline of the geology of the vicinity of Moscow). Moskva.

Pécsi, M., 1963 — Die periglazialen Erscheinungen in Ungarn. *Pet. Geogr. Mitt.*, Jhg. 107.

Penck, A., 1938a — Das Klima der Eiszeit. *Verhandl. III Intern. Quart.-Konferenz*, Wien, 1936.

Penck, A., 1938b — Die Strahlungstheorie und die geologische Zeitrechnung. *Ztschr. Ges. Erdkunde z. Berlin.*

Petrascheck, W. E., 1934 — Sandklüfte in Braunkohle. *Centralbl. Min., Geol. u. Paläont.*, Abt. B: Geol. u. Paläont.

Péwé, T. L., 1959 — Sand-wedge polygons (tesselations) in the McMurdo Sound region, Antarctica. *Amer. Jour. Sci.*, vol. 257.

Péwé, T. L., 1962 — Ice wedges in permafrost, Lower Yukon river near Galena, Alaska. *Biuletyn Peryglacjalny*, no. 11.

Pfuhl, E., 1932 — Über die Schichtenstörungen in den unteren Sanden der Tongruben von Glindow (bei Werder i. M). *Ztschr. f. Geschiebeforschung*, Bd. 8.

Popov, A. I., 1953 — Osobennosti litogeneza allyuvialnykh ravnin v uslovijakh surovogo klimata (Characteristics of lithogenesis of alluvial plains under severe climatic conditions). *Izv. Akad. Nauk SSSR, ser. geogr.*, no. 2.

Popov, A. I., 1955 — Proiskhozhdenie i razvitie moshchnogo iskopaemogo lda (The origin and development of fossil thick ground ice). *Materialy k osnovam ucheniya o merzlykh zonakh zemnoj kory*, vyp. 2; Moskva.

Popov, A. L., 1957 — Geologicheskie i geomorfologicheskie usloviya territorii Podmoskovskogo stacionara (Geological and geomorphological characteristics of the area of the sub-Moscow station). In: Sezonnoe promerzanie gruntov i primenenie lda dlya stroitelnykh celej. Moskva.

Popov, A. I., 1959a — Gruntovye zhily na severe Zapadnoj Sibiri (Ground veins in the northern part of West Siberia). *Voprosy fiz. geogr. polyarnykh stran*, vyp. 2.

Popov, A. I., 1959b — Karty merzlotnogeomorfologicheskikh — periglacialnykh — obrazovanij na territorii SSSR (The maps of periglacial phenomena within the territory of the U.S.S.R.). *Voprosy fiz. geogr. polyarnykh stran*, vyp. 2.

Popov, A. I., 1959c — Periglacialnye i drugie zonalnye merzlotnye yavleniya — sovremennye i drevnie (Periglacial and other zonal phenomena — recent and fossil). *Vestnik Moskovskogo Univ., ser. biol. pochv., geol., geogr.*, No. 2.

Popov, A. I., 1960 — Periglacialnye obrazovaniya severnoj Evrazii i ikh geneticheskie tipy (Periglacial phenomena of northern Eurasia and their genetic types). In: Periglacialnye yavleniya na territorii SSSR. Moskva.

Popov, A. I., 1961 — Paleogeografiya plejstocena Bolshezemelskoj tundry (Paleogeography of the Pleistocene of the Bolshezemelskaya tundra). *Vestnik Moskovskogo Univ., ser. geogr.*, No. 6.

Popov, A. I., 1962a — Pokrovnye suglinki i poligonalnyj relief Bolshezemelskoj tundry (Covering silts and polygonal relief of the Bolshezemelskaya tundra). In: Voprosy geograficheskogo merzlotovedeniya i periglacjalnoj morfologii. Moskva.

Popov, A. I., 1962b — O psevdomerzlotnykh obrazovaniyakh (On the pseudo-periglacial phenomena). *Vestnik Moskovskogo Univ., ser. geogr.*, No. 3.

P o p o v, A. I., 1963 — Plejstocenovye otlozheniya v nizhnem techenii r. Pechory (The Pleistocene deposits in the lower Pechora valley). In: Kajnozojskij pokrov Bolshezemelskoj tundry. Moskva.

P o p o v, A. I., 1965 — Podzemnyj led (Underground ice). *Podzemnyj led*, vyp. 1; Moskva.

P o p o v, A. I., K o s t y a e v, A. G., 1962 — Karty periglacjalnykh obrazovanij Azii, sovremennykh i sredneplejstocenovykh (Periglacial maps of recent and middle-Pleistocene phenomena of Asia). In: Voprosy geograficheskogo merzlotovedeniya i periglacjalnoj morfologii. Moskva.

P o s e r, H., 1947a — Dauerfrostboden und Temperaturverhältnisse während der Würmeiszeit. *Naturwiss.*, Jhg. 34.

P o s e r, H., 1947b — Auftautiefe und Frostzerrung in Boden Mitteleuropas während der Würmeiszeit. *Naturwiss.*, Jhg. 34.

P o s e r, H., 1948 — Boden- und Klimaverhältnisse in Mitteleuropa während der Würmeiszeit. *Erdkunde*, Bd. 2.

P r i c e, P. H., L u c k e, J. B., 1942 — Primary limestone structures of West Virginia. *Amer. Jour. Sci.*, vol. 240.

P r y a k h i n, A. I., 1958 — Merzloto-geologicheskie yavleniya v tretichnykh i chetvertichnykh otlozheniyakh dolin rek Kamy, Vyatki i Beloj (Periglacial phenomena in the Tertiary and Quaternary deposits in the valleys of the Kama, Vyatka and Belaya rivers). *Nauchn. Dokl. Vysshej Shkoly*, ser. geol.-geogr., no. 3.

R a v s k i j, E. I., A l e k s a n d r o v a, L. P., V a n g e n g e j m, E. A., G e r b o v a, V. G., G o l u b e v a, L. V., 1964 — Antropogenovye otlozheniya yuga Vostochnoj Sibiri (Anthropogene deposists of the southern part of East Siberia). *Trudy Geol. Inst. Akad. Nauk SSSR*, vyp. 105.

R e m i z o v, I. N., 1961 — Iskopaemye sledy „vechnoj" merzloty i ikh znachenie dlya stratigrafii chetvertichnykh otlozhenij Ukrainy (Fossil traces of "perennially" frozen ground and their significance for stratigraphy of Quaternary deposits of Ukraine). In: Prirodnye resursy Levoberezhnoj Ukrainy i ikh ispolzovanie, t. 1; Kharkov.

R e t t g e r, R. E., 1935 — Experiments on soft-rock deformation. *Bull. Amer. Assoc. Petrol. Geol.*, vol. 19.

R i c h t e r, R., 1952 — Fluidal-Textur in Sediment-Gesteinen und über Solifluktionüberhaupt. *Notizbl. hess. L.-Amt f. Bodenforschung*, Bd. 6.

R o m a n o v s k i j, N. N., 1960 — Merzlotnye struktury oblekaniya — novyj vid pseudomorfoz po povtorno-zhilnym ldam v chetvertichnykh otlozheniyakh (Veneering frost structures). *Biuletyn Peryglacjalny*, no. 7.

R o m a n o v s k i j, N. N., 1961 — O stroenii Yano-Indigirskoj primorskoj allyuvialnoj ravniny i usloviyakh ee formirovaniya (The structure of the Yana-Indigirka coastal alluvial plain and the conditions of its development). *Merzlotnye issledovaniya*, vyp. 2; Moskva.

R ó ż y c k i, S. Z., 1958 — Próba odtworzenia procesu formowania się rzeźby polodowcowej. Eksperyment geomorfologiczny (summary: An experiment in geomorphology reconstructing the formation of glacial relief). *Acta Geol. Polonica*, vol. 8.

Schenck, E., 1955 — Die periglazialen Strukturbodenbildungen als Folgen der Hydrotationsvorgänge im Boden. *Eiszeitalter u. Gegenwart,* Bd. 6.

Schott, C., 1932 — Das Problem des Dauerfrostbodens in den Randgebieten des norddeutschen Inlandeises. *Ztschr. Ges. Erdkunde z. Berlin.*

Schönenberg, R., 1954 — Zur Geologie des Devon-Kulm-Gebietes bei Buchenau a. d. Lahn. *Ztschr. Deutsch. Geol. Ges.,* Bd. 105.

Schwarzbach, M., 1950 — Ein Pseudoeiskeil aus den Albaner Bergen bei Rom. *Geol. Rundschau,* Bd. 40.

Sekyra, P., 1956 — The development of cryopedology in Czechoslovakia. *Biuletyn Peryglacjalny,* no. 4.

Sekyra, J., 1960 — Působeni mrazu na půdu — kryopedologie se zvlástnim zřetelem k ČSR (summary: Frost action on the ground — cryopedology, Czechoslovakia). *Geotechnica,* 27; Prague.

Selley, R. C., Schearman, D. I., 1962 — The experimental production of sedimentary structures in quicksands. *Proc. Geol. Soc. London,* No. 1599.

Selzer, G., 1936 — Diluviale Lösskeile und Lösskeilnetze aus der Umgebung Göttingens. *Geol. Rundschau,* Bd. 27.

Shancer, E. V., 1962 — Problema granicy neogenovoj i chetvertichnoj — antropogenovoj-sistem (The problem of the Neogene-Quaternary boundary). *Trudy Kom. po izuch. chetvert. perioda Akad. Nauk SSSR,* t. 20.

Shchukin, I. S., 1963 — O tak nazyvaemykh "periglacjalnykh yavlenij" (On the so-called "periglacial" phenomena). *Vestnik Moskovskogo Univ., ser. geogr.,* no. 5.

Shepard, F. P., Einsele, G., 1962 — Sedimentation in San Diego Trough and contributing submarine canyons. *Sedimentology,* vol. 1.

Sheveleva, N. S., 1964 — Drevnie merzlotnye yavleniya v allyuvii srednechetvertichnogo vozrasta v rajone Krasnoyarska (Fossil periglacial phenomena in alluvial sediments of mid-Quaternary age in the Krasnoyarsk region). In: Problemy paleogeografii i morfogeneza v polyarnykh stranakh i vysokogore. Moskva.

Shrok, R., 1950 — Posledovatelnost v svitakh sloistykh porod (The sequence in the stratified formations). Moskva.

Shulc, S. S., 1964 — Ob izuchenii planetarnoj treshchinovatosti (On the study on planetary cracking). In: Deformaciya porod i tektonika. Moskva.

Shumskij, P. A., 1960 — K voprosu o proiskhozhdenii zhilnogo podzemnogo lda (On the origin of fissure-ice). *Trudy Inst. Merzlotovedeniya Akad. Nauk SSSR,* t. 16.

Siuta, J., 1962 — Rola gazów fermentacji beztlenowej w kształtowaniu powierzchni glebowej (summary: The part played by oxygen-free fermentation in forming the soil surface). *Przegl. Geogr.,* t. 34.

Skrylnik, P. P., 1964 — Genezis bugristo-zapadnogo reliefa v bassejne r. Ilima (The origin of hummocky- and pitted relief in the Ilim river basin). *Doklady Inst. Geogr. Sibiri i Dalnego Vostoka,* vyp. 6; Irkutsk.

Skrylnik, P. P., 1965 — Psevdomorfozy ledyanykh zhil kak sledy bolee shirokogo rasprostraneniya v proshlom poligonalno-zhilnykh ldov v Nizhne-Ilimskom rajone — yug Srednej Sibiri (Pseudomorphoses of ice veins as the traces of fossil existence of polygonal vein ice in the lower Ilim region — southern Central Siberia). *Izv. Vost.-Sibirskogo otdel. Geogr. Obshch. SSSR*, t. 63.

Smith, A. J., Rast, N., 1958 — Sedimentary dykes in the Dalradian of Scotland. *Geol. Mag.*, vol. 45.

Soergel, W., 1932 — Diluviale Frostspalten im Deckschichtprofil von Ehringsdorf. *Fortschr. Geol. u. Paläont.*, Bd. 11.

Soergel, W., 1936 — Diluviale Eiskeile. *Ztschr. Deutsch. Geol. Ges.*, Bd. 88.

Sokolovskij, I. L., 1955 — Ob iskopaemykh sledakh „vechnoj" merzloty v chetvertichnykh otlozheniyakh zapadnoj chasti USSR (On the fossil traces of "perenially" frozen ground in the Quaternary deposits of western Ukraina). *Doklady Akad. Nauk SSSR*, no. 4.

Sokolovskij I. L., 1958 — Lessovye porody zapadnoj chasti SSSR (Loesses in the western part of the U.S.S.R.). *Trudy Geol. Inst. Akad. Nauk SSSR*, ser. geomorph., chetvert. geol., vyp. 2.

Stainbrook, M. A., 1945 — The stratigraphy of the Indepedence shale of Iowa. *Amer. Jour. Sci.*, vol. 243.

Steche, H., 1933 — Beiträge zur Frage der Strukturböden. *Berliner Verhandl. Sachs. Akad. Wiss. Leipzig*, Math.-Phys. Kl., Bd. 85.

Steeger, A., 1944 — Diluviale Bodenfrosterscheinungen am Niederrhein. *Geol. Rundschau*, Bd. 34.

Steusloff, U., 1952 — Periglazialer "Tropfen"- und Taschenboden im südlichen Münsterlande bei Haltern. *Geol. Jhb.*, Bd. 66.

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

Straaten, L. M. J. U. van, 1954 — Sedimentology of recent tidal flat deposits and the psammites du Condzoz (Devonian). *Geol. en Mijnb.*, vol. 16.

Straaten, L. M. J. U. van, 1956 — Structural features of the „Papzand" formation at Tegelen (Netherland). *Geol. en Mijnb.*, vol. 18.

Sukhodrovskij, V. L., 1962 — Sklonovye processy v periglacjalnoj zone Zemli Franca Josifa (Slope processes in periglacial zone of Franz Josef Land). *Izv. Akad. Nauk SSSR, ser. geogr.*, no. 6.

Sullwold, H. H., 1959 — Nomenclature of load deformation in turbidites. *Bull. Geol. Soc. Amer.*, vol. 70.

Svensson, H., 1962a — Ett mönster i marken. *Svensk Geogr. Årsb.*, vol. 38.

Svensson, H., 1962b — Ice-wedge in fossil tundra polygons on the Varanger peninsula. *Svensk. Geogr. Årsb.*, vol. 38.

Ten Haaf, E., 1956 — Significance of convolute lamination. *Geol. en Mijnb.*, vol. 18.

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

Treskin, N. A., 1964 — Relikty poligonalnykh gruntov i proyavlenie poligonalnosti v centranykh rajonakh Evropejskoj chasti SSSR (Relict polygonal grounds and evidence of polygonal pattern in central part of the European U.S.S.R.). *Bul. Kom. po izuch. chetvert. perioda Akad. Nauk SSSR,* No. 29.

Tricart, J., 1956 — Cartes des phénomènes périglaciaires quaternaires en France. *Bull. Serv. Carte Géol. France.*

Tricart, J., 1960 — Manifestations périglaciaires de Quaternaire ancien en France. *Biuletyn Peryglacjalny,* no. 9.

Troll, C., 1944 — Strukturböden, Solifluktion und Frostklimate der Erde. *Geol. Rundschau,* Bd. 34.

Troll, C., 1947 — Die Formen der Solifluktion und die periglaziale Bodenabtragung. *Erdkunde,* Bd. 1.

Troll, C., 1948 — Der subnivale oder periglaziale Zyklus der Denudation. *Erdkunde,* Bd. 2.

Tutkovskij, P. A., 1899 — K voprosu o sposobe obrazovaniya lessa (On the origin of loess). *Zemlevedenie,* t. 6.

Tutkovskij, P. A., 1909 — Iskopaemye pustyni severnogo polushariya (Fossil deserts of the northern hemisphere). *Zemlevedenie,* kn. 1—4.

Vasilev, Y. M., 1958 — O sledakh proyavleniya merzlotnykh processov v chetvertichnykh otlozheniyakh Severnogo Prikaspiya (On the traces of permafrost processes in Quaternary deposits of Northern Caspian coast). *Izv. Akad. Nauk SSSR, ser. geol.,* no. 12.

Vassoevich, N. B., 1953 — O nekotorykh flishevykh teksturakh — znakakh (Some flysch structures — hieroglyphs). *Trudy Lvov. Geol. Obshch.,* ser. geol., vyp. 3.

Vaumas, E. de, 1964 — Phénomènes cryogéniques et systèmes morphogénétiques en Méditerranée orientale (Chypre, Galilée). *Rev. géogr. phys. et géol. dyn.,* vol. 6.

Vejsman, L. I., 1965 — Poligonalno-zhilnyj led Alaski i sopredelnoj territorii Kanady (Polygonal vein-ice of Alaska and confined Canada). *Podzemnyj led.* vyp. 1.

Velichko, A. A., 1965 — Kriogennyj relief pozdneplejstocenovoj periglacjalnoj zony — kriolitozony — Vostochnoj Evropy (Cryogenic relief of the periglacial zone of Eastern Europe during the Late Pleistocene). In: Chetvertichnyj period i ego istoriya. Moskva.

Velichko, A. A., Morozova, T. D., 1963 — Mikulinskaya iskopaemaya pochva, ee osobennosti i stratigraficheskoe znachenie (Mikulino fossil soil, its character and stratigraphic significance). In: Antropogen Russkoj ravniny i ego stratigraficheskie komponenty; Moskva.

Viete, G., 1953 — Über die erstinterglazialen Schotter der Salzke zwischen Bennstedt und Langenbogen. *Bergakad.,* Jhg. 5.

Viete, G., 1961 — Probleme der dynamischen Geologie des Quartärs in Nord- und Mitteldeutschland. *Prace Inst. Geol.* t. 34; Warsaw.

Vilenkin, V. L., Remizov, I. N., 1961 — Nablyudeniya v kraevoj lednikovoj i prilednikovoj zonakh Sumskoj i Poltavskoj oblastej (Investigations of glacial and periglacial border zones in the Sumsk and Poltava regions). In: Prirodnye resursy Levoberezhnoj Ukrainy i ikh ispolzovanie, t. 1, Kharkov.

Vinogradov, B. V., 1955 — Makropoligonalnost glinistykh ravnin (Macropolygonal pattern in clayey plains). *Doklady Akad. Nauk SSSR*, t. 104.

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. geogr.*, no. 1.

Vtyurin, B. I., 1964 — Kriogennoe stroenie chetvertichnykh otlozhenij na primere Anadyrskoj nizmennosti (Cryogenic structure of Quaternary deposits as exemplified by Anadyr Lowland). Moskva.

Washburn, A. L., Smith, D. D., Goddard, R. H., 1963 — Frost cracking in a middle-latitude climate. *Biuletyn Peryglacjalny*, no. 12.

Weinberger, L., 1944 — Frostpalten und Froststrukturen in Schottern bei Leipzig. *Geol. Rundschau*, Bd. 34.

Woldstedt, P., 1955—1958 — Das Eiszeitalter. Grundlinien einer Geologie des Quartärs. Bd. I—II, Stuttgart.

Wood, A., Smith, A. J., 1958 — The sedimentation and sedimentary history of the Aberystwyth grits (Upper Leandoverian). *Quart. Jour. Geol. Soc. London*, vol. 114.

Yan Huaj-zhen, Yan Sen-yuan, 1957 — New data on the Quaternary periglacial deposits in the lower Yangtse. *Kesyue tunbao*, no. 8 (in Chinese).

Zubakov, V. A., 1965 — Plejstocenovoe oledenenie severnogo polushariya — statika kriosfery (The Pleistocene glaciation of the northern hemisphere). In: Antropogenovyj period v Arktike i Subarktike, *Trudy NIIGA*, t. 143.