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SOME PERIGLACIAL PROBLEMS IN POLAND

Abstract

The author makes an attempt to classify the cryoturbations occurring in Poland. He draws special attention to involutions classifying them as: fold-like, pillar-like and amorphous. Among soliflual structures he distinguishes cylindrical solifluxion beeing the result of the flow speed difference between sandy and clayish masses of earth on a slope. The second problem presents the development of periglacial phenomena within individual glaciations. The author investigates these phenomena in time and space. Each periglacial zone splits up into sub-zones of varying microrelief and of different frost phenomena. These sub-zones change their position following the development or retreat of glaciation. When comparing the cryoturbations, it must be remembered that they originated not only in different glaciations, but also in different phases of the same glaciation. Therefore the apparently synchronous phenomena may eventually turn out as unsynchronous ones. The last problem under investigation is the question concerning the oldest periglacial zone in Poland. The author puts forward a hypothesis that the so-called „preglacial" deposits of south and middle Poland originated under periglacial conditions. They correspond to the oldest periglacial period in Poland.

INVOLUTIONS AND SOLIFLUAL STRUCTURES

The type of frost phenomena depends on the position of the layer in which they occur. These phenomena may generally be divided into two groups: soil structures in horizontal and in inclined layers. This is the simplest division. It is, however, not quite accurate, for between both these groups exist intermediate transitional soil structures, which at times make the proper classification difficult.

From the periglacial phenomena occurring in horizontal surfaces cryogenic disturbances have been distinguished. For these the author and J. Dylik (*7*) have adopted Denny's and Sharp's term *involution.* In the present situation, which abounded in morphographically and genetically indefinite disturbances, it proved to be a satisfactory and practical solution. The adopted term did not suggest anything in advance. It left the door open to future investigation, which was to discover new types of those phenomena and increase the possibility of solving their genetic sense. Therefore, in comparison with American authors, we have given the term *involution* a wider meaning.

J. Dylik (*7*) gives examples of involutions, in whose formation the frost sorting process of loose material played a decisive role. It is not difficult to link these Pleistocene periglacial phenomena with structural soils of the present Arctic region, about which W. Meinardus (*26*) speaks: „Under the term of structural soils it should be understood the type of ground, which assumes a definite structure after separating the stones from the earthy particles of soil".

Beside this type of involutions, arising by the motion of individual particles, another kind of those disturbances has been encountered. The process consists in the mutual shifting of layers, lenses and other

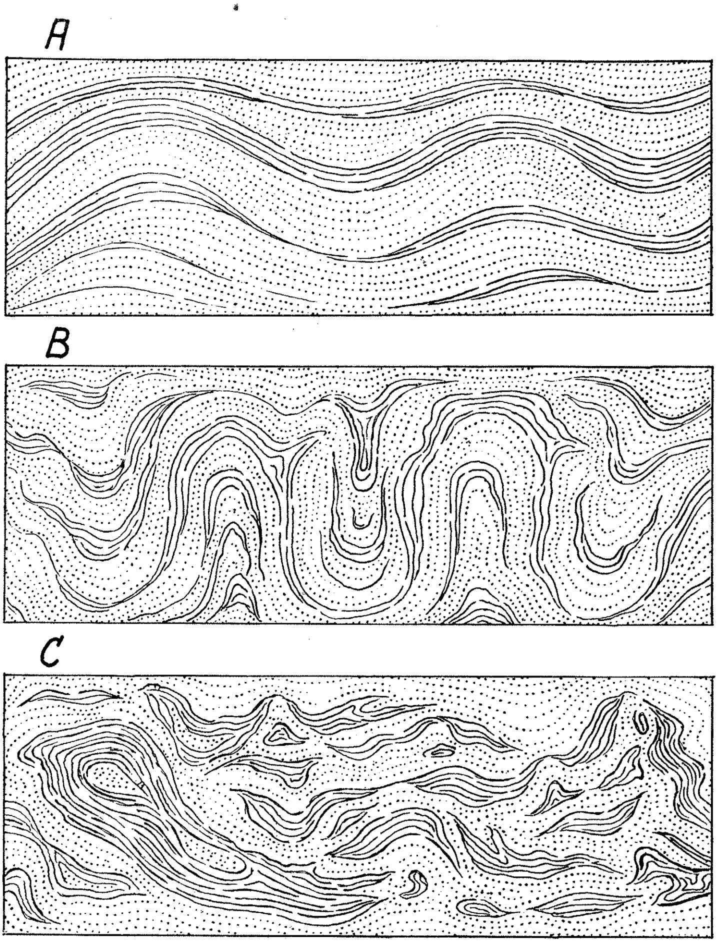

Fig. 1. Schematic examples of fold-(A), pillar- (B) and amorphous- (C) involutions
dots — sandy material; dashes — clayey material

less shapely pockets of material of fluid, semi-fluid or plastic consistence. We classify these disturbances in three groups: fold-, pillar- and amorphous structures (fig. 1). It is not difficult to state that these three types represent different formative stages of the same cycle. Owing to the involution original structure of the deposit disappears.

If the material, in which the cryoturbatic cycle was proceeding, had originally a stratified structure (e. g. water deposit), then as the involutions develop, the outline and the original pattern of layers become more and more blurred. In fold involutions the primary structure of a deposit is clearly visible; it is difficult to discern it, however, in amorphous involutions (pl. 1, 2).

This type of involutions is formed by the action of the following processes: 1. action of pressure on a moist and thereby plastic mass of soil accompanied by its freezing both from top and from bottom; 2. equalizing movements of soil resulting from melting of lenses, layers and veins of ground ice. This phenomenon has much in common with what C. Troll (*35*) calls micro-solifluxion.

Examining involutions the author has come to the conclusion that many of them correspond to the microrelief of bugor tundra, that is to Iceland thufurs. These hummocks occur in such places, where under the turf strong vertical movements of soil are taking place. The movements are due to the action of frost. These movements contribute to the rise of involution disturbances. It must be added that in such dynamic soils the ground ice is easily cummulating. The Pleistocene involution tundra may be compared with the tundra of north-east Europe (European part of USSR) described by A. A. Grigoriev (*12*), I. N. Gladcin (*11*) and Livierovskij (*21*).

Another type of cryoturbatic structures investigated in Poland for many years is solifluxion. This was the object of special study by M. Klimaszewski (*23*) in the Carpathians and by J. Dylik (*8*) in the Łódź Upland. The latter author has distinguished the Polar, frost type of solifluxion under the term of *congelifluxion*.

In the Pleistocene deposits of Poland have been found all types of solifluxion, known at present in Arctic regions. These types are: *free* and *bound solifluxion* of J. Büdel (*3*) and *plicated solifluxion* of K. Bryan (*2*). According to J. Dylik (*7*) all these types of slope mass movements had taken place on the frozen subsoil and therefore they should be considered as congelifluxion. J. Dylik quotes examples from the area of middle Poland and supplies detailed descriptions of congeliflual structures of each of the above-mentioned types.

The main object of the author's research was the bound solifluxion, that is the slope movements of entire layers of soil. Beside the frequently occurring *layer solifluxion* characterizes by its long lenses and layers extended according to the slope, the author has distinguished a particular type of periglacial slope structures under the name of *cylindrical solifluxion*.

In cross section these are the kettle-like, roundish forms composed of concentric layers of clay, sand or gravel. In such an arrangement they resemble the structures described by K. Gripp (*14*) under the name of *Brodelböden.* Their longitudinal section, however, is not exactly like the Brodels of Gripp. We see here spindle-like forms, thick and circular on top, extended down the slope. They become wedge-like in this direction. The cylindrical solifluxion arises when the degree of fluidity of the down-slope moving masses is not uniform. The layer, which has a higher internal friction and thereby is less mo-

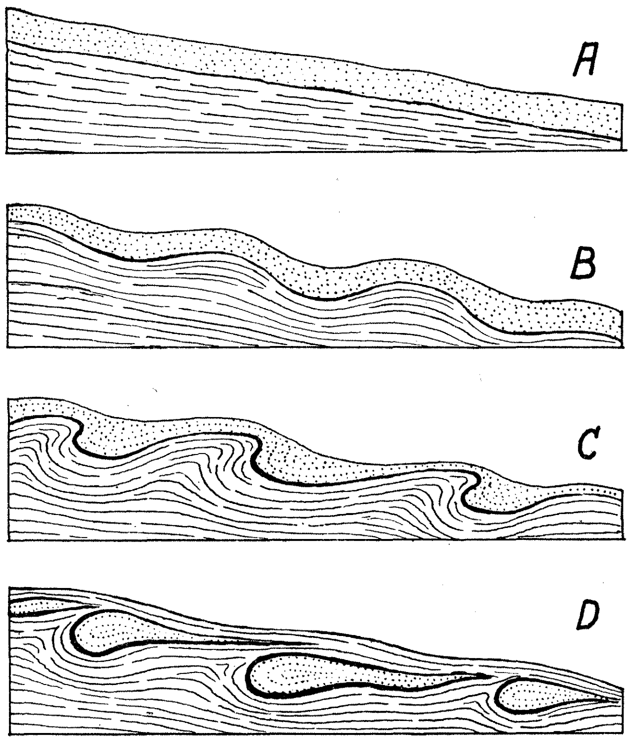

Fig. 2. Stages of development of cylindrical solifluxion

bile, occurs most often on the surface. It may be the weathering horizon, blown sands or the material from which rain water has washed away finer particles. The evolution of the structure proceeds gradually. Silt and clay masses flow down faster embedding and surrounding the layers of sand. The cycle of these changes is shown by the diagram (fig. 2) in which the individual stages of structure evolution have been duly emphasized. This type of solifluxion is not infrequent. The author identified it in 1951 mainly on the basis of a few, thoroughly investigated examples from the Lublin Upland (*17*). Later on he found out that this solifluxion is frequent in the periglacial phenomena of south-west Poland.

Cylindrical solifluxion, like some involutions, was linked up with the microrelief of tundra bugors, including their slope variety. The swellings and hummocks (fig. 2), in which patches of tundra slime force themselves out to the surface, are exactly the bugors. On slopes these evolve among others into tundra craters, that is ground sources known in Greenland from descriptions by A. Quervain (*29*) and P. Gelting (*10*) and also from author's own investigations (*16*). The cylindrical solifluxion in Spitsbergen has been described by W. Dege (*5*). This type of forms and structures in the Soviet sub-Arctic regions was known to V. N. Sukachev (*32*) and I. N. Gladcin (*11*).

THE PERIGLACIAL ZONE IN TIME AND SPACE INTERPRETATION

As the periglacial zone we call an area extending from the boundary of the ice-sheet, that is from the glacial zone to the Polar forest limit. This is the definition of space. The Pleistocene periglacial zone corresponds in time with the glacial or periglacial periods. Both these ideas should be compared and associated with each other. Periglacial facts and phenomena will then become elements of space—time Cartesian system of coordinates.

The limits of Pleistocene periglacial zone have changed their location: they shifted southwards and northwards following the changes of the climate. The European periglacial area is most frequently identified with the phase of maximum glaciation. This is, however, wrong; it is necessary to take into account that before and after the maximum of glaciation the periglacial zone had a different location than it did have in the extreme glacial phase. It was moved over to the north areas where the ice-sheet advanced or from where it retreated.

The climatic conditions in the contemporary periglacial zone are not uniform. A. A. Grigoriev, an eminent expert in this field (*12*, *13*), has divided this area into the Arctic and sub-Arctic. J. Büdel (*3*) followed later his example. Besides, Grigoriev distinguishes two zones within the sub-Arctic: northern, or close-to-arctic sub-Arctic, and southern, or close-to-boreal sub-Arctic. The periglacial zone is therefore composed of three zones which differ one from another in climate, vegetation and depth of summer thawing of soil i. e. in thickness of the active layer of frozen ground, in structure of this layer and in microrelief of the surface. The two latter facts are from the view-point of morphological and climatic periglacial investigation extremely important. It is obvious that, for instance bugors (thufurs) are typical phenomena of the sub-Arctic area, and structural soils, derived from sorting processes, are typical for the Arctic regions.

It has been author's aim to find out this climatic zonal arrangement in periglacial structures and forms of Poland basing the investigation mainly on the data taken from the Lublin Upland. The problem quite correct from theoretic point of view proved difficult and extremely complex in practice. Later it turned out that these difficulties were due to lack of a sound basis on which the periglacial phenomena found at different parts of the investigated area could be synchronised. They are the deposit profiles which originated in one glacial period and which are found to possess more than one horizon of cryogenic structures. These horizons differ one from another and they give good measure of climatic change in the same periglacial phase. The author observed pillar involutions which had been repeatedly cut by ice-wedges. The period of bugor tundra was followed by the period in which on the superficial part of frozen ground was carved a pattern of ice-veins and wedges.

The above-mentioned facts seem to indicate that the theoretic assumptions concerning the movement of internal zones in the periglacial area (as distinguished by A. A. Grigoriev, *13*) are right and justified by theory. It may therefore be imagined that in the time of the last glacial period each part of the area of middle Poland had originally a mild subarctic climate, and it was becoming more severe as the ice-sheet advanced, i.e. as the thermic curve of the glacial period deepened. This area was then covered by the arctic climate zone with the corresponding microrelief and its characteristic pattern of frozen ground.

Basing on all these assumptions and on evidence from the Lublin Upland, the author made a diagram showing the inconstancy of periglacial phenomena in middle and southern Poland during the last glaciation (fig. 3). The diagram is largely theoretic and not always properly supported by evidence.

The basis of the diagram is fixing the situation of periglacial zone during the maximum and at the close of the glacial period. The southern zone limit, i.e. the Polar forest limit ran at the time of maximum glaciation along the bord of the Carpathians or slightly to the south of these mountains (according to W. Szafer's investigation, *33*). The breadth of the periglacial zone in Poland was nearly 500 km[1]. At the close of glaciation the forest limit passed through middle Poland (the data according to W. Szafer, *24*). In this way we find two reference points both on the time and space axes. This enables us to follow the change of position in periglacial zone on the graph. Considering general knowledge concerning the climate of glaciation, it has been accepted that the succession of changes after the maximum of glaciation was twice as quick as before the maximum. The assumed disposition of the Pleistocene subarctic zones and of the arctic area has been drawn on the diagram in analogy with the present Euro-Asian periglacial zone.

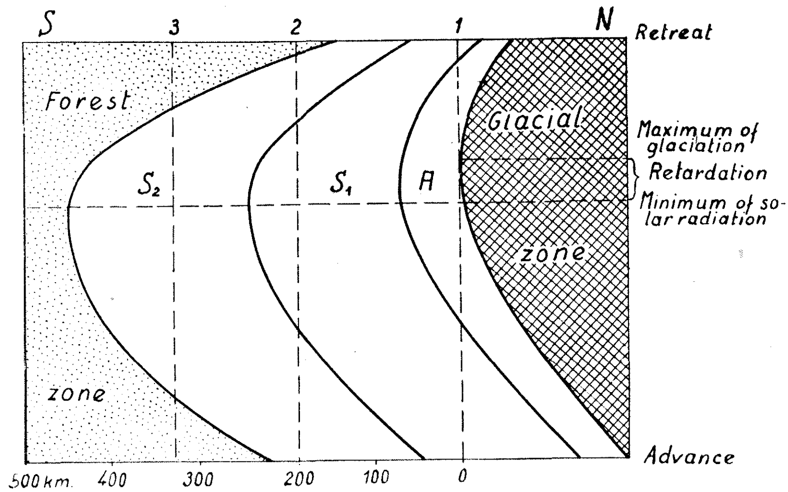

Fig. 3. Periglacial zone in time of the last glaciation in Poland
A — arctic zone (detrital); S_1, S_2 — sub-arctic zone (tundra); 1. maximum range of the last glaciation; 2. northern edge of Uplands; 3; border of the Carpathians

By the requirement of the time—space analysis of periglacial facts, the author wishes to emphasize the importance of the time factor. The time of origin of cryogenic structures may be estimated on the basis of their stratigraphic situation. The author thinks that so far this moment has not been given proper consideration in the contemporary synthesis of the European periglacial phenomena (e.g. H. Poser,

[1] Herewith the author is correcting the error which had crept into his paper of 1951 (*17*), where the breadth of the zone in Poland was estimated for **1000** km. The error appeared then also in the enclosed diagram. The diagram of the present paper (fig. 3) corrects the error. It was the breadth of the Pleistocene periglacial zone of western Europe that reached **1000** km.

27). The reliability of synchronisation of these phenomena is not sufficient. The soil disturbances compared as synchronous may have originated at different phases of periglacial time, i. e. from its different climatic zones. Only the space factor has been considered i. e. spatial situation, but not their position in time.

A great step forward has been recently made in the stratigraphical investigations of Pleistocene formations in Poland. There exists convincing evidence that the ice-sheet entered the area of Poland at least four time. The particular glaciations consisted of two or three cold phases separated by interstades. An exceedingly cold phase occurs also within the Great Interglacial (Mindel-Riss). E. Rühle (*28*) has found in the northern part of our country glacial deposits, which come from the same period. Thus we find at least 10 glacial horizons in Poland.

Each glaciation corresponds to a different periglacial zone. Its development or decay was in close connection with the advance or retreat of the ice-sheet. Furthermore, the periglacial zone was more responsive to climatic changes than the ice-sheet. We can expect therefore that in individual glacial phases the area was changing its location.

The situation of Pleistocene periglacial zones has been shown in the following diagram (fig. 4). The basis adopted here was the quantity and range of glacial horizons according to Rühle (*28*). The diagram refers to the 20th meridian which cuts Poland in its maximum extent. There exists a certain conformity in the situation of these glacial horizons and climatic changes expressed therewith with the curve of Milankovič. It is why the time axis of the diagram, i. e. the duration period of particular glaciations and interglacial times, has been set on this curve. The range of periglacial zones of all glaciations has been determined following the well known data concerning the location of this zone during the last glaciation in Poland. It amounts 500 km. at the time of maximum extension of the ice-sheet. This is of course the minimum value giving only the area of tundra and arctic periglacial zone without intermediate periglacial influences, as was the case with boreal forest. It should be imagined that in this generalized picture each periglacial maximum is represented by such arctic and subarctic zone arrangement as shown in previous diagram (fig. 3).

Our diagram reveals a very important fact which generally escapes our intention. Poland is the area of middle Europe which was undergoing the periglacial processes most persistently and in a very strong degree. In all glaciations the area of our country remained totally or partly within the range of periglacial zone. The above conclusion holds ground even, if the diagram will prove slightly erroneous. It will then, of course, require correction, that is a certain move of the glacial and periglacial zones in this or in other direction. The periglacial zone

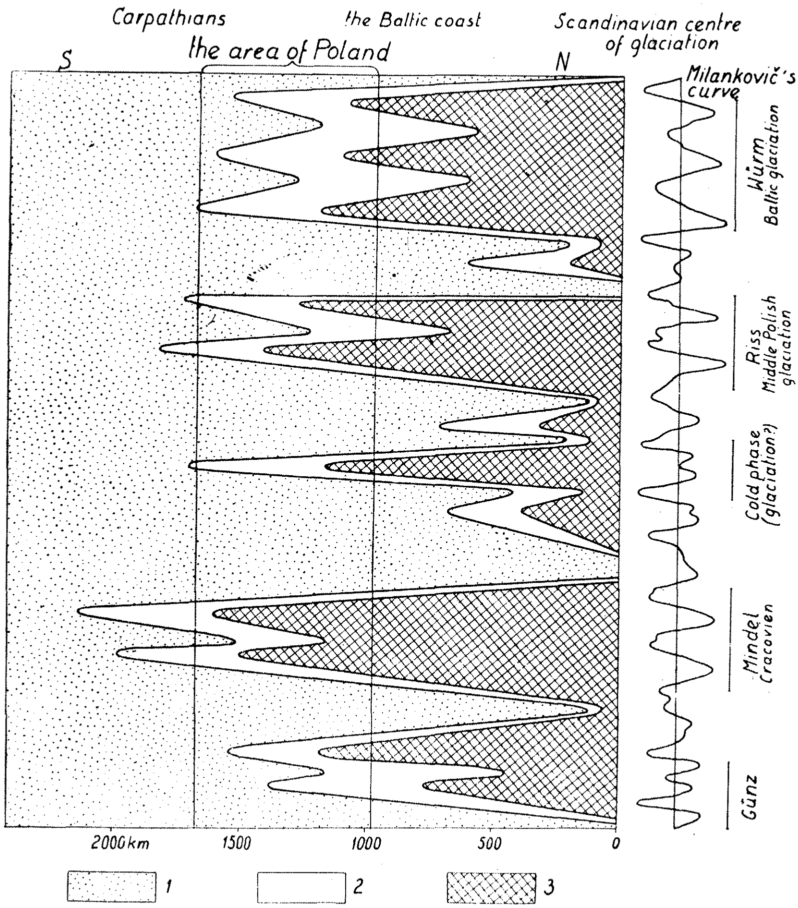

Fig. 4. Scheme illustrating location of periglacial zone in Poland during particular glaciations. Extent of glaciations according to E. Rühle
1. forest zone; 2. periglacial zone; 3. glacial zone

of the last (Baltic) glaciation dominates by its optimal position within the border of our country. It is quite obvious that the last periglacial period has affected at large the relief of Poland.

The diagram also stresses the importance of sub-fossil and fossil periglacial zones. The first type represents periglacial surfaces of older glaciations, which had been remodeled in later glaciations and in a new periglacial environment. It is obvious that between these periglacial periods is formed a relief of the interglacial times of distinct peculiarity. The example is the periglacial surface of Middle Polish glaciation, overlaid by the Baltic periglacial phase. The Lublin Upland may be regarded here as the most typical. There on its surface survived till now the traces of accumulation covers as also the relief of, at least, two periglacial zones.

The other type, that is, the fossil periglacial surfaces occur under the covering of glacial deposits. The knowledge concerning these surfaces is scarce. It is to be believed that each glacial horizon hides under its formations some periglacial surface. Undoubtedly the most interesting is the very old surface buried under the moraines of maximum glaciation. Let us examine this problem separately.

THE OLDEST PERIGLACIAL PERIOD IN POLAND

This period should be parallelled with the oldest glaciation, about which our knowledge is unfortunately scarce and uncertain. It precedes the Cracow glaciation (Mindel) of W. Szafer (*33*) and, in chronology of six glacial periods of B. Halicki (*15*), it corresponds probably with the first two glaciations. So to a large extent it is a postulated and not confirmed „Szczecin" glaciation. Considering the general stratigraphy of Pleistocene in Europe, it should be expected that the cooling down of Günz and pre-Günz („Donau glaciation") ought to have left some traces in the stratigraphic horizon, which is located lower than the moraines of Cracovien. Traces of this cooling down have been discovered in the flora of Mizerna profile near Czorsztyn by W. Szafer (*34*). B. Halicki (*15*) and E. Rühle (*28*) have found in this horizon glacial formations. It is therefore probable that this ice-sheet covered north and middle Poland and reached almost the Lublin Upland (*18*, *22*). It follows therefrom that the whole south Poland with the Carapthians and Sudetes and adjoining areas belonged to the periglacial zone of this glaciation.

The problem under discussion is connected with the problem of the limit between Tertiary and Quaternary age on the area of our country. As more precise data are not available an idea of the so-called „preglacial" formations has been introduced, i. e. deposits devoid of northern (Scandinavian) material and located under the oldest glacial formations having no distinct features (fauna and flora first of all) of the Tertiary. In these deposits we find the oldest cryoturbations, which may be considered as evidence for the oldest periglacial zone.

The Lublin Upland provides us with examples. In the bottom of glacial formations occur gravels and sands containing quartz, lydites and flints, which the author and M. Turnau - Morawska once qualified as preglacial formations (*19*). In the northern part of the Upland in between gravels and glacial deposits (with crystalline material of the north) there occur patches of loess-like silts. They possess typically soliflual structure.

J. Czarnocki (*4*) has written about similar formations lying at the bottom of Quaternary deposits of Swiętokrzyskie Mountains (Łysogóry). J. Samsonowicz (*30*) mentions an old sub-moraine loess from Łopatki in the environs of Opatów.

A remainder of old preglacial formations occur also in the areas of south-west Poland. They have been lately found in the Sudetes and in the basin of Jelenia Góra. The best display of them is at Jelenia Góra, in a brick-kiln, located southward from the town (fig. 5). In an exten-

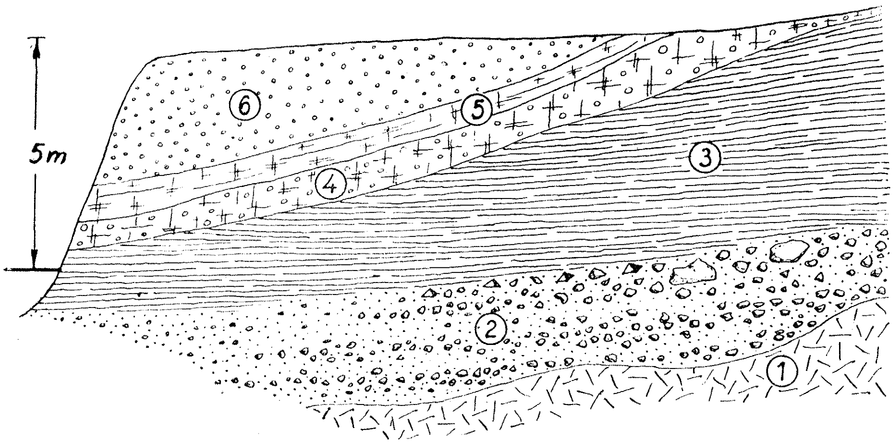

Fig. 5. Terrace profile of Kamienna Valley, south of Jelenia Góra
1. granite of Karkonosze; 2. preglacial detrital material and sand, eologlyptoliths on surface; 3. varved clay; 4. boulder clay; 5. soliflual boulder clay; 6. the terrace fluvial gravel

sive area, under boulder clay and a thick layer of varved clay (8 m. in thickness) it has been exposed detritus and sand consisting exclusively of local rocks (the granite of Karkonosze). These are the deposits brought from slopes of nearby hills and set at bottom of the basin (pl. 3). The type of material and the structure of the deposit indicate rainwater acting under the continental climatic conditions: rhythm, alternate occurrence of detritus and sand in vertical profiles. Nearer to the slopes of the basin occur in these deposits some traces of landslides and gravitational creeping, soliflual in character. There are to be found granite blocks of varying size, marvellously smoothed by wind (pl. 3). Some of them have the form of typical faceted stones with surfaces carved in eolian way by grooves and flutes. Characteristic eolian activity is to be seen also on the surface of knobs in the granite bedrock. Here has been found a large faceted stone, 3 m. in diameter (pl. 4).

Advancing from the north deep into the Sudetes the ice-sheet found such a bottom surface in the basin of Jelenia Góra. The surface had been submerged in an ice-dammed lake and covered with varved clay and moraine. The glaciation under discussion is the oldest glaciation in Sudetes and corresponds at least with the Middle Polish glaciation, or, which is more likely, with the Cracovien. Therefore the detrital cones from the bottom of Jelenia Góra basin, devoid of northern material, constitute the local preglacial. This relative age had once been ascribed to them by G. Berg (*1*). The author thinks it to be not only preglacial, but periglacial as well. In fact, the author has not discovered here typical cryoturbations, except for some weak traces of solifluxion; however, the great accumulation of detrital material, the typical texture of arid deposit, the occurrence in it and on its surface of wind-worn stones indicate that the described formation originated under conditions of dry and probably cold desert. Sharp-edged and quite unweathered feldspars (as a rule they are kaolinized in Tertiary deposits) and close stratigraphic neighbourhood of glacial deposits may serve as an evidence.

The author quoted the Sudetic preglacial formations more in detail to draw attention to their „climatic" characteristics, which so far have often been omitted. Since J. Lewiński's investigation (*20*) on the preglacial formations of Warsaw's and Łódź's neighbourhood, the number of known localities of these formations has considerably increased. They occur in the Polish Lowland under a thick series of glacial deposits. They are also to be found in the Polish Uplands and in the Carpathians, being preserved here in remnants at bottoms of old basins and valleys. On the ground of investigations in the Lublin Upland (*18*) the author is inclined to believe that the preglacial deposits belong already to the Quaternary age; they are the reflection of the glaciation which had not reached middle and southern areas of Poland. It has been sufficiently testified by W. Szafer (*34*) that this deep climatic shift opening Pleistocene marks itself in the deposits of Carpathian basins (Mizerna, Czorsztyn). Also E. Rühle (*28*) classifies the deposits of the Polish preglacial time as belonging to the Quaternary. The very fact of abundant gravel-and-detrital sedimentation which is linked up with strong mechanical weathering and with periodic changes of water level in rivers may serve as a measure of climatic cooling at the time of origin of these deposits. Further climatic evidence is the cold flora of Mizerna profile.

To make sure that these preglacial deposits are simultaneously periglacial formations, it would be necessary to prove that periglacial cryoturbations occur in them. Unfortunately our knowledge in this respect is rather scarce, because the mentioned formations are known from drilling, and not from exposure. Therefore the above given facts from the Lublin Upland and Sudetes appear important to the author. They deal with the presence of solifluxion and eologlyptoliths in preglacial deposits. The phenomena indicating wind action in these deposits have also been found by J. Lewiński (*20*); he considered them as evidence of a warm but not a cold desert.

It is worth remembering that the characteristics of periglacial climate are commonly and, since a long time, well known from preglacial deposits of southern coast of England (detritus from the formation *head*, *36*). S. Mazenot (*25*) has recently given information about cryoturbations from preglacial formations in the vicinity of Lyon.

The time which had elapsed between the warm Pliocene and the fully developed Cracovien (Mindel) was relatively long and might have enclosed several cold climatic phases. It is doubtful whether all these phases on our territory have already had periglacial climate. The transition from Pliocene to Pleistocene was slow and it is impossible to determine at present when the first visible signs of periglacial phenomena began to appear in the deposits of this period, i. e. in „preglacial" formations. The fact should also be borne in mind that the first great glaciation in Poland (that of Cracovien — Mindel) was preceded by its own periglacial phase beginning and preceding the given glacial cycle. Frost structures in the direct subsoil of deposits of this glaciation may be, and most often are derived from the very periglacial phase and not from a separate glaciation, older than the Cracovien. As for Sudetes one should reckon with the possibility that periglacial deposits and their cryoturbations are even younger. It cannot be excluded that the Middle Polish glaciation (Riss) attained here its maximum range. It was this glaciation only that had reached inside the mountains. The local preglacial formations may therefore correspond with the Cracovien.

It follows that the problem of periglacial origin of preglacial deposits of Poland contains many unexplained points. It may be cautiously stated the existence in Poland of some preglacial series of deposits differing in age. Among them are formations which correspond to the old distinct glaciation, as yet little known in Poland. There are also deposits which originated at the time of younger glaciations, e. g., Cracovien. Many facts indicate that these formations originated in a dry, cold and quite periglacial sedimentary environment. They are therefore the remainder of the oldest period, or, rather of the oldest periglacial periods in Poland.

Translated by M. Zieliński

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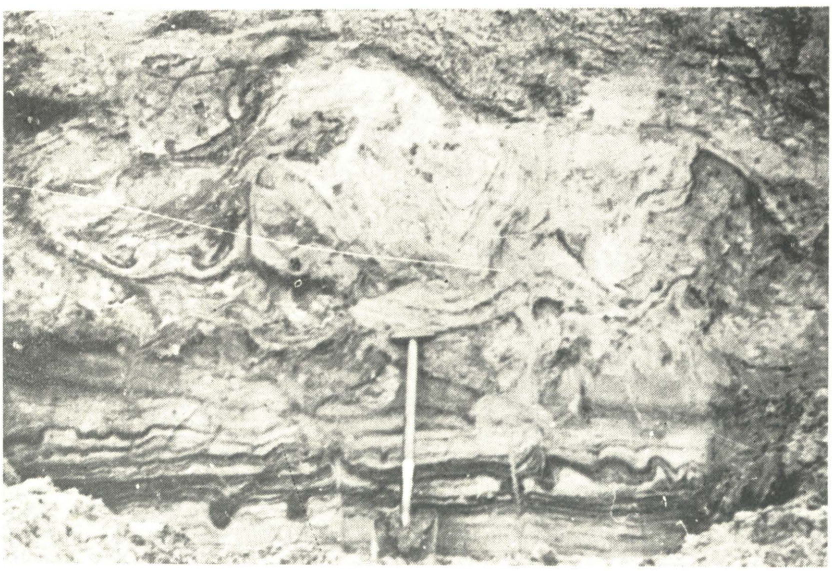
photo by A. Jahn, 1953

Pl. 1. Fold- and pilar involutions in Pyskowice (Silesia)



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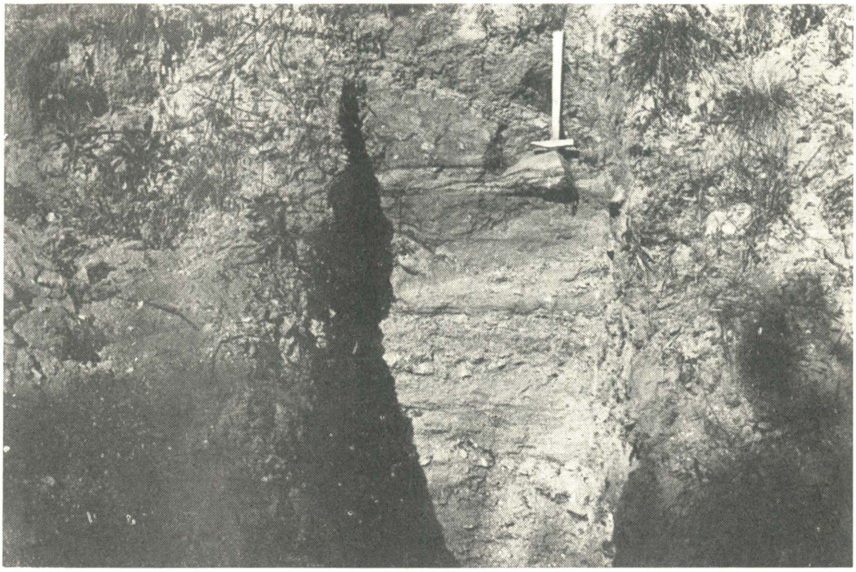
Pl. 2. Amorphous involutions at Milejów near Lublin



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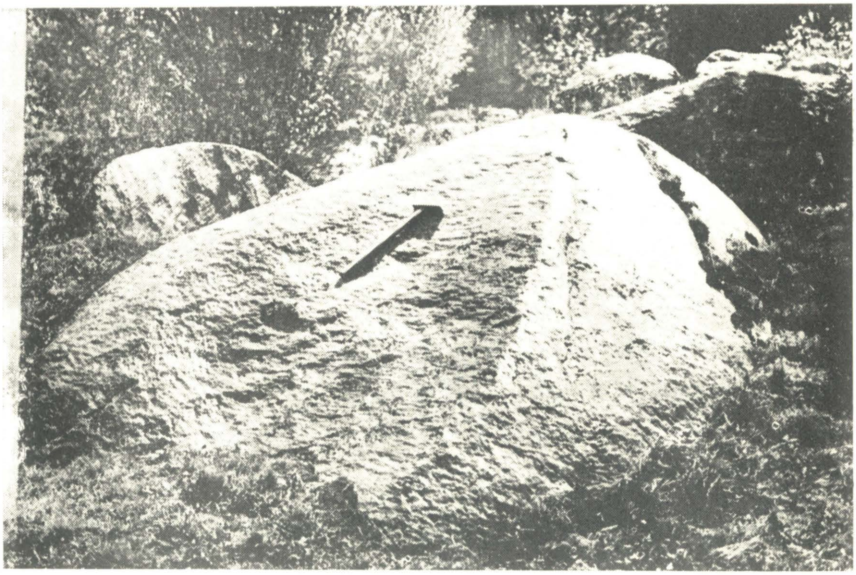
Pl. 3. Jelenia Góra. Sandy-detrital preglacial formations with traces of soliflual structure. On their top (hammer) faceted stone in its natural position. The eologlyptolith borders preglacial formations and varved clay



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Pl. 4. Wind-worn granite knobs occurring within preglacial surface in the vicinity of Jelenia Góra