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FROST FISSURES IN LOESS DEPOSITS

Résumé de l'auteur

L'auteur a distingué dans la couverture de loess deux types génétiques des structures de fentes dues à la contraction thermique: les structures à remplissage secondaire saisonnier, correspondant à la phase de croissance du Würm et les structures à remplissage secondaire, développées dans deux horizons stratigraphiques de la phase de climax du Würm — l'un dans la partie plus ancienne et l'autre dans la partie plus récente.

Les structures de fentes à remplissage secondaire saisonnier ne se sont développées que dans la zone active du pergélisol. Les fentes dues à la contraction thermique se manifestant en automne, se remplissaient tout de suite de l'eau qui y gélait. Au printemps, lors de la fonte de la glace le matériel des parois des fentes et de la surface migrait vers les fonds des fentes. Ce processus s'est répété bien des fois.

Les structures des fentes à remplissage secondaire se sont développées aussi bien dans la zone active que dans le pergélisol. La glace de fentes dans le pergélisol s'est formée pendant vue période relativement longue. Au fur et à la mesure que le sommet du pergélisol s'abaissait, la glace de fentes fondait et à ce temps le matériel provenant du voisinage le plus roche des fentes y tombait à force de gravité.

The fissures are of great paleogeographical importance, especially those with secondary infilling after fissure ice. They have engaged a good deal of attention. Detailed investigations embrace frost-fissure polygons originating at present time in permafrost areas, as well as fossil Pleistocene structures. In Poland this problem has been widely discussed (DYLIK, 1956, 1963, 1967; DYLIK, DYLIKOWA, 1960; GOŹDZIK, 1967; JAHN, 1951, 1969; JAHN, CZERWIŃSKI, 1965; MARUSZCZAK, 1968; MALINOWSKI, MOJSKI, 1960; MOJSKI, 1965).

According to JAHN (1970) the development of polygons in the area of Poland took place at the mean annual temperature lower than —3°C, while GOŹDZIK (1973) holds that it was beneath —5°C, the minimum temperatures being often lower than —20°C and even —30°C. The development of frost-fissure structures requires great thermal gradient characteristic of the continental climate in relatively short period of time (DYLIK, 1963; ROMANOVSKIJ, 1973; VTYURIN, VTYURINA, 1960).

In the loess areas there have several horizons with such structures been recognized as belonging to the last cold period. Some authors have distinguished as many as 5—6 horizons, i. e. in the area of Lower Saxony and Hesse (ROHDENBURG, 1967), in the loess area in Poland (JAHN, 1969, 1970). According to JAHN the oldest horizon of fissures came into being immediately after the Brörup Interstadial, the subsequent three ones developed after the Paudorf Interstadial in the upper part of Pleniglacial (above the Komorniki horizon), and in the waning phase of the Würm – the fissure structures appeared in one or two horizons. It seems that there have been distinguished too large a number of fissure horizons with the origin attributed to thermal contraction. The fissure structures occurring in loesses are of various dimensions: from large forms of several meters in depth to tiny fissures, and from fissure polygons of several tens of meters and more in diameter to small ones of less than 1 m across.

With all probability the dehydration gave rise to some of these fissures but the discernment between the frost- and dehydrational structures is difficult. The most reliable criterion is the size of fissures and of polygons. The dehydrational structures are generally much smaller and form little polygons, whereas those originated due to thermal contraction are bigger and form larger polygons. The dehydrational fissures are commonly 0.5 m deep, only occasionally deeper, and in their upper parts less than 20 cm wide. The net of these tiny fissures is dense, the diameters of polygons are several tens of centimeters to 1–2 m (Kaplina, Romanovskij, 1960, page 2). Under specific ground and moist conditions there can develop the dehydrational polygons of greater sizes, up to 100 m with fissures 1m wide (Goździk, 1973) and 3 m deep (Słowański, 1963).

The dehydrational fissures reach the depth of desiccation; in the loess areas it has never been very deep, especially in places where during the formation of fissures the deposits were only several meters thick. As loesses are fine-grained sediments with a great general porosity, there is a preponderance of capillary pores with a high table of capillary water. In these sediments the desiccation zone has always been shallow. During the interglacial a dense mantle of vegetation protected the ground from an excessive drying. In the cold periods the vegetation was poorer but permafrost formed an impermeable layer which retained a high ground water table. In summer the desiccation zone did not exceed 0.5 m owing to the capillary attraction. It seems that in loesses only tiny polygonal fissures reach 0.5 m of depth and, only exceptionally, greater ones are probably associated with desiccation. Slightly larger fissures must have originated in the valley loess where the oscillations of moisture were much greater and some dehydration cracks could have been linked with those formerly developed and lower lying (Pl. 14).

The tiny fissures from the Würmian waning phase described by Maruszczak (1954) are likely to be the examples of such dehydrational fissures. These small fissures occur in small depressions in which the ground was at least seasonally strongly moistened. Such conditions favoured rather the development of dehydrational fissures and to a lesser degree the development of thermal contraction, which has been emphasized by Goździk (1973). The origin and stratigraphical position of some other horizons of fissure structures are also obscure.

The present author's investigations carried out in the loess area have revealed two kinds of fissures which may be associated with thermal contraction. They occur in three stratigraphic horizons and are the fissures with secondary seasonal infilling and the fissure structures with secondary infilling.

FISSURES WITH SECONDARY SEASONAL INFILLING

The lowermost horizon of fissures with secondary infilling came into being during the waxing phase of the Würm. They have been considered as pseudomorphoses after the tree-root system (Grabowska-Olszewska, 1963; Klatka, 1970; Różycki, 1967; Straszewska, Kopczyńska, 1961). This horizon is characteristic of the arid loess areas (Jersak, 1973a), and of common occurrence in central and eastern parts of Poland, excepting their northern fringes. It has not been encountered in the humid zone so far. Such a distribution of the fissure structures with secondary seasonal infilling rather excludes their dehydrational origin (Cegła, 1972). In the humid zone the differences in the ground moisture were much greater than in the arid one. In Western Poland, where the influence of humid climate has been stronger,

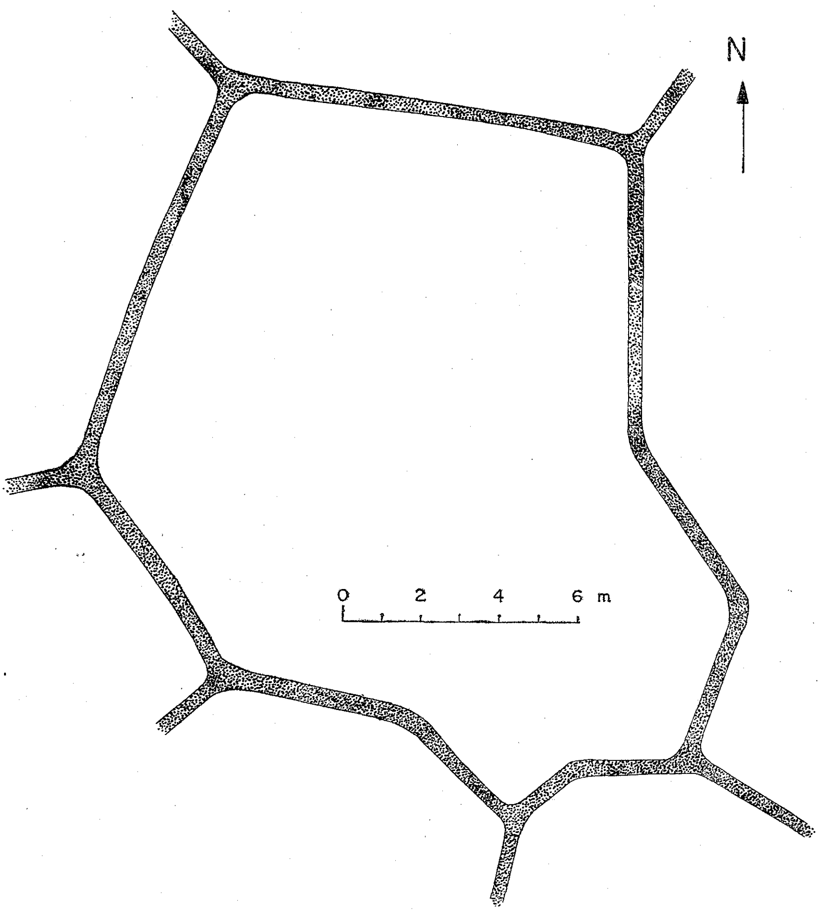

Fig. 1. Hrubieszów — brickwork "Feliks", the Lublin Upland. Fissure polygons with secondary seasonal infilling; generation of large polygons

the deposits were periodically moistened at a greater rate than in central and eastern Poland. This is evidenced by the traces of strong gleyfication in western Poland. Periodical desiccation occurred throughout the whole loess area in the Polish Southern Uplands.

The net of fissures with seasonal secondary infilling from the older part of the Würm comprises three generations of polygons: large, middle and small polygons. The largest ones, from 4 m to over 10 m in size are characterized by fissures 20—50 cm wide in their upper part and 1.5—2.5 m deep (Pls. 1, 2; Fig. 1). The diameter of polygons of the middle generation reaches to about 1—2 m, the width of the fissures does not exceed 10 cm, and their depth is 1 m (Pl. 3). The generation of the smallest polygons, 30—50 cm in diameter, displays tiny fissures, 1—2 cm wide, whose depth reaches up to some decimeters only; because of their sizes they are inconspicuous and therefore can be easily overlooked, especially in the vertical cuts.

All the generations of polygons from the older part of the Würm, dissecting the Eemian soil (Fig. 2) are infilled with the distinctly stratified material: dark-and light grey (Pl. 4). The dark layers come from the destroyed accumulational horizon of the soil lessivée while the lighter material comes from the leached horizon of the same soil belonging to the soil complex of the Nietulisko I type (Jersak, 1973b).

This type of fissure structures had originated before the final formation of the interstadial chernozems from the Würmian waxing phase. The fissures do not cut chernozem and in the majority of exposures the fissures are not filled with chernozem. However, the author has observed the fissure structures filled with chernozem; they were fissures with seasonal secondary infilling at Żyć Samborzecka, on the Little-Poland Upland (Pl. 15). At Hrubieszów the structures of this type are cut by the molehills (Pl. 5) which should have been connected with some period of the development of chernozem in the Würmian waxing phase, during several warmer oscillations (Jersak, 1973b). The fissure structures with secondary seasonal infilling originated in some cold stage separating warmer oscillations (Fig. 2).

The fissures from the waxing phase of the Würm developed in the active zone of permafrost and at least some of them are the frost fissures. On account of their size only two generations of smaller fissures can belong to dehydrational type. The largest polygons were formed due to thermal contraction, which is best proved by the fissure structures at Lenarczyce (Dylik, 1963) and at Błogocice on the Little--Poland Upland (Pl. 6) where they cut sands and gravels. The dehydrational fissures have never been formed in sands and gravels (Goździk, 1973; Jahn, 1951).

These fissure structures are called by Romanovskij (1973) the fissures with secondary seasonal infilling after the elementary ice veins. Katasonov (1958) and Popov (1959) call them „żyly odgibania" (filled veins) and „żyly zapolnieniya" (sag fissures). In autumn, when the temperature rapidly falls down, some tiny fissures of thermal contraction were formed in the freezing active zone. They were immediately filled with water which was getting frozen. The minute ice veins infilling the fissures persisted till the spring. In spring the material creeping down

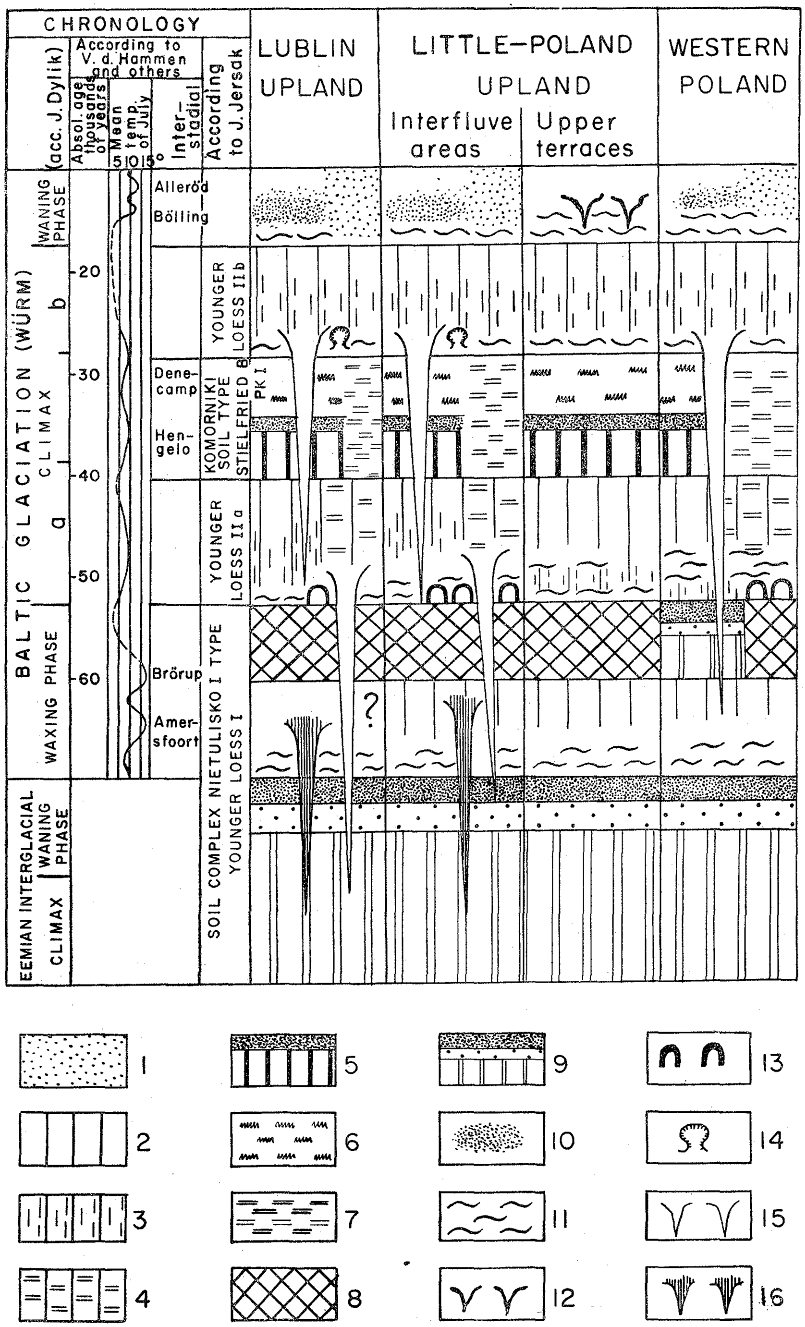

Fig. 2. Stratigraphical position of fissure structures

1. eolian sands; 2. non-gleyed loess; 3. gleyed loess; 4. boggy loess; 5. arctic brown soil; 6. pseudo-gleyed soil; 7. boggy soil; 8. chernozem soil; 9. soil lessivée; 10. soil of the initial stage of development; 11. slope deposits; 12. erosional cut; 13. folded involutions; 14. injectional structures; 15. fissure structures with secondary infilling; 16. fissure structures with secondary seasonal infilling

from the surface and walls of the upper parts of fissures entered into the voids left after the melted ice. This process repeated every year promoting the formation of vertical lamination and because not all the laminae reach the same depth the structures are the widest in their upper parts and become narrower downwards. Unlike other fissures they have not sharp tips. In the bottom of the structures there usually are several elementary layers, sometimes bent. ROMANOVSKIJ (1973) points out that such sideward gradual merging of fissures takes place on the contact line with the zone of permafrost. In the generation of the largest polygons, the cracks occurred even every year, whereas in the generations of smaller polygons the cracks caused by thermal contraction appear more rarely when the temperature falls down rapidly. The dehydrational contraction cannot be excluded, especially in the smallest polygons. The thermal contraction is often associated with the desiccation fissures. In places where the dehydrational cracks occur in summer, the thermal contraction fissures may develop in autumn and in early winter. Sometimes the desiccation fissures can be filled with water that becomes frozen in autumn. The further development of these dehydrational fissures resembles that of the frost contraction fissures.

Disturbances in the deposits surrounding the fissures with secondary seasonal infilling are inconspicuous. Generally, the fissures cut the unstratified sediments altered by pedologic processes. In the exposure at Odonów, the fissures with secondary seasonal infilling cut the fossil soil and associated horizon with pseudo--stratification caused by an unequal accumulation of iron oxides. The ferruginous pseudo-layers are bent down in the closest vicinity of the fissures; in some places there are visible vertical displacements of the fault type (Pl. 7).

Somewhat different character have the fissure structures with secondary seasonal infilling occurring on slopes. The fissures on the Vistula valley-side at Życ Samborzecka can serve as a good example of such structures. In this exposure several generations of intersected fissures occur. There is a dense net of fissures near the old surface from which they develop (Pl.15). The net of the intersected fissures was formed due to the slope processes. On the flat surfaces of interfluves, where the slope processes did not operate, the cracks of thermal contraction appeared year by year in the same places. On the other hand, on slopes, where these processes were active, the new system of fissures cutting the older polygons was successively formed.

On slopes there are also some bent fissures which are vertical in their bottom parts and higher up they are bent according to the sloping of the then surface. The movement that caused the bending of fissures took place at the end of their development. Sometimes, from the point of bending there are little vertical fissures running upwards; they came into being after the movement of slope material had been finished. The bent fissures are much less common in the loess areas than in the Łódź region (GOŹDZIK, 1967). The author had only met them in the Miechów loess mantle at Odonów near Kazimierza Wielka.

FISSURES WITH SECONDARY INFILLING

Fissures with secondary infilling are encountered in the whole loess area in Poland. They originated during the climax of the last cold period (DYLIK, DYLIKOWA 1960; GRABOWSKA-OLSZEWSKA, 1963; JAHN, 1956, 1969, 1970; JAHN, CZERWIŃSKI, 1965; JERSAK, 1965, 1969; KOZŁOWSKI, 1964; MALINOWSKI, MOJSKI, 1960; STRASZEWSKA, MYCIELSKA, 1961; WALCZAK, 1952). These fissures occur in two stratigraphical horizons: in the older and younger parts of the Würm climax. The older horizon originated during the accumulation of the lower part of the younger loess IIa, while the younger horizon developed during the sedimentation of the lower part of the younger loess IIb. The structures of the older part of the climax of the last cold period are less common. They mainly occur on the Lublin Upland, more rarely on the Little-Poland Upland and are probably absent from western Poland. The fissure structures from the younger part of the Würmian climax occur across the whole area of Poland (Fig. 2).

It is difficult to define the stratigraphical position of some fissure structures with secondary infilling because of the differentiation of loess thickness, especially of the younger loess IIa. On slopes the younger loess IIa is strongly reduced and sometimes it is entirely lacking. Hence, in some sites the upper parts of younger fissures that begin directly above the soil complex of the Nietulisko I type can be ranked to the older part of the Würm climax. In places, where the younger loess IIa is not reduced, the fissures with secondary infilling of the same age as the former ones, do not cut the soil complex of the Nietulisko I type; they have been considered as belonging to the second part of the Würm climax. In some sites the younger loess IIb is reduced and then the fissures with secondary infilling are near the present-day surface. Such a situation is at Łopatki where the thickness of the younger loess IIa is about 5 m, while the younger loess IIb is only about 2 m thick. Therefore, the fissure structures with secondary infilling occurring in this site originated during the accumulation of the lower part of the younger loess IIb have been thought to younger than they really are. In JAHN's paper (1970) they are ranked to the waning phase, i. e. to the Younger Dryas.

The fissures with secondary infilling originated in the Würm climax are of various sizes. The large fissures, 4—5 m deep, form polygons of 10—20 m to over 30 m in diameter (Figs. 3, 4). The smaller fissures, 1.5—2 m deep, form polygons 5 or more meters across (Pl. 9). The fissures with secondary infilling, shorter than 1—1.5 m, display distinct traces of truncation. Such denuded fissures occurring on slopes are known from the western Roztocze, at Sąsiadka (MALINOWSKI, MOJSKI, 1960) and from the Opatów—Sandomierz loess mantle at Nietulisko Duże (JERSAK, 1965: Pl. 12).

The large fissures are widened and funnel-shaped in their upper parts (Pls. 8, 10—13), and wedge-like in the lower parts. The upper widened part of a fissure is 1—2 m, but most often 1—1,5 m deep, the width is 2 m or occasionally more.

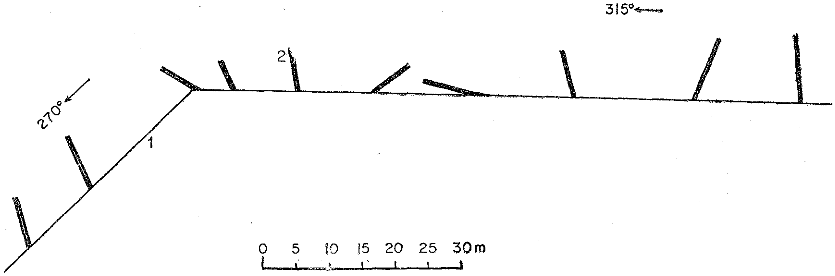

Fig. 3. Łopatki, brickwork. The Lublin Upland. Fissure structures with secondary infilling from the younger part of the Würm climax

1. wall of exposure; 2. fissure structures

This part of the wedge developed in the active zone of permafrost (DYLIK, 1963; JAHN, 1970; POPOV, 1959). According to the depth of the widened part of fissures it may be inferred that the active zone of permafrost reached down to 1.5 m. Some small deflections from this value appear in western and eastern Poland. The various

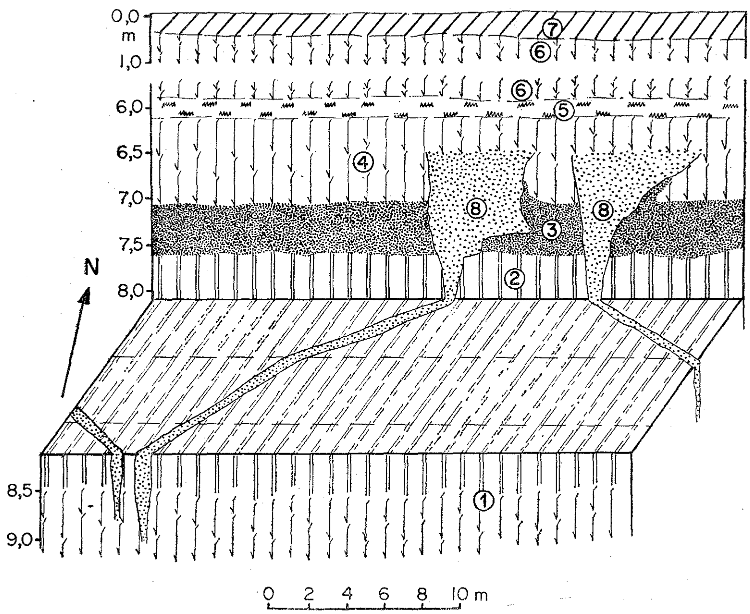

Fig. 4. Hrubieszów – brickwork „Feliks". The Lublin Upland. Fissure structures with secondary infilling of the older part of the Würm climax

1. upper older loess; 2. illuvial horizon of soil lessivée; 3. chernozem; 2-3. soil complex of the Nietulisko I type; 4. younger loess IIa; 5. pseudo-gleyed soil of the Komorniki type; 6. younger loess IIb; 7. present-day arable horizon; 8. fissure structures with secondary infilling

thickness of the active zone in the loess area was caused rather by local factors than by climatic changes.

The upper widened parts of these fissures developed in a certain phase in similar way as the fissures with secondary seasonal infilling, though the arrangement of material in them is different: material in the fissures with secondary infilling fails to display a vertical lamination which is characteristic of the fissures with secondary seasonal infilling. It is a result of the two stages of filling up the wide parts of fissures. Due to the thermal contraction the small fissures were first formed; every year they were filled with material flowing down from the nearsurface deposits. The next stage of infilling took place during the melting of fissure ice in lower parts of the wedges. From their upper parts the material fell down owing to gravity, and then was replaced by the new one. Such a mode of infilling of the widened part of a fissure produced the following pattern: the loess occurring in the lower part is of the same age as the fissure itself and the patches of strongly brecciated material derived from the closest vicinity (MANILA, 1960). In the middle and upper parts of the widened fissure the material is somewhat younger. The loess is indistinctly horizontally stratified in the upper parts of the fissure structures.

The lower, wedge-like parts of fissures developed in permafrost; initially they were filled with fissure ice (DYLIK, 1963; GOŹDZIK, 1973; JAHN, 1970; POPOV, 1959; ROMANOVSKIJ, 1973). This wedge-like parts have some 30-50 cm in width and 1-2 m in depth, and occasionally even more. While fissure ice was melting the lower part of the fissure filled up with the sediment falling down due to gravity from the upper part which developed in the active zone, as well with a strongly brecciated material from the walls. This material can be particularly often met in the nods of fissure structures (Pl. 8).

Smaller fissure structures do not generally display any distinct widening in their upper parts; they have more regular wedge-like outlines and brecciated material does not occur in them but sporadically.

All these fissures are characterized by the following pattern of surrounding material: the adjacent layers are most often upward curved but sometimes also downwards. In some sites the surrounding layers on one side of the wedge are bent upwards, and on the other — downwards. The sharpest bending appears at the upper part of the fissure structure, which has been pointed out by some authors (DYLIK, 1963; GOŹDZIK, 1973; KATASONOV, 1958; PÉWÉ, 1962; ROMANOVSKIJ, 1973). Here, the curvatures reach up 1m (Pl. 8). Very often the layers are pressed or even disrupted (Pl. 11). In few places there are preserved traces of swells of the old surface that occurred along the fissures (JERSAK, 1965: photo 7). Most of them were destroyed during the melting of ground ice. According to GOŹDZIK (1973) the most characteristic of the wedges with primary infilling are tiny faults (Pls. 12, 13). They were formed during the melting of ground ice. The gravitational subsiding gave rise to numerous small displacements of stair-like pattern descending towards fissure. Along the individual faults the displacements amount from several to some tens of centimeters.

FISSURES OF INDEFINITE ORIGIN

In slope and valley deposits from the climax of the last cold period, besides the two horizons of fissures described above, there are also others, whose origin has not been elucidated so far. They are chiefly small cracks as those in the site at Zwierzyniec, in Cracow that have been described by SAWICKI (1952). There, above the horizon which can be considered as pseudo-gleyed soil of the Komorniki type there are fissure structures (younger) with secondary infilling and higher up a number of tiny cracks can be seen. The same type of tiny fissure structures is preserved at Włostów near Opatów in the valley loesses rhythmically stratified, accumulated during a periodically hampered drainage. Some of loess sediments are of lacustrine- and others of fluvial character. The exposure displays numerous fissures from several centimeters to 2—3 m deep and less than 20 cm wide. The short fissures occur much more frequently. Only in the deeper fissures there is sometimes material from outside but not necessarily along the full vertical profiles. The short fissures are of crack character which resemble small faults or they are only outlined by the curvature of layers (Pls. 14, 16). Usually the layers of surrounding material are slightly bent upwards some tens of cms from a fissure structure, but at the borders they are strongly bent downwards. Between closely spaced fissures the layers are arched upwards.

Such fissure structures developed simultaneously with sedimentation of the deposits. Most of them take their beginning — as at Zwierzyniec in Cracow — in the clayey horizons, which SAWICKI (1952) has called the vegetation horizons because of the spots caused by the oxydo-reduction processes. The deposit being strongly gleyed proves that at least a part of these fissures is of the dehydrational origin and they underwent a slight deformations due to frost processes. Even if the formation of these structures had been caused by thermal contraction they should not be treated as the indices of climatic changes as JAHN suggests (1970). In the larger fissures it is clearly visible that the periodically recurring cracks were connected with the former, lower lying ones, while the smaller sporadically formed cracks did not meet the former ones. The larger cracks renewed with the sedimentation of deposit are often broken (Pl. 14). The younger loess was deposited in severely arid and cold climate which favoured the development of both the dehydrational and thermal fissures in depressions. Evidence of repeated degradation of permafrost is lacking for the second part of the climax of the last cold period.

SOME FISSURES OF INDEFINITE STRATIGRAPHICAL POSITION

The fissures in the well-known exposure at Tarzymiechy on the Wieprz raised a special interest and discussion (DYLIK, 1956; DYLIK, DYLIKOWA, 1960; JAHN, 1952, 1956; ŚRODOŃ 1956) as well as those occurring in the Miechów loess mantle at Topola (DYLIK, DYLIKOWA, 1960; KLAJNERT, 1961). At Tarzymiechy the stratigraphy of the deposits dissected by a wedge and of the overlying sediments is open to

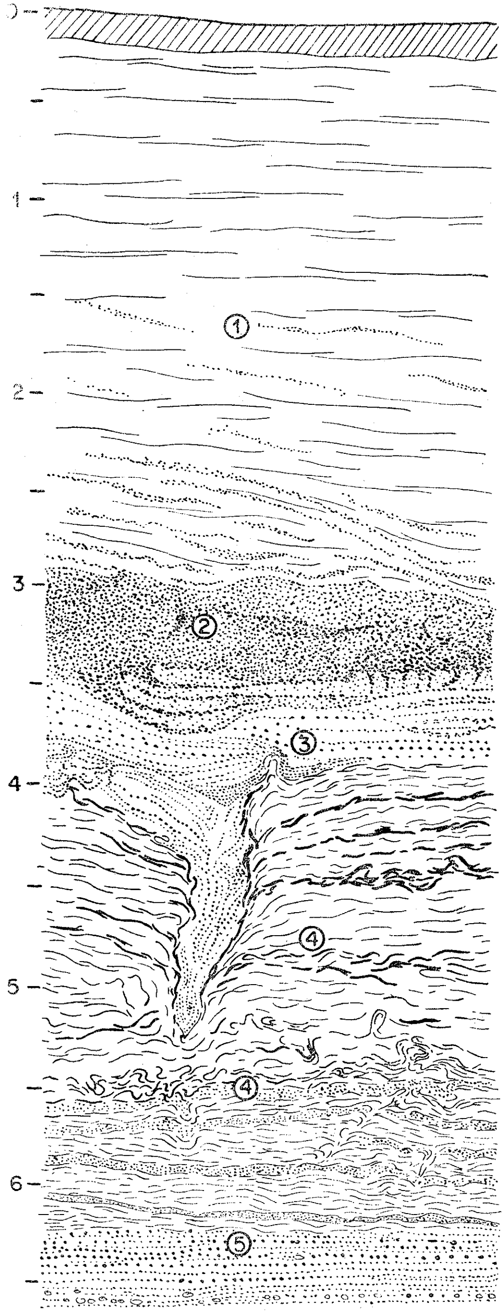

Fig. 5. Topola. The Little-Poland Upland (after DYLIK, DYLIKOWA, 1960)

1. bright streaked loess — younger loess IIa and IIb; 2. chernozem soil — upper soil from the complex Nietulisko I; 3. bedded limestone gravels; 4. brown-greenish silts; 3-4. waxing phase of the Würm (?); 5. bedded gravels with predominance of limestone grains and northern rock admixture — the Eemian Interglacial (?)

discussion. DYLIK (1956) accepts ŚRODOŃ'S (1956) opinion that both the varved Dryas clays and the wedge that cuts them belong to the maximum stage of the Middle Polish glaciation, whereas the overlying deposits are from the Warta stage of the same glaciation. MARUSZCZAK (1972) expressed the same opinion, however JAHN (1956) holds that all the deposits belong to the last cold period. JAHN'S opinion seems to be very persuasive since the sandy-silty deposits overlying the fissure and the Dryas clays are characteristic of the valley loesses from the second part of the climax of the last cold period. On the interfluve these deposits pass into the younger loess IIb. In the exposure at Piliszkowice (JAHN, 1952), beneath the rhythmically varved silts, resembling those from Tarzymiechy, there is fossil soil preserved; it is of the soil complex Nietulisko I that belongs to the Eemian interglacial and waxing phase of the Würm (JERSAK, 1973b). The character of the fissure at Tarzymiechy and its stratigraphical position indicate that it is the structure with secondary infilling from the younger horizon originated in the younger part of the climax of the last cold period.

The fissures at Topola have also been attributed to the Middle-Polish glaciation (Fig. 5), but it is difficult to define precisely the origin of the fissures preserved in this exposure. They are rather small. The infilling material displays a distinct vertical stratification; the overlying chernozem belongs to the waxing phase of the Würm. The soil is of the same age as the chernozem developed in the top part of the soil complex of the Nietulisko I type.

Such a succession of sediments indicates that the fissures and surrounding sandy-silty deposits at Topola may be dated at the Würmian waning phase. The Topola fissures have the same stratigraphical position as frost-fissures with secondary seasonal infilling.

Translated by Z. Apanańska

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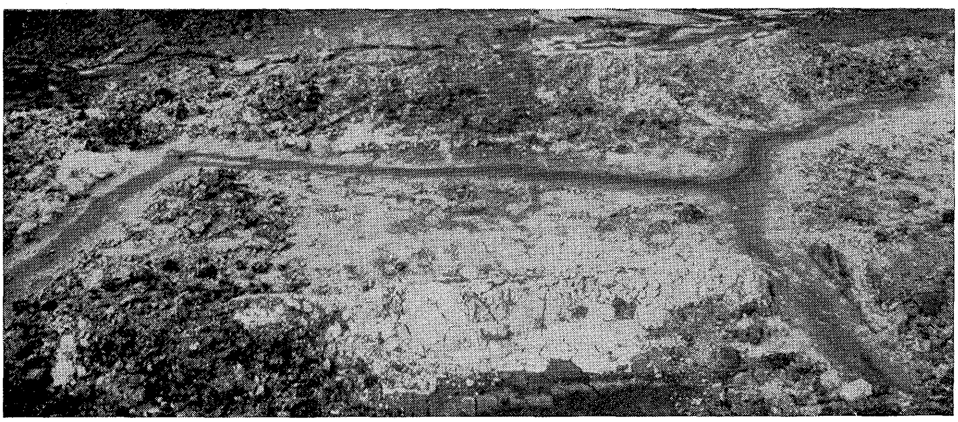
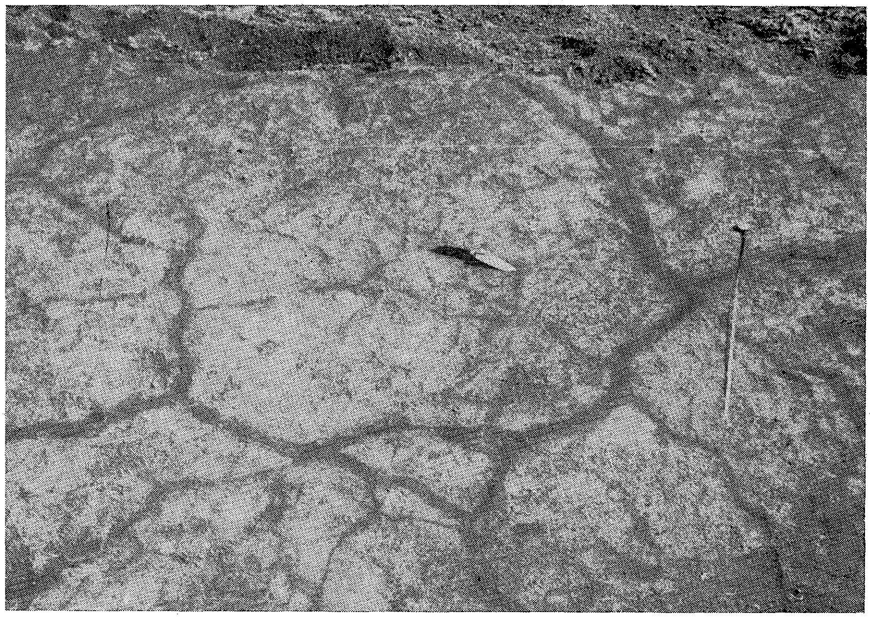
Pl. 1. Hrubieszów, brickwork „Feliks", the Lublin Upland. Horizontal section, some 7 m deep. Fissure polygons with secondary seasonal infilling. Generation of large polygons

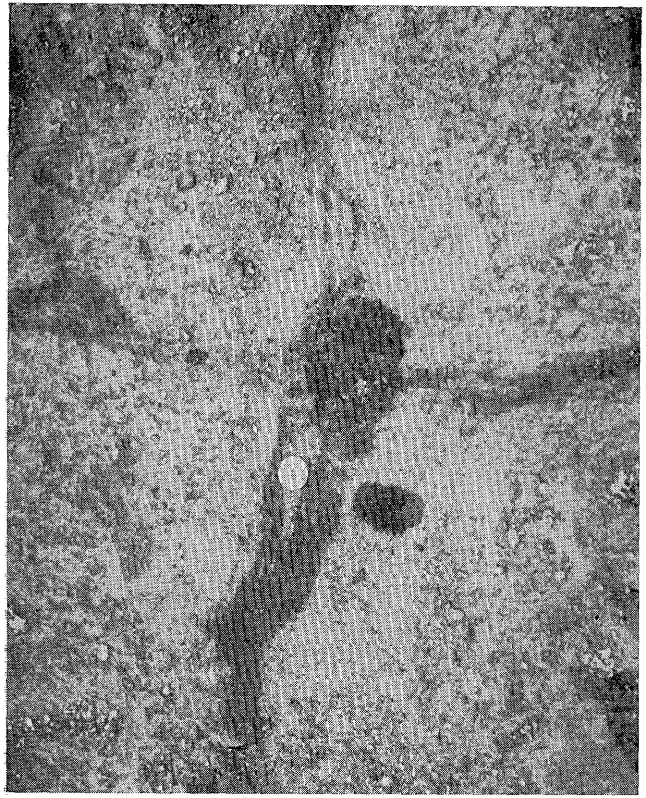


Pl. 2. Hrubieszów, the Lublin Upland. Fragment of fissure polygon with secondary seasonal infilling. Generation of large polygons

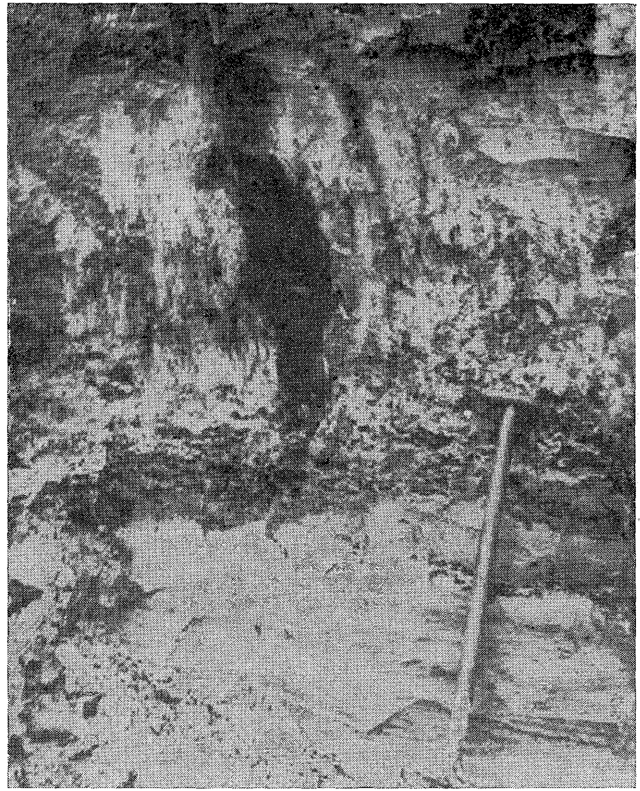


Pl. 3. Hrubieszów, the Lublin Upland. Fissure structures with secondary seasonal infilling. Generation of middle and small polygons

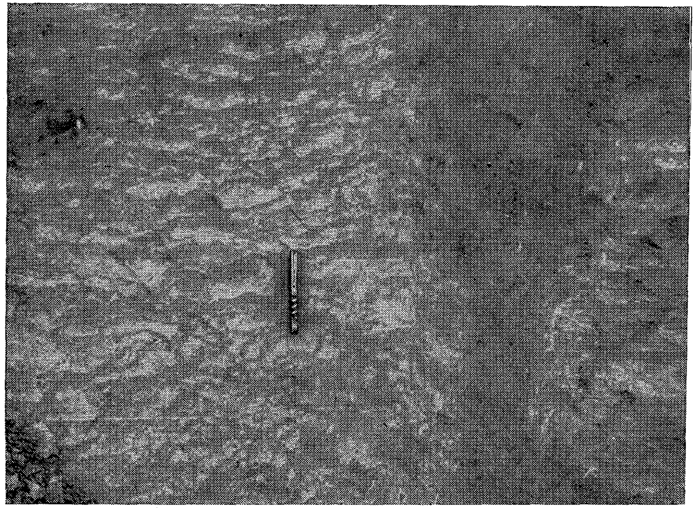
Pl. 4. Hrubieszów, the Lublin Upland. Fragment of fissure structure with secondary seasonal infilling. The structure filled with stratified material



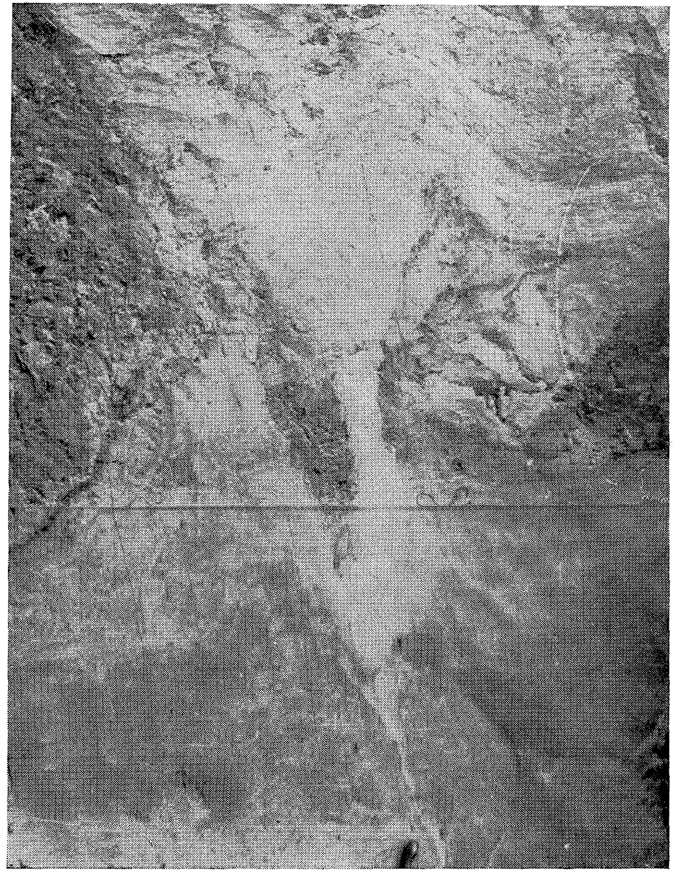
Pl. 5. Hrubieszów, the Lublin Upland. Fragment of fissure structure with secondary seasonal infilling of middle generation, cut by mole-hills



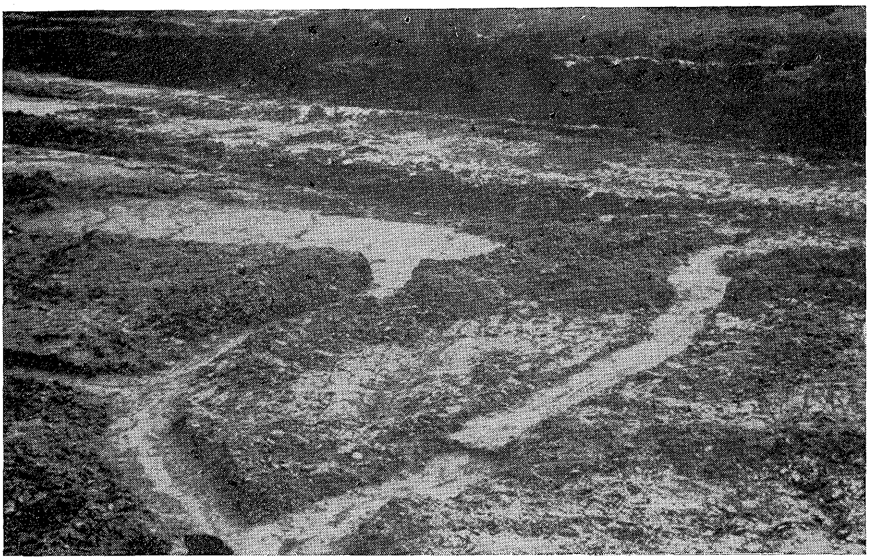
Pl. 6. Błogocice, the Little-Poland Upland. Fragment of fissure structure with secondary seasonal infilling, it cuts sands and gravels in the bottom part



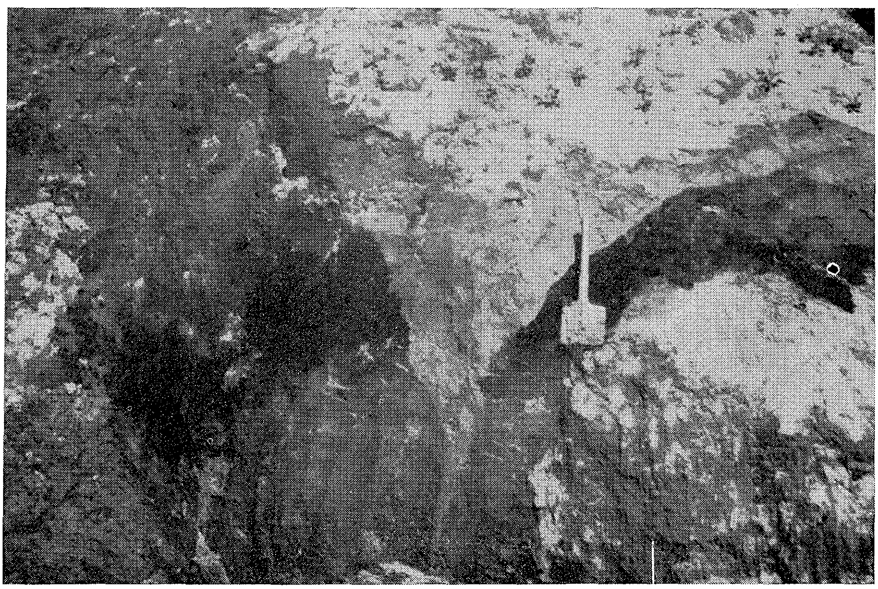
Pl. 7. Odonów, the Little-Poland Upland. Fissure structure with secondary seasonal infilling; near the fissure some faults and bent pseudo-layers, amassments of iron oxides



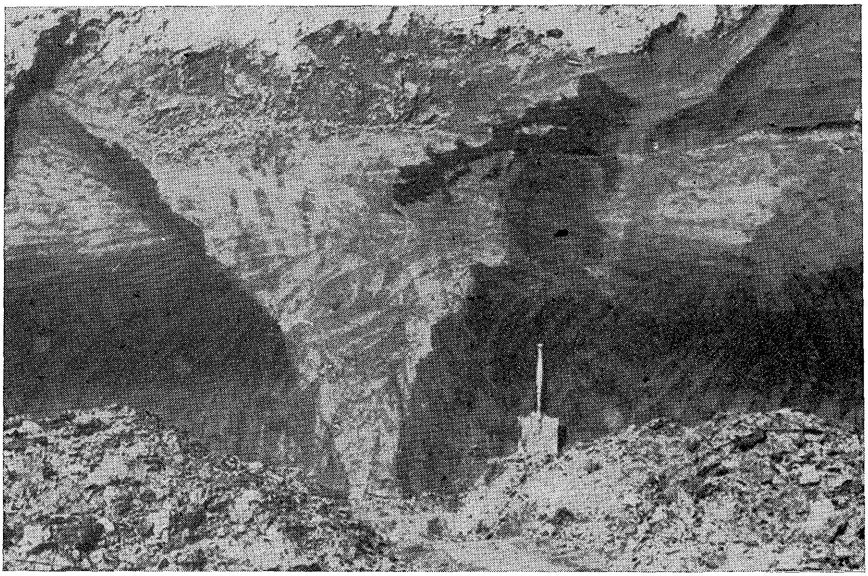
Pl. 8. Łopatki, the Lublin Upland. Fissure structure with secondary infilling and packets of breccia. Horizon of the younger part of climax of the last cold period



Pl. 9. Hrubieszów, the Lublin Upland. Fissure structure with secondary infilling, generation of smaller polygons. Horizon of the older part of climax of the last cold period

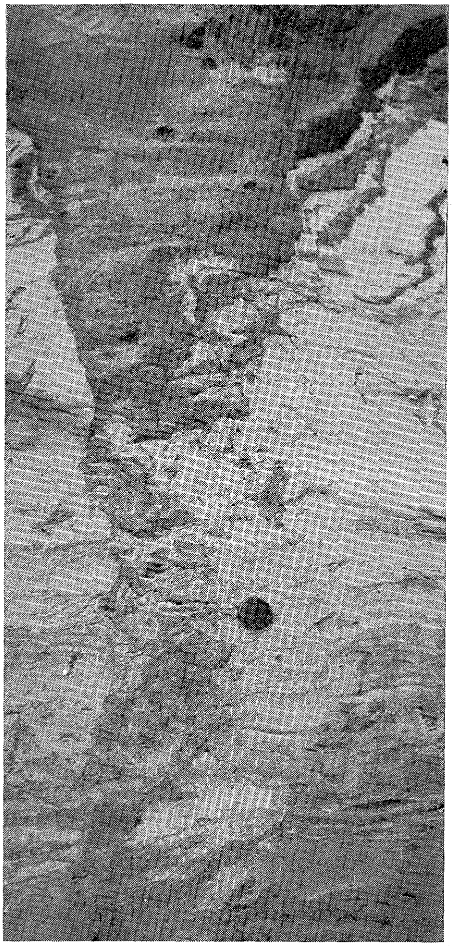


Pl. 10. Nieledew, the Lublin Upland. Fissure structure with secondary infilling. The older part of climax of the last cold period

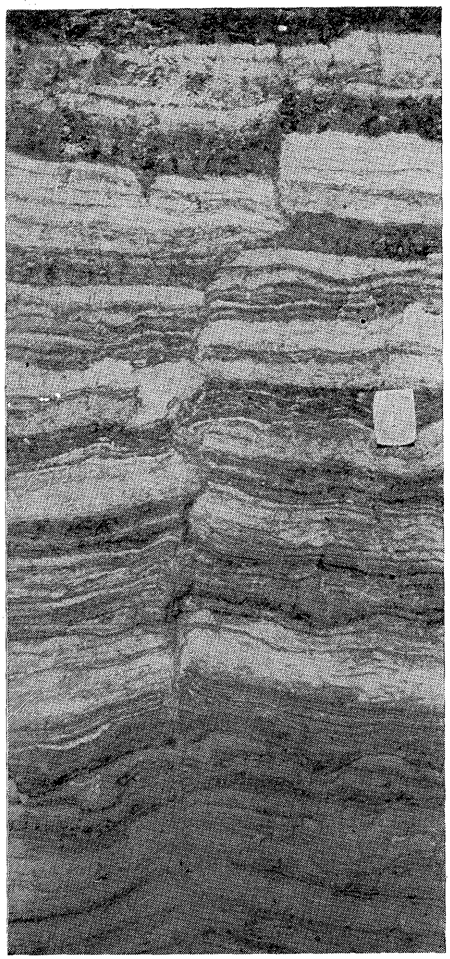


Pl. 11. Hrubieszów, the Lublin Upland. Fissure structure with secondary infilling, horizon of the older part of climax of the last cold period

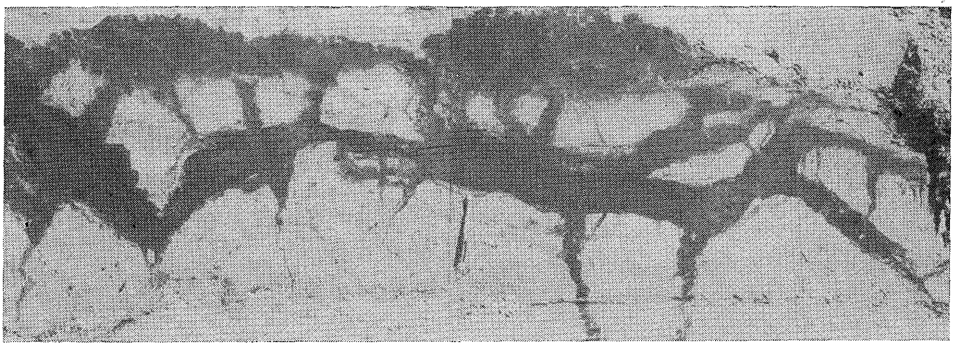
Pl. 12. Kunów—Stawiska, the Little-Poland Upland. Fissure structure with secondary infilling, in vicinity some faults; younger part of climax of the last cold period



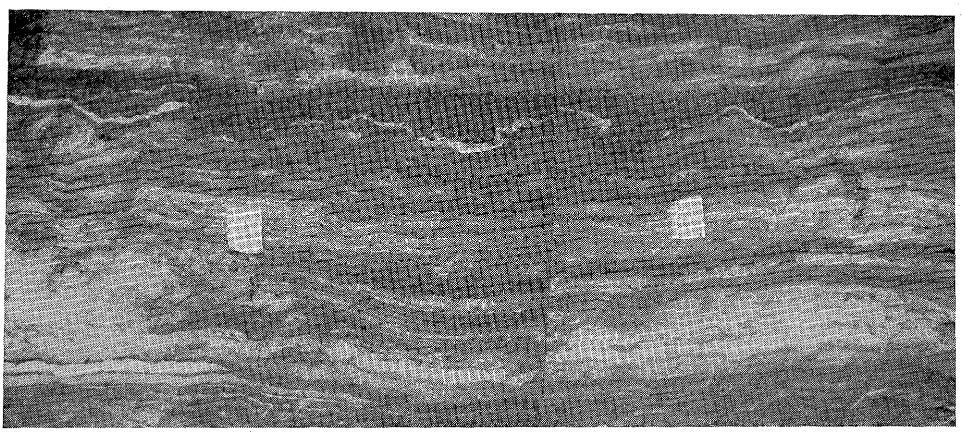
Pl. 13. Krowiarki, Western Poland. Fissure structure with secondary infilling. In the vicinity some faults. Younger part of climax of the last cold period



Pl. 14. Włostów, the Little-Poland Upland. Deep fissure structures of indefinite origin, "broken". Younger part of climax of the last cold period



Pl. 15. Życ Samborzecka, the Little-Poland Upland. Intersected fissure structures with secondary seasonal infilling. The structures filled with chernozem



Pl. 16. Włostów, the Litte-Poland Upland. Small fissure structures of indefinite origin