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# THE DEVELOPMENT OF THE DRWĘCA VALLEY SLOPES IN THE LATE-GLACIAL PERIOD

(on the basis of two profiles: the gravel pit, Kurzętnik and concrete works, Nowe Miasto Lubawskie)

The development of slopes of the Drwęca river valley started simultaneously with the formation of the recession end-moraines of the Pomeranian stage. In the foreland, the melt-waters gave rise to the outwash plain and passed farther into the valley outflow. After a time, the Drwęca river valley with the system of the late-glacial and Holocene terraces was formed there. In the late-glacial period the vigorous slope processes denuded the slopes of the outwash plain and of the upper river terraces (Fig. 1) producing such characteristic forms as small denudational valleys and troughs. At the same time the accumulation of slope deposits took place.

## (1) GENETIC CLASSIFICATION OF PERIGLACIAL SLOPE DEPOSITS BASED ON LITHOLOGIC FEATURES

Downwash sediments occurring in the concrete works at Nowe Miasto overlay the so-called outwash terrace, i.e. formed by glacial melt-waters, the altitude of which is 100 m. These sediments, 0.5—0.75 m in thickness, are composed mainly of stratified silts and sands showing rhythmically alternated bedding. The layers dip gently, 1—2°, to the Drwęca river. The first, 0.25 m thick, silty series is separated from the next one of the same thickness — composed of sands and gravels with discontinuous but characteristic lamination — by a 2—5 cm sand layer strongly saturated with the iron compounds. These sediments occur also on the slope of the outwash terrace where they intensively increase in thickness.

The sediments are continuous which was observed in the cross section.

They also fill up the shallow, wide trough-like depression cut out on the slope of the outwash terrace and connected with the surface of the Drwęca upper terrace at an altitude of 90 m. It is cut in the older sub-morainic glaciofluvial deposits and in clays overlain by stone pavement. Figure 2 represents the section that, dissecting this form diagonally, shows its filling and its relation to the terrace which in this place is of erosional character. In the fossil slope and on the bottom of this form, there are sands and gravels with pebbles among which many are completely weathered. The layer is barely 2—10 cm thick and displays traces of gleyfication. It is covered by downwash deposits consisting of several truncated series; the lowest wedging downslope consists of three layers varying mainly in colour, their mechanical composition being much alike. These are fine sands with a predominance of 0.1 mm grains which occur abundantly in each layer: 65%, 60% and 50% respectively. The dust material (0.06 mm in diameter) is also

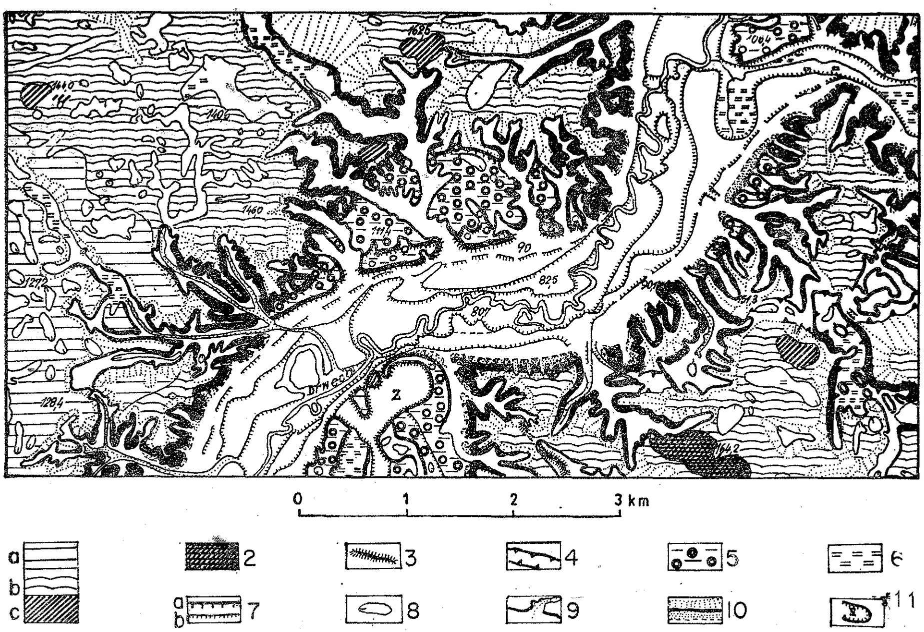


Fig. 1. Morphological sketch of the vicinity of Kurzętnik

1. moraine plateau: (a) flat, (b) undulated, (c) hilly; 2. morainic hills; 3. eskers; 4. subglacial channels; 5. outwash-terraces; 6. peat flats; 7. edges of valleys (a), and outwash- and river-terraces (b); 8. dead-ice hollows; 9. denudational small valleys and troughs; 10. degradation and aggradation zones; 11. gravel pits

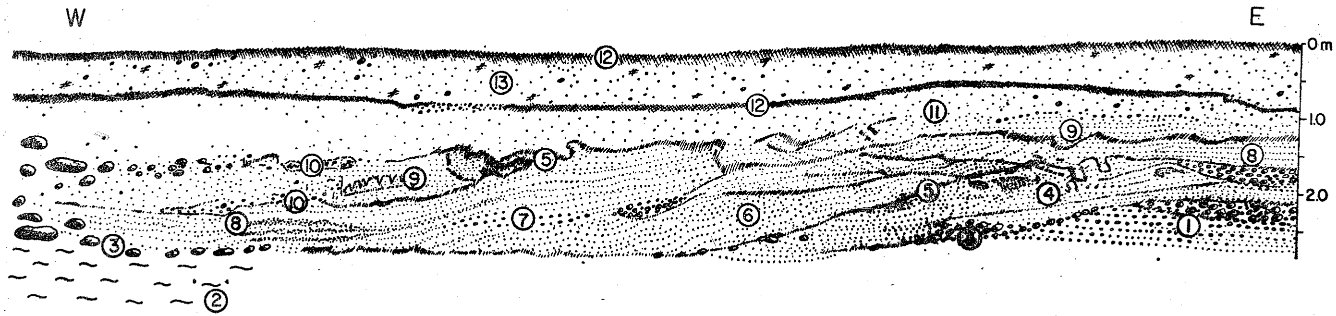


Fig. 2. Nowe Miasto, concrete works. Cross-section through the trough on the slope of outwash terrace, 100 m above sea level

1. glaciofluvial sands and gravels with bedded small boulders and gravels in the top, partly weathered; 2. chocolate clays; 3. clayey deposits and boulders covering the trough bottom, and stone residuum (the top of erosional Drwęca terrace); 4. stratified sandy and silty deposits, disturbed, at the top — series I; 5. ferruginous band; 6. stratified sandy and gravelly deposits — series II; 7. lenses of stratified coarse sands and gravels; 8. stratified sandy and gravelly deposits — series III; 9. light-coloured stratified fine sands filling the finger-like hollows and separating two series of congelifluxion deposits; 10. lower and upper congelifluxion series composed of clay and boulders; 11. unstratified sads and fine gravels; 12. present-day and fossil humus horizons; 13. soil colluvium

frequent, it amounts to 10% and increases upwards (20%), but the coarser particles are poorly represented. These deposits are horizontally bedded and present a counterpart of the lowest sand layer covering the outwash terrace. In he highest layer there can be observed structures resembling cylindric congelifluxion structures (Pl. 1). Under them, the stratification is obliterated. It is difficult to decide whether they are really cylindric congelifluxion structures or load casts.

The next series of sediments, separated by a ferruginous band, consists of bright sand and gravels, the thickness of which increases downslope. Plate 1 shows this series with layers intercalated by ferruginous bands; the typical lamination is also well seen. The grain-size curves reveal a poor sorting of the material. There may be observed a small percentage of 0.7—0.2 mm grains, more frequent finer grains — for the most part 0.1 mm in size — and fairly abundant dust.

The change of sedimentary environment is evidenced by the occurrence of the variously sized sands and gravels in the next series. Its thickness also distinctly increases downslope. This series

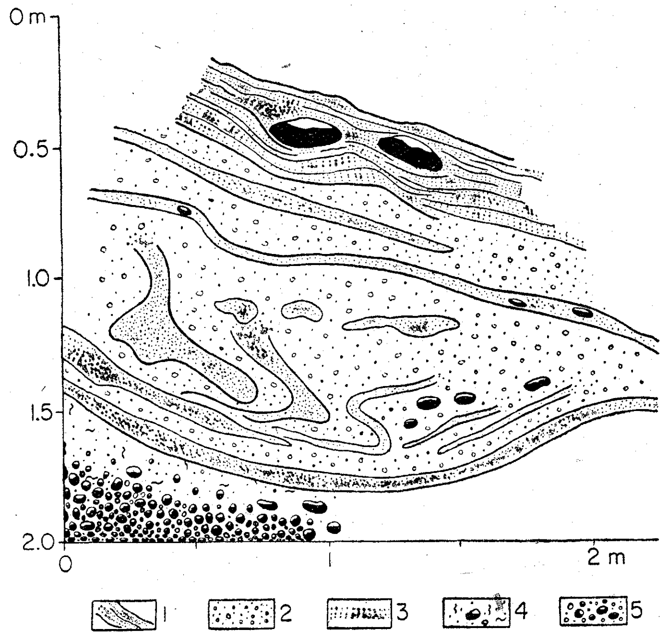


**Fig. 3.** Congelifluxion deposits on the slope of small denudational valley
1. disturbed silts with small boulders; 2. unstratified heterogeneous sands and gravels; 3. fine sands; 4. clayey sands and gravels; 5. gravels and boulders

marks the end of the accumulation of downwash sediments. The occurrence of coarser and more differentiated grains provides evidence of an increase in the downwash activity, probably due to a change of the climatic conditions.

C o n g e l i f l u x i o n d e p o s i t s are frequently found throughout the area in question. They are of various appearance. During the Symposium excursion not all the types of the deposits were presented, but they should be described for a better elucidation of the slope development in this region.

The example of bound congelifluxion is the profile near Kurzętnik, in the upper part of slope, grading 14—15°, of a small denudational valley. In the middle part, the slope inclination increases up to 24° and congelifluxion deposits disappear. These are fine-grained sands and silts with variously-sized stones. The original structure and sequence of these sediments can be readily observed (Fig. 3).

The most common congelifluxion deposits are the structureless sands with pebbles and boulders. Their morphologic situation as well as their character displays a great variety. They occur in the upper parts of slopes, on the bottoms of small denudational valleys (Fig. 4) and on the bottoms and slopes of the denudational troughs

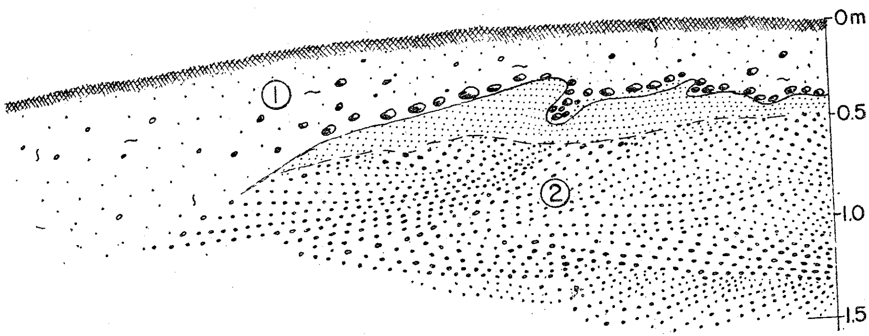


Fig. 4. Section in the upper slope segment of a denudational small valley
1. unstratified sands with small boulders, stone horizon in the bottom part; 2. glaciofluvial sands and gravels with silts in the top part

(C h u r s k a, 1965a, 1965b; C h u r s k a, G a l o n, R o s z k o, 1967); they partly mantle the outwash plain and upper terraces of the Drwęca (C h u r s k a, 1965b). The most striking difference of their nature is expressed either by the presence or the absence of stones and their position in the structureless sand mass. The stones can be met in the bottom part as well as scattered throughout the whole bed.

The sand is for the most part variously-grained, more or less clayey or with a large admixture of dust. It does not display any stratification. Their congelifluxion character is evidenced by their slope situation, presence of the "slope scythes" (*Hackenschlag*) (Churska, 1965, p. 24), and by the downslope increase of their thickness, often with typical swellings or squeezings of the transported sandy-pebble mass on the thawed substratum. The long axes of pebbles being oriented according to the slope also speak in favour of the congelifluxion character.

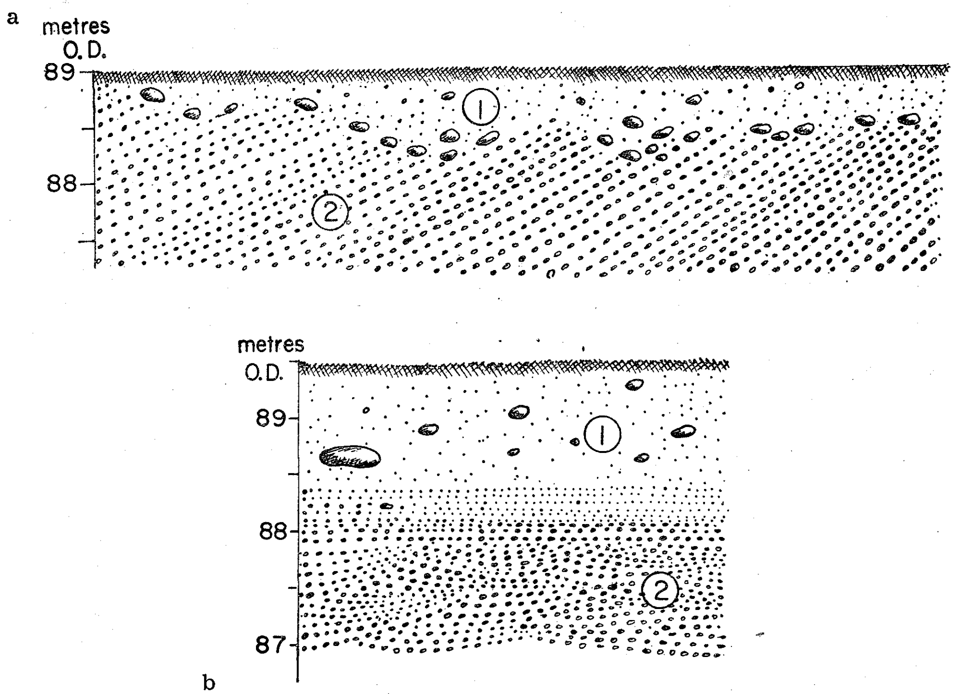


Fig. 5. Two sections in the upper terrace
1. unstratified sands with boulders; 2. glaciofluvial sands and gravels of the upper terrace

On flat surfaces, the congelifluxion sands with stones sometimes display cryoturbations (e.g. at the outlet of the denudational valley to the upper terrace at Kurzętnik) which produced the uneven and undulated pocket-like bottom of the sands (Fig. 5a). On the same terrace at Kurzętnik, farther from the slope, the sands occurring on the flat surface also contain stones chaotically distributed within the whole sediment (Fig. 5b).

Particular attention should be paid to the deposits filling small denudational valley (Fig. 6, 7). The material which fills the bottom of the valley at Kurzętnik and that which occurs on its slopes are heterogeneous. The lower series lies directly on the substratum material. It fills up the fissures in the substratum and covers it with an uneven layer. This series does not show any sorting. Tcgether with the most numerous pebbles and gravels of 10 cm in diameter there are also boulders 0.5—0.75 m and variously-grained sands and silts. Their thickness ranges from 0.20 m to 0.75 m, the

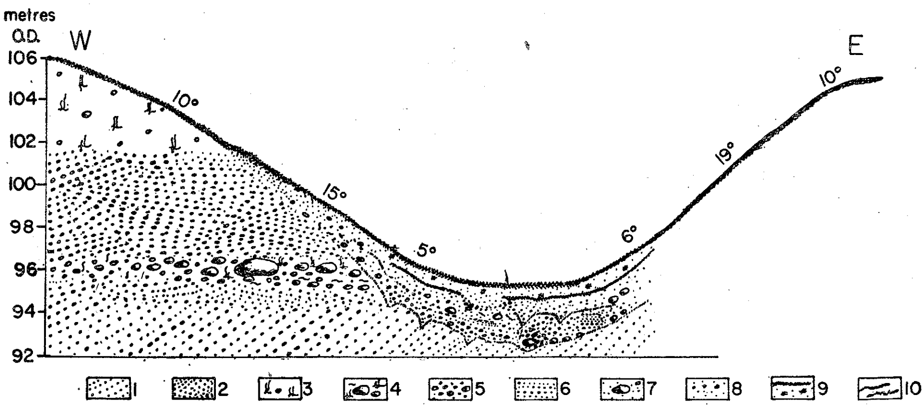


Fig. 6. Kurzętnik. Cross-section through the denudational small valley
1 glaciofluvial sands; 2. glaciofluvial gravels; 3. brownish boulder clay; 4. residuum of greyish-green boulder clay; 5. boulders, gravels and sands of the lower series; 6. stratified sands intercalated by ferruginous bands; 7. boulders, gravels and sands of the upper series; 8. sands and gravels, structureless; 9. present-day and fossil humus horizon, soil colluvium; 10. ferruginous bands

mean thickness being 0.5 m. The long axes of the stones are parallel to the inclination of the valley slopes and bottom. This material also occur in the upper, less inclined part of the slope, whereas in its middle, steeper part grading more than 15°, it is lacking. On the basis of the data presented it seems justifiable to regard this material as congelifluxion.

Between the above described series and the next one which is composed of similar material, there is a layer of sands, whose thickness negligible at the bottom (some 30 cm) increases in the upper part of the slope to 1 m. The sands are poorly sorted, they contain grains of various size, most numerous being of 0.1 mm, the dust and 10% of gravels. The material is in some places distinctly stratified but in others, on the bottom and slopes, it is only slightly diversified by the ferruginous compounds. The ferruginous bands and sporadic tiny charcoals seem to indicate the fossil substratum of the soil, which in turn must have been destroyed by the renewed congelifluxion processes. These processes gave rise to the next series of sediments which differs from the former by the greater amount of gravels (55%) and smaller quantity of stones, as it can be seen in the figure 8. Sands and gravels prevail here. The longer axes of the stones are oriented like those in the first series. In both layers the stones are strongly weathered and disintegrated into angular debris.

The ascertainment of the bipartition of the sediments in the series presented above is of considerable importance. Lembke (1955/56) and Schultz (1956) describing the similar deposits mention one series of the covering deposits and ascribe them to the congelifluxion sediments. Moreover, Lembke holds that the layer was enriched by removal of the small particles by water.

The upper series of the congelifluxion sediments in the denudational valley probably corresponds to the sediments in the upper terrace (Fig. 5). The thickness of the deposits in question does not exceed 1.5 m.

The slope clay in the site at concrete works should also be considered as congelifluxion sediments. It is discontinuous and supplemented with accumulations of mostly weathered stones. This congelifluxion clay is separated by the sands which are as well-sorted as dune sands, but with a great admixture of the dust. These sands fill the characteristic "fingers", perhaps the traces of roots, which, together with a large amount of iron compounds, may indicate the presence of the subsoil of fossil soil, non-existent at present, and which was destroyed in the same way as in the valley at Kurzętnik.

There was also found another type of congelifluxion sediments in the neighbourhood of Kurzętnik, which was not presented to the members of the Symposium excursion, on account of the transport difficulties. There are rhythmically bedded sediments composed of clays with mostly weathered stones and of sands (Pl. 2). They bear traces of the activity of congleifluxion and downwash processes. The sediments overlay the terrace and they are generally related with the system of denudational troughs. The layers dip to the river at 2°.

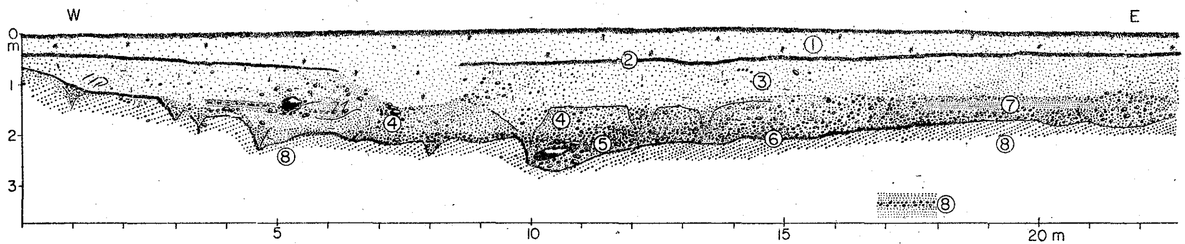


Fig. 7. Kurzętnik. Cross-section through the bottom of small denudational valley

1. humus horizon and soil colluvium; 2. fossil humus horizon; 3. clayey, various-sized sands and gravels, structureless; 4. boulders, pebbles, gravels and sands of the upper series; 5. boulders, pebbles, gravels and sands of the lower series; 6. ferruginous bands; 7. stratified sands; 8. glociofluvial sands and gravels

## (2) CLASSIFICATION OF PERIGLACIAL SLOPE PROCESSES

On the basis of the above data it may be assumed that the described types of sediments originated as the result of two essential slope processes, the downwash and congelifluxion, as well as due to the overlapping of these processes on each other.

## (4) ESSENTIAL FEATURES OF PERIGLACIAL SLOPES

## (7) THE ROLE OF PERIGLACIAL MODELLING IN THE DEVELOPMENT OF POLYGENETIC SLOPES, BOTH PLEISTOCENE AND PRE-PLEISTOCENE

The system of denudational valleys developed on the slopes of the Drwęca valley imprints the most peculiar pattern of slope relief. The denudational valleys are connected with the Drwęca upper terrace but they did not form any fans, which means that they originated when the Drwęca waters took away the material supplied by them. Because the correlative sediments are lacking, it is hardly possible to say what processes were responsible for

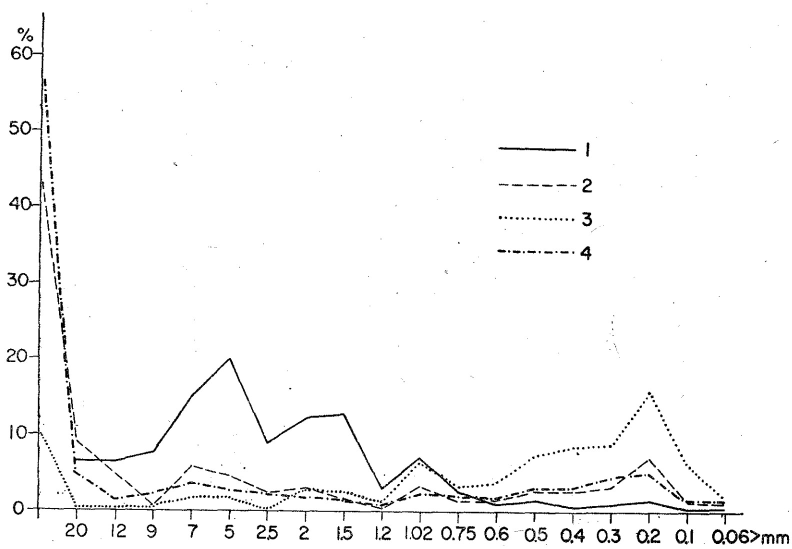


Fig. 8. Kurzętnik. Grain-size curves of substratum sediments and of deposits filling the bottom of a denudational valley

1. glaciofluvial sands and gravels; 2. boulders, pebbles, gravels and sands of the lower series; 3. stratified sands irregularly striated by ferruginous bands; 4. boulders, pebbles, gravels and sands of the upper series

the formation of these land-forms and when they operated. Thus, the inferrence should be as follows: On the basis of the sequence of facts and dating of the peats from the valley bottom (C h u r-s k a, 1965) it may be assumed that the processes in question took place in the early phase of the late-glacial period, most probably in the oldest Dryas. In this time, the most intrinsic features of slope relief were formed.

From the analysis of the morphologic features it may be inferred that these land-forms originated as the result of the periodically running water, operating as downwash and later concentrated along the axis of these small valleys.

The activity of downwash processes led to the smoothing of the relief by filling the depressions. Such infilling obliterated the former relief, as it is, for instance, visible in the buried small trough-like valley near concrete works. Downwash operated here on valley slopes inclined at 10—12°. Its rate and intensity gradually increased and climatic conditions must have changed because in the slope sediments the downwash deposits are overlain by congelifluxion clay. The accumulation of congelifluxion deposits smoothed the upper parts of slopes, which can be observed today, but congelifluxion activity failed to change the steep valley slopes as did the accumulation, which, too small in comparison with these land--forms, was unable to change the valley bottom. However, interaction of downwash and congelifluxion gave rise to the sedimentation of slope material on the terrace, but at the same time they produced a dense and regular net of slope troughs which in turn dissected the slope and smoothed its profile. Thus, the denudational troughs played the role of drainage.

Small changes in slope development in the Holocene could not efface the pattern of the periglacial relief. The last main outline of the relief formation fell into the late glacial period under the periglacial conditions which is attested by the character of the sediments and land-forms, so it may be assumed that also in Northern Poland the periglacial modelling of slopes took place, though the short and unrepeated periglacial period failed in producing any deep transformations of slopes. The problem whether this modelling was accomplished on permafrost or on the seasonally frozen ground has not been so far solved because no incontestable evidence of the existence of permafrost in the late glacial period in this area has been found (D y l i k, 1963).

*Translation by Z. Apanańska*

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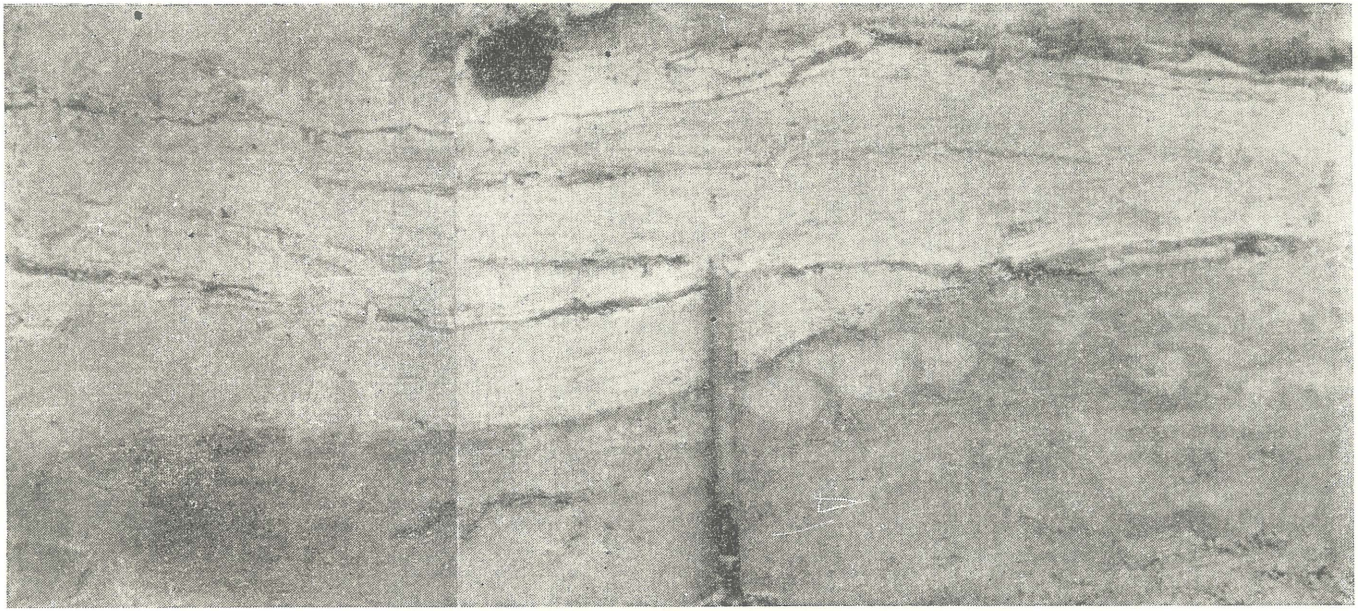

Pl. 1. Characteristic pattern of stratification and distribution of the deposits (I and II series) filling the denudational trough

Pl. 2. Rhythmically stratified deposits overlying the terrace step