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STRATIGRAPHY OF CRYOTURBATE STRUCTURES IN THE WÜRM-AGE DEPOSITS IN THE SOUTHERN PART OF THE DOROHUCZA BASIN (LUBLIN UPLAND)

INTRODUCTION

In the course of geologic mapping a number of cryoturbate structures have been observed occurring in the southern part of the Dorohucza basin (Lublin Upland). The area investigated included also the westerly slopes of the Chełm hills and the easterly slopes of the Giełczew plateau. The present article is intended to supplement the previous work by the writer (Mojski 1957) concerning the near-by western areas. The continuation is most fully developed in the section on the stratigraphy of cryoturbate structures, while the problem of the conditions under which they originated and their paleogeographic significance are only briefly and tentatively discussed.

The cryoturbate structures of the Dorohucza basin are presented — as have been those from the region of Piaski Luterskie (Mojski 1957) — on the background of the total stratigraphic sequence of deposits from the last glaciation. The number (about 70) of localities exhibiting such structures permits a statistical approach to the problem of their distribution and variability in the vertical section.

STRATIGRAPHY

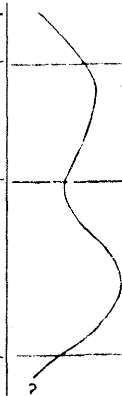
PRE-WÜRMIAN DEPOSITS

Deposits of the upper Maestrichtian are developed in two faciae: calcareous marl to the north-east, marbles and limestones to the south, form the bedrock of the area in question. Petrographic differentiation is the chief factor controlling the character of the relief.

Cretaceous hills in the region of Krynica and Pawłów are overlain by Tertiary deposits, 25 m thick. They are composed of glauconite-quartz sands of Oligocene-age and quartz sands including at the top siliceous and siliceous-mussel crusts of Sarmatian age.

Table I

Stratigraphy of Younger Pleistocene deposits in the southern part of the Dorohucza basin

Age			Chronology (according to Gross 1958)	Southern part of the Dorohucza bassin			Swidnik plateau surrounding of Piaski Luterskie, J. E. Mojski 1957	Intensity of cryoturbation in the deposits of the Dorohucza basin
				Deposits	Thickness	Character of contact		
Baltic glaciation	Decline of Baltic Glaciation (Kataglacial Phase)	Younger Dryas	10 000	dusts and pulverulent sands	up to 1 m	concordant	covering formations	
		Allerød Older Dryas Bølling	11 000 12 300 13 250	slope sands with striae of organic material, fluvial and lacustrine sands	2 m average, max. up to 6 m	erosional- -denudational	upper sands	
	Maximum stage	Pomeranian phase Northern Great Poland phase Southern Great Poland phase	17 000 (?) 25 000	loess, mainly in alluvial, subarerial and solifluctional facie	3 m average, max. up to 7 m	concordant (?)	sands and silts	
	Anaglacial phase			fluvial sands	above 5 m	erosional- -denudational	lower sands	?
Aurignacian interglacial			28 000 40 000	fossil soil in the valleys of Łopa and Borowica, peat in Zakręcie (?)	up to 2 m		fossil soil in the Giełczew valley and in Wygnanowice	
Glaciation				loess, mainly alluvial and solifluctional, Dryas silts	above 10 m	? erosional (at the contact with Eemian deposits	fluvial sands	?
Eemian Interglacial			50 000	peat in Zakręcie (?)				

A discontinuous cover of Quaternary deposits rests on the eroded and denuded surface of the Maestrichtian deposits. They attain their maximum thickness (64 m) in the Wieprz valley. In the valley sides and the Cretaceous slopes, the thickness of Quaternary deposits decreases and varies

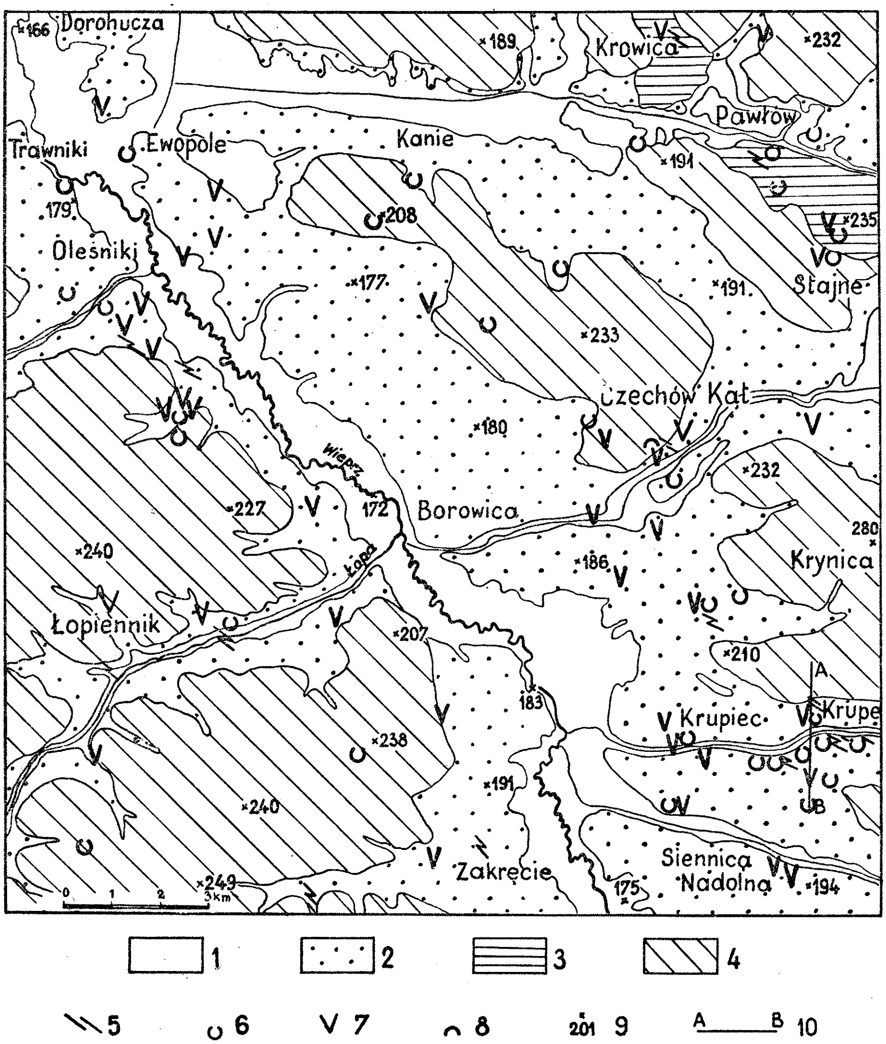


Fig. 1. Distribution of cryoturbate structures on the background of the principal units of geologic composition

1 valley floor deposit — Holocene; 2. würmian deposits, principally terraces, sands overlying loess and loess — Pleistocene; 3. pre-würmian deposits, mainly boulder clay — Pleistocene; 4. marbles, limestones and marls — Maastricht; 5. localities with congelifluction structures; 6. localities with involutions; 7. localities with cracks and wedges; 8. localities with other structures; 9. elevation above sea level in meters; 10. line of section A—B

widely. The oldest among the Quaternary layers are sands with gravels and preglacial silts occurring in the floor of Wieprz river valley (Mojski 1960 a) and loess-like silts (A. Jahn 1956), that were so far quite unknown. They are overlain by glacial and extraglacial deposits of the Riss glaciaton appearing in the form of boulder clay, terminal morainic, fluvioglacial and other features. Of younger age are the sands, the loess, both alluvial and solifluctional and the silts including a characteristic assemblage of cold-climate flora (*Betula nana*, *Dryas octopetala*).

It is believed that the latter deposits probably correspond to the post--Riss and pre-Würm glaciations. They are overlain by weathered formations such as the fossil-soil horizons in both the valleys of the Łopa river and the Borowica torrent. Similar deposits occurring in the Giełczew valley (J. E. Mojski 1957) and perhaps also the peat in Zakręcie (A. Jahn 1956) are likely to belong to the same category.

WÜRMIAN DEPOSITS

The present-day surface of Pleistocene deposits consists of sediments from the last, Würm glaciation. They widely vary in both facie and stratigraphy. In the valleys, they are composed of fluvial sands overlain by loess, on the slightly denuded surface of which rest alluvial slope sands. In several places, these are in turn overlain by a pulverulent formation due to weathering and wind-action, that represents the youngest Pleistocene formation in this region. In slopes, the sequence of layers is similar, although the fluvial sands underlying loess are here replaced by slope sands. Also the loess and the overlying sands show here a more diversified lithology dependant on the composition of the slope.

As the cryoturbate structures in question occur within würmian deposits, the latter are going to be described in greater detail.

The fluvial sands initiating the sedimentary cycle occur principally in the valley of the Wieprz river and in those of its major tributaries. The sands consist of medium- and coarse-grained particles including a constant admixture of Cretaceous gravels and Scandinavian rocks. The pattern of stratification indicates vigorous transportation by water (fig. 2, 3, 4, 5).

No frost structures have been found in these deposits, though their top portion is likely to have originated under periglacial conditions. Evidence arguing in favour of this assumption has been reported by A. Jahn (1956) from adjacent areas where the outcrops of such sands are better developed.

Loess occurs in three faciae which are: alluvial, solifluctional (slope) and subaerial. The alluvial facie is predominant. As evidenced by the

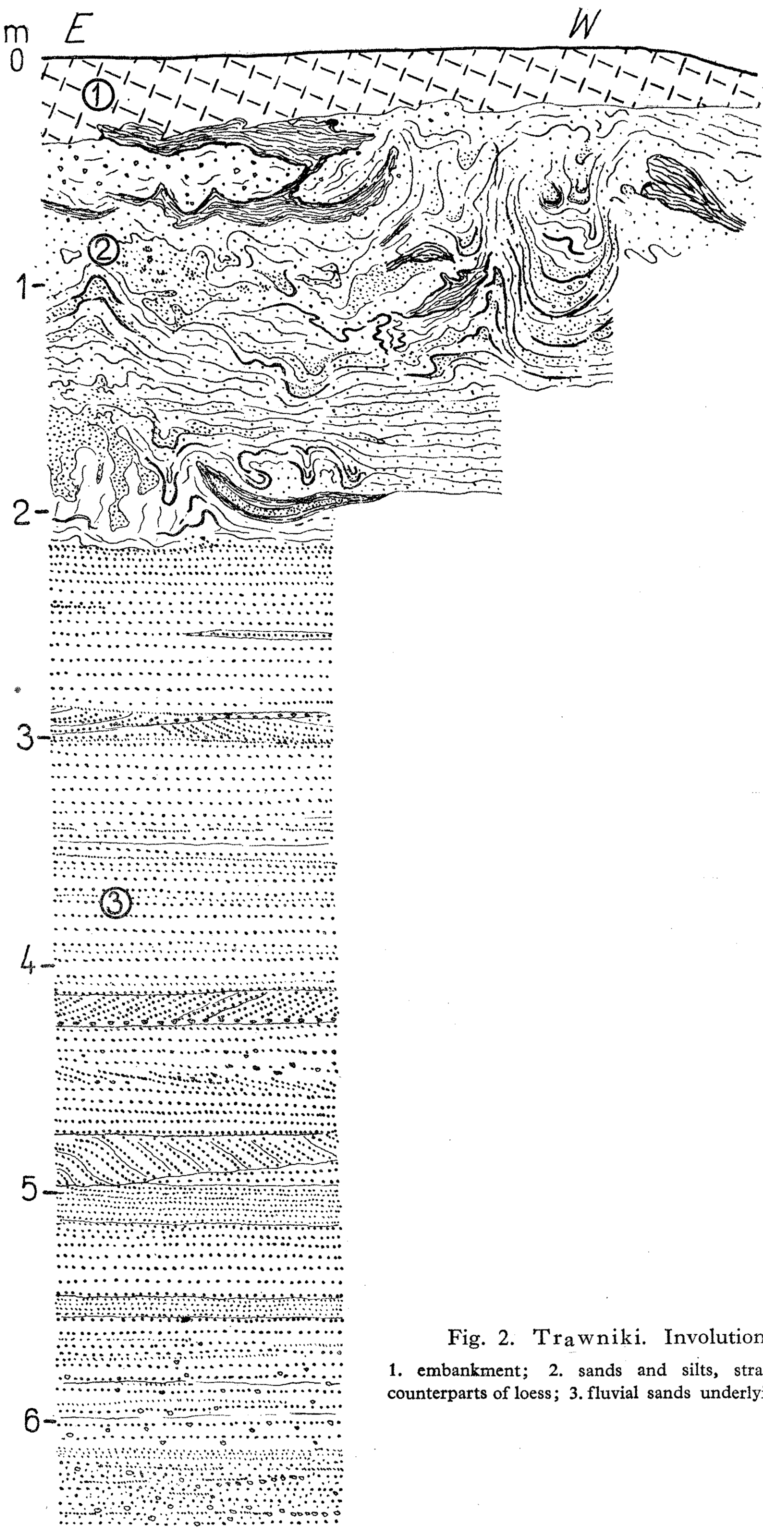


Fig. 2. Trawniki. Involutions

1. embankment; 2. sands and silts, stratigraphic counterparts of loess; 3. fluvial sands underlying loess

occurrence of periglacial structures within this facie (see below) and as further confirmed by recent works on the conditions under which it originated, the facie is clearly a periglacial one. In the loess, periglacial structures are represented by congelifluctional disturbances, involutions, cracks and wedges. Relatively dominant are the two first types of disturbance, as they occur in over 50% of the total number of localities which display such structures in a well-defined stratigraphic position. All the various types of cracks and wedges can be found here in more or less equal proportions (tab. II).

Table II

Occurrence of cryoturbate structures in würmian deposits in the southern part of the Dorohucza basin

Deposits	Congelifluction structures		Involutions			Cracks and wedges			Other structures
	free	bound	fold	pillar	amorphous	cracks	round tipped wedges	sharp tipped wedges	
pulverulent formations	1	1			2				1
slope, lacustrine and fluvial sands	2		4	1		10	3 8	2	
loess	1	9	1 3	4 6	5 3	1 6	3 2	5 1	2
fluvial sands									
structures with non-defined stratigraphic position			3		1	4	1	5	1

A fact that merits attention is that disturbance becomes increasingly severe towards the top of the loess layer (examples of which will be presented in the next section of the present article). This shows that conditions favouring its development did not prevail until a period subsequent to the initial stage of loess accumulation. This situation is found the same in the alluvial loess. In contrast, the cryoturbate structures occurring in the subaerial facie seem to disappear surfaceward.

Like the loess, also the overlying sands exhibit three faciae of slope, fluvial, and lacustrine origin. Most extensive are the slope and lacustrine sands. Each of the faciae exhibits different features although some of the deposits show an intermediate character.

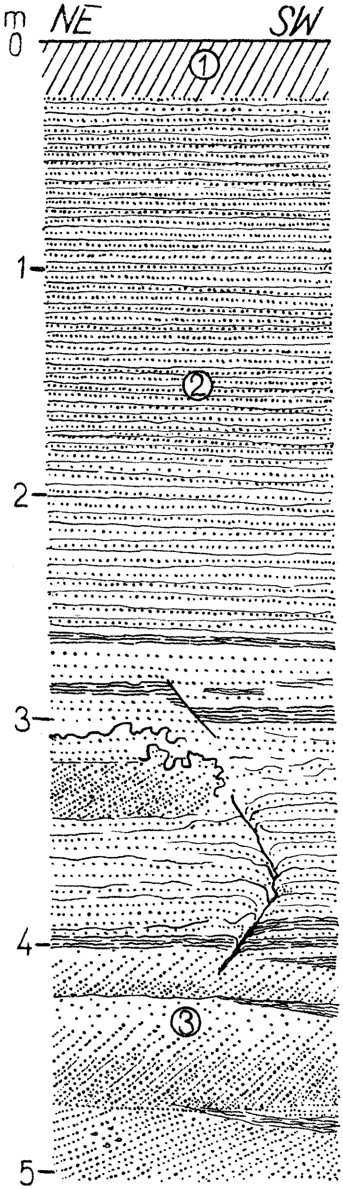


Fig. 3. Ewopole. Crack

1. soil; 2. fluvial and fluviolacustrine sands overlying loess; 3. fluvial sands underlying loess

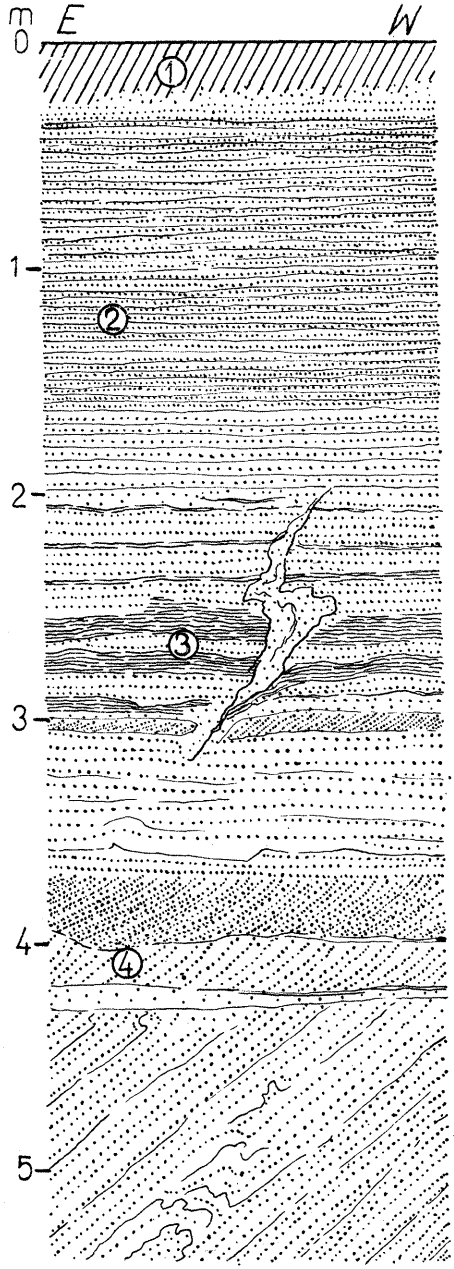


Fig. 4. Ewopole. Ice-wedge

1. soil; 2. sands overlying loess; 3. sands and silts, stratigraphic counterpart of loess; 4. fluvial sands unerlying loess

Slope and lacustrine deposits, especially their downward parts often show a varved mode of stratification, expressed by variations in grain-size and color (pl. 2, fig. 4). In their top-portion, the slope sands contain an admixture of gravelly material in the shape of striae and lenses of angular marl gravels, decalcified marble fragments, Tertiary rocks and crystalline gravels, that form an undulating pattern. In the fluvial-sand facie, these gravels are dragged out into thin, discontinuous horizontal striae. In contrast, the lacustrine sands contain no coarse material.

The dip of layers in the slope-sands varies widely (pl. 3). However it frequently increases towards the top, contrary to the observations by Dylik (1955) in the corresponding formations of the Łódź region. Whole complexes of layers dipping in various directions are here a common phenomenon, that testifies to variations in both the rate of deposition and the direction in which the slope material was transported. In the case of non-organized longitudinal sheet-flow, such processes may have easily contributed to the formation of episodic enclosed depressions, that soon became filled with finer material. Certain trends in the removal of material may have formed depressions in places where lenses of ground-ice had melted away. The fact is likely to have taken place towards the close of the period during which the slope sand accumulated.

Fluvial sands overlying loess are here but rarely encountered. As the valleys became filled with slope sands, the activity of running waters (rivers) gradually decreased until they finally, during the terminal phase of accumulation, carried but a small quantity of waters and were strongly meandering.

At the same time, a large, though shallow lake was formed in the Wieprz valley, extending probably far northward into the so-called lake-district of Łęczna—Włodawa (T. Wilgat 1950, 1954).

The observations presented in section 3 of the present paper indicate that the slope-sands are due to downwash rather than congelifluction. Related views are held by S. Kozarski (1958) and Ł. Pierzchałko (1956) concerning similar deposits from other areas of Poland. Hence, preponderance of downwash over congelifluction may be held to characterize temperate periglacial environments. Diversification in types of ice-wedges in the area investigated tends to confirm this view (section 3).

The pulverulent formations overlying the slope sands, occupy reduced area. They have about 1 m in thickness and occur generally in flat culminations of terraces. Small patches are also noticeable in several places on the upper knick-point of the terrace edge (fig. 6). Such a situation resembles that of dunes and thus points to the contributory role of eolian processes in the genesis of the dusts. Eolian transportation is further

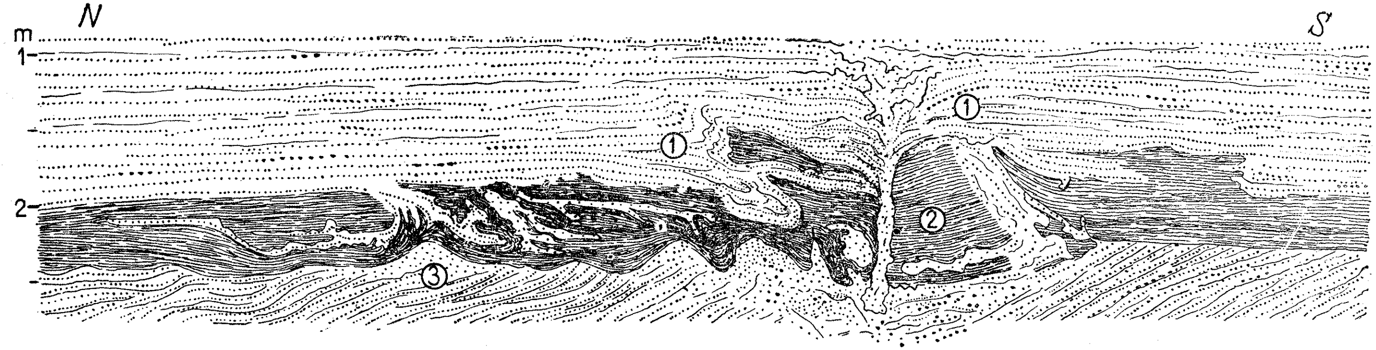


Fig. 5. Oleśniki. Ice-wedge

1. sands overlying loess; 2. loess in alluvial facie; 3. sands underlying loess

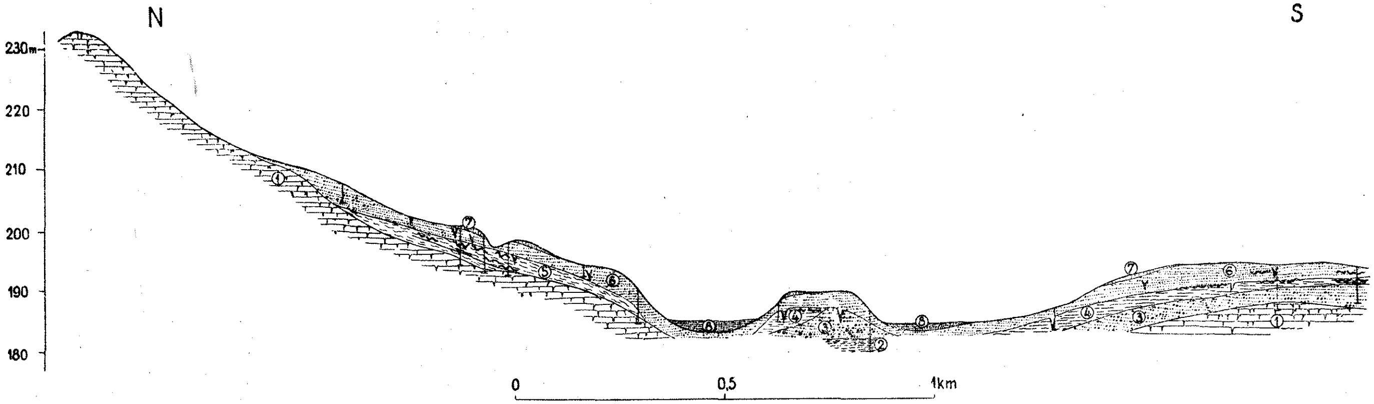


Fig. 6. Cross section A—B

1. Cretaceous marl; 2. Dryas silts — pre-würmian deposit; 3. fluvial sands underlying loess; 4. alluvial loess; 5. slope loess (congelifluction); 6. sands overlying loess; 7. pulverulent formations; 8. valley-floor deposits — Holocene; vertical lines indicate test localities situated along the line of section; interrupted vertical lines indicate test localities projected upon the line of section from a distance of ca 200 m

evidenced by the fine-grained composition of the deposits and the absence of stratification. However, the latter may as well be the result of post-glacial weathering.

These pulverulent formations the writer correlates with the covering formations previously identified in the region of Piaski Luterskie (J. E. Mojski 1957) and other similar formations occurring in the Lublin Upland (A. Jahn 1956; W. Pożaryski 1953) and adjacent areas.

In the present paper, the Baltic (Würm) glaciation is conceived as the terminal period of the Pleistocene, later than the Aurignacian interglacial (which the author regards as corresponding to the Göttweig interstadial — J.E. Mojski 1959-1960 b). According to this interpretation the sands underlying the loess should be regarded as corresponding to the anaglacial phase, and those overlying it, as corresponding to the kataglacial phase of the same glaciation. The period separating the interstadial Bölling to the younger Dryas inclusively, the writer regards as a kataglacial phase. Loess accumulation occurred during the intermediate period of glaciation and that of the pulverulent formations — at the close of the kataglacial phase, during the younger Dryas.

Evidence to support this dating has been presented in another paper (J. E. Mojski 1960 c). Thus, the age of each of the particular horizons previously recognised by the writer in the region of Piaski Luterskie (J. E. Mojski 1957) could be determined with greater precision. It fully corresponds to the views held by other authors (W. Pożaryski 1953; J. Dylik 1956; A. Jahn 1956; H. Maruszczak 1957). This more exact determination of the lower age limit of the sands overlying loess (below the Bölling interstadial) seems to be accurate, especially if the increasing importance of this interstadial in the stratigraphy of the close of the Pleistocene be taken into consideration (H. Gross 1958; T. van der Hammen 1957).

CRYOTURBATIONS

In the area investigated, cryoturbate structures were found in nearly 70 localities. About 60 of them occur in würmian deposits. The number corresponds proportionally to that of the relation between the number of exposures with deposits of that age and that of exposures with older Pleistocene ones.

Both cryoturbate structures and würmian deposits are undoubtedly of the same age. As shown in tab. II nearly all the structures are formed either in loess or, more frequently in younger deposits. Hence, they are either of the same age as the loess or — in the majority of cases — somewhat younger.

According to a number of writers, not all the types of periglacial structures require the presence of permafrost. Without entering into the essentials of this controversial problem, it may be stated that cryoturbations, by providing qualitative evidence of a quite definite sedimentary environment assume a special importance in both paleogeographic and stratigraphic constructions. Thus, the zone of cryoturbate disturbances occurring in the Pleistocene deposits outside the extent of the latest glaciations, actually represents a stratigraphic index, whether its origin was or not associated with greater or lesser cooling of the climate. A similar character of climatic and consequently also stratigraphic index may be ascribed e.g. to varved clays. Although not a sediment due to direct glacial accumulation, they unequivocally define the paleogeographic environment.

According to the distinction generally accepted, the structures in question are here divided into: congelifluctional, involutional and crack- or wedge-like. Apart from them, some structures much larger than the former occur sporadically. It is difficult to determine their character, because of the reduced sizes of the majority of exposures and excavations.

However, the above classification becomes increasingly formal. Despite many attempts to correlate types of fossil structures with processes and relief-forms occurring within present-day periglacial areas — such correlations still remain unsatisfactory. Such a classification is therefore largely exterior instead of being genetic. With this idea in mind, has the writer conducted his investigations of the structures and derived the conclusions suggested by their occurrence.

There may be still another new and, in a sense, critical approach to cryoturbate structures. In some cases, these structures clearly differ in age from the deposits within which they occur. This fact tends to minimize if not to entirely disqualify the significance they might represent for a knowledge of the conditions under which these deposits were formed. It has been therefore recently pointed out that a distinction should be made between structures that are syngenetic and those that are epigenetic relative to the deposits, principally as concerns cracks and wedges (G. Gallwitz 1949; V. Šibrava & V. Kroutlík 1957; „Osnovy geokriologii" 1959, p. 297—318).

In the field, both these types are not easily recognisable, and the criteria applied by various workers seem to be either too vague or not entirely convincing. In the work cited above („Osnovy geokriologii"), the distinction made between contemporary syngenetic and epigenetic wedges occurring in Siberia, is based upon such differences as the situation of ice-bands within either of these types. Such a criterion cannot possibly be applied to fossil formations. It thus becomes also impossible to study the eventual modifications, obliterated by subsequent processes, to which the deposits filling the structures and that might repeat the previous arrangement of ice-bands, may have been subjected.

Congelifluction structures, occurring in deposits due to solifluction on slopes (A. Jahn 1951, p. 259) are syngenetic in the full sense of the term, whereas part of the congelifluction structures due to microsolifluction (A. Jahn 1951, pp. 250 and 259) may be epigenetic, having originated within the active zone.

Structures of the involution type may be *a priori* regarded as predominantly epigenetic, as the active zone in which involutions are formed often involves deposits of wholly different ages (e. g. involution zones in interloessial soil horizons).

The difficulty of discerning syngenetic structures from epigenetic ones was, in the area investigated, increased by the fact that the zones of disturbance have on the whole a very negligible thickness. This is mainly due to erosion and denudation, which destroyed the deposits including their top and, in several places, perhaps the entire zone of cryoturbation as well. A number of other difficulties and still unsolved, though essential problems concerning cryoturbate structures have been pointed out by J. Dylik and R. Raynal (1958).

CONGELIFLUCTION STRUCTURES

About 75% of the congelifluction structures occur in loess, thus constituting one of the leading characteristics of this facial variety i. e. of solifluction loess. Congelifluction structures are here not readily recognisable, the deposits being fairly homogenous in grain-size. Disturbances occur principally in the form of tiny folds and reduced surfaces of discontinuity, inclined in one direction. However in several places, the continuity of single bands is preserved along a stretch of a few meters. In numerous exposures, sets of bands wedge in the form of distinctly storeyed downflow lobes.

Packets of layers disturbed by congelifluction frequently alternate with regularly bedded ones. In places where the loess base is visible, congelifluction structures tend to disappear gradually downward.

Such a character indicates that the disturbances are due to bound congelifluction, that is characterized by the movement of whole agglomerates of particles. A good example of that type of congelifluction is provided by the cross section appearing in the exposure at Krupe (fig. 7,

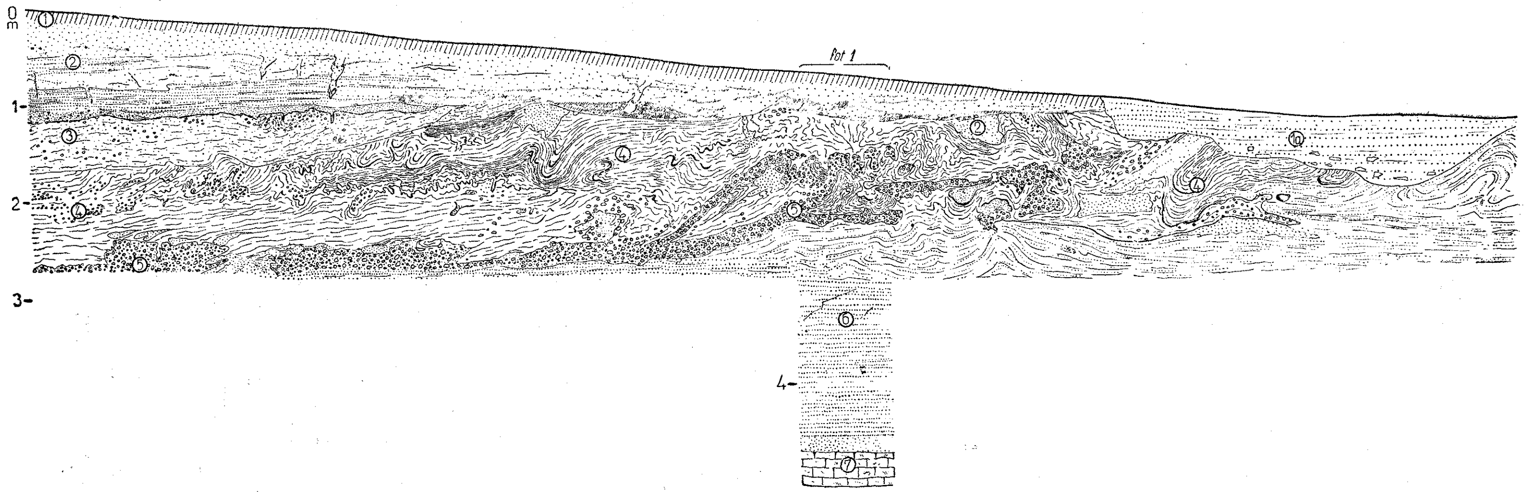


Fig. 7. Kruppe. Congelifluction structures, involutions, cracks and wedges

1. soil; 2. sands overlying loess in slope facie; 3. sandy silts with debris of decalcified marl; 4. silts with debris of marl, both decalcified and non-decalcified; 5. marl debris with sand; layers 3, 4 and 5 are stratigraphic counterparts of loess; 6. sands underlying loess; 7. Cretaceous marl

pl. 1). Disturbances involve here the layers from 3 to 6 inclusively. Most conspicuous are the congelifluctional deformations in layer 4 and 5 in the central and the northern part of the wall. The type of solifluction described for the first time by A. Jahn (1951, p. 260—262) and termed by him *rolled solifluction* was found to occur here (between 1—3 m). The pillar involutions, appearing in the congelifluction zone of this exposure, are likely to have originated somewhat later.

Worthy of note is the denuded character of the contact between layers 3 and 4 in the northern part of the wall. This surface of denudation has no stratigraphic significance and arose as a result of destruction of the surface of the older downflow lobe by that of the younger one.

Character of the deposits, thickness of the congelifluction zone, discordance of surfaces and situation of the deposits on the slope, all tend to confirm the assumption that the formation is a fossil congelifluction terrace — a periglacial relief-form that has been described both from the present-day zone (S. G. Boch & I. I. Krasnov 1951; R. S. Sigafoos & D. M. Hopkins 1952) as well as from the fossil one (J. Dylik 1955).

Structures produced by bound congelifluction occur likewise in an excavation near-by the exposure described, at a depth of 3,8—5,0 m (fig. 8). In both cases, the congelifluction deposits coincide in age with the period of loess accumulation, and are genetically related to the solifluction facie of this deposit.

The remaining 25% of localities with congelifluction structures occur within slope sands and pulverulent formations. Only those localities have been marked in the map, whose congelifluctional origin appeared least uncertain. In many other cases they may be due to solifluction or even to various deformations caused by fluvial accumulation. Such questionable structures are presented in pl. 3.

An important problem arises in connection with such structures namely that of the criteria to be applied in order to distinguish between congelifluction structures occurring in sandy deposits and such structures that, though having a similar appearence were not formed under permafrost conditions.

In the localities marked in the map, the congelifluction structures occurring in sand resemble the type of free congelifluction which, according to J. Dylik (1952, p. 82 et al.) is to be attributed to environments characterized by a climate more severe that the one associated with bound congelifluction.

On the other hand the slope, fluvial and lacustrine sands show a predominance of the mode of stratification that usually characterizes aqueous environments where pseudo-congelifluction structures are predominant.

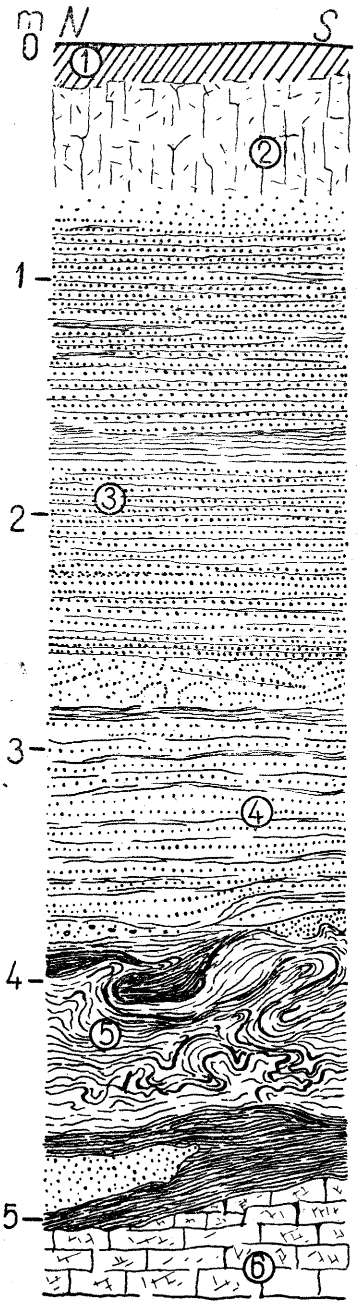


Fig. 8. Krupe. Congelifluction structures

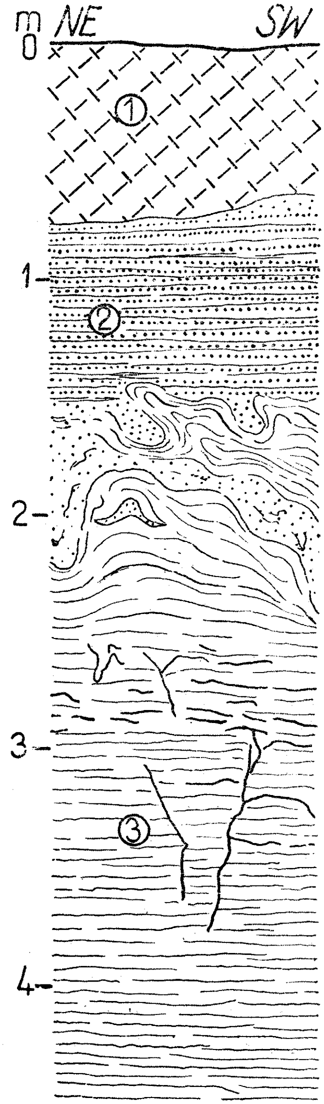


Fig. 9. Krupe. Involutions and cracks

1. embankment; 2. sands overlying loess; 3. loess in alluvial facie

1. soil; 2. silts and pulverulent clays; 2. sands overlying loess in slope facie; 4. sandy silts; 5. clayey silts with striae of accumulational soil layer and lences of sand; layers 4 and 5 are stratigraphic counterparts of loess; 6. Cretaceous marl

The stratigraphic situation of these deposits within the würmian sedimentary sequence argues against their having been deposited during a colder climatic phase than that of loess accumulation. This contradiction has been pointed out by A. Jahn (1956, p. 332).

The present writer believes that the structures referred to as free congelifluction must not be necessarily indicative of a severely cold climate, but may have resulted from the properties of the material in which they were formed. Bound structures that are so characteristic of fine-grained deposits (clays, silts) are not likely to develop in sands which are deprived of substances easily absorbing water.

INVOLUTIONS

Involutions are more frequently encountered than congelifluction structures, although they are associated with them by their occurrence in the same deposits and localites i. e. dominantly in loess horizons (about 70%). According to the classification of A. Jahn (1951, p. 246) they usually belong to either the pillar or the amorphous type (17 localities). In four places only fold involutions were found to occur in the loess. Examples of involutions are presented in figures 2, 7, 8 and in pl. 1.

Involutions are, like congelifluction structures grouped in the top portion of the loess, principally in its alluvial facie. The involution zone is no more than 1 m in thickness. This does not, however, represent its initial value, the top of the layer being frequently truncated by erosion. This shows that the involutions originated prior to the deposition of the overlying sediments and provides evidence of changes in paleogeographic conditions. However, in six cases the involutions were found to involve both the loess and the overlying sands. Owing to the contrasting petrographic character of these deposits, the involutions are very well-defined.

CRACKS AND WEDGES

Most numerous are the localities displaying cracks and wedges. In some of them even two separate generations are visible in the vertical section. At about 10 localities out of a total number of 40, it has not been possible to determine the exact age of the structures.

The following structures are regarded as belonging to the group of cracks and wedges: (a) cracks *sensu stricto* i. e. such structures as represent traces of a surface that is marked within the exposure by a disjunction of layers, (b) ice-wedges, relatively wide and short with rounded tips and (c) ice-wedges, somewhat narrower, deeper, tapering and in several places passing into cracks.

a. The direction of the cracks is approximately vertical. Their depth generally ranges from 0,2 to 3 m. The amplitude of downcast is no more than 5—10 cm. In several places the wedges alternatively widen and narrow. The line of fissure is emphasized by both down- and up-curling of layers, within the deposit (fig. 3, 4, 7, layer 2, meters 0—2). Such contortions are better marked in pelithic deposits e. g. in alluvial loess (fig. 9).

b. Wedges with rounded tips have a depth averaging 0,5—1,0 m, a width of up to 0,2 m, a direction clearly departing from the vertical and an irregular contour. Their most constant feature is their rounded tip, below which there is no trace of any disjunction of the deposit.

Such formations occur most commonly in the top portion of slope sands overlying loess, and are filled with similar sands. This clearly indicates that the formation of ice-wedges and their infilling were episodic phenomena relative to that of sedimentation. Furthermore, the occurrence of wedges at different depths proves that the conditions under which they originated were controlled by local factors. Alone the larger number of wedges within the upper portion may — though must not necessarily — indicate increasing severity of climatic conditions.

The heads of the wedges are tilted in downslope direction and thereby testify to gravitative movement of the deposits at the period of thaw (fig. 7 and 11). These illustrations clearly show that round-tipped wedges induce up- and down-curling of the deposits within which they developed.

c. Sharp-tipped wedges range from 0,7 to 3,0 m in depth and 0,1 to 0,4 m in width of top-portion. Their direction is more vertical than that of the round-tipped wedges. In the vertical section some of these forms appear highly symmetrical. A characteristic feature of these wedges is their gradually narrowing downward part which finally becomes a mere crack. Larger forms are associated with surfaces of disjunction on either side, wherefrom blocks lying near-by the wedge wall have been projected lower downward (pl. 8).

Sharp-tipped wedges occur commonly within the top of loess. Yet, as may be inferred from the eroded surface of this deposit they are mostly deprived of their upper part (fig. 10 and 11). Therefore, the sizes given above are not these of the primary wedges, which were probably much larger.

Cracks are equally common in loess and in the overlying sands (tab. II). Both types of wedges show a marked irregularity in vertical distribution.

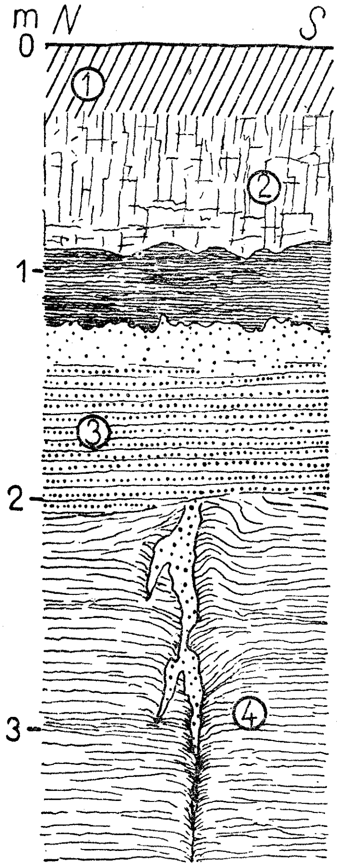


Fig. 10. Siennica Nadolna. Sharp-tipped wedge

1. soil; 2. silts and pulverulent clays; 3. sands overlying loess in slope facie; 4. loess in alluvial facie

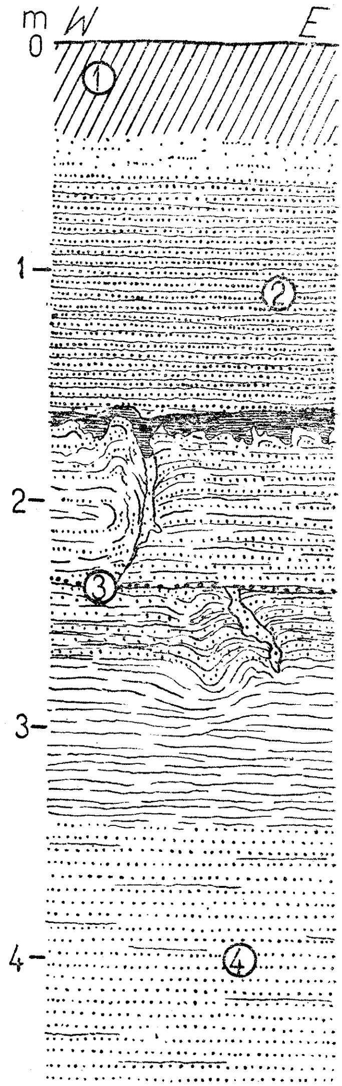


Fig. 11. Czechów Kąt. Two generations of wedges

1. soil; 2. sands overlying loess; 3. loess in alluvial facie; 4. fluvial sands overlying loess

Round-tipped wedges are twice as frequent in slope sands than in loess, whereas sharp-tipped ones are, on the contrary, three times as numerous in loess than in sands.

It is generally accepted (P. Black 1954; J. Dylik 1956) that ice-wedges constitue the most reliable structural leading feature of deposits that have been subjected to permafrost and that therefore the conclusions derived from the analysis of these formations are most valuable.

The division of the wedges in the Dorohucza basin is in conformity with their classification from the region of Piaski Luterskie. Hence, the conclusions regarding the genesis of the latter are also applicable to the former (J. E. Mojski 1957, p. 462—464). On the basis of these conclusions, the round-tipped wedges may be regarded as episodic formations, and the sharp-tipped ones as rather indurated, syngenetic structures. The episodic character of the former type has been already pointed out above. This view has been also favoured by other authors (J. Dylik 1956, p. 216—217; A. Jahn 1951, p. 256—259). It may seem rather surprising that all the works dealing with wedge-like structures from the present-day periglacial zone, fail to mention round-tipped wedges (e. g. „Osnovy geokriologii" 1959). This might suggest that such structures are either independant of periglacial environment (as pointed out by A. Jahn 1951, p. 257) or that the usual classification of ice-wedges is not a genetic one and therefore is hardly applicable to paleoclimatic considerations. Another alternative explanation is that the periglacial conditions under which ice-wedges developed in our country differed from those prevailing to-day in permafrost areas.

This is a typical example of the problem resulting from correlation of fossil formations with present-day formations and processes.

OTHER STRUCTURES

In several cases, the cryoturbate deformations could not be classified according to the system adopted. This applies chiefly to large formations observed either in the walls of extensive exposures or in those of closely spaced excavations. Similar deformations had been observed previously in the region of Piaski Luterskie (J. E. Mojski 1957, loc. 19, p. 448—454).

In the Dorohucza basin, an example of such formation is that in the exposure at Ewopole (pl. 1) where below the overloessial sands that are here developed in the fluvial and the lacustrine facie, appears a correlate of loess in the form of silts interbedded by fine-grained sands. The photograph clearly shows that the contact between these horizons is eroded. Within the loess appears a visibly anticlinal formation of about 15 m in intersectional width of wing. The height of the formation before its destruction must have been at least 5 m.

CONCLUSION

These observations regarding the mode of formation and the distribution of cryoturbations in the deposits from the last glaciation occurring in the Dorohucza basin, may be summarized as follows:

1. Cryoturbations occur within three of the youngest horizons, among the four that correspond the to Würm glaciation (tab. II). The structures occur at various depths of these deposits but disappear in the lower part of the second horizon (loess) and in the upper part of the fourth horizon (pulverulent formations). Alone crack- and wedge-like structures increase in number towards the top of the sands overlying the loess (third horizon).

Such variations in the vertical distribution of these structures points to an amelioration of the conditions favouring their formation at the time of loess accumulation and to their deterioration during the period of sedimentation of the overlying sands, as well as to the fact that, toward the close of the latter period, at the time when the pulverulent deposits were formed, these conditions may have temporarily improved.

2. The surface of discordance occurring between the loess and the overlying sands may be the result of some change in climatic conditions. The contrasting character of these deposits also argues in favour of this assumption. However, the change was not so considerable as to cause the decay of permafrost. This is evidenced by the presence of frost-structures, that disturbed both loess and sands.

All these facts seem to suggest that at the close of the Würm glaciation, erosion and denudation progressed within frozen deposits. There is no evidence whatsoever to support the hypothesis that increased erosion was associated with disappearence of frozen ground. This conclusion would thus tend to contradict the previous statements made by the writer (J. E. Mojski 1957, p. 473—478).

However, the climatic conditions prevailing throughout the periglacial zone and the resultant thickness of the active layer are likely to have been subjected to fluctuations.

3. Analysis of the material and the known distance that separated the area of the Dorohucza basin from the ice-sheet during the Würm glaciation, prove that at the period of maximum development of periglacial phenomena (within the loess horizon) the area investigated was situated in the tundra sub-zone of permafrost (S. Z. Różycki 1957, p. 53, tab. I).

Translation by T. Dmochowska

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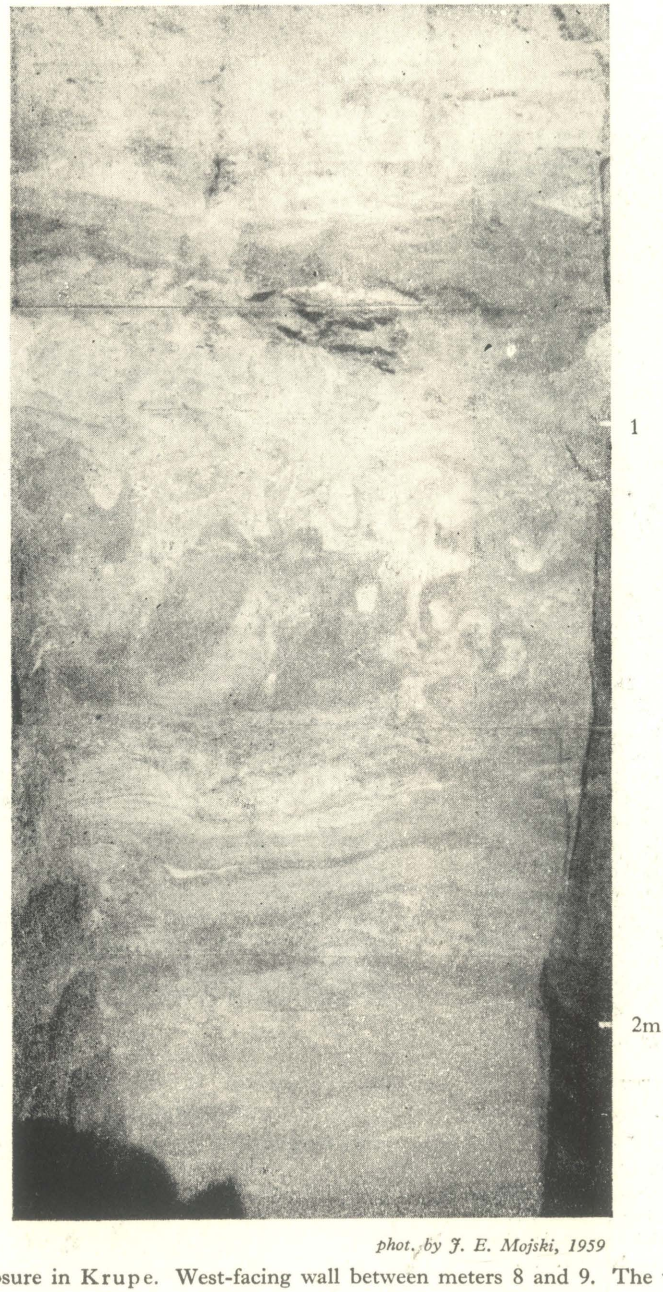
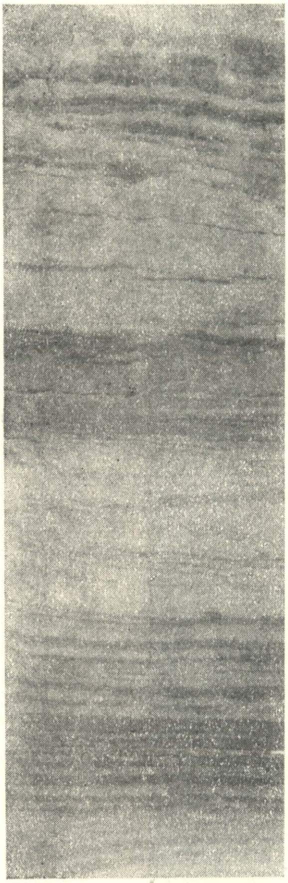


phot. by J. E. Mojski, 1959

Pl. 1. Exposure in Krupe. West-facing wall between meters 8 and 9. The whole wall is presented in fig. 6

0,0—0,6 m — silts and pulverulent clays; 0,6—0,8 m — sands overlying loess in slope facie; 0,8—2,5 m — — stratigraphic counterparts of loess, composed of silty-clayey waste of Cretaceous marl, sand and limestone debris. Well-marked disturbances due to congelifluction and involution. The deposits correspond to layers 4 and 5 in fig. 6



phot. by J. E. Mojski, 1959

Pl. 2. Exposure in Krupiec. North-east facing wall

To a depth of 1,5 m — silts and pulverulent clays with ferruginous striae; below 1,5 m — sands overlying loess in slope facie with bands of silts

phot. by J. E. Mojski, 1959

Pl. 3. Exposure in Siennica Nadolna. North-facing wall

Sands overlying loess in slope facie with pseudo-congelifluctional formations

phot. by J. E. Mojski. 1957

Pl. 4. Exposure in Ewopole, south-west of the village

Depth of exposure ca 4 m, height of a—b wall ca 1,2 m; length of a—b wall ca 35 m;

0,0—2,5 — sands overlying loess. Lower portion in fluvial facie with gravels at the base. Upward the same gradually pass into lacustrine sands;

2,5—3,7 — silts and sands, stratigraphic counterparts of loess, forming a non-defined cryoturbate structure whose top is truncated by erosion

phot. by J. E. Mojski, 1958

Pl. 5. Exposure in Ewopole, west of the village. Ice-wedge in fluvial sands overlying loess

Length of formations ca 0,8 m. The sharp-tipped wedge developed subsequently into a round-tipped one without disturbing the downward part of its initial shape

phot. by J. E. Mojski, 1958

Pl. 6. The same exposure as in pl. 5

0,0—0,7 m — silts and pulverulent clays; 0,7—1,3 m — cracks and wedges in fluvial sands overlying loess

phot. by J. E. Mojski, 1959.

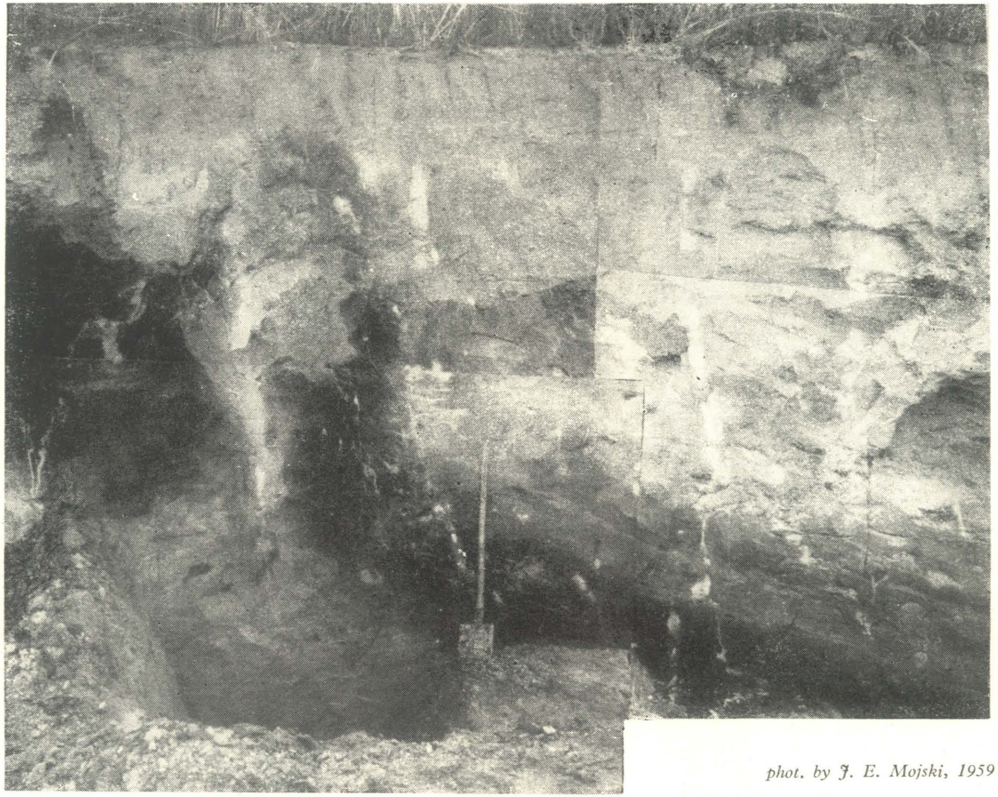
Pl. 7. Exposure in Czechów Kąt. North-facing wall

Height ca 1 m. Crack formed in slope sands overlying loess

phot. by J. Trembaczowski, 1958

Pl. 8. Exposure in Zakręcie. Wall facing north-west

Height of wall ca 2,2 m. Crack in slope sands overlying loess. Top of loess visible below (dark layer)



phot. by J. E. Mojski, 1959

Pl. 9. Exposure in Czechów Kąt. Wall facing north-west

Height of wall ca 3 m. Ice-wedge in fossil soil of uncertain age (Aurignacian or Eeemian interglacial)
The wedge is filled with silts and fine-grained sand