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CHRONOLOGICAL PROBLEMS OF THE PATTERNED SOILS OF HUNGARY

Most of the patterned soils (cryoturbation phenomena) described from the periglacial areas of Central Europe have been dated by the respective workers from the Last Glaciation (Büdel 1959; Dylik 1956; Dücker 1954; Ebers 1954; Jahn 1956; Kaiser 1960; Sekyra 1960; Poser 1948; Velichko 1958). Cryoturbations dating from the Riss and Mindel Glaciations have been encountered much less often (Kaiser 1960; Fink 1960; Suchel 1954; Weinberger 1954). This is understandable, as the sedimenst of the Last Glaciation often cover and overlap the deposits of earlier glaciations or the older rocks have, in part, fallen victim to denudation.

Very thorough investigations are necessary in order to determine the age of formation of the individual types of cryoturbation features, since the formation of certain feature types requires different climatic conditions even under the same lithological, relief and hydrogeological conditions. Classification cannot be performed merely on the basis of the size of the features, as the polygons that have been formed e.g. under the same type of glacial climate within one and the same area may differ by their dimensions. The observations carried out in the present periglacial areas testify that within the larger, more deep-reaching polygons smaller, less deep--reaching ones may synchronously be formed (Büdel 1960; Tricart 1950). The form assemblage of patterned soils has been further complicated by the periodical oscillations in the penetration of frost to smaller or greater depths.

In the course of our research work we have, however, discovered such a spectrum of the Hungarian patterned soils (Pécsi 1958, 1961, 1963) which has permitted to establish a chronological succession of the cryoturbation phenomena.

LATE WÜRMIAN CRYOTURBATION PHENOMENA

While performing the chronological division of the Hungarian cryoturbation features, we first considered the time of accumulation of the terrace gravels, which is relatively well known. The cryoturbation patterns occurring in the most recent Pleistocene terraces and sediments were statistically evaluated. In the fluviatile sediments deposited at the end of the Last Glaciation (in the first flood-less terraces and in talus fans dating from the end of the Würm) we usually found simple and peculiar cryoturbation patterns — ice wedges, ice sacs, cryoturbated layers — the vertical range of which measured but a few dcm (figs. 1, 2). The formation of these

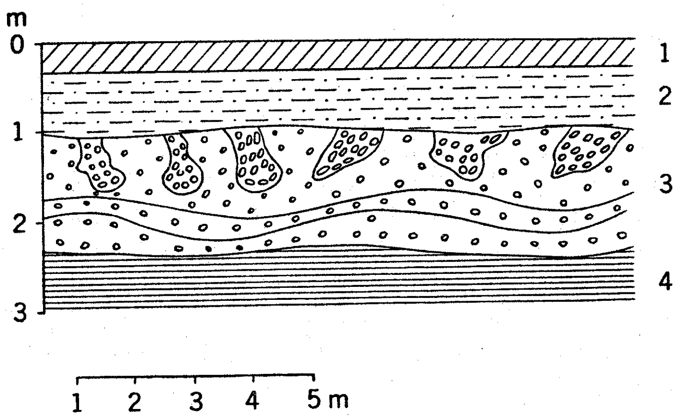

Fig. 1. Cryoturbations dating from the end of the Würm glaciation. Budapest, exposure on the edge of the flood plain

1. artificial dam; 2. brownish-yellow Holocene flood-plain silts; 3. Late Würmian terrace gravels, in their upper part there are irregular ice sacs and wedges filled with sands and silts, below which wavy stratum deformations are seen; 4. Oligocene clays

patterns in fluviatile sediments can be interpreted in such a way that a considerable part of the river bed, or the surface of the talus fan, respectively, has been exundated due to the low water level during the winter half-year, in other words, that the cryoturbation features are likely to have been formed either synchronously with, or somewhat later than, the time of sedimentation. In the loose sandy-gravelly sediments the frost effect became intensive because of the high position of the ground-water table. In the coarse-grained sediments the cryoturbation processes may generally take place only if the position of the ground-water table is high.

The features in question which are commonly simple and not deep--reaching must have been formed in the final, colder climatic phase of the Last Glaciation during which at the beginning more humid, later on drier, cold climatic types prevailed, periodically with frozen subsoil. This period can be correlated with the older and the younger Dryas phase (Late Würm) on the basis of the stratigraphic and morphologic conditions set in parallel with foreign analogies.

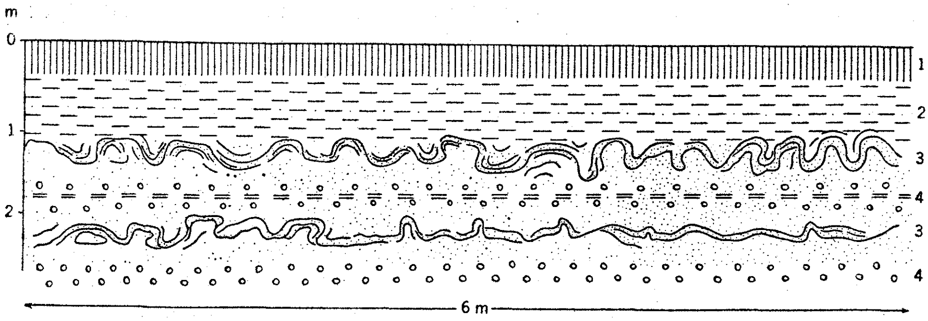

Fig. 2. Slight Late Würmian cryoturbation covered by flood-plain silts on a young alluvial fan of the Danube in its Little Plain reaches

1. humus-sandy flood-plain silts; 2. calcareous sandy flood-plain silts; 3. 20 to 30 cm thick cryoturbated fine sands dissected and patterned by silt bands; 4. sandy gravels. This type of cryoturbation is similar to the cryoturbation features which can be observed in the foreland of Salpaussälka, Southern Finland. On the basis of this similarity its formation can be ascribed to the Salpaussälka stage (Virkkala 1960)

The sediments in which the above-mentioned cryoturbation form types are encountered may locally be buried by some dcm thick flood-plain sands and silts, or they are covered by a quicksand blanket, or by sand dunes, respectively. Hence, no sediments other than Holocene ones overlay them.

CRYOTURBATIONS FORMED DURING THE EARLY AND MIDDLE WÜRM

On the terraces dating from the beginning of the Würm Glaciation (Second flood-less terrace No. II/b), on alluvial fans of the same age as well as on the surfaces of terraces formed during the Riss Glaciation, several generations of patterned soils could be observed. On the surfaces of the second flood-less terraces ranging along the Danube and its big tributaries and on the alluvial fans corresponding to them, one finds a group of cryoturbation features which can be easily differentiated from the previous types. The fossil fauna found in several cases in the terrace gravels on the banks of the Danube (*Elephas primigenius*, *Coelodonta antiquitatis*, etc.) has permitted to date this terrace horizon from the beginning of the Würm Glaciation.

The surface of these terraces is overlain by a slope-loess sheet of various depth in the montainous reaches of the valleys. As a matter of fact, the second flood-less terrace horizon (*Hochterrasse*) has two types: (a) in case of the alluvial terrace type the terrace gravels are commonly barren. This is principally true for the alluvial terraces of the Little Plain reaches of the Danube and for its tributaries falling on this section. Here, possibilities for a fluvial accumulation existed properly during the phases of both glacial and interglacial climatic types; (b) in case of the valley-terrace type the terrace gravels are overlain by a thick loess cover.

(a) In those terrace sections where the terrace gravels are barren or are covered but by 1 to 1,5 m thick sandy silts, two generations of cryoturbation features can be found in the upper portion of the gravel layer (fig. 3). On the second flood-less terrace of the Danube we can observe an assemblage of ice wedges and ice sacs as well as gravel polygons and cryo-depressions penetrating down to a depth of about 1,5 to 2 m. These larger elements are cut by smaller ice wedges and cryoturbation features penetrating to a few dcm. Their types correspond with those occurring on the first flood-less terrace. The smaller features may be considered as a second generation because after the formation of the group of larger features a clayey-loamy cover has been formed on the surface of the terrace. The material of this cover has been used up for the formation of the smaller cryoturbation elements. There are places where it can be shown that the formation of the larger features was followed by soil formation. The remnants of these soils are found, again, within the smaller features, while in the larger ones they are lacking.

The formation of the larger cryoturbation features occurring in the second flood-less terrace of the Danube, i.e. the formation of the older generation, can be ascribed to the main phase of the Würm Glaciation. This is suggested by the fact that analogical features may be found in the clayey-loamy slope deposits affected by solifluction and slopewash, the age of which appears to correspond to the Last Glaciation.

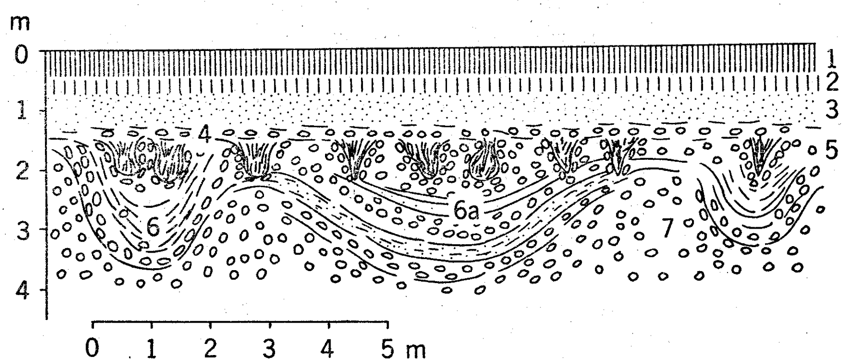

Fig. 3. Cryoturbation type occurring on the second flood-less terrace of the Danube

1. chernozem; 2. remains of a former brown forest soil; 3. calcareous quicksand; 4. gravel pavement; 5. relatively small ice sacs and ice wedges filled with sands and sandy silts. II-nd cryoturbation generation; 6. 1,5 to 2,0 m thick gravel polygon; the inner core is made up of sandy silts, sandy calcareous silts, with scattered gravel grains; 6a. slightly bent sand and gravel layers affected by cryoturbation; 7. gravels of the second (No. II/b) flood-terrace of the Danube

On the other hand, some exposures of the second flood-less terrace, or alluvial terraces, of the tributaries (fig. 4) suggest, when considering the palaeopedological data, that we have to reckon with an additional soil formation that took place in the interglacial period after the deposition of gravels. For instance, in the exposure shown in figure 4 such a red clay-bearing soil has been formed on the surface of the terrace gravels, the

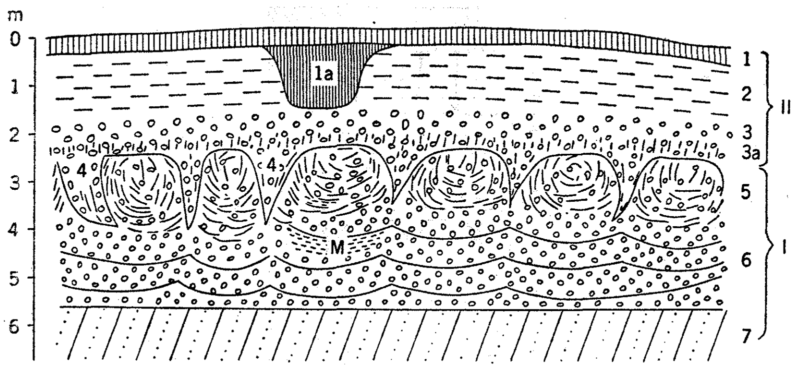

Fig. 4. Assemblage of Würm cryoturbation features of several phases. Gravel sheet beyond the Rába River

1. meadow chernozem; 1a. Neolithic pit that was used by the primitive man as his home; 2. loessy loam affected by solifluction; 3. lower portion of the fine-gravels with a calcareous matrix; redeposited by solifluction (3a); 4. ice wedges filled with sandy-calcareous silts; 5. kettle- and barrel-shaped polygons; the gravel grains are coated by brick-red clay. Before the formation of polygons the brick-red sandy-clay ground had formed a continuous layer; 6. terrace gravels disturbed by frost; 7. Upper Pliocene sands; M — remains of calcareous sand

formation of which suggests the existence of a sub-mediterranean arid climate. A climatic type like this may most probably have developed in the interglacial periods. This would mean that the red clays of the exposure at Kerecsend, the remnants of red soil in the gravel pit at Vép and the red clay-bearing soils of similar position in other localities of Hungary must have developed during the last interglacial period. On the other hand, the mingling by means of cryoturbation of the polygons with the red soil embedding them, has taken place at the beginning of the Würm Glaciation, while the ice wedges have come into being in the main phase of the Würm. The groupe of these older Würmian cryoturbations also appear to have been formed during the existence of a more humid, cold climatic type and of an arid, cold one which followed each other. In fact, the polygonal network of the ice wedges was developed under the influence of an apparently later frost process (beginning of the main phase of the glaciation), as it cracked and fractured the kettle-shaped normal polygons.

(b) There are also often found exposures where the terrace is covered by slope loesses or loams and where in the upper horizon of terrace gravels the assemblages of the above-discussed cryoturbation types have not been formed. In such cases the terrace gravels were covered first with pelitic

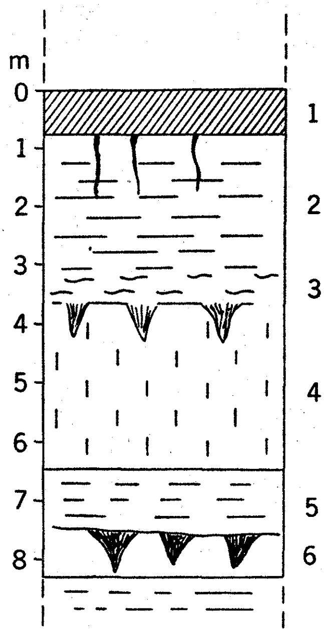

Fig. 5. Phases of sedimentation on slopes between two fossil soil zones within the Last Glaciation. Generalized profile

1. from the lower horizon of the buried chernozem soil, some cracks filled with lime penetrate downwards. Their formation requires dry continental steppe climate (chernozem-forming climate) with relatively little rainfall and periodically frozen soil; 2. slope loess or sandy loess exhibiting a finely laminated and foliated structure. Its formation requires a climate: little rainfall but accumulation of snow in winter, a temperature colder than in the previous case, permanently frozen soil (permafrost) or subsoil frozen at least during the greater part of the year. The material is carried and deposited on the slope by slow flowing melt-water (cataglacial phase); 3. loess or sandy loess exhibiting fine-stratified, foliated structure with patterns of slight cryoturbations. During its formation the climatic conditions may have been similar to the previous case, but the amount of precipitations is likely to have been a little greater. These conditions exerted a favourable influence on the formation of slight cryoturbation features (more humid type of the cataglacial phase); 4. massive loess, sometime with ice wedges in the top. Their formation is confined to the driest and coldest climate (waxing phase of glacial climate); 5. stratified slope loess and sandy loess with redeposited soil remains. This type goes on loosing its stratification as one proceeds in the lower part upwards. It passes slowly and continuously into the massive loesses overlying it. Accordingly, the humidity of the climate becomes more and more reduced. We have to suppose that the soil was either constantly or periodically frozen at the time of the formation of these sediments, as at the beginning of the cryoturbation process set in the underlying fossil soil, too. And if the underlying soil were formed under the influence of a forest climate (6), then the stratified slope loess that was deposited on this soil surface came into being under more rainy but cool climatic conditions by means of redeposition by solifluction (anaglacial phase); 6. fossil soil. It may also be a chernozem one, but brown forest soils are encountered more frequently. The soil zone has been locally disturbed by frost phenomena (ice wedges, solifluction formations). The brown forest soil has been formed under conditions of such a warm and rainy climate which, as suggested by our observations, must have existed usually — but not without exception — during the interglacial or interstadial periods (warm, humid deciduous forest climate)

materials by means of solifluction (anaglacial phase) and then the formation of polygons and later that of ice wedges proceded on these sediments, and finally the layer disturbed by polygons and ice wedges was covered with eolian deposits (climax phase). In some exposure the eolian series was, in turn, overlain by slope loesses or loams through the medium of a solifluction mechanism of material transport (cataglacial phase). In the latter sediment suit the traces of a few phases of soil formation can also be recognized. In Hungary forest-soil types and chiefly chernozem soils or horizons of humus accumulation have been developed in the slope deposits overlying the second flood-less terrace, as a function of the prevalent climatic type and of the orographic conditions . It can also be detected in slope loesses that during the cataglacial climatic phases of varying intensity of the Late Würm two or three accumulations of sediments by means of solifluction and slopewash have taken place mainly in corrasion valleys (dells) and on slopes. These accumulations were interrupted by short periods of soil formation or of accumulation of humus.

Where the second flood-less terrace is overlain by loessy and loamy slope deposits intercalated by several soil horizons, the ice wedges and cryoturbations occur in the fossil flood-plain soil which is next to the surface of the terrace gravels. These ice wedges are usually filled with eolian loesses, sands or solifluction slope loesses lying above the fossil flood-plain soil.

The soil zone interrupted by ice wedges is covered by stratified slope loesses, and farther upwards in the cross-section it becoms more and more massive. However, before passing over into the next fossil soil, a new foliated loamy loess interlayer makes its appearance (cataglacial phase, fig. 5). A similar succession of sediments may be repeated even three-four times, in part or fully, on the second flood-less terrace of the narrower valley section, notably at the points where, as already mentioned, no form assemblages of cryoturbation phenomena of multiple generation are found in the upper part of the terrace gravels (fig. 5).

CRYOTURBATION PHENOMENA OF THE RISS GLACIATION

That patterned soils, types of cryoturbation features older than the Würm Glaciation occur in Hungary, may be inferred, with good reason, from the phenomena manifesting themselves in the exposures of the older terraces. In this respect the most convincing data are provided by the syngenetic cryoturbation patterns appearing on the Early and Lower Pleistocene alluvial terraces IV and V. In addition, this is suggested by the soil frost features observable on the surface of the older Pleistocene alluvial fans and terraces and interrupted by repeated soil formations.

On the borders of the Little Plain and of the Great Plain, on the surfaces of the alluvial terraces IV the sedimentation finished by the end of the Mindel Glaciation. This is evidenced by the faunistic remains to be found in several exposures (M. Kretzoi 1953; M. Mottl 1941). It is the general opinion that the terraces IV and the alluvial ones in the valleys of the

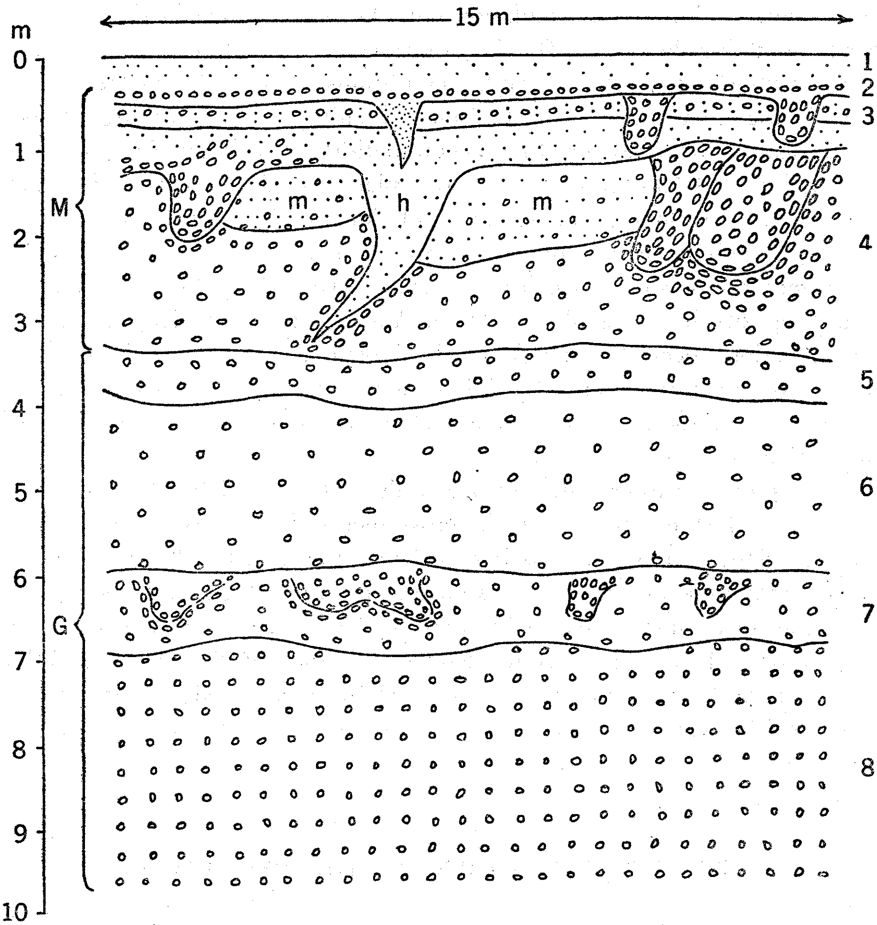

Fig. 6. Cryoturbation types of the successive Riss and Würm periglacial phases; the oldest alluvial terrace in the southern part of Budapest

1. Holocene quicksand; 2. gravel horizon; 3. smaller gravel sacs dissected by sand intercalations; 4. gravels embedded in a red-brown loam including ice wedges, ice sacs and gravel polygons; 5. red-brown gravels with unconformable surface; 6. horizontally bedded yellow sandy gravels; 7. slightly cryoturbated red-brown gravels; 8. horizontally bedded greyish-yellow sandy gravels; G — Günz gravels; M — Mindel gravels; m — fine lime dust; h — calcareous sands filling or surrounding the ice wedges

Danube and of its tributaries have become exempt from flood as a result of erosion and tectonic movements that had taken place in the Mindel—Riss interglacial. Hence, the frost effect of the Riss and Würm Glaciations displayed its feature-shaping activity on their surfaces. As good examples of the frost soil types developed in terraces IV may be mentioned the gravel pits near the Meteorological Observatory and the cemetery at Pestlörinc (fig. 6), and those in the northern part of Kemeneshát (fig. 7) as well as the gravel pit at Sashegypuszta near Györ (fig. 8). It is commonly characteristic of these exposures that even three generations of cryoturbation features can be observed and that two fossil soil layers are inter-

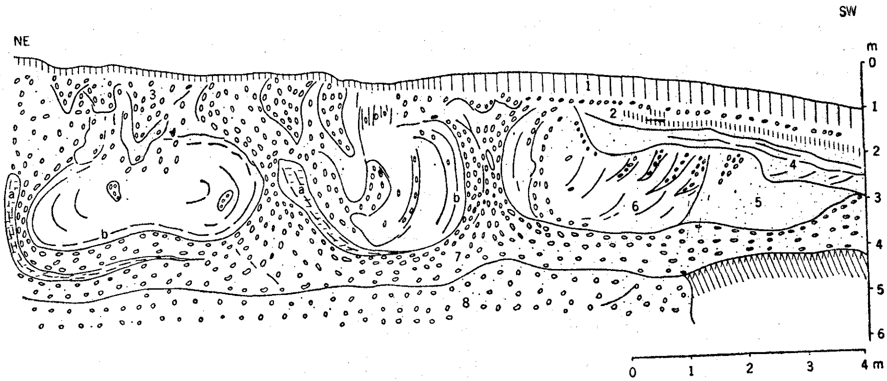

Fig. 7. „Barrel"-shaped macropolygons including gravel pockets. One of the characteristic Rissian cryoturbations. Western edge of the Kemeneshát gravel sheet (Ostffyasszonyfa)

The macro-features were later overlain by „gravel sacs" and during a later process the cryoturbations of the older dell were fractured by the incision of dells. The gravel sheet represents a part of the Early Pleistocene alluvial fan of the Rába River; 1. greyish-brown forest soil; 2. limy accumulation; 3. younger ice sacs and collapsed ice wedges; 4. coarse-grained yellow sands with „kovárvány" bands; 5. compact vivid-red loamy sands; 6. barrel-shaped macro-polygon filled with golden yellow sands and vivid-red loamy sand bands; it is surrounded by a massive gravel blanket consisting of gravels of concentric orientation. The sand filling material of semicircular arrangement includes gravel bands of similar, arched orientation; 7. red-brown gravels coated with clay; 8. reddish-yellow fine gravels coated with clay; a — deformed clay lens; b — vivid--red loamy sands

calated within them, of which the older one is in every case a forest soil type. The terrace III of the Danube on the Little Plain dates from the Riss Glaciation. It has earlier been ranked as the Riss Glaciation on the basis of its relative position. In recent years in the surroundings of Györ some tooth remnants of *Elephas antiquus* were extracted from this terrace. The Hegyeshalom gravel pit in the foreland of the Parndorf Plateau also furnished remnants of *Elephas antiquus*. In the latter area very wide-spread and frequent periglacial frost soil types are known (fig. 9).

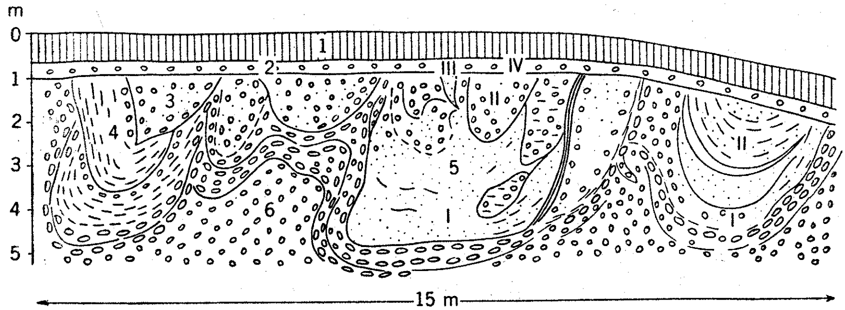

Fig. 8. Riss and Würm cryoturbations of several phases. Gravel pit on the Sas Hill at Györ. The exposure is situated on the older alluvial fan of the Danube on the Little Plain

The following processes can be distinguished: I — older macro-polygons (Riss glaciation; II — the larger polygons are penetrated by smaller ones; III — group of ice wedges (Würm climax); IV — solifluction gravel horizon (Late Würm); 1. chernozem soil; 2. gravel pavement; 3. gravels filling ice wedges; 4. calcareous sands and silts of ice sacs; 5. sand filling the sacs; 6. terrace gravels disturbed by frost phenomena. The limit surface between the polygons of I-st and II-nd generation are enveloped by red soil blankets

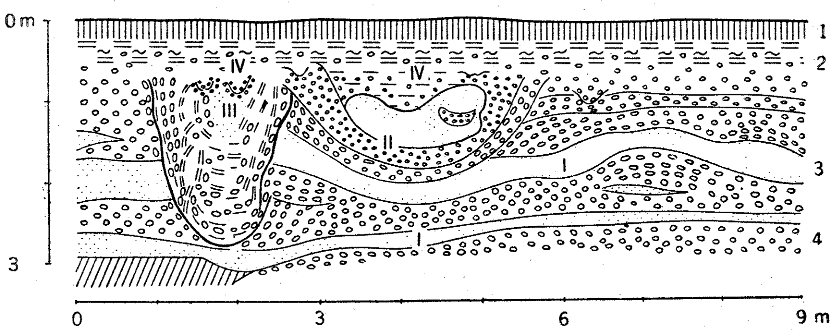

Fig. 9. Rissian and Würmian cryoturbations at Mosonszolnok on the Danube alluvial fan of the Little Plain

1. meadow chernozem soil; 2. pale-yellow sandy clays including scattered and heaped gravel grains which are slightly affected by cryoturbation; 3. cryoturbated sand and gravel layers; 4. coarser gravels

Successive phases of frost action that affected the surface after the gravels of the alluvial fan had been deposited; I — thin undulated sand layers deformed by frost action. Their formation may have taken place in the upper horizon of a permanently frozen ground; II — kettle-shaped polygons which appear to have been formed synchronously with the previous deformation through frost action. In the centre of the polygon the finest material, i.e. the sand forms isolated pockets which are surrounded by sands with finer gravels and then by a coarser gravel layer, both in semicircular arrangement. The polygons here do not contain the clay or silt fraction anywhere (one of the characteristic types of Rissian cryoturbations); III — after the formation of polygons the surface was overlain by sandy clays and loessy silts. Further on, 2 to 3 m deep „sacs" filled with sandy clays, some gravels and sands were formed. These „sacs" apparently intersect the older polygons and even the deeper-seated sand layers affected by cryoturbation. The formation of the clayey sacs has been, as seen distinctly, a process much later than the former one. They represent, obviously, remnants of a network of ice wedges which were deformed later (Würm climax); IV — finally, sandy clays covering the surface underwent, again, cryoturbation which represented a rather feeble process (layer 2; Late Würm type). This was the material, on which the meadow chernozem soil was formed during the Holocene

The cryoturbation types developed in terrace III, or in the alluvial fans, which may be held for products of the Riss Glaciation are much more deep-reaching, complex than those developed in the second flood-less terraces, so that they can be distinguished, though not quite easily, from the former. The data testify that a considerable number of soil frost phenomena dating from the Riss Glaciation can be detected in the territories of Hungary, too.

Much more difficult is to identifly and recognize the feature remnants and deposits of the solifluction processes which took place during the Riss Glaciation. In fact, during the Last Glaciation these processes, together with the intermediary interglacial processes, mostly removed the feature remnants and/or sediments of the Riss Glaciation or of the earlier glaciations from the slopes which were covered by younger sediments.

That solifluction processes on slopes took place during the Riss Glaciation, can be inferred from the sediments to be found on the slopes of the dells within the hill country and mountainous reaches of the river valleys of Hungary. In this connection an interpretation of the genesis of morphological forms may, above all, provide useful information and orientation, as the faunistic data available are still rather sporadic ones.

LOWER PLEISTOCENE OR EVEN OLDER CRYOTURBATION PHENOMENA

As to the Lower Pleistocene (Mindel, Günz and Danube Glaciations) cryoturbation phenomena, we may conclude but from the feature remnants of synchronous cryoturbations occurring in other regions. Convincing evidences of Günz or Mindel cryoturbations, respectively, have been furnished by the exposures of the oldest alluvial fan of the Danube in the region of Budapest (figs. 6, 10). The gravels of the high-seated alluvial fan situated on the north of Budapest, between Cinkota and Mogyoród have earlier been held for Upper Pliocene formations, and so has been the lower horizon of the gravels at Pestlörinc. Since the cryoturbation features have become a matter of common knowledge even concerning these alluvial fan gravels, the time, at which the gravels filling the oldest alluvial fan terrace of the Danube were accumulated, may be determined as corresponding to the beginning of the Pleistocene. It is possible that this accumulation does not date from the Günz Glaciation in a classical sense, but from the Danube Glaciation which had preceded the Günz Glaciation. In this connection we may cite an example even concerning the Austrian reaches of the Danube. The author, under the guidance of prof. Fink, studied once the Danube terraces in the region of Linz and they could observe there three additional, well-developed Danube terraces above the gravel sheet dating from the Günz Glaciation in terms of Penck's division (*Älterer Deckenschotter*). Two terraces lying above the *Älterer Deckenschotter* held by A. Penck for a Günz formation have proved to belong still to the Pleistocene, as in the exposure of the second gravel deposit

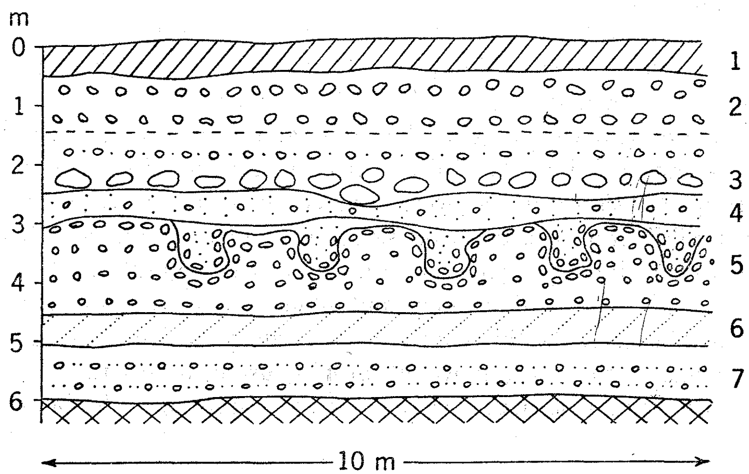

Fig. 10. Type of Early Pleistocene syngenetic „cryoturbation" on the early Pleistocene alluvial fan of the Danube on the south-eastern border of the Little Plain (Banai Hill). In this region the Danube displayed an accumulative activity during several glacial phases

1. chernozem soil; 2. coarse gravels with some sand; the individual gravel grains exhibit a mosaic-like arrangement; 3. coarse gravels discordantly overlying the series (4), among the gravels there are even as big ones as 20 to 30 cm in diameter; 4. fine-grained sands with scattered gravels; 5. Early Pleistocene cryoturbation, sand sacs penetrating into gravel layers; 6. fluviatile sands; 7. fine-grained gravels (1 to 3 cm in diameter) with sands

(terrace VII) above the terrace in question some syngenetic cryoturbations have been discovered so that the uppermost terrace, i.e. terrace VIII can only be ranked as Upper Pliocene.

CHRONOLOGY OF PLAIN- AND SLOPE SURFACES

While determining the age of cryoturbation types we had to invoke the morphological position and the chronological conditions of the terraces. However, these evidences proved to be insufficient. Since theoretically the types of several glacial frost soils may be found on the surfaces of the older terraces, the age of the terrace and its relative position are not always sufficient to clear the problem. We have been given very important information by the analysis of fossil soils. The remnants of several soil types permitted to trace a succession of processes. Beside evaluation of palaeo-pedological data, the correlation of the dells and cryoturbation types — which was considered jointly with the above-mentioned factors — also contributed to the solution of the problem. As a matter of fact, the cryoturbation features occur even in such dells which have been developed on terraces of well-determined age, and the dells have been the scene of sediment accumulation of solifluction-slopewash mechanism interrupted by soil formation of several phases.

As to the chronology of the cryoturbation types, there is naturally a number of additional problems to be solved, yet on the basis of the multilateral relationships detected so far the frost soil types of several generations provide some possibilities for the determination of the relative age of terraces, horizons or of some slope-surface portions, too. In addition, the recognition of the periglacial frost soil types provides information as to the intensity of the changes in the Holocene surface relief, the denudation of slopes and the destruction of the generous soil. On the surfaces of slopes where the periglacial features are available below the soil profile the denudation of the Holocene surface plays, naturally, a subordinate role, so that it may be neglected. If opposite conditions are the case, it must be admitted that the surface has been modelled and denuded in Holocene times. This would imply to determine the degree of these changes through the medium of other methods.

Our observations suggest that two surface groups have to be strictly distinguished at the chronological evaluation of the Pleistocene frost phenomena: (a) on the completely even, broad terrace and alluvial surfaces where neither eolian, nor slope deposits have been deposited, the Pleistocene periglacial cryoturbation phenomena manifest themselves in a different way as compared with (b) the valley terraces or slope surfaces on which eolian or slope sediments have been deposited.

(a) On the even, flat surfaces (terraces, alluvial fans, fluviatile plains) which were subjected to frost action during several successive glaciations distinct generations of cryoturbation features were developed. On the basis of the genetical and statistical evaluation, estimation of the successive cryoturbation types one can conclude as to the relative age of such flat surfaces. In the course of the chronological evaluation the fossil soils or products of weathering developed between the cryoturbation generations should also be taken into consideration.

(b) On the valley terraces or slopes covered with eolian and slope sediments the cryoturbation processes characteristic of the flat surfaces have been thrust into the background, as the slope sediments have been accumulated by solifluction-gravitation processes. In compliance with the exposition and with the lithology of the slope surfaces, very diverse solifluction processes may have taken place on the slopes even within one and the same period.

Whereas e.g. on the flat surfaces polygons have been formed, on the slopes soil stripes (*Streifenböden*), festoon features, various stratified slope sediments of solifluction mechanism may have come into being. The equivalent of the ice-wedge polygons of the flat surfaces is a network of cracks on the slopes. The formation of this network was followed, as a rule, by the deposition of eolian sediments during the existence of very dry cold climatic types. After all, in the slope sediments deposited during the Last Glaciation several stratified or massive packets dissected by 3 or 4 fossil soil layers can be distinguished. They are occasionally disturbed by cryoturbations as well. The number of the fossil soil horizons is usually greater in the slope loesses and dells than in the loesses covering flat surfaces or plateaus. A generalized scheme constructed by the example of a number of exposures and inferred from the structure of the sediments and cryoturbation features intercalating two Würmian soil zones is shown in fig. 5.

Typization and evaluation of the features of the Pleistocene fossil slope- and flat tundra phenomena provide some methodological aspects for a chronological division of the sediments and surface features of the former periglacial regions. While interpreting the processes, one has to consider separately the peculiar conditions of the flat and slope surfaces. On the slope portions where during the Last Glaciation slope deposits were accumulated a much greater variability of processes sensible to oscillations of climate can be detected than on the flat surfaces.

References

Büdel, J. 1959 — Periodische und episodische Solifluktion im Rahmen der klimatischen Solifluktionstypen. *Erdkunde,* Bd. 13; p. 297—314.

Büdel, J. 1960 — Die Frostschutt-Zone Südost-Spitzbergens. *Colloquium Geographicum,* Bd. 6, Bonn; 105 p.

Dylik, J. 1956 — The periglacial structures at Tarzymiechy and their significance for the morphogeny and stratigraphy of the Quaternary. *Biuletyn Peryglacjalny,* nr 3; p. 107—118.

Ebers, E. 1954 — Die Periglazial-Erscheinungen im bayerischen Teil des Eisteizlichen Salzach-Vorlandgletschers. *Göttinger Geogr. Abhandl.,* H. 15; p. 9—15.

Fink, J. 1950 — Leitlinien einer österreichischen Quartärstratigraphie. *Mitt. Geol. Ges. Wien,* Bd. 53; p. 249—266.

Jahn, A. 1956 — Some periglacial problems in Poland. *Biuletyn Peryglacjalny,* nr 4; p. 169—183.

Kaiser, K. 1960 — Klimazeugen des periglazialen Dauerfrostbodens in Mittel- und Westeuropa. *Eiszeitalter u. Gegenwart,* Bd. 11; p. 121—141.

Kretzói, M. 1953 — A negyedkor taglalása gerinces fauna alapján (Die Gliederung des Quartärs auf Grund der Wirbeltierfauna). Alföldi Kongresszus, Akadémiai kiadó, Budapest; p. 89—99.

Mensching, H. 1953 — Die periglaziale Formung der Landschaft des unteren Werratals. *Göttinger Geogr. Abhandl.,* H. 14; p. 79—128.

Mottl, M. 1941 — Az interglaciálisok és interstadiálisok a magyarországi emlösfauna tükrében (Die Interglaziale und Interstadiale im Spiegel der Säugetierfauna Ungarns). Beszámoló a Földt. Int. vitaüléseinek munkálatairól (Berichte über die Arbeiten d. Debattensitzungen d. Ung. Geol. Inst.); 42 p.

Pécsi, M. 1959 — Entwicklung und Morphologie des Donautales in Ungarn. Akadémiai kiadó, Budapest; p. 345.

Pécsi, M. 1961a — Die wichtigsten Ergebnisse geomorphologischer Forschungen des Quartärs in Ungarn. in: Stand der ungarischen Quartärforschung. *Inst. Geol., Prace,* t. 34 (Quaternary of central and eastern Europe), Warsaw; p. 287—311.

Pécsi, M. 1961b — Die wichtigeren Typen der periglazialen Bodenfrosterscheinungen in Ungarn. *INQUA VIth Congress, Abstracts of papers*; p. 95—96.

Pécsi, M. 1963 — Die periglazialen Erscheinungen in Ungarn. *Petermanns Geogr. Mitt.,* Jhg. 107; p. 162—182.

Poser, H. 1948 — Boden- und Klimaverhältnisse in Mittel- und Westeuropa während der Würm-Eiszeit. *Erdkunde,* Bd. 2; p. 53—68.

Sekyra, J. 1960 — Působení mrazu na půdy. Kryopedologie se zvláštním zřetelem k ČSSR (summary: Frost action on the ground. Cryopedology with special reference to Czechoslovakia). *Geotechnica,* vol. 27, Praha; 164 pp.

Suchel, A. 1954 — Studien zur quartären Morphologie des Rilagebietes. *Göttingen Geogr. Abhandl.,* H. 17; p.

Tricart, J. 1950 — Le modelé des pays froids, fasc. 1: Le modelé périglaciaire. *Cours de Géomorphologie,* 2e partie, fasc. I, CDU, Paris.

Velichko, A. A. 1958 — Structures périglaciaires dans le bassin de la Desna moyenne et leur importance pour la stratigraphie et la paléogéographie. *Biuletyn Peryglacjalny,* nr 6; p. 257—270.

Weinberger, L. 1954 — Die Periglazialerscheinungen im österreichischen Teil des eiszeitlichen Salzach-Vorlandgletschers. *Göttingen Geogr. Abhandl.,* H. 15.