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CONCERNING THE BASIC GEOMORPHOLOGICAL PROBLEMS OF THE EAST SLOVAKIAN LOWLAND

INTRODUCTION

The present contribution gives a survey of the morphological development of the East Slovakian Lowland based on field investigation joined to mapping. The East Slovakian Lowland forms the extreme northern outlying portion of the Alföld, in Czechoslovakian territory.

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Concise morphographical-structural survey. The East Slovakian Lowland extends along the lower courses of the rivers Laborec, Topľa, Ondava, Uh, and Latorica. It represents a large and monotonous territory. Its height above sea level at the place where the river Bodrog leaves the territory of Czechoslovakia is about 95 m., while at the place where the Laborec reaches the Lowland from the Humenské Highlands, its height is 135 m. The flat surface of the Lowland is in a large measure varied by a net of dead arms of rivers. In the central and southern parts there are sand dunes which rise on an average from 7 to 10 m. above the level of the Lowland. Greater vertical differences from 50 to 180 m. may be met with locally in the form of volcanic exotic blocks having the shape of a cone, or in flat table-like structures. The present day flat lowland relief arose mostly through the accumulative action of rivers on the subsiding territory. The lowland is a structural plain of an accumulative, and at the same time of a fault block character. The fault-block structure, however, as a result of a strong "masking action" of Quaternary sediments is exposed in the relief only to a lesser degree.

The Lowland at its western and northern boundaries changes into a more rugged territory — the foothill degree, which is marked by a relief of hillocks. The height above sea-level varies between the limits 150—400 m. with relative vertical differences of 60—120 m. It stretches over a belt 0.5—12 km. wide. This belt is preserved mostly on Neogene sedimentary and volcanic rocks and only locally it occurs on the germanotype structure of the central Carpathian Paleogene System, along the Humenské Highlands. These are properly speaking pediments developing at the foot of the mountains surrounding the Lowland.

From the flat relief of the Lowland in the south western portion there strikingly rises the upland the Zemplínske vrchy in a north west south east direction, in the shape of an elongated belt of about 14 km. long and 7.5 km. wide. It rises to 350 m. above the level of the Lowland and represents, in the given region the oldest and most complicated structure. It belongs to the kernel highlands of the Western Carpathians and morphologically it forms a complex horst structure with local effusions of Neogene volcanites along the boundary.

The volcanic arch Vihorlat—Popričný forms to the East Slovakian Lowland a natural barrier to a great extent from the north, with an expressive lowering Podhorská voda, where a conventional boundary is laid between these orographic wholes. The Vihorlat has the shape of an irregular horse-shoe, open to the south. Its highest peak of the same name has an altitude of 1074 m. The western part of the Vihorlat Highland rises strikingly, varying from 500 to 800 m., and it has a plateau-like character. The volcanic arch largely built up of pyroxenic andesites and of pyroclastic rocks. It comes into contact withe the East Slovakian Lowland in expressive fault slopes. The Highland has a complex fault structure with the expression of a strato-volcanic build.

On the western side the boundary of the Lowland is formed by the Slánske Mountain range which has roughly a north south direction. The relatively uniform massif is divided by transverse windig-saddles into five groups. While the altitude of the backs of individual groups varies from 700 to 900 m., the saddles are from 350 to 450 m. high. The Highland has a strato-volcanic build on which there are mostly Sarmatian and Pannonian andesites and their pyroclastic rocks. At the end of the volcanic activity the erosive tectonic processes are strongly felt; for this reason the Highland has a young fault-horst structure.

The Ondava upland merges into the East Slovakian Lowland largely by a hilly relief, epscially by its ridge reaching the Lowland between the rivers Ondava and Laborec. In the north the hillocks rise to about 200 m. above sea-level and it gets gradually lower towards the south where it reaches the level of the Lowland near Michalovce. It is built up mostly of Neogene rocks of a sedimentary and to a lesser extent of volcanic origin. The hilly spur gets into contact with the flat relief of the Lowland, mostly by expressive fault slopes.

As the second oldest structure beside the Zemplín hilly country the Humenské Highlands are wedged between the hilly spur of the Ondava Highland and the western part of the Vihorlat. It runs in a north west to south east direction having a breadth of 2 — 3 and a length of 12 km. Near Porúbka it sinks under the volcanic rocks of the Vihorlat. The Humenské Mountain range represent a very expressive morphological whole, rising above their environment 300—400 m. They are mostly built up of mesozoic limestone and dolomites. From the morphological viewpoint they from a neotectonic horst structure.

The state of investigation up to the present. There is very little information given in literature concerning the geomorphology of the East Slovakian Lowland. Concise references are made to some surface forms, occurring above all in studies in geology but they have only a historical significance today.

Already F. Richthoffen (26) along with the geological conditions of the Vihorlat noted some striking surface forms. Between the Starý and Michalovce, he mentions the terrace of the Laborec, and on the southern slopes of the Vihorlat he refers to the alluvial cones. Q. Stache (34) deals with our territory in a much more detailed manner. He gives a concise characteristic of the quaternary geological conditions of the region east of the Laborec. He mentions the geographical distribution of eolian sands. He generally considers as loess the mighty Quaternary weatherings of the volcanites. I. Trenkó and V. Šauer (35, 38) come to the knowledge of the young subsidence of the Lowland. The basic information concerning the distribution of sand dunes is given by Št. Janšák (9) who, at the same time, tries to introduce a classification of dunes according to their form. The study concerning the south east portion of the Lowland, with a geomorphological map, comes from the author of this article (15). In further studies about this region he contributes to the konwledge of the young movements of the earth's crust, of the crust of weathering on the volcanic rocks and he gives a solution to the over-all geomorphological problems of the territory (16, 17, 18, 19, 20). L. Šlahor (36) classifies the deposits of loess and sands from the neighbourhood of Kráľovský Chlmec into W_3. For clearing up the geological development of the Lowland, much has been done by the works of the authors dealing with the study of the East Slovakian Neogene (2, 5, 22, 28, 29, 37, 41) and others. The partial problems of the Neogene are solved in these works. Up to the present, there is no collective elaboration of the Slovakian Neogene, although we can give a few attempts at a more collective comprehension of the problems (3, 8, 30). The geological conditions of the Zemplín and Humenské Moutains are dealt with in the studies above all by Z. Roth and B. Bouček — A. Přibyla (1, 27).

The problems of the volcanic mountains are dealt with in several works (8, 30, 31) in which there is question especially of petrographic descriptions, as well as the time classification of the individual stages of volcanic eruptions.

NEOGENE DEVELOPMENT OF THE STRUCTURAL PLAIN

Amongst the given structures in the investigated territory the East Slovakian Lowland represents the youngest unit, the development of which has not yet been completed, but geos on even today. As it is evident from the concise characteristics of the marginal structures , the substratum of the Lowland is formed by older fault-fold structures of the Central Carpathians. The breaking and submersion of them came about in the course of the Neogene as a result of the germanotype tectonics. The differentiated movements went on along the Carpathian faults (NW—SE, NE—SW) and also (N—S) (29, 30). As a result of this fact the old layers of the Lowland during the Neogene were disintegrated into a system of blocks, mostly non-uniform and of a subsiding character. Upon theses subsiding blocks there were deposited sea, lake and finally fresh water sediments at various time intervals. The East Slovakian Lowland did not represent and, even today, does not represent any unified sedimentary space.

The first indications of subsidence are realized in the northern portion of the Lowland in a not relatively wide belt in the NW—SE direction. There is question here of the flysch development of the lower Miocene with a prevalence of shales and sandstones. The greater part of the territory was at that time dry land on which the denudation of the Paleozonic, Mesozoic and older formations was taking place. The lower-Neogene sediments are found today folded in the given region of the hillocks, while in the more southern parts of the district of Pozdišovce they have not been investigated by boring even to a depth of 3000 m. (8). The sediment of the Tortonian are much more distributed. The present southern foreland of the Vihorlat was still a high block on which the denudation of pre-Neogene formations was taking place. In the sedimentation space, however, as a result of steady subsidence, an intesive sedimentation mostly of clayey material takes place to a thickness of 1800 m. (8). Towards the end of the Tortonian the water pool disappeared and, on the borders, river sedimentation takes place. To this period belongs the gravel formation over Tarnava in which the greater portion consists of limestones and dolomites of the Humenské Highlands.

In the Sarmatian further districts began subsiding which up to that time had been high blocks. At that period the water pool was spread nearly over the whole Lowland besides the NW border portions and also the district of the upland Zemplínske vrchy (hilly country). In the Sarmatian there was question above all of the epeirogenic subsidence. The thickness of sediments amounts to 730—1000 m. (8). There is mostly question about pelitic sediments in which there are also found traces of a considerable volcanic activity.

Towards the end of the Sarmatian and in the lower Pannonian there went on an expressive denudation in the region of the East Slovakian Lowland. In the upper Pannonian there came again to a subsidence of the territory on a rather wide scale. In the northern portions of the territory, roughly in the space between the Ondava and the Laborec, the gravels of the Pozdišovce formation are laid down which, towards the south, cross over into a varied series reaching a thickness of 300 m. in the district of Malčice (8). The Pozdišovce formation is composed mostly of the flysch gravels, to a lesser degree of hornstones and quartzites. Very likely in the upper Pannonian in the period before the Levantine stage, there occurred in East Slovakia an immense volcanic activity, the products of which were pyroxenic andesites and their pyroclastic rocks. In the Levantine there occurred again a subsidence in the region of the Lowland and in the foreland of the Vihorlat there is accumulated an upper coal series and the so-called varied series (5). Since in the given series there are found positions of gravels mostly of young pyroxenic andesites and stain-coloured clays, they must be assumed as correlated sediments of the upper Pliocene denudation. It must be emphasized that on the basis of geomorphological methods of investigation it has been found that fault disturbances break both the varied series of strata and the Quaternary sediments.

Volcanic action. The development of the structural plain has been strongly influenced by the volcanic action manifesting itself in the youngest periods of the Neogene. In the faults of the Carpathians and N—S direction there came to a heaping up of volcanic material, — there arose mostly surface forms of volcanic action. The manifestations of volcanic action are known in the lower Sarmatian. There is here question above all of the buried volcanic structures of the pyroxenic andesites in the district of Malčice and Markovce (8) the base of which is found at a depth of 2000 m. At this period there arose also further stratovolcanites in the southern portion of the Lowland in the neighbourhood of Kráľovský Chlmec and in the wider neighbourhood of the upland Zemplínske vrchy. In the present-day relief of the Lowland there are morphologically expressed only more raised blocks, having the character of cones or inclined tables with expressive fault slopes. Volcanic action is also more intensively expressed in the N—S fault disturbance in the Slánske Mountain range, where on the one hand effusions of acid products occur and on the other of amphiboles of pyroxenic andesites and of their pyroclastic rocks. The first stages of the building of these mountains begin above all in its southern and central portions. In the northern regions of the Lowland, from the lacustrine pool, in the upper Sarmatian, cones of rhyolites projected only in isolated necks in the district of Michalovce and also near Beňatina. By the effusions of the amphiboles of pyroxenic andesites in the SW marginal portion of the present Vihorlat, the Sarmatian volcanic action ends. The occurrence of them on the surface between Tarnava and Kaluža produce fault-erosive formations, partially preserved very probably also in the structures of a hypoabyssal character. As it will be shown later, at that period the volcanic arch Vihorlat-Popričný practically did not exist yet, and the Slánske Mountain range begins to appear only partially. The most immense volcanic activity occurred in East Slovakia in the upper Pannonian, or at the latest in the middle Pliocene in connection with the effusion of pyroxenic andesites and of their pyroclastic rocks. During this period there arose the mountains Vihorlat and Popričný with the characteristic stratovolcanic build and volcanic activity occurred also in the Slánske Mountains during which their building was completed. During the quiet intervals of the volcanic activity, on the horizontally deposited lava flows the crust of weathering arises in the Vihorlat and the Popričný, belonging to the siallitic-allitic type of weathering (19). After the volcanic activity there occurred again the phase of levelling, during which the margin of the Lowland was denuded to the so-called river level, cutting down even young pyroxenic andesites in the Vihorlat and the Popričný.

Development of the relief of the structural plain. From the given analytical part it follows that the study of the relief by morphological methods begins in the Tortonian in connection with the emergence of the upland Zemplínske vrchy and also of the Humenské Highland, as it is proved by the gravel formations at their margins, witnessing their denudation. Both Highlands from the Tortonian were jutting out like islands in the surrounding dry land and water pools, with a steady tendency to being raised. This tendency is also expressed in the Sarmatian, as it is evidenced by the effusions of the volcanic rocks at their margins, in particular in the upland Zemplínske vrchy. Here and there in the Lowland outcrops of volcanic necks are found in places with lava sheets at the foot. Towards the end of the Sarmatian, in connection with the Attic mountain building phase, the water pool disappeared and in the lower Pannonian denudation took place in the whole territory. Levelling goes on also in the neighbouring hilly regions which projected only a litte above the flat relief of the Lowland. This denudation was interrupted by new movements very likely during the Rhodanian stage in connection with the most intense volcanic activity in Eastern Slovakia, when there occurred a heaping up of the chief masses in the Slánske Mountain range and the rise of the Vihorlat and Popričný. While during the first phase of these movements in the marginal highlands there occurred the raising and deformation of the existing denudation level, in the region of the Lowland, on rather large areas, subsidence is manifested and the Pozdišovce gravel formation is being laid down, but does not contain yet rolled pebbles of pyroxenic andesites. In connection with the effusions of pyroxenic andesites in the Vihorlat and the Popričný, it is necessary to remember the fact that young volcanites were partly effused on the denudation surface of the Humenské Highland, which contributes to their dating. We therefore consider the crests of the Humenské Highland as the remains of the denudation level of the upper Sarmatian, but chiefly of the lower Pannonian age. After the rise of the Vihorlat and Popričný denudation again took place in the upper Pliocene — Levantine. At this period the denudation level begins to be formed which, as a piedmont is preserved at the boundary of the Lowland. Its height above sea-level is generally around 100 m. above the contemporary water courses, but in the basin of the Laborec we can notice its apparent convergence along the course. The marks of this niveau are preserved in the rift valley of the Laborec through the Humenské Highland whence it continues on both sides of the course in a rather wide belt, and in the district of Michalovce it sinks below the younger sediments of the Lowland, so that it is no longer expressed morphologically. At the southern boundary of the Vihorlat the corresponding level begins to appear more to the east in the district of Poruby beneath the Vihorlat and, towards the east, at the foot of the Popričný, it is already developed in the classical form. At the eastern foot of the Slánske Mountain range the level preserves a relatively constant height above the chief water courses. This height especially north of Sečovce through the remodelling by periglacial processes acquires the form of glacis. The level is developed also at the margins of the upland Zemplínske vrchy especially in the neighbourhood of Luhyňa and Cejkov. It must be remarked that the upper Pliocene level at the eastern foot of the Slánske Mountain range, further at the spur of the Ondava Highland, as well as on the left side of the Laborec, between Krivošťany and Michalovce, is laid most probably upon the lower Pannonian denudation level. The primary level in the upper Pliocene rises at the southern foot of the volcanic arch Vihorlat — Popričný and cuts the young pyroxenic andesites. It was formed with the participation of the lateral erosion of rivers and the pediplaning activity.

The age of this level may be determined relatively correctly as the upper Pliocene on the basis of the following facts: a) its levelled surface is today divided by erosion valleys and only on fluves there is found the pre-Quaternary crust of weathering,

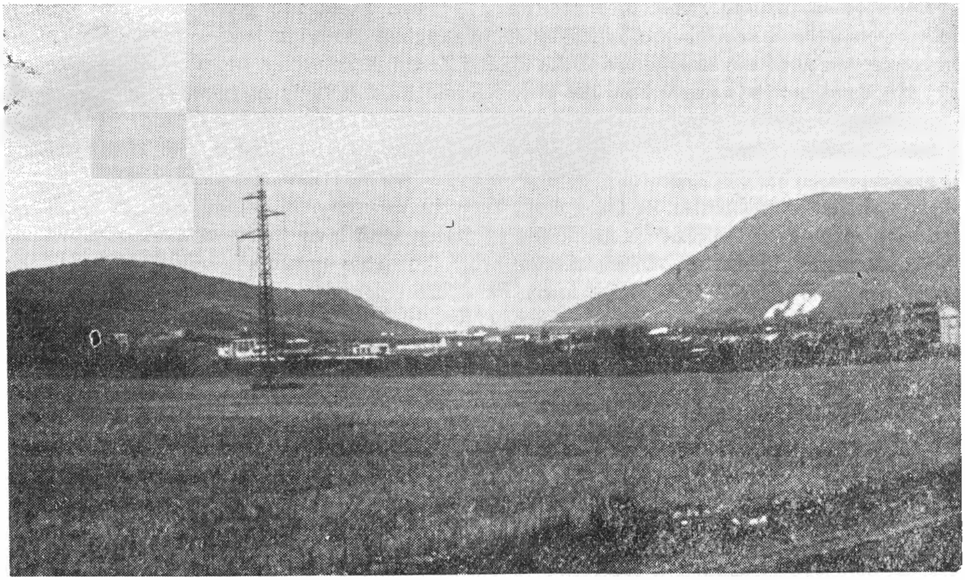


Fig. 1. Brekovská brána (Brekov Gate) — a breach valley of the Laborec through the Humenné mountain range. On the left-hand side marks of the Upper Pliocene terrace of the Laborec may be seen. (Photo by J. Kvitkovič.)

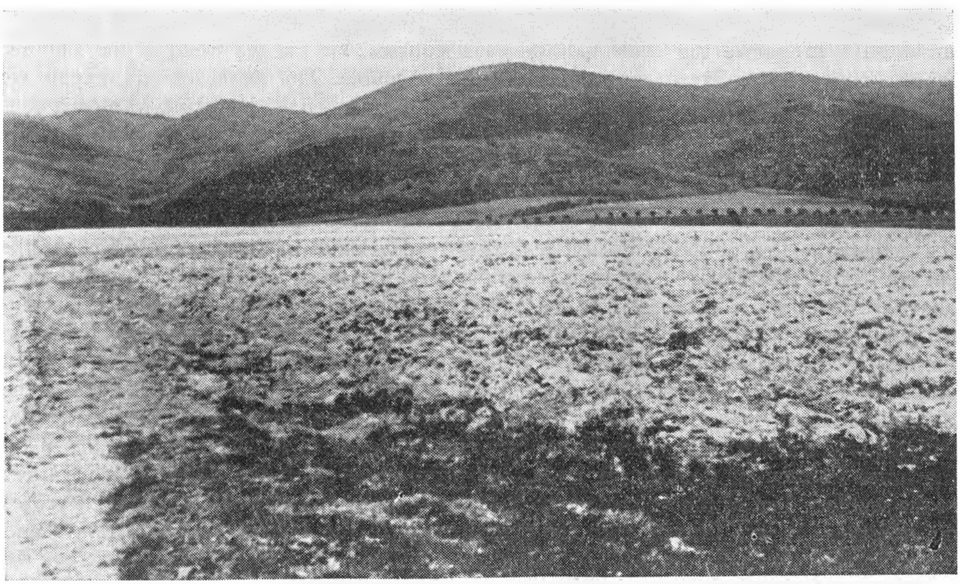


Fig. 2. The Upper Pliocene pediment and its contact with the Humenné Mountain range northwest of Oreské. (Photo by J. Kvitkovič.)

b) its surface cuts the Pozdišovce gravel formation (of the upper Pannonian age) and at the highest, the middle Pliocene pyroxenic andesites and their pyroclastic rocks, c) in the foreland of the denudation level south of Vihorlat and Popričný there was found the upper Pliocene (5) which contains its correlative sediments.

Along with the erosive division the young tectonic movements have conditioned the deformation of this level, as the hydrothermally changed andesites prove it in a range of localities, as well as the slope of blocks and the deposition of periglacial alluvial cones (frans) in a normal stratigraphic sequence on the subsiding blocks (16).

QUATERNARY EVOLUTION OF THE TERRITORY

From the survey of the Neogene evolution of the territory it follows that at that time our territory had acquired its fundamental morphological features which were more smoothly formed through the influence of morphogenetical processes in the Quaternary period. The resulting mark of these processes is the peculiar periglacial relief with specific surface forms and sediments.

Processes of weathering. The periglacial weathering was centred above all upon the levelled belt of the territory of mountain foot degree which is in a great measure built up by Neogene rocks both of sedimentary and volcanic origine. Among the sedimentary rocks the clays above all were subject to weathering, marly clays and a variety of flyschoid rocks, considerably distributed in the foothills of the Humenské Highlands and on the ridge of the hillocks between the Ondava and the Laborec. On the clays and the marly clays weathering proceeded very rapidly. The final product consisted of dusty and clayey particles which were quickly carried off. For this reason in the inter fluves there occur only weak positions of weathering. Only in the localities where the erosion was weaker, there occur sheets to thickness of some metres which genetically pass over to the basic rocks. The flyschoid variety of rocks was also subject to frost weathering and solifluction. This fact is, in the end, shown also in the terrain, where in the interfluves there are not found mighty eluvial weatherings, but only a thin sheet of brown-yellowish earth of a heavy clayey fraction, with the occurrence of sharp-edged fragments of shales and sandstones. Properly speaking there is here a preserved transient horizon to the rocky substratum. Weathering on andesite rocks was favoured by the lithological properties themselves. Fractures arisen already at the hardening of the lava flows were considerably made use of for circulation by rain and ground waters. Besides this the non-equilibrium state of upper lava flows is caused by the mutual alternation of lava flows with pyroclastic rocks. As a result of this fact there is produced a gravitational falling off, or sliding of freed blocks, or slides of lava flows themselves.

Spatially the clay-dusty earths of yellow up to brown shades distributed on the levelled inter fluves and reaching a thickness of 0.5—7 m. are most distributed in the foothills (district of the andesite rocks). These weatherings at first sight have some marks of similarity with loess (they contain a considerable amount of particles of dusty fractions 30—40 %), although in a detailed study we see that they differ from typical loess. In studying them I have come to the conclusion that on the levelled backs between the "loessoid sediments" and the substratum there does not exist any sharp boundary but there is a gradual transition between them. For this reason the earths similar to loess which cover the volcanic soils may be called the Pleistocene crust of weathering which is connected by close genetic transitions with the parent rocks. This is also confirmed by the analysis of heavy and clayey minerals. At their rise beside the weathering caused by frost, chemical weathering has also made itself felt, as it may be shown by the presence of clayey minerals of the montmorillonite group.

Slope modelling and its forms. The slope modelling in the studied territory was spatially limited in substance to the foothills, since the Lowland with regard to its plain characteristic was modelled by running water, or by the action of the wind. The sediments of the slope modelling have a wide distribution in the studied area. In non-uniformly thick mantles they cover the slopes up to a gradient of 15—20° and this both on the flyschoid and on the volcanic rocks. In numerous exposures their thickness varies between 0.5—4 m. while at the foot of the slopes the thickness reaches 12—15 m. (above all in the region of

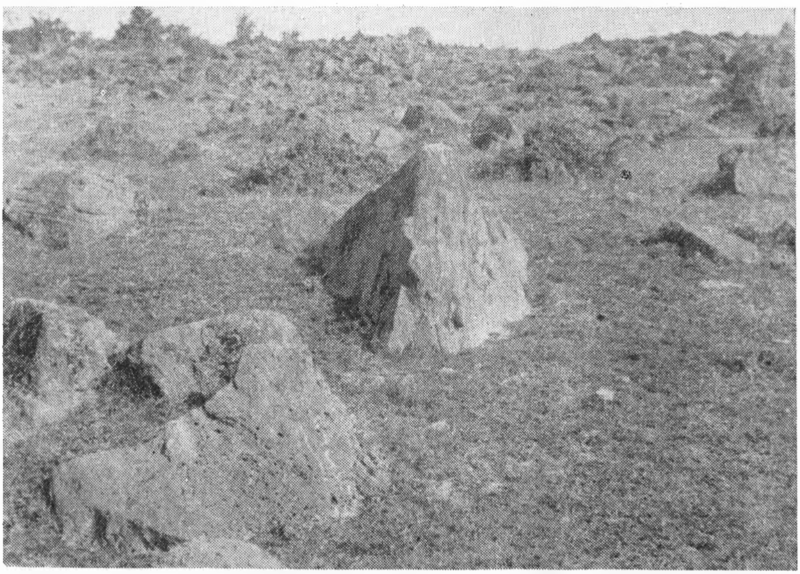
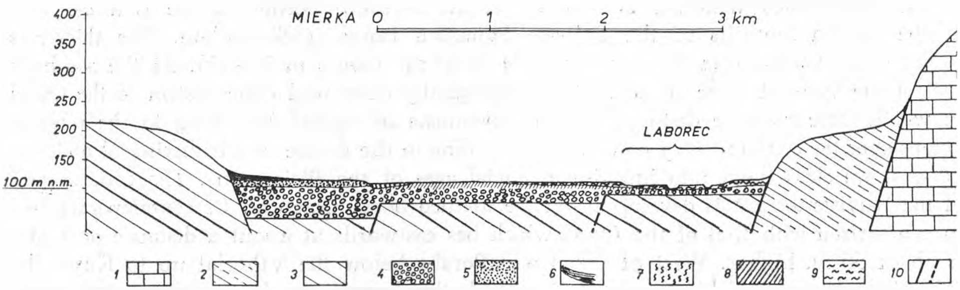


Fig. 3. Solifluctional creeping of blocks down a slope on the pediment of Popričný range near Petrovce. Photo by J. Kvitkovič.)

andesite rocks). From the analysis of slope sediments in the studied area we learn that with the soft dusty-clayey sediments up to the clayey ones, congelifluctional structures are rarely found. There is here question of the so-called free congelifluction, in the terminology of the Polish authors (6), which is the most widely spread. Structures of bound congelifluction occur rather seldom. The intensity of congelifluction processes on the volcanic rocks is explained by the fact that in places where there were advantageous morphological conditions, there occurred movements of block material from broken up andesite currents, which was centred in valleys, where their further movement was directed by the course of the valley itself. The diameter of the blocks amounts to more than 2 m. Our territory is relatively poor as regards surface forms of slope modelling. Among typical forms those most developed are above all dells and periglacial scarps.

The work of running water. The work of running water was expressed in our territory both in the form of destructive division of already existing older forms of the relief (in the foothills) and in the form of creation — accumulation which conditioned the rise of new surface forms in the region of the Lowland. I should emphasize that the formation of both kinds of surface forms took place in a close relation with very young contemporary differentiated tectonic movements which were still more strengthened by strong climatic oscillations. From the river terraces on the Laborec in the lowland spur, north of Michalovce, two steps of low terraces are known (16), it is true if we do not count the level of the Lowland itself to a height of 2—4 m. above the contemporary river bed. The terraces converge downstream and near Michalovce they sink under the younger Quaternary sediments of the Lowland. It seems that the 14—16 m. terrace near Zbudza is tectonically deformed. In the section of the Laborec south of Michalovce, further on the Uh and the Latorica, river terraces in the Lowland do not occur. The old Pleistocene



Profile 1. Schematic profile through a northern extremity of the East Slovakian Lowland (north of Pusté Čemerné and Staré). 1 — Mesozoic of the Humenné Mountain range, 2 — sediments of the Paleogene to Mid-Neogene on the foothill of the Humenné Mountain range (an Upper Pliocene pediment), 3 — sediments of the Burdigalian — Tortonian stage (an Upper Pliocene pediment), 4 — Pleistocene clayey-gravelly sediments, 5 — Young Pleistocene clayey-sandy sediments of a low terrace, 6 — deluvial deposits, 7 — Old Holocene silty-clayey sediments of longitudinal depressions, 8 — sandy-loamy sediments of an Old Holocene aggradational embankment, 9 — clayey-sandy sediments of a recent aggradational embankment, 10 — ascertained and assumed faults.

accumulation is buried under younger sediments. From the analysis investigating borings in the Lowland it follows that the pre-Quaternary substratum is found at different heights at which the thickness of Quaternary sediments is tectonically limited and varies from 5 to 100 m. (16). From this it may be seen that the Quaternary sediments were laid down upon a non-uniformly subsiding substratum. Only on the Ondava, nearly in the whole of its lowland section, is there a well-preserved terrace of 4—7 m. which is called the Trebišov terrace. From what has been said it follows that the East Slovakian Lowland already in the Quaternary period represented a depression into which the rivers of the Lowland were flowing and depositing their sediments. The filling up of the depression took place by way of cone accumulation, by translocation of the river courses. This alluviation may be also observed in the Holocene period, in particular from the spreading of the aggradation embankments.

In the contact of the border mountains with the Lowland, or with the piedmont the action of the rivers was expressed by the deposition of periglacial alluvial cones. Their formation was strongly influenced by Quaternary tectonics. In places where the Lowland was subsiding, the differentiation of individual cones is made more difficult. In places where there was no subsidence, generations of older cones are dissected and younger cones are embedded in them. Mostly this way of deposition of cones occupies the territory from the Qauternary depression beneath the Vihorlat up to the Vojnatin fault slope in the piedmont of the Popričný. The cones have a gradient of 1—6°. They run together downstream and sink into the structural plain. The system of periglacial alluvial cones of the consequent torrents forms expressive only the piedmont of the volcanic arch to a breadth of 1—13 km. Southwards the gravels of the alluvial cones are wedged between equivalent clayey, or sandy-clayey sediments. The calibre of the material decreases downstream. It must be remarked that in the gravel material at a distance of 2—3 km. from the mountains there are found in places blocks of 0.7—1.5 m. while near Gajdoš at a distance of about 12 km. there are found rolled pebbles of 1—5 cm. as well as of 20 cm. The granulometric character of the material is evidence of the quick and irregular sedimentation of the torrents during high waters. The contact of the older cones with the substratum at the northern border of the Lowland and at the eastern foothills of the Slánske Mountain range is discordant. The thickness of the cones varies from 0.5 (near Vinné) to 67 m. (south of Úbrež). At the southern foot of the Vihorlat there is the best morphologically developed cone system of the Okna in which there may be distinguished 4 generations of cones. According to the relative height over the contemporary course and according to the degree of weathering of andesite gravels, we class them into individual glacial ages of the Pleistocene. The cone system of the Hlivište torrent is developing on the uplifted horst structure. Its contemporary bed in comparison with that of the Okna which lies eastwards at about a distance of 3 km. is about 50 m. higher. West of Okna and Poruba below the Vihorlat up to Kusin the subsiding character of the territory, in which the deposition of cones went on in the normal stratigraphic sequence, is shown morphologically very expressively. Here only the two youngest generations could be delimited, while the youngest cone lies on the cone of an older generation. Another sequence of cones may be observed in the transition territory, namely in the region of the Tarnava, Vinne and Kaluža torrents. Here it was possible to delimit also two generations of cones, but with the difference that the older cone lies 1—3 m. above the younger one, in which there flows the present-day cut-in torrent. But it was not possible to find whether the older cone represents one or more cone generations. Alluvial cones at the foot of the Slánske Mountains are also composed of andesite material. Magnificent cone systems are developed along the torrents of Zamutov, Lomnica, Olšava, Ternavka and others. The cones of Bačkov torrent in the form of an extensive fan, sink and come to an end before the Parchovany horst structure. The torrent itself is influenced sensitively by the horst and changes its course from NE to S. During the Holocene there took place the erosion and resedimentation of cone material along the water courses.

Work of the wind. An important exogenetic factor during the dry periglacial phases was the wind which, on one hand took part in the destruction of the relief, and on the other created peculiar accumulative forms. We meet with both kinds of work also in our territory where there were extraordinarily suitable conditions for its action (an unfixed river system, an unusually low gradient of rivers and a great amount of alluvium, etc.). During the low water in cool dry periods there begins the blowing off by the wind of soft material and the deposition of it in typical surface forms, loess tables, sheets and in the case of sand, into dunes. From our knowledge up to the present it follows that the eolian activity in our territory begins by the deposition of loess. A relatively preserved loess table in the Lowland extends south of Laškovce and continues in a 3—6 km. wide strip up to Oborin. It is the Malčice loess table with enclaves of saline soils. A small loess sheet is also found in the district of Drahňov, and loess is also found at the foot of the Slánske Mountains in the Sečovská Polianka, Trebišov, Čeľovce, Lastovce districts, etc. From the observation of the succession of heavy minerals from the Malčice loess table

Map 1. The general geomorphological map of the East Slovakian Lowland and adjacent regions. 1 — dissected relief of volcanic mountain ranges of low mountain and highland nature, 2 — upland relief on fault-fold structures, 3 — structural-denudation plateaus, 4 — dissected pediments (Upper Pliocene), 5 — morphologically conspicuous fault slopes, 6 — horsts with more intensive uplift, 7 — strong residuals, 8 — exovolcanic bodies (necks, veins) etched into relief, 9 — lava streams etched into relief, 10 — conspicuous saddles, 11 — deeply cut V-shaped valleys, 12 — periglacially remodelled erosive valleys of pediments, 13 — asymmetrical valleys of pediments, 14 — breaches, 15 — low terraces, 16 — young accumulation plain with a subsidence tendency: a — region of recent aggradation (recent aggradational embankments), b — region of an Old-Recent aggradation (aggradational embankments and river flats of the Old Holocene), c — swampy depressions unfilled with aggradation, d — depressions unfilled with aggradation, but with a more intensive tectonic subsidence, 17 — periglacial alluvial cones, 18 — sand dunes and covers, 19 — loess covers, 20 — currents, 21 — lines of profiles, 22 — settlements. (Compiled by J. Kvitkovič, drawn by V. Bulka)

and the loess from the locality of Drahňov it follows that it is considerably different. From an abundant representation of hypersthene, which is so typical for andesites, it is possible to judge that at Drahňov the volcanic constituent is considerably represented. On the basis of the fauna from the Malčice loess table which has been determined by L. Kalaš, we conclude that the deposition of the loess was done in the period W_2. The foundation of the loess table extends under the level of the contemporary water courses.

Between the valley of Čierna voda and the eastern border of the old Holocene aggradation embankment of the Laborec there is found another loess table with the occurrence of marshy loess — the Inačov loess table. It has subsided and in the lowland relief it is not

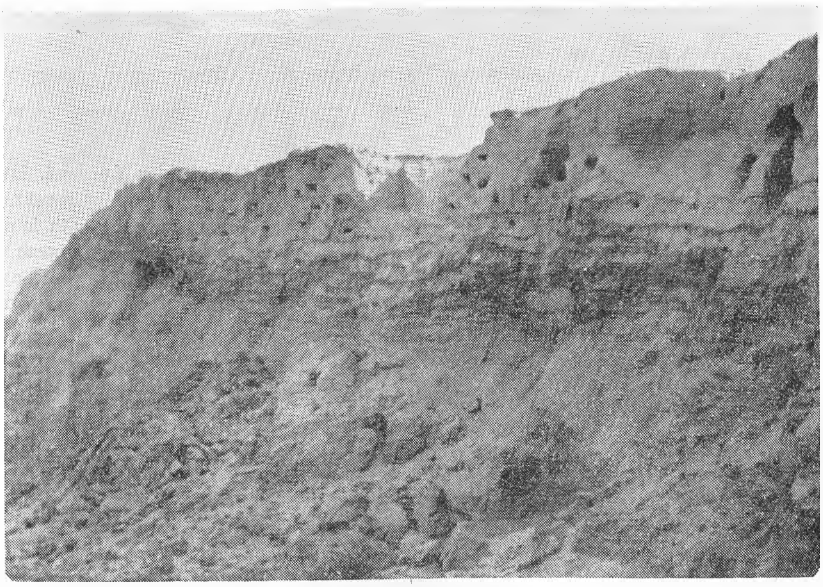
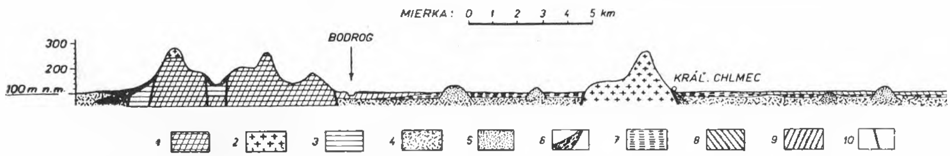


Fig. 4. A sand-dune near Hrušov Dvor. On the profile a characteristical horizon of dunes — alternation of thin layers of compact clayey sand and of loose sand may be seen. (Photo by J. Kvitkovič.)

expressed morphologically. On the contrary, it lies still 0.5—2 m. lower than the level of aggradation embankments of the river Laborec. The fauna found there consists of species characteritic for shallow marshes from the youngest Pleistocene (W_3).

Another eolian sediment which is considerably distributed in the region of the Lowland consists of blown sands. On the whole they have a loaf-like form and they are often joined in longitudinal or transverse dunes. Barchans also occur in isolated cases. In the geological build of dunes, there is a striking horizon, beginning regularly at a depth of 1 to 1.5 m. and it reaches to a depth of 3 m. and in isolated cases up to 4.5 m. It is a horizon in which the red-brown compact small layers of the clayey sand with a thickness of 1—10 cm. alternate with layers of the same thickness as those of the loose grey-yellow or yellow sand. The compact small layers of the clayey sand are moderately wavy and they are developed on the slopes of the dunes (Fig. 4). The view about the rise of this horizon is not uniform. G. László (21) considers it as ortstein caused by pedogenetic processes. L. Šlahor regards it as a layer podzol also caused by pedogenetic processes (36).

The author of these lines pointed out another possibility of its genesis, namely that at the rise of the layers mentioned the essential task was played by solifluction in conditions of a periglacial climate (15). P. Kriváň has come to similar conclusions (13). On the basis of these facts the age of the dunes may safely be put to the periglacial period, very likely to the end of W_3. The sand dunes have been formed by winds from a northern direction (15, 20). From the granulometric aspect there is question mostly about fine grained sands. The grains are relatively imperfectly worn out. The petrographic content of the dunes is formed by grains of quartz 70—80 %. The minerals of a heavy fraction are represented in a small degree. From the analysis of the relation of dunes to the sub-



Profile 2. Schematic cross profile of the southern part of the East Slovakian Lowland. 1 — Paleozoic and Mesozoic structures of the Zemplín Mountain range, 2 — andezites of the Sarmatian stage, 3 — Neogene sedimentary rocks. 4 — Pleistocene clayey-sandy sediments with interstratified beds of gravels, 5 — sand-dunes (W_3), 6 — deluvial sediments, 7 — Holocene sandy-clayey sediments of river flat, 8 — sandy-clayey-loamy sediments of an Old Holocene aggradational embankment, 9 — clayey-sandy sediments of a Young Holocene aggradational embankment, 10 — dislocations.

stratum it follows that the dunes do not lie on the present-day surface of the structural plain but jut out from it (Prof. No. 2). Beside the cumulative activity of the wind in our territory the erosive action of it also proved by the Eolian depressions and local wind-blown sand in the Holocene.

System of interglacial and Holocene modelling. The interglacial periods in the course of the periglacial cycle have always meant an interruption, at least for a time, of the periglacial processes which were replaced by relief building processes of a mild humid climate. With the beginning of a warmer period, the action of the mechanical weathering, of the processes of slope modelling and of the wind is weakened and, on the contrary, the chemical weathering begins to have a greater significance, the action of non-organized and organized running water, which is becoming the chief modelling agent in transforming the forms of the relief of the periglacial cycle. The rise of minerals of the montmorillonite group in the mantle-rock belongs very likely to this period, and further the rise of most of the erosive forms created by the action of running water, or by the processes of slope modelling. In the Holocene the erosive action of running water is seen especially in the regions of the foothills, chiefly the deepening of valleys and in the lateral erosion. In the case of permanent river courses a considerable task has also been played by periodical running water which has conditioned the rise of erosion on the piedmont. The effect of the Holocene relief-forming processes up to the present is relatively weak, so that the territory bears the character of the relief imprinted on it by the periglacial cycle.

Neotectonics. In the region of the Lowland we cannot meet with forms of relief the genesis of which cannot be explained without admitting the existence of young movements of the earth's crust. Beside the non-uniformly inclined blocks in the piedmont region which sensibly influence the consequent torrents by the depth of water-cut or deposition of periglacial alluvial cones in the normal stratigraphic sequence, in the region of the plain itself there are found neo-tectonic horsts and fault troughs. All the volcanic exotic blocks stand out as horst structures along with the interrupted and morphologically mildly exposed belt of territory in the foreland of the Vihorlat and the Popričný. From their morphological analysis it follows that there is question of horst structures of the upper Pliocene up to the Quaternary periods (16). From the surface forms with a more negatively moving tendency within the frame of the generally subsiding Lowland we must mention the Quaternary fault trough below the Vihorlat and the depression near Senné (Fig. 5).

From what has been said above it follows that the present-day Lowland, on the whole,

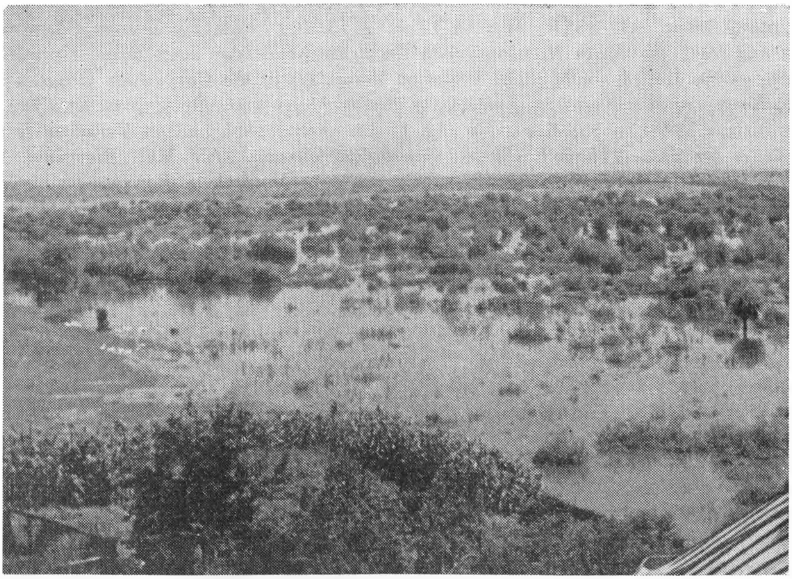


Fig. 5. View at a depression near Senné after the period of summer rains. (Photo by J. Kvitkovič.)

inherited the subsiding tendency from the Neogene which, with certain qualitative differences, continues in the Quaternary, too. This is evidenced by the great thickness of the Quaternary sediments (ca. 100 m.) the occurence of "buried" sand dunes, peat and fossil soil horizons in the structural plain, as also the seizmic activity of the territory and the negative differentiations in the repeated measurements of the level (10, 11, 16, 17, 18, 39).

The relief of the East Slovakian Lowland is the reflection of the tectonic and climatic changes which took place in the Neogene and the Quaternary periods.

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K ZÁKLADNÝM GEOMORFOLOGICKÝM PROBLÉMOM VÝCHODOSLOVENSKEJ NÍŽINY

Východoslovenská nížina sa začala vyvíjať v oblasti veľkých neogénnych poklesov kôry. Staršie centrálno-karpatské štruktúry vrásovo-zlomového charakteru v jednotlivých obdobiach neogénu nerovnomerne poklesávajú pozdĺž porúch karpatského a S—J smeru. Na poklesnutých kryhách sa ukladali morské, jazerné a napokon sladkovodné sedimenty. Časti hlboko poklesnutého podkladu nížiny nachádzame vo vynorených kryhách Zemplínskych vrchov a Humenského pohoria. Obe tieto orografické jednotky sa začali morfologicky prejavovať v tortóne, vystupujúc z okolitého morského bazénu a súše, ako o tom svedčia polohy štrkov na ich obvode. V súvise s mladomiocénnymi a pliocénnymi pohybmi kôry do vývoja Východoslovenskej nížiny mocne zasiahol vulkanizmus. Dnes prevažne erózno-zlomové tvary na vulkanických štruktúrach stratovulkanického charakteru nachádzame jednak v oblasti samotnej nížiny, kde vystupujú ako vynorené kryhy a tiež v sopečných pohoriach po jej obvode. Podľa doterajších výsledkov mocnosť neogénnej výplne nížiny presahuje 3000 m (8). Z litologickej analýzy neogénnych sedimentov a zachovaných povrchových tvarov môžeme sledovať vývoj reliéfu viac-menej už od tortónu. V sarmatskom období z jazerných bazénov sa naďalej vynárali Zemplínske vrchy, Humenské pohorie a ojedinele stratovulkány, najmä v južných častiach nížiny a v strednej a južnej časti Slanského pohoria. Zaniknutím sarmatského jazera sa v našom území začína rozsiahla denudácia, za ktorej došlo k zarovnávaniu v priľahlých Východných Karpatoch, Zemplínskych vrchoch, Slánskom a Humenskom pohorí, keď dochádza k vzniku úrovne, ktorá v Západných Karpatoch má označenie stredohorská úroveň (24). Po rhodanskej fáze pohybov došlo k jej deformácii. V terajších okrajových častiach nížiny najmä na východnom úpätí Slanského pohoria pozdĺž Ondavy a severne od Michaloviec tento povrch ostal pomerne nízko, prípadne poklesol a v priestore zhruba medzi Ondavou a Laborcom dochádza naň k uloženiu pozdišovskej štrkovej formácie. Po vzniku sopečného oblúka Vihorlat-Popričný a dovŕšenia výstavby Slanského pohoria sa začína vo vrchnom pliocéne opäť denudácia. Zarovnaný povrch odpovedajúci tejto fáze nachádzame najmä na južnom úpätí Vihorlatu-Popričného, kde zrezáva pyroxenické andezity (16, 19). Do tohto zarovnaného povrchu treba začleniť aj dnešné pedimenty na úpätí Slanského a Humenského pohoria. Tieto pedimenty sa založili na panónskom zarovnanom povrchu. Keďže oblasť z hľadiska pohybov bola pomerne stabilná, vo vrchnom pliocéne bola opäť premodelovaná jednak laterálnou eróziou riek, jednak pediplanačnou činnosťou. Túto úroveň nachádzajúcu sa v našom území v zásade okolo 60—120 m nad súčasnými tokmi riek paralelizujem s obdobným zarovnaním povrchom v Západných Karpatoch — poriečnou rovňou (24). Keďže tento povrch zrezáva jednak pozdišovskú štrkovú formáciu, jednak pyroxenické andezity, o jeho vrchnopliocénnom veku niet pochýb. Z tohto obdobia pravdepodobne pochádzajú ochudobnené štrky roztrúsené na pedimente Humenského pohoria s valúnmi pyroxenických andezitov a tiež flyšové štrky s výskytom kremeňa z podhoria Vihorlatu od Choňkoviec. Za valašskej horotvornej fázy a v priebehu kvartéru bola poriečna úroveň značne deformovaná (16).

Základné morfologické črty Východoslovenskej nížiny, ktoré vznikli v neogénnom období, boli v pleistocéne stvárňované vplyvom morfogenetických činiteľov periglaciálneho prostredia. Mrazové zvetrávanie bolo sústredené predovšetkým na zarovnaný pás podhorského stupňa a podliehali mu neogénne horniny sedimentárneho, ako aj vulkanického charakteru. V teplejších interglaciálnych a interštadiálnych obdobiach uplatňuje sa aj chemické zvetrávanie. Na vulkanitoch vzniká mocná kôra zvetrávania žltohnedých odtieňov farby s výskytom ílovitých minerálov montmorylonitovej skupiny. Zo svahovej modelácie je najviac rozšírená tzv. voľná kongeliflukcia. Povrchové formy svahovej modelácie sú zastúpené predovšetkým eróznymi údoliami, úvalinami a periglaciálnymi zrubmi. Široká oblasť nížiny je prakticky bez terás. Stretávame sa tu s kolmáciou riečnych sedimentov, ktorú podmieňujú negatívne pohyby kôry. Mocnosť kvartérnych sedimentov v severných častiach nížiny sa pohybuje od 5—45 m, kým v južnejších dosahuje až 100 m. Holocénna akumulácia je 2—8 m, a je zachovaná v starších a recentných agradačných valoch pozdĺž riek a tiež v pozdĺžnych zníženinách medzi valmi a najmä v tektonicky intenzívnejšie poklesávajúcich depresiách. Z hľadiska pohybovej intenzity prechodnú oblasť k severne ležiacim pohoriam tvorí nížinný výbežok nad Michalovcami, kde sú vyvinuté dva terasové stupne, pravda, ak odhliadneme od vlastného niveau štruktúrnej roviny. Na styku nížiny s okrajovými pohoriami, resp. podhorským stupňom riečna činnosť sa prejavovala ukladaním periglaciálnych náplavových kužeľov. Ich formovanie najmä na južnom úpätí Vihorlatu silne ovplyvňovala prevažne poklesová tektonika (16), takže pri jednotlivých svahových tokoch sa často stretávame s rozdielnymi formami ich uloženia, ako napr. na Okne, Porubskom, Hlivištskom, Kusinskom, Tarnavskom potoku a i. Mocnosť kužeľov kolíše od 0,5 m (pri Vinnom) až do 67 m (južne od Úbreža). Na úpätí sopečného oblúka Vihorlat—Popričný je morfologicky najlepšie vyvinutý kužeľový systém Okny, v ktorom môžeme rozlíšiť 3, resp. 4 generácie kužeľov. Podľa relatívnej výšky nad súčasným tokom podľa stupňa zvetrania andezitových štrkov a výskytu involučných štruktúr ich zaraďujeme do jednotlivých glaciálov pleistocénu. Na ostatných tokoch v dôsledku kvartérnej tektoniky sa dajú morfologicky vyhraničiť 2, prípadne 3 generácie kužeľov. Na úpätí Slanského pohoria periglaciálne náplavové kužele sa prejavujú výraznejšie, napr. na Zamutovskom potoku, Lomnici, Ternavke ap. Nízke terasy ako ich zachytáva prehľadná geomorfologická mapa sú tektonicky deformované.

Pre eolickú činnosť v oblasti Východoslovenskej nížiny boli v pleistocéne veľmi priaznivé podmienky. Podľa fauny, ktorú určil L. Kalaš, z Malčickej sprašovej tabule usudzujeme, že k ukladaniu spraše došlo v období W_2 a Inačovská tabuľa s výskytom močiarovej spraše sa sformovala v období W_3. Viate piesky prevažne vo forme bochníkov, pozdĺžnych a priečnych valov, ojedinele barchanov a garmad, vznikali koncom W_3 (15, 20, 36).

Východoslovenská nížina je veľmi vhodným územím pre štúdium mladých pohybov zemskej kôry. Styk podhorského stupňa s priliehajúcimi pohoriami je tektonický. Podobne možno povedať aj o vzťahu vlastnej roviny k podhorskému stupňu. Zlomové svahy sú upravené eróznymi procesmi. Rozšírenie neotektonických štruktúr a ďalších povrchových tvarov v oblasti nížiny zachycuje prehľadná geomorfologická mapa. Z geomorfologickej mapy a priložených profilov vyplýva, že aj v jednotvárnom nížinnom reliéfe možno pri podrobnejšom výskume vyhraničiť nevýrazné povrchové tvary s vlastnými zákonitosťami vývoja, ku ktorým treba prihliadať pri zásahoch do geografického prostredia, obzvlášť takých, ako sú rozsiahle vodohospodárske úpravy v oblasti samej nížiny.

Profil 1. Schematický profil severným výbežkom Východoslovenskej nížiny (severne od Pustého Čemerného a Starého). 1 — mezozoikum Humenského pohoria, 2 — paleogénne až strednoneogénne sedimenty na úpätí Humenského pohoria (vrchnopliocénny pediment), 3 — burdigal-tortónske sedimenty (vrchnopliocénny pediment), 4 — pleistocénne štrkovo-ílovité sedimenty, 5 — mladopleistocénne piesčito-ílovité sedimenty nízkej terasy, 6 — deluviálne sedimenty, 7 — staroholocénne ílovito-kalové sedimenty pozdĺžnych depresií, 8 — hlinito-piesčité sedimenty staroholocénneho agradačného valu, 9 — piesčito-hlinité sedimenty recentného agradačného valu, 10 — zlomy zistené a predpokladané.

Profil 2. Schematický priečny profil južnou časťou Východoslovenskej nížiny. 1 — paleozoické a mezozoické štruktúry Zemplínskeho pohoria, 2 — sarmatské vulkanity, 3 — neogénne sedimentárne horniny, 4 — pleistocénne piesčito-ílovité sedimenty s vložkami štrkov, 5 — pieskové presypy (W_3), 6 — deluviálne sedimenty, 7 — holocénne ílovito-piesčité sedimenty poriečnej nivy, 8 — hlinito-ílovitopiesčité sedimenty staroholocénneho agradačného valu, 9 — piesčito-ílovité sedimenty mladoholocénneho agradačného valu, 10 — zlomové poruchy.

Obr. 1. Brekovská brána — prelomové údolie Laborca cez Humenské pohorie. Na ľavej strane vidieť náznaky vrchnopliocénnej terasy Laborca (Foto J. Kvitkovič).

Obr. 2. Vrchnopliocénny pediment a jeho styk s Humenským pohorím SZ od Oreského (Foto J. Kvitkovič).

Obr. 3. Soliflukčné zliezanie blokov po svahu na poriečnej rovni Popričného pri Petrovciach (Foto J. Kvitkovič).

Obr. 4. Pieskový presyp pri Hrušovom dvore. V profile vidieť charakteristický horizont dún — striedanie vrstvičiek kompaktného ílnatého piesku s vrstvičkami sypkého piesku (Foto J. Kvitkovič).

Obr. 5. Pohľad na depresiu pri Sennom po období letných dažďov (Foto J. Kvitkovič).

Mapa 1. Prehľadná geomorfologická mapa Východoslovenskej nížiny a priľahlých oblastí. 1 — rozčlenený vrchovinný až hornatinný reliéf vulkanických pohorí, 2 — stredohorský reliéf na zlomovo-vrásových štruktúrach, 3 — štruktúrno-denudačné plošiny, 4 — ploché chrbty poriečnej rovne (vrchný pliocén), 5 — morfologicky výrazné svahy podmienené tektonicky, 6 — hrasti s intenzívnejším tektonickým zdvihom, 7 — tvrdoše, 8 — vypreparované exovulkanické telesá (sopúchy, žily), — 9 vypreparované sopečné prúdy, 10 — výrazné sedlá, 11 — svahové, hlboko vrezané V doliny, 12 — erózne údolia periglaciálne premodelované v oblasti poriečnej rovne, 13 — asymetrické údolia poriečnej rovne, 14 — prelomové údolia, 15 — nízke terasy, 16 — mladá akumulačná rovina s tendenciou poklesávania: a — oblasť súčasnej agradácie (recentné agradačné valy), b — oblasť staroholocénnej agradácie (staroholocénne agradačné valy a poriečne nivy), c — agradáciou nevyplnené močaristé depresie, d — agradáciou nevyplnené depresie s intenzívnejším tektonickým poklesom, 17 — periglaciálne náplavové kužele, 18 — pieskové presypy a pokrovy, 19 — sprašové pokrovy, 20 — toky, 21 — ťahy profilov, 22 — osady. (Zostavil J. Kvitkovič, kreslil V. Bulka.)