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THE DEVELOPMENT OF THE NATURAL LANDSCAPE IN SLOVAKIA DURING THE QUATERNARY

Résumé

Les auteurs présentent l'histoire géologique depuis la fin du Tertiaire, d'une partie de la chaîne des Carpathes, à savoir la Slovaquie.

Au cours du Pliocène supérieur, le territoire de cette région a subi des soulèvements tectoniques accompagnés de mouvements différentiels. Pendant tout le Quaternaire, ces mouvements ont eu tendance à se poursuivre.

Les données dont on dispose et qui se rapportent au début du Quaternaire sont trop rares pour permettre l'établissement de cartes paléogéographiques détaillées. Un essai a cependant été présenté pour l'interglaciaire Danube–Gunz pour lequel 4 types de paysage ont été reconnus. Les périodes glaciaires Mindel, Riss et Würm montrent beaucoup de faits communs dans les types de paysage quoique l'extension des glaciers alpins ait été différente. Pour ces périodes, 4 types de paysage ont été distingués. Une division plus grande a été possible pour les périodes interglaciaires. Huit types de paysage ont étéreconnus pendant l'interglaciaire Mindel–Riss et sept pendant le Riss–Würm. Pendant l'Holocène, des changements graduels se sont aussi produits. L'influence humaine a joué à cette époque une rôle essentiel.

Abstract

The authors discuss the geological history since the end of the Tertiary, of the part of the Carpathian Mountains forming Slovakia.

During the upper Pliocene, this region experienced tectonic uplift including differential movement. These movements tended to continue throughout the Quaternary.

The available data relating to the beginning of the Quaternary are too few to permit the construction of detailed palaeogeographical maps. An attempt has, however, been made for the Donau–Günz Interglacial, for which four types of landscape have been recognized. The cold periods Mindel, Riss and Würm have many features in common in landscape development although the extent of the alpine glaciers varied. For these periods four types of landscape have been distinguished. A greater subdivision is possible for the interglacial periods, eight landscape types being recognized for the Mindel–Riss and seven for the Riss–Würm. During the Holocene gradual changes have occurred and man has played a significant role.

Slovakia, the eastern part of the territory of Czechoslovakia, forms from the standpoint of Quaternary an interesting region in central Europe. It is largely mountainous with characteristic elongated mountain ridges and distinct depressions between them. The southern part of territory is formed by extensive lowlands. The whole belongs to the Carpathian mountain system, or more precisely, the West Carpathians.

Looking deeper back into the history of the geological development of our territory throughout the Quaternary, we find that it reaches deeply to the pre-Quaternary periods, especially the Neogene and mainly the Pliocene. In those times, due to the influence of the varying site of differentiated tectonic movements, the steplike dissection of the territory into regions of lowlands and rising ranges with depressions, resulted in the fundamental features of the present-day relief.

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In the Upper-Pliocene Slovakia displayed repeated tectonic uplift as a unit with partial differentiated movements, keeping this trend practically throughout the Quaternary. As a consequence of this uplift the distinct delimination of the individual orographic units occurred, while in the depressions of middle and low altitudes the lakes retreated completly, as was also the case in the lowlands. In the river valleys the so called riverain plains formed, with the essential part of the stream system, while volcanic activity terminated. The climate was of a subtropical (Mediterranean) character.

The geological development of our territory throughout the Quaternary follows on from the preceding periods, but displays some specific features. The duration of climatic changes and the influence of tectonics were reflected not only in the alternating action of complex of the physico-geological processes of sedimentogenesis, pedogenesis etc., but also in the changes of other natural environmental components (fauna, flora, etc.). The intensity of changes was subject to certain height and zonal differentiation.

Donau Glacial

A considerable cooling resulted in the retreat of markedly subtropical plant species and the development of oak, elm, fir, pine and especially spruce. Birch also appeared. The climate was not very cold. The higher parts of the high-mountain region (even the Tatra) did not rise high enough above the forest boundary for alpine-type glaciation to be possible. Glaciogenic sediments are not known; in river valleys the first high fluvial formed, and in the near-foothill parts of the mountains, alluvial cones.

Donau/Günz Interglacial

A gradual warming up of the climate set in and some elements of the subtropical flora gradually returned from the lowlands to the depressions and mountain slopes while the conifers retreated. At this time the more important deposits of freshwater limestones originated (Pažica, Čerená near Ludrová, Modzole near Vyšné Ružbachy). Also typical was the formation of highly rubefied fossil soils with *Braunlehm* plasma. It was a relatively warm interglacial, warmer than the following ones.

According to the data available a rough reconstruction outline of development indicates that the following types of landscape were present during the Donau/Günz Interglacial; (1) a forest landscape with thermophilous forests and exotics in the lowlands, depressions and on slopes of medium-high mountains, with distinct rubefied brown earths on fluvial, fluvio-lacustrine and slope sediments, and on solid carbonate and noncarbonate rocks; (2) a forest landscape with deciduous to mixed forests on medium-high mountains and on slopes of high mountains with brown earths on slope sediments, semi-solid and solid carbonate and noncarbonate rocks; (3) high-mountain meadow with grass vegetation, (the rocky parts being without vegetation), in high-mountain parts turf soils on crystalline rocks.

Günz Glacial

This was characterized by a sudden change of climate which acquired even a subarctic character. As a consequence of this change the representatives of subtropical vegetation, and also of deciduous plants disappeared; in depressions and lowlands mainly pine, spruce and fir-tree forests grew. So far there is not enough data to indicate whether the High Tatra was glaciated in that time. In river valleys the 2nd high fluvial terrace, in near-foothill parts alluvial cones, formed. Problematic is formation of glaciofluvial cones in the foothill of the High Tatra. During a distinct oscillation of temperature in the Günz, deciduous plants are recorded to be widespread.

Günz/Mindel Interglacial

We have not yet enough data for the reconstruction of the natural conditions of this period. In general it may be said that a relatively warm interglacial was concerned, characterized by the formation of an important pedocomplex of rubefied forest soils.

Mindel Glacial

The beginning of the Mindel Ice Age was marked by the advance of the northern glacier, which reached as far as the Ostrava area and the northern foreland of the High Tatra. With the onset of the continental glaciation on our territory the climate changed to full arctic. The high parts of the mountain ranges had a nival character without vegetation but with centres of Alpine glaciers in the High Tatra and permanent snowcover, with more intense frost weathering of bedrock, the carrying down of weathering products, mainly by solifluction, and their accumulation. The extent of alpine-type glaciation in the Mindel in the High Tatra, contrary to later glaciations, has not been established unambiguously so far. On the foothills of high mountains, on medium-high mountains and in high-lying depressions a tundra country formed with thin vegetation of lower plants (lichens and mosses), with primitive frost soils, displaced by intense solifluction and frost weathering of bedrock. In the foreland of the High Tatra glaciofluvial cones formed; in river valleys the third high river terrace developed (more recent investigations show that essentially two terrace benches were formed), and on near-foothill parts of the mountain-ranges periglacial cones formed. In medium-lying depressions a forest-tundra country with thin grassy and forest vegetation developed, with formation of primitive soils on loose sediments. In lower-lying depressions, in lowlands and partly also in low and middle parts of river valleys a cold steppe-forest country developed with primitive soils and increased wind activity. Owing to the activity of wind, drift sands were deposited in the Záhorie lowland in the Zohor-Plavec depressions, (which are buried now), as well as loess on the uplands of the Danube lowland.

The Great Mindel/Riss Interglacial

Compared with the preceding glacial period, this is characterized by a total warming up and humidification of the climate, intense soil-forming processes, the formation of freshwater limestones (Horbek near Vyšne Ružbachy, Skaličky near

Lúčky, Skála near Liptovské Sliače etc.), the development of plant cover, a reduction in frost weathering, decrease in wind activity, cessation of solifluction, and the retreat of glaciation in the High Tatra on our territory. The surface areal washing down erosional activity of streams may be considered as the main sculpturing factor of the territory. The development of plant cover was first characterized by the prevalence of coniferous forests, and later their retreat to higher areas but the end of the interglacial was characterized again by the lowering of the limit of coniferous forests. From this interglacial we have also the first finds of Early Paleolith. Within this interglacial we also note a cold oscillation, which is characterized by formation of loess horizon intercalated in the pedocomplex.

The character of landscape units in Slovakia was of a zonal type in the time of the Great Interglacial; so far the following types of landscape have been distinguished: (1) a hydromorphic grassy-forest landscape on riverain plains in lowlands, with swamp soils on fluvio-palustrine sediments; (2) a hydromorphic forest landscape with soft meadow forests on riverain plains with flood-plain and meadow-soils on fluvial sediments; (3) a forest landscape with hard meadow forest on river terrace benches and sunken parts of uplands with rubefied brown earths and gleyed soils on fluvial sediments, loess and loose slope sediments; (4) a steppe-forest to steppe landscape on river terrace benches, uplands and slopes of lower mountains with rubefied brown earths on fluvial sediments, loess and loose slope sediments; (5) a forest landscape with thermophilous deciduous forests in depressions and on slopes of medium-high mountains with rubefied illimerized and brown earths and terra fusca on noncarbonate bedrock and loose sediments; (6) a forest landscape with mixed forests in medium-high mountains and on foothills of high mountains with brown earths and terra fusca on noncarbonate and carbonate rocks and sediments; (7) a forest landscape with mixed forests in medium-high mountains and on slopes of high mountains with brown podsolized soils on noncarbonate and carbonate rocks; (8) high mountain meadows with grass vegetation in high-mountain parts with brown and primitive stony earths on solid rocks.

Riss Glacial

As in the Mindel, the northern continental glacier reached the Ostrava area and the northern foothills of the High Tatra. With the onset of the glaciation the change of the climate in favour of cooling proceeded. In high-mountains parts a nival character developed without plant cover and with centres of Alpine glaciers in the High Belanské and Western Tatras. The glaciation of the Low Tatra is debatable but more recent investigations point to glacial activity in this mountain range. The other mountain ranges were characterized in high-mountainous parts by a permanent snow cover, with increased frost weathering of the bedrock, the carrying down of weathering products, mainly by solifluction and their accumulation in foothill parts. The glaciers in the High Tatra were about 1 km longer than those of the previous glaciation. On the foothills of high mountains and of medium-high mountains and in high-lying depressions a tundra country formed with a thin vegetation of lower plants (lichens and mosses), with primitive frost soils, displaced by

intense solifluction activity, and also frost weathering of the bedrock. In the foreland of glaciated mountains glaciofluvial cones formed, and in river valleys the middle terrace benches (1st and 2nd middle terrace), as well as periglacial cones. In medium-lying depressions a forest-tundra with thin grassy and forest vegetation developed with primitive soils on loose sediments. In lower-lying depressions, in lowlands and partly also in river valleys a cold steppe-forest developed with thin primitive soils and higher wind activity. In connection with the activity of wind the accumulation of drift sands in the Záhorie lowland and of loess in the Danube lowland and partly on the East Slovakian lowland were evident. The question of the Treén Interglacial, represented by a soil complex in the loess — PK V, has not yet been resolved.

Riss/Würm Interglacial

Throughout this interglacial in Slovakia the climate got gradually warmer and moister. The average annual temperature attained nearly 13 °C. Changes of climate were also reflected by ecological changes. The geological development is characterized by the intensive formation of soils, of freshwater limestones (Hrádok near Gánovce, Dzeravá skala near Vyšne Ružbachy, Drienok near Bešeňová, Sobocisko near Spišské Podhradie etc.), a gradual increase in the plant cover, diminished frost weathering, decreased wind activity and a total retreat of Alpine glaciation into high mountains. The main sculpturing factor of the surface was the areal washing down and erosional activity of streams. Due to the activity of streams the main forms which originated in the preceding periglacial cycle, were remodelled, valley bottoms deepened, and on the slopes landslides formed, mainly in flysch rocks. Scouring activity became also more intense on the loess uplands of the Danube lowland. At the beginning of the interglacial proper birch-pine forests started to advance towards the north along the river valleys from the southern lowlands. Then gradually the pine became prevalent in these forests, as well as warmth-loving species such as elm, ash, alder and later oak. These forests reached considerable altitudes, including the higher-lying depressions. Next, due to continued warming up, pine retreated and was replaced by more thermophilous deciduous trees. Pine moved to higher areas and extremely dry soils. Coniferous forests extended to higher altitudes. In the stage of optimum development of vegetation in the Last Interglacial thermophilous woody plants spread more abundantly, to the upper forest limit approaching 2000 m in altitude. The termination of the climatic optimum was reflected in the vegetation by increasing conifers and in the last phase by the predominance of birch and pine.

This warm interglacial period created conditions favourable to man as is testified by the find of a cranium cast from Gánovce and finds of Mousterien age.

In the Last Interglacial the landscape was also zonal in character. We have distinguished the following landscape types so far: (1) a hydromorphic forest landscape on riverain plains in lowlands, with swamp soils on fluvio-palustrine sediments; (2) a forest landscape with hard meadow forest on river terrace benches and lower parts of the uplands, with brown earths and gleyed soils on fluvial sediments, loess and loose sediments; (3) a steppe-forest landscape on the river terrace benches of

uplands and on the foothills of low mountains with brown earths on fluvial sediments, loess and loose slope sediments; (4) a forest landscape with deciduous forest in depressions and slopes of medium-high mountains with brown earths and illimerized soils on loose sediments; (5) a forest landscape with mixed forests in medium-high mountains with brown and podsol earths and terra fusca on noncarbonate and carbonate rocks and sediments; (6) a forest landscape with coniferous forests on mid-mountain and high-mountain areas with brown and podsol earths and podsols on solid rocks; (7) alpine meadows in high mountains with turf and primitive soils on solid rocks.

Würm Glacial

After the Last Interglacial period, due to the repeated advance of the continental glacier, changes of climatic conditions recurred. The continental glacier front was at a greater distance from our territory than in the preceding glacial. A total cooling of the climate was evident, with increasing aridity and an average annual temperature of ± 3 °C. The high-mountainous parts assumed the character of nival country without plant cover, with centres of Alpine glaciation and permanent snow cover. The Alpine glaciers formed in the High, Belanské, Western and Low Tatras, with the possible glaciation of the Pilsko, Babia Mt. and the action of névé glaciers in the Mala Fatra. The highest number of glaciers has been found in the Tatra, (in the Western Tatra 18, High Tatra 21, Belanské Tatra 10 and Low Tatra 14). On unvegetated surfaces intense frost weathering took place. Resulting from glacial activity were glaciogenic sediments (lateral and frontal moraines). Four moraine systems are known corresponding to three Würm stadials and the Late Glacial. Due to solifluction weathered material was displaced. In the foothills of high mountains, on mid-mountains and in high-lying depressions tundra developed with a thin vegetation of lower plants (lichens and mosses), with primitive frost soils displaced by solifluction. Intense frost weathering of bedrock and deflation activity by wind were also evident. In the fore-land of glaciated mountains glaciofluvial cones formed and in river valleys the low terrace, in near-foothill parts of mountains, low periglacial cones. In depressions at middle elevations a forest-tundra country with a thin grassy and forest vegetation, accompanied by the formation of primitive soils, developed. In lower-lying depressions, in lowlands and partly also in river valleys, the lower and middle courses, a cold steppe-forest country with primitive soils and more intense activity of wind developed. The wind blew mainly fluvial sediments of the lowlands to form drift sands and relatively a thick accumulation of loess. Fluvial activity of streams and solifluction activity, mainly on uplands, are also known.

In the Last Glacial the character of the climate was not uniform; distinctly colder periods (stadial oscillations) alternated with moderately warmer ones (interstadial oscillations). Evidence for these oscillations of temperature comes from the end moraines (e.g. in the High Tatra) and loess sheets. In the loess sheets the lower loess horizon W_1 is separated from the middle W_2 by fossil soils of black earth type, PK II. The loess horizon W_2 is usually separated from the upper horizon

W_3 by an initial soil, PK I, often gleyed, or disturbed by cryoturbation. In the relatively warmer interstadials conifers generally predominated, in the colder stadials herbs. The climatic changes were also reflected in the fauna. From the period of the Last Glacial and Late Glacial about 182 localities with different industries are known, Mousterian, Szeletian, Aurignacian, Gravettian, Swiderian and Magdalenian.

Holocene

As present knowledge shows, even after the Last Glacial the distribution of landscape types did not remain unchanged in Slovakia. The development of the Holocene on the whole territory essentially displays a relatively uniform pattern and in its overall character is an analogue of Pleistocene interglacials. The changes in the structure of landscape types are mainly due to changes of the climate. After the cold climate of the Würm Pleniglacial first an alternation of more distinct cooling off and warming up, accompanied by humidification, set in. At the beginning of the Holocene, in the Preboreal, however, a relatively sudden and definitive increase in temperature with moderate decrease in precipitation occurred. In the Boreal, climatic conditions may be roughly compared with those of the present-day, perhaps somewhat warmer and towards the end of the period, also drier. In the Atlantic the climate kept on warming up, mainly in the second half, and got much wetter. As in Europe in general, this was a climatic optimum. In the Subboreal the climate was characterized by the temperatures of the preceding period, though precipitation decreased. The climate during the Subboreal displayed a slight decrease in temperatures and a gradual humidification. Climatic conditions then stabilized and reached present-day ones.

At the beginning of the Holocene (Preboreal), in high-mountain ranges a general retreat of glaciers is observed, only névé fields formed (in the High Tatra), but they did not extend beyond the cirques. The névé fields have survived at about five places in the High Tatra, owing to shading by the southern rock walls, but their area has diminished in the last fifty years. Parallel with the retreat of Alpine glaciation the limit of periglacial processes shifted. At present-day they are active above the timber line and essentially coincide with the extent of nival landscape during the glacials. Concerned are processes of rock shattering connected with frost weathering, talus movement, development of structural soil forms (polygonal soils, stone-paved, garland soils, lysinové soils, etc.).

In the Holocene, slope processes and thus the formation of slope sediments were generally reduced on our territory. In mountain ranges rocks fell down and rolled away, resulting to development of large stone avalanches, large loamy talus strips and talus cone strips. There was a fairly considerable amount of sheet-wash. Sliding processes displayed a great activity, often on flysch rocks, also wash-out and in the mountains snow avalanches. Similarly as in the interglacials, wind activity decreased in the Holocene, being slightly revived in the lowlands during the Subboreal. Relatively intensely developed activity of the organized flow of running water characterizes the Holocene. In the high-mountain ranges its activity is largely restric-

ted to disintegration of glaciogenic and also glaciofluvial sediments; in the mid-mountain region it is more of an erosional-accumulation character, in the lowlands more of an accumulation character or is restricted to lateral erosion. In river valleys are quite clearly evident two riverain plain levels. The higher step is at relative heights of 3—6 m above the river level, the lower one, usually forming a narrow strip along the stream beds, is periodically inundated. A characteristic feature of the Holocene in our conditions is the formation of freshwater limestones (restricted to the mountain region), and the formation of low bogs and peat. The formation of cave sediments should be also mentioned. Due to the warming up forests advanced rapidly. With the development of plant cover went the development of soil-forming processes, the optimum development being during the Atlantic. The distribution of soil types is of zonal character and has remained till now.

A significant feature of the Holocene in our country, compared with the interglacials, is the influence of man on the natural environment. While the influence of Paleolithic man on nature was limited (he introduced mainly changes into the animal world), in the Holocene his influence increased so that nowadays we may speak of man as a direct factor, a natural or geological force, having influence on the changes in nature. His influences were deeper and more heterogenous in the Neolithic when, besides hunting he was also dealing with agriculture, cattle-breeding and permanent settlement. The most significant changes were caused by man in historic times, especially in the last two centuries, when for example the strong impact of man on the forests started, (generally in the time of Valachian colonization), then the development of mining.

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