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DEVELOPMENT OF KARST CANYON SIDES IN MILD HUMID CLIMATE

(According to Field Observations Made in Moravian Karst)

Vývoj svahů krasových kaňonů v mírném humidním klimatu (podle pozorování v Moravském krasu). — Erozní prohloubení paleogenních úvalovitých údolí, podmíněné výkyvy klimatu a nápory saxonského orogénu v burdigalu a ve svrchním helvetu, vytvořilo hluboké krasové kaňony Moravského krasu. Jejich původní příkré svahy byly rozčleněny po odnosu tortonských výplní v stupňovité lišty i izolované skály a rozevřely se tak, že nemají v příčném profilu tvar „V" nýbrž tvar rytířského erbu. Způsobuje to nerovnoměrné zvětrávání svahových ploch ve vertikálním směru, čímž horní části zůstávají příkré a ke dnu kaňonu se při rostoucím konkávním prohnutí jejich sklon snižuje. Přítomnost mocných holocenních a recentních sutí na lištách svědčí, že jde o proces vývoje svahů v mírném humidním klimatu, působící v závislosti na struktuře karbonátů. Projevil se již ve svrchním pliocénu a v teplých obdobích pleistocénu. Důležitými složkami tohoto procesu jsou exposice svahu, rozdíly v denní teplotě, insolace a voda mrznoucí v puklinách, podmiňující silnou tvorbu sutí s izolačním účinkem na pohřbené části svahů.

The Central European karst regions display several distinguishable landscape forms and correlative sediments belonging to the different types of the fossil and recent climate. Consequently they appear to be convenient for the evidence of the intricate morphogenetic and morphographic relations turning out among the older and younger landscape features in dependence on the climate changes. The results of the field observations being made on the dry canyon sides in the Moravian Karst (Czechoslovakia) may be a contribution to the acquaintance with the slope development especially in the mild humid climate.

The Moravian Karst is the largest outcrop of the well faulted and dislocated Devonian limestones in the eastern part of the Bohemian Mass. The limestones are surrounded by the silicates from all sides and their layers are levelled at several niveaus. The different type, the age and the belonging mesoforms of those surfaces of levelling were determined newly through the Mesozoic, Tertiary and Quarternary sediments and weathering products (V. Panoš, 1961, 1963). The surfaces of levelling are divided by the valley pattern, which cuts up the carbonates and the silicates rather uniformly. The polycyclic valley development depends on the climatic changes as well as on the crustal movements and doming of the Bohemian Mass in the foreland of the Carpathian fore-deep during the Paleogene-Neogene stages of the Saxonic orogene.

The oldest of the present valley forms, i.e. the relatively shallow dry vallies and the valley-like depressions displaying the very typical dish-like cross-

section and the flat gradient curve being often not uniform yet, originated in the upper part of the Paleogene at least (V. Panoš, 1961, 1962). The valley sides are widely concave in the lower parts, but they become to be steeper upwards, so that the valleys are separated of the surrounding surfaces of levelling rather distinctly. Some valley sections at the border of the limestone region were remodelled by the lateral erosion and corrosion of the allogene water courses into the marginal valley-poljes (semipoljes) at the close of the Paleogene, the bottoms of which were cut up by the deep blind valleys at the close of the Neogene and filled up by the fluvial deposits in the Lower Pleistocene. The karst pediplanation as well as the process of the slope-peeling cause the retreat of the undermined limestone slopes at the level of the sedimentary surface up to present time (V. Panoš, 1957, 1962).

The striking incisions interfere in the shallow valleys at the different distances of the marginal valley-poljes and alter for the deep dry canyons with the steep and irregular gradient curve. The karst canyons pass nearly without any morphographical changes into the deep valleys being cut into the silicates. Some strong karst springs appearing in the lower sections of the karst canyons feed the tributaries of the Svitava-River. The karst canyons and the valleys in their continuation were cut into the bottoms of the Paleogene valley forms during the Lower Miocene. The deepening finished before the Lower Tortonian sea transgression already and the karst canyons became to be dry owing to the advanced karstification by the successive and relatively great sinking of the level of erosion (V. Panoš, 1961, 1962). The Lower Tortonian marine sediments were cleared out of the upper and middle canyon sections during the Pliocene, but nevertheless they persist in the lowest sections of some canyons under the Pleistocene fluvial and slope deposits up to present time (V.Schütznerová-Havelková, 1958). There are hundreds of caves being arranged at some distinct levels above and under the present canyon bottoms.

Some short sections of the canyon sides display the high vertical scarps extending from the canyon bottoms to the parting edge of the Paleogene valley bottom relics. The cross-sections of those constricted parts of the canyons look like the high and very narrow capital letter "U" with the upper dish-like cross-section of the Paleogene valley. These canyon sections are concerned as the relics of the original forms of the deep narrow karst gorges being cut into the Paleogene valley pattern (V. Panoš, 1961).

However the canyon sides are rather open yet in the majority of their sections. They consist of several differently inclined, even or gently concave surfaces of the clastic rock waste (a melange of the coarse and fine debris in variable proportions). These inclined planes are divided by the unevenly high, steep or overhanging scarps at different levels. Sometimes the inclined debris slopes occupy nearly the whole plane of the canyon side. Somewhere the scarps are divided into the isolated rocks projecting along the canyon on the inclined

debris slope. Mostly the debris-mantles cover the forms of the rock substratum. The burried forms of the slope appear like the variably large and irregurarly inclined benches being cut in the plane of the limestone slope. The benches are arranged in the variably high steps. The join of the frontal edges of the individual benches appears in the valley cross-section like a curve being gently concave at the canyon bottom but becomming straighter and steeper

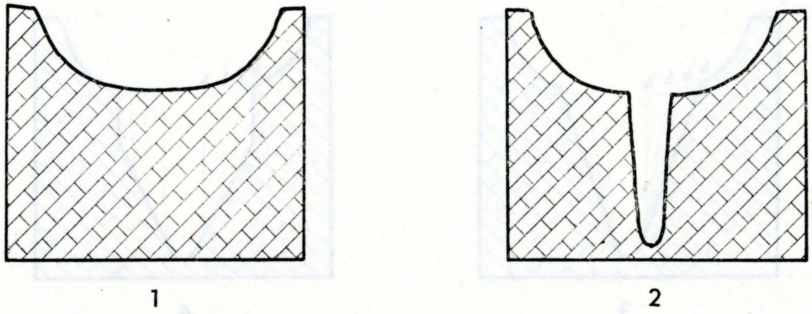


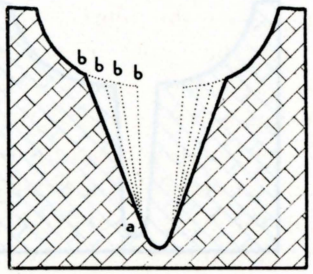
Fig. 1 — Cross-section of dish-like Paleogene valley.
Fig. 2 — Cross-section of Paleogene valley and of originally "U" shaped Lower Miocene karst gorge.

upwards and passing nearly fluently in the vertical line, which is determined by the frontal plane of the uppermost marginal scarps. Consequently the cross-sections of the canyons and of the older shallow valleys display some similar features, whereby the benched canyon cross-section looks like the escutcheon or armorial bearing (V. Panoš, 1961) and it differs by it from the "V" shaped cross-section of the valleys in other than carbonatic structures.

Generally the features of the open karst canyon sections have to be suggested as the fossil fluvial-erosive cyclic forms of the valley sides being transformed by the younger processes. The intensity of the disintegration of the original karst gorge sides culminated as late as their deepening was interrupted. The benched slopes have been explained usually as the periglacial forms of the cold Pleistocene periods, i.e. as the altiplanation terraces and frost-riven cliffs with the production of the congelifract and with its soliflual transportation (e.g. J. Birot, 1956, etc). Though the periglacial processes did disintegrate the older landscape forms of the Moravian Karst, moreover the activity of some other than periglacial processes follows of the debris slope analysis. Besides the angular fine-grained debris of the proved periglacial origin there is a lot of the clayey corroded coarse waste belonging to the warmer humid periods. Such debris overlies the Lower Tortonian marine deposits, the Pleistocene fluvial sediments and the Subatlantic travertines. It interbeds fluently or finger-likely in the Pleistocene fluvial deposits and in the Holocene cave-floor sediments containing the Neolitic and Middle Ages cultural horizons

very often. Consequently such debris must be suggested as the product of the several prae-, inter- and post-Pleistocene warmer humid periods (V. Panoš, 1957, 1961). The Holocene origin of the waste was proved in the number of other Czechoslovakian karst regions not only by the stratigraphic but also by the paleontologic methods (V. Ložek, 1963, etc.).

Basing on the field observations and using some experiences of H. Mortensen



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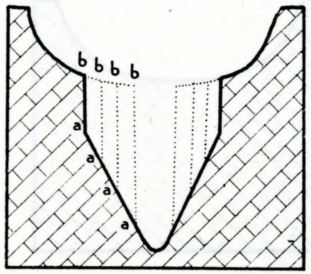

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Fig. 3 — Schematic development of "V" shaped valley with supposed down-wearing slopes (according to E. Richter).

Fig. 4 — Schematic development of "V" shaped valley with supposed back-wearing slopes and debris slopes (according to W. Penck).

(1960) it may be possible to explain the strange cross-section of the karst canyon sides by the unequal breaking of the slope equilibrium. Of course any explanation must take account of the variable structure of the well faulted and fissured limestones, which encouraged the differential action of the erosional processes depending on the climate. However the stability of the slope is not uniform on the whole slope plane in the vertical direction, when even the structure would be homogene. The weathered zone of the free face in the upper parts of the slope breaks down more easily than the weathered zone in the lower parts can do. Consequently the lower parts of the slope reach the higher grade of weathering as it is evident by the variable corrosive and mechanical widening of the cleavage fissures at the individual levels of the observed canyon sides. Few open joints only appear in the solid limestone of the free face, whereas the rocks in the lower part of the slope display the cubic cleavage or platy parting. The rare open joints limit the certain blocks of the weathered limestones, which separate slowly of the free face and break down. Hereby the new and new zones of the solid limestones have been exposed to the action of the exogene processes. Moreover the fragments originating in the fallen blocks and covering the lower parts of the slope help to slack up the process of weathering. Consequently the nearly equal value of the maximal angle of stability in the upper parts of the steep canyon sides has been reduced successively in the direction to the canyon bottom. In this manner the benches

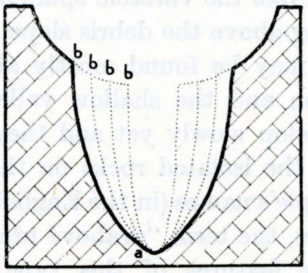
being covered usually by the debris originate on the karst gorge sides and the valley cross-section obtains by the successive opening the typical features akin to the escutcheon.

The free face does not develop even in the horizontal direction along the canyon sides uniformly. The less jointed zones of the limestones resist the weathering and keep the high grade of stability for a long time. They separate of the surrounding free face at the beginning like the variable spurs and later like the completely isolated rock masses rising above the debris slope. Having somewhere the height of about 40 m they may be found mostly along the destructed parting edge between the canyon and the shallow valley sides. Being once separated the rock masses develop slowly yet and they persist on the slope for a very long time. Because the isolated rocks on the valley sides have been indicated by the various people's names (in the English papers e.g. stacks, rock-bastions, buttresses, tors etc), the term "svahové hřebenáče" (the valley side cliffs) is proposed for the features of this type by the author.

Moreover the slope stability is controlled by the climate. The principal factors appear to be the exposition, the insolation and the water freeezing in joints. The upper parts of the permanently naked slopes are exposed to the intense activity of the day-night temperature changes, which appear to be the most important agent in the present climatic conditions. The amplitude of temperature reaches there its day-night value even more than of 30° C. The lower parts of slopes, especially those in the N—S passing canyon sections, are insolated either for a short time at noon only or not in the least. Consequently there the temperature oscillations are smaller than in the upper parts of the slopes being exposed to the insolation for a longer time during the day. Among the valley sides displaying the similar structural characteristics the slopes facing south are destructed and opened more than are the opposite ones. The water freezing in the fissures owing to the day-night temperature changes attacks the limestones very intensively in the present climatic conditions, as may be seen of a number of blocks falling free to the canyon bottom very often. On the contrary the debris, as well as the vegetation, are very important for the reduction of the temperature amplitude. The underground ice persists in the interstices among the components of the clayey-stony debris up to the close of May usually. The creating underground ice heaves the fragments on the debris slope indeed, but because of its slow melting or sublimation no distinct gravitation movements — except the subsidence — appear in the debris. The more intense movements appear in the debris covers being undermined by the water sources at the foot. The componental movements in the debris-mantle down the slope display the catastrophic velocity in the observed canyons, when the debris contains a lot of the clayey admixture having the function of the slippery devices after the debris was all wet. The debris

masses move even on the slightly inclined benches like the little debris-avalanches to the canyon bottom sometimes at heavy rains.

Consequently it may be concluded, that the karst canyon sides in the Moravian Karst display in the present stage of development neither the features akin to the uniformly inclined planes of the down-wearing slope (as it is suggested by E. Richter, 1900, O. Lehmann, 1933, H. Lehmann, 1954, a.o.) nor to



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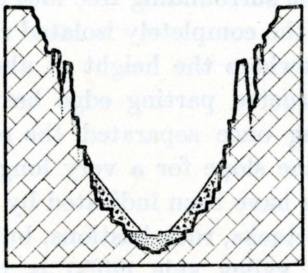

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Fig. 5 — Ideal cross-section of escutcheon-like karst canyon developing in mild humid climate.
Fig. 6 — Real cross-section of karst canyon in Moravian Karst in present development.

the intricate form consisting of the back-wearing and successively lowered free faces and of the oblique, by debris covered rock planes (according to the conception of W. Penck, 1924). The ascertained opening and benching of the originally more or less vertical sides of the dry karst gorges depends on the mild humid climate generally. This development started already in the mild humid periods at the close of the Tertiary, carried on in the transitional warmer humid periods of the Pleistocene interglacials and interstadials and reaches its climax in the Postglacial warmer and humid forestal climate as well as in the present mild humid climate inclinating slightly to the continentality and being characterized by the warmer summer and autumn and by the colder spring and winter with the changing precipitations. The carbonates appear to be the less resistant rocks in the climate of those types.

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