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ON THE DEVELOPMENT OF SLOPES IN THE NEOVOLCANITES OF WESTERN BOHEMIA

In the wider fore-land of the Tertiary stratovolcano of the Doupovské hory Mts. in West Bohemia a number of geomorphologically conspicuous heights, representing relics of neovolcanic formations, arisen in the main (mostly Lower Miocene) volcanic stage of the Bohemian Massif, can be found. Next to projecting fillings of volcanic chimneys there are elevations of the type of table mountains, arisen on lava sheets of basalts. They rest on the residues of a lowered Early Tertiary levelled surface, covered here and there with relics of Paleogene or Neogene sediments. This ancient buried surface, in places with fossil weathered rock of the crystallinicum, lies, as a rule, distinctly higher than the surrounding younger (Neogene) levelled surface on the rock of the Teplá-Barrandien crystallinicum and Permocarboniferous. The geological and geomorphological conditions of these volcanic heights entailed great differences in altitudes with regard to the surrounding relief and enabled the rapid development of their marginal slopes, especially under the conditions of the Pleistocene periglacial climate.

Neovolcanic table mountains are a characteristic feature of the relief of the Plzeňská pahorkatina Hilly Land, of the Tepelská vrchovina Highland and partly also of the Slavkovský les Forest. As typical examples of the development of the marginal parts of these mountains we are mentioning here brief characteristits of the slope conditions of Mts. Chlumská hora (650 m a. s. l.) and Kozelka (660 m) in the Manětínská kotlina Basin and of the Třebouňský vrch Height (824 m) in the Tepelská vrchovina Highland.

Mt. Chlumská hora (650 m) in the southeastern part of the Manětínská kotlina Basin to the northwest of Manětín forms a table mountain of nepheline basanite, stretching in the northwest-southeastern direction in a length of 4 km. It represents a slightly undulated flat ridge up to plateau, measuring 300—500 m in width. Its relative height above the surrounding relief on the Permocarboniferous rocks reaches 100—200 m. The basanite sheet of Mt. Chlumská hora, between 300 and 500 m thick, lies on a thin layer of tuffs and tuffites (to 5 m). Under them are sandstones and conglomerates or sands and gravels of Oligocene age of about 25 m in thickness (R. Tásler-V. Skoček 1964), resting on red-brown clays, claystones, sandstones and conglomerates of the Permocarboniferous.

From the viewpoint of the development of slopes and slope processes, the southeastern end of Mt. Chlumská hora, narrowing into an asymmetric ridge 609 m high is most noteworthy. The eastern slope of this ridge ends in a small plateau in a lower position. On the slope between the ridge and the plateau distinct fissures, reaching to a distance of 30 m from the southern edge of the ridge, have developed. They run in the directions h 4—5 and h 6—7 in 4—5 rows. Their distinctness increases in the direction of the ridge edge. They reach a length of 3—50 m, a width of 0,5—2 m, and a depth of 0,5—4,5 m.

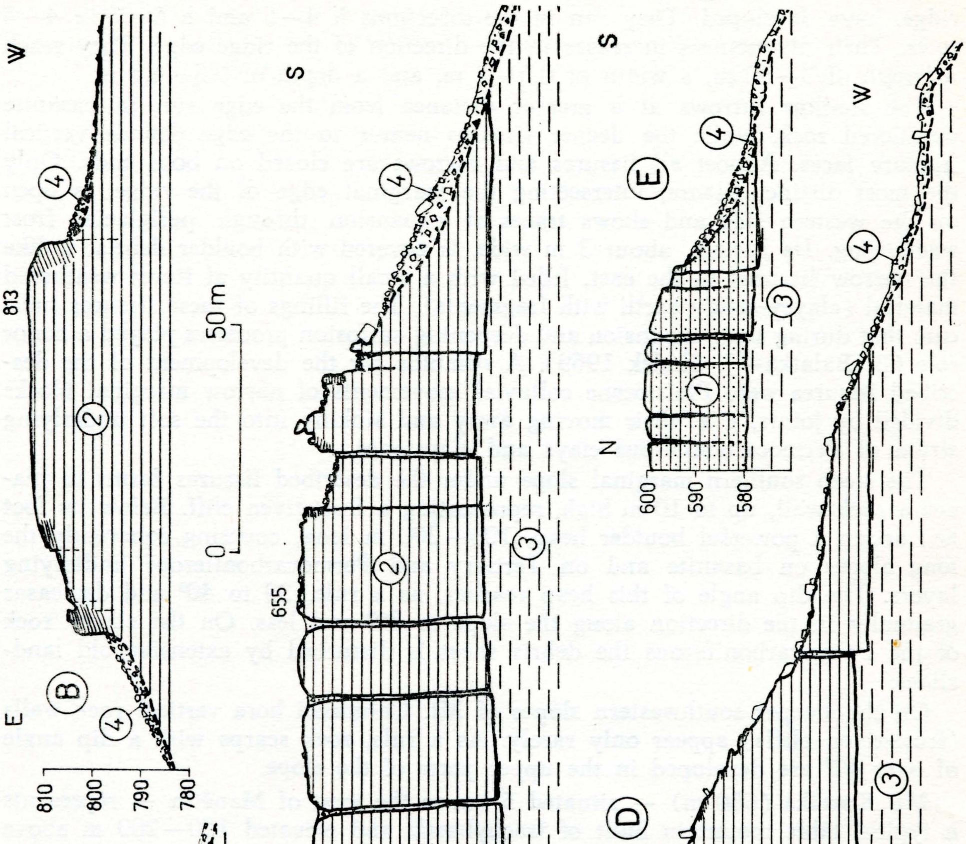
The shallow furrows at a greater distance from the edge run in basanite weathered rock, while the deeper fissures nearer to the edge denude vertical fracture faces. Almost all fissures and furrows are closed on both ends. Only the most distinct fissure, intersecting the marginal edge of the ridge, is open on the western side and shows traces of expansion through periglacial frost weathering. Its bottom, about 3 m wide, is covered with boulder debris, unlike the narrow fissures in the east, filled with a small quantity af finest weathered material (clayey-sandy earth with fragments). The fillings of these fissures indicate that during their expansion and deepening suffosion processes played a major role (B. Balatka—J. Sládek 1969). A stimulus for the development of the described fissures were Pleistocene colluvial movements of narrow marginal blocks divided by joints, i. e. their moving away and sinking into the soft underlying strata of Permocarboniferous clays and claystones.

The steep southern marginal slope under the described fissures forms in places a rock wall, up to 10 m high, representing a frost-riven cliff. Below its foot has arisen a powerful boulder heap, 100—200 m long, covering coherently the long slopes on basanite and on Tertiary and Permocarboniferous underlying layers. The dip angle of this heap reaches, as a rule, 30 to 40^0 and decreases gradually in the direction along the slope to 20^0 and less. On the clayey rock of the Permocarboniferous the debris sheet is disturbed by extensive old landslides.

On the steeper southwestern slopes of Mt. Chlumská hora vertical rock walls (frost-riven cliffs) appear only rarely. As a rule, rock scarps with a dip angle of over 40^0 are developed in the upper parts of the slope.

Mt. Kozelka (660 m) — situated 5 km to the west of Manětín — represents a typical table mountain built of trachybasalt and elevated 130—200 m above the surrounding relief. Its top plateau, about 1 km long and 30 to 150 m wide, for the most part, very gently dips in the northern direction (at an angle of 2 to 5^0) and displays minor differences in altitude (max. 10 m). The thickness of the trachybasalt layer is estimated to be 40—50 m according to the geomorphological relations. The volcanic body rests on claystones and sandstones of the upper red series of strata of the Permocarboniferous (R. Tásler-V. Skoček 1964) in an altitude of between 610 and 620 m. The top plateau is bordered, for the most part, by conspicuous marginal edges, below which steep slopes with rock walls (frost-riven cliffs) are developed in the trachybasalt. The steep slopes below them and especially lower on Permocarboniferous rock are covered with boulder piles and a sheet of boulder debris covering coherently the entire foot of Mt. Kozelka. The foot of Mt. Kozelka proper lies in an altitude of 560 to 570 m.

The top plateau of Mt. Kozelka is divided into two parts separated by a gentle saddle (in the altitude of 651 m) — the eastern (Doubravický vrch Height 659 m) and the western (Kozelka 660 m). The development of the marginal slopes and the destruction of the top plateau can be best followed in the region of the Doubravický vrch Height, running out towards the northeast in a narrowing spur. On the plateau of the Doubravický vrch Height arose elongated furrows running, for the most part, in the westsouthwest-eastnortheastern direction and being up to 75 m long, and up to 10 m wide and 1 to 3,5 m deep in the upper part. They are arranged into several strips, of which the most



1. Schematic cross profiles of the neovolcanic heights in West Bohemia. A — Mt. Chlumská hora, B — Branišovský vrch Height, C — Doubravický vrch Height, D — Mt. Kozelka, E — Mt. Chlumská hora. 1 — nepheline basanite, 2 — trachybasalt, 3 — Permocarboniferous clays and claystones or sandstones and conglomerates, 4 — boulder heaps and streams.

striking ones are developed in the uppermost parts of the marginal slopes (especially to the south). In the western direction, with the width of the plateau increasing, their size is reduced and the depressions have the character of shallow dish-like sink-holes. On the other hand, in the direction of the east, where the plateau narrows down to several metres, these furrows are strongly destroyed through the influence of periglacial frost processes.

The narrow northeastern end of the ridge is completely broken up into rock blocks and boulders. The mentioned furrows are asymmetrical in the cross section. They follow in places the boundaries between the steps on the plateau, sinking from south to north. The differences in height between these steps are negligible, reaching maximally 5 to 6 m, and demonstrate together with the existence of blind furrows a slight subsidence of the individual trachybasalt blocks, limited by joints largely running parallel to the marginal edges of the plateau. Subsidence of the blocks was made possible by the plastic clayey Permocarboniferous underlying stratum of trachybasalt.

In the development of the numerous depressions on the plateau of the Doubravický vrch Height a significant role was also played by suffosion processes during which the fine-grained material of weathered rock was washed into the extended joints and the remaining rough boulders filled in places the bottoms of the blind furrows (B. Balatka-J. Sládek 1969). These furrows were affected on the edges of the plateau by intensive periglacial frost weathering, the result of which are numerous frost-riven cliffs and small cryoplanation terraces, arisen on the extended bottoms of former furrows. The marginal furrows, therefore, have in places today the character of short canyons, especially to the south and the southeast of the Doubravický vrch Height.

Mighty boulder heaps on the southern slope of the Doubravický vrch Height, 200—250 m long, stemming from disintegrated frost-riven cliffs, demonstrate the fast Pleistocene regression of the marginal slopes of the table mountain.

In the north, the eastern part of the Doubravický vrch Height falls by a conspicuous frost-riven cliff with a vertical rock wall measuring up to 20 m in height. The development of this cliff can be followed on the vertical joints which, in places, are bordered by rock columns and narrow blocks. Below the rock scarp are developed boulder heaps with a dip angle of 30 to 35^0, passing over into a narrow cryoplanation terrace, 5—10 m wide, with an inclination angle of max. 10^0.

The top part of Mt. Kozelka in the west, unlike the Doubravický vrch Height, has a plateau only insignificantly disturbed by furrows (only at the elevation 660 on the western fringe). Instead, there are very perfectly developed forms of frost weathering of trachybasalt to be seen here. In the west the top plateau of Mt. Kozelka ends in a frost-riven cliff, measuring 150 m in length and 15—20 m in height. At the foot of the wall, short canyon-like depressions up to 10 m wide and running parallel to the rock wall have arisen in places. These depressions represent widened former furrows, founded on separating blocks of trachybasalt. The long steep slopes under the frost-riven cliffs, dipping at first at an angle of 30 to 50^0, lower at $20—25^0$, are covered with mighty boulder heaps and rock streams. The individual rock blocks reach a diameter of up to 6 m. Characteristic forms of frost weathering of trachybasalt have also developed in the western part of the southern slope of Mt. Kozelka (rock towers, frost-riven cliffs, small cryoplanation terraces). Older debris on the lower slopes, built of Permocarboniferous rock, is disturbed by numerous consolidated landslides, appearing along the entire foot of Mt. Kozelka and the Doubravický vrch Height. The slopes with boulder accumulations in the topmost part under the rock cliffs (on young boulder heaps) are of convex shape, while in the greater part of the further profile they are concave.

The Třebouňský vrch Height (824 m) is the largest table mountain in the southeastern part of the Tepelská vrchovina Highland. It is built of trachybasalt of about 100 m in thickness, resting on sandy, clayey, and tuffaceous Miocene volcanic series. The substratum of these sediments is formed of double mica schists to paragneiss of the Teplá-Barrandien crystallinicum, on which a levelled surface at an altitude of 650—700 m has arisen in the wider surroundings. The highest part of the Třebouňský vrch Height in the north forms a plateau in the west-east direction, from where a broad ridge runs out towards the south (Branišovský vrch Height 813 m). To the southeast the Třebouňský vrch and Branišovský vrch Heights enclose a small conspicuous round basin of tectonic origin, whose bottom lies more than 200 m under the top parts of the Třebouňský vrch and Branišovský vrch Heights.

From the viewpoint of the development of slopes, the Branišovský vrch Height with a subsidiary ridge represents apparently a younger lava sheet. The asymmetry of the ridge in the cross profile depends on the inclination of the thin trachybasalt plates towards the east up to the northeast (the angle being 10—20^0). In accord with this, the top plateau of the Branišovský vrch Height is also inclined towards the east (the angle of dip making 2—5^0). The inclination of the trachybasalt plates resulted in a varying intensity of the cryogenic processes on the eastern and western slopes. While the eastern slope, for the most part, is smooth and has rock walls only in places in the southernmost part, a coherent frost-riven cliff of 2—6 m in height and 350 m in length has arisen in the west. At the foot of the frost-riven cliff a boulder heap with a dip of 20—25^0 has formed which runs out into a gently dipping cryoplanation terrace of 3—10^0 inclination and about 100 m wide. The frost-riven cliff, which is 8—10 m high, borders the ridge of the Branišovský vrch Height also in the south.

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The study of the slopes of neovolcanic heights in West Bohemia has shown that a major role in their development has been played by frost processes under the conditions of the Pleistocene periglacial climate. There have been characterized here typically developed frost-riven cliffs and cryoplanation terraces, whose origin was also furthered by favourable geomorphological conditions. The character of the destruction relief features was determined here by the plate-like parting of neovolcanic rock, so that the resultant forms are analogous to the forms arisen in the crystalline rock. The cryogenic processes were further eased by profuse jointing of volcanic rock which divided the eruptive body into a number of blocks. Under suitable geological and geomorphological conditions a gentle movement of these blocks and opening of the fissures, on which suffosion processes in the central parts of the plateaus took place, has occurred. On the margins of the plateaus the furrows arisen on fissures were a suitable medium for effective periglacial frost processes. The colluvial movements of blocks in neovolcanites are of the same nature as similar phenomena in the region of the Cretaceous rock of the Bohemian Tableland (J. Pašek 1968). The most intensive movements of these blocks are dated back to the periglacial periods of the Pleistocene.

The destruction of surfaces and marginal slopes of table mountains is, therefore, the result of three types of different processes, i. e. subsidence of blocks, suffosion, and periglacial frost weathering. The decisive factor here was Pleistocene frost weathering, the accumulation products of which point to a recession of the slopes in the Pleistocene over several tens of metres.

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K VÝVOJI SVAHŮ V NEOVULKANITECH ZÁPADNÍCH ČECH

Neovulkanické stolové hory, charakteristický prvek reliéfu severní části Plzeňské pahorkatiny a území Tepelské vrchoviny a Slavkovského lesa, představují relikty lávových příkrovů, vzniklých v hlavní (převážně spodnomiocenní) vulkanické fázi Českého masívu. Spočívají na zbytcích sníženého starotřetihorního zarovnaného povrchu, krytého místy relikty fluviálně limnických třetihorních sedimentů. Tento starý povrch, místy s fosilně zvětralými horninami krystalinika, pohřbený neovulkanickými příkrovy, leží zpravidla zřetelně výše než okolní mladší (neogenní) zarovnaný povrch na horninách tepelsko-barrandienského krystalinika a permokarbonu.

Studium svahů typických neovulkanických vrchů v západních Čechách (Chlumská hora 650 m a Kozelka 660 m v Manětínské kotlině, Třebouňský vrch 824 m v Tepelské vrchovině) ukázalo, že rozhodující úlohu při jejich vývoji sehrály mrazové procesy v podmínkách pleistocenního periglaciálního klimatu. Byly zde zjištěny typicky vyvinuté mrazové sruby i kryoplanační terasy, jejichž vznik byl podmíněn i příznivými geomorfologickými poměry. Ráz destrukčních tvarů byl zde určen destičkovitou odlučností neovulkanických hornin, takže výsledné formy jsou analogické tvarům vzniklým v usměrněných krystalických horninách. Kryogenní procesy byly dále usměrněny hojným rozpukáním vulkanických hornin, které rozdělilo vulkanická tělesa na řadu ker. Za vhodných geologických a geomorfologických podmínek došlo k mírným pohybům těchto ker a k rozevírání trhlin, na nichž probíhaly intenzívně sufózní procesy v centrálních částech plošin. Na okrajích plošin byly rýhy vzniklé na trhlinách vhodným prostředím pro účinné mrazové periglaciální procesy. Svahové pohyby ker v neovulkanitech jsou stejného rázu jako obdobné jevy v oblasti křídových hornin České tabule (J. Pašek 1968). Nejintenzívnější pohyby těchto ker se kladou do periglaciálních období pleistocénu.

Destrukce plošin a okrajových svahů stolových hor je tedy výsledkem tří druhů rozdílných procesů, tj. odsedání ker, sufóze a periglaciálního mrazového zvětrávání. Rozhodujícím činitelem zde bylo pleistocenní mrazové zvětrávání, jehož akumulační produkty ukazují na ústup svahů v pleistocénu až o několik desítek metrů.

1. Schematické příčné profily neovulkanických vrchů západních Čech. A — Chlumská hora, B — Branišovský vrch, C — Doubravický vrch, D — Kozelka, E — Chlumská hora. 1 — nefelinický basanit, 2 — trachybasalt, 3 — permokarbonské jíly a jílovce, popř. pískovce a slepence, 4 — balvanové haldy a proudy.

K obrázkům na křídové příloze

1. Trachybasaltová stěna s odsedlým skalním blokem na západním svahu Kozelky v Manětínské kotlině. Foto B. Balatka.
2. Rozpadlý mrazový srub ve východní části Doubravického vrchu v Manětínské kotlině. Foto J. Sládek.

1. Trachybasalt wall with a subsided rock block on the western slope of Mt. Kozelka in the Manětínská kotlina Basin. Photo B. Balatka.

2. Destroyed frost-riven cliff in the eastern part of the Doubravický vrch Height in the Manětínská kotlina Basin Photo J. Sládek.