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PARALLELS BETWEEN KARST RELIEF AND GRANITE RELIEF: CASE STUDY OF THE BOHEMIAN HIGHLANDS, CZECH REPUBLIC

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ABSTRACT. Similarities between the development of granite inselbergs of the Žulovská pahorkatina Hillyland and karst inselbergs of the Bělská pahorkatina Hillyland in the NE part of the Bohemian Highlands are discussed as examples of parallels between karst relief and granite relief.

KEY WORDS: inselbergs, granite relief, karst relief.

1. INTRODUCTION

Similarities between relief and limestone relief have been recognized by a number of geomorphologists [Jennings 1985; Thomas 1994; Twidale 1990]. It is clear that the understanding of karst geomorphology should be brought firmly into the broader thinking about landforms occurring on silicate rocks. The fact that limestone dissolution is both complete yet reversible, appears to set karst processes apart from the incongruent, saprolithic weathering of the silicate minerals. Yet Thomas (1994, p. 351) argues that the controlling processes of both systems are similar. The chemical reactions in both cases are advanced by continued water inputs and favored by warmer temperatures. They are also mediated by microbial productivity and the formation of soil acids that donate protons to the weathering system. As a consequence of these factors, warm and wet conditions favor etch processes, whether they are congruent or incongruent in their operation. In terms of the role of etch processes, perhaps the most important observation is to note that in the case of the Bohemian Highlands, both saprolithic weathering in granitoid areas and limestone dissolution in marble areas has led to both a highly accidented relief (inselbergs in granitoids, cone karst in marbles) and to an almost flat plain in close juxtaposition. Of course there remain important differences and these mainly attach to the roles of surface drainage.

2. THE BOHEMIAN HIGHLANDS

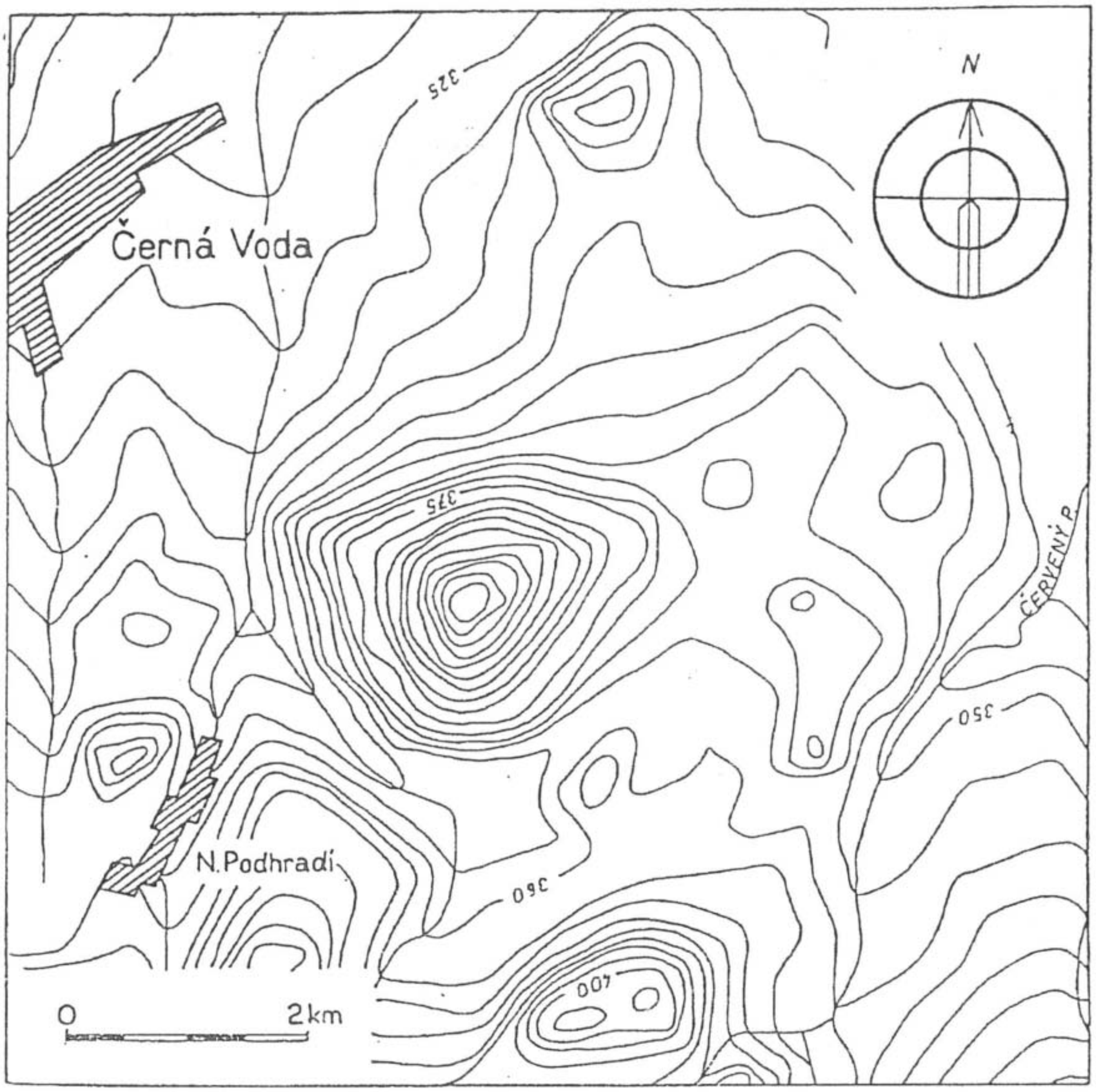
The Bohemian Highlands represent the eastern sector of the European Hercynian platform. The geological development of the Highlands was complex and of long duration. It culminated in the Variscan orogeny with the emplacement of numerous plutons and extensive regional metamorphism. The Highlands are a rather markedly limited unit within the framework of the Variscan mountain ranges in Central Europe. They display a rhomb–like shape and dominate over the surrounding plains. The present general character is the extensive Central Bohemian Basin (around the capital of Prague approx. 220 m a.s.l.) rimmed by marginal mountain ranges (highest point Mt. Sněžka 1602 m a.s.l.). Structurally, they now consist of three basic elements: (1) the Precambrian (Cadomian) basement, (2) the Variscan (Paleozoic) unit and the overlying (3) a post–Variscan platform cover [Suk ed. 1984]. The form is that of an old massif bevelled by planation and morphologically rejuvenated by Tertiary and Quaternary block tectonics.

The whole area was worn down to a surface of low relief at some time during Mesozoic, giving the surface known as the pre–Cretaceous peneplain. Tectonic movements brought about the subsidence of the northern part of this surface and the transgression of the Cretaceous sea. After marine transgression, a new phase of planation began, culminating in the development of the Paleogene planation surface, on which a weathered mantle, mostly kaolinitic and often more than 100m thick, was formed. Rejuvenation and dissection of the surface, due to neotectonic movements, set in during the Neogene and Quaternary. The saprolithic mantle was extensively destroyed. Its removal exposed the basal surface of tropical weathering (weathering front), giving rise to the so–called Czech etchplain, a new Pliocene–Quaternary planation surface. The surface morphology of this etchplain is controlled by the differential resistance of the underlying rocks to tropical weathering. The parallels between the development of granite and karst relief of the Bohemian Highlands as result of tropical climate of the Mesozoic and Paleogene are striking.

The most noticeable are those parallels found in the north–eastern horst–like sector of the Bohemian Highlands which has been uplifted above the adjacent plateau country in the Sudeten block and of the pre–Sudeten block piedmont hilly relief (called the Žulovská pahorkatina Hillyland and Bělská pahorkatina Hillyland) near the boundary between the Czech Republic and Poland (see Map No. 1). The Žulovská pahorkatina Hillyland is an area of 107 sq. km built of granitoids the Žulová pluton of the Paleozoic age. The pluton consist of several main intrusions, following each other closely during Variscan orogenesis. Basic portions of the pluton, in the vicinity of the village of Černá Voda are formed by granodiorite and amphibole – biotite diorite.

The core is composed by so–called "main granite" (medium to coarse–grained) and granodiorite (highly quartzose) in between the towns of Žulová and Vidnava. So–called "marginal granite" with predominant K–feldspar forms the rim of the "main granite".

The Bělská pahorkatina Hillyland has an area of 111 sq. km and is composed of metamorphic rocks (mostly gneisses) and of marbles. In the marbles tropical cone



MAP. 1

karst developed during wet and hot climate [Czudek, Demek 1960].

3. TROPICAL CLIMATES OF THE PAST IN THE BOHEMIAN HIGHLANDS

In the Upper Cretaceous and Paleogene till the middle Oligocene a savannah climate, with a dry winter, which can be compared with type Aw of Koeppen was found in the Bohemian Highlands. After the very dry climate in the middle Oligocene (BShw), the climate of the constantly humid tropical rain forest (Af) set–in in the upper Oligocene, and lasted until the middle Miocene. In the lower Pliocene the savannah climate (Aw) set–in again, this time at the turning point between the Lower and Upper Pliocene exchanged for the temperate climates of the end of Tertiary and Quaternary Periods.

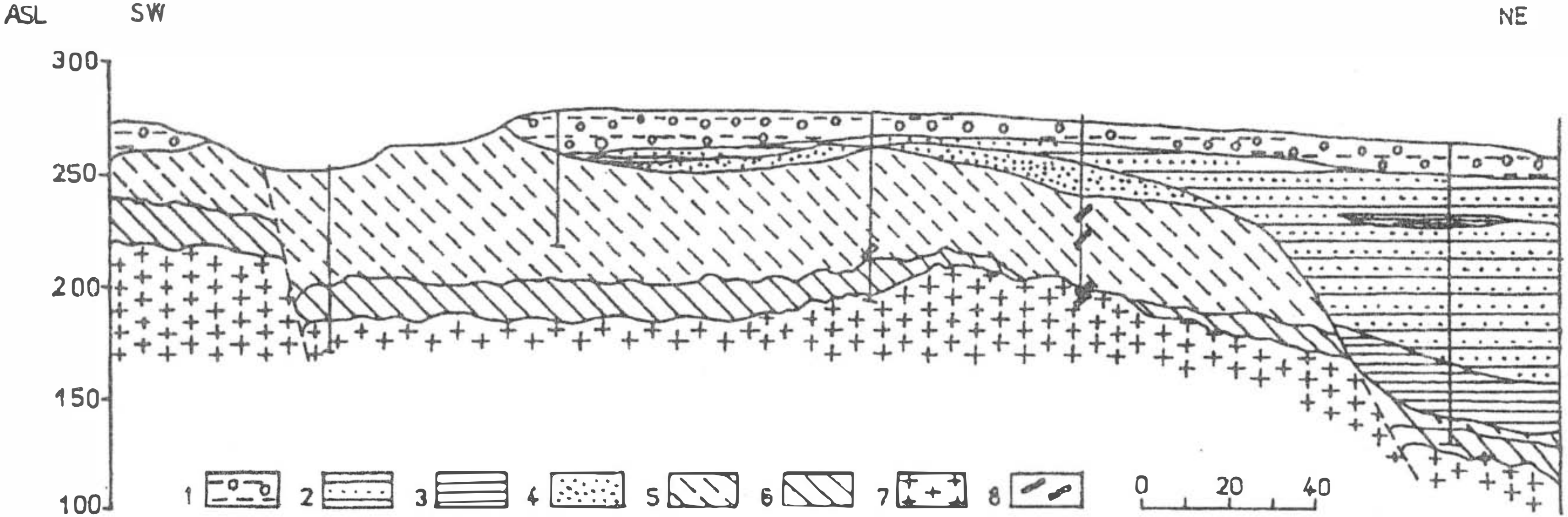


FIG. 2. Geological cross section through the Vidnava deposit. Explanations: 1. fluvioglacial deposits of the Saale (Central–Poland) Glaciation, 2. claey sands, clays, co–called granite detritus, 3. claey coal, coal clays, 4. kaolinitic sands, clays, co–called secondary kaolin, 5. residual kaolin with completely decomposed feldspars, 6. residual kaolin with incompletely decomposed feldspars, 7. the Žulová granite, 8. quarz veins.

4. Tropical Kaolinitic Saproliths in the Piedmont Hillylands

On the pre–Sudetic block, on both sides of the Czech–Polish state boundary, a large deposit of tropical kaolinitic saprolite has been known since 1786 [Milický, Kabát, Křelina 1985]. The deposit is situated at the northeastern edge of the Žulovská pahorkatina Hillyland on the territory of the Czech Republic and in the vicinity of town of Biskupow in Poland. The parent rock of these tropical kaolinitic mantle is coarse–grained "main granite" of the Žulová pluton. In some places is the parent granite tectonically jointed and some rock grains were crushed. The intensity of rock decomposition is decreasing with depth.

Between fresh granite at greater depths and topsoil at the surface, the saprolite is not uniform and three zones can be identified (upper, middle and lower) based on one degree of granite decomposition, color, mineralogy, and so forth. The boundaries among these zones are not sharp, depending on grain size and jointing of the parent granite. In the upper zone felspars are completely decomposed and white kaolinite prevails. The upper, the completely decomposed zone is reaching along joints into middle zone forming something like roots.

The middle zone shows the in–situ nature of the saprolite formation with some preserved structures of the original granite. Undisturbed joints and many quartz veins [Milický, Kabát, Křelina 1985, p.208] are evident. The degree of decomposition of biotite is very variable and depends on the texture and structure of the granite, its porosity and jointing and on the intensity of weathering due to the circulation of solutions. Along quartz veins kaoline is red and ochre in color. The thickness of the upper and middle zones averages between 40 and 50 m, but in some parts of the deposit it reaches up to 90 m.

In the lower zone the green is typical color of the kaoline due to a lower degree of weathering [Milický, Kabát, Křelina 1985, p.208]. The structured regolith contains rounded core stones. In spheroidal weathering, a number of shells of weathered granite wrap around the corestone. The weathering front is evidently quite irregular according to some bore holes taken at a depth of about 150 m below the upper surface of the saprolite.

5. Relief of the Granite Area

The northern foothills of the Sudeten Mts. constitute a typical inselberg landscape [Gellert 1931] in which isolated hills, many of them resembling the bornhardts of tropical areas, rise above the planation surface with its remnants of the former kaolinitic mantle.

The relief of the Žulovská pahorkatina Hillyland is formed of two groups of landforms. A typical feature of the relief is the occurrence of both a plain with a multi-convex relief situated at heights of 300 m to 380 m a.s.l., and prominent isolated inselbergs with tops from 378 to 526 m a.s.l. The plain is formed by a high number of relatively low cupola-shaped elevations of the rock surface separated by flat basins. Small basinal rock forms are widespread in the planated surface. They probably reflect the shape of the weathering and have been exposed by stripping [Thomas 1994, p.379]. Although suffosion forms have developed over silicate rocks, beneath the kaolinic saprolite cover they are not as developed as the subterranean drainage in marbles of the Bělská pahorkatina Hillyland.. For this reason, granite basins in the Žulovská pahorkatina Hillyland are different in shape from cockpit karst depressions, being linked in many cases by surface drainage channels. It is clear that basins respond to structure, in a negative sense, in the same manner as granite inselbergs reflect positive structural and mineralogical control.

Elevations of plain with multi–convex relief exhibit an oval groundplan and gentle convex slopes. The transitions among elevations and basins are smooth. The relative height of the elevations is mostly 20 to 30 m. The study of exposures and the pits allow us to distinguish two types of elevations. The first type consist of low granite exfoliation domes (ruwares, half–oranges, meias laranjas). They developed by the sheeting of thin slabs (mostly 5 to 20 cm thick) along vault–like arranged planes. The second type consist of elevations formed of groups of woolsack boulders (core–stones). The bedrock crops out in some cases in the form of tors surrounded by boulders. The core–stones are frequently surrounded by saprolith. Ruwares prevail. There is no evident bedrock control over the topography. But, in the field, changes in granitoids' composition and fabric can be quite subtle and may neither be recognized during field geomorphic mapping nor on specimens. Frequently they occur at scales which prohibit the mapping of structural boundaries on available maps.

Inselbergs (bornhards) tower above a plain with multi–convex relief. The bornhards occur either separately or in groups. They have an oval groundplan, bare surfaces, domelike summits and precipitous slopes. On their tops and in the upper parts of the slopes are remnants of exfoliation sheets as much as 1 m thick. Many small forms of weathering and erosion have developed on inselbergs (tafoni, weather–pits, lapies, honeycombs, rock niches and hollows – see [Demek 1964].

In basins among ruwares and bornhardts remnants of tropical saprolith with high content of kaolinite are found. Therefore, the surface of the Žulovská pahorkatina Hillyland is interpreted as an etchplain emerging from deep tropical saprolith which is preserved in the northeastern part of the Žulovská pahorkatina in the vicinity of the town of Vidnava.

6. Tropical Relict Karst in the Bělská pahorkatina Hillyland

In the SE, the Žulovská pahorkatina Hillyland is immediately linked to the Bělská pahorkatina Hillyland built of metamorphic rocks (mostly gneisses) and of marbles of the basement of the Bohemian Highlands.The white colored marbles are middle to coarse grained, with corns from 1 m to 5 mm in diameter. The marbles are compact, without clear bedding and irregularly jointed. In the marbles, cone karst with caves and karst hydrography has developed in periods of tropical climate. According to [Bosák ed. 1989, p.118] this cone karst is from the Paleogene to the Lower Miocene Paleokarst. The karst cones are separated by cockpit depressions filled by in–situ kaolinized sediments with a high kaolinite content [Bosák ed. 1989, p.122]. Similarities between inselberg development in granite relief of the Žulovská pahorkatina and carbonate rocks of the Bělská pahorkatina are intriguing.

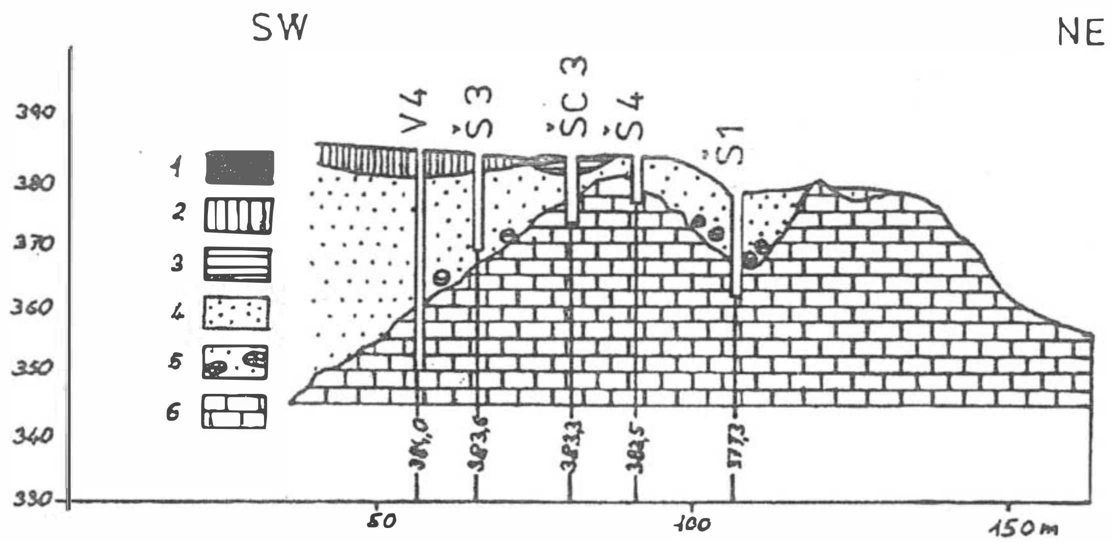


FIG. 3. Cross section through karst inselberg in the village of Supíkovice [Kotisová 1956–57, from Czudek, Demek 1960]. Explanations: 1. antropogenic deposits, 2. slope deposits, 3. brown loam with sandy layers and fragments of marble, pegmatit and aplit, 4. fluvioglacial sands with gravels, 5. blocks of marble, 6. marble.

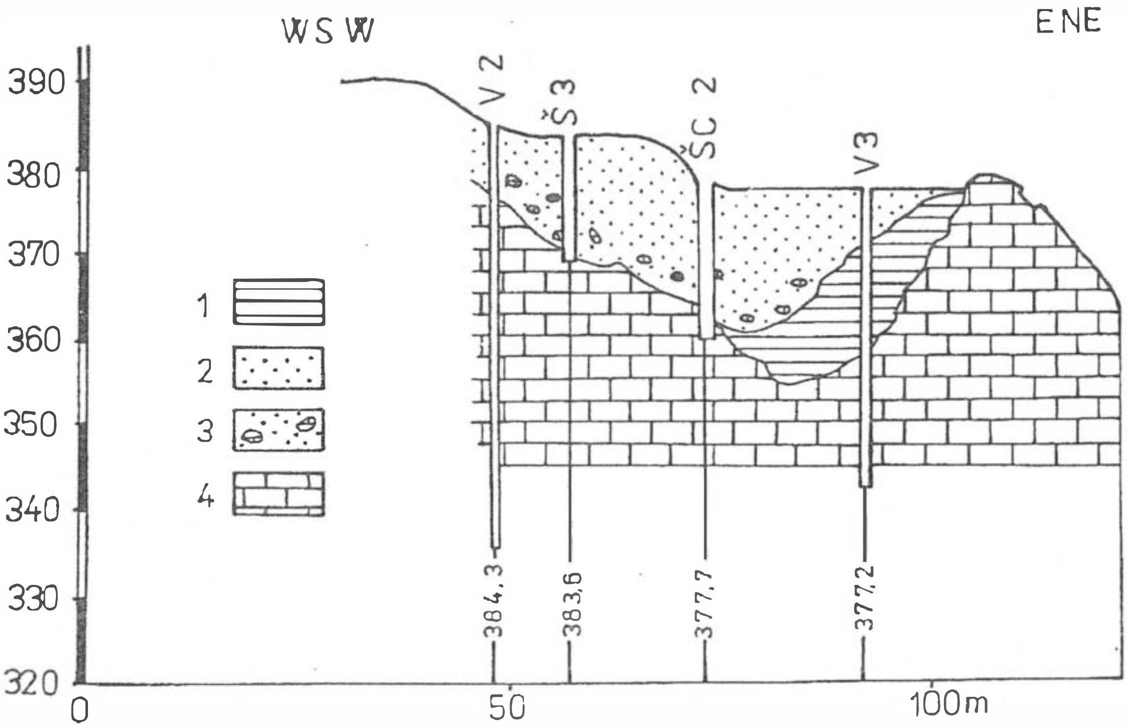


FIG. 4. Cross section through quarry on the top of karst inselberg in the village of Supíkovice [Kotisová 1956–57, from Czudek, Demek 1960]. Explanations: 1. Yellow and brown loam with layers of red–brown fosil saprolith with very weathered blocks of marble, pegmatiti and aplit, 2. Fluvioglacial sands with gravels, 3. Blocks of marbles in sands. 4. Marbles.

Bělská pahorkatina Hillyland is an undulated country formed by broad ridges and wide open valleys. Ridges are composed of Pleistocene glacial and fluvioglacial (outwash plain) deposits. Some karst cones are buried below the Quaternary deposits, other rise above the plain as karst inselbergs. A typical example represents Špičák Hill (482 m) near the village of Supíkovice in Silesia. A conical hill with steep slopes is built of white crystalline limestone (marble), which is interlaid with metamorphosed pararocks. The top rises 32 m above the surrounding outwash plain. On the top of the hill are castellated rocks. During the Saale Glaciation Špičák hill formed a nunatak. The thickness of the fluvioglacial deposits of the Saale glaciation is at least 40 m.

A cave system developed in this karst inselberg at two levels. The upper cave level developed at the elevation 460 m a.s.l. Cave profiles developed during the tropical climate were changed by glacial melt water into typical heart cross-section. The lower cave level has large areal extent (up to Poland).

Another karst inselberg is opened by marble quarry in the central part of the village of Supíkovice (see fig. 3 and 4).

7. Conclusions

Examples of granite inselbergs of the Žulovská pahorkatina Hillyland and karst inselbergs of the Bělská pahorkatina Hillyland discussed in this case study shows that similarities between the development of granite relief and the relief of carbonate rocks during a past tropical climate are intriguing.

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SHODY MEZI KRASOVÝM GEORELIÉFEM A ŽULOVÝM GEORELIÉFEM NA PŘÍKLADU Z ČESKÉ VYSOČINY, ČESKÁ REPUBLIKA

Jaromír DEMEK

V článku autor poukazuje na nápadné shody krasového reliéfu Bělské pahorkatiny a žulového georeliéfu Žulovské pahorkatiny v severovýchodní části České vysočiny. Bělská pahorkatina je tvořena krystalickými břidlicemi (hlavně rulami) a mramory fundamentu Českého masivu. Sousední Žulovskou pahorkatinu skládají žuly Žulovského plutonu prvohorního stáří. Obě oblasti prodělaly dlouhý geologický a geomorfologický vývoj, v němý se střídalo několik fází hlubokého zvětrávání a odnosu v teplém vlhkém podnebí svrchní křídy až středního miocénu. Ložisko kaolinických zvětralin granitoidů (obr. 2) o mocnosti až kolem 150 m se rozkládá kolem města Vidnavy a zasahuje až do sousedního Polska [Milický, Kabát, Křelina 1985]. Na většině území Žulovské a Bělské pahorkatiny však byly tropické zvětraliny odneseny a byla obnažena bazální zvětrávací plocha. Dnešní zarovnaný povrch této části České vysočiny je proto klasifikován jako etchplén. Etchplén sestává jednak z poměrně plochého základního zarovnaného povrchu a jednak z žulových a mramorových ostrovních pahorků a vrchů (mapa 1). Žulové ostrovní pahorky a vrchy v Žulovské pahorkatině mají tvar bornhardtů [Demek 1964; Ivan 1983]. Mezi nimi jsou ploché sníženiny vyplněné kaolinickými zvětralinami, zčásti bezodtokové. V Bělské pahorkatině jsou ostrovní pahorky vyvýšeninami kuželovitého krasu (obr. 3 a 4), oddělené sníženinami typu cockpit vyplněnými in-situ kaolinizovanými sedimenty s velkým obsahem kaolinitu [Czudek, Demek 1960; Bosák ed. 1989]. Podle [Bosák ed. 1989] tento kuželovitý kras je paleokrasem paleogenního až spodnomiocenního stáří.

Geomorfologickým vývojem v teplém vlhkém podnebí svrchní křídy až středního miocénu vznikl na granitoidech a mramorech nápadně shodný georeliéf s žulovými a krasovými ostrovními pahorky a vrchy, obklopenými plochým základním zarovnaným povrchem. Rozhodující geomorfologické pochody typu etchingu v krasových i nekrasových horninách byly podobné [viz Thomas 1994, str. 351]. Rozdíly jsou v typu odvodňování, které v krasovém území je jak povrchové, tak podpovrchové (jeskynní systémy sahající z území ČR až do sousedního Polska). Uvedený příklad umožňuje zařadit krasovou geomorfologii do širšího kontextu vývoje georeliéfu na silikátových horninách.