*Geogr. Fis. Dinam. Quat.*
*21 (1998), 23-26, 2 figg.*

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# GRANITE LANDFORMS IN SOUTH MORAVIA (CZECH REPUBLIC)

**ABSTRACT:** IVAN A. & KIRCHNER K., *Granite landforms in South Moravia (Czech Republic).* (IT ISSN 0391-9838, 1998).

The pre-Variscan Dyje and Brno Massifs were unmantled and deeply eroded already before the Devonian. The massifs were strongly affected by Variscan nappe tectonics, accompanied by cataclasis and mylonitisation. These processes were not favourable for the evolution of typical granite topography. On the extensive regional planation surface the only remarkable features are relics of a very trick kaoline weathering crust (80-100 m). Although tropical weathering was the primary process in formation of kaolines, the importance of Variscan nappe tectonics is undisputable.

Granite landforms are more frequent in the Dyje Massif, probably owing to the deep level of denudation and less intense shattering. They occur on the southeastern marginal slope of the Bohemian Massif and in the deep river valleys, especially in the Dyje canyon. On the marginal slope, the most conspicuous forms are inselbergs. Some of them were buried under Miocene sediments and later partly exhumed. Tors and microforms (weathering pits, exfoliation) are rare. In the meandering Dyje canyon the granite forms are numerous and in general they are also younger. Most common are the valley-side granite tors and block fields. Microforms, *e.g.* tafoni and pseudolapiés, mainly occur on the south-facing slopes.

KEY WORDS: Granite inselbergs, Podyji National Park, Bohemian Massif.

**RIASSUNTO:** IVAN A. & KIRCHNER K., *Paesaggi nei graniti della Moravia meridionale (Repubblica Ceca).* (IT ISSN 0391-9838, 1998).

I massicci pre-varisici di Dyje e Brno furono smantellati e profondamente erosi già prima del Devonico. I massicci furono fortemente interessati dalla tettonica a falde varisica, accompagnata da fenomeni di cataclasi e milionisi. Questi processi non furono favorevoli all'evoluzione della tipica topografia dei graniti. Sull'estesa superficie di spianamento regionale, gli unici notevoli lineamenti sono i resti di una crosta caolinica molto spessa (80-100 m). Sebbene l'alterazione di tipo tropicale sia stato il processo primario nella formazione del caolino, l'importanza della tettonica varisica è indubbia.

Le tipiche forme nei graniti sono più frequenti nel Massiccio di Dyje probabilmente in ragione del profondo livello di denudazione e una meno intensa frantumazione. Esse si rinvengono sui versanti sudoccidentali del Massiccio Boemo e nelle profonde valli fluviali, specialmente nel canyon di Dyje. Sui versanti periferici, le forme più evidenti sono gli inselberg. Alcuni di essi furono seppelliti sotto i sedimenti del Miocene e più tardi parzialmente esumati. Tor e microforme (cavità da alterazione ed esfoliazione) sono rari. Nel sinuoso Canyon di Dyje le forme nei graniti sono numerose e in generale sono più giovani. Più comuni sono i tor granitici nelle valli e i campi a blocchi. Microforme, come ad esempio tofoni e pseudolapiez, si trovano principalmente nei versanti esposti a mezzogiorno.

TERMINI CHIAVE: Inselberg granitici, Parco Nazionale di Podyji, Massiccio Boemo.

## INTRODUCTION

The study area in South-Moravia, the Podyji National Park, is situated along frontier between Czech Republic and Austria was established in 1991. The 235 m deep canyon of the Dyje River is a main landscape feature incised below the featureless ancient etchplain. The canyon is cut into the crystalline basement of the southeastern margin of the Bohemian Massif at its contact with the Western Carpathians Depressions (Foredeep). The SE marginal slope of the massif facing the Carpathian Foredeep is another distinct landscape feature (Ivan & Kirchner 1994a).

The eastern part of the Podyji National Park is composed of Cadomian biotite granite and granodiorite of the Dyje Massif (ca 550 Ma BP; Scharbert & Batík, 1980). During the Variscan orogeny the massif was strongly affected by nappe tectonism, mylonitization and retrograde metamorphism and became the core of a complex structure known as the Dyje Dome. These processes were important in post-Variscan subaerial denudation, characterized by hot wet climate and deep chemical weathering. Therefore, remnants of the kaoline weathering crust (somewhere more than 100 m thick) preserved on the flat etchplain surface may be partly related to retrograde metamorphism, schistosity and mylonitization (Ivan & Kirchner 1994b).

There are abundant micro- and mesoforms of different origin and age in granite both on the eastern marginal

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*The research project was supported by the Czech Academy of Sciences (grant No 31 459) and grant from the Ministry of Environment of the Czech Republic (No 774/93). In the 1996 research is continuing with support of the Czech Academy of Sciences (grant No A3086601).*

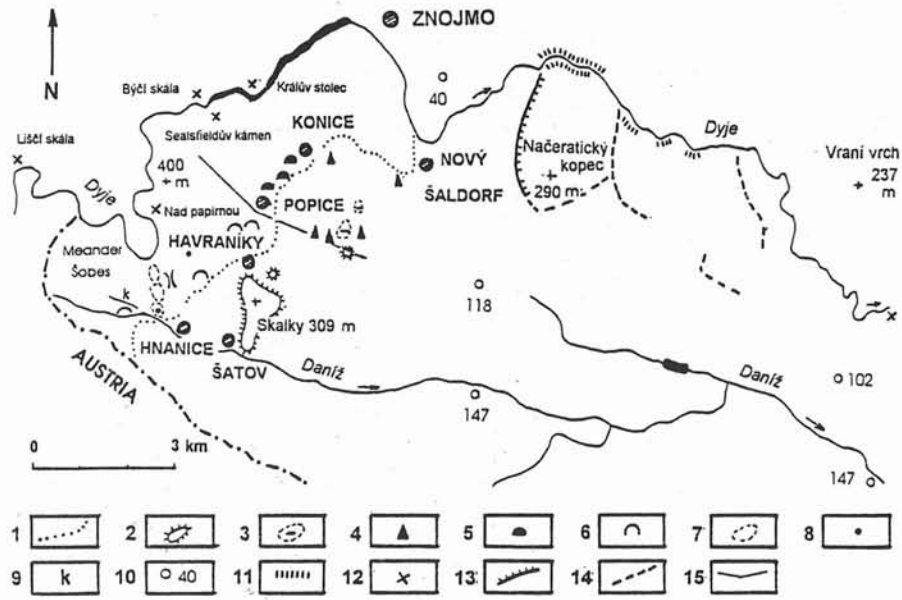


FIG. 1 - Main granite landforms in the southeastern part of the Bohemian Massif. 1) foot of the marginal slope of the Bohemian Massif; 2) distinct inselbergs surrounded by Miocene and Quatemary sediments; 3) flat surface of granite, in the same level as younger sediments; 4) sharp granite protrudings above Miocene and Quaternary sediments; 5) low exfoliation domes; 6) exfoliation; 7) less distinct inselbergs; 8) summit tors with corestones and weathering pits; 9) outcrops of kaolinized granite (growan); 10) boreholes with thickness of Miocene and Quaternary sediments; 11) steep slopes of the Dyje river in the gap through to Krhovice horst; 12) most important groups of granite valleyside tors in the Dyje canyon; 13) distinct fault scarp of the Krhovice horst; 14) other morphologically distinct faults; 15) geomorphological profile (fig. 2).

slope of the Bohemian Massif and in the Dyje canyon. Large blockfields only occur in the canyon, while the inselbergs only on the marginal slope of the Bohemian Massif and in its foreland (fig. 1). No distinct features such as typical tors or inselbergs are present on the etchplain, with the only exception of some low exfoliation domes (ruwares), and rudimentary tors close to upper edge of the Dyje canyon or above the eastern marginal slope of the Bohemian Massif (Ivan & Kirchner 1995).

## GRANITE LANDFORMS ON THE BOHEMIAN MASSIF

The southwestern marginal slope of the Bohemian Massif is part of a flexure-like structure composed of basement rocks. It faces the Carpathian Foredeep filled by Miocene and Quaternary sediments. The some tens of kilometers wide flexure with an amplitude of some thousands metres, is deformed by several, mostly antithetic, faults with displacements of some tens or few hundreds metres. The flexure is mostly buried under Miocene deposits and the marginal slope of the Bohemian Massif is only its uppermost part. The thickness of the Miocene sediments along the footslope is up to 150 m (Čtyroký, 1991). Towards the basin centre the sediments become thicker and in front of the Carpathian nappes the basement lies at ca 3000 m depth. To the east Jurassic limestones also occur below Miocene clays and sands. The sediments rest unconformably on an ancient planation of the crystalline basement. It is probable, that entire marginal slope of the Bohemian Massif was originally covered by Miocene sediments and was ressurected by subaerial denudation only after regression in the Upper Miocene.

The marginal slope probably developed as early as the Upper Paleogene in connection with orogenic movements in the Eastern Alps and Western Carpathians along the convergent margins of the Eurasian and African plates. Its denudation took place not only in subaerial environment but coastal processes were probably also important. The marginal slope and its complicated relief was submerged during repeated marine transgressions. Their deposits, sands, gravels and clays are found in very different topographic positions at present (Čtyroký, 1991; Steininger, & Roetzel, 1991). In the area of the Podyji National Park topography of the marginal slope of the Bohemian Massif is relatively uniform, in other parts, however, also great fault embayments exist, filled by estuarine deposits. Consequently, slope evolution lasted, in comparison with the Dyje canyon, longer and much more complicated.

Although weathering and denudation have been the principal geomorphic processes, the marginal slope is primarily tectonic in origin. The flexure-like deformation is complicated by fault tectonics, also evident in the present-day relief (Karásek, 1985). In the adjacent part of Austria seismic activity is reported along the important Diendorf Fault of southwestern alignment (Figdor & Scheidegger, 1977; Scheidegger, 1976). Some major elevations in front of the slope are classified as horsts. The cross profiles of these blocks are mostly assymetrical and the planation surface remains are tilted to the east, towards the Carpathian Foredeep. The greatest block, the Krhovice horst, is cut by the short transverse valley of the Dyje. Along with the general southwestern trend of the marginal slope, in some younger phase of faulting the north to south trend was also important. This is apparent both in the Krhovice horst and in the Dyje canyon.

The marginal slope is very gentle, only some tens metres high and ca 2 km wide in the Podyji National Park (fig. 2). The slope profile is mostly smooth, locally granite protrudes. The remnants of the Lower Miocene sands and gravels with perfectly rounded pebbles are also preserved both along upper and lower slope segments. At village of the Konice, the pavement composed of monomict quartz, well-rounded fine-grained pebbles occur above the upper edge of the slope, at ca 360 m altitude. West of the village Hnanice, the polymict coarse gravel with well-rounded granite boulders rests on weathered granite. On the other hand, in the abandoned sand-pit west of Hnanice, approximately at the same altitude, the granite weathered into gruss (with perceptible clay content) passes gradually into only weakly altered rock below thin loess cover.

The most distinct features of the slope and its adjacent foreland are small isolated hills, protruding from smooth slope profile or flat foothill of Miocene sediments (fig. 2). The landforms are classified as low exfoliation domes (ruwares) or inselbergs. Most of them are strongly damaged by human activity, both by quarrying and farming. Although rock pavements, weathered surfaces and blocks are numerous, microforms and typical corestones are scarce. The typical tors, rounded boulders and some weather pits occur only on the upper edge of slope at the villages Havraníky and Hnanice. The boulders are subangular or partly rounded, however surrounding rock is only weakly weathered. It is probable, that coastal processes were important in modellation of inselbergs and destroyed most of their subaerial microforms and weathering products. Well-rounded pebbles also occur, but no traces of abrasion in the granite bedrock are visible. The structure and profile of the marginal slope are equally complicated. South of the town of Znojmo, main part of the slope is composed of the Miocene and Quatemary sediments and only indistinct (some 2-4 m high), mostly sharptopped residual hills were exhumed in the middle and lowermost part of the slope (fig. 2). Between the villages of Konice and Popice the uppermost part of slope is characterized by low rounded hills (at altitude 313-328 m) which are separated from the highland by low cols.

The hills between the villages Popice and Hnanice and again between Šatov and Havraníky trend generally to the north, diagonally to the southwest direction of the marginal slope and schistosity of rocks. Nevertheless, schistosity and jointing are important controls of microfeatures. On the top of hill Na skále (306 m) tors, up to 2 m high with two embryonic weathering pits occur. The tors consist of densely jointed biotite granite, with subvertical joints at 55-75°, above only weakly weathered granite. Between the villages Nový Šaldorf and Šatov, low and flat granite elevations on the slope protrude above the Miocene sediments from the foot up to upper edge of the slope. Most marked are the oval inselberg Pustý kopec (264 m, relative height 15 m, fig. 2) and the similar hill in Havraníky. Between the villages Popice and Havraníky, the midslope shows a gently inclined smooth rock surface with exfoliation slabs. Granular disintegration seems to be an important process at present.

A very complicate topography in front of the marginal slope is found between the villages Havraníky, Šatov and Hnanice. A ca 2 km long residual ridge of 20 m maximum height (Skalky 312 m), presents a less advanced stage of isolation of elevations from the highland massif. Its foot is not so distinct as at Pustý kopec and the slopes are less steep.

## GRANITE LANDFORMS IN THE DYJE CANYON

Generally, the granite landforms in the Dyje Canyon are much younger and more abundant than inselbergs and tors on the marginal slope of the Bohemian Massif. The Dyje Canyon is thought to be superimposed from Lower Miocene (Ottnangian 17.5-19 Ma BP) brackish sands and gravels (Batík, 1993). In the Upper Miocene marine sediments were deposited in the Carpathian Foredeep adjacent to the marginal slope of the Bohemian Massif. Consequently, canyon formation probably only started when the upper part of the marginal slope was recovered from below the Upper Miocene sediments (although some shallow valleys probably existed already in the Miocene). The present drainage pattern may differ from the pattern developed after the marine regression in the Upper Miocene. An abrupt change of direction of the Dyje Canyon from the southeast to northeast in the area of the Šobes meander and residual gravel in the col (ca 40 m above of the canyon floor) suggest possible change in valley pattern and flow direction even in the pre-Quatemary period.

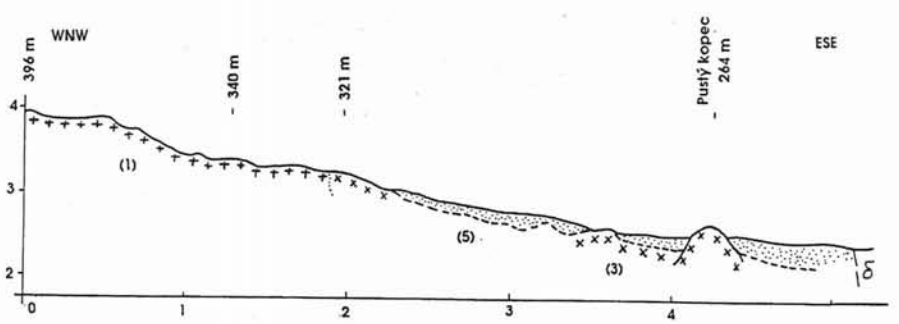


FIG. 2 - Profile across the eastern marginal slope of the Bohemian Massif at Popice. 1) biotite granite; 3) orthogneiss; 5) Miocene sediments.

Hundreds of granite tors occur in the canyon of the Dyje and its tributary valleys. They are mostly of valleyside type according to present classification (e.g. Ehlen, 1991) with a few summit tors, only 1-4 m high, situated on the lowered planation surface at the upper rim of the canyon. The rounded boulders and corestones suggest their two-stage origin. The schistosity and subvertical joints were very important in their formation.

The valleyside tors, on the other hand, mainly occur on steep slopes or canyon walls and are up to some tens of metres high. They occur everywhere, both in lower and upper slope segments. The densest pattern of tors is found on the outer concave slopes of incised meanders and at mouths of tributary valleys, where spur type tors are common.

The most impressive forms of tors are found at localities of Liščí skála-Hájka, Králův stolec (King's Table), Sealsfieldův kámen (Sealstield's stone) and Nad Papírnou (fig. 1). In the development of valleyside tors vertical joints were very important, but their tops are often determined by horizontal joints, particularly where tors occur in several levels, e.g. at Liščí skála (Fox rock). The valleyside tors are single-stage forms with mechanical weathering and gravitational loosening being most important. This is evidenced by huge accumulations of angular debris and blocks, forming many taluses, block streams and blockfields. The largest blockfields are under high vertical rock walls and some tens metres wide. In some localities, mainly in section of canyon between the Šobes meander and the town of Znojmo, the blockfields extend from upper rim of the canyon to its bottom. At the locality Nad Papírnou well-rounded river pebbles are also found in blockfields.

The uppermost tors at edge of canyon are also influnced by more recent (pre-Quaternary?) chemical weathering, as shown by granular disintegration and microforms of alveolare weathering type (tafoni). The tafoni at Liščí skála developed in the weakly weathered schistosed biotite granite is up to 150 cm deep, complicated by «rock window» about 0.5 m wide and 0.25 m high. It is located in the tor, situated direct under the upper rim. Exfoliation was another important process and the sheets are mostly some tens of cm thick.

The steep concave meander slope at Liščí skála is dissected into several narrow ridges or ribs, composed of tors arranged in steps, some of them 15-20 m high. In their formation, joints of north-northeastem direction (200-210°) were most important. The tors of ridges are separated by subvertical cross joints trending ENE (95-120°, schistosity planes are SSW).

Similar forms have been found at Králův stolec, where pseudolapiés and perched blocks are the most interesting features. Here the bulk of granite debris was used for construction of terraces, not only on cultivated slopes of ca 15°, but also in very steep (up to 25-30°) tributary valleys and gullies. In the bottom of such a gully, 12 terrace steps were made, practically from the head to the bottom of the Dyje Canyon. Some fields have an area of only a few $m^2$. In our opinion, favourable microclimate (perhaps for vineyards) motivated terrace building.

## CONCLUSION

In the Bohemian Massif the granites and granodiorites are widespread. Typical granite landforms, such as inselbergs, tors and different microforms (weathering pits, pseudolapiés) were studied mainly in the late Paleozoic (Variscan) granites (Demek, 1964). The area of the older (Cadomian) granites is smaller and rocks are also mylonitised and cataclased (Brno and Dyje Massifs). Therefore, they are less liable to development of typical granite topography. The Dyje Massif is surprisingly rich in granite features (especially in tors) if compared to the Brno Massif. This can be explain by relatively less intensive tectonic shattering and deeper weathering. Owing to the prolonged post-Variscan, mostly acyclic, denudation and planation, supplemented and completed probably by marine abrasion, the regional planation surface is very flat and almost featureless. On the marginal slope of the Bohemian Massif and in the Dyje Canyon, however, granite forms of different type and age are abundant.

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