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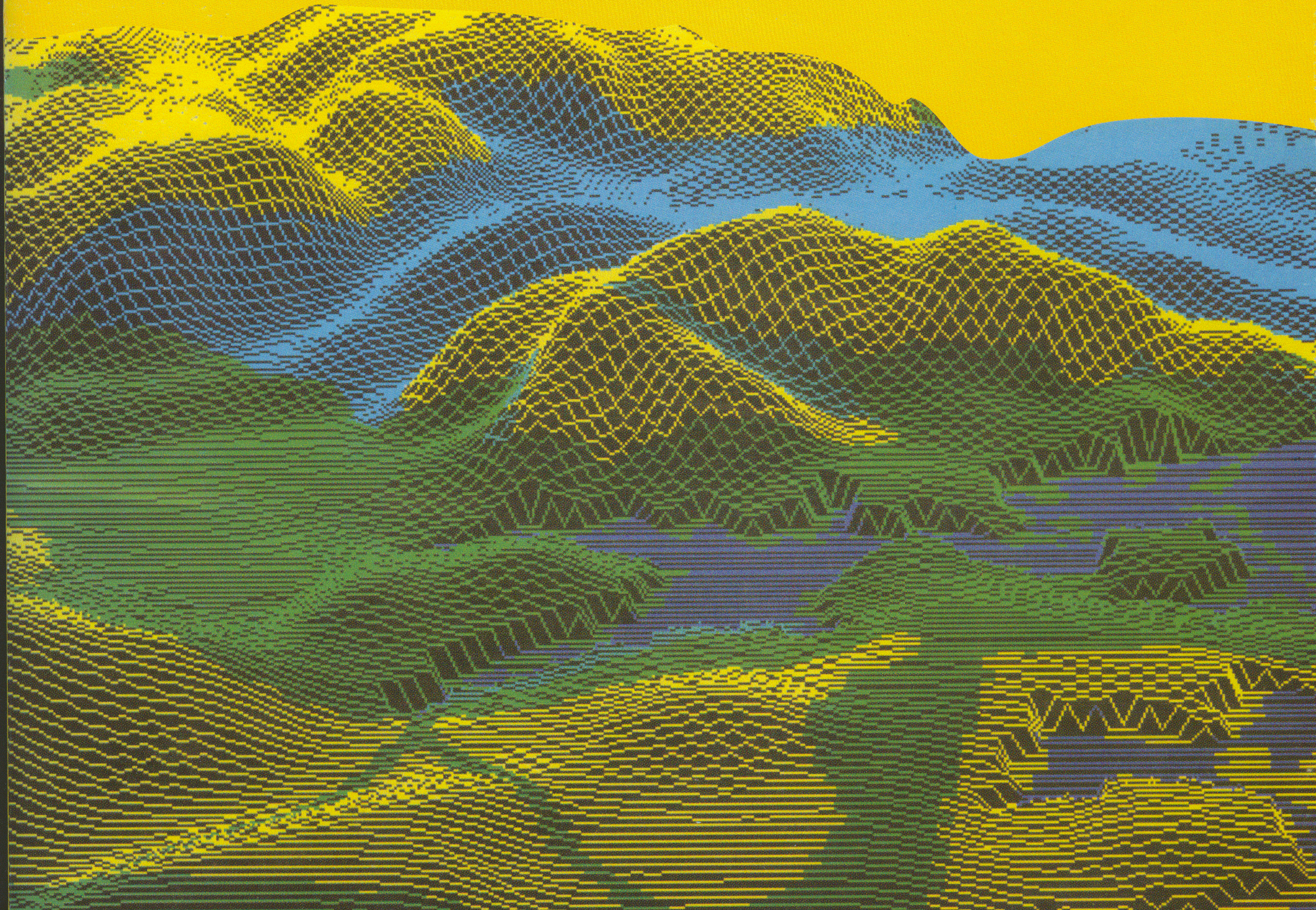

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Contents

Articles

Reports

Morphotectonics of SE margin of the Bohemian Cretaceous Basin, two half-grabens and their surroundings north of Brno (Moravia)

Antonín Ivan

Abstract

In the paper, morphotectonics of the SE marginal part of the Bohemian Cretaceous Basin as well as of two half-grabens and their surroundings north of the town of Brno is discussed. The pre-Variscan basement in the SE part of the Bohemian Massif, between the Carpathian Foredeep and the Bohemian Cretaceous Basin was strongly affected by Young-Saxon germanotype tectonics. North of Brno, relics of the downfaulted Upper Cretaceous sediments are preserved mainly in tectonic depressions and owing to the relief inversion, also at some divides. Relations among the half-grabens and Saxon structures in the Bohemian Cretaceous Basin are also discussed. Other problems are denudation chronology (including the Moravian Karst) and river pattern development.

Abstrakt

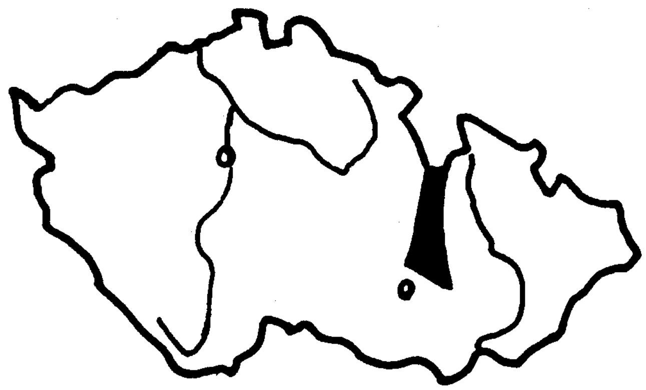
V článku je diskutována morfotektonika jv.okraje České křídové pánve, dvou polopříkopů a jejich okolí severně od Brna. Předvariský fundament jv.části Českého masívu mezi čelní karpatskou hlubinou a Českou křídovou pánví byl silně porušen mladosaxonskou germanotypní tektonikou. Zbytky svrchnokřídových sedimentů se uchovaly nejen v depresích, ale v důsledku inverze reliéfu jsou také na rozvodích.Je diskutován vztah polopříkopů k saxonským strukturám v České křídové pánvi. Blanenský prolom je jjz. pokračovánín ústecké synklinály. Dalšími diskutovanými problémy jsou denudační chronologie (včetně Moravského krasu) a vývoj říční sítě.

Key words: geomorphology of the SE part of the Bohemian Massif, Saxon tectonics, half-grabens, Bohemian Cretaceous Basin

1. Introduction

The post-Hercynian (Saxon) germanotype tectonics, characterized by intensive block-faulting both of the pre-Mesozoic basement and its sedimentary cover, resulted in horsts and grabens topography in the eastern part of the Bohemian Massif. North of the town of Brno, between the Bohemian Cretaceous Basin on the NW and the Carpathian Foredeep on the SE, two synclinal structures of half-graben type originated, in which the Upper Cretaceous sediments are preserved. At present, after the longterm subaerial denudation interrupted by marine transgression in the Miocene (Lower Badenian 16,5 - 15,5 m.y.) and complications caused by younger phases of tectonism, we found the relics of the Upper Cretaceous sediments and of the Miocene deposits in two narrow discontinuous zones of the NW and NNW directions in very different topographic positions and altitudes (Fig.1). A larger and more distinct structure in the surroundings of towns of Blansko and Kunštát is referred here to as the Blansko-Kunštát zone; the less striking zone in the sourroundings of Boskovice and the village of Valchov is referred to as the Boskovice - Valchov zone. However, only the SE parts of the zones are well-defined structures and topographic depressions known as the Blansko and Valchov Grabens (Zapletal, 1932; Kettner, 1960). In the NW parts of the structures, the Upper Cretaceous sediments are in higher altitudes, in some cases forming conspicuous buttes. Their position resulted from tectonic tilting of graben fillings along their long axes as well as from antithetic nature of major faults. At present, the Upper Cretaceous sediments are found in the rather complicated and dissected landscape in the altitude of 230-580 m.

Lithological and paleogeographical relations between the Upper Cretaceous sediments of the two zones and the Bohemian Cretaceous Basin are apparent especially in the Blansko - Kunštát zone. This also



applies for several large isolated remnants of the Upper Cretaceous sediments north of the Boskovice - Valchov zone. They are called "islets" (e.g.Vachtl et al., 1968), and are not analysed here, however.

The relics of the Upper Cretaceous sediments of both zones are 20-30 km from the contact of the SE margin of the Bohemian Massif with the Carpathian Foredeep. Towards the SE, in the adjacent part of the Western Flysch Carpathians, the Upper Cretaceous sediments occur e.g. in the Pavlovské vrchy (Hills), about 40 km from the SE margin of the Bohemian Massif.

2. Relationship between half-grabens and basement structure

The half-grabens north of Brno are located in the contact area of three important terranes or crystalline blocks of the eastern part of the Bohemian Massif (see e.g. Mísař and Dudek, 1993). The western block, Moravosilesicum, consists partly of the Svratka dome, a complex nappe structure with gneiss core mantled by two-mica schists, phyllites, limestones and amphibolites. The block is bordered on the NE by metabasites of the Letovice and Polička Units belonging to the block of the Bohemicum. On the SE, the Moravosilesicum is bordered by the Brunovistulicum, consisting of granitoid rocks of the Brno Massif (mainly by granodiorites and metabasites). Towards the E and N, the Brno Massif is hidden by the Devonian and Lower Carboniferous (Culm) sediments of the Drahanská vrchovina (Highland). The sediments were folded intensely during the Variscan tectogenesis.

The contacts among blocks were modified and masked by late Variscan structure of the Boskovice Furrow originated along the Boskovice - Diendorf fault. The furrow, trending NNE, is in fact also the half-graben about 70 km long, filled with the moderately deformed Upper Carboniferous and Lower Permian (Stephanian - Autunian) continental deposits. The sediments are classified as posttectonic molasse (e.g. Katzung, 1988). The present topographic nature of the depression resulted both from differential erosion of weak sediments and neotectonic reactivation of some of the faults. The largest, not remobilized part of the furrow dividing the structure into two parts belongs to the Českomoravská vrchovina (Highland). Some margins both of the Českomoravská vrchovina and Drahanská vrchovina (Higlands) are also composed by sediments of the furrow (Fig.1).

Thus, the term Boskovice Furrow, as used by geologists and geomorphologists, is not unambiguous. As a downfaulted structure, the furrow is larger than the present topographic depression. The Boskovice Furrow originated after the climax of Variscan tectogenesis. However, episodic tendencies to sinking in the whole contact area of three crustal blocks repeated during the post-Paleozoic platform regime. This is exemplified by remnants of the Jurassic and traces of the Lower Cretaceous sediments between the towns of Brno and Svitavy (Eliáš, 1981; Krystek and Samuel, 1978). Later, the Bohemian Cretaceous Basin originated as an intracratonic depression trending generally ESE. Its general trend turns to the SSE in western Moravia and not only the N part of the Boskovice Furrow, but also the supposed area of Jurassic sedimentation was affected. This direction change was predisposed by the trend of Variscan structures in the Moravosilesicum. Owing to the direction change, the Bohemian Cretaceous Basin extended towards the S, probably as far as to Brno, where it linked up with the sea in the area of the present Carpathians (Malkovský, 1979). This is supported by the Upper Cretaceous sediments in the northern vicinity of Brno, e.g. in the Svinošice Graben (Demek - Novák et al., 1993) and perhaps also by problematic gravels at Soběšice (the northern suburb of Brno), interpreted by Krejčí and Štelcl (1987) as possible remnants of the Lower Cretaceous sediments assigned in the Moravian Karst to the Rudice Formation (Fig.1).

The N-S direction was important during the Variscan tectogenesis in the northern surroundings of Brno as demonstrated e.g. by downfaulting of Lower Devonian sediments of the Old Red type in the Babí lom tectonic zone N of Brno (Dvořák, Karásek and Netopil, 1975; Roupec, 1994). Many faults were reactivated during young-Saxon movements (Krejčí, 1964; Ivan, 1992). The Upper Cretaceous sediments were deposited on tropical weathering planation surface with a thick mantle of saprolite. The Cenomanian and Turonian sediments are less than 200 m thick in the half-grabens, whereas in adjacent parts of the Bohemian Cretaceous Basin their thickness is almost 400 m and also younger formations are preserved. The sediments are intensely mined for ceramic and building purposes, especially in the Blansko - Kunštát zone.

After regression of the Upper Cretaceous sea, the young Saxon tectonic movements took place mainly in subaerial environment and denudation regime. Numerous faults, flexures, assymetric folds and high-angle thrusts originated (Malkovský, 1979, 1980). Amplitudes of the most intensive movements in the eastern part of the Bohemian Cretaceous Basin which partly overlaps sediments of the Boskovice Furrow exceeded 1000 m (Malkovský, 1977).

In the pre-Variscan basement of the eastern part of the Bohemian Massif, downfaulted blocks of the Upper Cretaceous sediments of both zones are cross structures. From the NW to the SE, the Blansko - Kunštát zone crosses the eastern part of the Svratka Dome, the Boskovice Furrow and partly also the Brno Massif. In the Boskovice - Valchov zone the Boskovice Furrow and Brno Massif are also dislocated. At its NW end, however, the relation to metamorphic rocks of the Svratka

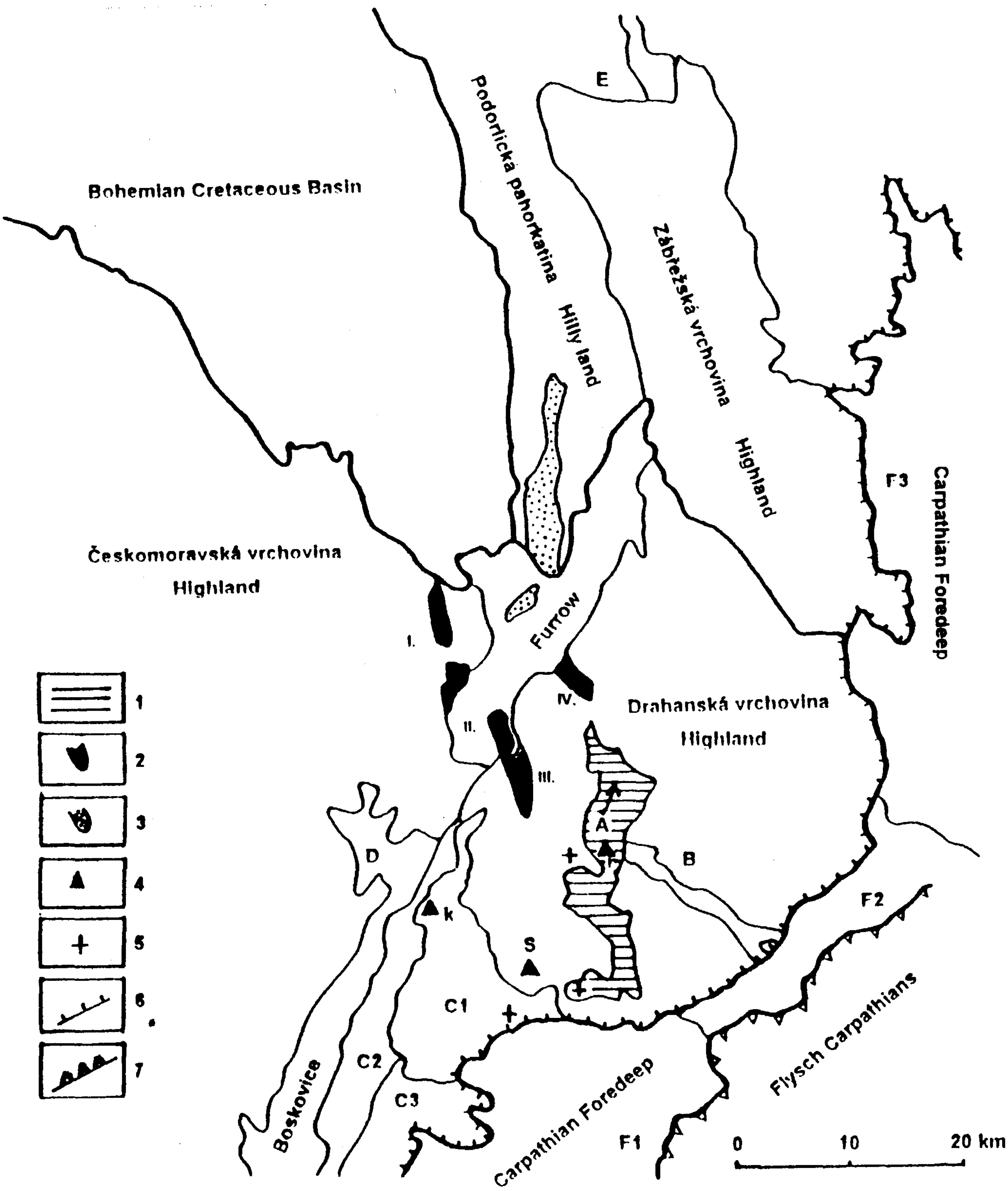


Fig.1. Main occurences of Mesozoic sediments in the northern surroundings of Brno: 1.Devonian limestones, 2.Upper Cretaceous sediments of the Blansko - Kunštát a Boskovice-Valchov zone. I-III Northern, middle and southern segments of Blansko - Kunštát zone. IV Valchov Graben. 3.Upper Cretaceous sediments in the "islets" of the Bohemian Cretaceous Basin. 4. Isolated relics of the Cretaceous sediments in the northern surroundings of Brno: k-Kuřim, s -Soběšice, r-Rudice. 5.Relics of the Jurassic sediments. 6. Marginal slope of the Bohemian Massif. 7. Front of the West Carpathians. Symbols of geomorphological units: A-Moravian Karst, B-Jedovnice - Račice Graben, C1- Brno Basin, C2 - Lipovská vrchovina (Highland), C3- Prštická pahorkatina (Hilly land), D -Tišnov Basin, E -Králíky Graeben, F -Outer Carpathian Depressions (Carpathian Foredeep), F1- Dyjsko-svratecký úval (Graben), F2- Vyškovská brána (Gate), F3 Hornomoravský úval (Graben).

Dome is not clear, because of complete denudation of the Upper Cretaceous sediments. Accordingly, although the two zones are crossing three very different geological a geomorphological units, the half-grabens as distinct topographic depressions are developed only in granitoid rocks of the Brno Massif. On the SE, the half-grabens are closed at the contact of the granitoid rocks with the folded Devonian and Culm sediments of the Drahanská vrchovina (Highland).

3. The Blansko - Kunštát zone

The Blansko-Kunštát zone is 26 km long and 1-5 km wide. It extends from the valley of the Křetínka river on the NNW to the junction of the rivers Svitava and Punkva on the SSE. The original continuity with the Bohemian Cretaceous Basin in the NNW was lost due to entire denudation of the Upper Cretaceous sediments in the valley of the Křetínka. On the SSE, at Blansko, the zone ends on a diagonal fault trending SE. In this place, the Svitava R. enters a deep tranversal gorge. The Blansko - Kunštát zone can be divided into three segments (I- III in Fig.1) according to their topography, position of the Upper Cretaceous deposits and basement structure (see also Vachtl et al., 1968). Although the whole zone is bordered by the Semanín fault on the SW, a distinct scarp related to this fracture is only in the southern segment. The Semanín fault is a complicated step-like fracture with the Upper Cretaceous sediments on the downthrown block only. From the upthrown block, the Upper Cretaceous sediments were denuded entirely.

3.1 The northern segment in the Českomoravská vrchovina (Highland)

From the geomorphological viewpoint, the segment is situated in the NE marginal part of a huge elevation of the Českomoravská vrchovina (Highland). The segment is about 10 km long and its downfaulted blocks are not well-defined neither structurally nor topographically. In the segment, the Upper Cretaceous sediments attain the highest elevation (up to 580m). Owing to denudation as well as antithetic nature of the Semanín fault, the Upper Cretaceous sediments are preserved only as a narrow strip along the fault trace.

Denudation of the Upper Cretaceous sediments resulted in the formation of a small depression, the Křetín Basin, at the NNW end of the segment (Fig.12). The exhumed pre-Upper Cretaceous planation surface on its bottom truncates metabasites of the Letovice Unit at the altitude of 400-420 m (Fig. 7). The planation surface is flat, only with sporadic residual hills (Zvejška, 1948, Fig.1).

Structure of crystalline basement is very complex in the segment. The Semanín fault coincides with ancient fracture along which metabasites of the Letovice Unit were thrusted over schists of the Svratka Dome (Jenček, 1963). The present position of the Upper Cretaceous deposits is owing to the post-Upper Cretaceous rejuvenation of the Semanín fault. However, not only the Semanín fault, but also the whole Svratka Dome were remobilized (Hrádek, 1982) and even the marginal part of the Lower Permian sediments of the Boskovice Furrow was partly involved in the process.

Remobilization of the Svratka Dome is demonstrated by a dome-like deformation of the buried pre-Upper Cretaceous planation surface (angular unconformity), apparent mainly along the long axis of the segment (Fig.2, see also Zvejška, 1944). In the Křetín Basin the exhumed surface is at the altitude of 400- 420 m, on the quer axis of the dome at Kunštát at the altitude of 500 m. Further southward, the planation surface descends to the altitude of about 350 m at Lysice. On metabasites, the rests of lateritic weathering crust on the exhumed planation surface were found (Vachtl et al.,1968; Bezvodová, 1988). Several cross faults trending NW (Röhlich, 1958) were important in the remobilization, too. As it will be shown later, the highest part of the segment is at the same time a threshold between the Blansko - Kunštát zone and the Ústí syncline, a very important structure of the Bohemian Cretaceous Basin.

Several conspicuous buttes, (Brablecův kopec 546 m, Křib 583 m, Milenka 580 m and Chlum 512 m), standing above the partly exhumed pre-Upper Creta-

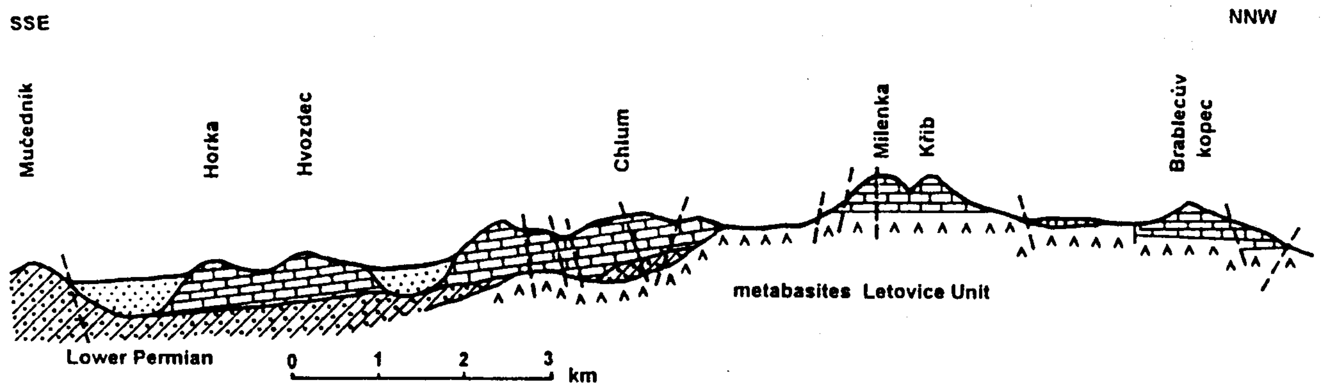


Fig.2. Profile along the long axis of the northern segment of the Blansko - Kunštát zone (according to J.Vachtl et al.1968). The dome-like deformation of buried pre-Upper Cretaceous planation surface is conspicuous.

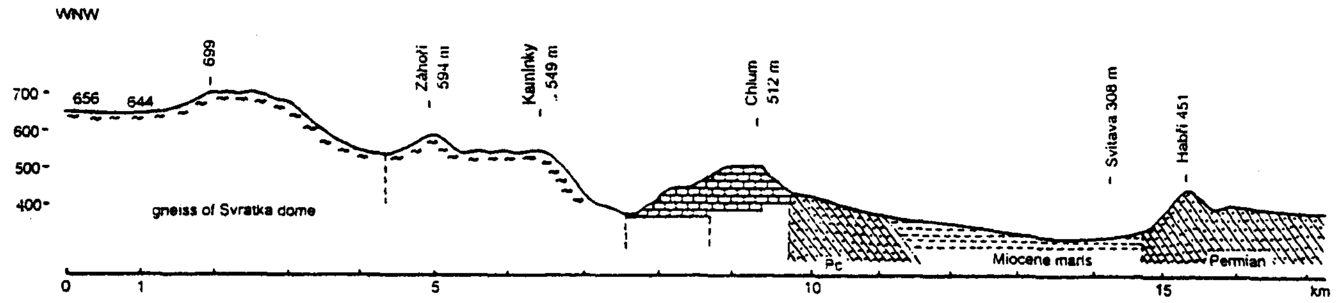


Fig.3.Profile across the western part of the Českomoravská vrchovina (Highland), the Svratka Dome and northern segment of the Boskovice - Kunštát zone and the Boskovice Furrow (northern part of the Lysice Depression filled partly by Miocene deposits).

ceous planation surface, are the only denudational remnants of originally thicker and more extensive cover of the Cenomanian and Turonian deposits (Figs. 2,3, and 13). Some of them, especially the Milenka and Chlum are flat-topped mesas.

South of Kunštát, the Semanín fault is followed by a small water course of the Umoří trending SSE (towards the Boskovice Furrow). The striking fault-line valley developed along the water course with the high steep western slope built of schists and the low gentle eastern slope of the Upper Cretaceous deposits.

3.2 The middle segment in the Boskovice Furrow

The middle segment of the Blansko - Kunštát zone crosses the old tectonic structure of the Boskovice Furrow trending NNE (Fig.1), filled by the Upper Paleozoic sediments perhaps more than a thousand meters thick. The structures cross each other at the angle of 45°. Geomorphologically, the middle segment presents a part of the intramontane depression of the Boskovická brázda (Furrow). In the segment, the furrow is only 5 km wide.

Similarly as in the northern segment, the structure of the downfaulted Upper Cretaceous sediments is assymetric (Fig.3, 4). The structure of the Boskovice Furrow is also assymetric, however in the opposite direction. Its major disturbance, the Boskovice-Diendorf fault is bounding the furrow on its eastern side. This originally normal fault was transformed into a high-angle thrust (Jaroš, 1958a) dipping to the ESE. The Permian sediments dip gently to the ENE owing to rotation. Thus, the Upper Cretaceous deposits of the Blansko - Kunštát zone and underlying the Permian sediments of the Boskovice Furrow are dipping in the opposite direction.

The base of the Upper Cretaceous sediments at the Semanín fault in the West is at lower altitude (perhaps about 100 - 200 m) than in the northern segment. Besides this, the Cenomanian and Turonian sediments occur both in the western and eastern parts of the segment.

The very different topography of the middle segment corresponds with complex geologic structure. Generally, two contrasting relief types were recognized in the segment (see Demek et al., 1987). The lower and more uniform part in the W was designated as the Lysice Depression, while the higher and more dissected one in the E as the Krhov Ridge.

The Lysice Depression, adjacent to the Semanín fault, presents a shallow flat-bottomed basin about 4 km wide. Both in the N and S, the depression is closed by thresholds built of Permian sediments. The higher southern threshold, was named Žernovník Horst. Although composed of the Permian sediments, it belongs geomorphologically to the Českomoravská vrchovina (Highland). The planation surface in its summit parts truncates the Permian sediments and towards the W also the gneiss of the Svratka Dome. The northern

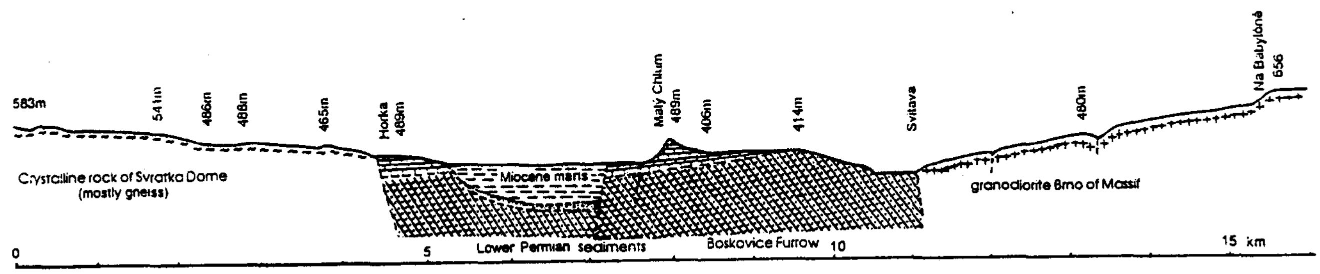


Fig.4.Profile across the E part of Českomoravská vrchovina (Highland), middle part of the Blansko - Kunštát zone (Lysice Depression and Krhov Ridge) and W part of the Drahanská vrchovina (Highland). The Malý Chlum is example of relief inversion.

threshold (Chrudichromy Hilly land) is lower and it separates the Lysice Depression from the northernmost part of the Boskovice Furrow called the Malá Haná. In our opinion, the Lysice Depression and Malá Haná form together a unit which we designate as the Lanškroun - Černá Hora Depression. Its main part developed in structure of the Orlice Permian, that is the NNW continuation of the structure of the Boskovice Furrow.

The eastern slope of the Českomoravská vrchovina (Highland) facing the Lysice Depression is complicated by several small embayments, especially at mouths of small watercourses.There are two low buttes in front of the slope, the Hvozdec (418 m) and Horka (482 m), built by the Turonian deposits. They are situated along the trace of the Semanín fault and present the only remnants of the Upper Cretaceous sediments in the western part of the segment.

The unusual bow-shaped planform of the Lysice Depression conforms with the direction of the Boskovice Furrow only partly (Fig.2). The bottom of the Lysice Depression slopes down towards the E from the foot of the Českomoravská vrchovina (Highland) at the altitude of about 380 m. At the village of Skalice nad Svitavou, the bottom passes into the wide floodplain of Svitava at the altitude of 305 m. Towards the S, between the villages of Jabloňov and Bořitov, the slope encounters the western slope of the Krhov Ridge.

The Lysice Depression is crossed by small right tributaries of Svitava R., Úmoří and Býkovka, which circumfluent the Krhov Ridge. The broad valley of the lowermost Býkovka is cut in the Upper Cretaceous sediments and interconnects the southern part of the Lysice Depression with the Blansko graben.

The bottom of the Lysice Depression is composed of Lower Badenian sediments covered by the Quaternary loess. Marine sands and marls (with thin tuff intercalations) are known for long time already. Their great thickness (about 200 m), however, was demostrated only recently. Surprisingly, they are underlained by Lower Permian deposits (Jurková, 1975). Absence of the expected Upper Cretaceous sediments in boreholes is an evidence of intensive pre-Badenian denudation. Thus, with the exception of Hvozdec and Horka (hills), the Upper Cretaceous sediments on the downfaulted block adjoing to the Semanín fault were eroded. It is possible, that a water course existed in the Boskovice Furrow before the Miocene marine transgression (see chap. 8). The Semanín fault was not active in this segment after the Lower Badenian and this is also the reason, why it is difficult to determine its course across the Boskovice Furrow.

The eastern part of the middle segment, the Krhov Ridge,is an oval elevation of the N-S direction, situated between the Lysice Depression in the W and the gorge-like valley of the Svitava R. in the E. The valley separates the Krhov Ridge from the Drahanská vrchovina (Highland).

In the ridge, the area composed of the Upper Cretaceous sediments is larger than in the Lysice Depression (Dvořák,1953; Dvořák and Havlena, 1957). The most prominent forms are two high mesas, the sharp-topped Velký Chlum (464 m) and the flat-topped Malý Chlum (489 m).The mesas are beautiful examples of relief inversion. The summit flat of the Malý Chlum is gently inclined to the SW, towards the Lysice Depression. The mesas are surrounded by a flat erosion surface at the altitude of 380-420 m sloping to the S. The surface truncates both the Cenomanian and Lower Permian sediments at the same level. Towards the E, the surface rises to the narrow structural ridge (390 - 450 m) built by more resistant Permian beds. The steep eastern slope of ridge faces the gorge-like valley of the Svitava River.

In our opinion, the oval groundplan of the Krhov Ridge, the high position of the Lower Permian sediments at its eastern margin above the assymetric gorge-like valley of the Svitava R. suggest possible involvement of the ridge in dome-like uplift of the adjoining part of the Drahanská vrchovina (Highland). The uplift was probably younger than downfaulting of the Upper Cretaceous deposits along the Semanín fault.

The southern part of the Krhov Ridge is somewhat narrower and it is crossed by the Boskovice-Diendorf fault. During the downfaulting of the Upper Cretaceous sediments, this short section of the Boskovice - Diendorf fault (here with the local name the Klemov fault; Zvejška, 1944) was reactivated and functioned in the Blansko - Kunštát zone as a cross fault. However, the movements had the opposite direction in this episode than movements in the Upper Paleozoic (Jaroš, 1958a). The topographic effects of the post-Cretaceous (Saxon) movements, however, are not apparent in the present topography.

3.3 The southern segment - the Blansko Graben in the eastern part of Drahanská vrchovina (Highland)

In the Blansko Graben, the most distinct part of the zone, the Upper Cretaceous sediments are underlained by granitoid rocks of the Brno Massif. The graben penetrates as a wedge-shaped depression towards the SSE into the elevated part of the Drahanská vrchovina (Highland). In the S, the graben ends as a faulted brachysynclinal closure, only 0,5 km thick.

These adjacent uplifted blocks are the Hořice Horst in the W, and the more complicate but less uniform elevated area of the Adamovská vrchovina (Highland) and Moravian Karst in the E. The latter are discussed in chapter 7. The Hořice Horst is a relatively small morphostructure elongated in the N-S direction, composed

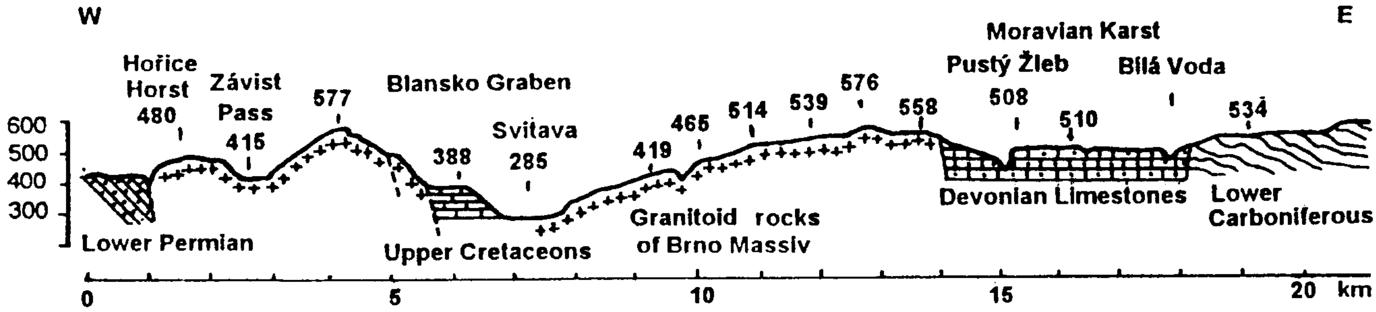


Fig.5 Profile across the Hořice Horst, Blansko Graben and Moravian Karst.

of granodiorites and metabasites. The flat summit parts at the altitude of about 550 m are slightly inclined to the S. The horst is assymetric in cross profile with a steeper eastern slope on the Semanín fault (Figs. 5 and 11).

The Adamovská vrchovina (Highland) adjoining to the graben is also built of granodiorites. Towards the E, it passes into the Moravian Karst composed of Devonian limestones. The two units are parts of a large dome-like morphostructure in the core of the Drahanská vrchovina (Highland)(Hrádek and Ivan, 1974).

The steeper eastern slope of the Hořice Horst facing the Blansko Graben is 7 km long and maintains the original NNW-SSE direction of the Semanín fault. The horst slope is beginning in the NNW, at place, where the Semanín fault crosses the Boskovice - Diendorf fault. The amplitude of fault movements is about 300 m (based on the thickness of the Upper Cretaceous sediments and the height of the fault scarp). On the SSE, the slope ends on the diagonal fault trending SE. The Semanín fault was classified by Zapletal (1932) and Zvejška (1944, 1953a) as high-angle thrust. The profile of Zvejška suggests also some collapse structures. In the opinion of Demek (1956), the slope is a composite fault scarp according to Cotton s classification (1950).

The opposite longer and gentle eastern slope of the Blansko Graben is thought to be an exhumed pre-Upper Cretaceous planation surface (e.g. Štelcl, 1964). It is composed of granodiorite and participates in the dome-like deformation of the Drahanská vrchovina (Highland).

There are several interesting features connected with this eastern slope of the graben:

1) Unusual N-S direction characteristic just of the Brno Massif.
2) Lenght of the slope is 13 km, in comparison with only 7 km of the western slope of the graben. But only the southern part of the slope faces the graben, while the northern one faces the gorge-like valley of the Svitava R. between the villages of Skalice n. Svitavou and Rájec.
3) Height of the slope is decreasing in the N - S direction from 350 m (above the confluence of the rivers of Svitava and Bělá) to a less than 200 m at Blansko. The slope passes upwards into a broad flat ridge with remnants of a younger planation surface (Musil at al., 1993). Inclination of this younger Paleogene (?) surface in top parts of the ridge to the S, from 650 m to 450 m corresponds with inclination of the top parts of the Hořice Horst. Consequently, the two planation surfaces intersect above the eastern graben slope.
4) The slope is dissected by short left tributary valleys of the Svitava R. The valley pattern is a combination of rectangular and fan-like features. The valleys are mostly assymeric in cross profile, the slope facing the graben beeing higher. In our opinion, the pattern suggests combination of a dome-like deformation and fault movements. The prevailing direction of the valleys is NE-SW. The NW-SE trend perpendicular to the major one occurs only between Rájec and Doubravice nad Svitavou.
5) The Miocene marine transgression was also important and resulted in the deposition of basal clastics, sands and marls and at last of the Litothamnion limestones. Neubauer (1969) found the Miocene (Lower Badenian) sediments even in several small valleys in the lower part of the slope. In addition, the Miocene sediments occur also under the floodplain of Svitava R. in the graben, and even in the more than 100 m deep karst valley of Punkva R. (left tributary of the Svitava). Occurence of the Miocene sediments also in a part of the valley cut in granodiorite (Schütznerová - Havelková, 1957, 1958) introduced many difficult problems, especially as regards erosional history of the Moravian Karst (see chap. 6).

The Blansko Graben is used by the Svitava River, but its N-S direction shows that the Semanín fault was of secondary importance for the location of its course. The valley of Svitava R. was cut already before the Lower Badenian.

The Upper Cretaceous sediments are in the deepest position below the bottom of the Svitava valley in the northern part of the graben at Rájec. Southwards, the graben becomes gradually narrower and the base of the Upper Cretaceous sediments on its bottom rises. In the abandoned quarry at the railway station in Blansko, the remnants of the Upper Cenomanian sediments only a few meters thick are resting with angular unconformity on deeply weathered granodiorite (some tens a meters above the Svitava floodplain).

Maximum thickness of Cenomanian and Turonian sediments in the Blansko Graben is more than 160 m (Vachtl et al., 1968). Except for a small remnant east of Rájec, the deposits are present only in the western part of the graben on the right side of the Svitava valley (again near the Semanín fault). At Rájec, the Upper Cretaceous sediments are known also below the floodplain of Svitava R.

The erosional surface, developed on the Upper Cretaceous sediments at the foot of western granodiorite slope of the Hořice Horst, is at the altitude of 380 m, about 100 m above the floodplain of Svitava. The surface is built of the Turonian sandstones and is probably partly structural.

4. The Boskovice - Valchov zone and the Valchov Graben

In the zone, not only the area of Upper Cretaceous sediments is lesser and thickness of deposits reduced by denudation to only some tens of meters, but characteristic forms such as buttes present in the Blansko - Kunštát zone are lacking. Remnants of the Upper Cretaceous sediments are preserved mainly in the SE part of zone. Relics of the Badenian marls, clays and Litothamnion limestones (Zvejška, 1953b) suggest, that most of the Upper Cretaceous sediments was denuded before the Miocene marine transgression.

The Boskovice - Valchov zone is only 7 km long and about 3 km wide. Its NW-SE trend crosses perpendicularly the Boskovice Furrow, just at the eastern margin of Boskovice, probably near the Boskovice - Diendorf fault. The fault is not distinct in the present topography (this is the same situation as in the middle segment of the Blansko - Kunštát zone).

The only occurence of the Upper Cretaceous sediments resting on the Permian deposits (and corresponding therefore to the middle segment of the Blansko - Kunštát zone) is preserved at the village of Chrudichromy, about 2 km NW of Boskovice. The Cenomanian and probably also Turonian sediments (Vachtl et al., 1968) crop out on the top of broad rounded ridge at the altitude of about 420 m. The WNW slope of the ridge composed of Permian claystones and sandstones trends NNE, as well as the whole of the Boskovice Furrow. The slope is more than 100 m high, facing the northern part of the Lysice Depression.

The eastern part of the zone, the Valchov Graben, is both the structural and topographic depression (Fig.1). The Valchov Graben penetrates wedge-like towards the SE into higher parts of the Drahanská vrchovina (Highland). The graben is underlained with granodiorite of the Brno Massif. The bottom of the graben rises from the altitude of 380 m in the NW to 520 m at Valchov in the SE. The high elevation of the Upper Cretaceous sediments at Valchov is owing to uplift in a broad faulted brachysynclinal closure of the graben. The graben is assymetric in cross profile (Fig.6A). The higher and steeper slope on the SW originated on the Bělá fault. The fault scarp or fault-line scarp composed of granodiorite is up to 200 m high (Fig.6A). Towards the SE, however, it passes into folded Culm sediments and its height diminishes rapidly.

The graben bottom inclined to the SW towards the base of the higher slope suggests an antithetic dip. The graben is drained transversally by the Bělá R., left tributary of Svitava R. The Bělá is incised below the base of the Upper Cretaceous sediments in the graben. The combined rectangular and fan-like features of the drainage pattern of the Bělá suggest an influence of faults and dome-like deformations in their development. In Boskovice, the Bělá R. crosses the graben and enters a gorge about 3 km long and more than 250 m deep. The gorge crosses the uplifted marginal part of the Drahanská vrchovina (Highland) (Fig.6B). Towards the SE, the graben is closed by a step-like slope of the N-S direction, forming a brachysynclinal closure. In it, granodiorite is in tectonic contact with the Culm sediments. The importance of Variscan fault tectonics in the formation of brachysynclinal closure is indicated by vertical dip of the strata of Devonian limestones (forming the Němčice - Vratíkov zone, Dvořák et al., 1984) sandwiched between the granodiorite and Culm sediments (Fig.6C). In the limestones, the Neogene tropical karst phenomena were studied by Panoš (1964a). East of the brachysynclinal closure, the highest parts of the Drahanská vrchovina (Highland) with an extensive planation surface at the altitude of 700 -735 m are present.

5. Saxon fold structures at the E margin of the Bohemian Cretaceous Basin adjoining to the half-grabens

The major fold structures of the southeastern part of the Bohemian Cretaceous Basin, the Ústí syncline and Potštejn anticline were been recognized relatively early. In the present landscape, the Ústí syncline is more conspicuous than the Potštejn anticline. The two structures are several ten km long, but only their southern parts are discussed here.

5.1 The Semanín fault and Saxon tectonics along the southern margin of the Bohemian Cretaceous Basin

The Semanín fault is one of the most important fractures in the eastern part of the Bohemian Cretaceous Basin (Malkovský, 1979). The fault affected the eastern steeper limb of the Potštejn anticline near its contact with the Ústí syncline. The Upper Cretaceous sediments of the Potštejn anticline on the upthrown block are at the higher altitude and they are also more denuded than those of the Ústí syncline.

Between the town of Česká Třebová and the village of Svojanov, the Semanín fault runs to the S and the Upper Cretaceous deposits are present both on the upthrown and downthrown blocks. The fault is the most distinct where the Upper Cretaceous sediments are underlained with granodiorite of the Polička Unit (Vachtl et al., 1968). In the less rigid crystalline schists the, fault is not clean-cut and probably flexure deformation prevails. This seems to be the case in the surroundings of the vilage of Radiměř, where the Upper Cretaceous sediments of the Potštejn anticline are not faulted and some authors characterize the structure as a flexure or homocline (Radiměř flexure; Frejková, 1960; Fajst, 1969). The Semanín fault consists of two branches (Fig.9). Together with bending of the Potštejn anticline, the total displacement is more than 200 m (Vachtl et al., 1968; Malkovský, 1977, 1979).

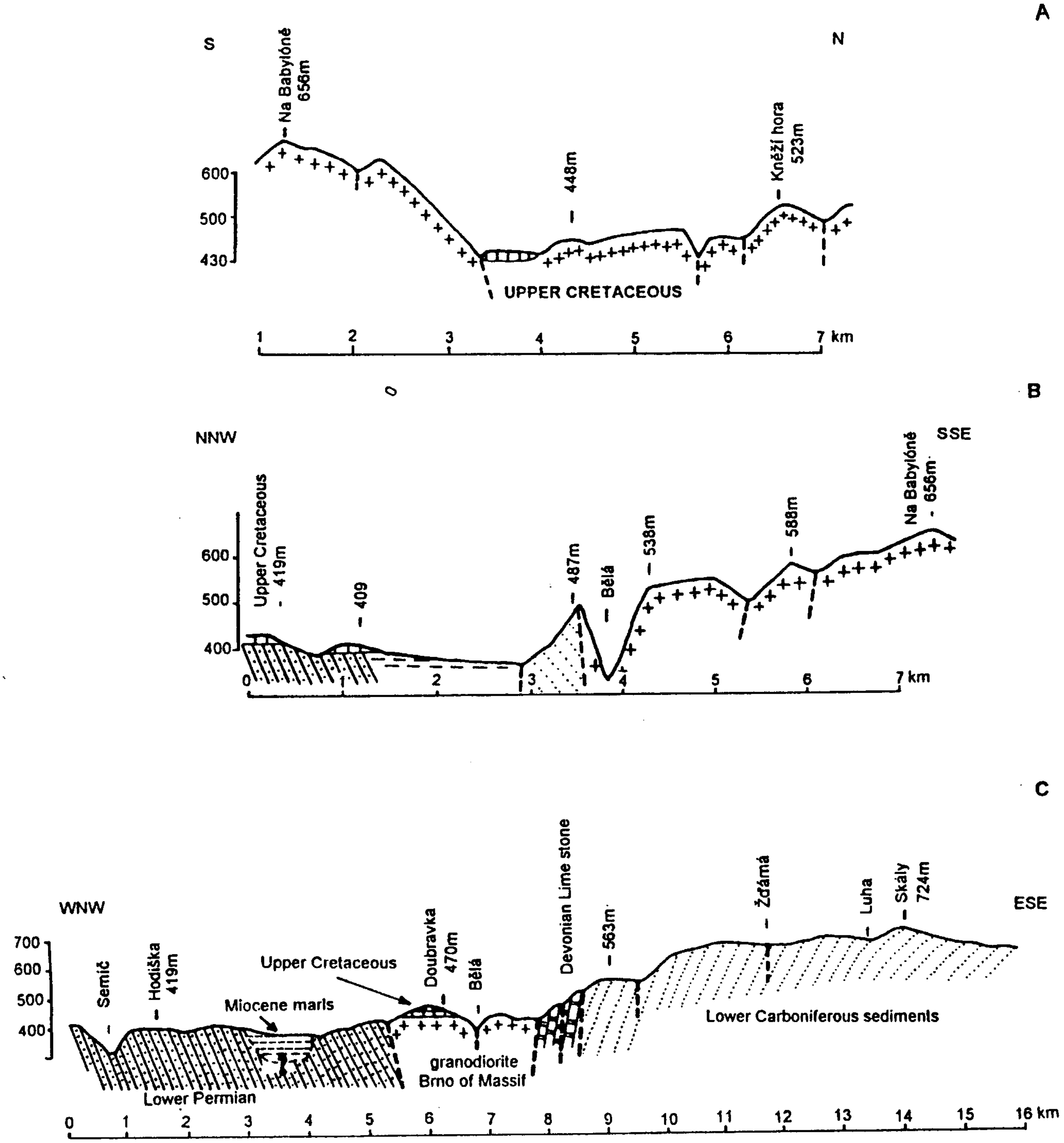


Fig.6 Profiles across the Valchov Graben and adjacent part of the Drahanská vrchovina (Highland).

Below deposits of the Bohemian Cretaceous Basin relations between the fault tectonics (including the Semanín fault) and the crystalline basement are very complex, especially at the contact of the Letovice and Polička Units. Metabasites of the Letovice Unit trend southwards and they were interpreted as a fissure feeding channels governed by tectonics (Mísař, 1974). Importance of the N-S direction is supported also by magnetic anomaly in the surroundings of Svitavy (Kopecký, 1992).

The contact between the Polička and Letovice Units is partly hidden by Permian sediments. Nonetheless, it seems that the Semanín fault and contact of the Letovice and Polička Units do not coincide. Northwest of the village of Svojanov, the Upper Cretaceous deposits were partly denuded from the upthrown block of the Semanín fault and the ancient tectonic zone between the Letovice and Polička Units (the Svojanov mylonite zone) was exposed (see Mísař, 1962). Between Svojanov and Rohozná, the Semanín fault and Svojanov mylonite zone are about 2-3 km apart. The two fracture zones run almost parallel towards the S or SSW, used by the uppermost courses of the Křetínka R. (along the Svojanov mylonite zone) and its left tributary, the Rohozenský potok Brook (along the Semanín fault). The rocks of the Svojanov mylonite zone, as described by Mísař (1962), are resistant to physical and chemical weathering, but in the quarry at the village of Stašov, some roots of the pre-Upper Cretaceous weathering are visible. The Svojanov mylonite zone was not active in the post-Cretaceous period. This is evidenced by parts of the exhumed pre-Upper Cretaceous planation surface at the altitude of about 640 m. The two water courses were superimposed from the Upper Cretaceous sediments. They are trending towards S, even though the basement surface below the Cretaceous sediments is inclined to the N (toward the axis of the Bohemian Cretaceous Basin).

The exhumed crest of the Potštejn anticline W of Stašov at the altitude of 640-660 m, was described as Stašov ridge by Fajst (1969) and presents an almost perfect planation surface. Southwards, the surface ascends and it is dissected by deep valleys. In the surroundings of the village of Hlásnice, the surface is preserved only on some tops of high residual hills (e.g. Panský vrch 700 m). At the contact of the Bohemian Cretaceous Basin and the Českomoravská vrchovina (Highland) at Svojanov, the uncovered trace of the Semanín fault meets the northern closure of the Svratka Dome (this was the key area in the conception of Variscan nappe tectonics introduced at the beginning of this century). Practically at spike of the closure, the Semanín fault turns to the SE and stretches along the Křetínka R. for about 10 km as far as the Křetín Basin (Ivan, 1989). In contrast, the older and more important Svojanov mylonite zone continues to the S, maintaining its original direction.

Between the villages of Svojanov and Křetín the Upper Cretaceous sediments occur only on the downthrown block (Fig.7). The Semanín fault is also composed of two parallel branches here. However, only some their parts are used by the Křetínka valley. The southern branch is partly used by the Křetínka R. between the villages of Svojanov and Bohuňov, the northern one between Bohuňov and Křetín.

The southern branch of the Semanín fault is used by the Křetínka R. downstream of Svojanov in the reach about 2,5 km long. The floodplain in the valley of Křetínka R. is about 100 m wide and the narrow ledge of the exhumed pre-Upper Cretaceous planation surface is present on the left valley slope at Svojanov (at the altitude of 520 m, about 90 m above the floodplain). Displacement on the southern branch of the Semanín fault is about 100 m at Svojanov (Fig.7C).

At the village of Nová Lhota, the Křetínka R. departs from the fault trace, turning to the ESE. In the narrow saw-cut valley about 3 km long, the floodplain is only poorly developed and also rapids occur in the channel. On the other hand, the fault branch continues in its original SE direction and its elevation above the valley bottom progressively rises. In our opinion, the relation between the fracture and the valley suggests a thrust fault, although flexural bending is also possible. At the village of Bohuňov, the fault branch is located in the middle part of the right valley slope.

At Bohuňov, the more important northern fault branch crosses obliquely the Křetínka valley and turns to the SE. In the point of crossing the valley also assumes the SE direction. Downstream, the whole right valley slope of the Křetínka is developed on the upthrown block, built of different crystalline rocks. In our opinion, this right valley slope facing the Bohemian Cretaceous Basin is at the same time a southern marginal fault scarp (or a resequent fault-line scarp) of the basin. On the opposite downthrown block of the northern fault branch, the left valley slope is built by the Upper Cretaceous sediments (Fig.7B).

As a result, cross profile of the Křetínka valley downstream of Bohuňov is quite different. The valley becomes broad and open with a floodplain as wide as 200 m. The cross profile of the valley is assymetric, both height and inclination of valley slopes differ substantialy. The right valley slope (facing the NE) is stepped, only moderately inclined and up to 280 m high. The lower part of the slope consists of metabasites of the Letovice Unit, while the upper one of very variegated rocks of the Svratka Dome. Alike in the northern segment of the Blansko - Kunštát zone, the rocks of the Letovice Unit were thrusted over rocks of the Svratka Dome (Jenček, 1963). The parallelism of the narrow strips of rocks (gneisses, phyllites, quarzites and crystalline limestones) of the Svratka Dome and of the Semanín fault complicates the slope profile and this is also the reason, why influences of lithology and fault tectonics are hardly separable.

The opposite left valley slope, on the other hand, is only 130-160 m high, but relatively steep. The slope is composed only of the Upper Cretaceous deposits east of Bohuňov.The sediments crop out also at the base of slope and their presence below the floodplain of the Křetínka R. is not excluded. Downstream of the village of Horní Poříčí, the buried pre-Upper Cretaceous planation surface (angular unconformity) appears above the base of slope and rises (diverges) progressively downstream.

In the Křetín Basin the valley is narrow again, cut in metabasites. The floodplain is about 40-60 m below the exhumed planation surface on the basin bottom (Fig.7A).

It seems that the northern branch of the Semanín fault is followed by the Křetínka R. more strictly than the southern one. Downstream of Bohuňov, a distinct fault-line valley was created and original marginal character both of the Semanín fault and related tectonic scarp was obscured. The extensive erosion surface above the right valley slope at the altitude of 620-640 m is generally inclined to the S. The divide is just above the slope and this situation is similar to the west limb of the Potštejn anticline in the Bohemian Cretaceous Basin south of the town of Svitavy.

Above the lower left valley slope of the Křetínka R., the very flat surface truncates the Turonian sediments of the downthrown block of the northern branch of the Semanín fault at the altitude of 530 m. The base of slope is at the altitude 400 m at Bohuňov. As the exhumed pre-Upper Cretaceous planation surface above the

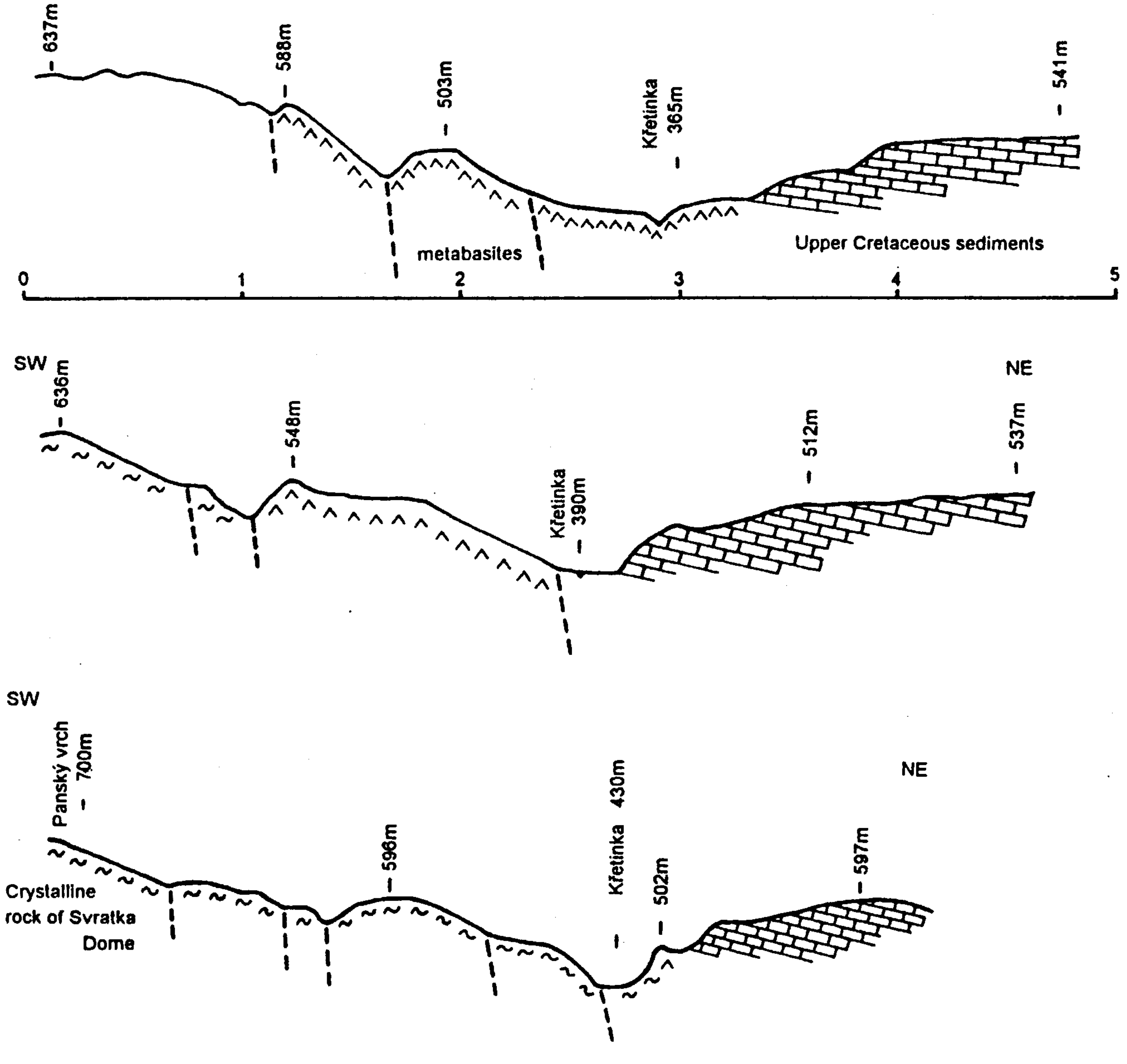


Fig.7. Profiles across the Křetínka valley.

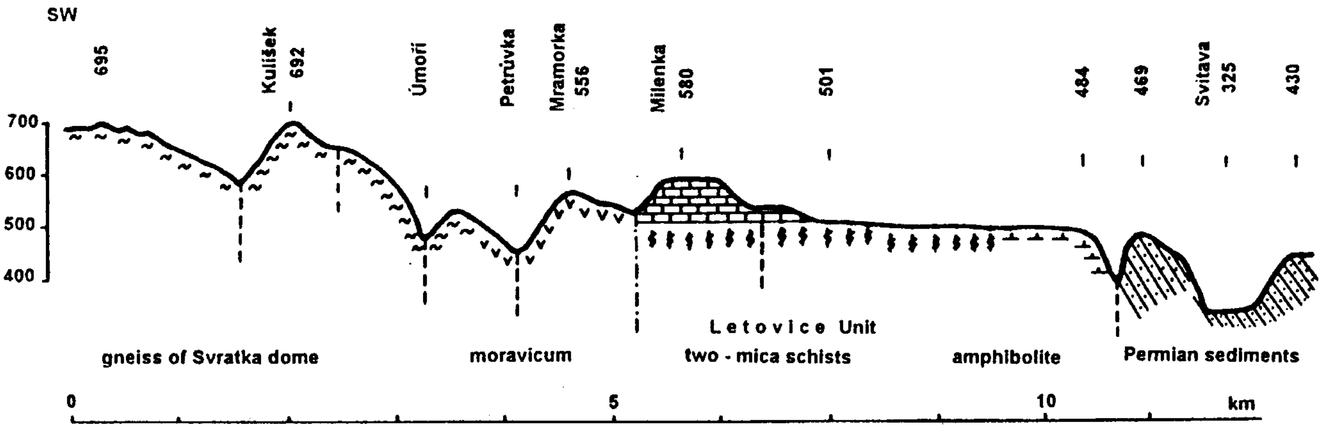


Fig.8. Profile across the northern part of the Blansko - Kunštát zone forming the threshold between the Blansko - Kunštát zone and Bohemian Cretaceous Basin.

higher right valley slope is in the altitude of 620-640 m, the total fault displacement on both branches combined with flexural deformation is at least 240 m. This corresponds well with data of Malkovský (1977) and Vachtl et al.(1968).

At Křetín, the Semanín fault turns again to the SSE and bounds the Blansko - Kunštát zone.

5.2 The Potštejn anticline and its southern continuation in the surroundings of Brno

The assymetric Potštejn anticline is a less distinct structure in the SE part of the Bohemian Cretaceous Basin. Because south of the town of Svitavy the Semanín fault is replaced by the Radiměř flexure, only a gentle slope developed instead of typical cuesta escarpment. The Kozlov Ridge associated with the anticline axis rises southwards culminating west of Stašov at the Baldeský vrch (hill) at the altitude of 693 m. The hill faces an exhumed pre-Cretaceous planation surface. The above mentioned flat Stašov ridge presents in fact an exhumed axial part of Potštejn anticline.

In the area of the exhumed pre-Upper Cretaceous topography between Stašov and Svojanov, the axis of the Potštejn anticline reaches the contact of the Letovice Unit and the Svratka dome. Here, in the drainage area of the Křetínka R., both the axis of the Potštejn anticline and the Semanín fault turn to the SE and run along the northeastern periphery of the Svratka Dome. The Křetínka R. also assumes this NW-SE direction.

The assymetric cross profile of the Potštejn anticline also persists in crystalline rocks. This is demonstrated both by the position of water divide direct above the right valley slope of the Křetínka R. and by longer tributaries of the Svratka R. directed to the S. In the surrroundings of Kunštát, the anticline axis turns to the SSE and crosses the eastern limb of the Svratka Dome.

The rocks of the eastern limb of the dome are predominately less resistant mica schists and at the village of Lysice also weak Lower Permian sediments are involved in the remobilized dome structure (see chap. 3.1). This is the reason why it is difficult to delineate the course of anticline axis here. The Svitava-Svratka water divide avoids these rocks, too. Generally, the divide runs in axial part of the Svratka Dome built of resistant Bíteš orthogneiss.

The Potštejn anticline crosses the Boskovice Furrow in the surroundings of the village of Černá Hora, but its

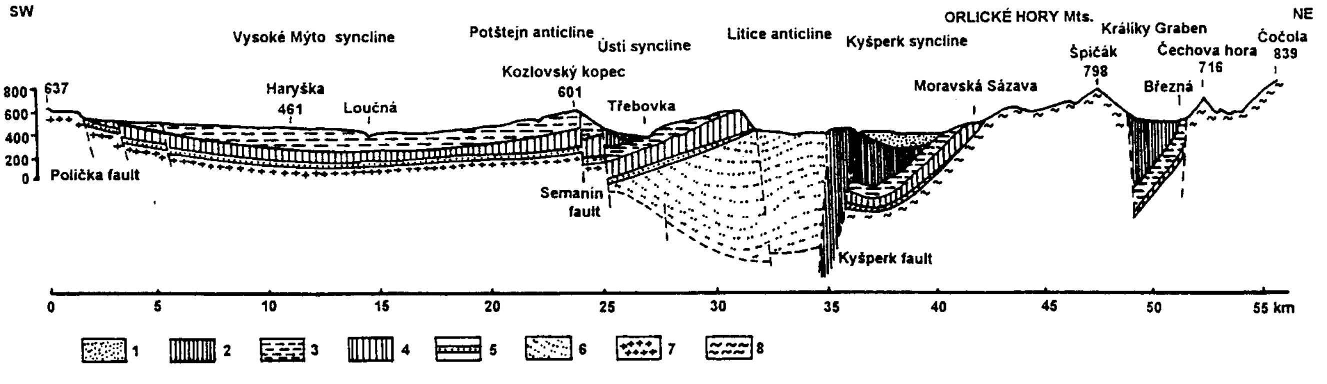


Fig.9. Cross profile of the Bohemian Cretaceous Basin, Orlické Hory (Mts.) and Králíky Graben (according to M.Malkovský,1977, modified)

course is not distinct morphologically. The presence of anticline is partly suggested only by the Žernovník Horst situated between the Lysice Depression and the northern part of the Brno Basin.

The Potštejn anticline affected significantly the course of the Svitava - Svratka water divide. Even though it runs generally southwards, south of Černá Hora it crosses the Žernovník Horst and the Závist Pass (415 m a.s.l.) in W-E direction. Then divide ascends to the top of the Hořice Horst (577 m) where it turns southwards again. In our opinion, the N-S ridge of the Hořice Horst coincides well with the axis of the Potštejn anticline. Moreover, south of the horst, the divide crosses perpendicularly the Svinošice Graben (of the W-E direction) and continues to the S along the axis of the Soběšice Dome as far as the north margin of Brno (Figs.10 and 12). The cross profile of the Hořice Horst is assymetric and as a result, the area west of the horst is drained towards the W into the Svratka R. This is true also for the part of the Svinošice Graben, from where the Kuřimka R. runs to the W through several gorges (Fig.10).

There were also changes in the river pattern owing to remobilization of the Svratka Dome. The upper courses of left tributaries of the Svratka, the rivers of Hodonínka and Lubě flowing towards E turn to the S suddenly west of the axis Potštejn anticline. We suppose, that they were tribututaries of the Svitava originally.

5.3 The Ústí syncline and its relation to the Blansko - Kunštát zone

The Ústí syncline is important mainly from the point of view of hydrogeology (Kříž 1975; Frejková 1960). In the surroundings of the town of Svitavy, the syncline is about 12 km wide. Thickness of the Upper Cretaceous sediments at the syncline axis is about 360 m. The Cenomanian and Turonian deposits prevail, however, younger Coniacian sediments are also preserved in the western part of the syncline. Control of the western margin of the Coniacian sediments by the Semanín fault, especially west of Svitavy seems to be probable. Lower Bądenian sediments are also present, mainly at the Main European Divide. Their occurences are in no relation to the fault tectonics.

Both the structure and topography of the Ústí syncline are assymetric in cross profile (Frejková, 1960; Kříž,1975, Fig.1). The axis of synline is situated in its western part, closer to the Semanín fault. The western limb of the syncline is shorter and steeper. It rises towards the crest of the Kozlov Ridge on the W and is affected by the Semanín fault. The planation surface on the bottom of syncline is at the altitude of 420 m near the village of Hradec n. Svitavou. On the contrary, the eastern limb of the syncline is wider and more gentle. Here, a very flat erosion surface almost paralell with bedding planes, rises towards the E up to 660 m and progressively truncates the older strata. The syncline axis ends in the Křetín Basin.

The main part of the Ústí syncline is drained by the Svitava R. towards the S. The river runs against the dip of syncline axis. At Svitavy, the channel is cut in the very flat syncline bottom and its gradient is extremely low (1 m per 1 km). Downstream, the river incises progressively into older formations, then into metabasites and in the town Letovice into the Lower Permian sediments. In more resistant rocks,the valley cross profile becomes V-shaped.Thus, the Svitava is an antidip stream.

The planation surface in the bottom of the Ústí syncline rises progressively not only to the E and W, but also from the N to the S. While south of the town of Svitavy the planation surface truncating the Coniacian sediments is at the altitude 420-450 m, downstream the surface rises up to 530 m (W of the town of Letovice), truncating the Middle Turonian Sandstone. This confirms the supposed antecedent origin of the Svitava valley (Neubauer, 1953) although its development was more complex.

In Letovice, the Svitava R. joins the Křetínka in a small depression of the Letovice Basin (Fig.12. Downstream of Letovice, the valley is narrower, cut in the Lower Permian conglomerates. They compose together with metabasites a threshold-like ridge trending WSW which separates the Ústí syncline and Letovice Basin from the Lysice Depression. On the ridge exhumed parts of the pre-Upper Cretaceous planation surface are preserved at the altitude of 520 m. The highest buttes of the northern segment of the Blansko - Kunštát zone are situated in WSW continuation of the threshold ridge (see chap. 3.1 and Fig.8).

5.4 Cuesta of the Hřebeč Ridge and the Litice anticline

As mentioned above, the eastern limb of the Ústí syncline is longer and gentler and towards the E it passes into the Litice anticline. The axial part of this structure was eroded (Fig.9) and a steep cuesta escarpment, named the Hřebeč Ridge, developed here. The cuesta is more than 50 km long and up to 150 m high, complicated by many embayments. The most complicating feature is a cross valley-like depression filled with the Miocene sediments at the village of Damníkov. The inconspicuous southern end of the escarpment NNE of the town of Letovice is connected with brachysynclinal closure of the Ústí syncline. While in the western limb of the syncline, the Upper Cretaceous sediments are preserved even in the brachysyclinal closure (west of Letovice), in the eastern limb of the closure, only small "islets" occur NNE of the Valchov Graben. In our opinion, denudation proceeded more rapidly where the Upper Cretaceous sediments are underlain with mostly the less resistant and unpermeable Lower Permian deposits. In comparison with crystalline rocks, no extensive rests of the pre-Upper Cretaceous planation surface are found on the Lower Permian sediments.

The cuesta escarpment faces a broad depression of the Moravská Třebová Basin originated owing to almost complete denudation of the Upper Cretaceous sediments in the core of the Litice anticline. The bottom of the basin composed of Lower Permian deposits at in the altitude of 350-450 m, however, the Badenian marine sediments are also widespread. Thus, the spectacular relief inversion in the core of anticline developed already before the Badenian. The Moravská Třebová Basin as a part of the Lanškroun-Černá Hora Depression is discussed shortly in chap. 3.2.

The eastern part of the Moravská Třebová Basin is complicated by the Kyšperk and Radkov faults and small Kyšperk syncline, all partly destroyed by the post-Cretaceous denudation. Especially the Kyšperk fault is a very ancient fracture along which Lower Permian sediments were downfaulted in the Uppermost Paleozoic. In the Uppermost Cretaceous or Tertiary, the Kyšperk fault was reactivated, but with opposite direction of the movements. The topographical effects of renewed faulting were also obliterated and tectonic inversion was accompanied by inversion of relief. Great thickness of the Miocene sediments in the axial part of the Kyšperk syncline suggests possible continuation of downwarping during deposition (Fig.9).

6. The Moravian Karst and its relation to the Blansko Graben

The Moravian Karst, "beautiful karst country of Moravia" (Ager, 1973, p.9), composed of folded and faulted Devonian limestones is situated between granodiorites in the W and the Culm graywacks, slates and sandstones ("Variscan flysch") in the E. From the geomorphological point of view, the Moravian Karst is situated close to the axial part of the dome-like structure of the Drahanská vrchovina (Highland). The N-S axis of this structure conforms well with general direction of limestones.

Variscan orogenesis was followed by long subaerial denudation and planation, completed probably in the Lower Mesozoic. Later, marine transgressions in the Jurassic and Cretaceous resulted in sedimentary covers. Thus, after renewed subaerial erosion, numerous relics of sediments, weathering crust as well as plenty of both surface and subsurface karst features, provide data for a reconstruction of landscape evolution. This fact was appreciated already at the beginning of this century.

The Moravian Karst is about 25 km long and 3 - 5 km wide. Its wider northern part is a shallow flat-bottomed depression at the altitude of 500 m. (Figs.5 and 11). Its bottom is in fact a planation surface truncating the folded Devonian strata. The surface is dotted by many deep karst depressions filled by Mesozoic unconsolidated sediments interpreted mostly as a reworked tropical weathering crust (named the Rudice Formation originated probably in the Lower Cretaceous). Some authors suppose the depressions beeing relics of a tropical karst of the cockit type (Panoš,1964a). The planation surface is about 100 m below adjacent flat surfaces on non-carbonate rocks and it is dissected by mostly dry widely spaced canyon-like valleys. According to Panoš (1964b), the canyons have a composite cross profile and were initiated already in the Paleogene.

As regards trends of the Moravian Karst (N-S) and the Blansko Graben (NNW-SSE), they converge toward the S at an acute angle. As the Blansko Graben dies out suddenly on the SSE in granodiorite of the Brno Massif, it does not cross the Devonian limestones. Thus the depressions do not intersect and the Blansko Graben and northern part of the Moravian Karst are different, but almost neighbouring landscape units separated only by a broad rounded ridge composed of granodiorite (Figs. 5 and 7). The planation surface of the Moravian Karst is about 200 m higher than the granodiorite bottom beneath the Upper Cretaceous sediments of the Blansko Graben.

While the pre-Upper Cretaceous planation surface of the eastern part of the the Blansko Graben was dome-like deformed, the karst planation surface (500 m) adjacent to the axial part of the dome-like deformation is almost horizontal. Therefore, there is a problem, if differences in the altitude and inclination between these planation surfaces are due to tectonic processes (updoming, faulting) or different processes of erosion.

There were many discussions about the origin and age of planation in this part of the Moravian Karst,but no univocal conclusion has been attained up to now. According to Musil et al. (1993a) the difference in elevation of planation surfaces truncating carbonate and silicate rocks existed in the Upper Jurassic already and then the Moravian Karst was probably covered by the Upper Cretaceous sediments in a thickness about of 50 m.

In our opinion, the unusual position of the planation surface in the N part of the Moravian Karst resulted probably from combined effects of young-Saxon tectonics (updoming of the Drahanská vrchovina Highland) and karst processes accompanied by climatic and paleogeographic changes. This is in accordance with the idea that karstification is one of etching processes.

The dome-like deformation of the Drahanská vrchovina (Highland) was probably an important factor in landscape evolution (Hrádek and Ivan, 1974; Hrádek,1983). Although the SE trending faults are numerous in the Moravian Karst (Dvořák et al.,1984), they were active mainly before the Upper Cretaceous, and in the present landscape are not so obvious. As mentioned above, in the closure of the Blansko Graben, the Semanín fault turns to the SE and crosses the Moravian Karst (probably as a branch of the Adamov fault zone) only with the fault-line effect (Demek,1960). Along the fault or series of paralel fractures remnants of the downfaulted Jurassic sediments are preserved at the village of Olomučany (Bosák, 1978).

In the central and southern parts of the Moravian Karst, movements along the SE trending faults led to a quite different relation between topographies underlain with carbonate and silicate rocks. Here, differences in elevation among landforms composed of rocks are negligible or even the surface truncating limestone is at higher altitude. At the village of Ochoz, a relief inversion developed in granodiorite at contact with the Devonian limestone (Dvořák and Pták, 1963; R.Musil et al.1993a). In our opinion, the limestone slope of the Babice Plateau, trending SE and facing the Kanice - Ochoz Graben is an obsequent fault-line scarp, associated with the southern branch of the Adamov fault. The southernmost part of the Moravian Karst takes part in the structure of the marginal slope of the Bohemian Massif facing the Carpathian Foredeep.

7. Problems of drainage pattern evolution of the SE part of the Bohemian Massif north of Brno

7.1 The complexity of the problem

The area under study is drained mainly by the rivers of Svitava and Svratka belonging to the Danube drainage basin. As regards their importance in evolution of the SE part of the Bohemian Massif, at least four points are worth to mention:

(1) Sources of both rivers are at the Main European Divide (Elbe - Danube) which crosses also the structural and topographic depression of the Bohemian Cretaceous Basin.

(2) Many authors believed that in the post-Cretaceous evolution, the Svitava R. was the most important watercourse in Moravia, which extended far to the N (for references see Balatka and Sládek, 1962).

(3) The SE part of the Bohemian Massif was mostly submersed also in the Lower Badenian. The sea flooded rather dissected landscape and many valleys or depressions were filled with the Badenian sediments (Czudek, 1984). North of the town Svitavy, the Badenian sediments are preserved even at the Main European Divide (at the altitude about 500 m). Thus, subaerial development of drainage pattern was not continuous owing to transgression. After the retreat of the sea, a new river pattern was established. However, not all buried valleys were exhumed. After sea regression, the rivers of Svitava and Svratka were emptied into the sea in the present Carpathian Foredeep near Brno. Folding and block-faulting in the Miocene or Pliocene was another cause of reshaping of the river pattern, whereas the role of climatic changes is not demonstrable.

(4) As mentioned above, the paleo-Svitava and paleo-Svratka were emptied into the Tethys or Paratethys during the Tertiary. Their mouths were located at the head of a huge fault embayment in the surroundings of Brno. This embayment functioning as an estuary (Stráník et al., 1992) was in fact the NW end of the Nesvačilka Graben (see Pícha, Hanzlíková and Cahelová, 1978). Thus, material washed from the Bohemian Massif including the Bohemian Cretaceous Basin, was transported through the graben into the flysch geosyncline. After regression of the Miocene sea and additional block faulting, the Brno Basin developed in place of the estuary.

It seems probable, that even before the marine transgression in the Upper Cretaceous, the drainage was directed towards the SE into the Tethys. The drainage was predisposed, at least partly, by fault tectonics. Vajdík and Vybíral (1973) supposed rivers guided by faults in the area of the present Blansko and Valchov Grabens and Vachtl et al. (1968) demonstrated that great thickness of the fresh-water deposits in the Blansko Graben was caused by downfaulting. According to Frejková (1975), the Cenomanian refractory clays in the Blansko - Kunštát zone are floodplain deposits.

The opinion prevails that the Upper Cretaceous sea retreated towards the NW. This is partly confirmed by the youngest Cretaceous sediments in the N parts of the Bohemian Cretaceous Basin. However, paleogeography was probably very complex. It seems possible that a connection between the Bohemian Cretaceous Basin and Tethys existed, at least during the maximum of the transgression. This is supported by presence of the Upper Cretaceous sediments in the flysch belt in the Western Carpathians (e.g. in the Pavlovské vrchy Hills in southern Moravia, see Stráník et al., 1995). Recent research has shown their preservation also in the Nesvačilka Graben (Hamršmíd, Krhovský and Švábenická, 1990).

The Bohemian Cretaceous Basin is separated from the Carpathian Foredeep by a belt of elevations trending NE or N (highlands of the Bobravská vrchovina in the surroundings of Brno, Drahanská vrchovina and Zábřežská vrchovina) at the altitude of 420 - 700 m. Thus, all important rivers of the Bohemian Massif flowing towards the foredeep cut long transversal gorges across the highlands. The highlands are in the fact, a forebulge, resulting from orogenic stresses in the Western Carpathians and subduction of the Bohemian Massif below the Carpathians.

7.2 The course of the Main European Divide and the drainage pattern in the eastern part of the Bohemian Cretaceous Basin.

Although the Bohemian Cretaceous Basin is an intracratonic basin surrounded by mountains, highlands and hilly lands, it is crossed by the Main European Divide (Elbe-Danube). In addition, some areas composed of the Upper Cretaceous sediments, at present separated from the major part of the Bohemian Cretaceous Basin, are drained by tributaries of the Oder (Odra) into the Baltic Sea. In result, the Elbe - Danube divide ramifies in northern Moravia into the Oder - Danube divide trending to the NE and the Oder - Elbe divide trending to the W.

In the Bohemian Cretaceous Basin, the Elbe - Danube Divide crosses important fold structures (Figs. 9 and 10). The divide course is irregular and the N-S and W-E trends alternate in connection with the crossing of structures. The lowest parts of divide are at syncline axes, the highest parts at anticline axes. The divide leaves the Bohemian Cretaceous Basin N of the town of Lanškroun.Here,the divide crosses the horst of the Orlické hory (Mts.) rising up to the altitude of 900 m. The eastern slope of the horst composed of resistant gneiss faces the Králíky Graben, presenting the southernmost part of the huge Klodzko Graben (in Poland) filled with the Upper Cretaceous sediments.

After crossing the Králíky Graben, the Elbe -Danube divide rises to the mount of Klepý (1143 m,called the Trojmorski Wierch in Poland), in the SW part of the Králický Sněžník (Mts.), where it ramifies into the forementioned two branches. The Elbe - Oder Divide runs towards the W (crossing the Králíky Graben once more) and the Danube - Oder Divide towards the E. The Mt. Klepý is the only point in the Bohemian Massif where divides of the three large European rivers (and three seas) meet. The Králíky Graben is interesting by great thickness of the Upper Cretaceous sediments, too (more than 730 m, mostly of the Coniacian age, Valečka, 1988).

Drainage of the Králíky Graben as well as of the Klodzko Graben is predominately longitudinal (N-S) but rather complicated (Fig.10). All major streams leave the grabens through gorges. In the S, the Králíky Graben is closed and separated from the Bohemian Cretaceous Basin by highland topography. In spite of some cross faults (NW-SE and NNW-SSE), main part of the Králíky Graben is drained to the S by the Březná R. (tributary of the Moravská Sázava R. coming from the Bohemian Cretaceous Basin). The other major rivers are Klodzka Nysa and Tichá Orlice. The Březná R. cuts the gorge about 15 km long. This feature is very similar to drainage of the Blansko Graben.

The drainage pattern of the eastern part of the Bohemian Cretaceous Basin north of Svitavy is in general radial. Water courses flowing to the W into the Elbe cross the N-S trending anticlines in water gaps cut mainly in the Upper Cretaceous sediments while the gorges of the rivers flowing to the E or S (the tributaries of the Morava R.) are cut in resistant basement rocks. It is also important, that the N-S axis of the Zábřežská vrchovina (Highland) (composed of crystalline rocks and folded Upper Paleozoic sediments) which separates the eastern part of the Bohemian Cretaceous Basin from the Hornomoravský úval (Graben, part of the Carpathian Foredeep) is parallel with fold structures in the adjacent part of the Bohemian Cretaceous Basin.

Some features of the drainage pattern of the eastern part of the Bohemian Cretaceous Basin are similar to the drainage pattern of the Klodzko and Králíky Grabens. As regards relation to geological structure, the main water courses are longitudinal and follow the axis of the Ústí syncline. The river of Třebovka (tributary of the river of Tichá Orlice and Elbe) flows towards the N and the Svitava towards the S. Only a small part of the Bohemian Cretaceous Basin is drained to the E by the rivers of Morávská Sázava and Třebůvka. Between headwaters of the Moravská Sázava and Třebovka, there is a short dry valley, forming the only break ("wind gap", Třebechovické sedlo Pass, 437 m a.s.l., Fig.10) in the cuesta of the Hřebeč Ridge.In it, the Badenian sediments rest on Lower Permian deposits. This is true also in the Lanškroun Depression, a northernmost part of the Lanškroun - Černá Hora Depression. In the gorge of the Moravská Sázava through the Zábřežská vrchovina (Highland) is a junction with the Březná R. coming from the Králíky Graben.

The Svitava probably used originally the Lanškroun - Černá Hora Depression. At present, however, northern and middle parts of the depression are drained by rivers of the Moravská Sázava and Třebůvka to the E (Fig.10). The Třebůvka flows to the N at first, but it turns to the E into a transversal gorge through the Zabřežská vrchovina (Highland).

Consequently, only a small southern part of the Lanškroun - Černá Hora Depression drained by the Semíč brook belongs to the Svitava drainage basin. It joins the Svitava R. in the northern part of the Lysice Depression.

The source of the Svitava is also in the eastern part of the Bohemian Cretaceous Basin. The Svitava (A - 1.146,9 km^2, L - 97,3 km) originates in a flat axial part of the Ústí syncline at the altitude of 465 m. It does not follow the syncline axis strictly and flows against dip of the floor of the basin. In this part of the drainage basin the tributaries are very short and restricted to the syncline only.

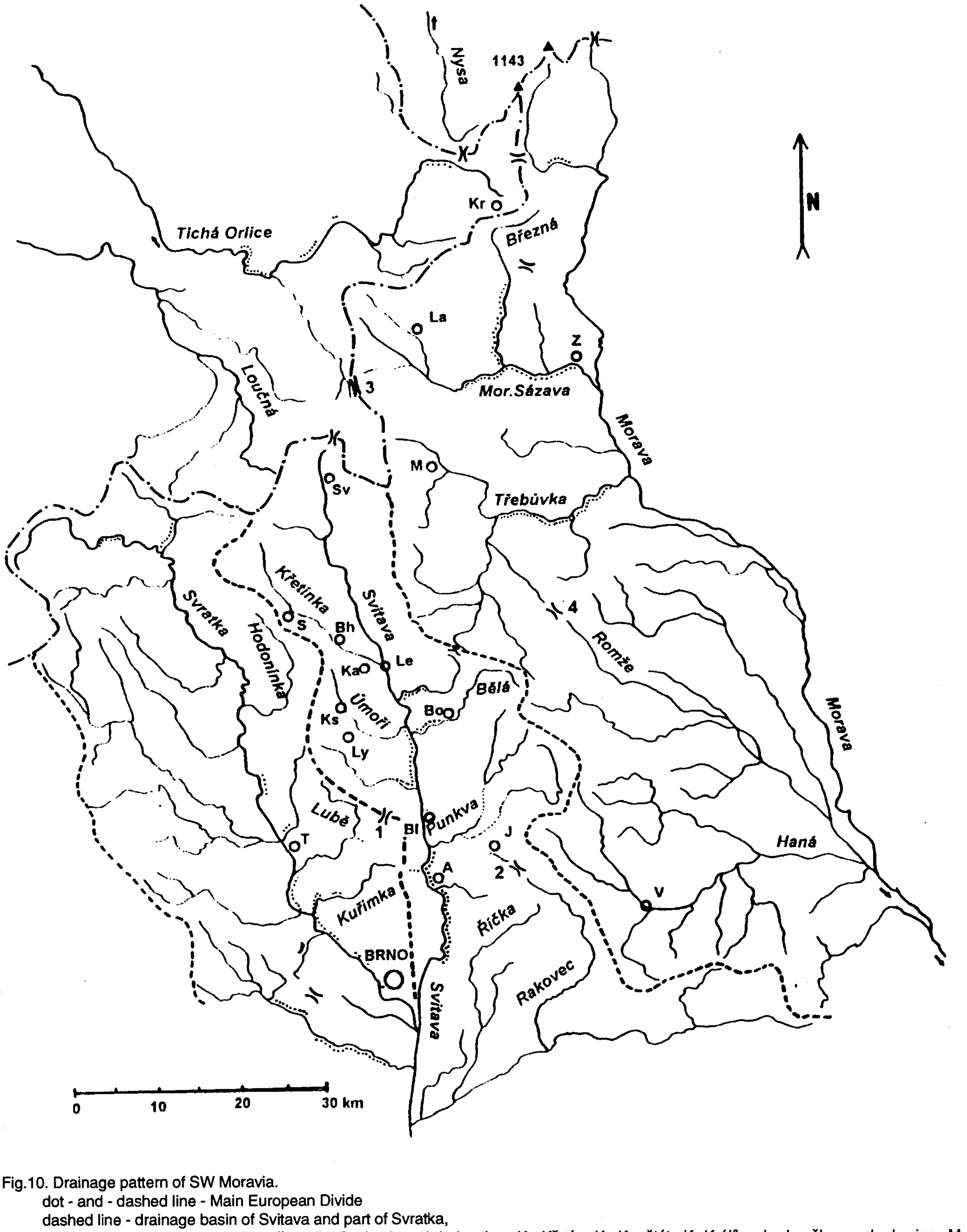


Fig.10. Drainage pattern of SW Moravia.
dot - and - dashed line - Main European Divide
dashed line - drainage basin of Svitava and part of Svratka,
A-Adamov, Bl-Blansko, Bh-Bohuňov, Bo-Boskovice, J-Jedovnice, Ka-Křetín, Ks-Kunštát, Kr-Králíky, La-Lanškroun, Ly-Lysice, M-Moravská Třebová, S-Svojanov, Sv-Svitavy, T-Tišnov, V-Vyškov.Passes and valley divides: 1 - Závist Pass, 2- valley divide in the Jedovnice-Račice Graben, 3- Třebechovice Pass, 4- divide between Romže R. and Třebůvka R. in the Drahanská vrchovina (Highland).

7.3 Svitava in the Lysice Depression and Blansko Graben, the problem of connection with the Carpathian Foredeep

Downstream of Letovice, the Svitava crosses the northern part of the Lysice Depression and continues towards the S into the Blansko Graben. The river makes use of neither tectonic directions of the Boskovice Furrow (NNE-SSW) nor of the Semanín fault (SSW-SSE), nor the major part of Lysice Depression. Instead of it, the Svitava breaks through resistant basement rocks along the contact of the Krhov Ridge with the Drahanská vrchovina (Highland) (see chap.3.2). In the gorge, the Svitava joins the Bělá R. (chap.4) and crosses obliquely the Boskovice-Diendorf fault. At the village of Rájec n. Svitavou the Svitava joins the right tributary of the Býkovka brook draining the southern part of the Lysice Depression.

The Lysice Depression was explained as a river valley (e.g. Jaroš, 1958b; Jurková, 1976). However, pedimentation by lateral planation of streams debouching from the adjoining highland, seems to be also possible. This is suggested by W-E cross profile of the depression. In it, an erosion surface truncating Lower Permian sediments below the Badenian deposits slopes down eastwards. The funnel-shaped mouths of some valleys coming from the Českomoravská vrchovina (Highland) (e.g. the Úmoří brook), and piracy described by Štelcl (1956) offer the support, too.

The Upper Cretaceous sediments were partly evacuated by the paleo-Svitava both from the Lysice Depression and the Blansko Graben before the Badenian (Figs. 4,5 and 11). The two depressions are connected by a wide valley of the Býkovka (brook). They are closed from the S by block-faulted elevations of the Žernovník and Hořice Horsts and by the Adamovská vrchovina (Highland).

The paleo-Svitava had four possibilities how to reach the Carpathian Foredeep, two from the Lysice Depression and two from the Blansko Graben. From the Lysice Depression, the Svitava could flow either through the Závist Pass in the Hořice Horst or across the Žernovník Horst. From the Blansko Graben, the river could continue either to the S through the granodiorite of the Adamovská vrchovina (Highland), similarly as the present Svitava, or turn to the SE across the Moravian Karst and the Drahanská vrchovina (Highland).

7.31 Possible drainage from the Lysice Depression

Numerous changes in the river pattern evolution of the Svitava R. during the Miocene and Quaternary between the Lysice Depression and the Brno Basin were supposed by Jaroš (1958b). He noted a tendency to an eastward migration of the Svitava R., from the crystalline basement of the Svratka dome to the Žernovník Horst in the Uppermost Miocene and than into the Závist Pass in the Lower Pleistocene. A critical point of the hypothesis is especially the age of sands and gravels at the village of Závist, interpreted either as the Miocene or Quaternary. According to Cicha and Dornič (1959), the sediments are marine by origin and were deposited in the Lower Badenian. Thus, the course of the Svitava R. through the Závist Pass in the Quaternary seems to be untenable. The difference in elevation of the Závist Pass and the present bottom of the Svitava R. in the Blansko Graben (about 150 m) argues against this course.

On the other hand, valleys filled with Badenian sediments exist in the southern continuation of the Závist Pass suggesting not only an integrated pre-Badenian river pattern, but also a possible fluvial function of the Závist Pass. The pass is probably guided by a fault. In our opinion, more detailed research is necessary.

7.32 Drainage from the Blansko Graben

The course of the Svitava R. from the Blansko Graben to the Carpathian Foredeep either southeastwards to the Vyškov Gate across the Moravian Karst or southwards to the Brno Basin has been discussed very much. The problem is more complex than the drainage from the Lysice Depression towards the Brno Basin.

7.321 Possible drainage across the Moravian Karst

In the southernmost part of the Blansko Graben, the Svitava R. joins the Punkva R. which drains partly (as an underground river) the northern part of the Moravian Karst. Its southwards course turns to the W where karst waters reappears at the surface. The lowermost course of the Punkva is a deep canyon cut in granodiorite. In the canyon, the Lower Badenian marine sediments were found below the present floodplain (Schütznerová-

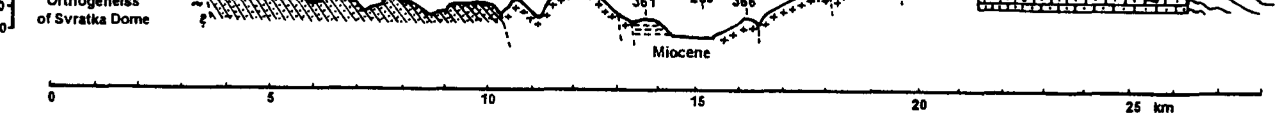


Fig.11. Profile across the Žernovník Horst,Hořice Horst,Blansko Graben and Moravian Karst.Note that in this part of the Blansko Graben, outcrops of the Upper Cretaceous sediments are absent.

Havelková, 1957,1958; Vilšer, 1962). The Badenian sediments occur also in the tributary valley of the Punkva at the village of Lažánky and beyond a local divide in the graben-like Jedovnice - Račice Depression, drained partly by the Jedovnický potok (brook), but mostly by the Rakovec (brook).

This led to a hypothesis that valleys of the lowermost Punkva and its tributary from Lažánky were used by the river connecting the Blansko Graben and the Vyškov Gate (Kettner, 1960). Two additional problems appeared, however. The first, importance of the underground of drainage of the Moravian Karst. The second, the problem of erosional or tectonic origin of the Jedovnice - Račice Depression (Dvořák,1995). A critical point of the hypothesis consits in the contact area of the Devonian limestones and Culm sediments on the E margin of the Moravian Karst near Jedovnice. The narrow Jedovnice - Račice Depression is drained to two opposite directions. The minor NW part is drained by the Jedovnický potok (brook) into the Svitava R. but not through the Punkva and its tributary valley at Lažánky. The Jedovnický potok (brook) is an allochtonous karst stream disappearing in the ponor at the Jedovnice. It continues as an underground stream towards the SW and reappears in the valley of the Křtinský potok (brook). It joins the Svitava in its gorge downstream of the Blansko Graben. Thus, an underground hydrography (ground-water capture?) of the Moravian Karst is involved in the problem of Svitava paleocourse, too (see R.Musil et al., 1993a).

The major part of the graben-like Jedovnice - Račice Depression is drained by Rakovec (brook) to the SE. The water divide between the Jedovnický potok and Rakovec brooks crosses the bottom of the depression E of Jedovnice at the altitude of 480 m. The Badenian sediments (more than 100 m thick) occur along the both streams.This SE part of the depression is about 20 km long and it ends suddenly in the S on the line of marginal slope of the Bohemian Massif (Fig.12). Here, the depression enters the Vyškov Gate which is a part of the Carpathian Foredeep. The drainage basin of the Rakovec (brook) is mostly only 4 km wide, without perennial tributaries. Slopes of this major part of the depression are composed of folded Culm sediments. They are very irregular in groundplan, partly zig-zag or rectangular, complicated by small embayment-like depressions.

The course of the depression is perpendicular to the marginal slope of the Bohemian Massif. Before crossing the margin, the depression ramifies into two branches, separated by a central isolated fault block with the top more than 150 m (437 m a.s.l.) above the bottom of depression. Hrádek (1980) described this configuration as a triple junction. The resemblance with the Y-type fault is also remarkable (see e.g.Brinkmann, 1972). It is worth to mention, that two branches of the depression belong to different drainage basins and the divide which crosses the central isolated block continues to the SE across the Carpathian Foredeep. This type of "bifurcation" occurs also in the Brno Basin (Ivan, 1992 and Fig.12).

As regards the relation of the graben to the basement structure, Dvořák (1993) noted a fault boundary in the Proterozoic basement along an axial depression between Jedovnice and Vyškov.

As to the origin of the Jedovnice - Račice Depression, opinions vary. According to some authors, the depression is of an erosion form, later filled with the Badenian sediments (Zeman, 1980; Dvořák, 1994, 1995). On the other hand, Krejčí (1967) pointed out some of its undisputable tectonic features. According to him, also the lowermost course of the Punkva cut in granodiorite is a tectonic valley, but this is less convincing. In our opinion, the Rakovec (brook) cut its valley in the bottom of the graben-like Jedovnice - Račice Depression, but time relations between vertical fluvial erosion, tectonics and Badenian marine transgression are too complex and not fully understood yet.

7.322 The Svitava gorge downstream of the Blansko Graben

At present, the Blansko Graben is drained towards the S. The gorge between the Blansko Graben and the Brno Basin is about 30 km long cut in granodiorite. But downstream of the town of Adamov, Devonian limestones crop out in the upper part of the left valley slope. Although the Svitava R. maintains generally the N-S direction, some NW and NNE sections alternate in its course. The cross profile of the gorge is also variable and several incised meanders occur, too. The most interesting features accompanying the Svitava gorge (but not discussed here in detail) are as follows:

(1) The short right tributary gorge of the brook of Šebrovka coming from the Svinošice Graben (Fig.12). The graben is filled with the Miocene sediments and the Upper Cretaceous sediments also occur.

(2) The canyon of the Křtinský potok (brook), the left tributary of the Svitava R. draining the middle part of the Moravian Karst (see chap. 8.321).

(3) The small basin at the town of Adamov developed along the branch of the Adamov fault (NW-SE) with a short tributary of barbed type.

(4) Downstream the village of Bílovice nad Svitavou the river is cut below the bottom of the Obřany Basin (Krejčí, 1964) in fact a "hanging" promontory of both the Nesvačilka Graben and the Brno Basin. Moreover, the promontory turns to the NE near Bílovice n. Svitavou and continues as the Řícmanice - Ochoz Graben (Demek et al., 1987) into the southern part of the Moravian Karst. The bottoms of both the Obřany Basin and Řícmanice-Ochoz Grabens are partly composed of Miocene (Ottnangian) sediments. The latter graben is believed to be a result of inversion of relief in the granodiorite (R. Musil et al., 1993a; Dvořák and Pták, 1963).

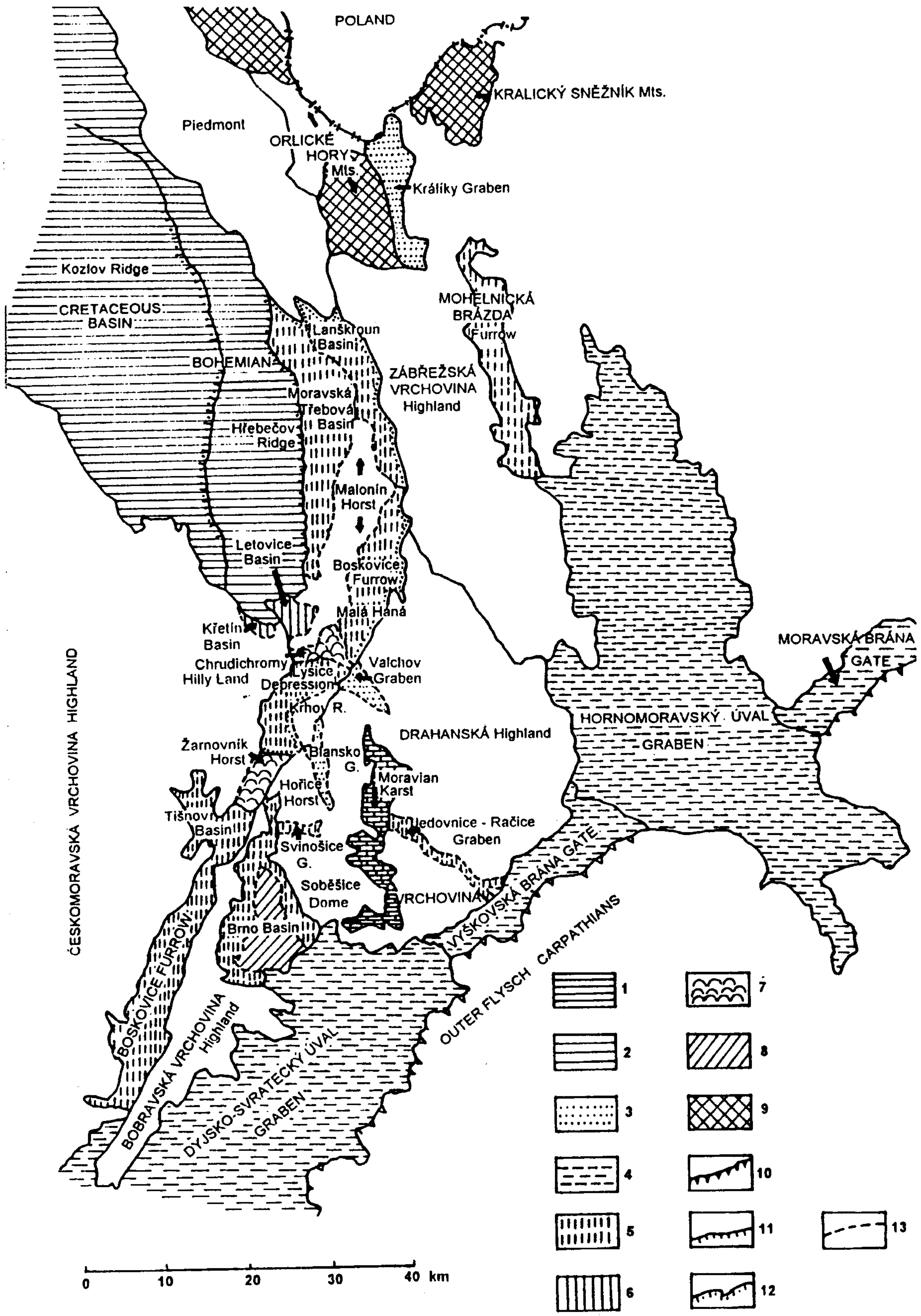


Fig.12.Some topographical features in the E part of the Bohemian Massif: 1- Devonian Limestones, 2- Upper Cretaceous sediments of the Bohemian Cretaceous Basin, 3- Upper Cretaceous sediments in the grabens, 4- Miocene sediments of the Carpathian Foredeep, 5- Miocene sediments in depressions in the Bohemian Massif, 6- depression without the Miocene sediments (Křetín and Letovice Basins), 7- thresholds in the Boskovice Furrow, 8- elevation in the Brno Basin, 9- mountains in the surroundings of the Králíky Graben, 10- Front of Carpathian nappes, 11- cuesta escarpment of the Hřebeč Ridge, 12- east slope of Kozlov Ridge, 13 a - boundary between Lanškroun and Moravská Třebová Basins, b - eastern boundary of the supposed Lanškroun - Černá Hora Depression.

The origin of the Svitava gorge downstream of the Blansko Graben was much discussed and both the antecedence and superposition were propounded. According to Demek, the gorge is antecedent (Demek et al., 1965) and Krejčí (1964) stated its guidance by a fault. In this connection, resemblance between the drainage of the Králíky and Blansko Grabens by southward trending gorges, diagonally to the NW - SE Variscan faults is spectacular. According to R.Musil et al. (1993b) the Svitava started to cut its gorge in the Paleogene already. The highest terrace of the Svitava (93 m) originated in the Pliocene. The prevailing part of its depth was cut in the Quaternary.

8. Problems of denudation chronology

The relics of kaolinic and lateritic weathering crusts, as well as the nature of buried topography demonstrate a very perfect planation before the Upper Cretaceous marine transgression. Thus, we classify this surface as a buried variety of the etchplain according to the scheme of Thomas (1989). The exhumed parts of the surface are preserved in many areas adjoining to the Bohemian Cretaceous Basin. The post-Cretaceous subaerial denudation in the Bohemian Massif resulted in a regional planation surface mostly referred to as Paleogene peneplain. This extensive planation surface truncates different rocks and structures, and also the Upper Cretaceous sediments. It is believed, that the planation surface had a low elevation above the general erosion base and this is the reason to consider it as a datum useful to estimate amplitudes of neotectonic movements (Kopecký, 1972). Relations between the post-Cretaceous movements and the Paleogene planation surface, however, are not well understood, especially in the Bohemian Cretaceous Basin and adjacent areas. The post-Cretaceous subaerial denudation was very long and no wonder that opinions about the more precise age of the Paleogene planation surface and mainly of block movements differ substantially. The main cause of difficulties is an absence of datable post-Cretaceous sediments, weathering crusts or duricrusts. The oldest post-Upper Cretaceous sediments in the E part of the Bohemian Cretaceous Basin, the Badenian basal clastics and marls, were deposited not only on the planation surface but also in depressions and valleys. Some authors suppose initiation of valley cutting already in the Paleogene (Panoš, 1964b; Dvořák, 1995).

In the area under study, the most extensive remnants of the Paleogene peneplain in the area of Upper Cretaceous sediments are supposed to be mainly in the Ústí syncline (Neubauer, 1953). Height differences among the remnants of the surface are explained by post-Paleogene tectonic deformations. The river pattern seems to be affected by the faults, too. The depression of Ústí syncline is tectonic, not erosional.

It is remarkable, that in the northern and central segments of the Blansko - Kunštát zone, surfaces on the mesas are underlain with the same formations (with an only exception of the buttte Chlum 512 m).This is true also in the Blansko Graben. However, it is possible, that the surfaces are at least partly structural.The surfaces in the surroundings of buttes are either exhumed pre-Upper Cretaceous surfaces (e.g. near Kunštát) or post-Paleogene but pre-Badenian in age. In the Krhov Ridge, the surface east of the butte of Malý Chlum truncates the post-Cretaceous and Lower Permian sediments.

The processes of exhumation of the pre-Upper Cretaceous planation surface took place from the time of sea regression and continue up to now. Therefore, from the paleoclimatic point of view, the buried surface was exhumed and reshaped by very different processes.

Depth of denudation of the exhumed pre-Upper Cretaceous planation surface composed of crystalline rocks is different, too. This is demonstrable especially in the Blansko - Kunštát zone. At Kunštát, at least 80 m schists corresponding to the present heigt of the Milenka mesa were denuded from the upthrown block of the Semanín fault after the exhumation. The original topographic effect of faulting was destroyed by differential erosion and relief inversion developed (Fig.13). The topographic position suggests that after denudation of the Upper Cretaceous sediments, deep chemical weathering continued. The most conspicuous relief inversion in the area under study, however, occurs where the Upper Cretaceous deposits are underlain with Lower Permian rocks.

The relief inversion is very common also in other parts of the Bohemian Massif composed of the Upper Cretaceous sediments. Large-scale inversion occured in northern parts of the massif (e.g. along Lusitanian fault, Louis 1961, Fig.42) and this feature of some Sudetes Mts. is mentioned also by Birot (1958). According to A.Jahn (1980, p.10) in the Polish part of the Sudetes:" The cause of the morphological inversion can be found in the peculiar character of the action of intertropical climate processes which react not to rock hardness, but to its hydrogeological properties such as porosity, permeability, chemical and mineral composition". In his interpretation, synclinal mountains evolved from parts of the North Sudetic and Intrasudetic throughs along the Main Sudetic Fault. An important factor in relief inversion evolution were differential tectonic movements, namely movements on the ancient Variscan faults. This is evident both in the Blansko - Kunštát zone and in the eastern part of the Bohemian Cretaceous Basin. In the northern segment of the Blansko - Kunštát zone, downfaulted Upper Cretaceous sediments were later uplifted and buttes originated on the local divide. On the other hand, in the Blansko Graben the sediments retained their original position and landforms presenting a relief inversion do not exist. An analogical contrast in the Polish part of the Sudetes present the Góry Stolowe (denuded anticline) and the Klodzko Graben.

In some depressions, the Badenian sediments buried a flat or gently inclined erosion surface truncating the pre-Mesozoic rocks, mostly moderately deformed Lower Permian sediments. The cuesta escarpment of the Hřebeč Ridge facing the large Lanškroun - Černá Hora Depression suggests possible pedimentation processes by retreat of the escarpment. In the Lysice Depression, the buried surface is sloping down from the foot of the Českomoravská vrchovina (Highland). The surface occurs also in embayments located where water courses leave the highland. Here, lateral planation by streams was a possible process. However, the period since formation of pediments to their burial by the Badenian sediments is unknown. Hassinger (1914) noted, that the pre-middle Miocene fault scarp (cuesta) in the surrounding of Lanškroun composed of the Upper Cretaceous sediments retreated 5-6 km after faulting. But since the Miocene, the retreat was only 1 km. More data are necessary, however, for both understaning and timing of the processes.

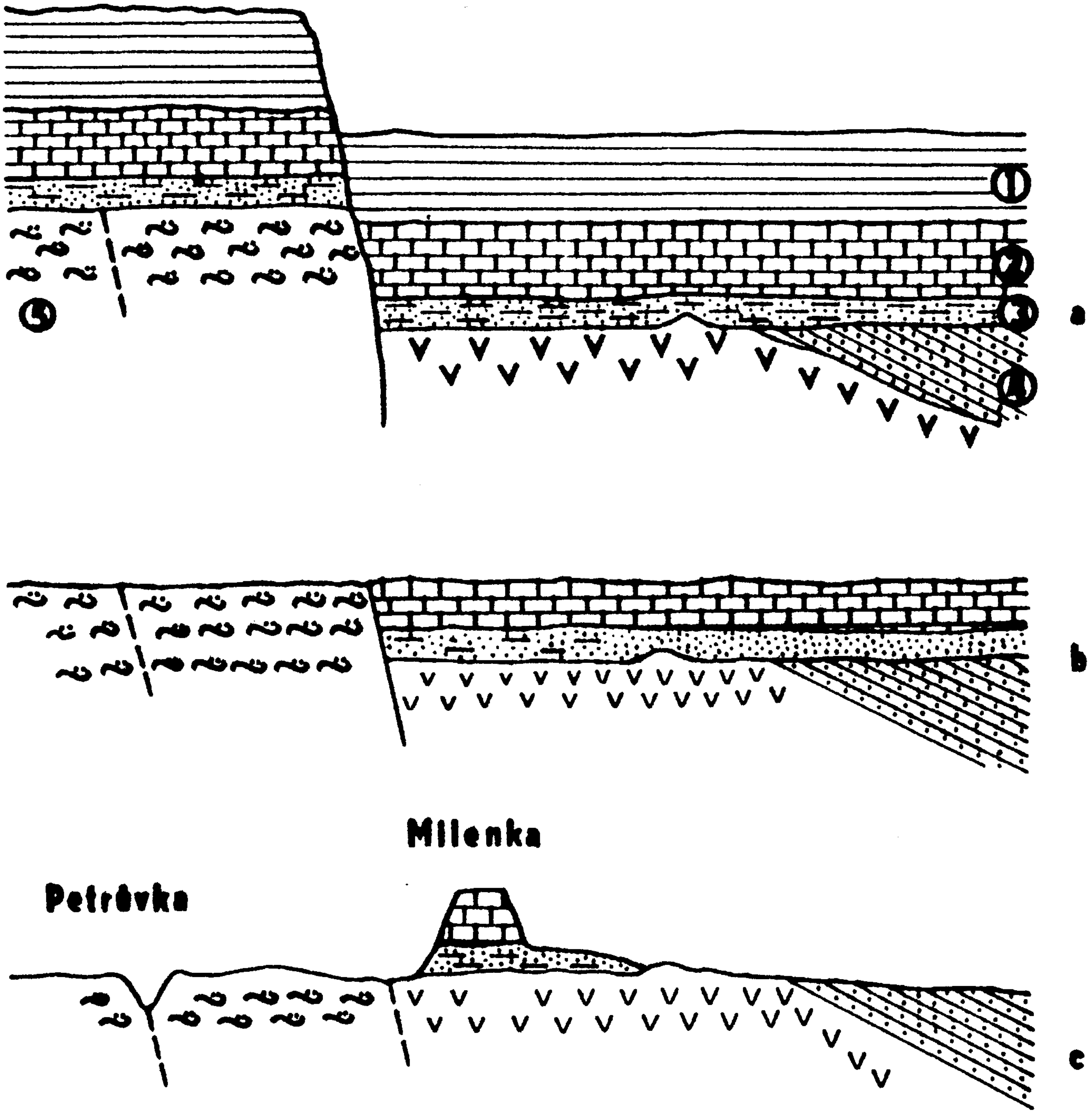


Fig.13. Inversion of relief along the Semanín fault in the northern part of the Blansko-Kunštát zone: 1- Upper and Middle Turonian sediments, 2- Lower Turonian sediments, 3- Cenomanian sediments, 4- Lower Permian sediments and metabasites of the Letovice Unit, 5- crystalline schists of the Svratka Dome.

Very different opinions were expressed also about the age of tectonic movements and deformations of the Upper Cretaceous sediments.

As mentioned above, some movements are evidenced already at the onset of Upper Cretaceous freshwater sedimentation (Vachtl et al., 1968). In the surroundings of Svojanov, Fajst (1969) demonstrated the existence of the Stašov ridge as a part of the Potštejn anticline at that time. In opinion of Malkovský (1977, 1979, 1980) the Ilsed phase in the Upper Cretaceous was perceptible. In the eastern part of the Bohemian Cretaceous Basin, synsedimentary movements were summarized by J. Soukup (in J.Svoboda et al., 1962). In the Klodzko Graben, strong synsedimentary movements took place especially during the Subhercynian phase (Jerzykiewicz, 1971). This was supposed also for eastern Bohemia (Vavřínová, 1946).

According to Kettner (1960), the age of the Blansko Graben is unclear, probably the Paleogene. In the scheme of tectonic movements of Malkovský, the major fold structures originated during the Savian phase in the Uppermost Oligocene - Lower Miocene. In contrast, Kopecký (1972) postulated the neotectonic age of all folds structures. According to him, the Potštejn anticline originated only in the Quaternary. This seems to be unrealistic.

In any case, it seems that the Young Saxon tectonic movements were long lasting or several phases occured at least. In the Miocene, the most intensive movements took place in the Blansko and Valchov Grabens affecting the very fractured rocks of the Brno Massif. This probably connects with proximity of the front of nappes in the West Carpathians located in the process of underthrusting of the Bohemian Massif below the Carpathians.

In fact, the nappe front of the Carpathian flysch thrusted over the Miocene (Karpathian) sediments resulted in a shift of the Carpathian Foredeep towards the NW and formation of the marginal slope of the Bohemian Massif. At present, the nappe front is only 20 km SE of Brno from the margin of the massif. In marginal parts of the Bohemian Massif, in the Drahanská vrchovina, Bobravská vrchovina and Zábřežská vrchovina (Highlands), a forebulge originated as a response to tectonic stresses in the Carpathians. It is possible that reactivation of some faults in the Boskovice Furow contributed to the formation of the forebulge. Importance of Variscan or older basement structure is supported by the fact, that dome-like deformations (the Svratka Dome, the Soběšice Dome) are present only in the Moravosilesicum and Brunovistulicum but not in the more consolidated Moldanubicum.

9. Discussion and conclusions

1. The Blansko-Kunštát zone and the Ústí syncline are similar tectonic structures. Their long axes, however, are inclined in opposite directions. In both structures, the Upper Cretaceous sediments are preserved mainly in western parts along the Semanín fault. The Blansko - Kunštát zone is narrower and more intensively faulted. The both structures are associated not only with the Semanín fault but also with the Potštejn anticline. The Semanín fault is composed of two step faults at least. The fault is most distinct in granitoids of the Brno Massif. In other parts, a process of bending into flexure was important, too. Some common features can be found also in the Blansko and Králíky Grabens. Thresholds between the Klodzko Graben and the Bohemian Cretaceous Basin, between the latter and the Blansko - Kunštát zone and between Blansko - Kunštát zone (Lysice Depression + Blansko Graben) and the Carpathian Foredeep (Brno Basin) have similar features. In the thresholds, drainage is directed southwards.
2. Young-Saxon tectonics north of Brno was differentiated in dependance on a very different basement structure of the Bohemian Massif and tectonic processes in adjacent parts of the Western Carpathians. The pattern of the major NW-SE faults was supplemented by faults of the NNW-SSE and N-S directions. The N-S trend was also important in the process of formation of forebulge in front of the Carpathians nappes in the Lower Miocene. The Blansko and Valchov Grabens are bounded on the E by slope of the domal uplift of the Drahanská vrchovina (Highland), complicated by N-S trending faults taking part in the dome-like deformation.
3. Some important S or SSE trending faults in the Bohemian Cretaceous Basin and in the half-grabens turn to the SE and some die out in western parts of the Drahanská vrchovina and Zábřežská vrchovina (Highlands). The Semanín fault turns to the SE in the closure of the Blansko Graben and crosses the Moravian Karst as a northern branch of the Adamov fault. Along the branch, several narrow blocks of the Jurassic limestone were downfaulted (P.Bosák, 1978). Similarly, the Kyšperk fault turns to the SE in the valley of the Nectava R., separating the Drahanská vrchovina from the Zábřežská vrchovina (Highlands). At the western foot of the Zábřežská vrchovina (Highland), small blocks of the Upper Cretaceous sediments are preserved on downthrown blocks. On the other hand, some faults suddenly end and the Upper Cretaceous sediments are found in a very exposed topographical situation. This is the case of the eastern fault of the Králíky Graben (the Upper Cretaceous sediments are preserved at Horní Studénky) and of the Radkov fault that dies out at Pěčíkov. Along the important Bušín fault (NW-SE) connecting the Králíky Graben and Mohelnická

brázda (Furrow) the northern promontory of the Hornomoravský úval (Graben), only an overfit fault-line valley developed. The Kyšperk fault is probably SE continuation of the Lusitanian fault.

4. The young-Saxon fault movements were at least partly inversional. Thus, the post-Cretaceous subaerial landscape evolution resulted in an inversion of the relief. The buttes of the Blansko - Kunštát zone are very instructive examples, but the tendency to relief inversion is apparent also in the Ústí syncline and in some marginal parts of the Bohemian Cretaceous Basin. In some cases, however, the relief inversion was probably inherited from the Lower Mesozoic (Babí lom Ridge, composed of the Lower Devonian conglomerates, Řícmanice - Ochoz Graben).
5. We believe that intensive denudation, including the formation of river valleys and depressions was important in the Lower and Middle Miocene (Karpatian and Badenian) in connection with thrusting of flysch nappes in the Carpathians (Czudek 1984, Dvořák 1995) and formation of the forebulge. In the Carpathian Foredeep situated between the forebulge and flysch nappes, rate of sedimentation was very high at these times (D.Vass and F.Čech, 1989).
6. Remnants of the Upper Cretaceous sediments at the western foot of the Zábřežská vrchovina (Highland) suggest that from morphostructural point of view, the western slope of the Zábřežská vrchovina (Highland) formed probably originally the eastern margin of the Bohemian Cretaceous Basin and western slope of the forebulge. This is true also for the western foot of the Drahanská vrchovina (Highland). Here, however, the location of this boundary was predisposed by the Boskovice - Diendorf fault.
7. The formation of the forebulge affected distinctly the evolution of drainage pattern in the eastern part of the Bohemian Massif. Although some water courses flowing from the Bohemian Cretaceous Basin to the E were guided by faults, they were blocked and beheaded (e.g. the river of Nectava). At present,only the rivers of Moravská Sázava and Třebůvka cross the Zábřežská vrchovina (Highland) in deep gorges and maintain their original courses initiated on the eastern limb of the Litice anticline. Between the depressions north of Brno (Blansko Graben and Lysice Depression) and the Carpathian Foredeep, development of drainage pattern was particularly complicated. Most complex was drainage evolution in the Moravian Karst. The deep valleys, especially transversal gorges, in the SE part of the Bohemian Massif as well as the valleys buried below the Miocene sediments of the Carpathian Foredeep and/or Flysch nappes present one of most difficult problem.

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Reviewer

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Outcrops of calcareous sandstones and marlestones of Lower Turonian (Upper Cretaceous) on the front of cuesta of the Hřebečovský hřbet (Ridge) in south part of Svitavská pahorkatina (Hilly land) near Chlum village, 40 km northly from Brno. (Illustration for the paper of A.Ivan)

Photo: Mojmír Hrádek