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Česká geologická služba

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Bohemian Cretaceous Basin

Stop 1. Belveder

(Valečka Jaroslav)

Belveder locality is located north of Děčín, in the upper part of a canyon-like Elbe River valley, on its right bank near the village of Labská stráň (Elbleiten). The valley is lined in its upper part by continuous, up to 75 m high rock walls, made up mainly of sandstones belonging to the Bílá Hora Formation or Schmilka Formation, respectively, the uppermost level of the valley being represented by sandstones of the Jizera Formation/Postelwitz Formation. The Belveder locality lies in the vicinity of a scenic terrace viewpoint situated on a flat top of a high rock block, at 160 m above the Elbe River level. The construction of the terrace was ordered by the prince Francis Charles Clary-Aldringen in the 18^{th} century. The terrace could be accessed by a straight lane-lined road leading from a nearby castle in the Bynovec/Binsdorf village. Adjacent to the terrace is a small sala terrena (garden pavilion) hewn in a several-meters high rock wall, overtopping the viewpoint terrace. The latter served not only as a viewpoint but also as a gathering place for prince´s guests listening to the performing orchestra, sitting in the sala terrena.

The visitors of the locality can study the boundary between the Bílá Hora and Jizera Formations. The boundary is sharp and morphologically marked in the field by a rock step. The surface of the Belveder viewpoint plateau coincides with an uneven sedimentary surface representing the top of the Bílá Hora Formation, marked by a ferricrete and burrows of Thalassinoides type (fig. 1). The middle and upper parts of the Formation are made up by hard, silicified medium to coarse quartz sandstones with an admixture of fine-conglomerate fraction locally concentrated into sharp, up to several decimeters thick interlayers. The Bílá Hora sandstones typically exhibit mainly tabular cross bedding. The sets of these sandstones are about 1 m thick and commonly form co-sets. The dip of the laminae in the cross bedded units trends mostly WNW, occasionally SE or even E. This development can be well-observed along a steep path leading from the viewpoint terrace down to the Elbe River. The coarse sandstones of the Bílá Hora Formation are sharply overlain by yellowish grey, well-sorted, fine- to medium-grained sandstones of the basal section of the Jizera Formation. They crop out along with sala terrena near the east margin of the viewpoint plateau. They are intensely bioturbated and thoroughly lack any current structures. The network of cylindrical, branching bioturbation structures classified as ichnogenus Thalassinoides is so conspicuous in forming a dominant fabric so that it can be described as “Thalassinoides event” (Fig. 2). The boundary between the Bílá Hora and Jizera Formations indicates a short depositional break, a termination of a dynamic sedimentation influenced by activity of strong bottom currents and by onset of relatively calm, fine sandy material sedimentation accompanied by intense bioturbation activity of decapods. The development of lithological boundary at Belveder is typical and easy to correlate both in outcrops and in borehole logs in the Bohemian-Saxon Switzerland west, as well as east of the Elbe canyon.

Fig. 1. A surface in the top wall of coarse-grained Bílá Hora sandstone with numerous Thalassinoides-type bioturbation structures. The Belveder scenic terrace viewpoint.

Fig. 2. Fine- to medium-grained, well sorted sandstones of lowermost part of the Jizera Formation. They exhibit a dense burrow system of the Thalassinoides-type ichnogenus. The wall of sala terrena near the Belveder scenic terrace viewpoint.

Stop 2. and 3. Sloup rock city: Introduction and geological framework
(Nádaskay Roland)

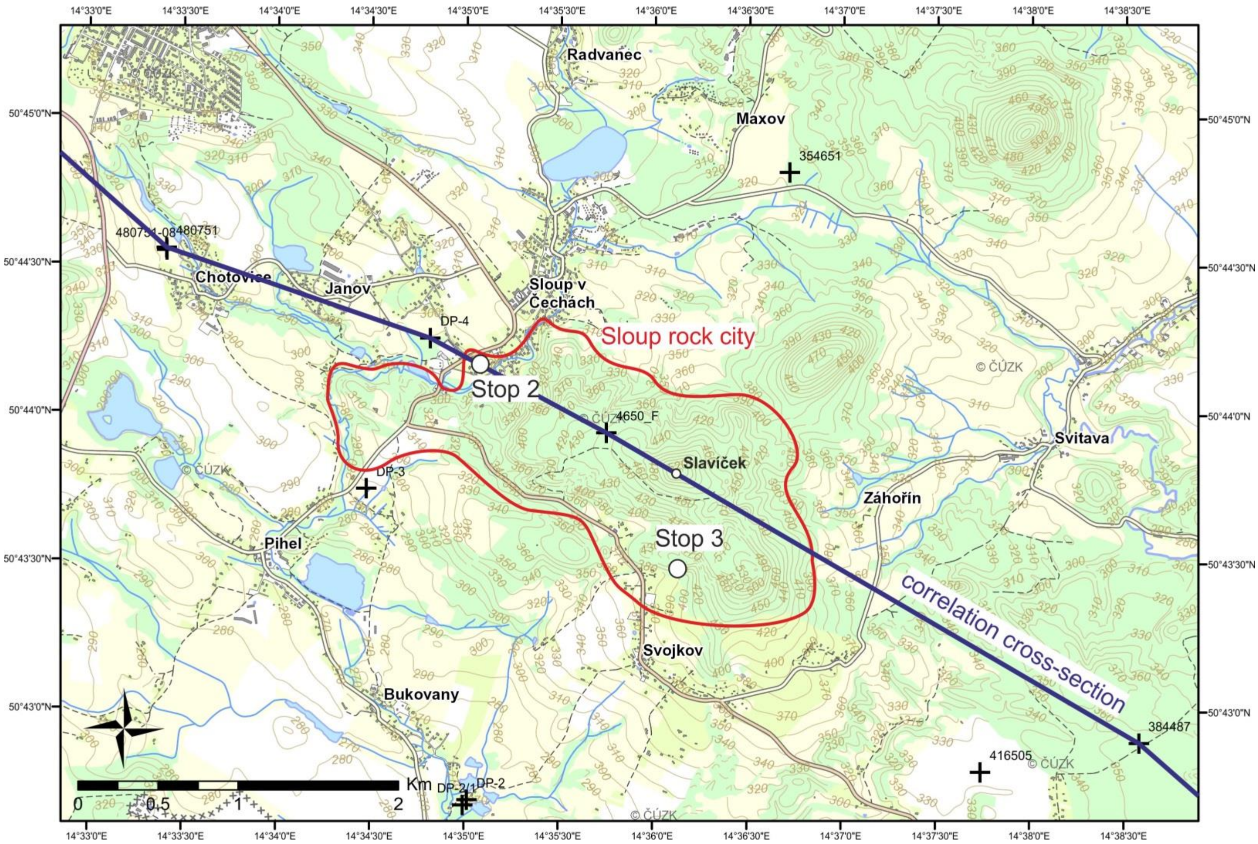


Fig. 3. Overview map showing location of stops 2 and 3 within Sloup rock city, located to the SE from Nový Bor. Blue line indicate correlation cross-section presented in fig. 5.

Sloup rock city, located in the NE-part of the Bohemian Cretaceous Basin, in the N-part of the hydrogeological region 4650. Most of the area is covered by deposits of Březno and Teplice Fms., Coniacian by age, except for the SE- part of the Fig. 3, where Upper Turonian deposits of the Jizera Fm. crop out. Stratigraphic position of the area of interest is illustrated by Fig. 4. The present-day structure of the BCB has been significantly affected by post-depositional tectonism, especially in the area of interest. As evidenced by well log-based genetic-stratigraphic correlation (Fig. 3), an array of normal fault is expected to be present on the NW-margin of the Sloup rock city, dividing two structural units, Lasvice Horst in the SE, and Nový Bor Graben in the NW, respectively. The latest significant deformation of the basin infill was caused by several phases of Oligo-Miocene extensional faulting due to formation of the Eger Graben (cf. Rajchl et al. 2009, Uličný et al. 2011).

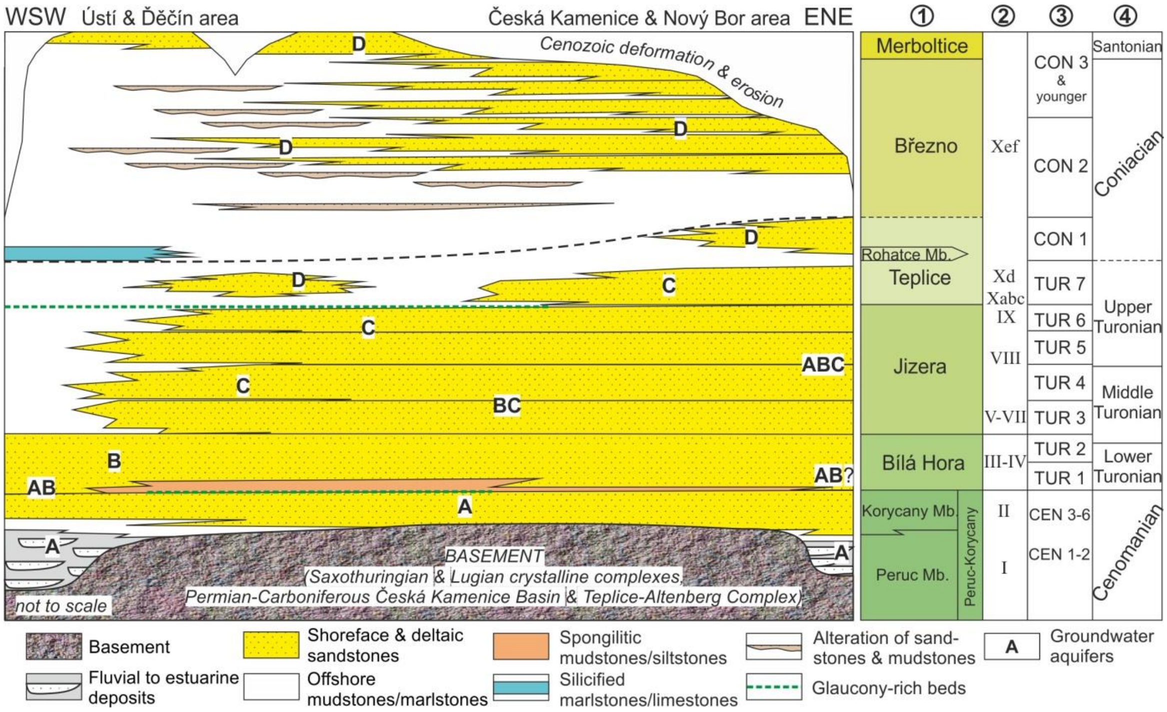


Fig. 4. Stratigraphy and lithofacies development of the NW-part of the BCB with indication of stratigraphic interval recorded by boreholes commented in the text. Explanations to stratigraphy: 1) regional lithostratigraphy after Čech et al. (1980); 2) informal litostratigraphy after Soukup (1955); 3) genetic stratigraphy (Uličný et al. 2009, 2015); 4) chronostratigraphy

Nový Bor Graben represents a marginal part of more extensive subsided structure, traditionally termed Benešov "syncline". The Upper Cretaceous deposits in this structural low reach up to 1000 metres, forming the thickest sequence within the entire BCB.

Most of the Březno Fm. is formed by coarse clastic deposits of the Březno Fm. (Coniacian), attributed to lithofacies group traditionally labelled as „quader“ sandstone (*sensu* Geinitz 1850). Coarse-grained deposits of the Březno Fm. overlie several tens of meters (180 m as evidenced by borehole 4650_A Skalice, to the W from the area of interest) thick fine-grained sequence composed of calcareous claystones and siltstones or marlstones. This sequence comprise, in places, few tens of meters thick alteration of fine-grained quartzose and argillaceous sandstones with mudstones/siltstones, termed „flyschoid“, or heterolithic facies, respectively.

Valečka (1979a) claimed that ("quader-") sandstones and coeval fine-grained facies were deposited in a shallow-water environment of an epicontinental sea with minimum seabed topography. Valečka (1979b) discussed a possible barrier island formation as a result of high clastic supply, presence of favourable current regime and a higher subsidence. On the basis of analysis of sedimentary structures, outcrop- and basin-scale depositional architecture,

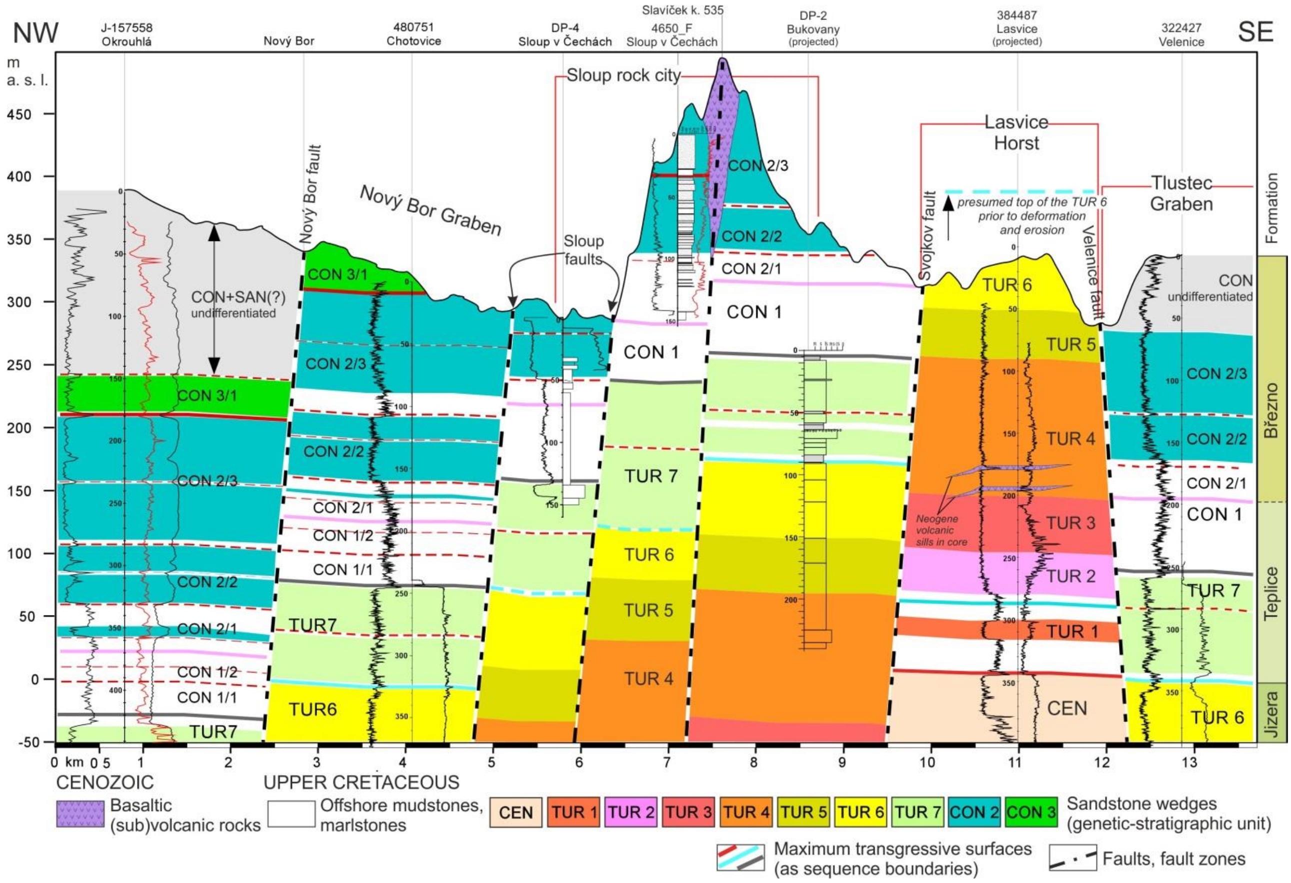


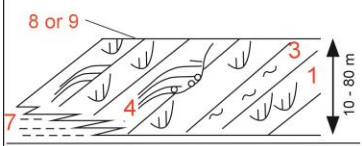
Fig. 5. Cross-section illustrating tectonic deformation of area in the vicinity of Nový Bor. Nový Bor and Tlustec Graben comprising young, Coniacian fill, are divided by NE–SW-oriented Lasvice Horst. Presence of an array of normal faults crossing the area of Sloup (NW margin of Sloup rock city) has been verified by borehole 4650_F. Modified after Nádaskay – Uličný (2014) and Uličný et al. (2015).

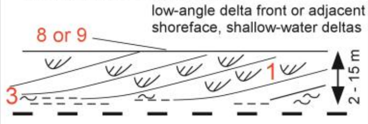
Uličný (2001) and Uličný et al. (2009) interpreted most of the Turonian and early Coniacian sandstone bodies in the northern and NW-part of the BCB as the deposits of coarse-grained deltas. However, origin of (“quader-“) sandstones bodies in the area of interest was not discussed in this work.

As for the so-called „flyschoid“ facies, Valečka & Rejchrt (1973) and Čech et al. (1987) assumed that its deposition resulted from periodical changes of current velocity during the basinward transport of the clastic material, although they conceded a marginal possibility of turbidity current action as well. Valečka (1984) supposed that transport of sand into areas of dominantly fine-grained deposition required the activity of occasional extreme storm events, although he considered amalgamated sets of sandstone as possible turbidites. In the depositional models of Uličný (2001) and Uličný et al. (2003a, 2009a), the heterolithic facies occupies the bottomset area of coarse-grained deltas and is interpreted as prodelta deposits with a significant influence of gravity flows caused by floods in the fluvio-deltaic system.

According to Nádaskay & Uličný (2014) relatively coarse-grained quartzose ("quader") sandstones, are interpreted as foreset packages deposited by progradation of deltaic depositional systems, seaward from the faulted edge of the basin. The thickness of the foreset package was used by Uličný (2001) to estimate minimum water depth available for progradation, with steep, high-angle foresets (H-type) typically associated with deep-water, Gilbert-type deltas, and the low-angle foresets (L-type) with shallow-water deltas. Correlation of outcrops to subsurface data in the Sloup v Čechách and Svojkov areas indicate a maximum thickness of a contiguous foreset package as much as 90 m, suggesting a depth of at least 90 m at the topset edge, most probably increasing downdip. The deposition on the prograding delta fronts was dominated by an interplay of two processes: (1) the primary deposition by gravity flows and (2) their subsequent reworking by ambient currents. Whereas the gravity-current deposits (represented by chute-channel fills) within foresets contain the coarsest part of the load carried by the sandy gravity flows, finer-grained parts stayed suspended longer and were deposited beyond the delta toes, forming the heterolithic bottomset facies.

	open foreset	chute fill	Typical lithofacies	Interpretation	Position in depositional model
H-type foreset packages high-angle delta front, deep to intermediate depth water deltas	●		1 - sandstones with small-scale trough cross bedding (Fig. 7C)	small-scale subaqueous dunes (few cm to few m)	current-reworked foresets
	●		2 - sandstones with large-scale cross-beddng (Fig. 7D)	large-scale subaqueous dunes (tens of m)	
	●	○	3 - bioturbated sandstones, silty to muddy admixture (Fig. 7I)	delta front with fine-grained deposition from suspension, higher biological activity	temporarily inactive or abandoned foresets
		●	4 - scour-based sandstone backset- (Fig. 7F) or sub-parallel stratification	supercritical deposition from suspension of upper plane bed or cyclic steps	chute-channel fills
		●	5 - massive sandstones, floating pebbles or graded clasts at bottom (Fig. 7G)	deposition from near hydraulic jump at slope break (Postma et al. 2009)	
	○	●	6 - sandstones with soft-sediment deforma-tion structures (SSDS) (Fig. 7G)	liquefaction due to rapid deposition, loading or seismic shock	deposits of gravity-driven downslope transport of sand
	bottomset		7 - alternation of mudstones/sandstones SSDS, bioturbation (Fig. 7H)	alternation of turbidites with fine-grained layers deposited during periods of low-sedimentation	prodeltas with activity of turbidity currents
L-type foreset packages low-angle delta front or adjacent shoreface, shallow-water deltas	open foreset		1 - sandstones with small-scale trough cross bedding (Fig. 7J)	small-scale subaqueous dunes (few cm to few m)	current-reworked foresets
	bottomset		3 - bioturbated sandstones, silty to muddy admixture (locally possible tran-sition into foreset)	delta front with fine-grained deposition from suspension, higher biological activity	sand-dominated bottomsets
Independent of H or L type: Facies covering truncation surfaces on top of foreset packages (aggradational topset strata not preserved)			8 - conglomeratic sandstone (Fig. 7K)	reworked delta plain clastics	transgressive lag
			9 - mud-rich sandstone with charcoal fragments (Fig. 7L)	reworked delta plain clastics and plant material	





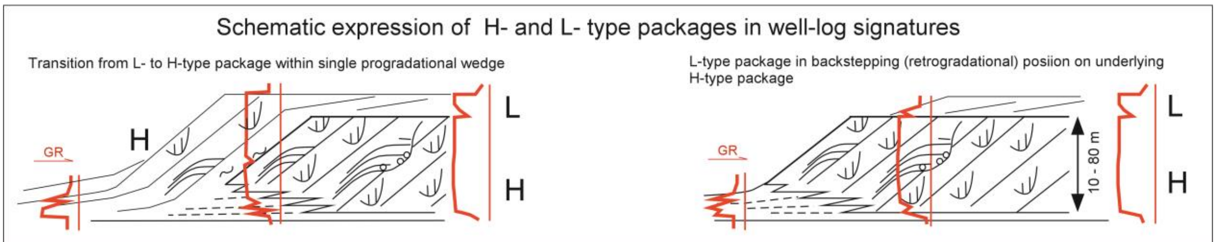


Fig. 6. Summary chart of the facies assemblages of individual geometric types of deltas and their depositional environments with respect to the proposed depositional model (Fig. 7). Inset sketches illustrate the principal features of the type-H and type-L foreset packages, with numbers of individual

lithofacies shown in cross-sections. The box at the bottom shows simplified examples of mutual relationships of H- and L-type foreset packages in dip-parallel cross-sections, and a schematic well-log response (GR – gamma-ray log).

Stop 2. Exposures of Coniacian sandstones in Sloup v Čechách village

The solitary rock under the Sloup Castle represents a typical exposure of H-type delta slope foresets. As evident from the photomosaic (Fig. 7), the section consists of southwest (220°) dipping foresets in a relatively steep inclination (15-20°), with large erosive chute channels incised in them at several places. In some cases, only backsets were deposited, without the underlying foresets being eroded. The middle part of the section exhibits a largest one among the slope troughs running across the whole section and besides the foresets, it cuts in its upper part the underlying, smaller erosional trough as well. The original backset lamination is absent, in some cases the slope trough being filled then with massive coarse sandstone having a sizeable admixture of a material coarser than 2 mm, including labile clasts. Unlike the foresets made up of fine- to medium sandstones, they are considerably coarser.
As shown by the correlation cross-section (Fig. 5) the exposure below the Sloup castle belongs to a huge, ca. 90 m thick complex of deltaic bodies, reached in the nearby Chotovice borehole 480751. Presence of both the foresets marked by sub-parallel lamination (and by subordinate occurrence of trough cross-bedding), plus the backsets and genetically akin erosional troughs indicates this deltaic body having been deposited in an upper-flow regime. The exposures spread all over the nearby Sloup rock city show a very similar character as those occurring below the rock castle. The Dědovy kameny locality serves as a good example (Fig. 8).

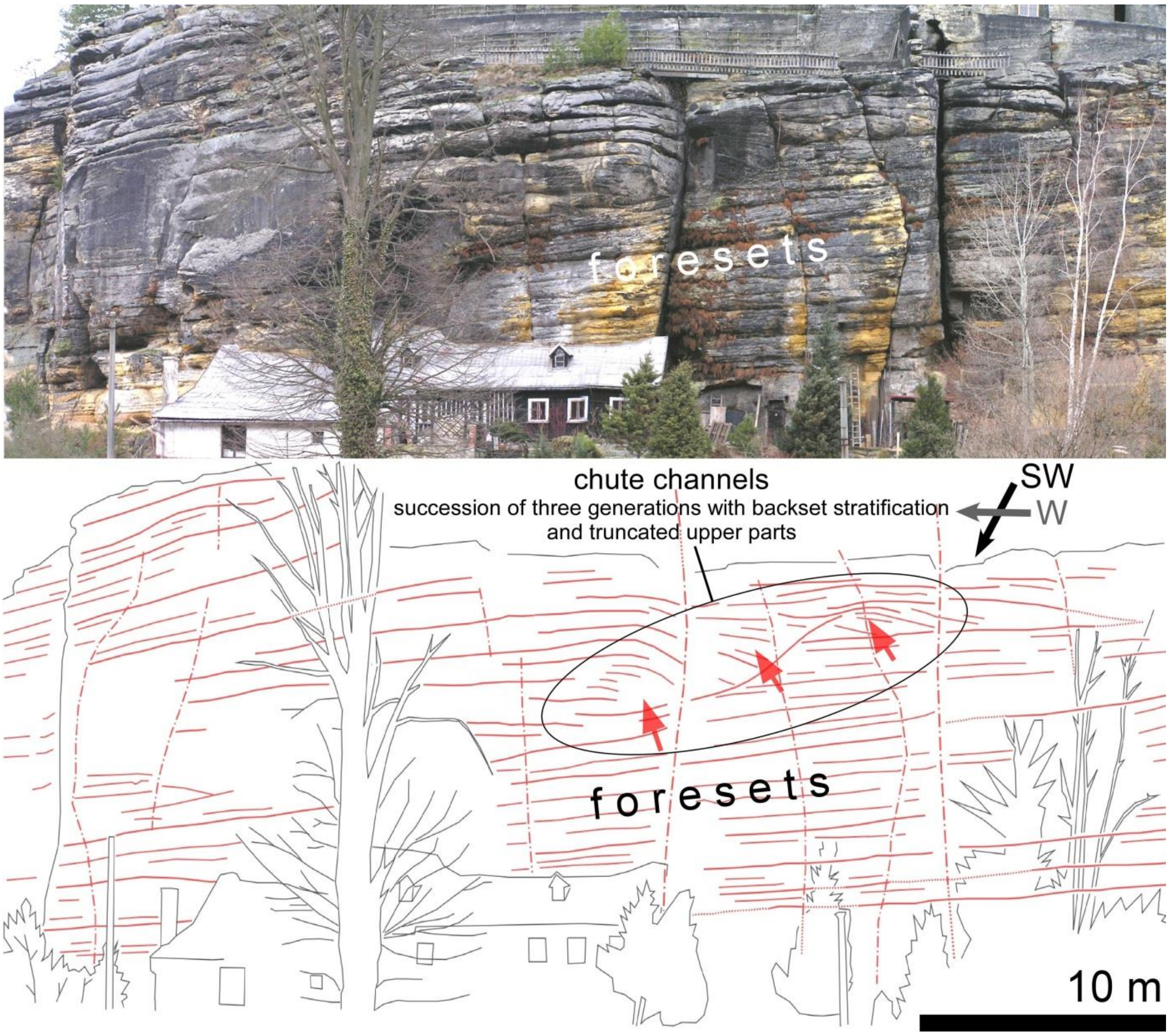


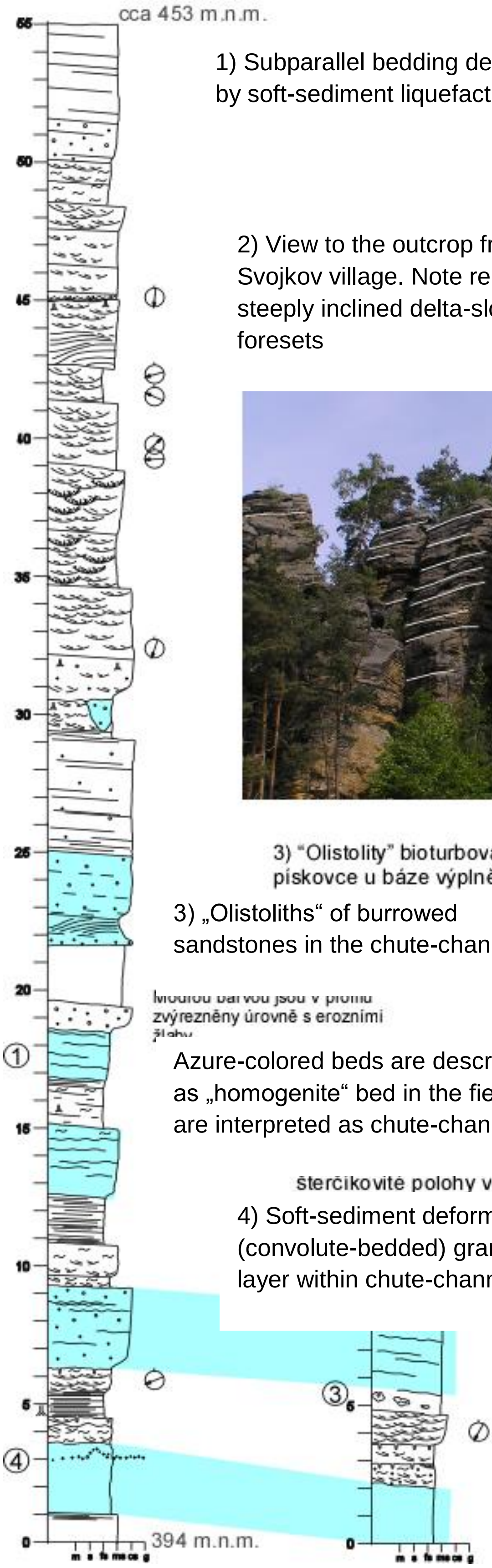
Fig. 7. Photomosaic of H-type foreset package (locality Rock Castle, Sloup v Čechách) interpreted as a part of the Sloup Rock City delta, sequence CON 2/3. The inclination of foresets (~15°) in the oblique cross-section is lower than the real dip angle. Black arrow: dip direction (220°), gray arrow: orientation of the outcrop wall (275°). Parallel-bedded foreset strata are cut by an irregularly eroded floor of the chute channel that was modified during filling by a succession of cyclic steps (backset strata). Note the transition from sharply onlapping backsets into aggrading, sub-parallel bedding conformable with the slope. Scale varies laterally due to perspective.

Stop 3. Exposures of Coniacian sandstones around the Slavíček hill (near Svojkov village)

Section Dědovy kameny (“Old man's rocks”) in the vicinity of Svojkov village represents a typical development of the quartzose sandstones of the Březno Fm. in the Sloup rock city. These are interpreted by Nádaskay & Uličný (2014) as a thick H-type foreset package, representing younger part of the stratigraphy, namely unit CON 2/3, presumably Middle Coniacian. Within Lužické hory Mts., H-type foresets of the Coniacian deltas typically crop out in large exposures in the Sloup area, near Radvanec, or in the Cvikov region, further to the NE.

The section can be divided in two parts, with lower part strongly dominated by deposits of gravity currents. Several “homogenite” bed can be recognized within the section (Fig. 8). They are formed by massive medium- to coarse-grained sandstone and are interpreted as chute channel fills. This facies contains a variety of soft-sediment structures related to thorough liquefaction and fluidization of the sediment. Convoluted relicts of stratification are indicated by white lines. The fluidization may be attributed to collapse of sediment fabric after rapid deposition, or to passage of seismic waves. In places, block of sandstones of contrasting lithology (often burrowed) are intrepreted in the channel fill massive sandstone as a kind of “rip-up” clasts. Although upper part of the section is dominated by reworking of foreset strata by tidal currents, as evidenced by abundant trough-cross beds, backset lamination is preserved in places. This indicate that foresets in the upper part of the section were deposited in the upper flow regine from downslope transported sand-laden suspension.

Section Svojkov – Dědovy kameny



1) Subparallel bedding deformed by soft-sediment liquefaction

2) View to the outcrop from Svojkov village. Note relatively steeply inclined delta-slope foresets

3) „Olistoliths“ of burrowed sandstones in the chute-channel fill

Azure-colored beds are described as „homogenite“ bed in the field, and are interpreted as chute-channel fills

4) Soft-sediment deformed (convolute-bedded) granule layer within chute-channel fill

Stop 4. Jurassic limestones
(Mrázová Štěpánka)

The Jurassic limestones crop out at several small localities near Doubice (Daubitz), Kyjov (Khaa) and Brtníky (Zeidler). They occur nowhere else in Bohemia.

Doubice – Vápenka (Vápenný vrch)
There are a number of abandoned shelf quarries and pit quarries in this locality. Abandoned and partly backfilled galleries occur in some of them. All the quarries are situated in a forest near the Doubice and Krásná Lípa (Schönlinde) road (Fig. 9).
The area lies near the Lusatian Fault, an important Saxonian discontinuous tectonic structure. In this area, the Fault separates the Late Cretaceous sediments from granitic rocks of Lusatian Massif. The geological setting is complicated, as there are Jurassic sediments and Permian rocks represented by volcanic rocks and sediments sandwiched between the Cretaceous and the granitic rocks (Fig. 10). The Jurassic and Permian occur in several minor tectonic blocks dragged upwards along the Lusatian Fault (Fediuk et al. 1958, Dvořák in Svoboda et al. 1964, Klein et al. 1971, Valečka et al. 1997). The blocks are confined by a system of strike-slip- and cross faults. The exposures in the abandoned shelf and pit quarries are the most extensive and significant outcrops of Jurassic platform sediments on Czech Massif´s territory. In the past, these Jurassic rocks were quarried as construction materials. Their exposures are discontinuous and are up to 130 m thick. Eliáš (in Klein et al. 1971) subdivided them into three lithological units, the oldest unit being the Brtnice Formation. It consists of basal, siliciclastic, mottled, greenish light grey, medium-grained sandstones. The younger unit, the ca. 100 m thick Doubice dolomite is a sequence of bluish grey to brown-grey dolomitic limestones and dolomites. The series of Jurassic deposits ends up with dark grey bituminous limestones, about 20 m thick. The dolomites and limestones are massive or thick-bedded, fragmented and contain marly interlayers at places (Fig. 11).
The sequence of the carbonate rocks often exhibits crushed zones. Only a stratigraphically unimportant fauna was found in the Doubice dolomites (Chrt 1957, Fediuk et al. 1958). Eliáš (in Klein et al. 1971) describes finds of ammonite *Hecticoceras hecticum* (Rein.), also described by Bruder (1886, 1887) near the Lusatian Fault.
The Pb-Zn and Cu mineralization found in the Jurassic sediments has no practical value (Chrt 1957). Chalcopyrite, chalcocite, pyrite, psilomelane and silver-bearing galena were found among the minerals, malachite and azurite being also abundant. In the northwestern and southeastern vicinity of the quarries, fragments and small outcrops of granitic rocks of the Lusatian massif and Permian quartz porphyries or even arkoses and sandstones with mudstone interlayers were found. They belong to the Vrchlabí and Prosečná Formations. The northwestern, western and southeastern surroundings of the quarries are known for the occurrence of fine-grained, slightly silty sandstones of the Březno Formation (the Upper Cretaceous, Coniacian). Two thin dykes of neo-volcanic rocks were found to occur in fragments and blocky outcrops in the close vicinity of the quarries. They are represented by

nepheline basanite, and/or nepheline tephrite with olivine admixture (Shrbený in Klein et al. 1971).

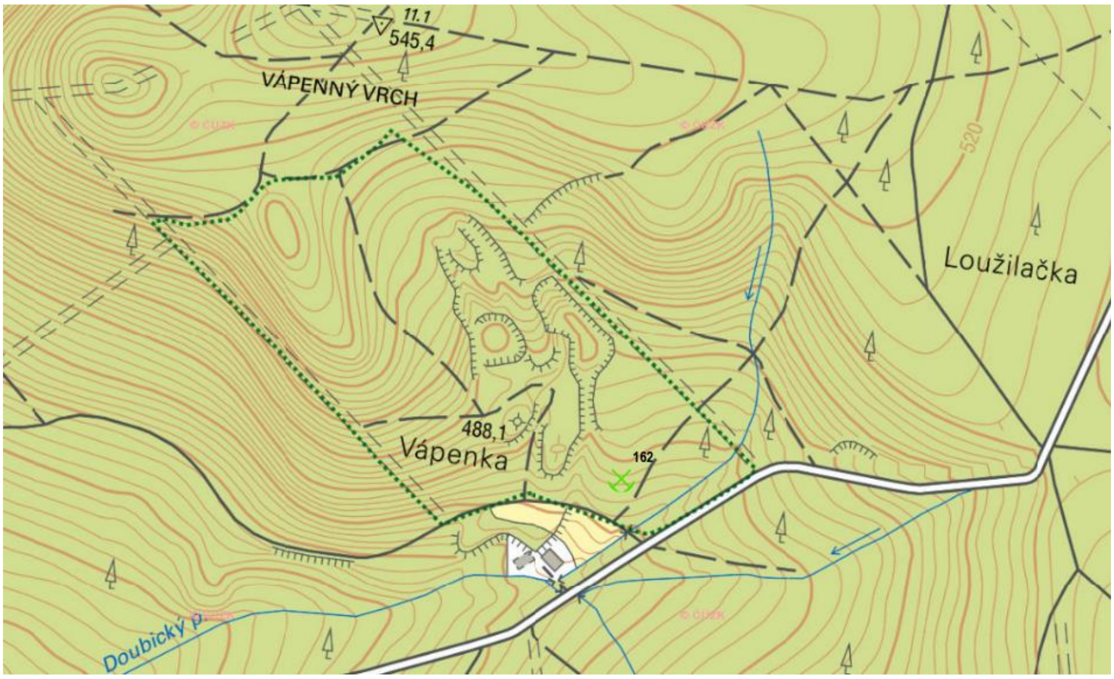


Fig. 9. The detail map with a number of abandoned shelf quarries and pit quarries on Vápenný vrch.

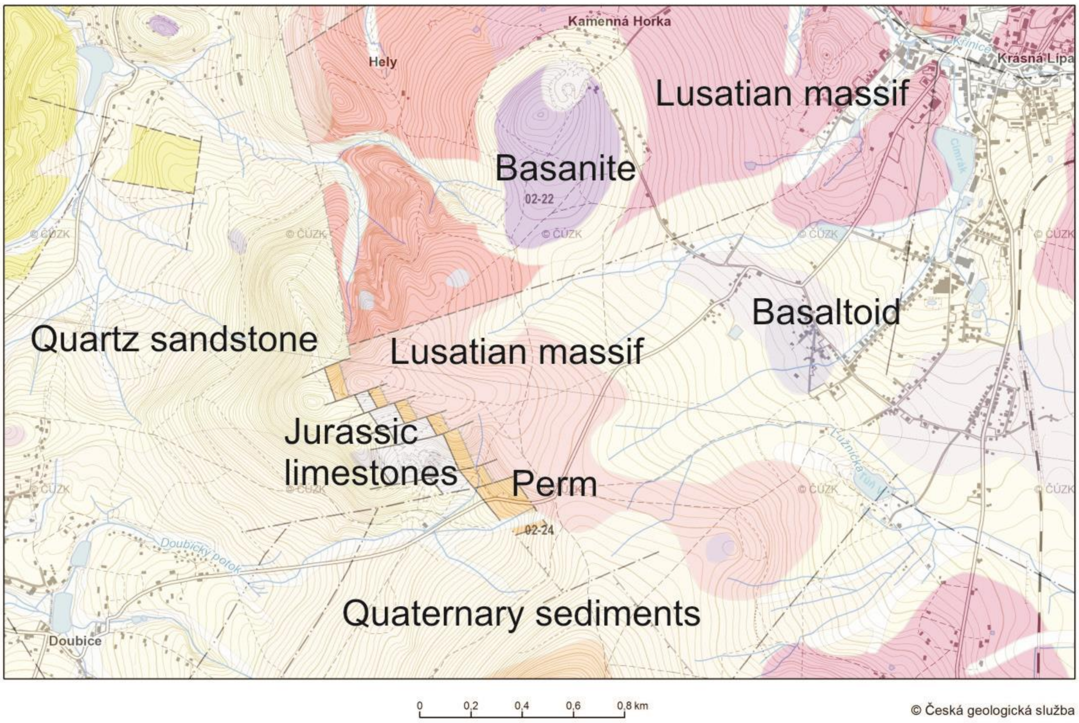


Fig. 10. The Geological map near Doubice – Vápenný vrch.

Fig. 11. The bluish grey to brown-grey dolomitic limestones and dolomites.

Stop 5. Milířka - Lusatian Fault

(Mlčoch Bedřich)

The Milířka stream bed forms a deeply incised valley, about 2 km south of Dolní Podluží village (Fig. 12.). Its name reminds us of the charcoal piles (die Meiler), where charcoal was burned for foundries, ore dressing plants and glassworks. The middle portion of the valley is associated with an important geological linear structure, the Lusatian Fault that separates the Lusatian granitic massif lying in the north from the sandstones of the Bohemian Cretaceous Basin in the south (Fig. 13). The granodiorites of the Lusatian Massif in the mid part of the valley protrude towards the valley´s southern part substantiating the existence of granodiorites being thrust over the Cretaceous sandstones (Fig. 14). Old mines are associated with the fault and they have been made accessible by ´a miner´s educational trail´ that runs through the whole valley from Dolní Podluží to the mountain saddle below the Ptačinec hill.

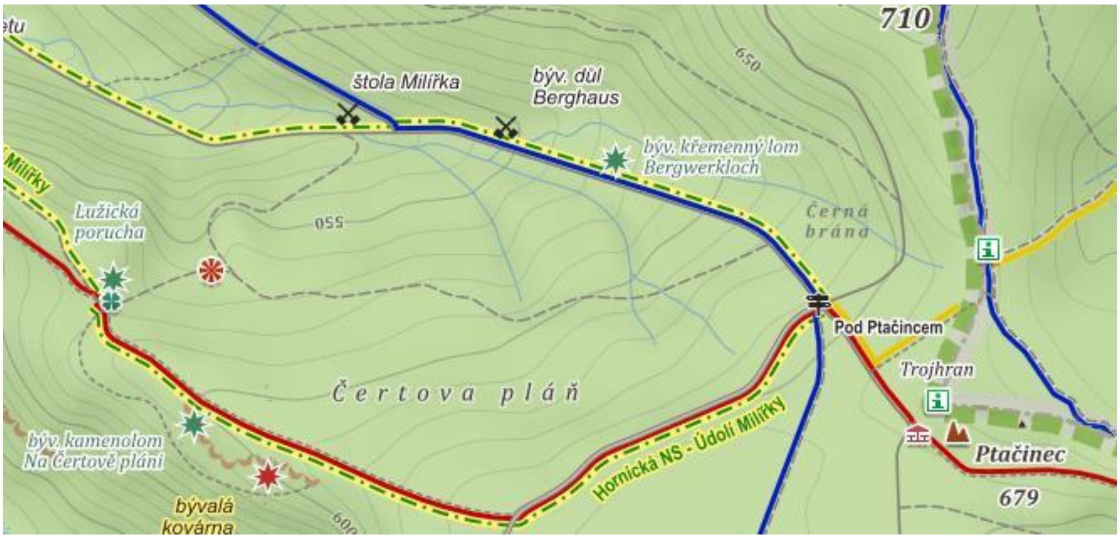


Fig. 12. The tourist map of the valley Milířka.

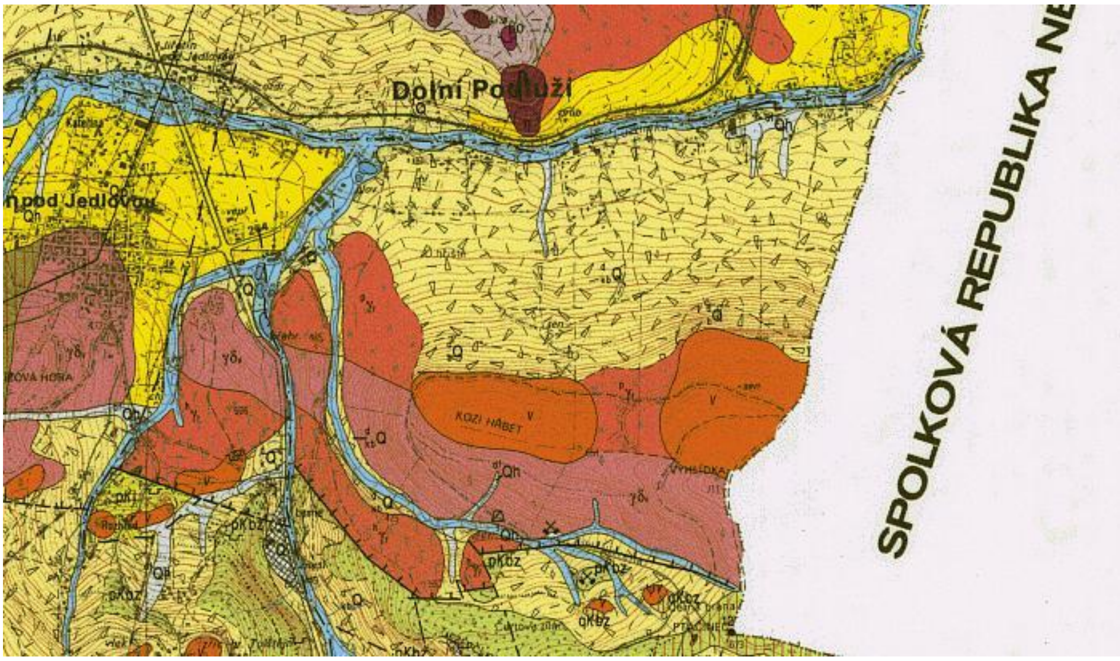


Fig. 13. The geological map around the Milířka stream.

Fig. 14. The abandoned quarry of Čertova stráň, the subhorizontal striations on the Lusatian Fault.

The oldest document bringing information about mining is a chart from 1474 giving permit to placer mining in the Tolštejn dominion. Adits were driven probably later, in the 16th century under the noble family von Schleinitz. Large amounts of quartz rubble occurring on some dumps indicate the exploitation of quartz for glassworks operating in this area since the second half of the 13th century. The mining activity here probably came to a close many years ago, since documents from the year 1800 only mention 200 to 300 years old shafts and galleries in the area. At present, four galleries are known to occur in the valley, out of which two are backfilled. Besides galleries, one can find remains of overgrown spoil pits and mine shafts almost everywhere. In the lower section of the valley an adit mouth occurs at the foot of the Kozí hřbet ridge (Ziegenrücken) at the site Knížecí studánka (Prince´s fountain), equipped with new brickwork in 2004. The adit mouth is mentioned in a document dated to the end of the 18th century and is called Anthony gallery (Antonsstollen). It is thought to have drained the diggings occurring higher-up in the hanging wall. Most traces of mining activity may be found in the midst of the valley that follows the Lusatian fault. The gallery, called nowadays **Milířka** is driven approximately northeastwards, following a granite and green-schist boundary. It is noted as a winter habitat of several bat species. The mouth entrance has been enclosed with bars since 1993. Big spoil heap cut nowadays by the stream bed belonged to the **Berghaus** mine, which is believed to be the biggest silver and base-metal mine in the Milířka valley. To the right of the Uhlířská cesta/Collier´s path, there is a shallow side valley called **Bergwerkloch** in the past. The valley is actually a quarry for quartz extraction, and it follows a quartz vein for a distance of about 240 meters. The quartz might have been quarried as a raw material for glass production in small glassworks that existed in the area as early as in the second half of the 13th century.

Stop 6. Dutý kámen near Cvikov (Hohlstein bei Zwickau in Böhmen) - Bohemian Cretaceous Basin

(Mrázová Štěpánka)

Dutý kámen (379 m a.s.l.) is a c. 600 m long forest-covered ridge, running southwards off the road from Cvikov to Kunratice, about 0.5 km from Drnovec. The ridge juts out 20-30 m above the surrounding area and consists of a silicified Cretaceous sandstone of the Březno Formation, intruded lengthwise by a 3-4 m thick Tertiary volcanic dyke called polzenite. That dyke occurs nowhere on the surface, its existence being corroborated by a road-cut digging in the nineteen seventies. The Dutý kámen is particularly notable by the columnar jointing of the above mentioned sandstone (Fig. 15).

The sandstone joints (“pillars”) on the Dutý kámen hill were brought about by the polzenite dyke, which, even though not protruding towards the surface, was accompanied by hot gas and steam. These ascended along the joints towards the surface heating the sandstone to a high temperature. This was not enough to melt the rock, but had caused its consolidation by silicification. The cooling that followed afterwards resulted in decrease in the sandstone´s volume and subsequently, its platy jointing or breaking into thin vertical slabs originated. In the nearest vicinity of the joints struck by the highest temperatures, transversal cracks formed breaking the sandstone into small fragments giving rise to tetra- to hexagonal columns. Away from the highest temperature loci, these columns first take the form of panel-shaped bodies, transiting into non-deformed blocky sandstone. On the Dutý kámen hill the columnar jointing of the sandstone is visible at several places, being best-developed on a 2.5 m high monadnock (protruding hillock) standing out approximately in hill´s central part.

Sandstone quarrying on Dutý kámen (Hohlstein) started since the beginning of the 19th century. Pits left after sandstone columns quarrying are still visible around the road in ridge´s northern part. Large sandstone blocks used to be extracted particularly in the surroundings of a viewpoint at the south end of the ridge. Sandstone was also extracted in a large quarry on the east slope, its main wall highlighting the relation of the sandstone columns to a long horizontal rock joint. In the southern part of the ridge there are numerous sandstone rock grounds that served to the Alpine Club Kunnersdorfer “Gebirgsverein für Nordböhmen” between 1913 and 1914 as a building site for the Körnerova výšina/Körnerhöhe scenic viewpoint with a rock-cut relief of the German poet Theodor Körner (1791-1813). A narrow staircase was hewn in the rock behind the relief leading to the flat top of the Široký kámen hill. There was an astronomic-geographical display board and a sundial here but only small vestiges of them are left. In the vicinity of the viewpoint there are several rock walls, the highest one being relatively narrow at its foot broadening higher-up and having a cavity

(Höhle) near the top. This cavity gave its name to the ridge Dutý kámen/Hohlstein/Hollow stone.

Fig. 15. The columnar jointing of sandstone.

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