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Field guidebook

Geology of the Saxonian and Bohemian Cretaceous Basin

9th-10th of May 2017

nur für den Dienstgebrauch

LANDESAMT FÜR UMWELT, LANDWIRTSCHAFT UND GEOLOGIE | Freistaat SACHSEN

ČESKÁ GEOLOGICKÁ SLUŽBA

VÚV TGM – Výzkumný ústav vodohospodářský T. G. Masaryka, veřejná výzkumná instituce

Saxon part

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Titel figure: Bohemian Cretaceous sandstone rocks in the Elbe River valley - View from Belveder to the Southwest (Photo: ResiBil project)

1. Introduction

Palaeogeography, depositional environment conditions and integrated stratigraphy of the Saxonian Cretaceous (Elbtal Group, Cenomanian to Coniacian) are described formation-wise following the current lithostratigraphy and the succession is placed in a regional context. The Elbtal Group formed in a narrow strait between the Mid-European Island in the southwest and the Lausitz Block in the northeast (West Sudetic or Lusatian Island). During the Late Cretaceous period, the Elbtal Group was situated in an important intermediate position between the temperate Boreal in the north and the Tethyan warm water areas in the south, and it shows a strong relationship in terms of litho- and biofacies to contemporaneous deposits and fauna of the Bohemian Cretaceous Basin. Lithologically, the Elbtal Group consists of marine sandstones, calcareous siltstones ("Pläner"), marls and marly limestones which are in part very rich in fossils. The overall sequence describes a transgressive–regressive megacycle with maximum flooding in the late Middle Turonian. Although sedimentation allegedly persisted into the later part of the Late Cretaceous, the youngest strata preserved today, dated into the Middle Coniacian. The rich fauna of the Cenomanian to Coniacian stages form the basis of the present fossil compendium.

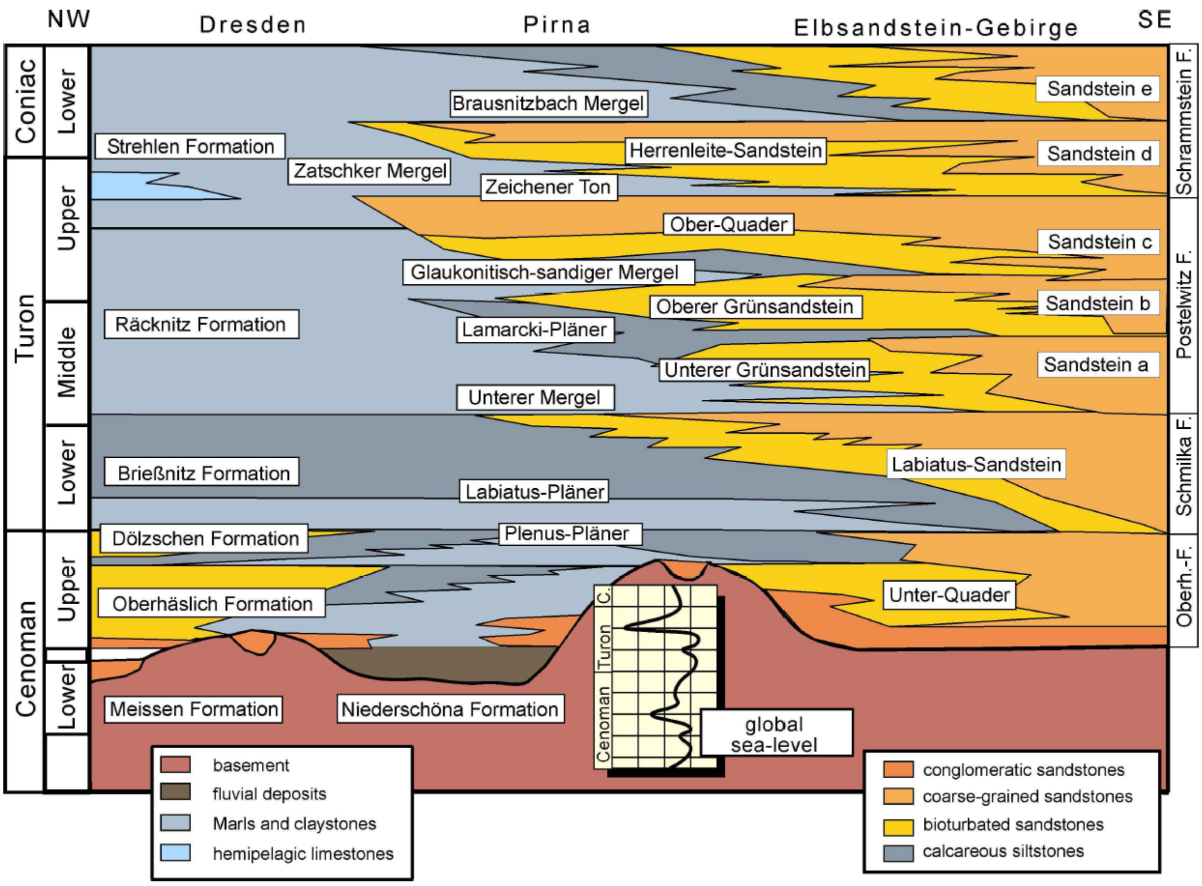

Fig 1: Simplified stratigraphic sketch of the Saxonian Cretaceous Basin from the basinal facies of Dresden to the coastal sandstones of the Elbsandstein Mountains, From: Voigt (1995).

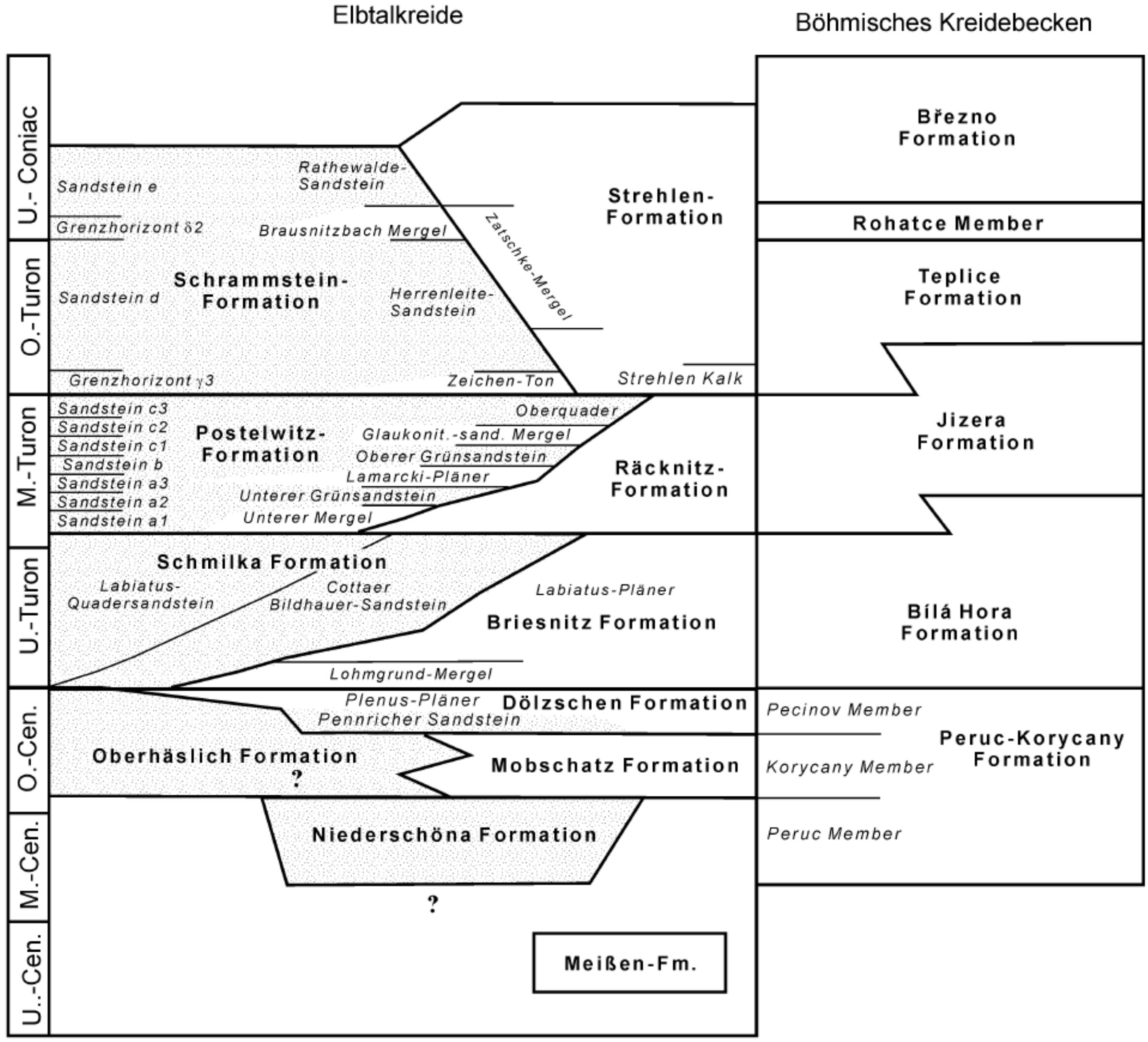

Fig 2: Lithostratigraphy of Cretaceous deposits in Saxony and correlation with the Bohemian Cretaceous. From: VOIGT (2007).

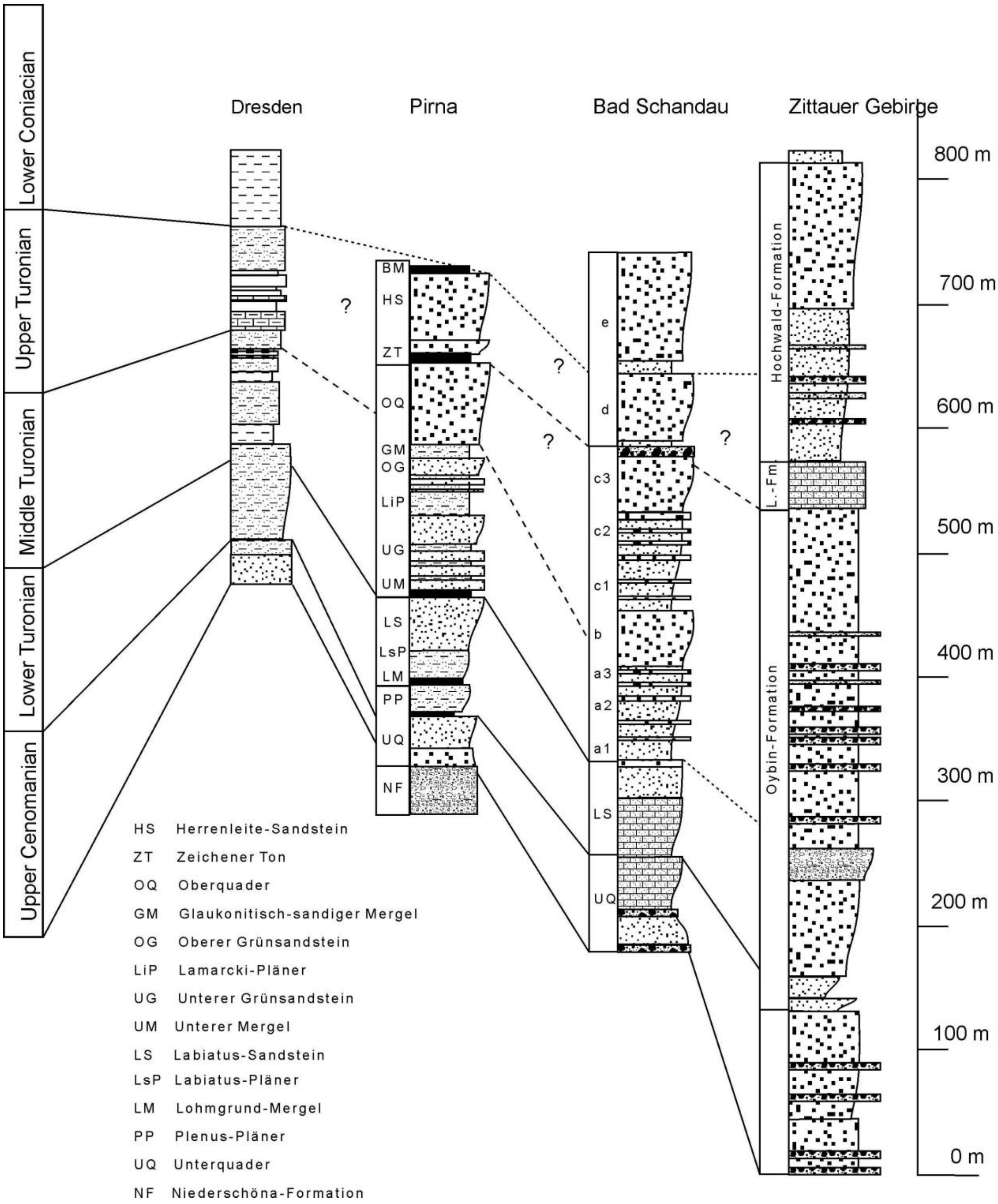

Fig. 3: Petrography of the Saxonian cretaceous from the basin facies (Dresden-Pirna) to the marginal facies (Elbsandsteingebirge, Zittauer Gebirge), From: VOIGT et al. (2012).

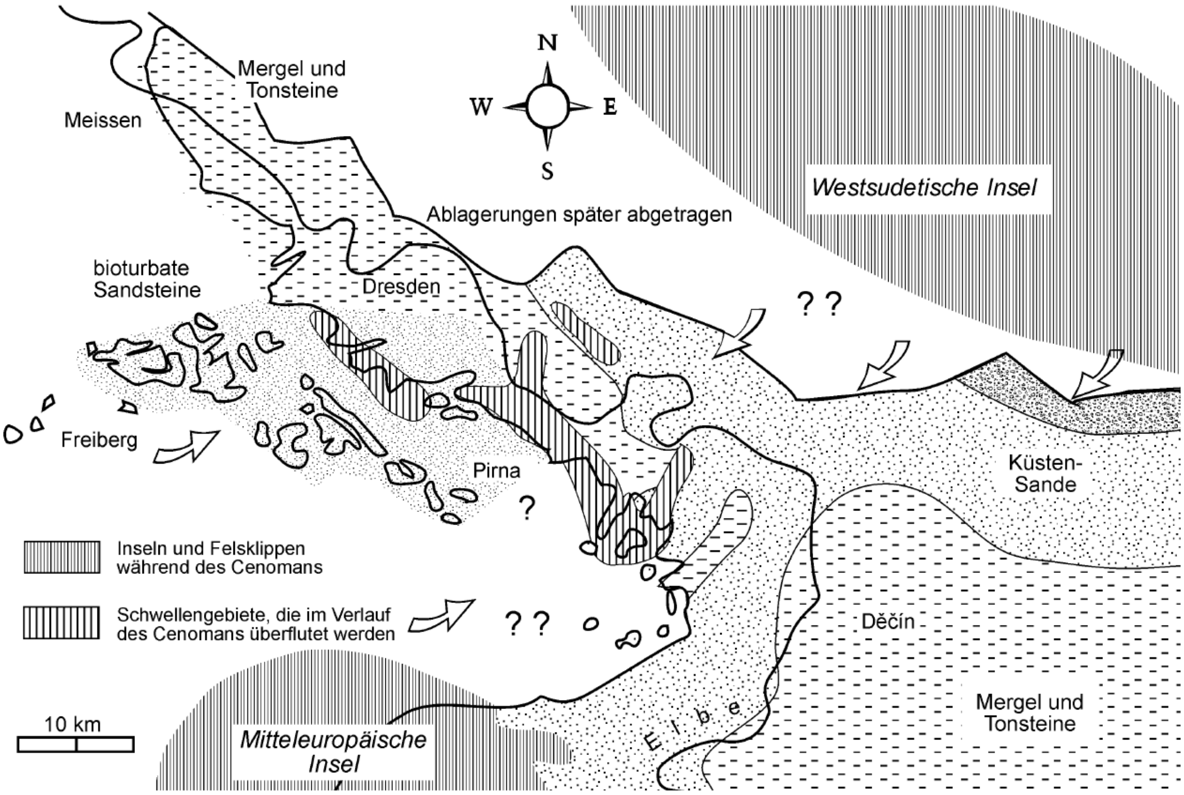

Fig. 4: Facies map of Upper Cenomanian, From: VOIGT (2007).

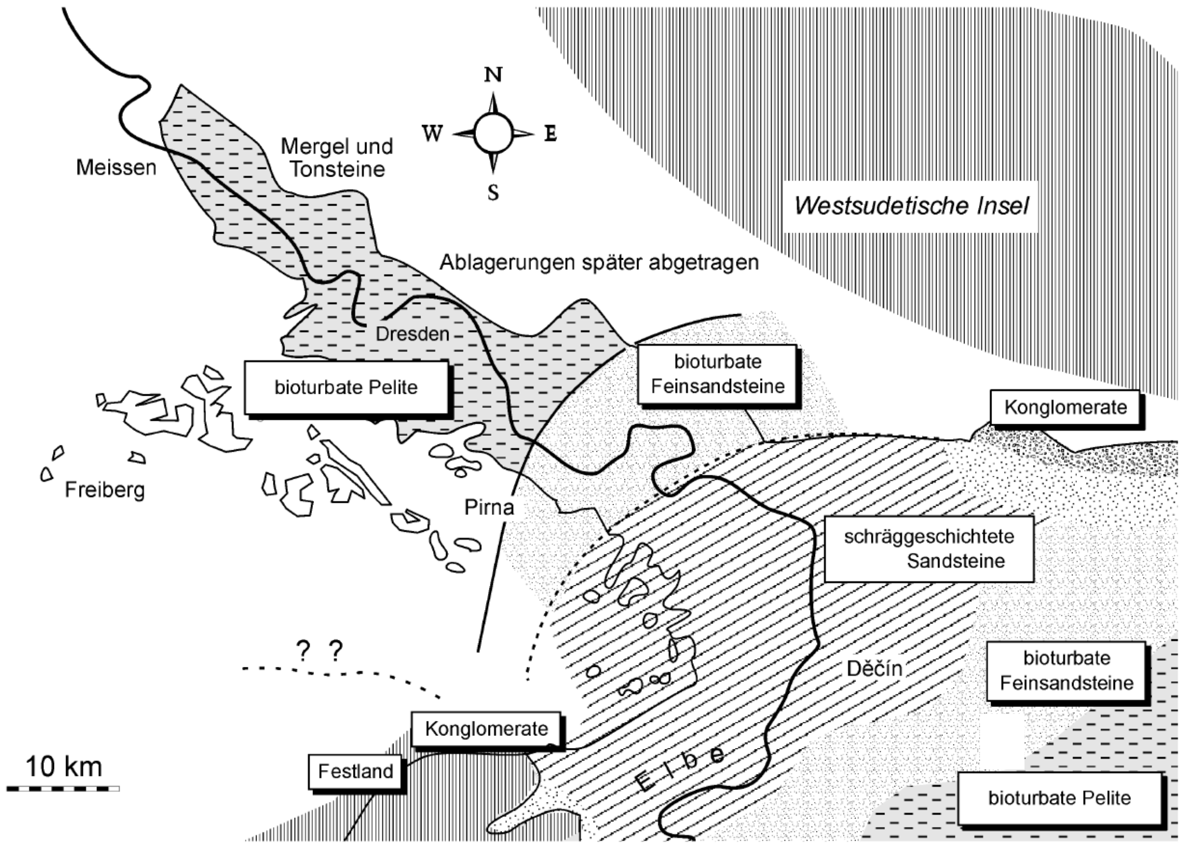

Fig. 5: Facies map of Lower Turonian/ basal Middle Turonian (Labiatus sandstone. From: VOIGT (2007).

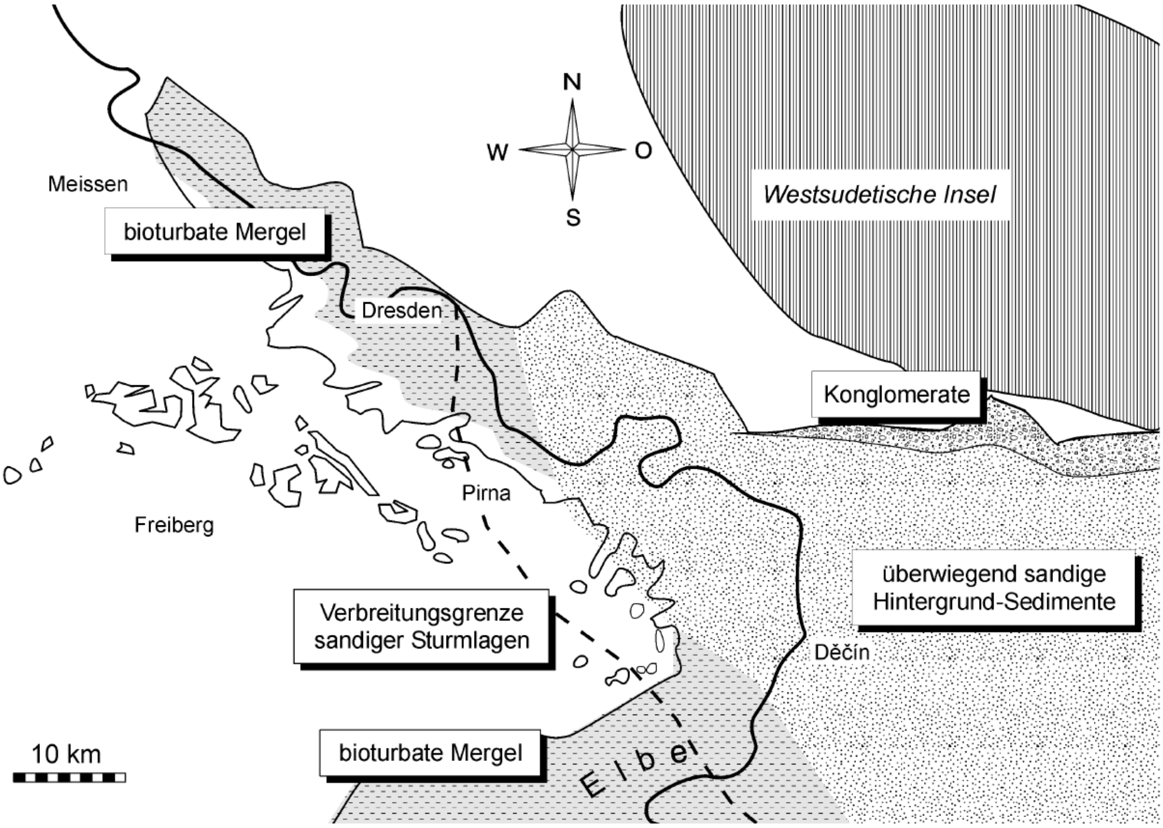

Fig. 6: Facies map of the higher Middle Turonian/ Upper Turonian. From: VOIGT (2007).

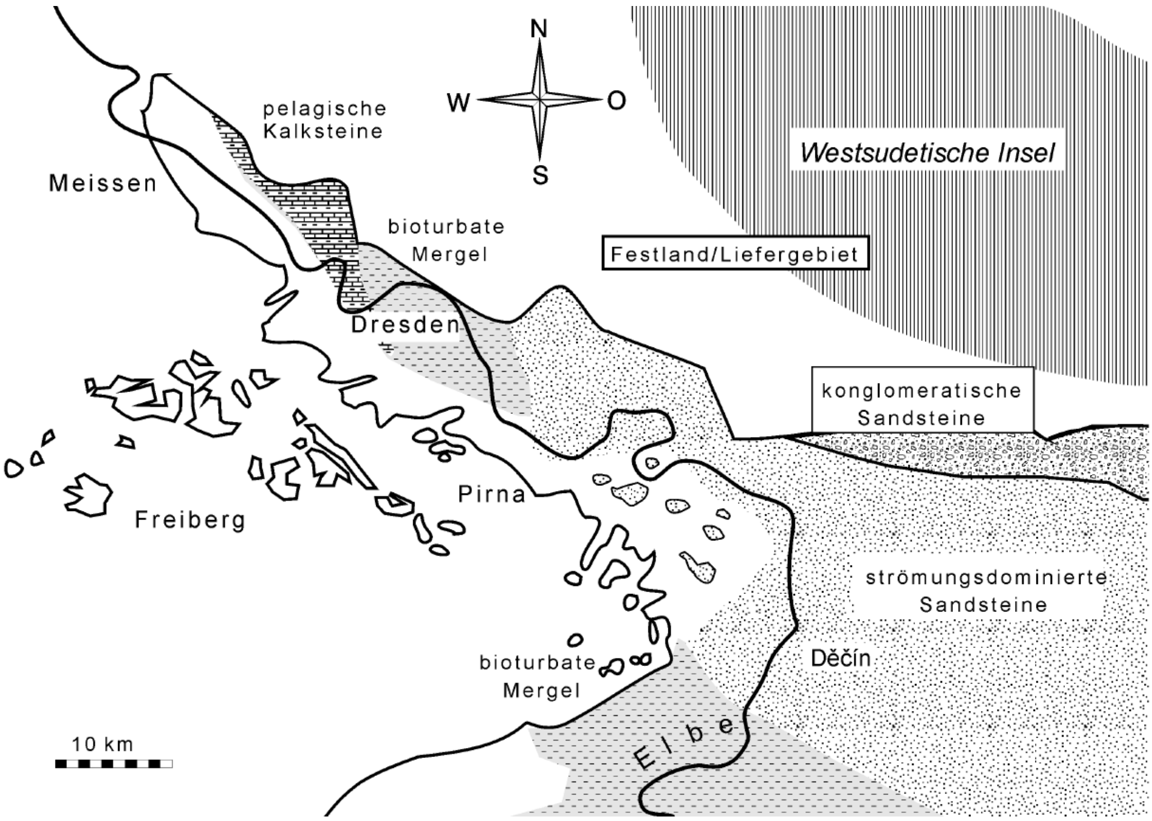

Fig. 7: Facies map of the higher Upper Turonian/ Lower Conacian. From: VOIGT (2007).

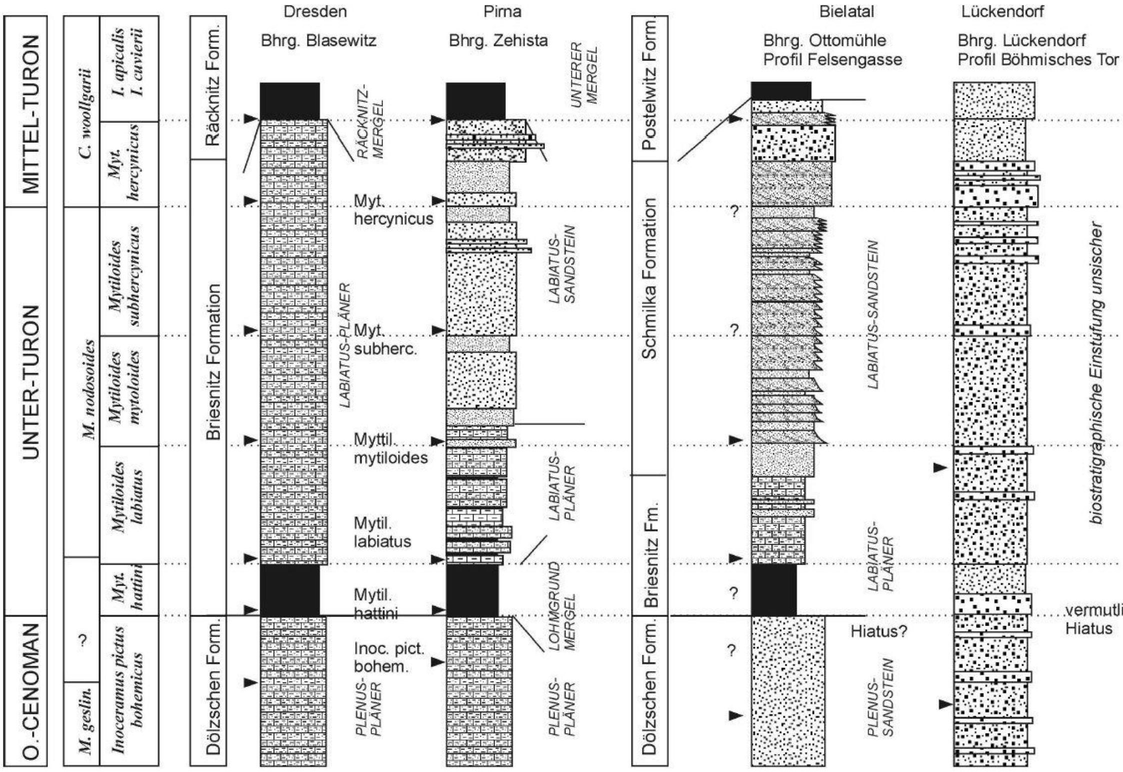

Fig. 8: Correlation of the Lower Turonian in Saxony on the base of borehole descriptions. The vertical extent of the profiles is not true to scale (does not correspond to the thickness) but to the extent of the biostratigraphic zones. The chronological extent of the biozones is not known. From: VOIGT et al. (2012).

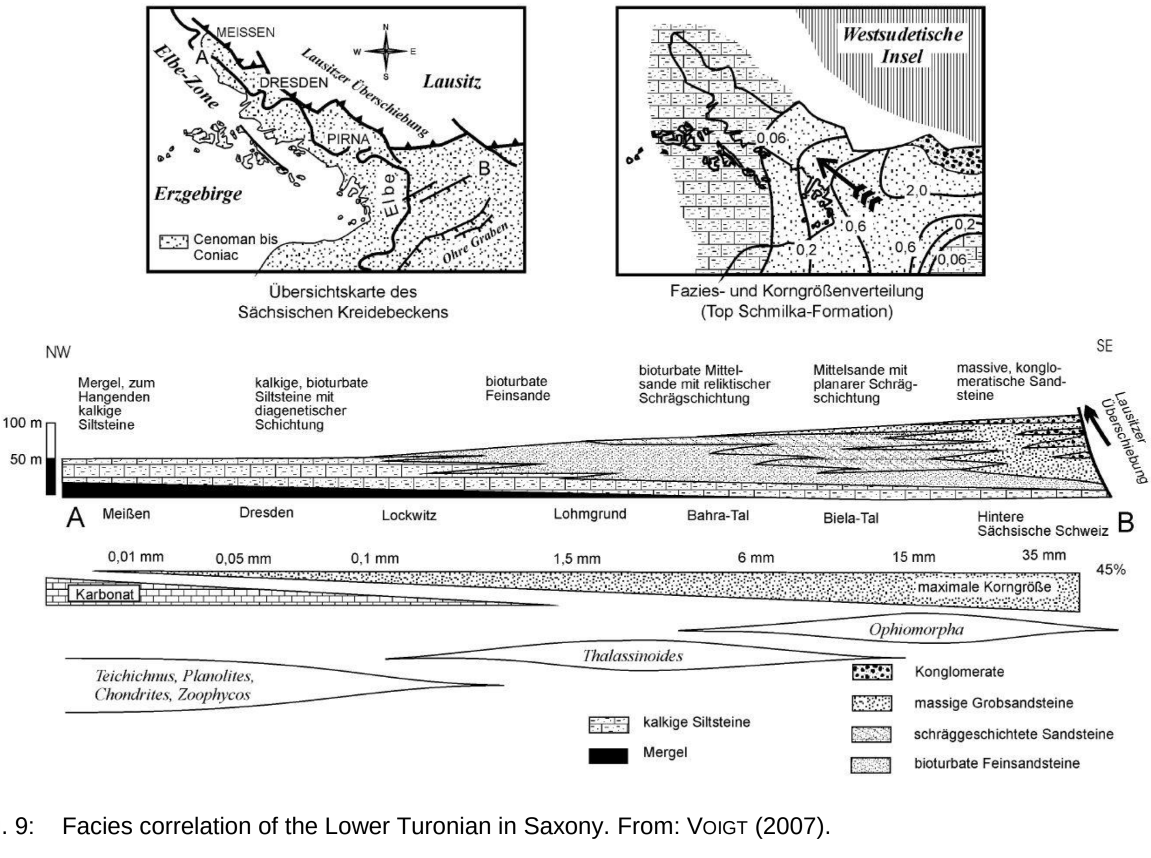

Fig. 9: Facies correlation of the Lower Turonian in Saxony. From: VOIGT (2007).

Excursion stops in Saxony

1. Kaiserkrone point with a view to Schrammstein Massif
2. Hockstein lookout point near Hohnstein

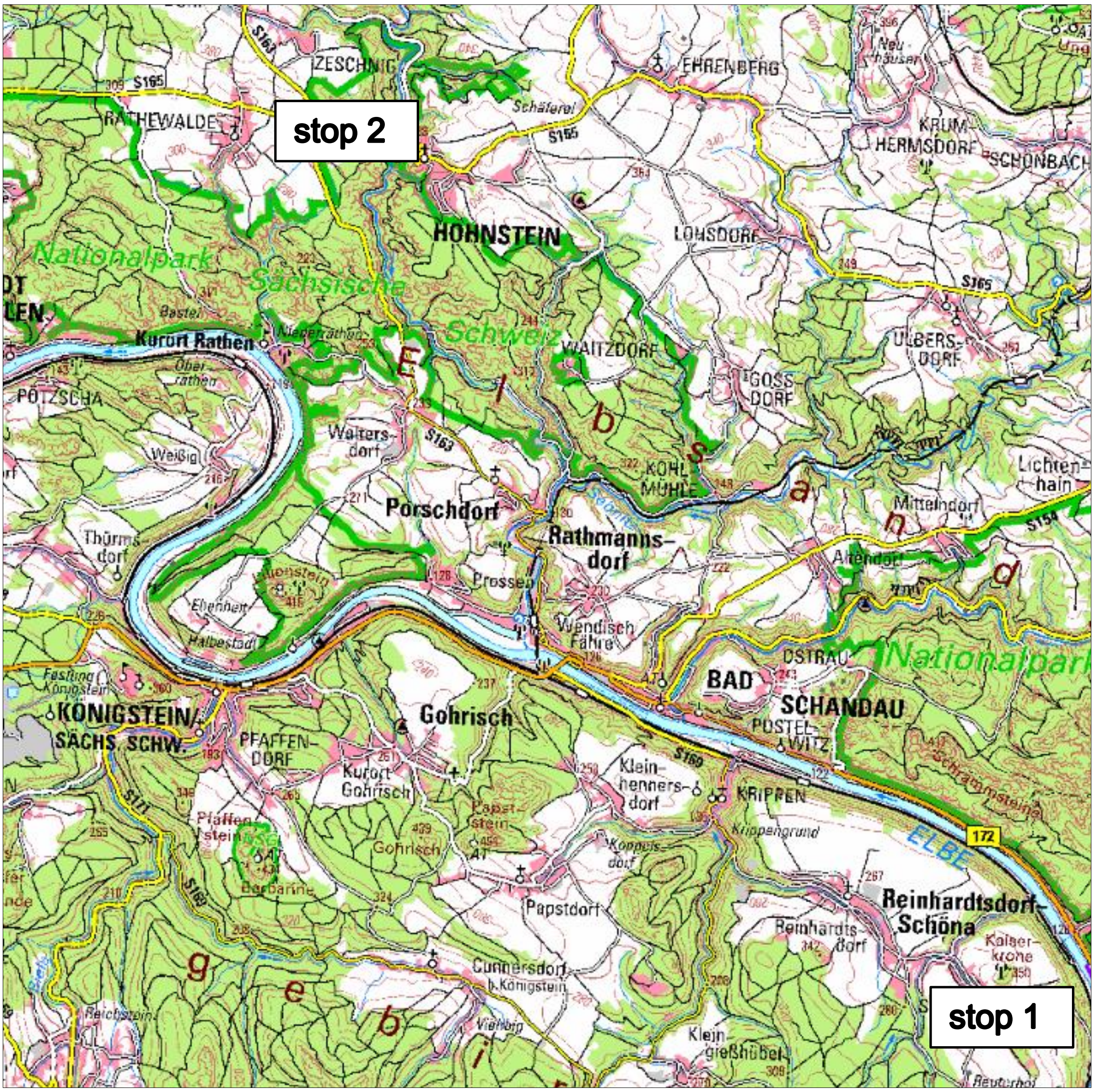

Fig. 10: Excursion stops in Saxony (In the background: Topographic map Staatsbetrieb Geobasisinformation und Vermessung Sachsen (GeoSN): http://geoportal.sachsen.de/cps/geosn)

Saxony - Stop 1

Location: Kaiserkrone point with a view to Schrammstein Massif. The Kaiserkrone is situated NW of Schöna close to the Bahnhofstraße, that proceeds down to the Elbe valley and left-elbian train stations of Schmilka-Hirschmühle and Schöna.

Stratigraphy: Turonian Postelwitz Formation (sandstones c1 – c3) and upper Turonian to lower Coniacian Schrammstein Formation (sandstones d and e); at Kaiserkrone only up to sandstone d (lower part), at Schrammsteinblick up to Sandstone e.

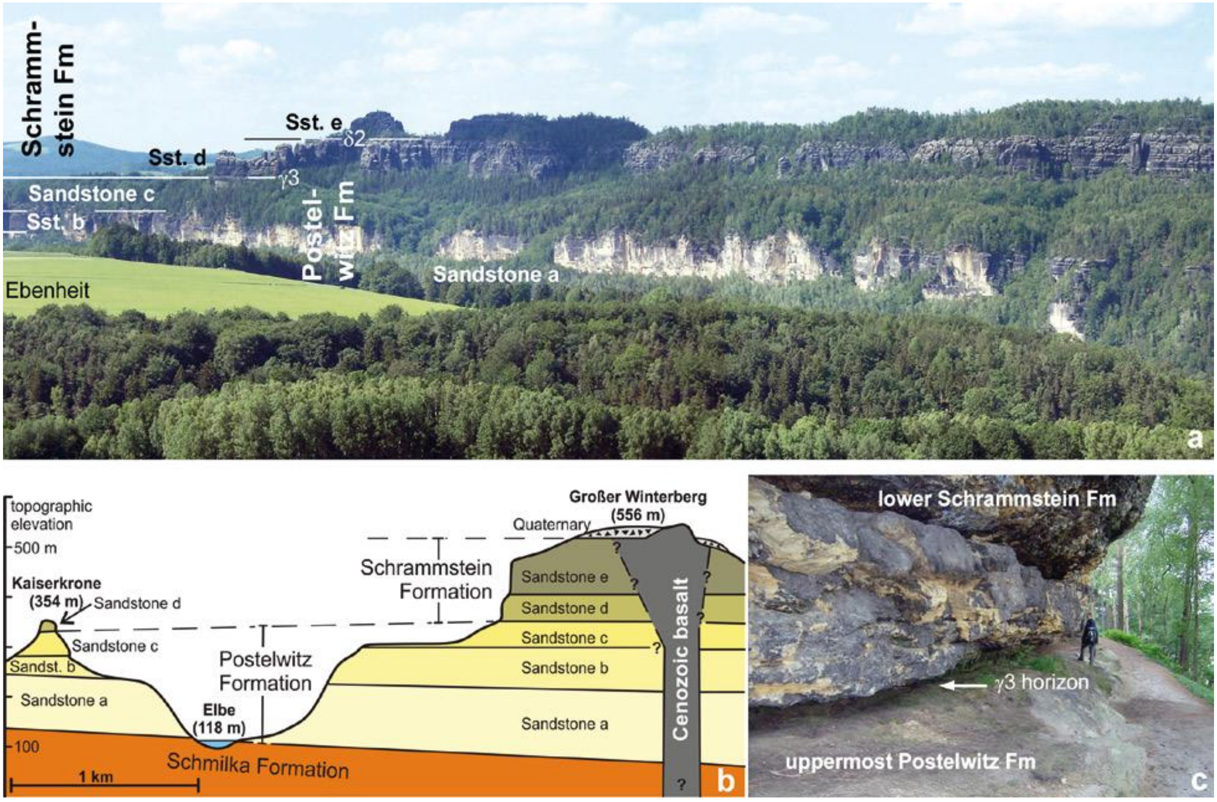

Fig. 11: Geomorphology and lithostratigraphy of the Saxonian Switzerland. a) view from the northern peak of the Kaiserkrone towards the Schrammstein Massif with indication of sandstone units, marker beds and formations. b) schematic cross-section from the Kaiserkrone to the Großer Winterberg. **c)** γ3 horizon at the Kaiserkrone. (From: WILMSEN & NIEBUHR 2014)

The Kaiserkrone is a typically small scaled table mountain of the Elbsandstein mountains that is strongly eroded. Its peak is subdivided into three single peaks by NNW/SSE striking joint sets, giving the peak a crown-like shape from a distance. The Kaiserkrone has an elevation of 354 m. It is easier to climb than the directly southward Zirkelstein (384 m). Further, the northern peak provides a remarkable view to the Schrammstein-Winterberg area where Lamprecht (1928, 1934) elaborated the classical formation of the rear Saxonian Switzerland and the subdivision into the sandstones a to e (Fig. 11 a). Besides, the wood covered hillside of the Kaiserkrone consist of the Upper Postelwitz Formation (sandstone c1 – c3), where the top ("crown") comprises thick bedded, coarse-grained sandstones of the sandstone d of the Lower Schrammstein Formation, which also contain portions of fine gravel (Fig. 11 b). Note the distinctive marker horizon γ3 that is situated between sandstone c3 of the Upper Postelwitz Formation and the sandstone d of the Lower Schrammstein Formation (Fig. 11 c), composed of a fine-grained matrix which is less cemented and forms distinctive gaps or caves due to the erosive propagation (note the granular material “Krümelsand”).

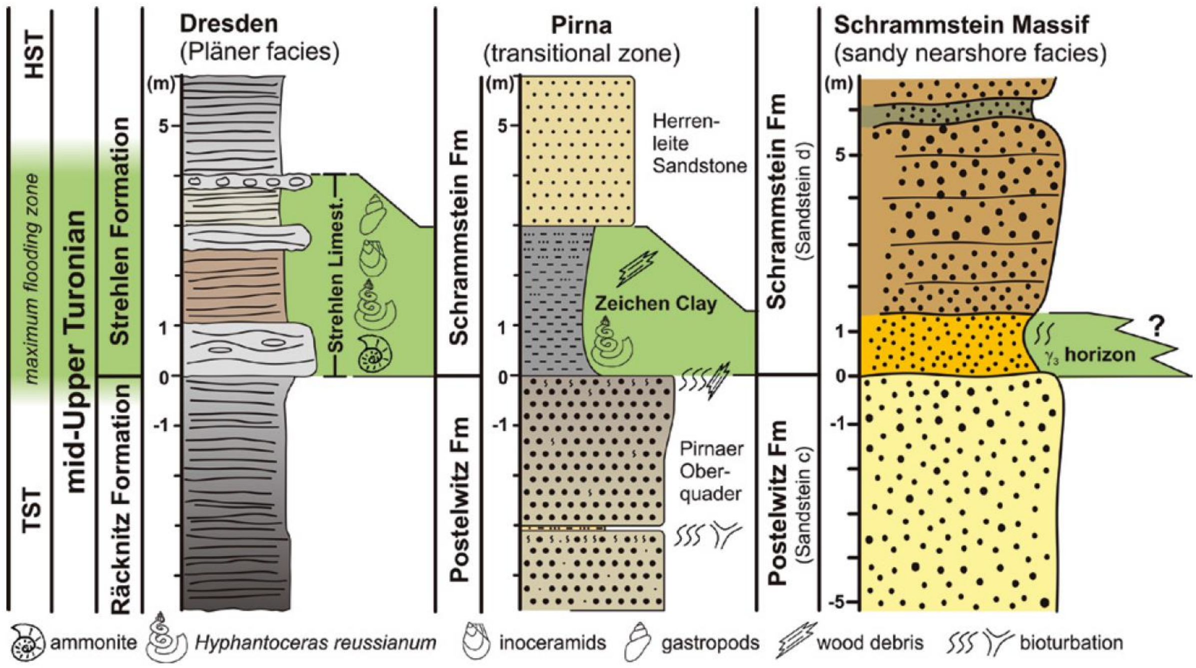

Fig. 12: Distal–proximal correlation of the Strehlen Limestone (lower Strehlen Formation, mid-Upper Turonian) with the Zeichen Clay (facies transition zone) and the γ3 horizon (Saxonian Switzerland) at the base of the Schrammstein Formation as a result of a maximum flooding zone; TST = transgressive systems tract, HST = highstand systems tract. Strehlen section after Tröger & Wolf (1960). From: WILMSEN & NIEBUHR 2014.

Many places exhibit alum weathering with its characteristic "Eating wounds", which are recognizable by the fresh, yellowish color of the sandstones. At the level of the γ3 horizon, a circular path leads around the three peaks of the Kaiserkrone. From the northern summit, the Postelwitz formation can be recognized very nicely at the remaining “Postelwitz quarries” in the geological profile at the slope of the Elbe river (especially sandstone a1 – a3, that were excavated as „Postaer Sandstein“; Fig. 11 a). The Schrammstein Massif is formed by approximately 50 - 60 m high, perpendicular rock walls of the sandstone d of the Lower Schrammstein Formation above the γ3 horizon. About 20 m below the peaks occurs another gap (δ2 horizon), which delineates the sandstone e of the Schrammstein Formation (Fig. 11 a), more often visible through the overgrown parts. The δ2 horizon comprises an approximately 4 m thick interval of thin-bedded, bioturbate fine-grained sandstones. The sandstone e reaches at least a thickness of 80 m at the Great Winterberg, while approximately 20 m are remaining at the “Schrammsteine” that form the top of the summit range. Only a few mountain tops of the Elbsandsteingebirge such as the Lilienstein and the Pfaffenstein have kept remains of the sandstone e.

Interpretation:

The stratigraphic boundary between the Postelwitz and the Schrammstein Formation constitutes a significant Upper Turonian marker horizon: The γ3 horizon represents a major transgressive event (well sorted, fine-grained marine quartz arenites) that correlates with the Strehlen and Weinböhlaer Limestone of the basin profiles of the Dresden area, and in addition with the Hyphantoceras event and the Zeichen Clay in the facies transition area (SEIFERT 1955, VOIGT 1994, TRÖGER & WEJDA 1997, JANETSCHKE & WILMSEN 2014, Fig. 12). The coarse-grained sandstones of the lower Schrammstein Formation mainly consist of quartz (with partly reddish color) but exhibit a poorly textural maturity (poorly sorting and roundness). Regarding the depositional environment, a coastal facies together with short transport of the detritus from the Lusatian Block can be observed. High sedimentation rates and therefore fast burial inhibited any further marine maturation of the coastal sand deposits. That led to the assumption of high subsidence in the area of the Lusatian Thrust and corresponding syn-sedimentary tectonics.

Further, the δ2 horizon shows an additional transgressional event affecting the coarse-grained coastal facies of the Schrammstein Formation. This is presumably an event of the Lowermost Coniacian, in particular when the correlation of the δ2 horizon with the Zatschke Marl is taken into account.

The presence of inoceramids of the Cremnoceramus-Waltersdorfensis and Cremnoceramus-deformis groups of the Lower Coniacian in the Zatzschke Marl near Pirna-Zatzschke is assured. However, sandstones c, d and e of the Schrammstein-Winterberg area only contain minor amounts of biostratigraphically useful fossils. All the important index fossils of the Upper Postelwitz Formation and the Schrammstein Formation, with the Lower Coniacian index-inoceramid Cremnoceramus inconstans from the borehole Rathewalde (TRÖGER 2008), derived from the transition area of the sandy to the marly lithofacies between Pirna - Wehlen - Rosenthal - Bielatal (see TRÖGER & VOIGT IN NIEBUHR et al. 2007, TRÖGER & NIEBUHR 2014).

Saxony - Stop 2

Location: Hockstein lookout point near Hohnstein. The Hockstein lookout is a cliff situated on the western slope of the Polenz valley. From the parking lot below the “Hocksteinschänke” a signposted hiking trail heading southeast to the Polenz valley. Across the Devil´s Bridge you can reach the Hockstein lookout point on top of a bluff.

Stratigraphy: Upper Turonian to Lower Coniacian Schrammstein Formation

Fig. 13: View from the Hockstein to the village of Hohnstein (Foto: ResiBil project).

The Hockstein consists of an articulated platform, whose almost vertical walls reign 100 m above the Polenz valley (Fig. 14). On the other side of the valley dominates the castle of Hohnstein surrounded by the village of Hohnstein to the NE (Fig. 13). From there, the Mühlbergstraße runs down in narrow bends to the Polenz valley and climbs up as Wartenbergstraße to the Hocksteinschänke. In 1958, the Lusatian Thrust was excavated during road works on the western side of the valley (Rast 1959). The Lusatian granodiorite was encountered in shallow NE-dipping tectonic contact with strongly jointed and silicified Turonian sandstones. Moreover, RAST (1959: 114) described a 20 to 30 cm thick zone of a "gray, silty, smeary substance" as product of "strongest pressing and grinding of the granite". In addition to this presumed mylonite, slickensides are also very frequent in the sandstones of the immediate surrounding, indicating the enormous stresses in a reverse fault. Unfortunately, the outcrop conditions and the accessibility of the profile at the Wartenbergstraße are severely restricted at the moment. Repeatedly, the sandstones of the Postelwitz and Schrammstein Formations near the Lusatian Thrust, are comprising intercalated matrix-rich breccia and conglomerates with gravel-sized components. Hence, indicating an increased topography in the vicinity and the availability of coarse clasts. The components are Jurassic limestones, limonite concretions, quartz, red siltstones and limonitic sandstone (HÄNTZSCHEL 1928, SEIFERT 1937, VOIGT 2009). Further, those elements pinch out to the west and therefore indicating an origin from the Lusatian block. Geomorphologically, the lithological change at the Lusatian Thrust is impressively demonstrated by the shape of the Polenz valley. In the northern part, the "Granitic Polenz valley" shows gentle slopes and an extended, meadow covered valley floor. Downstream to the south, the character changes rapidly to a canyon with steeply dipping walls. In the process, this narrow "Sandstone Polenz valley" carved out the sandstones d and e of the Schrammstein Formation (Upper Turonian to Lower Coniacian).

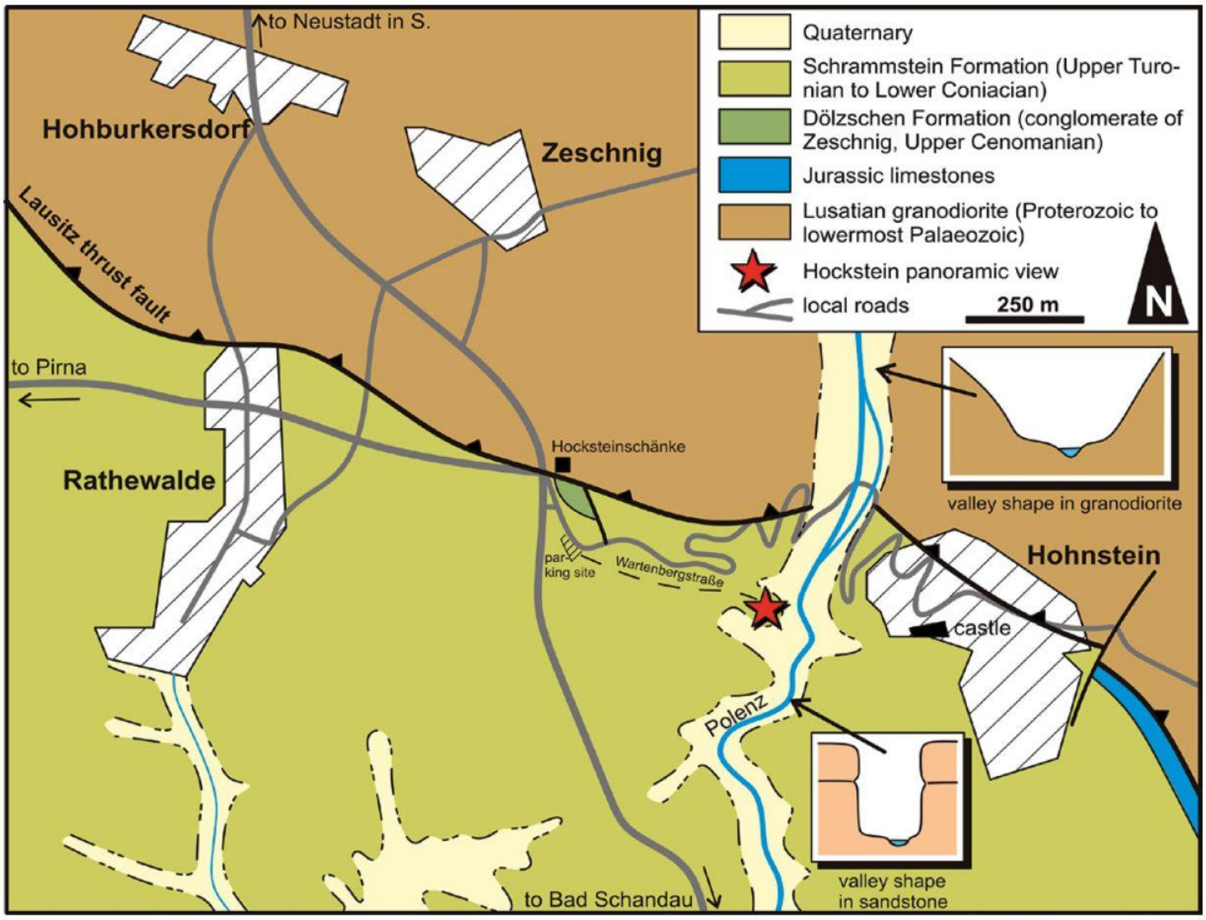

Fig. 14: Simplified geological map of the Hohnstein area (after RAST 1959) with position of the Hocksteinaussicht. From: WILMSEN & NIEBUHR 2014.

Interpretation:

VOIGT (2009) mentioned, that the Lusatian Thrust as north-east limiting structural element of the Saxonian Cretaceous Basin has been active since the late Cenomanian. Debris flow deposits in the sandstone rocks of the Postelwitz and Schrammstein Formations show, however, that the elevation and erosion of the Lusatian Block and the flexural subsistence of the edged trough is supposed to be intensified in the mid-Turonian stage. Until the early Coniacian mostly sedimentary cover was eroded in Lusatia (VOIGT 2009, HOFMANN et al. 2013). Also, the absence of layers which are younger than Coniacian age imply only speculative statements over the further course of the basin evolution. But it is assumed that recent 1000 m thick cover of the Cretaceous was substantially larger (VOIGT 2009), further expecting a similar chronological sequence for the Lusatian Thrust as like the “Harznordrand Fault” with an apex in the Santonian and Campanian (see: VOIGT et al. 2006).

References

HÄNTZSCHEL, W. (1928): Neue Aufschlüsse an der Lausitzer Hauptverwerfung bei Hohnstein (Sächs. Schweiz). – N. Jb. Mineral. Geol. Paläont., Beil.-Bd. 59, Abt. B: 80–116.

HOFMANN, M., LINNEMANN, U. & VOIGT, T. (2013): The Upper Cretaceous section at Schmilka in Saxony (Elbsandsteingebirge, Germany) – syntectonic sedimentation and inverted zircon age populations revealed by LA-ICP-MS U/Pb data. – Geol. Sax., 59: 101–130, Dresden.

JANETSCHKE, N. & WILMSEN, M. (2014): Sequence stratigraphy of the lower Upper Cretaceous Elbtal Group (Cenomanian – Turonian of Saxony, Germany). – Z. dt. Ges. Geowiss., 165: 179–208, Stuttgart.

LAMPRECHT, F. (1928): Schichtenfolge und Oberflächenformen im Winterberggebiete des Elbsandsteingebirges. – Mitt. Ver. Erdkunde, Jg. 1927: 1 – 48, Dresden.

LAMPRECHT, F. (1934): Die Schichtlagerung des Turons im sächsisch-böhmischen Elbsandsteingebirge. – Ber. mathem. phys. Kl. sächs. Akad. Wiss. Leipzig, 86: 155–186, Leipzig.

RAST, H. (1959): Geologischer Führer durch das Elbsandsteingebirge. – Bergakademie Freiberg Fernstudium: 1–224, Berlin (Dt. Verl. Wiss.).

SEIFERT, A. (1937): Die Gerölle im Turon-Sandstein entlang der Lausitzer Überschiebung im Elbsandsteingebirge. – Z. dt. geol. Ges., 89: 629–647, Berlin.

SEIFERT, A. (1955): Stratigraphie und Paläogeographie des Cenoman und Turons im sächsischen Elbtalgebiet. – Freiberger Forsch.-H., C 14: 1–218, Freiberg.

TRÖGER, K.-A. & WEJDA, M. (1997): Biostratigraphie der Strehlener Formation (Ob. Turon bis Unt.-Coniac) im Gebiet von Dresden. – Freiberger Forsch.-H., C 466: 1–17, Freiberg.

TRÖGER, K.-A. & VOIGT, T. (2007): Elbtal-Gruppe. – In: NIEBUHR, B., HISS, M., KAPLAN, U., TRÖGER, K.-A., VOIGT, S., VOIGT, T., WIESE, F. & WILMSEN, M. (Eds.), Lithostratigraphie der norddeutschen Oberkreide. Schrift-R. dt. Ges. Geowiss., 55: 50–66, Hannover.

TRÖGER, K.-A. (2008): Kreide – Oberkreide. – In: PÄLCHEN, W. & WALTER, H. (Eds.): Geologie von Sachsen. 311–358; Stuttgart.

TRÖGER, K.A. & NIEBUHR, B. (2014): Inoceramide Muscheln. – In: NIEBUHR, B. & WILMSEN, M. (Eds.): Kreide-Fossilien in Sachsen, Teil 1. Geol. Sax, 60(1): 169–199, Dresden.

VOIGT, T. (1995): Faziesentwicklung und Ablagerungssequenzen am Rand eines Epikontinentalmeeres – die Sedimentationsgeschichte der Sächsischen Kreide. – Diss., TU Bergakademie Freiberg: 1–130, Freiberg.

VOIGT, S., GALE, A.S. & VOIGT, T. (2006): Sea-level changes, carbon cycling and palaeoclimate during the Late Cenomanian of northwest Europe; an integrated palaeoenvironmental analysis. – Cret. Res., 27: 836–858, Amsterdam.

VOIGT, T. (2007): Die geologische Entwicklung der Elbtalkreide. - In: SIEDEL, H., FRANZEN, C. & WEISE, S. (Eds.): Elbsandstein – Beiträge zur Tagung des Arbeitskreises zur Erhaltung von Kulturgütern aus Stein (ARKUS) am 14./15. Juni 2007 in Dresden: 3–12, Dresden.

VOIGT, T. (2009): Die Lausitz-Riesengebirgs-Antiklinalzone als kreidezeitliche Inversionsstruktur: Geologische Hinweise aus den umgebenden Kreidebecken. – Z. geol. Wiss., 37: 15–39, Berlin.

VOIGT, T., FRANKE, J. & FRANKE, S. (2012): Kenntnisstandsanalyse zur Stratigraphie und Lithologie der Hinteren Sächsischen Schweiz. Erste Korrelations- und Messdaten. – GRACE Zwischenbericht, Jena.

VOIGT, T., FRANKE, J. & FRANKE, S. (2012): Excursion Materials. Saxonian Cretaceous Basin. Stratigraphy of the Elbsandsteingebirge. – EU-Project GRACE Excursion 27-11-2012. [Unpublished] .

VOIGT, T., FRANKE, J. & FRANKE, S. (2013): Grundlagen für ein geologisch-tektonisches Modell der Kreideablagerungen im Sächsisch-Böhmischen Grenzbereich im Rahmen des Ziel 3 – Projektes GRACE. – Abschlussbericht, Jena.

WILMSEN, M. & NIEBUHR, B. (2014): Stratigraphy and depositional setting of the Cretaceous in Saxony (Elbtal Group, Cenomanian – Lower Coniacian) - Geologica Saxonia., 60 (2): 347–369, Dresden.

Czech part

Česká geologická služba

Czech Republic – Stop 1

(Valečka Jaroslav)

Location: Belveder. It is a panoramatic viewpoint at the top of sandstone plateau on the eastern bank of Elbe river. The viewpoint is situated near the Hotel Belveder, west of Labská Stráň village.

Stratigraphy: Bílá Hora (power part) and Jizera (upper part of the section) Formations of presumably middle Turonian age. Boundary surface covering pavement of the viewpoint terrace.

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 18th 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.

Fig. 15: A surface in the top wall of coarse-grained Bílá Hora sandstone with numerous Thalassinoides-type bioturbation structures. The Belveder scenic terrace viewpoint.

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. 15). 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. 16).

Fig. 16: 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.

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.

Czech Republic – Stop 2 and 3 - Introduction and geological framework

(Nádaskay Roland)

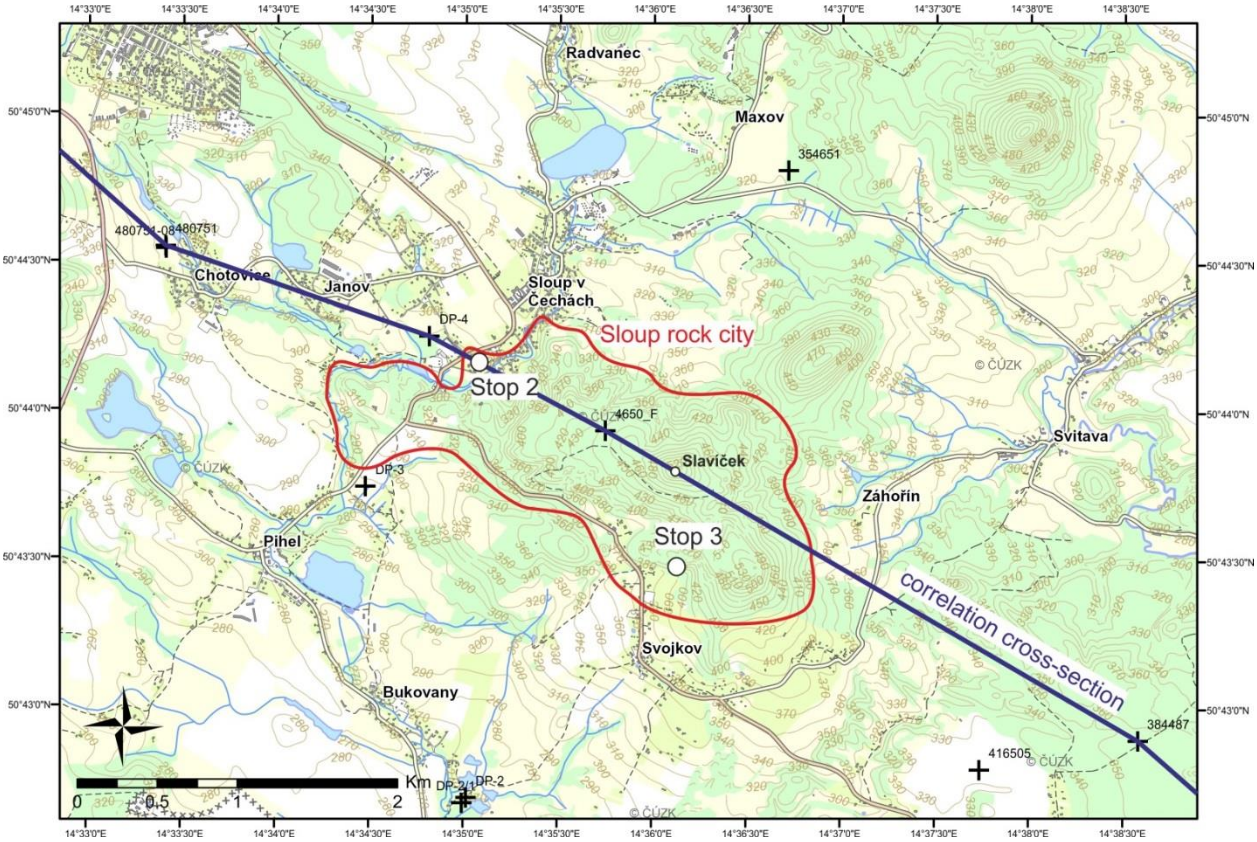

Fig. 17: Overview map showing location of stops 2 and 3 within Sloup rock city, located to the SE from Nový Bor. Blue line indicate correlation cross-section presented in Fig. 19.

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. 17, where Upper Turonian deposits of the Jizera Fm. crop out. Stratigraphic position of the area of interest is illustrated by Fig. 18. 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. 17), 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).

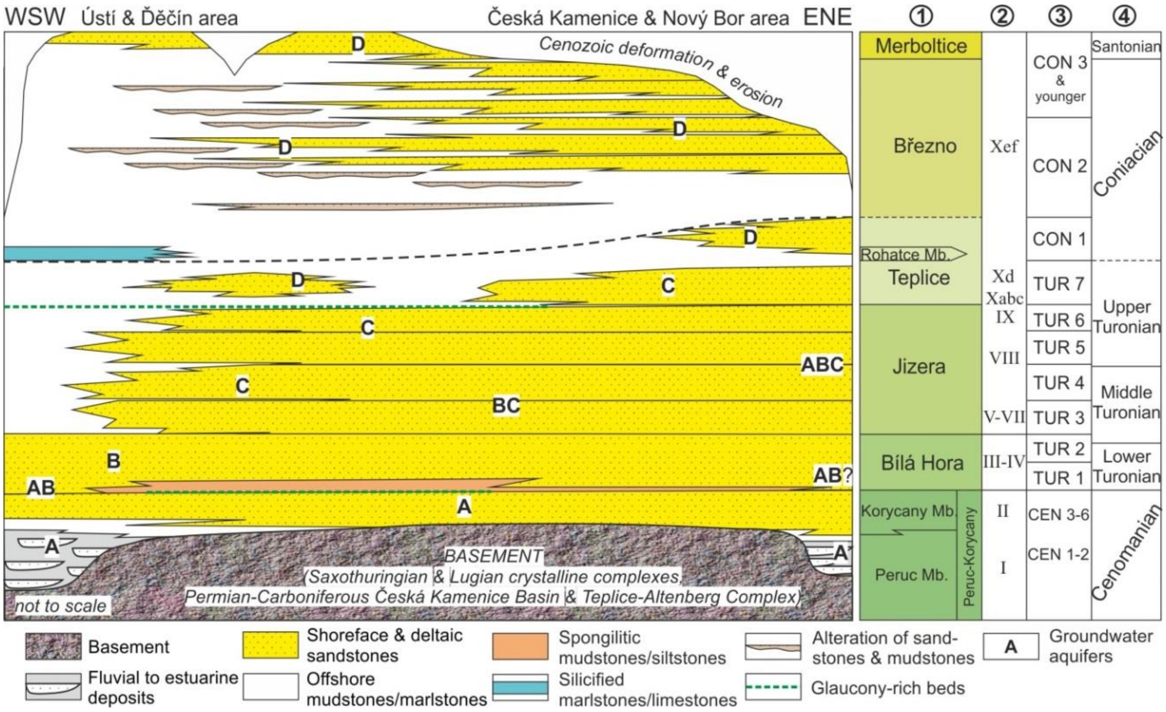

Fig. 18: Stratigraphy and lithofacies development of the NW-part of the BCB with indication of stratigraphic interval recorded by boreholes commented in the text. Explanations to stratigraphy: 1) regional lithostratigraphy after ČECH et al. (1980); 2) informal litostratigraphy after SOUKUP (1955); 3) 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 m, 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, 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.

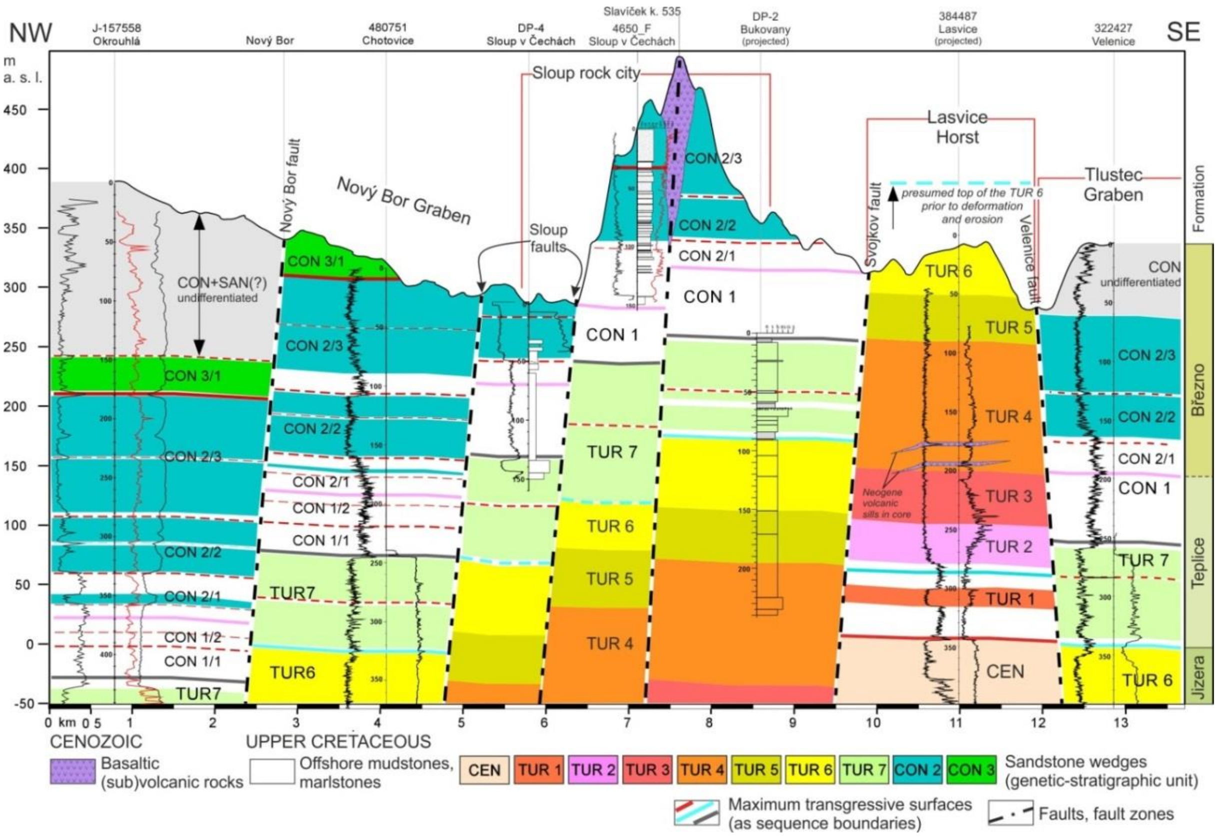

Fig. 19: Cross-section illustrating tectonic deformation of area in the vicinity of Nový Bor. Nový Bor and Tlustec Graben comprising young, Coniacian fill, are divided by NE–SW-oriented Lasvice Horst. Presence of an array of normal faults crossing the area of Sloup (NW margin of Sloup rock city) has been verified by borehole 4650_F. Modified after NÁDASKAY & ULIČNÝ (2014) and ULIČNÝ et al. (2015).

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.

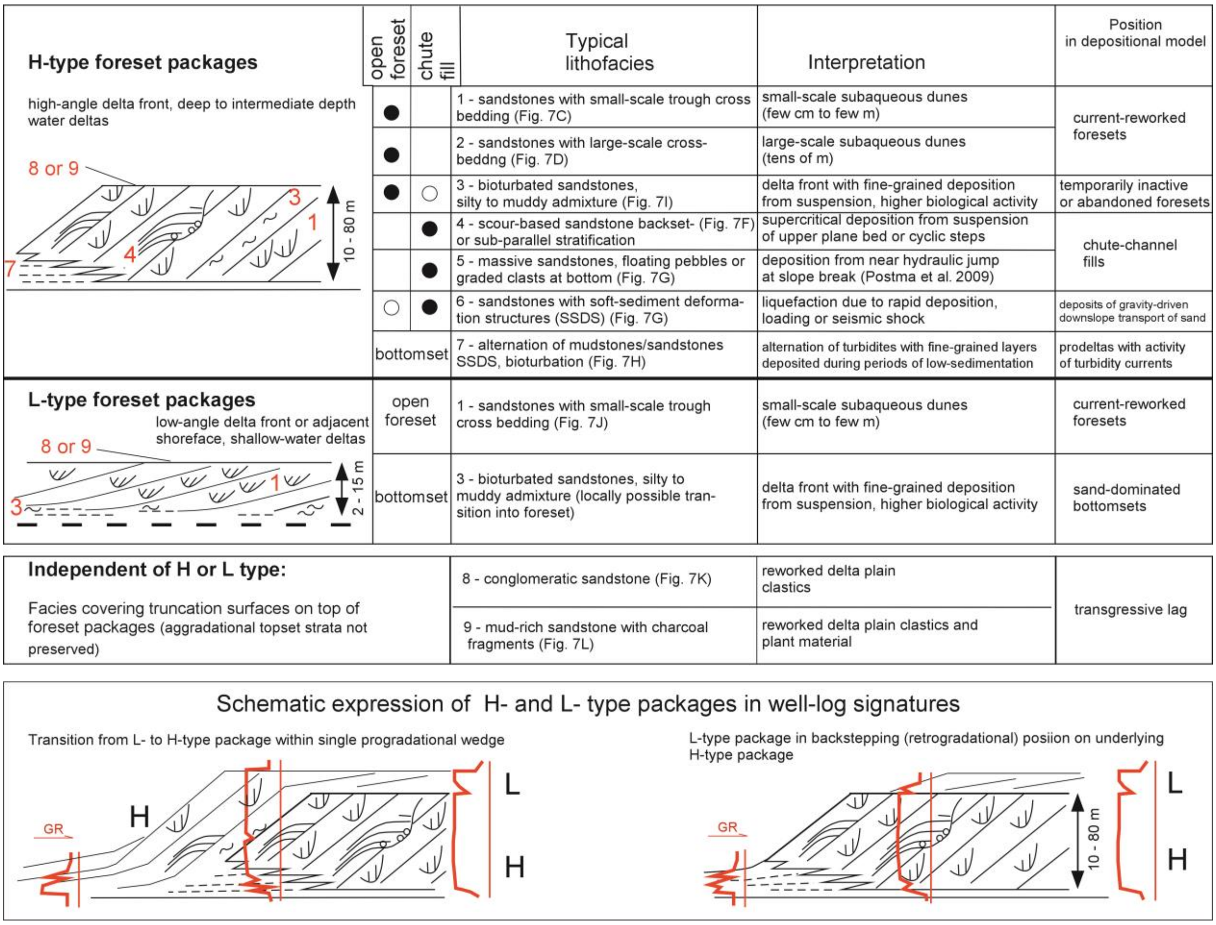

Fig. 20: Summary chart of the facies assemblages of individual geometric types of deltas and their depositional environments with respect to the proposed depositional model (Fig. 7). Inset sketches illustrate the principal features of the type-H and type-L foreset packages, with numbers of individual 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).

Czech Republic – Stop 2

(Nádaskay Roland)

Location: Exposures of Coniacian sandstones in Sloup v Čechách village. Section Sloup rock castle is located in the western part of Sloup rock city in Sloup village.

Stratigraphy: Březno Formation in sandstone development of early to middle Coniacian age.

The solitary rock under the Sloup Castle represents a typical exposure of H-type delta slope foresets. As evident from the photomosaic (Fig. 21), 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. 19) 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. 21).

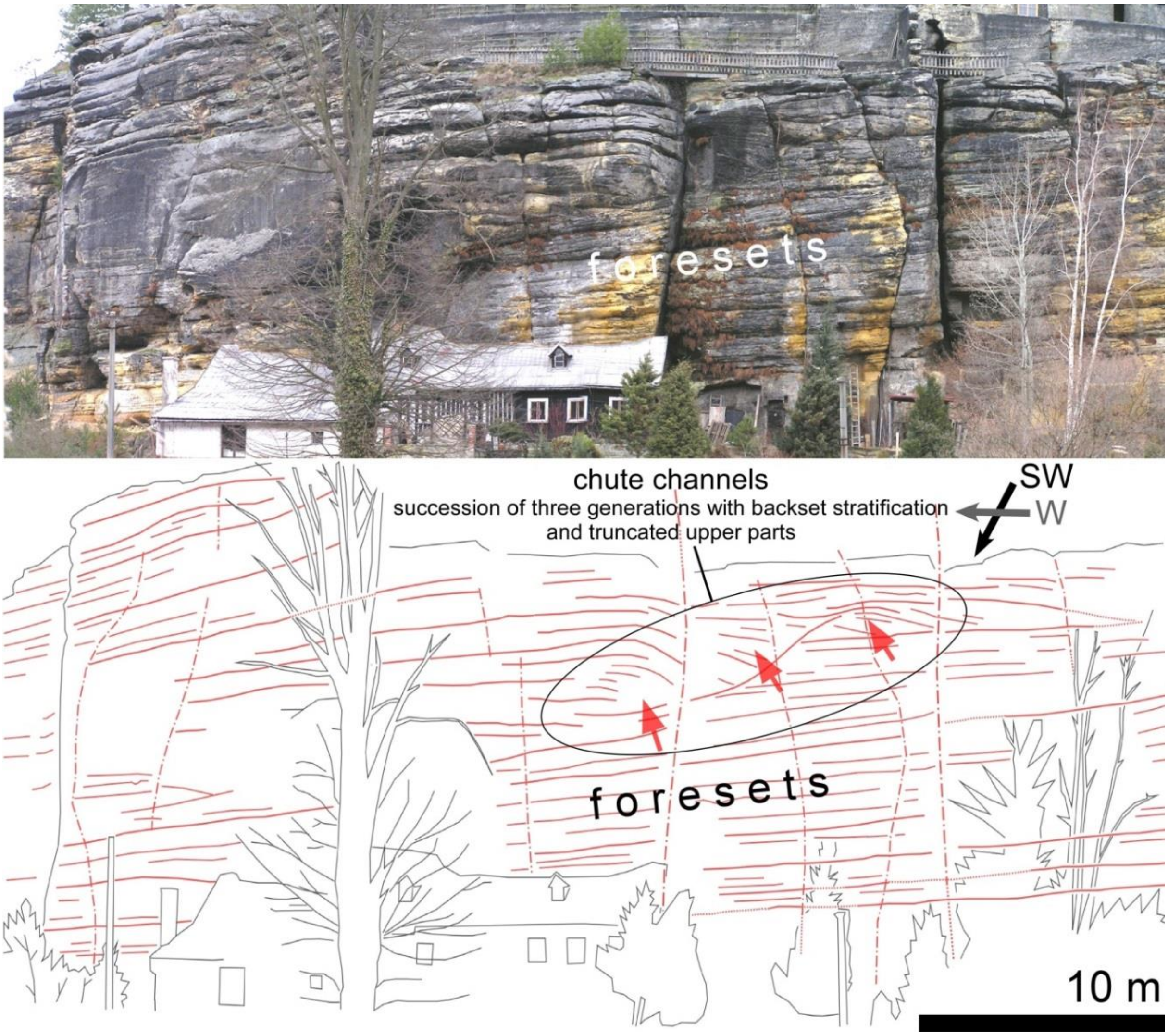

Fig. 21: Photomosaic of H-type foreset package (locality Rock Castle, Sloup v Čechách) interpreted as a part of the Sloup Rock City delta, sequence CON 2/3. The inclination of foresets (~15°) in the oblique cross-section is lower than the real dip angle. Black arrow: dip direction (220°), gray arrow: 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.

Czech Republic – Stop 3

(Nádaskay Roland)

Location: Exposures of Coniacian sandstones around the Slavíček hill (near Svojkov village). Section Dědovy kameny (Old man' rocks) is located in the eastern part of the Sloup rock city near Svojkov village.

Stratigraphy: Březno Formation in sandstone development of early to middle Coniacian age.

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. 22). 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 interpreted 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.

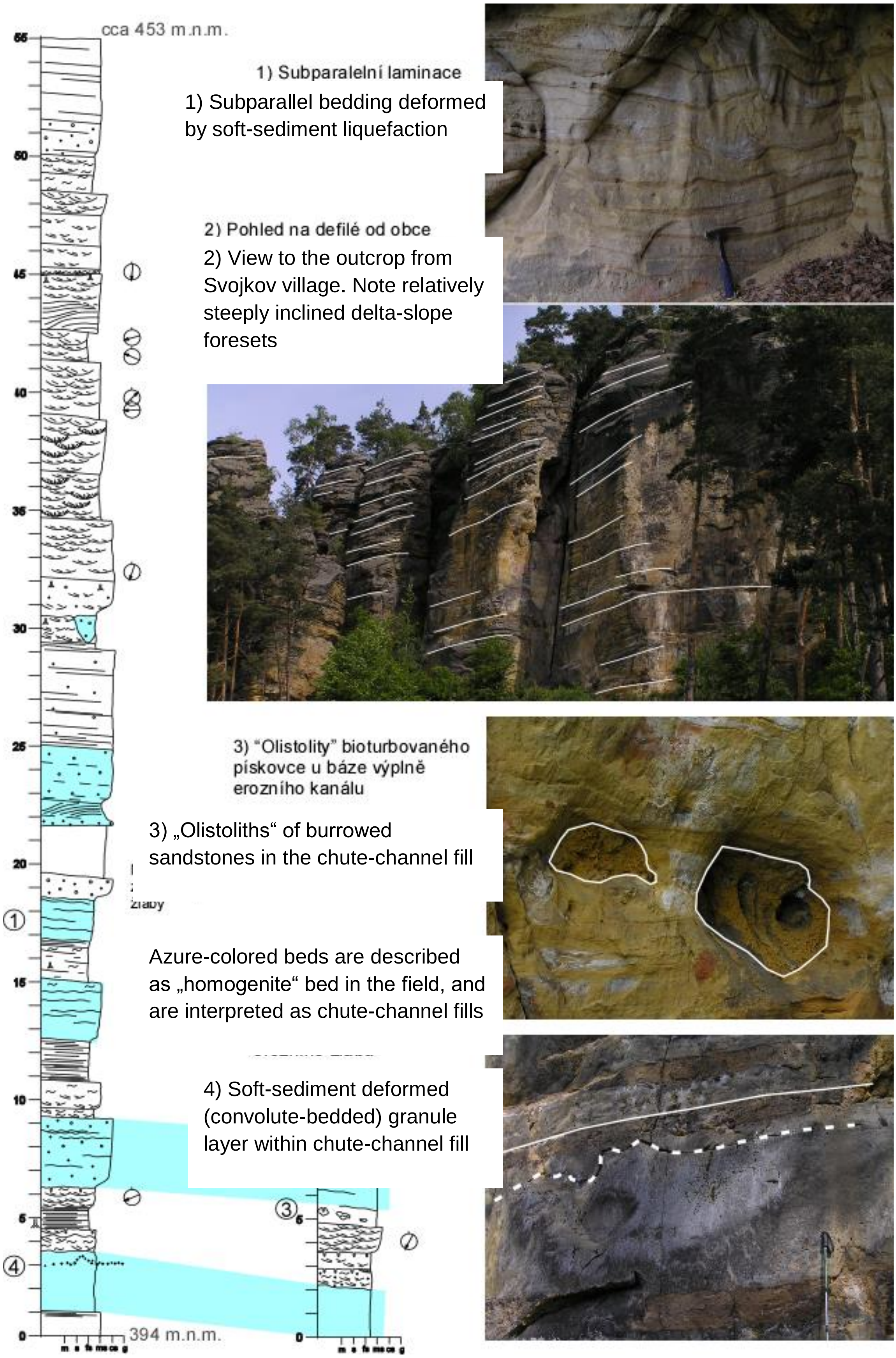

Fig 22: Section Svojkov – Dědovy kameny

Czech Republic – Stop 4
(Mrázová Štěpánka)

Location: Jurassic limestones at Doubice – Vápenka (Vápenný vrch)

Stratigraphy: Doubice Formation of presumed late Jurassic age (Oxfordian to Kimmeridgian according to Eliáš 1981).

The Jurassic limestones crop out at several small localities near Doubice (Daubitz), Kyjov (Khaa) and Brtníky (Zeidler). They occur nowhere else in Bohemia. 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. 23).

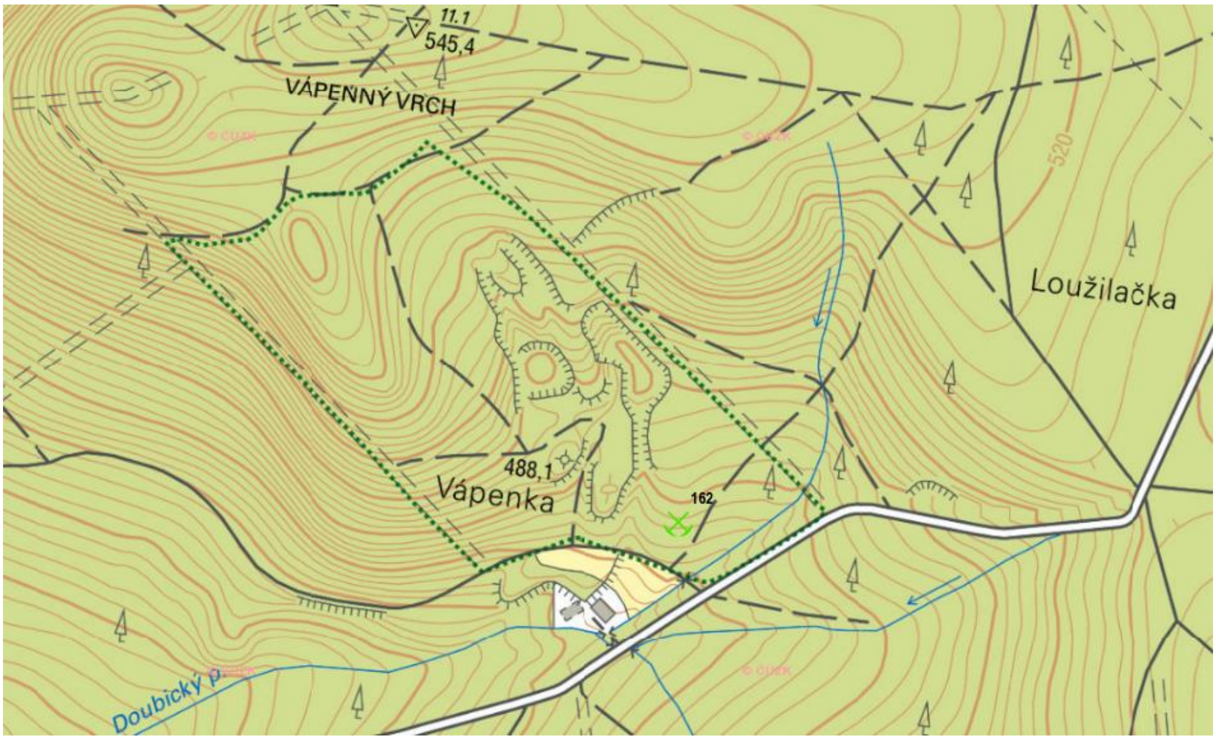

Fig. 23: The detail map with a number of abandoned shelf quarries and pit quarries on Vápenný vrch.

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. 24).

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. 25).

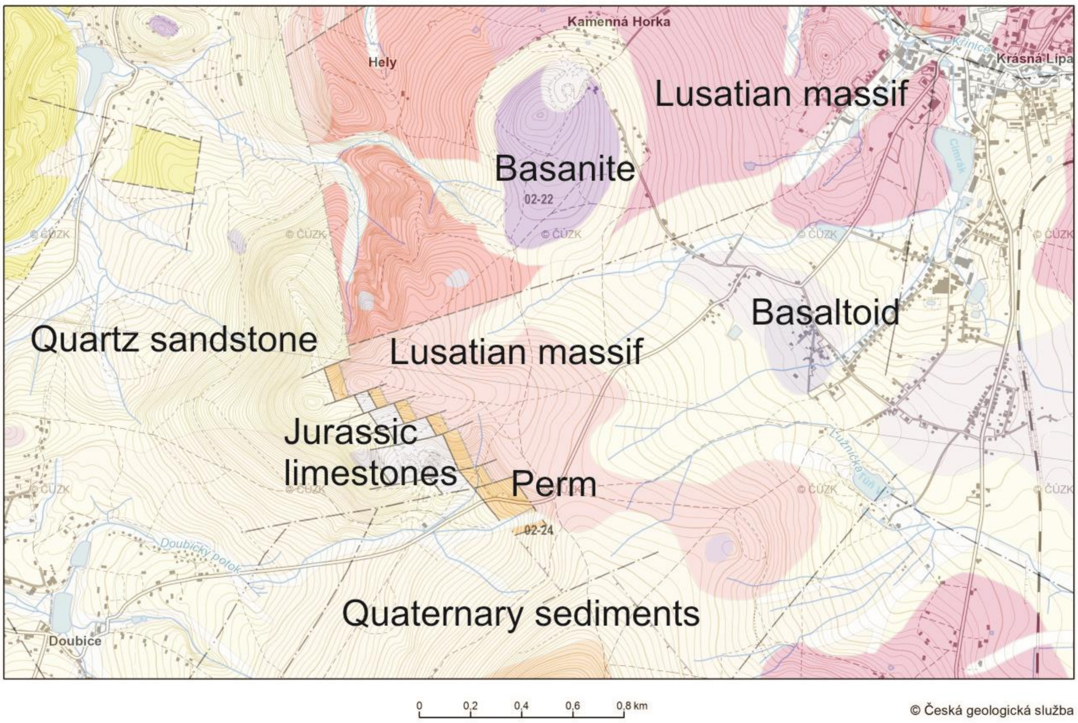

Fig. 24: The Geological map near Doubice – Vápenný vrch.

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. 25: The bluish grey to brown-grey dolomitic limestones and dolomites.

Czech Republic – Stop 5
(Mlčoch Bedřich)

Location: Milířka - Lusatian Fault

Stratigraphy: Cadomian granodiorites of the Lusatian Massif and sedimentary rocks along the Lusatian fault of Permian and Late Cretaceous age (presumably Cenomanian and Turonian)

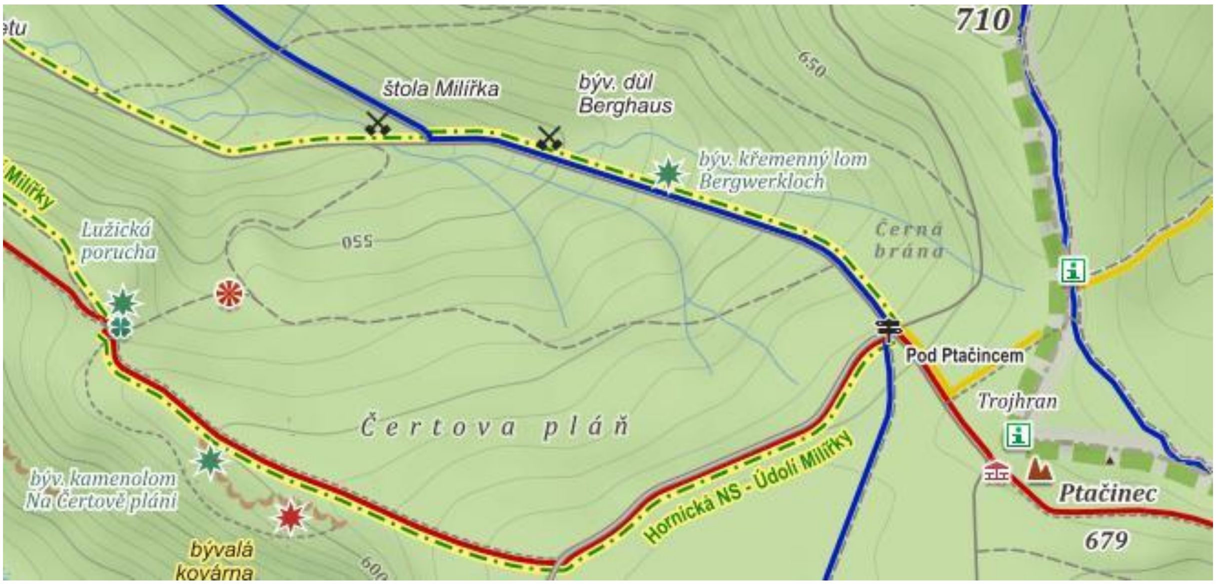

Fig. 26: The tourist map of the valley Milířka.

The Milířka stream bed forms a deeply incised valley, about 2 km south of Dolní Podluží village (Fig. 26). 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. 27).

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. 28). 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.

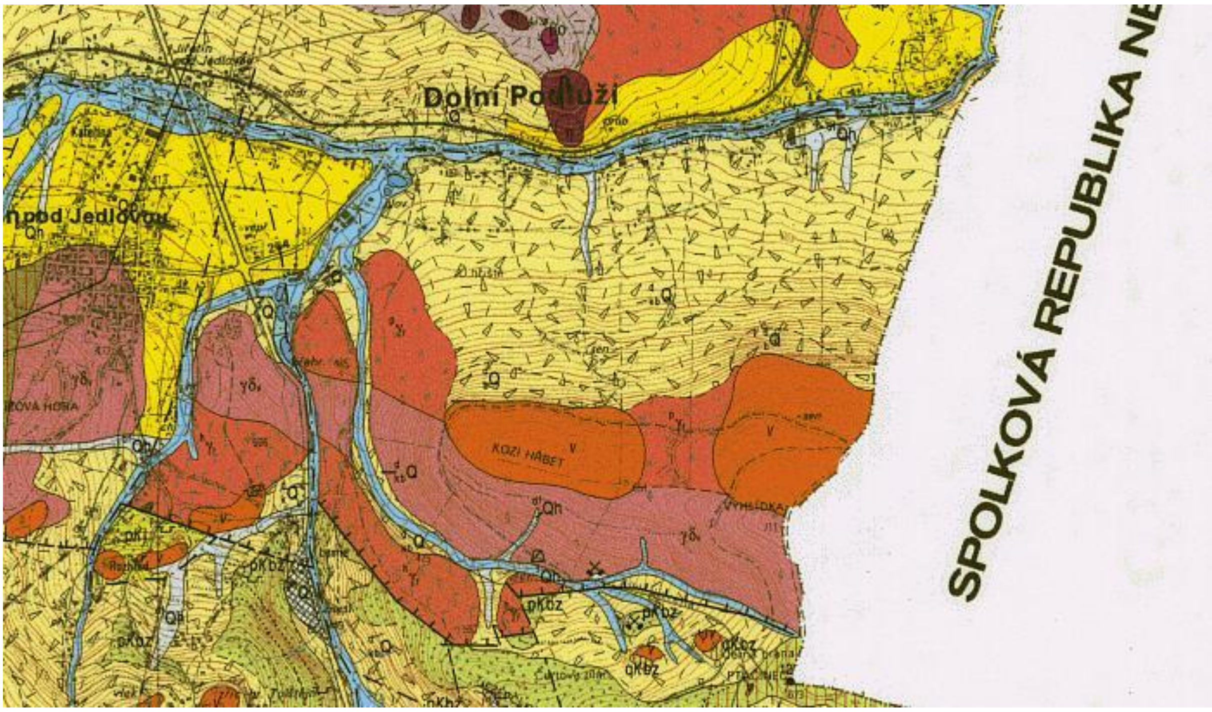

Fig. 27: The geological map around the Milířka stream.

Fig. 28: 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 m. 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.

Czech Republic – Stop 6

(Mrázová Štěpánka)

Location: Dutý kámen near Cvikov (Hohlstein near Zwickau in Bohemia, Cretaceous Basin)

Stratigraphy: Sandstone of Březno Formation of early Coniacian age. Polzenite intrusion of Tertiary (presumalby Oligicene–Miocene) age.

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. 29).

Fig. 29: The columnar jointing of sandstone.

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.

References

BRUDER, G. (1882): Neue Beiträge zur Kenntnis der Jura-Ablagerungen im nördlichen Böhmen. - S.B. Akad. Wiss., 85. Wien.

BRUDER, G. (1886): Neue Beiträge zur Kenntnis der Jura-Ablagerungen im nördlichen Böhmen. - S.B. Akad. Wiss., 93. Wien.

ČECH, S., KLEIN, V., KŘÍŽ, J. & VALEČKA, J. (1980): Revision of the Upper Cretaceous stratigraphy of the Bohemian Cretaceous Basin. – Věstník ÚÚG, 55: 277–296.

ČECH, S., HERCOGOVÁ, J., KNOBLOCH, E., PACLTOVÁ, B., POKORNÝ, V., SAJVEROVÁ, E., SLAVÍK, J., ŠVÁBENICKÁ, L. & VALEČKA, J. (1987): Svrchní křída ve vrtu Volfartice Vf-1. – Sbor. geol. věd, Geol., 4: 113–159.

Eliáš, M. (1981): Facies and paleogeography of the Jurassic of the Bohemian Massif. Sbor. geol. věd, Geol., 35, 75–144.

FEDIUK, F. et al. (1958): Geologické poměry území podél lužické poruchy ve šluknovském výběžku. - Rozpr. čes. akad. věd, mat.-přír., 68, 9. Praha.

GEINITZ, H.B. (1850): Quadergebirge oder Kreideformation in Sachsen: 44 S., Leipzig (Weidemann).

CHRT, J. (1957): Závěrečná zpráva o vyhledávacím průzkumu Lužická porucha. - Geofond Praha.

KLEIN, V. et al. (1971): Vysvětlující text k základní geologické mapě 1 : 25 000 list M-33-41-B-d (Chřibská). - MS Archiv ČGÚ. Praha.

KLOMÍNSKÝ, J. et al. (1994): Geologický atlas České republiky. Stratigrafie. - Čes. geol. úst., Praha

NÁDASKAY, R. & ULIČNÝ, D. (2014): Genetic stratigraphy of Coniacian deltaic deposits of the northwestern part of the Bohemian Cretaceous Basin. Z. Dt. Ges. Geowiss., 165 (4), 547–575.

NÁDASKAY, R. – VALEČKA, J. – ČECH, S. (in press): Příspěvek jádrových vrtů projektu Rebilance zásob podzemních vod k stratigrafii, sedimentologii a tektonice svrchní křídy v sz. části české křídové pánve. – Zpr. geol. výzk. 2017.

RAJCHL, M., ULIČNÝ, D., GRYGAR, R. & MACH, K. (2009): Evolution of basin-fill architecture in an incipient continental rift: the Cenozoic Most Basin, Eger Graben, Central Europe. – Basin Res., 21 (3): 269–294.

SOUKUP, J. (1955): Úprava stratigrafického členění a otázka hranice mezi turonem a senonem v české křídě. – Sbor. Ústř. úst. geol., 21, 633–673.

SVOBODA, J. et al. (1964): Regionální geologie ČSSR. - Díl 1, ÚÚG. Praha.

ULIČNÝ, D. (2001): Depositional system and sequence stratigraphy of coarse-grained deltas in shallow-marine, strike-slip setting: the Bohemian Cretaceous Basin, Czech Republic. – Sedimentology, 48 (3): 599–628.

ULIČNÝ, D., ČECH, S. & GRYGAR, R. (2003a): Tectonics and depositional systems of a shallow-marine, intra-continental strike-slip basin: exposures of the Český Ráj region, Bohemian Cretaceous Basin. Excursion Guide, First Meeting of the Central European Tectonics Group and Eighth meeting of the Czech Tectonic Studies Group. – Geolines, 16: 133–148.

ULIČNÝ, D., LAURIN, J. & ČECH, S. (2009a): Controls on clastic sequence geometries in a shallow-marine, transtensional basin: the Bohemian Cretaceous Basin, Czech Republic. – Sedimentology, 56 (4): 1077–1114.

ULIČNÝ, D., RAJCHL, M., GRYGAR, R. & ŠPIČÁKOVÁ, L. (2011): Roles of structural inheritance and palaeostress regime in the evolution of the Cenozoic Eger Graben, Bohemia. – Travaux Géophysiques XL (2011). Abstracts of the 9th Central European Tectonic Groups meeting: 87–88

ULIČNÝ, D. – ŠPIČÁKOVÁ, L. – CAJZ, V. – HRONEC, L. (2015): Podklady pro prostorový model hydrogeologicky významných stratigrafických rozhraní ve vybraných hydrogeologických rajonech. Geofyzikální ústav AV ČR. Závěrečná zpráva. – MS archiv Čes. geol. služba.

VALEČKA, J. (1979a): Paleogeografie a litofaciální vývoj severozápadní části české křídové pánve. – Sbor. geol. věd, Geol., 33: 47–81.

VALEČKA, J. (1979b): Barier island in the Bohemian Upper Cretaceous Basin. – Čas. mineral. geol., 24: 175–184.

VALEČKA, J. (1984): Storm surge versus turbidite origin of the Coniacan to Santonian sediments in the eastern part of the Bohemian Cretaceous Basin. – Geol. Rundschau, 73: 651–682.

VALEČKA, J. (ed.) et al. (1997): České Švýcarsko. Geologická a přírodovědná mapa 1:25.000.- ČGÚ, Praha.

VALEČKA, J. & REJCHRT, M. (1973): Litologie a geneze tzv. flyšoidní facie coniaku ve východní části Českého středohoří. – Čas. mineral. geol., 18: 379–391.