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# Examples of important geological localities in the Sudetes (Czech Republic)

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A b s t r a c t . This contribution provides a representative overview of several major geologic localities of the Czech part of the Sudetic (Lusatian) region. It contains examples of localities of Europe-wide importance from the Sudetic crystalline complexes, Palaeozoic (Silurian, Devonian, Carboniferous) fossil-bearing deposits as well as Jurassic and Cretaceous platform sediments. These localities are already protected by the Czech Government as national nature reserves, national nature monuments, or their protected status is in preparation.

Key words: geoconservation, network of European geosites, Sudetes, Czech Republic.

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S t r e s z c z e n i e. Artykuł daje reprezentatywny wgląd w kilka głównych geologicznych stanowisk czeskiej części Sudetów (region luzytański). Omówione zostały przykłady stanowisk o znaczeniu europejskim, reprezentujące krystaliczne kompleksy skalne, paleozoiczne osady z fauną (sylur, dewon, karbon) oraz platformowe utwory jury i kredy. Stanowiska te znajdują się już pod ochroną rządu czeskiego, jako narodowe rezerwaty i pomniki przyrody, albo ich status ochrony jest przygotowywany.

Słowa kluczowe: geoochrona, sieć europejskich geostanowisk, Sudety, Republika Czeska.

There is no agreement in the orographic, geographic or even geologic terminology and it is therefore hard to interrelate both national territorial denominations. The Sudetes is both a geographic and a geologic denomination. While this name has been and still is, widely used in Poland, it has been rather proscribed in the former Czechoslovak Socialist Republic. So it happened that the term Sudetes is utterly omitted in the *Geographic Encyclopaedia of the Czech Socialist Republic* (Demek (ed.), 1987). Here the name Sudetes has been superseded by the term "Krkonoše–Jeseníky System (Subprovince)". The latter is subdivided into the following parts: 1. The Krkonoše Region, 2. The Orlické hory Region, 3. The Jeseníky Region and 4. The Krkonoše–Jeseníky Piedmont.

Geologically, the mountain massifs on the Czech-Polish borderline are subdivided on the basis of two different geological classifications. Suess (1912) described the Variscan Moldanubian overthrust which separates two major geologic units of the Bohemian Massif — the Moldanubicum and the Moravo-Silesicum. The Ramzová overthrust, which separates the Lugicum from the Silesicum, is a continuation of this tectonic line in the Jeseníky area. On the contrary, Bederke (1925) and his followers subdivided the northern part of the Bohemian Massif into the West-Sudetic System and East-Sudetic System. Boundary between these two systems is situated on the contact of the orthogneissic core of the Orlice–Sněžník Unit and the Staré Město Group. These major geologic units are further subdivided into a number of subsidiary units which cannot be specified in detail here due to lack of space. This basement is covered by platform sediments of Permian, Triassic, Jurassic and Cretaceous age.

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## Examples of geosites of superregional value

### 1. The valley of Divoká Desná river, Kouty n. Desnou, NE part of the Czech Republic, Jeseníky Mts.

*Main features:* pre-Variscan crystalline basement, pearl gneisses, Devonian rocks, tectonic contact.

Numerous outcrops and large-scale exposures occur along the right bank of Divoká Desná river, stretching from the Dlouhá Stráň river dam up to the Jeseník–Šumperk road. The

largest defile of rocks is ca 100 m long and shows rock cliffs up to 10 m in height. The locality lies 18 km south of Jeseník and 20 km northeast of Šumperk. It is situated in the mountainous part of Hrubý Jeseník Mts. and lies in the Jeseníky Protected Landscape Area. Geologically, it forms part of a major tectonic unit — the Silesicum.

The locality comprises a section through pre-Variscan basement of the parautochthon of the Vysoká hole thrust sheet and through its Devonian allochthonous mantle in the overlying Výrovka thrust sheet. Variscan orogeny caused the basement to be folded, metamorphosed and displaced by alpinotype tectonics along with the Devonian rocks. The environs of the locality have been described in detail by Cháb *et al.* (1984).

The Kladsko, Králický Sněžník and Jeseníky area was studied by German authors of the classic era at the turn of the 19th and 20th centuries. Their works laid the fundamentals of European geology since they largely improved the knowledge of the Variscan orogen and delimited the basic large-scale tectonic units — the Lugicum and Silesicum. Particularly Becke (1892), Suess (1912), Bederke (1935), Fabian (1936), and Wilschowitz (1939) belong to the famous geologists who were active in this area. The following numerous post-war works of Czech and Polish authors focused on the structure, petrology and genesis of mineral deposits of this area. Pouba (1962), Mísař (1963), Chlupáč (1979, 1985, 1989, 1993) and Skácel (1989), are among the leading geologists who studied the Czech part of the area, Teisseyre (1960), Oberc (1969), Smulikowski (1979) and Don (e.g. 1990) were active in the Polish part. The Jeseníky area was newly mapped in detail by geologists of the Czech Geological Survey at the 1 : 25 000 scale in the 1980s (Cháb & Opletal, 1984; Cháb *et al.*, 1984, 1990). This mapping re-introduced the old thrust-sheet structure concept German geologists. The idea of thrust-sheet structure of the Jeseníky Mts. was still alive shortly after World War II. Later, partly due to the Soviet concept, the idea of alpine character of crystalline complexes of the Bohemian Massif was abandoned. It is the new mapping that has corroborated the existence of these structures in the Jeseníky Mts. The locality described here is one of the places where the thrust-sheet structure and related phenomena can be observed.

The Vysoká hole thrust sheet is, after Cháb *et al.* (1984, 1990), built up by the basement and its mantle rocks that are repeatedly thrust over each other at a low angle (the duplex system). The late Proterozoic rocks of the Desná Group acted as original basement for the early Devonian (Pragian) Vrbno Group.

The easternmost part of the section shows slightly retrogressively metamorphosed, garnet-rich biotite pearl gneisses („intrusiver Biotit–Orthogneis–Pearlgneis" of Wilschowitz, 1939). These are massive, grey rocks, pale-dotted in detailed view, which are least affected by retrogressive metamorphic processes. They show a confining or slightly plane parallel augen (ophtalmitic) structure and a porphyroblastic texture. Their lepidoblastic groundmass contains numerous plagioclase and garnet porphyroblasts. At places, the pearl gneisses take in xenolithic inclusions consisting of biotite-rich gneisses (up to several cm to 3 m in size) and of quartz (20–30 cm in size). The pearl gneisses were metamorphosed and folded in pre-Variscan phases, with the Variscan phase leaving only minimum overprinting.

During the Variscan orogeny retrogressively metamorphosed pearl gneisses affected in various degree of intensity were generated from the relict pearl gneisses. They lose their augen structure and gradually assume an irregularly lenticular leaflike fabric. They usually show a distinct plane parallel structure and dynamofluidal and mortar or porphyroclastic texture. They contain garnets which are corroded or replaced by biotite and plagioclase "pearls" which are often crushed. Chlorite muscovite as well as biotite are here the neomorphic micas. The gneisses are locally intruded by amphibolites which were formed by metamorphosis of mafic dyke rocks.

Moderately nonconformable horizons (tens of cm to several m in size) of metapegmatites that frequently contain tourmaline and garnet are relatively abundant. They strike mostly N–S.

The intensity of transformation generally grows towards the tectonic contact with Devonian rocks. Here, the rocks are intensely transformed into phyllonites with a blastomylonitic or heterogeneous lepidogranoblastic texture. They show a distinct leaflike structure, chlorite predominates among the micas, the rocks do not show any relict structures or any original minerals of the protoliths.

The overlying Vrbno Group was originally deposited on the rocks of the Desná Group. At places, alumina-rich rocks derived from metamorphosis of fossil weathering products occur on their boundary. The sequence starts with the Drakov quartzites (Lower Devonian, Pragian, former Siegenian) which are transitional into graphite-bearing biotite-muscovite phyllites. Black plagioclase gneisses, amphibolites and porphyroids follow. Variscan orogeny caused an almost complete separation of the Devonian rocks from their basement. The quartzites are at places entirely eliminated by tectonism, so that pre-Devonian rocks can be immediately overlain by phyllites or by other rocks. Here, the Devonian rocks form lower part of the Výrovka thrust sheet.

A tectonic contact with the overlying Devonian rocks is exposed on the right bank in the Divoká Desná river channel and in the rock defile above the river. The exposed overthrust fault dips NW to NNW at an angle of about 35°. Quartzites with underlying muscovite-biotite to biotite garnet-bearing gneisses alternate in tectonically induced positions. Thickness of the single rock "layers" is several centimetres to tens of centimetres. In the past, some authors erroneously interpreted these positions (by comparing them with similar sections) as "a gradual transition between the Siegenian quartzite and the underlying rocks of Silurian age". The existence of an over-thrust line is clearly corroborated by a sharply confined slice (several metres long and tens of centimetres thick) of a fine-grained, biotite gneiss with staurolite, intercalated between the quartzite and the phyllonite. The grey-white quartzite has accessory garnet, muscovite, biotite, zircon and ilmenite. The underlying highly retrogressively metamorphosed gneiss (up to phyllonite) has a considerably increased amount of garnet, which indicates rocks derived from metamorphosis of fossil residua. Quartzites and phyllites alternate higher up in the section, it remains unclear, however, whether the alternation is primary or secondary, due to a tectonic repetition. Remnants of a medieval adit accompa-

nied by tailing piles occur on the opposite river bank at the quartzite base. Gold was probably tentatively exploited there. An analysis of the quartzite indicated 0.27 g Au/t. Actually, the largest amount of old adits and collapse sinks in the whole Jeseníky Mts. are associated with the quartzites.

A discontinuous exposure of plagioclase gneisses ca 100 m in length is located farther westwards on the right Divoká Desná river bank. These are black, massive, but also platy to thick-bedded rocks which belong to the most attractive ones in the Jeseníky Mts. Their predominant rock-forming mineral is oscillation-zoned highly basic plagioclases (see Fabian, 1936 and Souček, 1977). They also contain biotite, 2-generation staurolite, a lesser amount of quartz and locally muscovite, garnet and ilmenite. They have their foliation planes deformed by $V_3$-folds and enclose relatively abundant quartz boudins deformed in the course of the main deformation phase.

**2. Velký Vápenný quarry near Jítrava,** SW slope of the Mount Velký Vápenný (790 m a.s.l.), E of the village Jítrava in the N part of the Ještědský Hřbet Mts., in the West Sudetes.

*Main features:* Devonian–Lower Carboniferous sequences, rich fossil fauna.

An almost isoclinal anticline with sharp crest and both flanks is exposed at the frontal face of the quarry (Fig. 1). The core of the structure consists of black pyrite-bearing phyllitic shales with goniatite and other fauna of the Lower Famennian (*Cheiloceras* Zone), the flanks are formed by grey platy and thicker bedded, in uppermost parts also laminated or nodular (light grey to pink) limestones in which a complete sequence of Famennian conodont zones was recovered. In the NE part of the quarry, overlying greenish phyllitic shales with rare trilobite fauna of the earliest Carboniferous crop out. The limestones are karstified and a cave with a specific dripstone decoration is situated in the central part of the exposed sequence (in the upper part of the anticline structure).

A reference section for the Upper Devonian and earliest Carboniferous in the Czech part of the West Sudetes region. Palaeontological locality (unique on the Czech territory), example of Variscan deformation of Devonian–Lower Carboniferous sequences, example of the grade metamorphism. It is also important from the viewpoint of history of geological knowledge (first finding place of fauna in the West Sudetic crystalline rocks on the Czech territory, reference point for diverse stratigraphic and tectonic concepts and hypotheses) (Fritsch, 1869; Koliha, 1929; Gallwitz, 1930; Kodym & Svoboda, 1948; Chlupáč, 1964, 1993; Zikmundová, 1964).

The locality is protected as nature reserve. It is one of the most important stratigraphic and palaeontologic localities in the Czech part of the West Sudetes.

**3. Hamerčická Skála near Koberovy,** an old quarry in the E slope of the Zbytský Potok (brook) valley, NE of the village of Koberovy, SW of the town Železný Brod, District Jablonec nad Nisou, the West Sudetes.

*Main features:* Palaeozoic carbonate sequence, fossils.

Exposure of a carbonate sequence of uncertain age (Cambrian or more likely Silurian or Devonian) which yielded palaeontological findings (arthropod possibly identical with *Silesicaris nasuta* Gúrich, spiral-coiled metamorphosed graptolites? or ichnofossils? in dark grey shale layers).

The quarry is proposed as nature reserve, because it is the only palaeontological locality which yielded body fossils in the

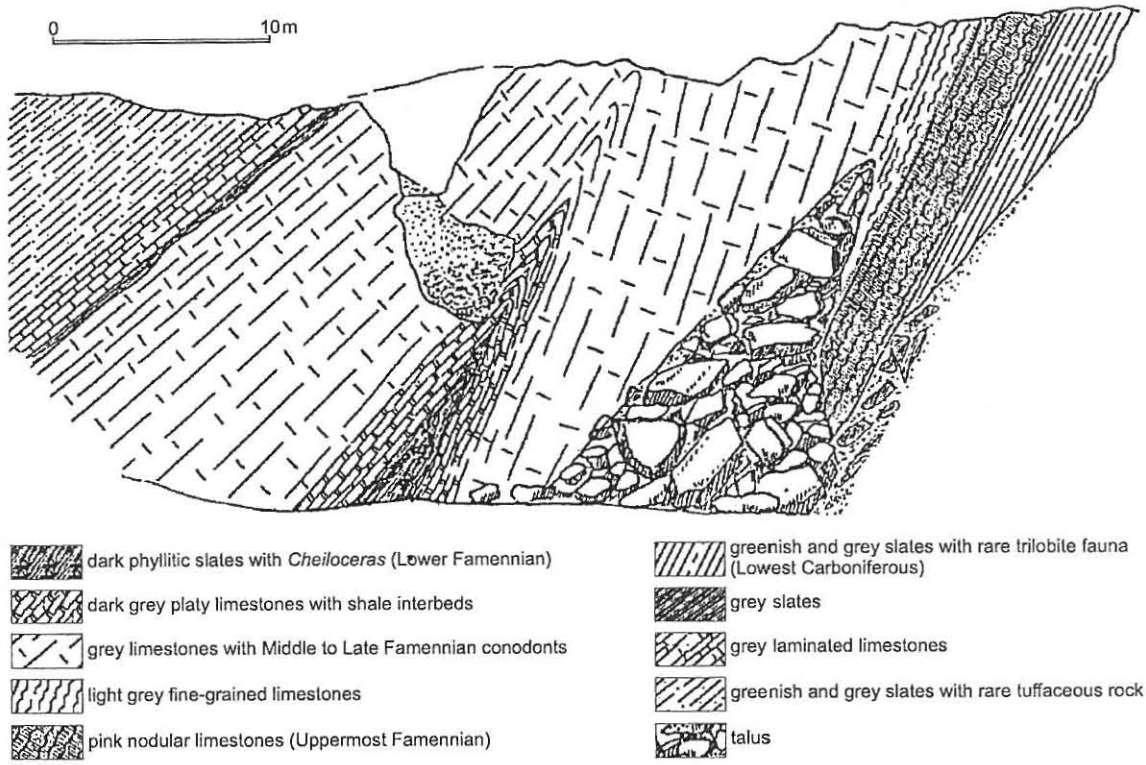


Fig. 1. Quarry at Velký Vápenný near Jítrava: anticlinal structure of Upper Devonian and Lowest Carboniferous beds (after Chlupáč, 1964)

Železný Brod Crystalline Complex (Chlupáč, 1953, 1993; Chlupáč & Horný, 1955; Svoboda, 1955; Chaloupský (ed.), 1989).

**4. Quarry Basa and the surrounding area near Světlá pod Ještědem,** a group of old quarries on the SW slope of the Ještědský Hřbet Mts., NE of the village of Padouchov, near Světlá pod Ještědem, District Liberec, in the West Sudetes.

*Main features:* Devonian sequence, Variscan metamorphism, rich palaeontological site.

The quarry Basa and other old quarries in its vicinity expose a carbonate sequence of the Ještěd Crystalline Complex: dark grey, thick- and thin-bedded crystalline limestones with local layers rich in stromatoporoid (*Amphipora*, *Stachyodes*) and coral (*Thamnopora*) fauna demonstrating a Middle Devonian (Givetian) age (Gallwitz, 1930; Chlupáč & Hladil, 1992; Chlupáč, 1993). Some layers also contain abundant remnants of thick-shelled brachiopods. All rocks are affected by slight, low-grade Variscan metamorphism. An example of coral-stromatoporoid facies of the Devonian, exceptional in the West Sudetes region.

An important palaeontological locality and an example of stratigraphic development of Devonian, stratigraphical reference locality and an example of metamorphism of demonstrable Variscan age.

The area is protected as nature reserve.

**5. Suchý Vrch near Vrbno pod Pradědem,** S and SE slopes of the Mount Suchý Vrch (941 m a.s.l.) NW of the village of Mnichov in the N surroundings of Vrbno pod Pradědem, in the E part of the Hrubý Jeseník Mts., District Bruntál, Moravo-Silesian region.

*Main features:* Devonian metamorphic rocks, fossils.

The quartzite debris, which come from the nearby outcrops of the Drakov Quartzite of Lower Devonian age, contains common fossils, particularly brachiopods, bivalves, ichnofossils, less frequent tentaculites, corals, trilobites, etc. preserved in metamorphic rocks of the chlorite to biotite zones. The richest palaeontological locality in the metamorphosed Devonian of the Jeseníky Mts. known since last century (Roemer, 1865; Wilschowitz, 1931; Špinar, 1950; Chlupáč, 1975,1989; Isaacson & Chlupáč, 1984).

A stratigraphic reference point for Devonian age of metamorphic rocks in the Hrubý Jeseník Mts., significant palaeontological locality, type locality of fossil assemblages, example of preservation of fossils in low-grade metamorphic rocks.

The locality is the nature reserve situated in the Hrubý Jeseník Protected Area.

**6. Stará Hora near Heřmanovice,** S and N slopes of the Stará Hora Mt. (1,043 m a.s.l.), W of the village of Heřmanovice in the E part of the Hrubý Jeseník Mts., District Bruntál, Moravo-Silesian region.

*Main features:* Lower Devonian rocks, fossils.

Numerous debris of the Drakov Quartzite (lower part of the Vrbno Group) with rich fauna of Lower Devonian age (brachiopods, bivalves, ichnofossils, rare corals, tentaculites, trilobites, etc.). Type locality of fossil assemblages of an extremely shallow-water environment.

Stratigraphic and palaeontologic reference locality, an example of preservation of fossils in regionally metamorphosed siliciclastic rocks of Lower Devonian age (Wilschowitz, 1931, 1932; Špinar & Mrázek, 1950; Chlupáč, 1975, 1989).

The locality is situated on the territory of the large-scale protected area of Hrubý Jeseník Mts.

**7. Doubice, in northern Bohemia,** 1.5 km NE of the center of the Doubice village and 10 km WSW of the center of the town of Varnsdorf.

*Main features:* Jurassic platform sediments, tectonic structure, mineralization.

The locality comprises several disused shelf and pit quarries, maximum 150 x 135 x 15 m in size. In some of the quarries, disused, partly back-filled adits have been found.

The quarries expose Jurassic platform sediments which were formerly extracted here as building materials. The discontinuous exposure of Jurassic sediments has a total thickness of ca 130 m Eliáš (*in*: Klein (ed.), 1971) subdivided the sediments into three lithologic units. He denominated the oldest unit, only 12–14 m thick, as the Brtníky Formation. This unit is built up by basal clastic sediments with a varicoloured streaky structure, consisting of greenish pale grey medium-grained sandstones. Younger unit, the so called Doubice dolomites (about 100 m thick) is made up of a sequence of bluish grey to brown-grey dolomitic limestones and dolomites. The whole Jurassic sequence is terminated by dark bituminous limestones, about 20 m thick. The dolomites and limestones are massive or thick-bedded, separating into blocks and they contain at places intercalations of clayey limestones and calcareous claystones. Crushed zones are frequent in the carbonate succession. Mostly, only stratigraphically unimportant fauna has been found in the Jurassic carbonates (Chrt, 1957; Fediuk (ed.), 1958). Eliáš (*in*: Klein (ed.), 1971) puts the find of an important ammonite *Hecticoceras hecticum* (Rein), described by Bruder (1882, 1886) from the Jurassic near the Lusatian Fault, to his Brtníky Formation. Eliáš (1994) ranges the Brtníky Formation to the Callovian, the overlying carbonates to the Oxfordian to Lower Kimmeridgian.

Exploration works have found an uneconomic Pb-Zn mineralization in the Jurassic sediments (Chrt, 1957).

Jurassic sediments at Doubice occur in several minor tectonic blocks accompanying the major Lusatian Fault. This fault forms in NW part of the Bohemian Massif the NE limit of sediments of the Bohemian Cretaceous Basin. In the wider surroundings of Doubice, the Lusatian Fault separates Cretaceous sediments from granitoids of the Lusatian Massif. Here, the fault has a character of a post-Cretaceous shear thrust (Fediuk (ed.), 1958; Dvořák, *in* Svoboda (ed.), 1964; Klein (ed.), 1971). Its overthrust plane dips at a moderate angle of 20–40 northeastwards (Coubal *et al.*, 1996; Valečka (ed.), 1997). During displacements on the overthrust plane also Jurassic blocks were dragged together with granitoids upon the Cretaceous. Permian rocks, indicated by fragments and small outcrops of quartz porphyries, arkosic sandstones and mudstones occurring in the vicinity of the quarries, were also

dragged together with Jurassic sediments upon the surface. Two small dykes of neovolcanic rocks represented by nepheline tephrite with olivine admixture and by nepheline basanite occur in the environs of the quarries (Klein (ed.), 1971). The quarries at this locality enable to study one of the few exposures of Jurassic sediments on territory of the Bohemian Massif. Geologic setting in the vicinity of the quarries indicates an extraordinarily complicated tectonic structure near the Lusatian Fault, which belongs to major discontinuous Saxonian-type structures in the Bohemian Massif.

With regard to its geologic setting (and occurrence of a mixed woodland with herb-dominated flora), the locality is protected since 1969 as a nature reserve 11.7 ha of area.

**8. Suché Skály near Železný Brod in NE Bohemia.**

*Main features:* Upper Cenomanian sandstones and conglomerates, cross-bedding, post-Cretaceous tectonics, rocky scenery.

Suché Skály Cliffs near Železný Brod can be considered as the most spectacular locality along the course of the deep-seated NW–SE-trending Lusatian (Lužice) Fault. They form a prominent rock wall 1300 m long, protected as a National Nature Monument.

The zone of the Lusatian Fault forms the NE boundary of the Bohemian Cretaceous Basin. The thickness of the Upper Cretaceous sediments rapidly increases towards the Lusatian Fault which indicates its synsedimentary activity. During the Alpine orogeny, the fault acted as a plane along which the Krkonoše–Jizera Crystalline Complex was thrust over the preserved fill of the epi-Variscan basins (Permian, Cretaceous). The fault plane dips to the NE to N, mostly at a low angle ca 30° (Coubal *et al.*, 1996).

In the Železný Brod area, a steep tectonic dip of the Upper Cenomanian sediments can be observed close to the Lusatian Fault. Within the Suché Skály Cliffs, the tectonic dip ranges from 45° to SW in the SE to 90° to SSW in the NW (Coubal, 1989). An increase in the dip angle is visible from the base of the cliffs to their tops where the bedding planes are slightly overturned (Fig. 2). Lithologically, the Upper Cenomanian sediments are medium- to coarse-grained quartzose sandstones with sharp-based conglomerate beds. Sets of trough and planar cross-bedding are present tens of centimetres to 1 m in thickness. Their foreset laminae orientations indicate prevailing northwesterly flows (Adamovič, 1991). These sediments are underlain by Permian melaphyres which plot into a map as a narrow strip along the Lusatian Fault. The Lusatian Fault itself runs either at the Permian/crystalline boundary or within the crystalline complex. Brittle deformation of the sandstones is the most prominent feature at Suché Skály. In their vicinity, the Cretaceous sediments are frequently deformed by transverse strike-slip faults (Fig. 3). The tectonic block of Suché Skály displays numerous striated silicified fracture zones and minor faults. Slickenside measurements on these planes allowed discrimination of a phase of ductile deformation (flexure) and four phases of brittle deformation (Coubal, 1990).

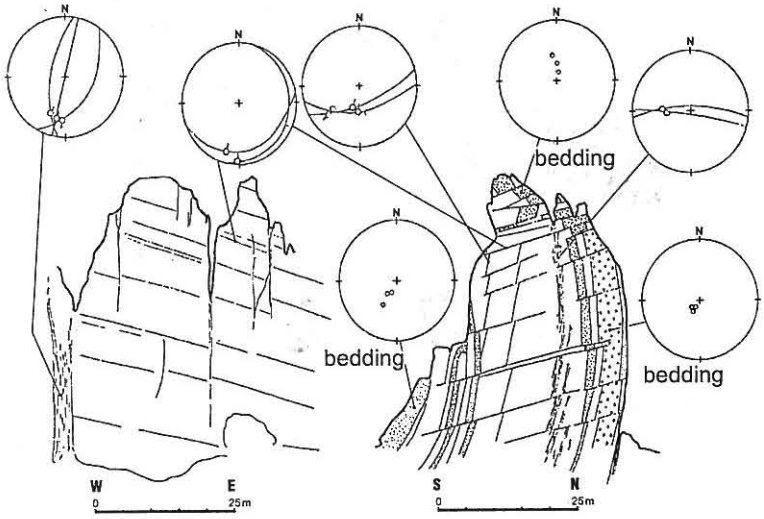


Fig. 2. Structural elements of the Suché Skály Cliffs, Cenomanian sandstones, N Bohemia

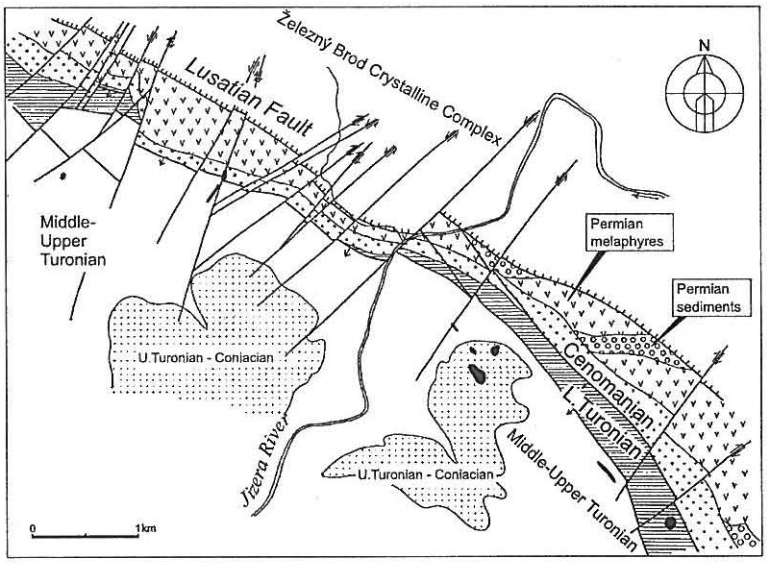


Fig. 3. Lusatian (Lužice) Fault in the area of Železný Brod, NE Bohemia

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