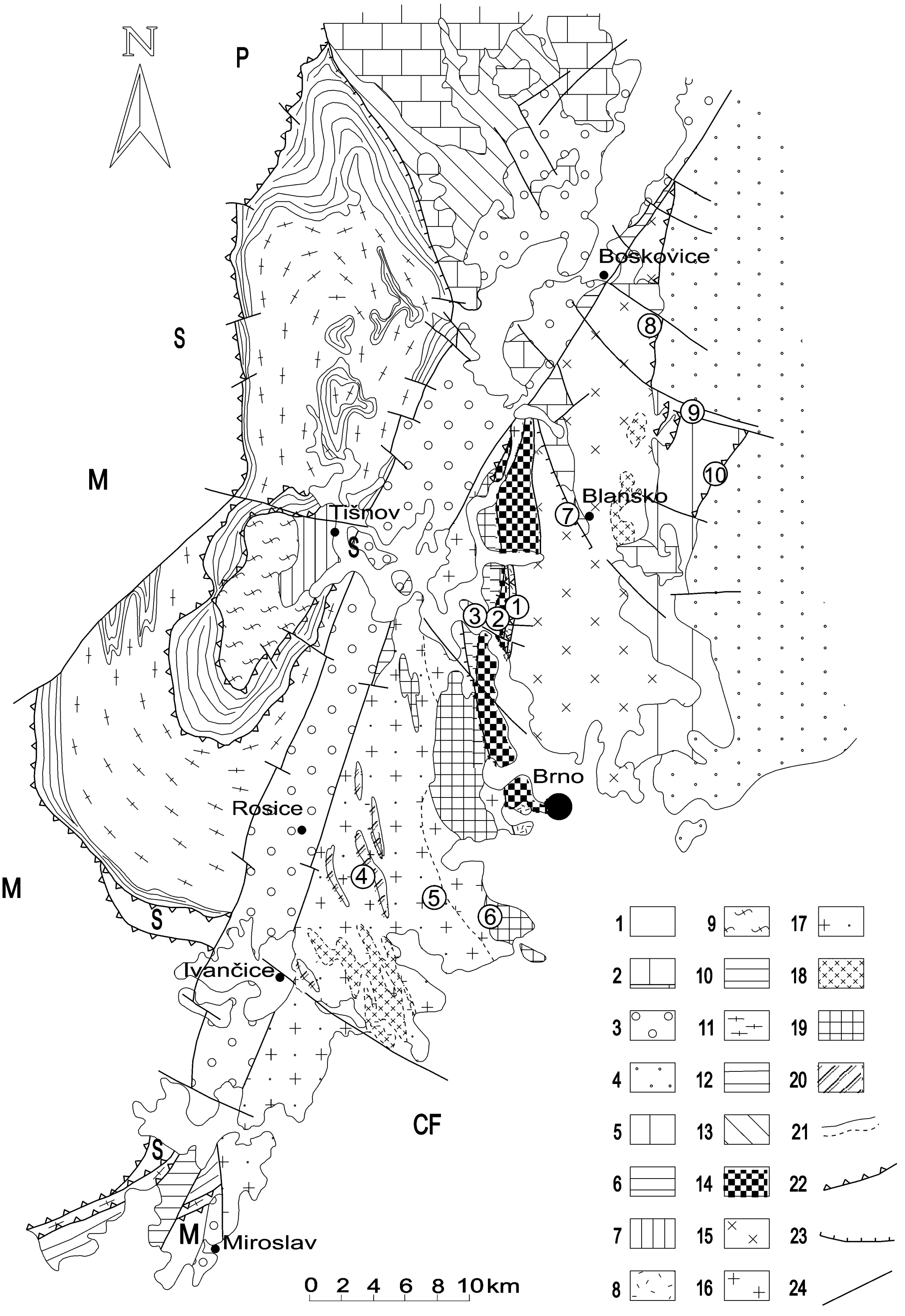

Fig. 1. Geological map of area with locations of excursion sites (numbers in circles). 1 - Quaternary and Tertiary; 2 - Cretaceous; 3 - Permian of the Boskovice furrow; 4 - Culm of the Drahany Upland; 5 - Palaeozoic limestones of the Moravian Karst; 6 - Palaeozoic rocks between the Boskovice furrow and the Brno massif (limestones, greywackes); 7 - weakly metamorphosed Palaeozoic limestones, sandstones and conglomerates of the Tišnov window; 8 - Devonian clastic sediments of the Babí lom zone; 9 - Deblín group and Svratka granite; Moravicum (10-12): 10 - Bílý potok group; 11 - Bíteš group; 12 - Olešnice group; 13 - Letovice crystalline complex; Brno massif (14-20): 14 - Metabasite zone (metabasalts, locally with rhyolites); 15 - hornblende - biotite granodiorite; 16 - leucogranite to granodiorite; 17 - biotite ± hornblende granodiorite ; 18 - tonalite; 19 - Diorite belt (diorites, ultramafites); 20 - metasedimentary wall rocks (gneiss, migmatite, calc-silicate rocks); 21 - lithological boundaries; 22 - nappe; 23 - thrust fault; 24 - fault; S - Svratka crystalline complex; P - Polička crystalline complex; M - Moldanubicum; CF - Carpathian Foredeep. Modified according to Svoboda et al. (1962) and Kalášek et al. (1963).

DAY 1
The Brno massif: geological setting

Pavel HANŽL and Jaromír LEICHMANN

The Brno massif is a complex of predominantly magmatic rocks of Cadomian age. It forms the largest exposed part of the huge Cadomian, mostly magmatic unit, which is covered by younger sedimentary complexes. The unit was called the Brunnia (Zapletal 1931), the Brno Unit (Mísař 1965, Suk 1986) or the Brunovistulicum (Havlena 1976, Dudek 1980). Zapletal (1931) situated the Brunnia between Fennosarmatia and Gondwana. According to Roth (1964), Dudek (1980), Suk (1986) or Zoubek (1992), the Brunovistulicum is similar to the Fennosarmatia. On the other hand, Franke (1989), Matte et al. (1990) or Finger et al. (1995) considered the Brunovistulicum to be a Cadomian terrane derived from the northern part of Gondwana. Brunovistulian granodiorites are compared mostly to the I type rocks of the circumpacific volcanic arc (Finger et al. 1989; Jelínek and Dudek 1993).

The Brno massif reflects the complex geological history starting with the Cadomian magmatic activity in the peri-Gondwanan magmatic arc. The Cadomian structures of the Brno massif and its position on the eastern margin of the Bohemian Massif were strongly affected by the Variscan orogeny and subsequently by the evolution of the Alpine orogeny.

The area of the Brno massif (Fig. 1) is approximately limited by the towns of Miroslav, Boskovice and Brno. It is bounded by the Devonian to Carboniferous rocks of the Moravian Karst and the Drahany Upland in the east, by the Neogene sediments of the Carpathian Foredeep in the southeast and by the marginal fault of the Boskovice furrow in the west. A few narrow tectonic blocks of the Devonian to Carboniferous limestones and greywackes are exposed at some places between the Boskovice Furrow and the Brno massif. The Upper Cretaceous sediments are preserved along the NW-SE-striking faults in the Blansko and Valchov troughs.

The Brno massif is composed of East and West granodiorite areas which are tectonically separated by the Metabasite Zone. Both the granodiorite areas are formed by calc-alkaline, mostly metaluminous rocks but they slightly differ in petrography, petrophysics, geochemistry and mineralisation (e.g. Hrouda et al. 1983; Melichar and Špaček 1995; Hanžl and Melichar 1997). The East granodiorite area is composed of granodiorites and tonalites. This rock suite represents plutonic rocks of a primitive volcanic arc. The West area is formed of granites, granodiorites tonalites and diorites representing rocks of a more evolved magmatic arc or active continental margin with affinity to S-granites. The common remnants of the roof pendants are preserved here. The radiometric ages in the range of 560 - 590 Ma were obtained mostly from basic members of the plutonic suite by van Breemen et al. (1982) and Dallmeyer et al. (1994).

Both the granodiorite areas are separated by the Central basic belt consisting of the diabase (metabasite) belt in the east and the diorite belt in the west (Zapletal 1928). The rock association of the Central basic belt - ultramafites + diorites (metagabbros) + diabases led some authors to a comparison of this zone with an ophiolite sequence or dismembered ophiolite (e. g. Mísař 1979; Weiss in Mísař et al. 1983). However, the interpretation of this zone remains still controversial. The term Metabasite zone was introduced by Dudek and Weiss (1963) for the eastern part of the Central basic belt of the Brno massif but later extended by Mísař (1979) to the whole Central basic belt. Leichmann (1996) interpreted both the plutonic and the volcanic parts of this belt as an ophiolite older than the surrounding granitoids which intruded into diorites. On the other hand, Hanžl and Melichar (1997) separated the Metabasite zone (diabase belt) from the diorite belt on the basis of field and geochemical data. The diorite belt represents an independent part of the wall rocks of the West granodiorite area while the Metabasite zone is interpreted as a tectonic slice formed by slightly metamorphosed volcanites of MORB composition (Hanžl et al. 1995) separating both the granodiorite areas of the Brno massif. The age of rhyolites from this zone was established by Finger et al. (1998) at 725±15 Ma.

Based on petrophysical data Hrouda et al. (1983) and Hrouda (1991) considered the Metabasite zone to be a zone of an important sinistral strike-slip movement. The sinistral sense of shearing was confirmed by structural kinematic indicators (Hanžl 1997). Thrusting of the Metabasite zone over the East granodiorite area (Zapletal 1926) is documented by the position of the Devonian (?) basal clastics, locally with the Givetian limestones (Hladil 1992), in the Babí lom zone as well as by the paleostresses orientation in these rocks (Roupec 1994) or geophysical data (Mitrenga and Rejl 1993).

Stop 1
Babí lom

Rostislav MELICHAR, František HUBATKA and Pavel HANŽL

A narrow N-S-oriented rocky ridge between the villages of Lelekovice and Svinošice in the northern vicinity of the city of Brno (Fig. 2). The ridge is formed by thick-bedded layers of quartzose conglomerates resistant to weathering and steeply dipping to the west. Conglomerates alternate with red arkosic sandstones and siltstones down the slope towards the east. The age of the clastic complex is believed to be Lower to Middle Devonian, because of the paleontologically dated limestones (Givetian, Hladil 1992) related to the Babí lom ridge.

The Devonian clastic sediments of Babí lom form a tectonic slice between the East granodiorite area of the Brno massif and the Metabasite zone. A narrow stripe of metabasalts along the

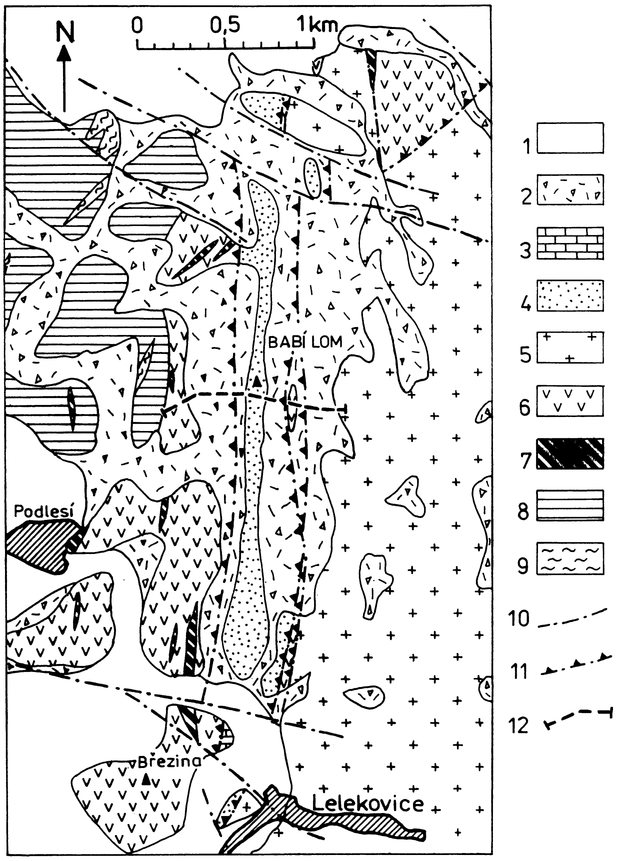

Fig. 2. Geological map of the Babí lom: 1 - loess; 2 - loam with stones; 3 - limestone (Givetian); 4 - Devonian basal clastics (conglomerate, arkosic sandstone); 5 - biotite granodiorite; 6 - metabasalt; 7 - metarhyolite; 8 - diorite; 9 - mylonitized granite; 10 - fault; 11 - thrust; 12 - situation of seismic section. Simplified according to Hanžl (1996).

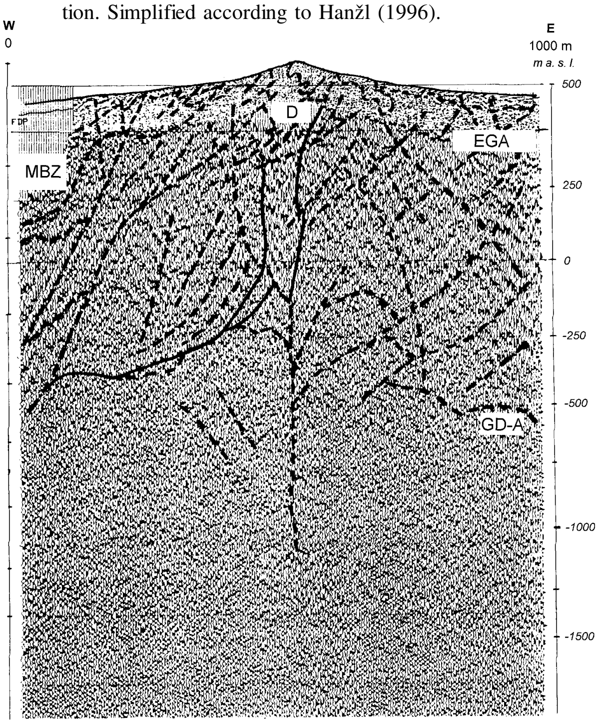

Fig. 3. Interpreted seismic section through the Babí lom ridge. Explanations: MBZ - Metabasite zone; D - Devonian conglomerates; EGA - Eastern granodiorite area; GD-A - granodiorite autochthone.

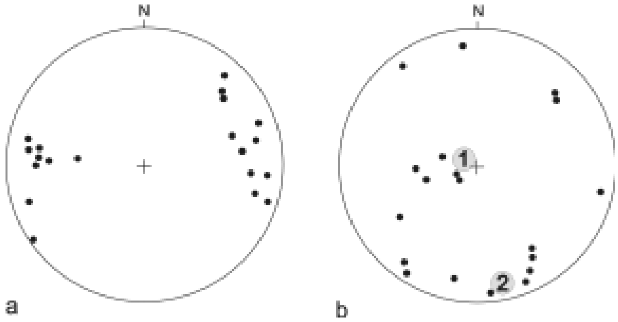

Fig. 5. Orientation of the main structures of the Babí lom rock ridge: a - axes of stylolite tooth; b - poles to quartzose veins, older generation (1), younger generation (2).

eastern contact can be interpreted as a relic (tectonic slice) of the Metabasite zone thrust over the East granodiorite area according to recent geophysical data (Fig. 3).

The study of a deeper geological setting of the Babí lom locality was based on the shallow reflection seismic measurements carried out along a 1 km long E-W profile (MS-BL-1) of the slalom line type. The main output of the measurements is represented by the time section. The extent of the time section given by the methodology of the measurement reaches 950 ms

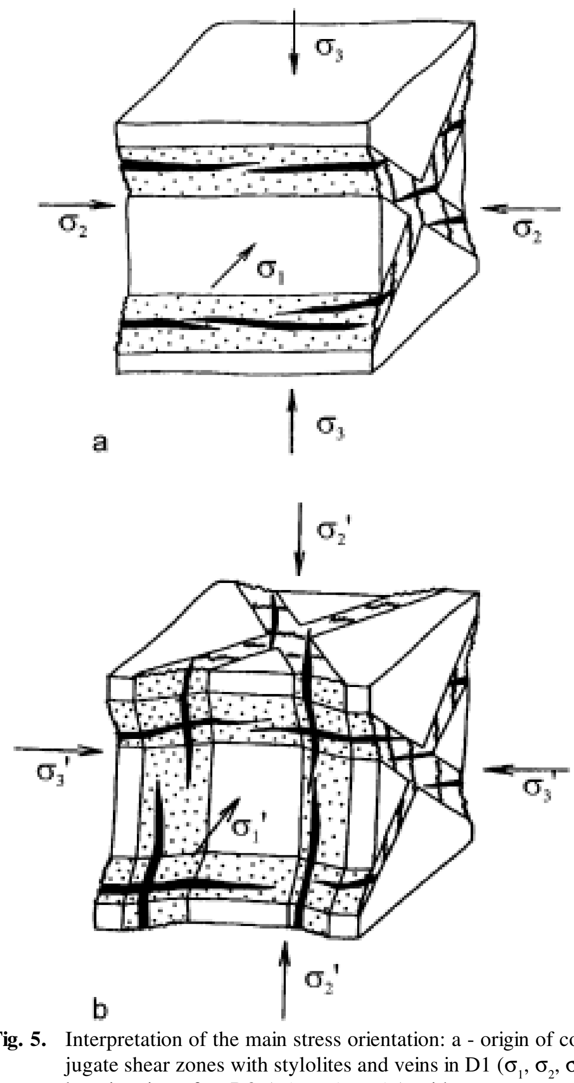

Fig. 5. Interpretation of the main stress orientation: a - origin of conjugate shear zones with stylolites and veins in D1 (σ_1, σ_2, σ_3); b - situation after D2 (σ'_1, σ'_2, σ'_3) with two systems of conjugate shear zones.

of the two-way travel time. The time-to-depth conversion was based on a theoretical speed model presuming the average speed in the upper parts of the crystalline complex to range from 4000 to 5000 ms^{-1}. This conversion shows the depth penetration of the measurement to be about 2500 m while the desired signal can be traced to the depth of about 1000 m.

The interpretation of the MS-BL-1 seismic section is based on the 3-D analysis of the wave field which scans frequency and shape differences in the signal. This enables the phase analysis of the seismic section based on the diverse echogenity of the wave field.

The main subdivision of the time section is related to the frequency character of the wave field. In the upper part down to the level of about 400 to 500 ms (-500 m above sea level), considerably lower frequencies were found connected with frequent disturbance waves which we interpret as a reflection of a strong tectonic deformation of the upper part of the crystalline complex with the thickness of about 1000 m. This part is herein interpreted as an allochthone. The location of the Devonian sandstones was based on an anomalous reflection echo. This interpretation also takes into consideration the existence of an oblique reflection period in the time range 410 to 460 ms (0.2 - 0.35 km), which was recognizable even at numerical data processing. The depth section shows the body of the Devonian sandstones to be almost vertical reaching to the depth of about 600 to 700 m. The base of thrusting lies at the depth of about 1000 m.

The western contact with the metabasites is a huge thrust fault parallel to bedding in the conglomerates and limestones. The thrust plane is exposed in the quarry near the southern end of the Babí lom ridge and dips steeply to the W (Roupec 1992). The thrusting movement is indicated by the asymmetry of drag isoclinal folds in limestones.

The deformation caused by variable and different mechanisms is a common feature of the Devonian conglomerates connected with the Brno unit. The Babí lom conglomerates were subjected to inhomogeneous pressure solution. Stylolites to slickolites and quartzose veins are developed here. The determination of E-W subhorizontal orientation of s1 was based on a detailed study of stylolites (Fig. 4a). Similarly, the distribution of quartz veins produced the orientation of σ_3. Two main groups of differently oriented veins were distinguished. The σ_3 is subvertical for the older ones and subhorizontal, N-S oriented, for the younger ones (Fig. 4b). The relative age of veins was inferred from their intersections. Both the studied structures, e.g. stylolites and veins, are either dissipated in the rock or concentrated in conjugated shear zones (Fig. 5a). These shear zones are very conspicuous for their white colour shining in the dark red conglomerates. The shear zones, similarly as the described veins, form two groups (Fig. 5b) with the orientation of σ_1 and σ_3 mentioned above (Roupec 1994). These two stages of small-scale deformation can be related to the older thrust and younger strike-slip movements along the Metabasite zone.

Stop 2
Opálenka

Pavel HANŽL

Abandoned quarry south of the village of Podlesí (2 km E of Kuřim), Metabasite zone of the Brno massif.

The Metabasite zone is composed of massive to fine-grained basalts, amygdaloidal basalts, medium-grained basalts (dolerites), tuffitic rocks and rhyolites. The rocks are metamorphosed in the greenschist facies conditions and basalts pass to greenschist in more deformed parts. Mafic minerals are usually represented by uralitized hornblende. Relics of pyroxene are very rare in the centre of large hornblende grains, laths of plagioclase are altered. Chlorite, epidote, uralite, quartz and albite are secondary minerals in basic rocks. Albite, epidote and quartz

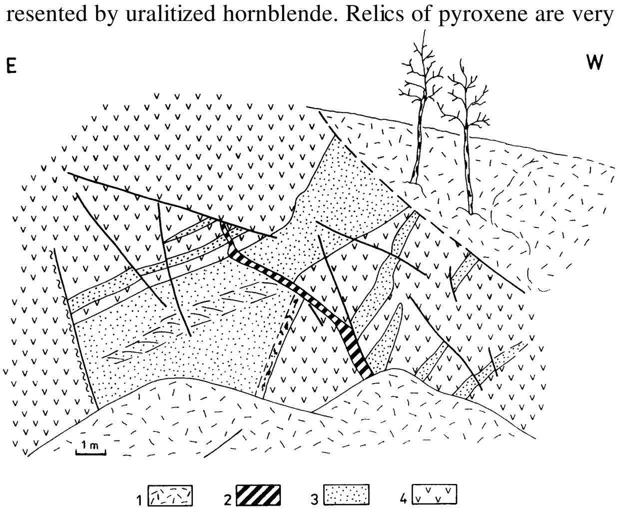

Fig. 6. A sketch of the western part of the main wall in the Opálenka quarry: 1 - debris; 2 - diorite porphyry; 3 - metarhyolite; 4 - metabasalt.

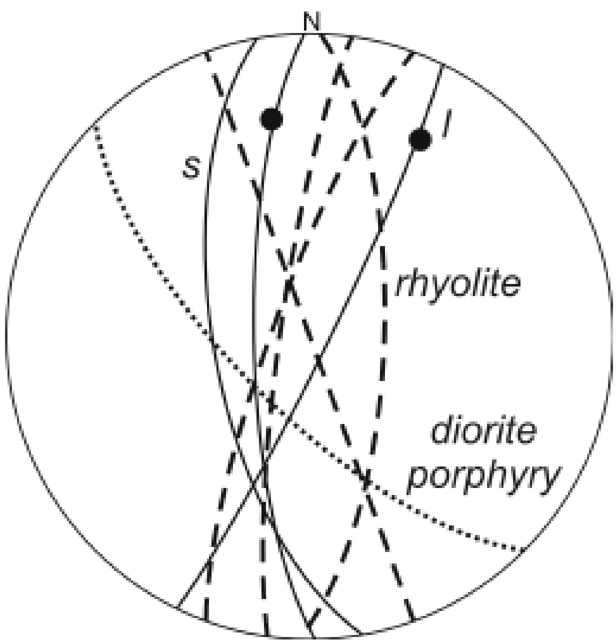

Fig. 7. Orientation of the main structures at the Opálenka quarry, s - foliation, l - lineation (equal area, lower hemisphere).

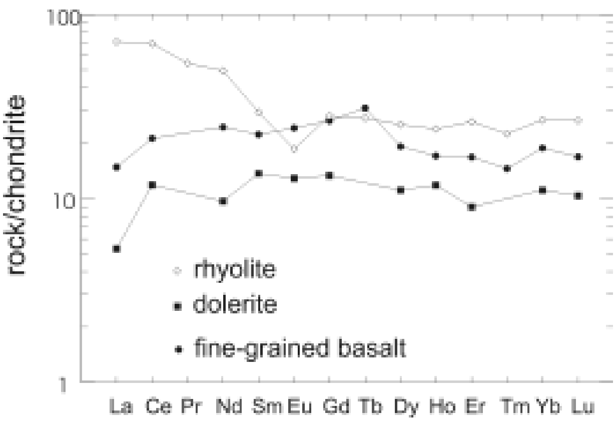

Fig. 8. REE-normalized patterns in metavolcanites of the Opálenka quarry. After Hanžl et al (1995).

are the common fill of the amygdules. Tuffitic rocks, dykes and layers of rhyolites are even less frequent.

The prevailing fine-grained, massive basalts with ophitic texture accompanied by medium-grained basalts (dolerites) are exposed in the quarry. The basalts are tholeiitic and they can be correlated with mid-ocean ridge basalts (Hanžl et al. 1995) based on trace and rare earth elements characteristics (Fig. 8). Depleted mantle as a source of basalts has been confirmed by new Sm/Nd data from the locality (εNd_{720} = +8.0 and +8.5, V. Janoušek - pers. comm.).

Layers (dykes ?) of rhyolites syngenetic with the basalts are exposed in the western part of the quarry (Fig. 6). The rhyolite was dated using zircon evaporation method to 725±15 Ma (Finger et al. 1998).

Non-penetrative, steep, N-S-striking foliation planes are developed in the Metabasite zone (Fig. 7). The sinistral sense of shearing is documented by the asymmetric pressure shadows along albite porphyroclasts, pyrite crystals and deformed amygdules, shear bands and S-C structures. Narrow shear zones in dolerites are now covered by a layer of waste deposits in the central part of the quarry. The metavolcanite complex is cut by a narrow dyke of diorite porphyry probably of Variscan age.

Stop 3
Kuřim - old quarry near railway

Pavel HANŽL and Jaromír LEICHMANN

Old quarry near the railway, SE margin of the town. Diorite belt of the Brno massif.

The diorite belt is a stripe of basic rocks along the contact of the West granodiorite area and the Metabasite zone of the Brno massif. Diorites are intruded by younger granodiorites. Contact with the Metabasite zone is modified by steep, N-S-striking faults. The diorite belt is composed of hornblende to hornblende-biotite diorites with relatively common small bodies of hornblendite, serpentinite and metagabbros in places with relics of cumulate structures.

The medium-grained hornblende diorite was exploited in the quarry. It is composed of plagioclase (andesine), hornblende and quartz. Apatite, titanite, zircon, opaque minerals and garnet are accesory. Diorites are strongly altered. Chlorite and minerals of epidote group are common secondary minerals. Enclaves of fine-grained, syngenetic microdiorites of the same composition are preserved in places. Broken dykes and boudins of cataclased aplite and pegmatite of simple mineral composition are frequent. The quarry face is cut by numerous dykes of diorite porphyry. These dykes have subvolcanic features (ophitic texture, amygdules). They have the composition of calc-alkaline, within-plate basalts (Hanžl et al. 1995). The petrologically identical veins from the Brno massif were dated by Šmejkal (1964) at 309 and 324 Ma using K/Ar method and from the Dyje massif by Dallmeyer et al. (1994) at 306 and 322 Ma using Ar/Ar method. Dallmeyer et al. (1994) interpreted these rocks as a manifestation of the Variscan post-collisional uplift.

A huge mylonite zone is exposed in the western part of the quarry. Rocks are strongly deformed with development of phyllonites and breccias along the zone. Different generations of striae indicate multistage evolution.

Stop 4
Skalka - Zlatý potok

Pavel HANŽL, Kristýna BURIÁNKOVÁ and Jiří BABŮREK

Small, abandoned quarry in the valley of the Zlatý potok Creek near the crossroads of forest roads, 4 km S of the village of Omice, metasediments in the wall rocks of the West granodiorite area of the Brno massif.

Large amounts of relics of the roof pendants of the West granodiorite area of the Brno massif are preserved between the Jihlava and Svratka Rivers. Migmatites and gneisses locally with calc-silicate rocks and small bodies of amphibolites, diorites and gabbros are exposed in narrow NW-SE-oriented belts.

Migmatitized gneisses intruded by biotite granodiorite are exposed at this locality. A granodiorite sill is concordant with the slightly NW-dipping foliation planes in gneisses. Strong migmatitization in gneisses is developed mostly along small apophyses derived from the main granodiorite sill. Small E-W oriented folds seem to be syn-intrusive (Fig. 9).

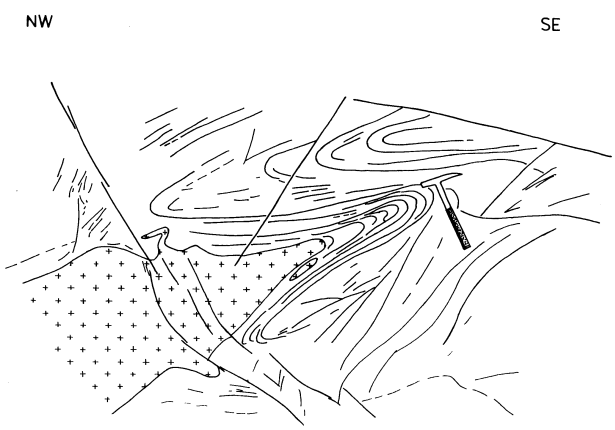

Fig. 9. A detail of relation between granodiorite sill and gneisses at the locality of Skalka.

Granite is a fine- to medium-grained rock composed of sericitized plagioclase (An_{25}), perthitic orthoclase, quartz and biotite. Apatite, zircon and titanite are accesory minerals. Secondary minerals are chlorite, sericite and epidote.

The biotite gneiss is fine-grained, banded rock composed of quartz, plagioclase (oligoclase), K-feldspar, biotite, muscovite, garnet. Kyanite, zircon, opaque minerals and tourmaline are accesory. Epidote, sericite, chlorite and actinolite are secondary. Feldspars are usually sericitized or slightly kaolinized. Fine needles of actinolite are enclosed in plagioclase. K-feldspars are perthitized, red-brown biotite is only in places slightly chloritized. Pale yellow, oval spots composed of sericite, chlorite and biotite can be interpreted as pseudomorphoses after cordierite. In places the rocks are migmatitized to granitized which is indicated by the separation of leucosome and melanosome into bands and by the zoned character of some plagioclases. Mineral association in gneisses can indicate the MP Barrovian metamorphosis overprinted by later LP peri-plutonic metamorphosis. Temperature estimated according to garnet-biotite thermometer (Williams and Grambling 1990) is 560°C for a pressure of 6 - 9 kbar. Zoning of garnet indicates a slight retrograde metamorphism.

Stop 5
Anenský mlýn

Jaromír LEICHMANN

An abandoned quarry, left bank of the Bobrava River, 2 km N of Ořechov.

Five main stages of pre-Alpine magmatic evolution of the West granodiorite area N of the Jihlava River have been recognized so far:

1 - Formation of the Cadomian or even older, mostly metasedimentary crust, composed of gneisses, calc-silicate schists, rare amphibolites, marbles etc.
2 - Emplacement of dioritic magma (584±5 Ma - van Breemen et al. 1982) into the metasedimentary crust, followed by melting of crustal rocks as a consequence of elevated heat flow and formation of S-type granodioritic magma.
3 - Differentiation of both magmas, their partial mixing and mingling, interactions with remnants of roof pendants.
4 - Rock-fluid alteration as a consequence of the emplacement of leucogranites forming dykes in older diorites and granodiorites.
5 - Late Variscan emplacement of dykes of basaltic andesites.

Stages 3 to 5 can be documented at the locality of Anenský mlýn. Diorites and granodiorites as well as tonalites (Fig. 10) originated by their mixing, strongly altered rocks and basaltic andesites are exposed in the quarry.

The diorites are amphibole or biotite-amphibole bearing, medium- to coarse-grained, dark grey rocks. They consist of zoned plagioclase (An_{50}core, An_{40} rim), amphibole (hornblende-edenite), biotite, quartz, ilmenite with a titanite overgrowth, zircon and apatite. The central zone in the plagioclase is usually strongly altered, the alteration products are white mica, epidote and acid plagioclase. No relics of pyroxene were found in the amphibole. This observation together with high contents of TiO_2 (1.06 - 1.48 wt. %) and K_2O (0.69 - 0.76 wt. %) in the amphibole suggest their magmatic origin. Some amphibole grains are replaced by biotite on the rim. Apatite appears in two morphologically different forms. The common long prismatic crystals (L/W > 20) are widespread in the diorites. Rarely, short prismatic (L/W=4) crystals appear in addition in the diorite inclusions. The short prismatic crystals are unusual in the basic rocks but very common in granites. The occurrence of both types in a mafic inclusion in granites indicates mixing of both magmas (Didier 1987). The diorites are relatively basic (51.5 wt. % SiO_2) but alumina-rich (18.5 %). The MgO (4.6 %), Cr (137 ppm) and V (190 ppm) contents are rather low. The TiO_2 (1.4 %), P_2O_5 (0.64 wt %), K_2O (2.3 %), Rb (75 ppm), Nb (23 ppm) and Y (34ppm) contents are, on the other hand, comparatively high.

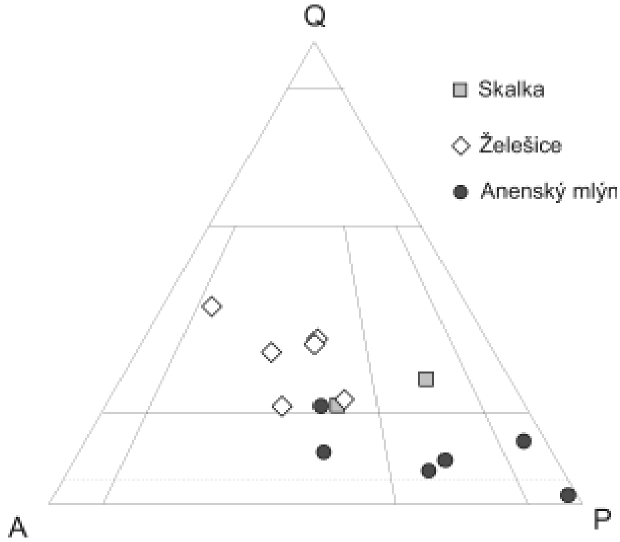

Fig. 10. Classification of plutonic rocks at the localities of Skalka, Anenský Mlýn and Želešice. Data by Staněk and Hanák (1973), Theimer (1978).

High concentration of LILE as well as low K/Rb ratio indicate a comparatively highly evolved source of diorites.

The diorites form xenoliths of different size in the granodiorites. The smallest xenoliths can be observed only microscopically as a few millimetres biotite + plagioclase spots in the light coloured granites. The maximum size of diorite relics (xenoliths) reaches 3 km in the map. The tonalites or granodiorites with frequent microgranular enclaves appear commonly at the contact between granodiorite and diorite as a product of their interaction. Sharp contacts between both rock types are less usual.

The granodiorites are, if not altered and inclusion-free, fine-grained and light grey coloured. They consist of subhedral plagioclase, sub- to anhedral K-feldspar, anhedral quartz, biotite, and accesory zircon, apatite, sphene and allanite. White mica, chlorite, epidote are the secondary phases.

Plagioclases are typically oscillatory-zoned. The central zone is usually altered. It consists mostly of oligoclase (An_{14}), white mica (muscovite with 2 - 24 % of paragonite molecule), epidote, zoisite and very small (up to 0.1 mm) K-feldspar grains. The non-altered zones between core and rim consist mostly of oligoclase with 22 - 24 % An. Albite (An_3), was found as a very thin zone on the rim. The K_2O content (0.07 - 0.25 wt. %) in the plagioclase is low.

K-feldspars host strongly altered plagioclases, biotite, chlorite and quartz. The myrmekites appear at the contact between plagioclase and K-feldspar. Elevated BaO (0.74 - 0.89 wt. %) and CaO (0.04 - 0.13 %) concentrations are typical. K-feldspar, which appears together with white mica, epidote and zoisite as an alteration product in the plagioclase, is enriched in FeO (0.07 wt. %), depleted in BaO (0.18 %) and free of CaO.

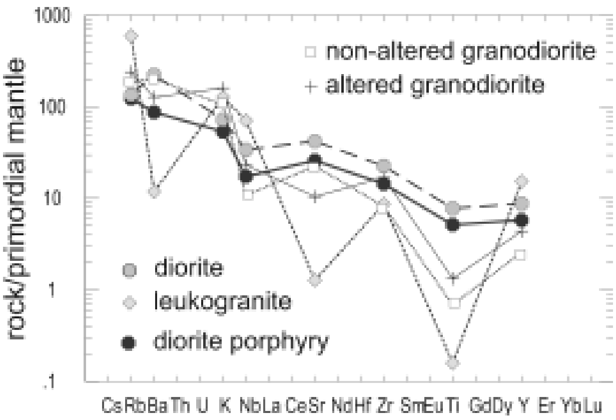

Fig. 11. Trace element distribution in the rocks of the Anenský Mlýn quarry. Normalisation after Sun (1982).

Biotite forms small subhedral grains which are often replaced by chlorite. The alteration is usually stronger on the rim.

The granodiorites are, from the geochemical point of view, rich in Al_2O_3 (14.96 - 15.64 wt.%), Na_2O (4.23 - 4.66 %) and Ba (849 - 1554 ppm) and poor in CaO (1.24 - 1.84 %) and Sr (197 - 427 ppm). The high alumina saturation index (1.14 - 1.20) indicates an S-type affinity of these granodiorites. The concentration of HFS elements (mostly Nb, Zr to a lesser degree Ti as well) shows a positive dependence on the biotite concentration. Biotite-rich samples exhibit elevated concentrations of Nb (15 ppm), Zr (324 ppm) and TiO_2 (0.27 wt.%). The lower values (Nb 9 ppm, Zr 80 - 147 ppm, TiO_2 0.13 - 0.21) are typical of biotite-poor members. The generally high concentration of LILE and low concentrations of HFS elements (Fig. 11) correspond well with typical volcanic arc granitoids of Pearce et al. 1984.

All the above mentioned rocks are often altered. The alteration zones are several metres thick, the altered rocks themselves are usually red coloured and coarser-grained than the unaltered ones. Only altered granites were studied in detail. The plagioclase is replaced by sericite, albite and perthitic K-feldspar, with frequent remnants of former plagioclase; biotite by chlorite and iron oxides. The altered rocks are, compared with the unaltered granitoids, enriched in SiO_2, K_2O, slightly in Rb, and depleted in MgO, Al_2O_3, CaO and BaO at the same time. The concentrations of elements like Zr, Y and Nb remain unaffected. The changeover in element concentrations is caused by impute of probably aqueous fluids rich in K and CO_2, which invoked the growth of secondary sericite and especially K-feldspar followed by the loss of Ca and Al from An-rich plagioclases and Mg from biotite. The Ca, Al, Mg and CO_2 were accommodated in numerous carbonate, epidote- zoisite or palygorskite veins and veinlets cutting the rock. The highly differentiated leucogranites frequently cropping out in the vicinity are the probable source of the fluids.

A vein of basaltic andesite cuts the whole magmatic sequence. The rock is dark coloured, very fine-grained, its mineralogical composition is simple - strongly altered plagioclase and amphibole. Plagioclases form phenocrysts only. Rare amygdules are filled with carbonates. The high contents of Ti, Zr, Y and Rb correspond to basalts with within-plate characteristics.

Stop 6
Želešice - abandoned quarry

Pavel HANŽL, Kristýna BURIÁNKOVÁ and Antonín PŘICHYSTAL

An abandoned quarry on the right bank of the Bobrava River, 2 km NW of the Želešice village, mafic and ultramafic rocks intruded by granites of the West area of the Brno massif.

Schistose metabasites (chlorite-actinolite, albite-epidote or epidote-actinolite schist and amphibolite) are exploited in the huge quarry on the left bank of the river. Sulphide mineralisation (pyrite, chalcopyrite, sphalerite) and magnetite are accesory or can be found in occasional veins or nests with carbonates and quartz. The isotopic composition of sulphur ($\delta^{34}S$ = -6 to 2 ‰ CDT) is related to the bacterial reduction of marine sulphate during the volcanosedimentary deposition at temperatures of about 50°C (Losos et al. 1995).

The abandoned quarry on the right bank of the Bobrava River was opened in mafic to ultramafic rocks formed almost solely by hornblende. The rocks are schistose (Fig. 12), having the character of amphibolites to green schists near the entrance

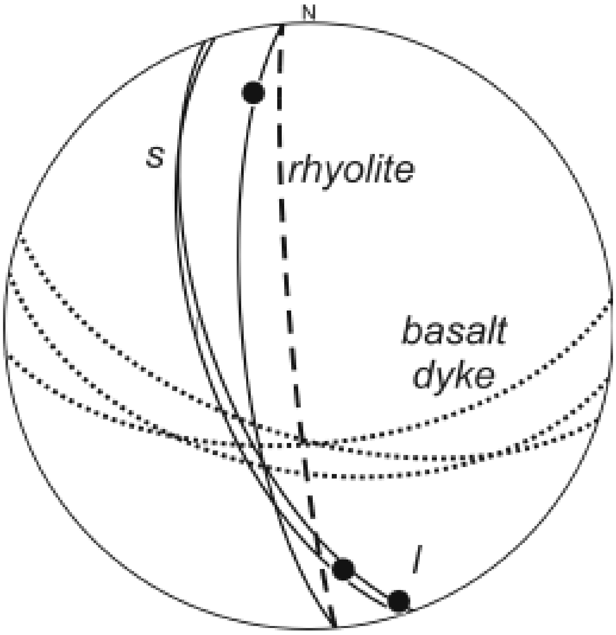

Fig. 12. Orientation of the structures at the Želešice quarry. s - foliation, l - lineation (equal area, lower hemisphere).

to the quarry. The hornblendites pass to medium-grained gabbrodioritic rocks in the eastern part of the quarry and are intruded by irregular bodies of red granites and by a thick dyke or stock of brown-red granite porphyry (rhyolite) which is furthermore cut by dykes of dark olivine basalts with thicknesses not exceeding one metre.

Mafic rocks of the Želešice quarry are basic to ultrabasic with their trace element patterns and very low REE contents indicating a primitive source. Depleted mantle is supposed to be the source of these rocks based on εNd_{580} values (+4.8 and +5.8) according to Ch. Pin (pers. comm.).

Olivine basalts are dark rocks composed of fine-grained ophitic matrix (plagioclase, chloritized amphibole and opaque mineral) with phenocrysts of destroyed pyroxene and sepentinized olivine. A sample of olivine basalt was analysed by K-Ar method in the Laboratory of Isotopic Geology, Geological Survey of Slovakia, Bratislava (working team led by I. Repčok) and yielded the following data (unpublished data of A. Přichystal): 434 ± 8 Ma (by isotopic dilution) and 438 ± 16 Ma (volumetrically). Compared with the latest geological time scale (Gradstein and Ogg 1996) the age corresponds to the Lower Silurian. Naturally, it needs a verification by another isotopic method.

Dykes and stocks of subvolcanic granite porphyry are composed of quartz-feldspathic fine-grained matrix. K-feldspar and quartz are common phenocrysts, plagioclase, biotite and hornblende are rare (Fig. 13). Xenoliths of hornblendites, diorites and xenocrysts of hornblende and feldspars are frequent. Neg-

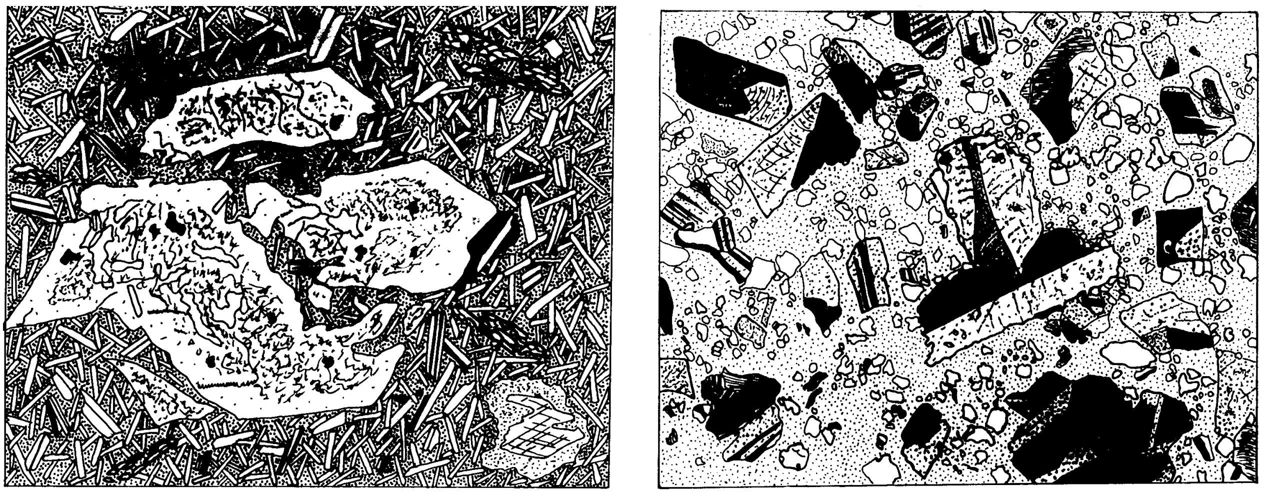

Fig. 13. Textures of subvolcanic rocks from the Želešice quarry: a - olivine basalt, lenght of view 3 mm; b - rhyolite with K-feldspar and plagioclase phenocrysts, lenght of view 2 mm.

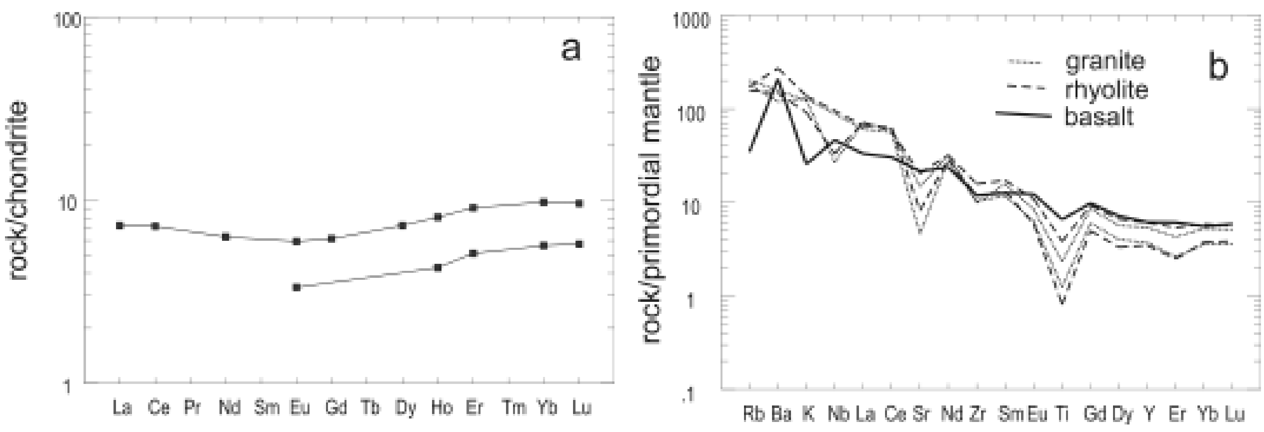

Fig. 14. Trace element distribution in selected rocks of the Želešice quarry, data by Hanžl and Melichar (1997): a - REE-normalized patterns for amphibolite; 2 - correlation of granites and rhyolites in spider diagram. Normalisation values according to Sun (1982).

ative εNd_{580} values (-1.6) in the granite porphyry point to a continental source (Ch. Pin - pers. comm.).

Medium-grained biotite granites to granodiorites prevail in the western part of the quarry. They are calc-alkaline, peraluminous. Field and petrographical data indicate some relationship between granites and subvolcanites. Transitional textures as well as trace elements and REE chemistry probably indicate cogenetic evolution of these rocks (Fig. 14).

Occurrences of bitumens described on fractures are related to the migration of hydrocarbons in the footwall of the Carpathian Foredeep (Schmidt 1970).

DAY 2
Palaeozoic sediments of the Drahany Upland

Jiří KALVODA and Rostislav MELICHAR

Moravosilesian Palaeozoic sediments can be generally divided in three different lithotectonic complexes: 1 - Pre-flysch, 2 - Flysch and 3 - Molasse complexes. Pre-flysch complex is Devonian to lowermost Carboniferous. Occurrences of the Cambrian and Silurian rocks indicate the existence of pre-Devonian sedimentary basins. The flysch complex consists of Lower Carboniferous siliciclastic turbidites (shales, siltstones, greywackes and conglomerates). Upper Carboniferous paralic to continental siliciclastics with coal dominate in the third molasse complex.

In the Moravosilesian Devonian Pre-flysch complex basinal and platform facies were originally described by Zapletal (1929). The presence of volcanites regarded Zapletal (1929) as a characteristic feature of basinal facies. Contrary to him Kettner (1935) distinguished carbonatic Moravian Karst facies and shaly Drahany facies. The work of Chlupáč and Svoboda (1963) meant a significant contribution to the understanding of the Moravosilesian Devonian. These authors defined 3 developments: basinal, platform and a new one - transitional. The outcrops of the transitional development were previously regarded by Zapletal (1929) and Kettner (1942) as tectonically convergent parts of basinal and platform development.

The Pre-flysch complex of the Drahany Upland is strongly folded and faulted and usually incorporated into tectonic melange of the flysch sediments which complicates the reconstruction of Devonian and Lower Carboniferous paleogeography. Kettner (1942, 1966) and Zapletal (1932) assumed that the recent zoning is only moderately modified original situation and the Moravian Karst and Čelechovice units represent two opposite margins of the same basin of SE-NW orientation. In this interpretation the central deep-water part of the basin (Stínava) was thrust over the flysch sediments and the western margin (the Brno massif and Devonian cover) was thrust over basinal sediments (the so-called Drahany overthrust, Kettner 1942).

A more mobilistic conception was proposed by Cháb (1986) and Chadima and Melichar (1996, 1998). They assumed that the Devonian basinal facies were overthrust across a long distance over the platform facies and the Moravian Karst and Čelechovice represent the facies of the same margin of a large basin. The thrust plane was folded and faulted during late thrusting, when the para-autochthonous Brno massif was incorporated into the final structure (Melichar and Kalvoda 1997).

A new idea on the structure and orientation on the Moravosilesian basin was presented in papers by Hladil (1988,1994) and Krs et al (1995). They assumed the original E-W orientation of the axes of partial subbasins and later rotation by approximately 90 degrees.

Kalvoda (1998, 1999) reconstructed the Moravosilesian foreland basin as a complicated series of half-graben subbasins of NW-SE direction where more pronounced passive rifting took place in the west. In this interpretation the passive rifting led to the origin of extensional half-graben subbasins, where initially the continental to marine sedimentation of basal clastics took place (Fig. 15). In the platform facies this clastic sedimentation was followed by reefal sedimentation, in the transitional and basinal facies by deeper siliciclastic sedimentation overlain by calciturbidites (Jesenec limestones, the so-called equivalents of the Macocha Fm.) accompanied by basic volcanism in the basinal facies (Fig. 16). The Famennian and Lower Tournaisian were intervals of maximum extension and deepening. Widespread calciturbidite deposition took place in platform areas while shales with radiolarites may indicate bottom submersion under CCD in basinal and transitional facies.

During the Variscan transpression the Pre-flysch complex in the west was incorporated together with flysch sequences in a nappe system and rotated while in the east the original orientation of facies zones can be traced. The tectonic structure of the Rhenohercynian Zone in Moravia is regarded in this interpretation as similar to the flysch belt of the Western Carpathians where pre-flysch formations were incorporated in flysch nappes in the east but sustained their para-autochthonous and autochthonous position further west.

In the Moravian Karst only the platform and transitional

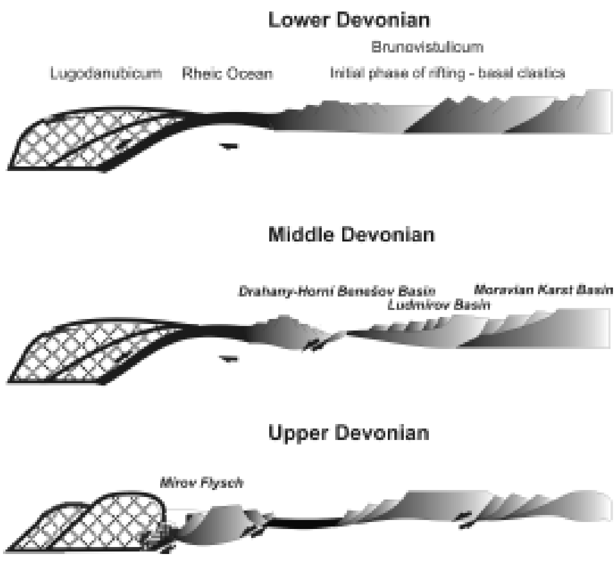

Fig. 15. Schematic picture showing the evolution of Devonian extensional basins on the passive Moravosilesian margin of Laurussia.

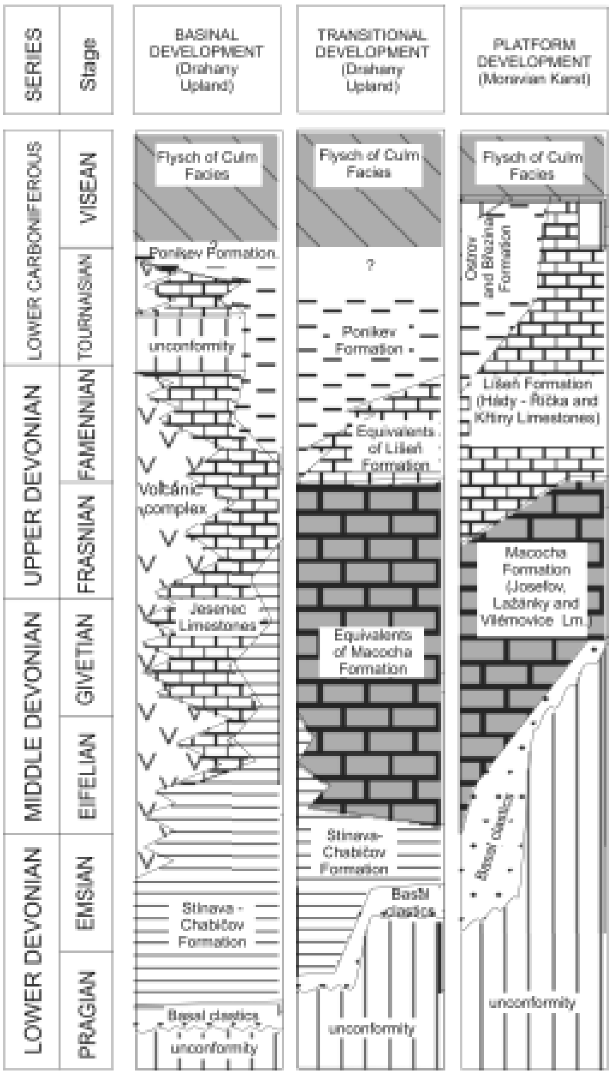

Fig. 16. Correlation scheme of the basinal, transitional and platform development (according to Bábek and Kalvoda in Kalvoda et al. 1998).

developments can be distinguished (basinal facies crop out only in one small section near Sloup). In both developments the sedimentation starts with basal clastics. The term basal "clastics" is used for at least three similar sequences:

1) Lower Cambrian (Jachowicz and Přichystal 1997) marine siliciclastics with variable and sometimes very high thickness (they have been found so far only in boreholes in SE Moravia),
2) Devonian quartzose basal clastics,
3) younger polymict clastics.

In the past the continental to marine complex (arkoses, conglomerates) provoked the idea of Devonian molasse and implied thus indirectly the existence of Caledonian orogeny which was not in good accord with other geological facts. In more recent interpretation they are regarded as initial sediments of passive rifting (see above).

In the platform development the basal clastics are overlain by the shallow-water reefal Macocha Fm. followed by the Líšeň Fm. composed mainly of deeper calciturbidites and hemipelagites. In the transitional development (Němčice-Vratíkov belt north of Moravian Karst) the Devonian and Lower Carboniferous sediments were deposited on more mobile basement. Basal clastics are overlain by the siliciclastic Stínava-Chabičov Fm. followed by equivalents of the Macocha and Líšeň Fms. (mostly calciturbidites) and by the Ponikev Fm. (Fig. 15, 16).

Devonian sediments of the Moravian Karst and underlying the Brno massif are cut by many thrust faults. Every thrust sheet is marked by a slice of granodiorites incorporated into limestones (Kettner 1942, Slavík and Melichar 1996). Limestones represented a common but not perfect lubricant of the thrust planes (see locality Valchov). Kettner supposed duplex structure in the whole limestone complex but later the vertical alternation of different types of limestones was explained as sedimentary cycles on the basis of detailed stratigraphy (Hladil 1988). The limits of separate thrust sheets in limestones are thus very hard to distinguish when the lithological maps are not satisfactory (see locality Hřebenáč).

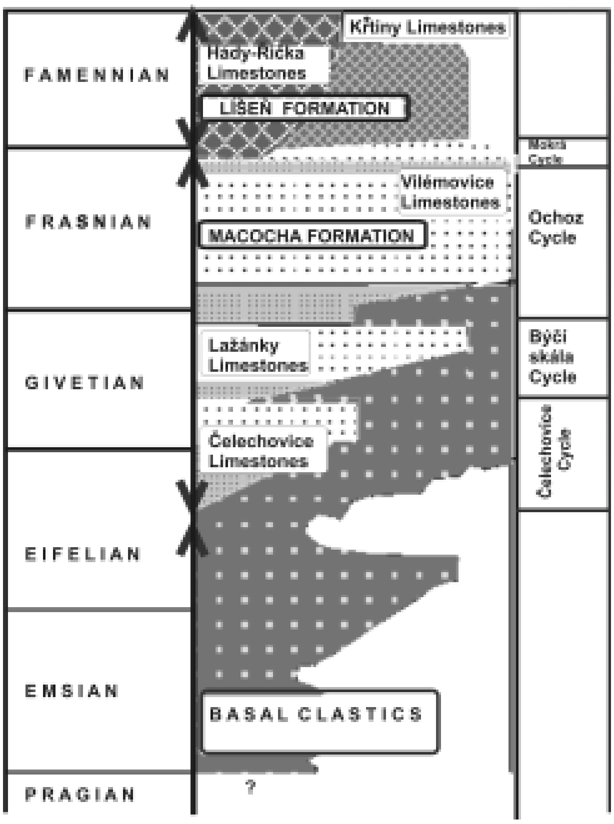

Fig. 17. Cycles and lithostratigraphic units of the Macocha Formation (modified according Hladil 1988).

Stop 7
Blansko - Dolní Lhota

Rostislav MELICHAR and Stanislav ČECH

Sand quarry near the Dolní Lhota (N of the town of Blansko) with exposed tectonic contact between the Brno massif and Upper Cretaceous sediments. The Upper Cretaceous sediments are conserved in a deep asymmetrical ramp valley, the so-called Blansko trough (Zapletal 1927).

The thickness of the Cretaceous sediments here is about 200 m. The Cretaceous complex in the quarry consists of two lithostratigraphic units: the Peruc-Korycany Fm. (Albian to Cenomanian) and the Bílá hora Fm. (Lower to Middle Turonian). The lower part of the Peruc-Korycany Fm. is composed of fluvial, deltaic and lagoonal sediments represented here by fine-grained dark brown sandstones with varying amount of limonite (they are visible only as tectonic slices at the tectonic contact) and by light pinkish or light to dark grey claystones. The upper part of the Peruc-Korycany Fm. is dominated by marine coastal sediments, mainly thick-bedded quartzose sandstones passing into fine-grained green glauconite sandstones. The Bílá hora Fm. (shallow marine deposits) is dominated by a transition from the light coloured sponge-spicule rock to sandstones with chert or ferrolitic nodules (Zvejška 1944, Peloušková red. 1989). The relatively high thickness of the Peruc-Korycany Fm. (about 125 m), which is anomalous in the eastern part of the Bohemian Cretaceous Basin, was explained by synsedimentary tectonic movement. Based on new paleontological investigation (Svobodová 1991) it is possible to explain this fact by the different age of the lower part of the Peruc-Korycany Fm. as well as by an earlier sea transgression in the Cenomanian.

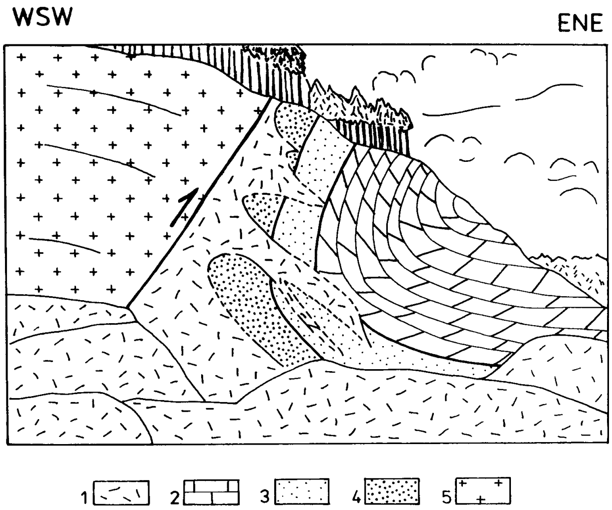

Fig. 18. A sketch of the thrust of the Brno massif granodiorite in the Dolní Lhota quarry: 1 - debris; 2 - Bílá hora Fm. (sandy marl); 3 - Peruc-Korycany Fm. (glauconite sandstone); 4 - Peruc-Korycany Fm. (sandstone). 5 - granodiorite.

The SW boundary of the Blansko trough is limited by a huge steep fault (fault zone). A tectonic limit of the Cretacous sediments is accepted beyond any question. Although the steep dips of Cretaceous strata have been obvious for a long time, the interpretation of the fault varies a lot: synsedimentary fault (Vachtl et al. 1968 etc.), normal fault (Kettner 1941 etc.) and a reverse fault or steep thrust (Zapletal 1932, p. 102, Zvejška 1944, Melichar, Hanžl 1996).

The thrust plane dipping to the WSW is well exposed in the SW part of the Dolní Lhota sand quarry (Fig. 18). The overthrust Brno massif is composed here by biotite granodiorite injected by numerous dykes of diorite porphyry. The prominent oblique striae preserved on the thrust plane plunge to the W and indicate sinistral thrusting. The vertical component of the movement is estimated at 370 m at least. The age of the faulting is inferred from its relation to paleontologically dated sediments as post-Turonian and pre-Badenian, which places the huge steep thrust fault among other saxonian faults: Železné hory F., Lužice F., Hronov-Poříčí F., marginal fault of the Králíky trough etc.

The Blansko trough is not just a few kilometres long, the whole structure continues for about 100 km to the NW (the Kunštát Cretaceous and the Svitavy synform).

Stop 8
Valchov

Rostislav MELICHAR, Jindřich HLADIL and Jaromír LEICHMANN

A large outcrop in the southwestern vicinity of the village of Valchov, medium- to coarse-grained granodiorites with incorporated slices of the Devonian limestones.

The granodiorites from this locality are intensively, nonpenetratively deformed. They consist of plagioclase, quartz, rare K-feldspar. Biotite and hornblende are totally replaced by chlorite, iron oxides, epidote minerals and carbonates. Sphene is altered to leucoxene with carbonate rims. Strong carbonatisation is characteristic. Carbonates replace Ca-rich minerals (hornblende, plagioclase and sphene) or form veins cutting the rock. Deformation is concentrated into narrow zones composed of sericite, chlorite, carbonate and broken quartz and plagioclase grains. The undeformed domains of granodiorite were found between the individual shear bands. These rocks can be compared with the common hornblende-biotite- bearing granodiorites from the northern part of the Brno massif.

The limestone slices (Fig. 19) in the granodiorites are very thin (10 cm) and long (several tens of cm to several metres). Limestones are light to dark grey in colour, usually banded. The fossils and their relics are very rare, because almost the entire volume of the limestone was altered by strong deformation (D1). The sediment was metamorphosed to the tectonomicritic rock

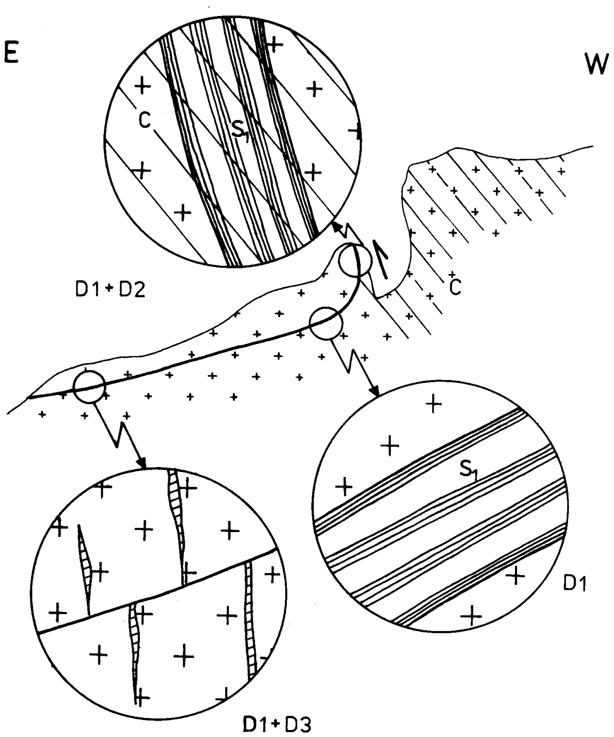

Fig. 19. A schematic profile through the Valchov outcrop. Details show different relations between carbonates and granodiorites, S1 - foliation, C - cleavage.

(mylonite), which is usually a situation rather unfavourable for any fossil identifications. However, it was possible to determine several thicker (1.5-2.5 mm) rotated domains, which fill swelling parts of tectonic laminae. Investigation of twelve polished thin-sections from the best locations shows that these microscopic domains are surprisingly rich in fossils, especially when foliation-parallel orientation of the sections was correctly followed. The fossil remains are smaller than 1 mm because all larger bioclasts were heavily damaged.

Two types of fossil remains are significant for the determination of the facies and approximate age of the sedimentary precursor:

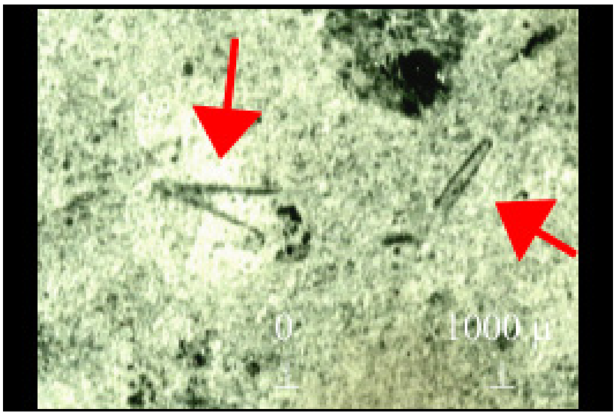

Fig. 20. Brachiopod spines from limestones incorporated into granodiorites.

1 - Styliolinid shells and brachiopod spines: Larger styliolinid shells form accumulations of a variety of circular, elliptical or conical sections (Fig. 20). Their calcite shells are recrystallized and dismembered. Small specimens with elevated content of organic matter and oxides were more resistant to damage relative to big specimens. Two of the small specimens show a very good preservation. Brachiopod spines look like straight or curved tubes (d = 70-80 micrometres), and the terminal fragments show retuse sub-oval ends. They apparently involved organic matter and they are very similar to spines and fibers of chonetid brachiopods.

2 - Broken trilobite eye: A nice section shows a part of a trilobite eye (Fig. 21), which is broken to three parts. These parts preserved the original curvature of the surface as well as structure of the cells. They were arranged in a straight line but not completely disintegrated. It is difficult to give some estimates about taxonomic position. However the facies with styliolinids (tentaculites) and possible chonetids (brachiopods) can hardly contain big proetids with eyes. Therefore, it is most likely a phacopid trilobite.

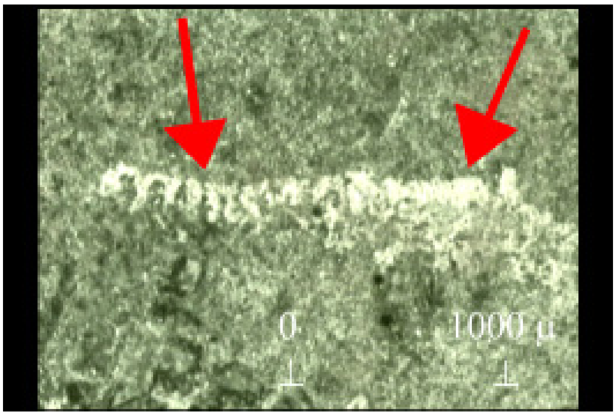

Fig. 21. Broken trilobite eye from limestones incorporated into granodiorites.

Other sections show some shadows, which can be compared with sections across small gastropods and bryozoans (fragments < 1 mm). These sections have an indicative value but cannot be taken as evidence, because the stage of alteration is high.

Although we are dealing with a tectonic facies, which is particularly unfavourable to preservation of the fossils, the remnants of styliolinids, chonetids and trilobites indicate the basinal facies of Devonian limestones, fairly similar to limestone lenses in the Petrovice Shale near Vratíkov or deep-water limestone facies of the Konice area.

Slices of banded limestones normally dip to the E (Fig. 19) and were subjected to younger strain (D2) in the western part of the outcrop as documented by the evolution of west-dipping cleavage. Phase D2 resulted in steep or overturned orientation of limestone slices in this shear zone (Buriánek and Melichar 1997). Only these parts were not subjected to subsequent large pressure solution (D3) with vertical s_1. The other undeformed (by D2) flat-lying slices were nearly completely dissolved and the carbonate material forms here a zone of strongly carbonatized granodiorites with vertical calcite veins.

Stop 9
Hřebenáč

Rostislav MELICHAR and Marek SLOBODNÍK

The locality lies 1 km south of the Sloup village, Moravian Karst. "Hřebenáč" is the name for a well-known attractive cliff in the northern part of the Moravian Karst. Extremely deformed Devonian limestones from the tectonic zone between two tectonic slices (small nappes) can be seen on this cliff, a relic of a large collapsed cave.

The limestones are white to light grey with prominent lamination. Some clasts of fossils are preserved in the rock. Late Middle Givetian age is considered for these limestones on the basis of finds of amphiporids and stachyodids in the surrounding rocks (Hladil 1999, pers. comm.), although in the map they are indicated as the younger light coloured Vilémovice Limestone (Frasnian).

The subhorizontal moderately west-dipping foliation planes evoke "sedimentary" lamination, but there is a strong stretching lineation indicating major strain in the rock. Asymmetrical pressure shadows indicate top-to-the NNE tectonic movement. Primary bedding is not distinct in large parts of the rock. Locally well visible bedding is modified by pressure solution sometimes resembling stylolites, which are very common here. The practically uniform distribution of this bedding was confirmed by structural measurements (Fig. 22). This pattern indicates complex folding. Axial fold planes are subhorizontal and parallel to the considered foliation (recumbent folds). Curved fold axes are subhorizontal with large dispersion in their trend (Fig. 22). These facts led to the idea of existing sheath folds in the rock, however an evident cross section was not found (Roupec and Melichar 1997). The huge recumbent fold in the eastern side of the Hřebenáč Cliff (Fig. 23) was one of the several arguments for Alpine-type folding in the Moravian Karst for Kettner (1949).

The mechanism of deformations was connected with pressure solution; besides, numerous stylolites and syntectonic veins can be observed. Both stylolites and syntectonic veins are deformed, refolded and reoriented.

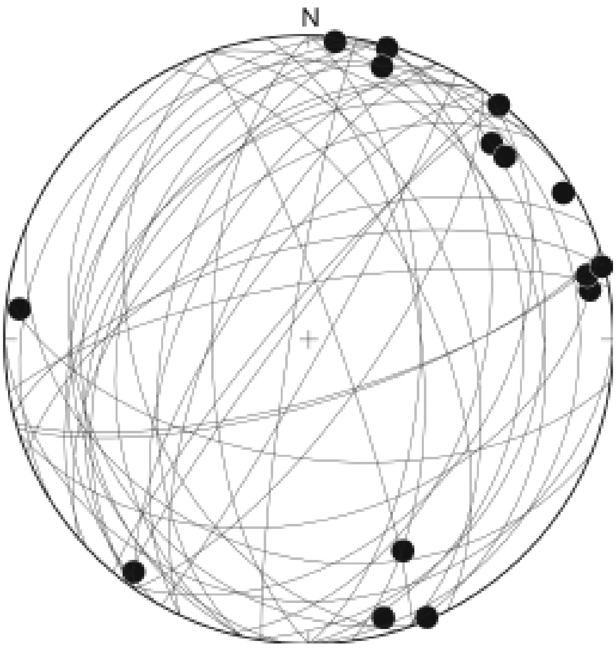

Fig. 22. Orientation of folded bedding planes (large bows) and fold axes (dots) on the Hřebenáč cliff (equal area, lower hemisphere).

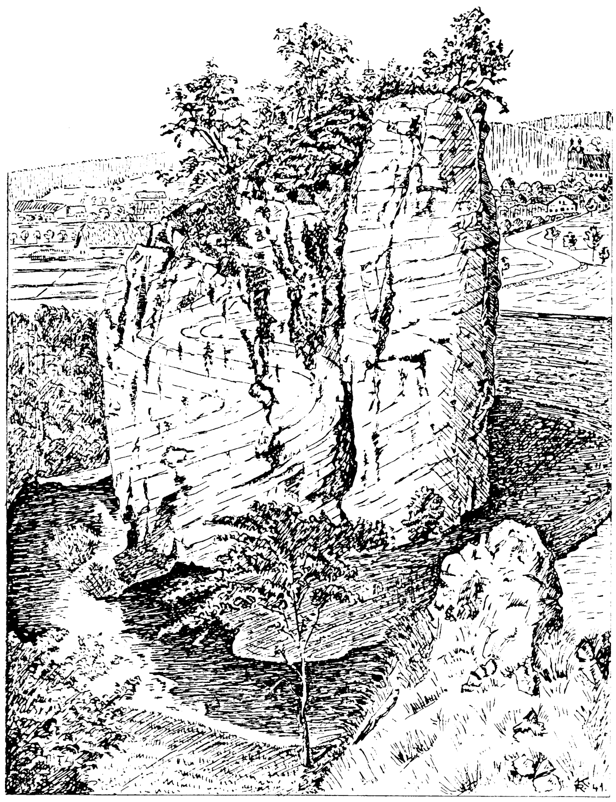

Fig. 23. Kettner´ s scheme of folded limestones on the Hřebenáč cliff (Kettner 1949).

Carbonate veins were studied in the vicinity and two principal genetic groups of calcite veins were found: syntectonic and posttectonic veins (Slobodník et al. 1997).

Syntectonic milky-calcite veins show very often fairly complex shapes. They have an irregular, sigmoidal shape, and are arranged in a dense network or en echelon arrays etc. The mineral assemblage of these veins is very simple - only calcite.

The temperature of homogenization (T_H) of primary fluid inclusions (FI) ranges between +60°C and +109°C (Amatérská Cave). Without pressure corrections we can consider these values as the lowest forming temperatures of syntectonic calcites. Salinity of trapped solutions (NaCl-H_2O system) is low, in the range of 1.4 - 7.45 wt. % NaCl eq. The fluids were derived from limestones during their deformation. They circulated within a limited volume of rocks with a small contribution of meteoric water.

Post-tectonic veins do not show a relationship to structures formed during the Variscan deformation events. Hydrothermal minerals fill joints of mostly NW-SE (NNE-SSW) strikes or cement breccia of limestones. The mineral assemblage is more varied. Coarse-grained calcites (approx. 3-4 populations) are associated with sulphides (reddish colour of calcite is produced by the presence of fine pigment of sphalerite) and minor quartz (Slobodník et al. 1995).

Microthermometric analyses of FI in calcites revealed the most frequent extent of T_H values between +45° and +85°C. Salinity of fluids ($NaCl$-$CaCl_2$-H_2O system) in calcites associated with sphalerites range between 14.8 and 23.4 wt. % $CaCl_2$ eq. These fluids represent basinal brines with typical features for the MVT-fluids.

Stop 10
Ostrov u Macochy, the road-cut near the mirror

Jiří OTAVA, Rostislav MELICHAR and Petr ŠPAČEK

Road cut and natural outcrops above the road at the NE margin of the Ostrov village (Fig. 24) display an overturned limb of a megafold in Upper Devonian Vilémovice Limestone of the Macocha Fm. and nodular Křtiny Limestone of the Líšeň Fm. The carbonate sequence is thrust over the Ostrov Shale (Lower Carboniferous) and rhythmites of the Rozstání Fm. (Viséan).

The oldest rocks are exposed at the upper edge of the steep slope. The light grey massive to thick-bedded limestones of the Vilémovice Member (Macocha Fm.) are of Frasnian (Upper Devonian) age. The thickness of the whole formation is about 1000 m. Downhill, the Vilémovice Limestone gradually passes into the pinkish nodular Křtiny Limestone of the Líšeň Formation. Its Famennian age was proved by conodont fauna. The content of reddish pelitic matrix increases downhill, i.e. into younger rocks. The lithologic change reflects the transition from sedimentation on a carbonate platform (Macocha Fm.) to the slope and pelagic sedimentation (Líšeň Fm.). The total exposed thickness of the Křtiny Limestone does not exceed first tens of metres.

Shard-like splitting olive green shales of the Ostrov Member may represent a transitional facies between the Upper Devonian limestones and Lower Carboniferous (Viséan) siliciclastics both in lithology and age (based on their setting on the contact), however no fossil have been found. The Upper Viséan siliciclastic rocks (shales, siltstones, greywackes) are exposed east of the road. These rocks belong to the turbidites of the Rozstání Fm, i.e. the youngest rocks at the site. The thickness of the whole formation situated in the central part of the Drahany Upland is estimated at about 1500 m. It is overlain by the Myslejovice Fm. in the east.

The carbonate sequence is set in a tectonically reduced overturned limb of a large drag fold originated during thrusting of the Devonian limestones over the Viséan siliciclastics. The strain grows towards the tectonic contact which is lubricated and marked by shales (Ostrov Member). Cleavage developed in the strained limestones, an oblique nodular structure was produced in the platy limestones and bedding planes were rotated. Foliation is defined by the orientation of ductile deformed fossils within the limestones of the Vilémovice Member (e.g., crinoids, ostracods, stromatopors) and of detrital parts of calcareous mudstone. Parameters of deformed symmetric pressure shadow of fibral calcite around quartz grain indicate the minimum stretch by about 200%. Pressure solution is evident from stylolites and fibrous veins. Two generations of calcite veins were observed,

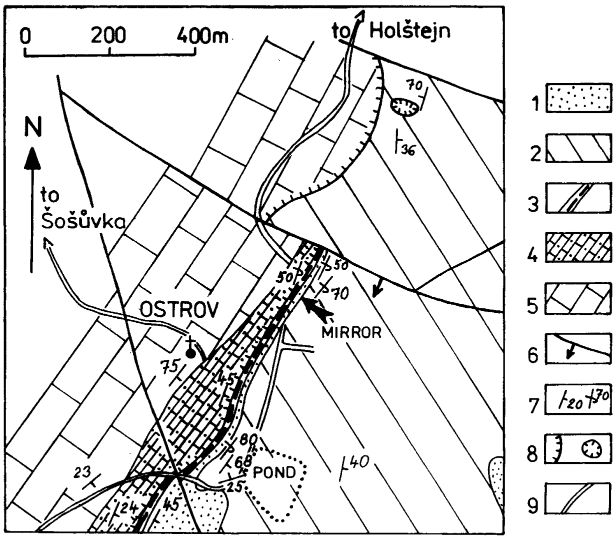

Fig. 24. Quaternary-free geological map of the area of Ostrov u Macochy (Dvořák 1997, modified). Explanation: Lower Carboniferous (Rozstání Fm., Visean) 1 - medium- to coarse-grained greywackes locally with shale clasts; 2 - rhythmites of dark shales, siltstones and fine-grained greywackes; 3 - olive-green siliceous shales of the Ostrov Member (Lower Carboniferous); 4 - nodular limestones of the Křtiny Member, Líšeň Fm. (Famennian); 5 - light grey limestones of the Vilémovice Member, Macocha Fm. (Frasnian); 6 - fault; 7 - strike and dip of bedding planes, overturned beds; 8 - thrust; 9 - main roads.

one of which is folded and reorientated into a direction subparallel to foliation. The younger one cuts the rock foliation. The rock can be determined as mudstone-wackestone with predominating micrite but the amount of micrite could have been strongly modified by tectonic deformation of the rock. The values of dip of intensive cleavage 316/20° and of the bedding 310/45° prove the overturned position of strata. Some of the tectonically underlying Upper Viséan rhythmites are in normal position, some beds are overturned (load casts, grading, relation between bedding and cleavage).

Several hundreds metres to the NE, a very interesting finding was made by Dvořák (1997): a small tectonic klippe of Devonian limestones overlying Upper Viséan shales and greywackes. The tectonic contact was proved by a prospecting ditch and it was possible to see its horizontal orientation.

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