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Geology of the Paleozoic rocks of the Šternberk-Horní Benešov Zone (Nízký Jeseník Mts., Northern Moravia)

Geologie paleozoika šternbersko-hornobenešovské zóny (Nízký Jeseník, severní Morava)

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Abstract: The Šternberk-Horní Benešov Zone occupies an important position in the middle of the Nízký Jeseník Mts. Paleozoic. Basic volcanic rocks were emplaced along structurally controlled crushed zone trending NNE-SSW from the Upper Emsian to Lower Viséan. Volcanic activity is believed to have strongly affected the sedimentation: the Rhenish litho- and even biofacies have changed into Hercynian facies in the middle of the Upper Emsian. Pelitic type of sedimentation lasted till the Eifelian when a shallow water limestone sedimentation began to prevail gradually. This sedimentation was partly substituted by deposition of siliceous shales with cherts since the Upper Frasnian. The Moravský Beroun Formation was locally deposited prior to the flysch sedimentation near Šternberk and Moravský Beroun. This formation consists of quartzose conglomerates and limestone breccia. The flysch sedimentation in the Šternberk region began during the Famennian and Tournaisian. The sedimentation in northern areas began as late as during the Lower and Middle Viséan. A composite anticlinal fan-like structure of the Šternberk-Horní Benešov Zone is thought to have developed mainly during sedimentation of the Horní Benešov Formation (the Lower and Middle Viséan) when it was squeezed out to the height of 3-4 km due to a collision of gneissic blocks of Proterozoic basement. These Devonian and Lower Carboniferous formations exhibit a relatively low grade metamorphism in contrast to adjacent east and west units.

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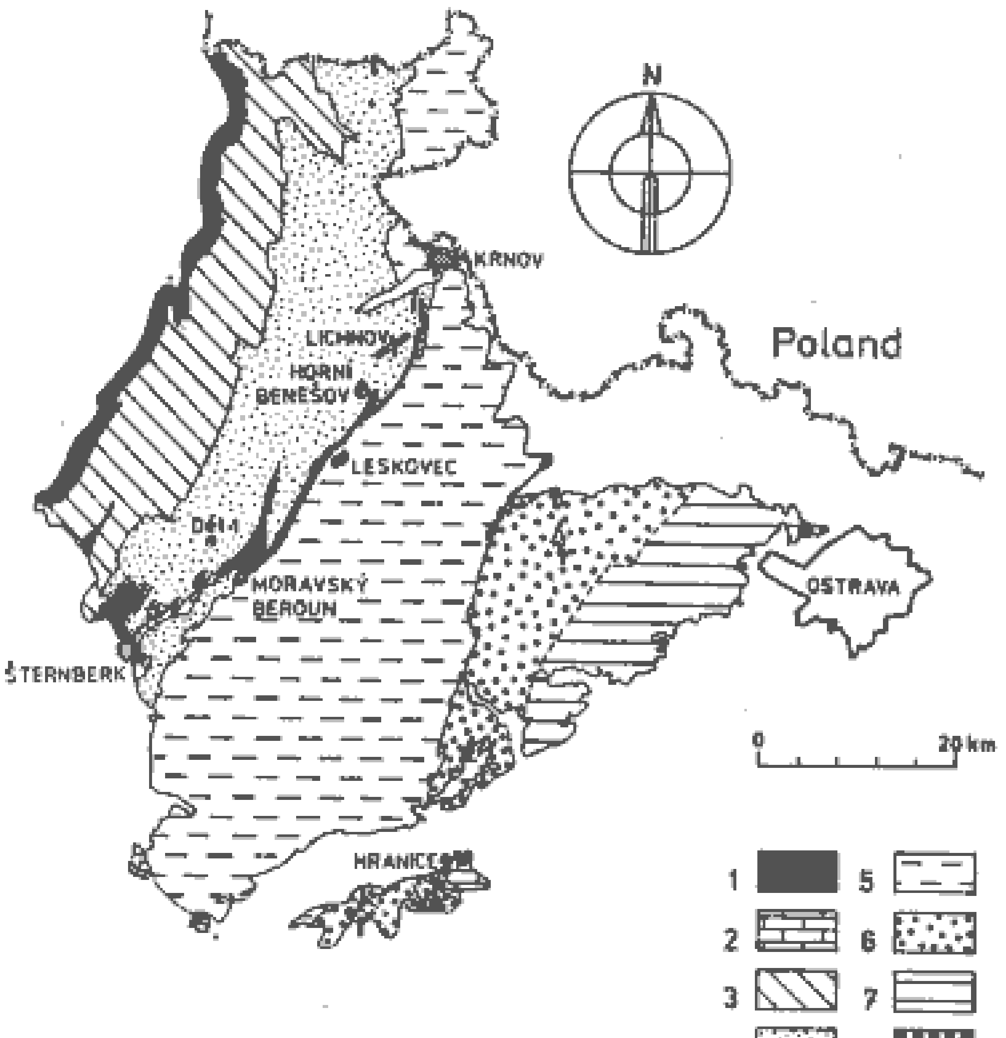
The Šternberk-Horní Benešov Zone cuts the Nízký Jeseník Mts. along a NNE-SSW trending line (Fig. 1). It shows a composite anticlinal structure with mostly westerly oriented vergency of overturned folds and reverse faults. The Zone is rimmed on both sides by deep, extensively folded, synclinoria that are filled up with Variscan flysch sediments: the Andělská Hora Formation (Famennian and Tournaisian) and particularly the Horní Benešov Formation (Lower and Middle Viséan) in the west - the Moravice Formation (Upper Viséan) in the east. The core of the anticlinorium is built up by mostly basic volcanic rocks (tholeiites showing an alkali trend - Přichystal 1985). Metamorphism of Devonian and Lower Carboniferous sediments within the anticlinorium is of meta-anthracite grade which is considerably lower than that of rocks of the same age occurring in neighbouring synclinoria (transition to the epizone). A complex inverse structure has developed from a mobile, strongly volcanic zone, due to a strong compression (Dvořák 1977). It can be compared with the Lahn-Dill structure of the Rheinish slate mountain range.

Relation to Proterozoic basement

Gravimetric maps (Blížkovský et al. 1977) indicate that the thickness of the granitic lighter mass layers is greater in the vicinity of the SSW part of the Šternberk-Horní Benešov Zone than of those located north of it. The thickness of Paleozoic rocks exhibiting high density appears to be also rather small. This seems to be caused most likely by relatively greater thickness of granitized Proterozoic crystalline basement. The gravity values increase toward the NNE which is parallel to the inclination of structural axes. The highest values were recorded in a transversal block between Leskovec in the south and the southern vicinity of Krnov in the north. A positive regional magnetic anomaly has been also reported from a transversal block located between the Vrbno Zone in the west and northern part of the Šternberk-Horní Benešov Zone in the east. The coincidence of positive gravimetric anomaly with positive magnetic anomaly indicates that Proterozoic basement has been only slightly consolidated, remained mobile and



1. Synoptic geological map of the Nízký Jeseník Mts.
1 - volcanics and sediments of the Šternberk-Horní Benešov and Vrbno Zones, 2 - mostly Devonian and Lower Carboniferous limestones near Hranice and its vicinity, 3 - Andělská Hora Formation (Famennian and Tournaisian), 4 - Horní Benešov Formation (Lower and Middle Viséan), 5 - Moravice Formation (Upper Viséan - Goα and βzones), 6 - mostly greywackes, 7 - mostly shales and siltstones (6, 7 - Hradec-Kyjovice Formation - Upper Viséan, zone Goγ and the base of the Namurian A), 8 - Ostrava Formation (the lower half of the Namurian A).

has been built up by mostly basic rocks. Consequently, Paleozoic rocks in this part of the Nízký Jeseník Mts. show maximal thickness. This is likely to be a reason why pre-flysch Devonian as well as Lower Carboniferous sediments near Leskovec and Horní Benešov do not contain detrital quartz. Proterozoic rocks either did not contain quartz or did not form large insular elevations from which the quartz could have been washed down. Another type of the Earth's crust might have been the host for a slightly different volcanism (with K-rich quartz keratophyre) to which a base metal deposit is thought to be related.

The vicinity of Šternberk (Fig. 3)

The Šternberk Paleozoic forms the southernmost structural unit within the Šternberk-Horní Benešov Zone of the Nízký Jeseník Mts. A large basic volcanic body constitutes a part of this unit. Volcanism of the area was studied in detail by Přichystal (1985).

The Stínava-Chabičov Formation (see Fig. 2)

The earliest fauna found in a farm-track near Chabičov is regarded as Upper Emsian (Chlupáč 1979). A rich tentaculitid, trilobite and crinoidal fauna was found in a few metres thick intercalation of dark calcareous shales with lenses of clayey limestones enveloped by volcan
Less abundant are brachiopods, corals, goniati
lamellibranches, hyolites and phyllocarids. Obrhel (19
described well preserved large fragments of terrest
flora. Patchy layer, its lenticular shape in envelop
volcanics and the remains of flora seem to argue
shallow water environment in a depression surrounded
volcanic rocks. From the chemical point of view, the c
material is regarded as mature or overmature. T
sedimentation is believed to have been quiet, in
protected environment which was occasionally affec
by lack of oxygene at the bottom. The type of fauna a
gives evidence for a quiet airless environment which
only occasionally disturbed by an oxidizing flow.

The Chabičov V-2 borehole was located 300 m NE
the described outcrop. A petrographically identical la
was penetrated by the borehole. It also penetrated volca
rocks some 200 m thick which underlie mostly clay sh
The basement of volcanics was not reached. The ma
part of a volcanic complex near Chabičov is of Lo
Devonian age. Fragments of underlying Emsian shale
well as limestones with tentaculitids, crinoids,
spheroids were found in the uppermost section of
borehole (down to 114 m) penetrating the Andělská H
Formation. Limestone intercalations begin to occur in
Stínava-Chabičov black shales, enveloped by volcan
in the lower section of the borehole (down to 270
There are two types of limestones: 1. biosparitic
biointrasparitic limestones with styliolina, segments
crinoids, fragments of trilobite exoskeletons as wel
with algae, algae pellets and peloids of microti
limestones. Fragments of crinoidal stems were
affected by micritization. An admixture of detrital qu
of silt size is frequent. 2. black micrite with scatte
dissolved radiolaria which were calcified. The occurre
of shales as well as limestones gives evidence for a qu
protected, rather lagoonal reducing environm
alternating with periods of extensive currents wh
brought in not only fragments of shallow water fauna fr
close vicinity but also detrital quartz from a rather rem
elevation of an old crystalline basement.

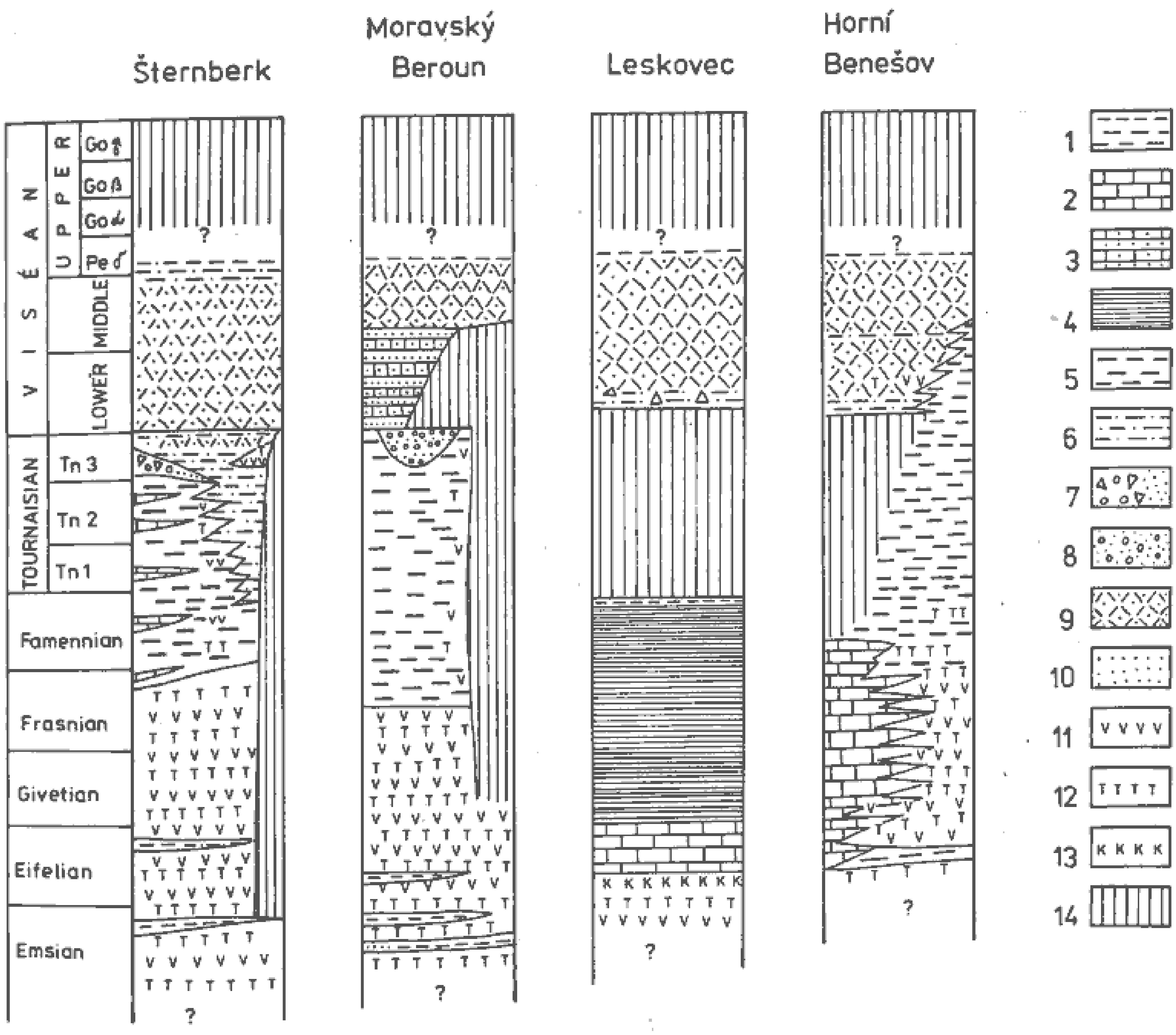
An interbed of grey limestone (microsparite
styliolina) was found in a similar intercalation of
shales NE of Řídeč. A few millimetres thick rhyth
disturbed by cleavage, remained preserved. Stylio
shells show an aureole of radial syntaxially grow
crystals of calcite. A conodont fauna of the Upper Ems
(lower part of the Polygnathus costatus patulus Zo
corresponds to the above mentioned macrofauna
Chabičov.

The Middle Devonian was paleontologically proved
the first time in the Hlásnice-2 borehole in an intercala
of black shales, sandy limestones (the Upper Eifelian,
Tortodus kockelianus Zone), and to a certain exten
laminated siltstones to sandstones. A sandy admix
appears to increase upward. Four intercalations 24 m

m and 17 m thick were found in the volcanic series. The limestones contain locally abundant tentaculitids, in other places ostracods and crinoids. They are regarded as biosparites and biomicrites. An organic admixture with pyrite is ubiquitous. Pellets are rare. Graded bedding in addition to conspicuous lamination was observed microscopically in several specimens. Often a smaller or greater admixture of silty and locally also sandy quartz, plagioclase and mica can be found. Zircon, tourmaline and rutile are accessory. Volcanic rocks occurring in the upper parts of the section are likely to be of the same age. Their thickness was found to vary considerably.

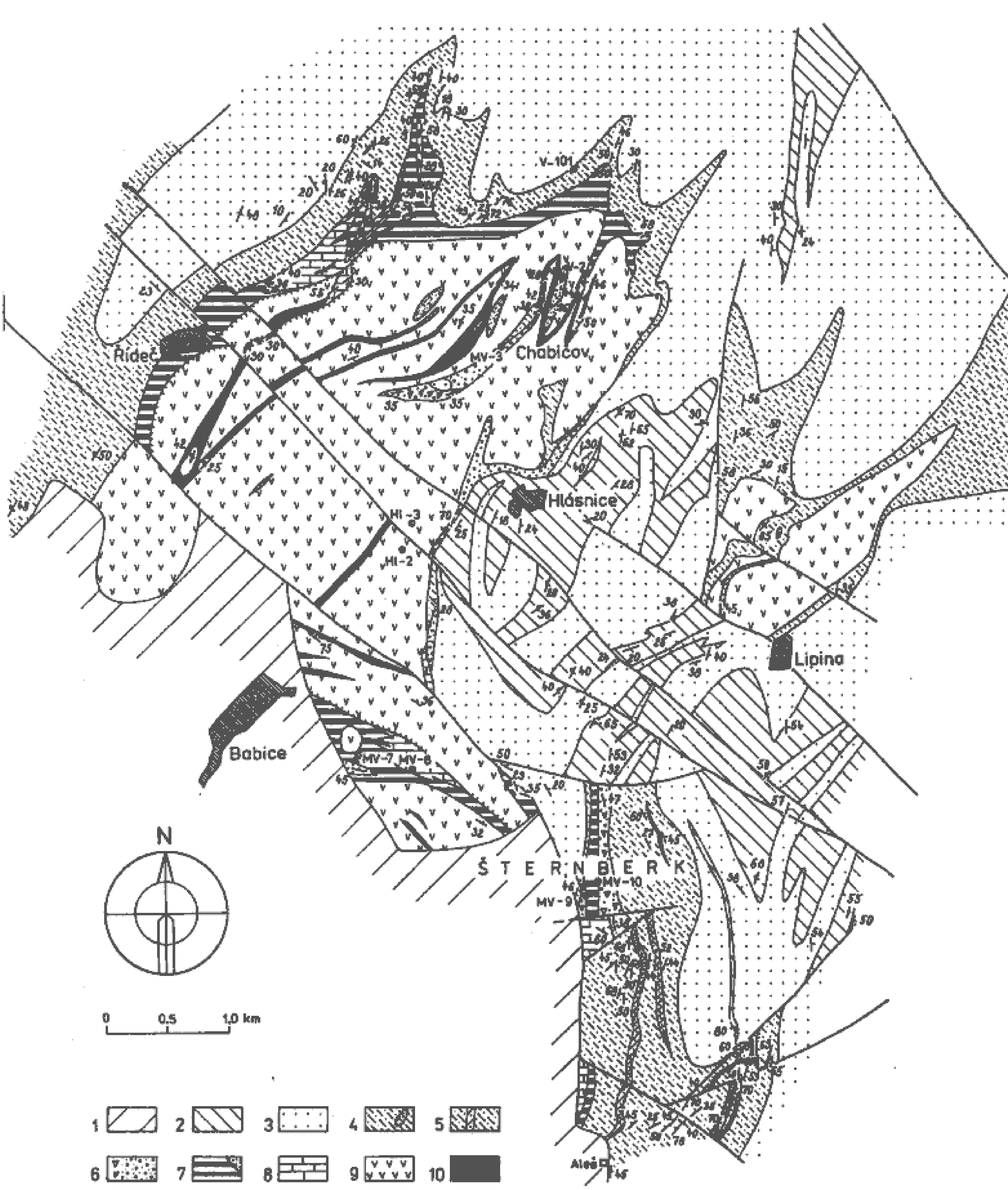
The Ponikev Formation, the Jesenec Limestone

From the viewpoint of stratigraphy, an intercalation of grey micrite in silliceous shales lying directly above volcanics along their western margin, is regarded as the earliest Upper Devonian that was paleontologically proved. It contains a conodont microfauna of the Upper Frasnian (the Palmatolepis gigas to the lower part of the Palmatolepis triangularis Zones). Almost all zones of the Famennian and Lower Tournaisian within the folded Ponikev Formation were defined on the basis of conodont



2. Stratigraphic schematic sections of the Šternberk-Horní Benešov Zone.
1 - dark grey clay shales (Stínava-Chabičov Formation - Upper Emsian and Eifelian), 2 - limestones (Jesenec Limestones - Eifelian to Tournaisian), 3 - sandy limestones and calcareous sandstones, locally with intercalations of shales ("Na výsluní" facies, lower - the base of the Middle Viséan), 4 - laminated grey and light grey limestones (Hněvotín Limestones - Frasnian and Famennian), 5 - siliceous shales with cherts (Ponikev Formation - Upper Frasnian to Middle Viséan), 6 - silty shales and siltstones (Andělské Hora Formation - Famennian and Tournaisian, locally this hatching marks also intercalations of shales in the Horní Benešov Formation), 7 - limestone breccia, quartz conglomerates and sandstones, 8 - quartz conglomerates and coarse-grained sandstones (7, 8 - Moravský Beroun Formation - Upper Tournaisian), 9 - greywackes (Horní Benešov Formation - Lower and Middle Viséan), 10 - fine-grained quartz sandstones in various stratigraphic levels, 11 - basic volcanics, 12 - basic tuffs, 13 - keratophyres, 14 - hiatus.

microfauna (Zikmundová 1964). The formation is several hundred metres thick and is exposed in a valley called Kalkgraben which is bordering the NW part of t volcanic series. Dark siliceous shales with black che



3. Map of bedrock geology of the Šternberk vicinity.

1 - Pliocene, 2 - shales, siltstones and fine-grained greywackes, 3 - greywackes (2, 3 - Horní Benešov Formation, Lower and Middle Viséan), 4 - sh with siltstone laminae, locally pebble shales and greywackes in places of transgression over Lower Devonian volcanics, 5 - silty shales with layer greywackes (4, 5 - Andělská Hora Formation, Famennian and Tournaisian), 6 - limestone breccia with quartz pebbles, quartz sandstones (Morav Beroun Formation, Upper Tournaisian), 7 - siliceous shales with cherts, near Babice with intercalations of quartz sandstones (Ponikev Formation, Up Frasnian to Tournaisian), 8 - limestones (Jesenec Limestones, Upper Frasnian to Tournaisian), 9 - basic volcanics, 10 - clay shale, locally sandy some places with limestone lenses (Stínava-Chabičov Formation, Upper Emsian and Eifelian).

passing through calcareous cherts and shales into slab-like microsparitic limestones are also known from the S and SE margin of the area under investigatigation.

Abundant, thickly bedded intercalations of fine-grained quartzose sandstone occur in strongly weathered shales of the Ponikev Formation. The sandstone shows bimodal distribution (coarser mode M - 0.45 mm, finer mode M - 0.16 mm), silicification and mosaic texture with muscovite on bedding planes. Heavy mineral assemblages (idiomorphic zircon - 0.3 vol.%, rounded zircon - 6.2 vol. %, rutile - 2.6 vol. %, brown, green and even blue varieties of tourmaline - 87.6 vol.%, amphibole - 3.3 vol.%) is identical with that of the Moravský Beroun Formation. It indicates a common source of detrital material.

An intercalation of calcareous sandstone, about 4 m thick, alternating with mostly dark micrites, was penetrated by the Šternberk MV-6 borehole, located near the western margin of the town of Šternberk. An increase of detrital quartz, obviously of plutonic origin, toward the south, indicates an island built up by granitoids and by a crystalline complex located south of the present occurrence of volcanics. The distribution of limestones is irregular, lenticular and appears to depend on local morphology of volcanics. Limestones seem to prevail in the south whereas siliceous shales replace them in the north. From the general extent and distribution of the Pokinev Formation and overlying rocks it becomes obvious that volcanic rocks at that time built an island which was gradually transgressed by the sea.

In a valley NE of a gamekeeper's lodge called Aleš, Koverdynský (1964) found fine-grained microsparitic and micritic laminated limestone which underlies quartzose sandstones. The basal part of the limestone contains a conodont fauna corresponding to the upper part of the Scaphignathus velifer Zone. Light grey, slab-like microsparitic limestones with intercalations of light green shales with conodont fauna of the upper part of the Palmatolepis marginifera Zone were found in another abandoned quarry. These are likely to be underlying dark limestones which occur in the above mentioned quarry.

The Andělská Hora and Moravský Beroun Formations

Siliceous shales of the Ponikev Formation gradually pass into black-grey clay shales in the north and north-west. Siltstone laminae and intercalations of fine-grained greywackes of the Andělská Hora Formation begin to increase gradually toward the top of clay shales. The beginning of the flysch sedimentation has a character of pulses. Rhythmites start to deposit first, to be followed later by an influx of coarser detritus. In places where the Ponikev Formation is missing, the Andělská Hora Formation lies directly on older volcanic series with intercalations of shales of the Stínava-Chabičov Formation (NE and NW of Chabičov and its vicinity). The Moravský Beroun Formation occurs in the roof of volcanics in some other places (S of Chabičov, NW of Hlásnice). The Moravský Beroun Formation was found to have been deposited on the Ponikev Formation at the SE margin of Šternberk and in a valley NE of the Aleš gamekeeper's lodge.

A calcareous subgreywacke occurs in the roof of the Stínava-Chabičov Formation NE and NW of Chabičov. It contains several cm large shreds of underlying clay shales, rare small quartz pebbles up to 2 cm in size, fragments of crinoidal stems, corals, bryozoa and brachiopods. The sandstone passes upward into black-grey shales in which layers of calcareous siltstones and fine-grained greywackes of the Andělská Hora Formation appear to increase. The sandstones occur mostly in places where abundant shales of the Stínava-Chabičov Formation allowed easier erosion of volcanosedimentary rocks (tuffs, tuffites), thus controlling the development of certain depression inside a volcanic elevation. A pebbly shale to breccia, having about 70 vol.% of clay-silty matrix, also occurs locally on the base of the Andělská Hora Formation. Fragments of underlying Emsian shales, phyllites, polycrystalline and monocrystalline quartz (90 vol.% of detritus) and even biogenic carbonate are enveloped in the above mentioned matrix. The rock exhibits a chaotic texture which corresponds to redeposited eluvium.

Light grey, fine- to coarse-grained quartz sandstones to subgreywackes occur in the roof of Lower to Middle Devonian volcanic rocks south of Chabičov and NW of Hlásnice. They contain intercalations of clay shales in the northern part of the area whereas in the southernmost part they pass into coarse-grained limestone breccia with quartz pebbles about 2 cm large. Fragments of dark grey slab-like micrite limestones are up to 30 cm long with a conodont fauna of the B. costatus Zone. The thickness of the layer does not exceed 10 m. Fine-grained quartz conglomerates in the roof of the Ponikev Formation were found in the boreholes Šternberk MV-9 and MV-10 located at the SSE margin of the town of Šternberk. They pass fast into calcareous coarse-grained quartzose sandstones and limestone breccias. Breccias consist of rounded quartz pebbles (up to 3 cm large) mixed with fragments of biosparitic, crinoidal and sandy limestones. Kaolinized feldspars occurring in sandy matrix and phosphorite nodules are typical. This alternation corresponds to the Moravský Beroun Formation the thickness of which varies between 20 and 30 m.

Blocks of limestone breccias were also found in ditches excavated in the town of Šternberk. Limestone fragments are 30 by 12 cm in size. Semirounded quartz pebbles (1-3 cm large) constitute 10-15 vol.% of the breccia. Sporadic fragments of black phosphorites are as much as 3 cm large. The matrix consists of coarse-grained calcareous sandstone. The following assemblage of heavy minerals occurs in sandstones: rounded zircon (including purple variety) - 75.7 vol.%, amphibole - 8 vol.%, tourmaline - 5.6 vol.%, idiomorphic zircon - 4 vol.%, rutile - 2.8 vol.%, colourless garnet - 1.6 vol.%, brownish garnet - 1.2 vol.%, sillimanite - 0.4 vol.%, staurolite - 0.4 vol.%. Breccias pass upwards into sandstones and these into black grey shales with laminae and intercalations of siltstones. They correspond to the Andělská Hora Formation in which intercalations of fine-grained greywackes more than 10 m thick were found to occur between the town of Šternberk and the gamekeeper's lodge Aleš. The heavy mineral assemblage is characteristic of the Andělská Hora Formation (Otava 1981).

Coarse-grained calcareous sandstones 1.1 m thick occur in the roof of the above described Jesenec Limestone in the south, exposed in the valley NE of the Aleš gamekeeper's lodge. They pass into gravel conglomerates (beds being 0.3 to 0.5 m thick), alternating with slab-like white-grey, fine-grained quartzose non-calcareous sandstones which are 20 cm thick. The thickness of sandstones and conglomerates increases up to 5 m toward the south. The following heavy mineral assemblage confined to coarse-grained sandstones to quartz conglomerates is characteristic of the Moravský Beroun Formation (relative proportions are in vol.%): rounded zircon (74.0 - partly pink), idiomorphic zircon (10.2), tourmaline (10.9), brown garnet (1.4), colourless garnet (0.4), red-brown rutile (1.1) and alterites (2.1). Tourmaline showing brown pleochroism prevails over the green variety in the ratio 2 : 1.

The Chabičov-101 borehole is regarded important for dating and mutual relationship of the Andělská Hora and Moravský Beroun Formations (Dvořák et al. 1983). It is located at the northern margin of volcanic series in the places where volcanic rocks were already originally plunging axially toward the NNE. Consequently, the overlying sediments reached here greater thickness. The inclination of beds in the borehole section varies between 30 and 40°. The borehole has penetrated the Andělská Hora Formation but did not reach the basement. The drill log showed shales with laminae of calcareous siltstones and intercalations of biomicritic and bioclastic limestones to be the most abundant. The latter limestones contain besides calcispheres and sponge spicules also conodont fauna of the Upper and Middle Tournaisian. No fauna was found in the lowest, 100 m thick section (false thickness). Sedimentation of the Andělská Hora Formation is likely to have begun already in the Lower Tournaisian. The oldest fauna discovered in the drill core was identified as contemporaneous with the youngest fauna which has been known from intercalations of limestones in the Ponikev Formation which is exposed in the Kalkgraben valley. The deposition of carbonate sediments and cherts continued on tops and slopes of the elevations whereas rather coarse-grained detritus of the Andělská Hora Formation was deposited in depressions. This has been proved in the Loděnice-101 borehole (SW of Moravský Beroun) which the Ponikev Formation contains a conodont fau of the lower part of the Famennian and passes into t Andělská Hora Formation.

Intercalations of black shales with framboidal pyri were also found in addition to limestones in t Chabičov-101 borehole. (Black shales contain 3.74 wt. $C_{org.}$ at the depth of 165.4 m.) Silicification occurs in bot the limestones and the shales. The highest grade silicification was found in thin layers of dark cherts ri in radiolarian fauna. It resulted from a lack of detritu Although the origin of cherts is related to biologic processes which are indicated by ubiquitous laminati (Kukal 1980), the postvolcanic processes are also thoug to have been a source of silica (Mísař 1957).

Two intercalations of limestone breccia wi phosphorites (12.9 wt % P_2O_5) were identified in t borehole, besides the above described rocks. A selecti phosphatization appears to occur even in some oth limestone layers. An occurrence of breccias argues for erosion of Famennian limestones situated on an uplift elevation. Redeposited conodont fauna of the B.costat Zone found at the depths of 163.05 and 163.8 m also giv evidence for such assumption. A fauna of the same a was identified in limestone fragments of the Moravs Beroun Formation toward the south.

Intercalations of quartzose sandstones found in t borehole (at the depth of 142-149 m) correspond to tho of the Moravský Beroun Formation. The sandstones a regarded as Upper Tournaisian, as follows from identifi fauna. Consequently, it becomes obvious that t Moravský Beroun Formation in the vicinity of Šternbe is of Upper Tournaisian age and represents a facies of t upper part of the Andělská Hora Formation. Even pebbl of basic volcanic rocks showing ophitic texture (in t borehole at the depth of 162.3 m) could have be redeposited from shallow water gravel deposits. Shal found in the borehole appear to be chemically mo mature (Al_2O_3/Na_2O ratio varies from 12 to 28.5) th shales of the Andělská Hora Formation (an average ra is 8.24 - Kukal 1980). Some mixing of more mature cl material drained from the Moravský Beroun Formati appears to have occurred there. Immature fine detritus w brought in from the west, from the rising Variscan medi mass (Dvořák 1978). An acid subsequent volcanism places of the present granitic massifs appears to connected obviously with that uplift. The deposition tuffite laminae (268.7 m) seems to result from an ac volcanism. Large effusions of basic volcanics betwe Lipina and Horní Loděnice (NE of Šternberk, cf. Dvoř 1963) represent a time equivalent of the acid volcanism

The area under study is thought to have been strong morphologically differentiated during the Upp Tournaisian. An elevation structure composed of a high metamorphosed crystalline complex was raised in t south. Its rise caused local sea regression. Rounded qua pebbles are thought to have been carried away from the weathered surface whereas limestone fragments came from an eroded shallow water rim of the elevation. This heterogeneous material was mixed together to form limestone breccia which alternated with quartzose conglomerates and sandstones (30-40 m thick). Toward the north, where the sedimentation occurred in the roof of volcanic rocks, the breccias passed into sandstones, and the thickness decreased. Shales and greywackes of the Andělská Hora Formation were deposited along the northern margin of volcanic series where the basement was sinking faster. (The thickness exceeds 250 m.) Both facies replace each other as indicated by intercalations of limestone breccias and quartzose sandstones which occur in shales of the Andělská Hora Formation. Conditions suitable for sedimentation of the Ponikev Formation are believed to have survived along the NW margin of the volcanic elevation. The sedimentation of limestones and cherts extended occasionally even into areas where rocks typical of the Andělská Hora Formation were deposited. Parts of volcanic elevations are thought to have been sticking out of the sea level in the form of small islands.

The Horní Benešov Formation

The Lower Viséan is characteristic of faster sinking of the whole elevation structure. Thick layers of fine-grained greywackes were deposited. However, volcanic rocks still formed a submarine elevation which prevented clastic material to move from the west to the east. As a result, we find greywackes which alternate with graded rhythmites to occur on the eastern slopes of elevations (NE of Šternberk). A layer of tuffaceous greywacke (Kukal 1980) was found at the base of the Horní Benešov Formation. This greywacke was also identified NW of Hlásnice, in the roof of the Moravský Beroun Formation.

Summary of the sedimentation and volcanism development in the vicinity of Šternberk

A stratigraphic-facies analysis showed the centre of the volcanic elevation to be of Lower Devonian age; part of it is Middle Devonian. The elevation was gradually flooded by the sea during the Famennian and Tournaisian. The centre of the volcanic elevation was rising during the Lower Frasnian to be denuded later. The tendency for uplifting lasted till the end of the Variscan tectogenesis. A relatively low grade metamorphism as compared with adjacent rocks may argue for this assumption. However, this cannot be applied to the elevation of the Proterozoic crystalline complex south of volcanic series which is thought to have had the highest position and to have supplied the basin with abundant detrital quartz. A reverse situation occurred during the flysch sedimentation when the elevation built by an old crystalline complex had sunk down to a great depth.

The rising of the centre of the volcanic elevation can be explained by structural emplacement of volcanics from the mobile zone between colliding blocks of the crystalline complex showing higher grade metamorphism and being of Proterozoic age.

The vicinity of Moravský Beroun

The Stínava-Chabičov Formation (Figs. 2,4 and Pl. 1)

A rich fauna of the lower part of the Upper Emsian is reported from the SE margin of the volcanic elevation near Čabová (Röhlich 1956, Chlupáč 1977). It comes from black-grey clay shales of the Stínava-Chabičov Formation. These rocks were penetrated by the Čabová MV-103 borehole. They were found to be closely associated with volcanic rocks: some gradual transitions from shales to underlying tuffites and tuffs were recognized. Strongly weathered fine clayey material (Al_2O_3/Na_2O ratio = 189) is believed to have been deposited there in reducing environment. Calcareous lenses up to 10 cm long containing sections of rugose corals are abundant. The fauna is of Rhenish character. Brachiopods of the spiriferoid group and trilobites are most abundant. About 30 m thick shales enveloping 30 cm thick intercalations of grey, fine-grained quartzose sandstone (locally as much as 20 vol.% of originally clay matrix) which shows a conspicuous bimodality (coarse modus 0.45 mm, fine modus 0.08 mm) were found to occur in a trench NW of Čabová. The assemblage of transparent heavy minerals (J. Otava) appears to be almost identical with the assemblage found in quartzites of Pragian age at the base of the Vrbno group (relative proportions are given in vol.%): garnet 0.2, idiomorphic zircon 1.3, rounded zircon 90.8, rutile 5.1, brown and green varieties of tourmaline 0.8, apatite 1.0, others 1.0.

The roof of the Čabová shales consists of tuffs derived from basic effusives. Intercalations of fine-grained shales in tuffs and tuffites occur approximately 30 m above the upper boundary of the Čabová shales. Only locally they contain abundant tentaculitid fauna and rare fragments of trilobite dorsal shields. I. Chlupáč identified *Illaenulla illaenoides* (Chl) and *Harpes* sp. Both the fauna and lithology of the shales already indicate a Hercynian character. They are thought to have been deposited in a quiet, only slightly flowing aqueous environment which is typical of bays. As far as the age is concerned, they correspond to a fauna which was found at Křišťanovice (Chlupáč 1974) in the higher part of the Upper Emsian-Dalejan. The fauna from Křišťanovice shows a relatively large diversity indicating a shallow quiet environment with a muddy bottom.

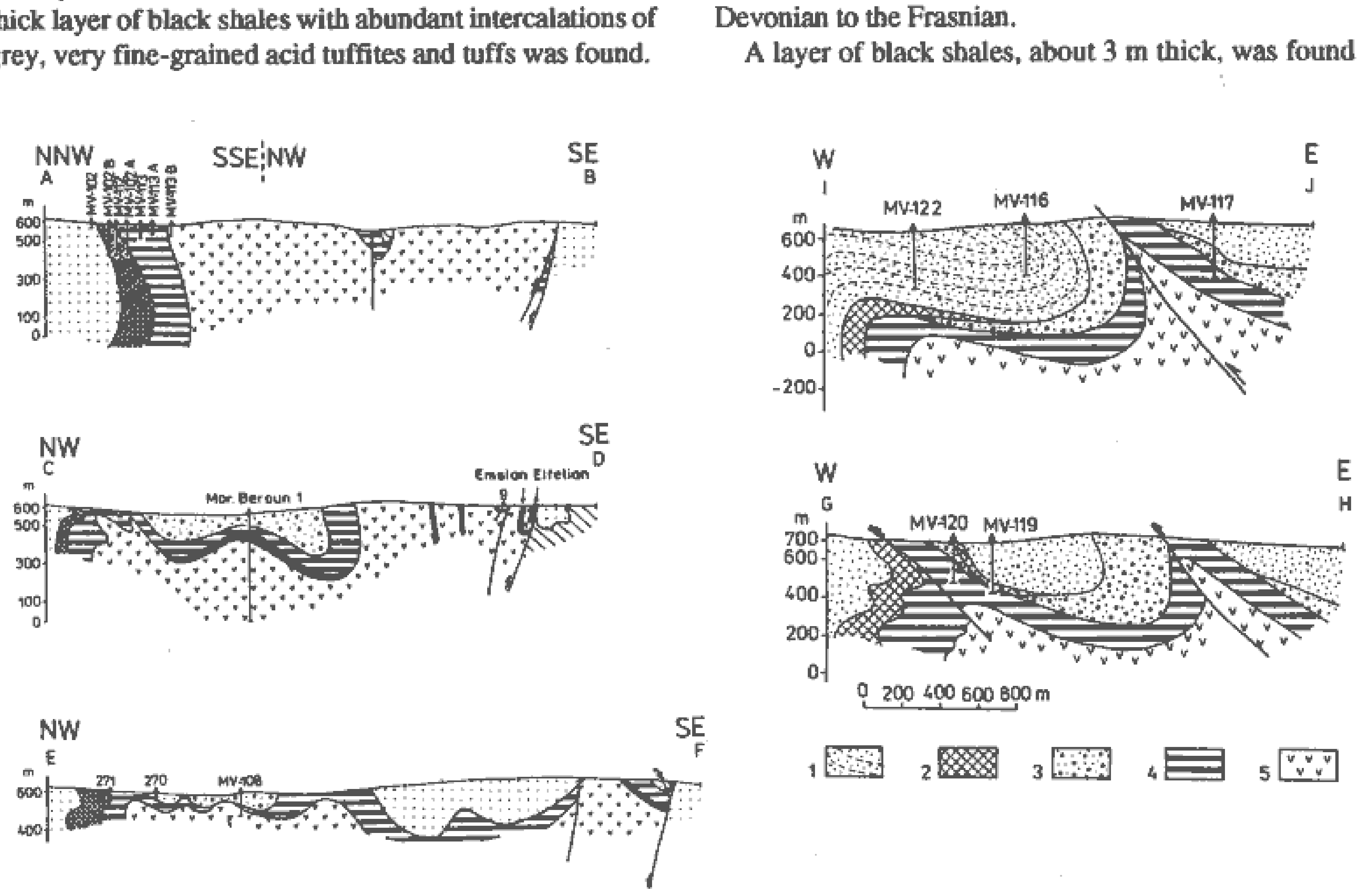
The author has found a trilobite and tentaculitid fauna in black fine-grained, partly tuffaceous, shales which occur at the northern margin of Čabová. Chlupáč indentified *Phacops (Chotecops)* af. *auspex* Chl. and *Cyphaspides* sp. pointing to an Eifelian age of this fauna. It is therefore obvious that there are intercalations of shales of the Upper Emsian (of the lower as well as the upper part) and also Eifelian age which occur at the base of volcanic series. The general thickness of shales and tuffs is very small. Oval nodules of iron ores up to 1 m large often occur in shales. They were mined in the past. Rare intercalations of dark tentaculitid limestones containing dispersed grains of volcanic quartz were found in black shales which were penetrated by the borehole MV-108. This find can be regarded as an evidence of close acid volcanism in the Middle Devonian and/or in the uppermost Emsian (Figs. 4,5 and Pl. 1).

In the roof of the Stínava-Chabičov Formation (alternating shales, tuffs and tuffites) there was found a volcanic series as much as 800 m thick in which effusions of basic lava alternate with tuffs. Two inclined boreholes (1 and 2), dipping 40° toward the NW, 300 m deep were drilled N of Moravský Beroun. They penetrated rather abundant layers of dark grey to black-grey, early diagenetic dolomites and black shales. Their thickness usually does not exceed 1 m. Exceptionally about a 10 m thick layer of black shales with abundant intercalations of grey, very fine-grained acid tuffites and tuffs was found.

Shales and dolomites locally occur as a filling cavities in basic volcanics, at some places they conta volcanic bombs. Dark colour, abundant pyrite (sphalerite), higher concentration of $C_{org.}$ in shales as we as an early diagenetic character of dolomites gi evidence that these sediments were deposited in shallo half closed basins having a strong reducing environme and high evaporation in hot climate. Detritus consisting basic as well as acid volcanics (high in MgO and al K_2O) was washed down from neighbouring areas in depressions in volcanic rocks flooded by the sea. T source of silicification is thought to have been in th weathered detritus. Acidic tuffaceous material is believ to have been wind-blown from a large distance.

No fauna was found at all (not even in thin section most likely due to very bad living conditions in these sma depressions. Accumulated organic matter may come fro a rich lithoral flora. The whole sequence of volcanic roc which alternate with sediments argues for repeat effusions in relatively short periods of time. The charact of the sediments indicates that effusions occurred in a ve shallow sea and/or under subaerial conditions. Terrestri environment allowed volcanic rocks to be weathered a clastic material then deposited in shallow depressio The exact age of the whole sequence is not known b assuming from their position it may be the Midd Devonian to the Frasnian.

A layer of black shales, about 3 m thick, was found



4. Geological sections through the northern vicinity of Moravský Beroun (marked in Pl. 1).
1 - greywackes with minor intercalations of siltstones and shales, 2 - calcareous sandstones and sandy limestones, locally with layers of shales - "Na výsluní" facies (1, 2 - Horní Benešov Formation), 3 - quartz conglomerates and coarse-grained sandstones (Moravský Beroun Formati 4 - siliceous shales with cherts (Ponikev Formation), 5 - basic volcanics with intercalations of dark clay shales of the Stínava-Chabičov Formation

occur in the uppermost parts of volcanic rocks. It was penetrated by the Beroun MV-106 A borehole at the depth interval of 17.6-25.0 m. It contains some pyrite laminae about 1 mm thick at the base. The layer is high in organic C (2.9 wt.%) and sulphur (2.15 wt.%). A strongly weathered clay material was deposited in a quiet, airless environment (Al_2O_3/Na_2O ratio = 176.8). Black shales occur again in the roof of volcanic rocks. They locally contain a tentaculitid fauna. A conodont fauna of the Palmatolepis gigas and Palmatolepis triangularis Zones (Zikmundová 1963) was identified there. Silty admixture is rare. The Al_2O_3/Na_2O ratio corresponding to 193 indicates that a strongly weathered clay material must have been steadily deposited in a quiet reducing environment.

The Ponikev Formation

The Stínava-Chabičov Formation passes very slowly toward the roof into dark grey to black-grey shales which show an increasing amount of chert laminae that are typical of the Ponikev Formation. Thin layers of black shales with pyrite begin to occur at their base. The arthropod *Angustidontus moravicus* was identified in one of these layers (Chlupáč 1978).

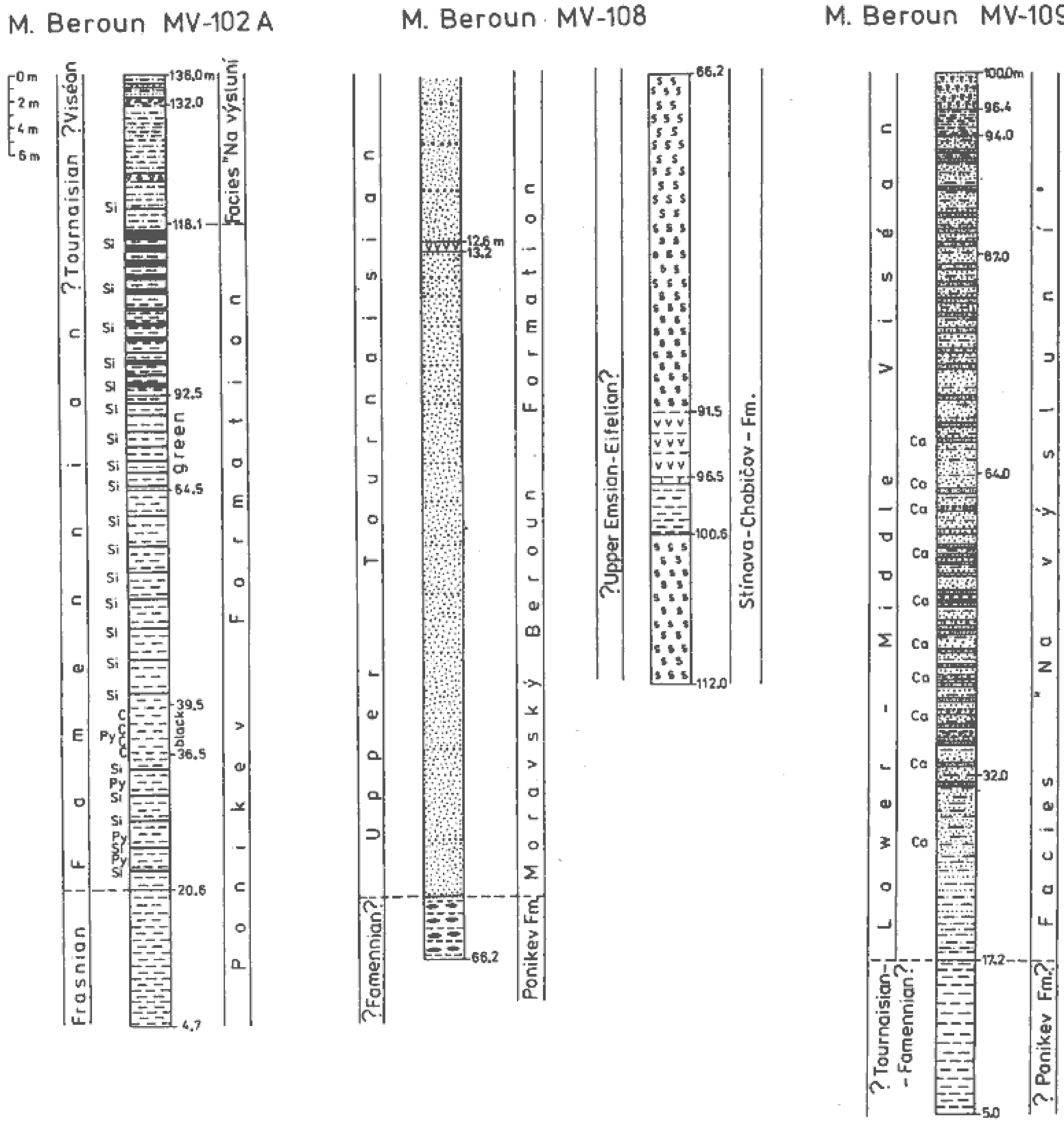
Siliceous shales are mostly black, locally green and rarely also red. The content of Al_2O_3 varies from 10 to 15 wt.%, the SiO_2/Al_2O_3 ratio fluctuates between 4.4 and 6.8. Black shales are low in MnO (0.027-0.052 wt.%) whereas green shales show an increase from 0.098 to 0.1 wt.%, and red shales give as much as 0.85 wt.% MnO. Similar distribution shows also MgO which in one analysis of green shales gave as much as 8.33 wt.%. This content argues for redeposition of detritus of older basic volcanics and its sedimentation in adjacent depressions. It also gives evidence of their emergence above the sea level. The concentration of FeO in black as well as in green shales appears to be also high (4.35-6.31 wt.%). On the contrary, the red shales show higher Fe_2O_3 concentration (4.89 wt.%) as compared with FeO (1.01 wt.%). The Fe_2O_3/FeO ratio clearly indicates that red shales were deposited in an oxidizing environment whereas green shales and particularly black shales were deposited in a reducing environment. The depositional environment is also reflected in concentrations of $C_{org.}$ and S. Black shales show as much as 4 wt.% C and up to 3 wt.% S. Higher concentrations of FeO and S are caused by an occurrence of pyrite which can be seen even with the naked eye. The contents of C in green and red shales are negligible. Higher concentration K_2O (4.82 wt.%) in red shales may perhaps reflect the grade of weathering processes.

A single analysis of black chert (showing SiO_2/Al_2O_3 ratio = 12.56) gave slightly higher concentration of C (1.19 wt.%) and even P_2O_5 (1.75 wt.%) which indicates the occurrence of conodonts. The content of CaO (2.74 wt.%) together with very low CO_2 (wt.%) also gives evidence of the presence of fossils. Cherts locally envelope layers of dark micrites. A conodont fauna of the Upper Frasnian, of the Lower and the lower part of the Upper Famennian (the Palmatolepis triangularis, P. marginifera, Scaphignathus velifer and Polygnathus styriacus Zones - Zikmundová, Chlupáč 1962) was found in the Ponikev Formation in broader vicinity of Moravský Beroun. Zikmundová also identified a conodont fauna of the uppermost Frasnian in the topmost part of the Moravský Beroun MV-102 A borehole. A conodont fauna of the P. marginifera to S. velifer Zones was found in the depth interval of 42-90 m, similar to the Loděnice-101 borehole (33-176 m, approx. 70 m of true thickness - the P.marginifera Zone). Although there is no paleontological evidence of the lowermost Famennian, it seems to be likely that the boundary between the Stínava-Chabičov and the Ponikev Formations in the vicinity of Moravský Beroun lies approximately in the uppermost Frasnian. About a 100 m thick section of the Ponikev Formation NW of Moravský Beroun (vicinity of the MV-107, 113 boreholes) appears to belong to the Upper Frasnian.

The most important geological information comes from the borehole MV-120. Fresh sediments of the Ponikev Formation in variegated facies were found at the depth interval of 58.0-108.0 m. The section was not completely penetrated. The true thickness exceeds 45 m. Transition into overlying sediments is gradual (see further): Black siliceous shales with abundant laminae of cherts (radiolarian chert) and lenticular nodules of pyrite occur in the uppermost part of the section (see Fig. 8). The cherts decrease downward to be gradually replaced by more abundant thin layers of black-grey biomicrites and rarely even bioclastic limestones. Some cherts may also represent silicified limestones. The limestones also contain fragments of strongly micritized shells of foraminifers and ostracods and particularly fragments of crinoidal segments. The uppermost layers of limestones are slightly sandy and contain a fragment of basic effusive rock. A thin layer of an acidic tuff was found at the depth of 60.4 m. No conodont fauna occurs in limestones.

Siliceous shales become downward dark grey and grey and contain rare laminae of cherts and then pass into grey-greenish shales with 1-3 m thick intercalations of grey cherts and rare 8 cm thick layers of dark grey bioclastic limestones. At the depth of 73.5 m, the following miniature conodont fauna was identified by O. Friáková: mostly species *Palmatolepis gracilis sigmoidalis* Ziegler and rare species *Polygnathus dissimilis* Helms et Wolska and *Spathognathodus stringosus* (Branson et Mehl). The fauna is likely to correspond to the lower part of the B. costatus Zone. In any case, it is of the uppermost Famennian age. Based on this assumption, the higher part of the Ponikev Formation can be considered Tournaisian in age. It exhibits mostly dark colour shades.

The lower section of the penetrated sequence (75-108 m) consists of light grey-greenish siliceous shales which

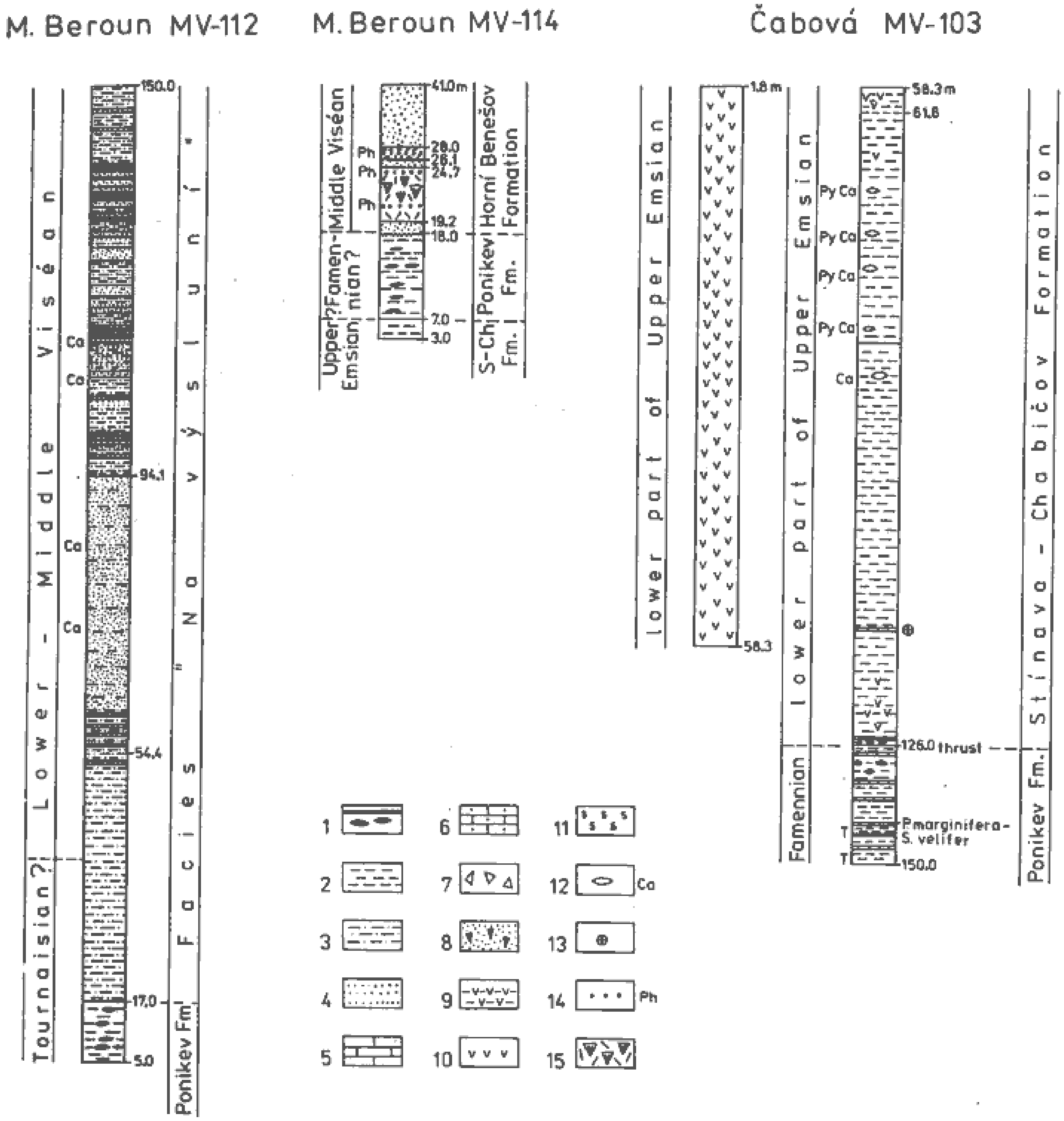


5. Survey borehole logs of the Moravský Beroun vicinity (transferred to true thickness; turned to original position when dealing with overthrown sequences).
1 - cherts, 2 - clay shales, 3 - silty shales with siltstone laminae, 4 - fine- to coarse-grained sandstones, 5 - limestones, 6 - sandy limestones, 7 - lim breccias, 8 - breccia composed of shale and sandstone fragments, 9 - basic tuffites, 10 - basic tuffs, 11 - spilites, 12 - lenses of limestones, 13 - r corals, 14 - phosphorite nodules, 15 - breccia composed of fragments of basic volcanics and shales.

alternate with purple red varieties. They contain layers of grey greenish cherts which are locally abundant and at places rather scarce. Their thickness varies mostly between 1 and 5 cm. A single layer of dark grey biomicrite about 1 cm thick was found at the depth of 107.5 m. Cherts contain locally rhombohedrons of calcite or single cubes of pyrite. An admixture of silty clastic quartz is rare. It is to be noted that purple red siliceous shales were found

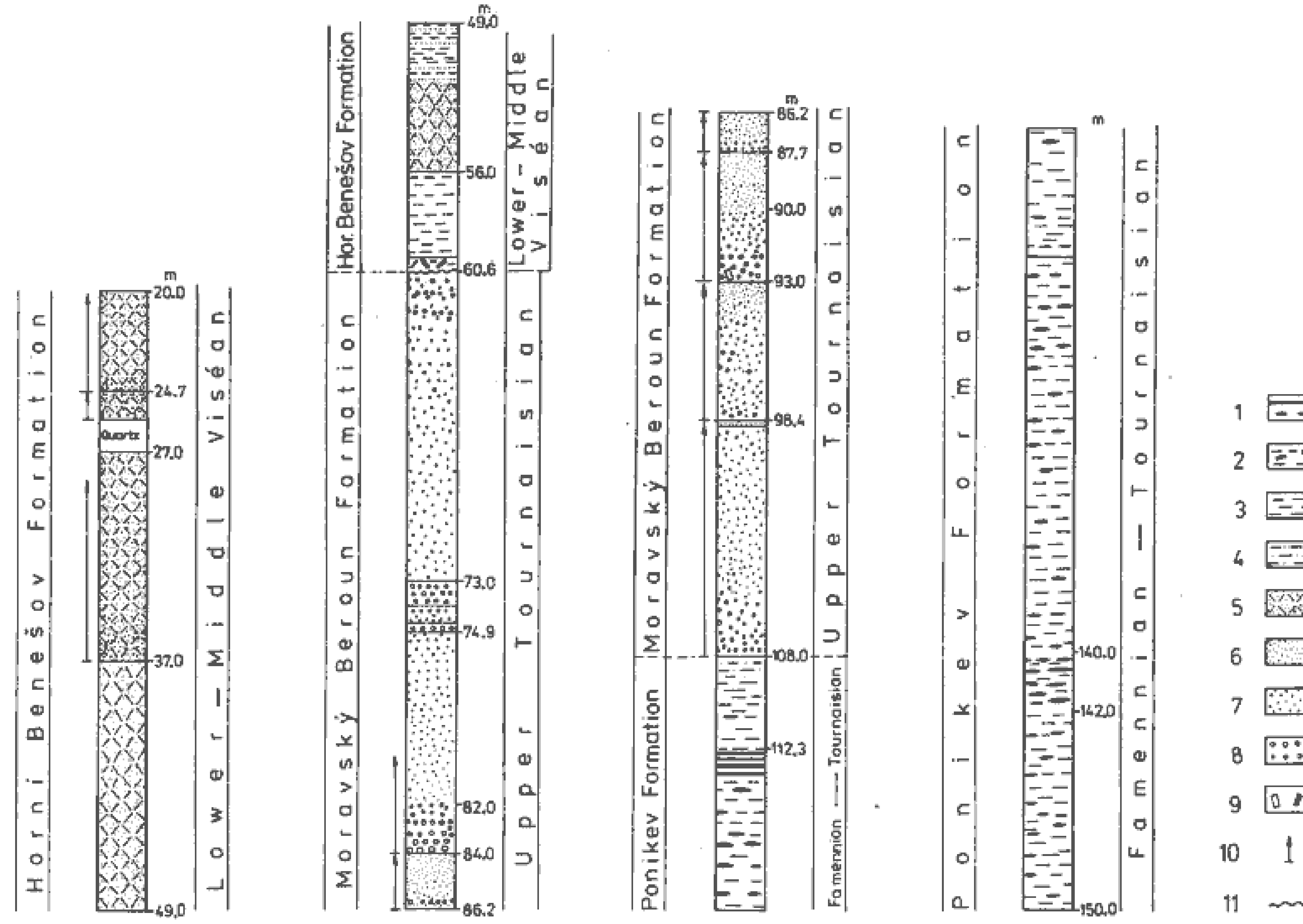
in the Šternberk-Horní Benešov Zone for the first tin

Rocks of the Ponikev Formation in the vicinity o MV 120 borehole were deposited in a quiet shallow w environment on the boundary of oxidizing and redu conditions during the Famennian. Emerged elevation basic volcanics are thought to have been expose weathering at that time and clastic material was depos nearby. Silica could have been released during weathe



of volcanic rocks or due to hydrothermal alteration. The subsidence is believed to have been very slow and sedimentation very condensed (penetrated true thickness of Upper Devonian beds is about 33 m). Further shallowing took place probably aroud the turn of the Devonian and Carboniferous due to even slower subsidence. The true thickness of the Ponikev Formation of approximately Lower and perhaps even Middle Tournaisian age is only 12 m. Numerous limestone intercalations with strongly micritized bioclasts point to a shallow water character of deposition. Accumulated organic matter and pyrite give evidence of strong reducing environment which is also indicated by the established Fe_2O_3/FeO ratio. It gives evidence of a badly ventilated bay occurring between volcanic elevations. The elevation margins were inhabited by sea crinoids and other fauna. Accumulation of their fragments led to a local formation of rather thin limestone layers. The micritization of bioclasts is strong, thus demonstrating a destructive activity of algae in shallow water environment.

The age of the upper part of the Ponikev Formation in a structural unit between Moravský Beroun and Křišťanovice is not known. Shales, which are weathered into grey-green varieties, constitute the direct roof of the Ponikev Formation at Křišťanovice. They contain abundant laminae of siltstones and are only some tens of metres thick. Their age is not known and neither has been established the age of the underlying black siliceous shales with chert. The Ponikev Formation is likely to extend as high as to the turn of the Tournaisian and Viséan and



6. The Moravský Beroun MV-117 borehole log. Transferred to true thickness.
1 - black cherts, 2 - siliceous shales, 3 - clay shales, 4 - silty shales and siltstones, 5 - fine- to coarse-grained greywackes, 6 - fine- to medium-grain quartz sandstones, 7 - coarse-grained quartz sandstones, 8 - fine-, locally medium-grained quartz conglomerates, 9 - clasts of shales and che 10 - graded bedding, 11 - sedimentation following a hiatus.

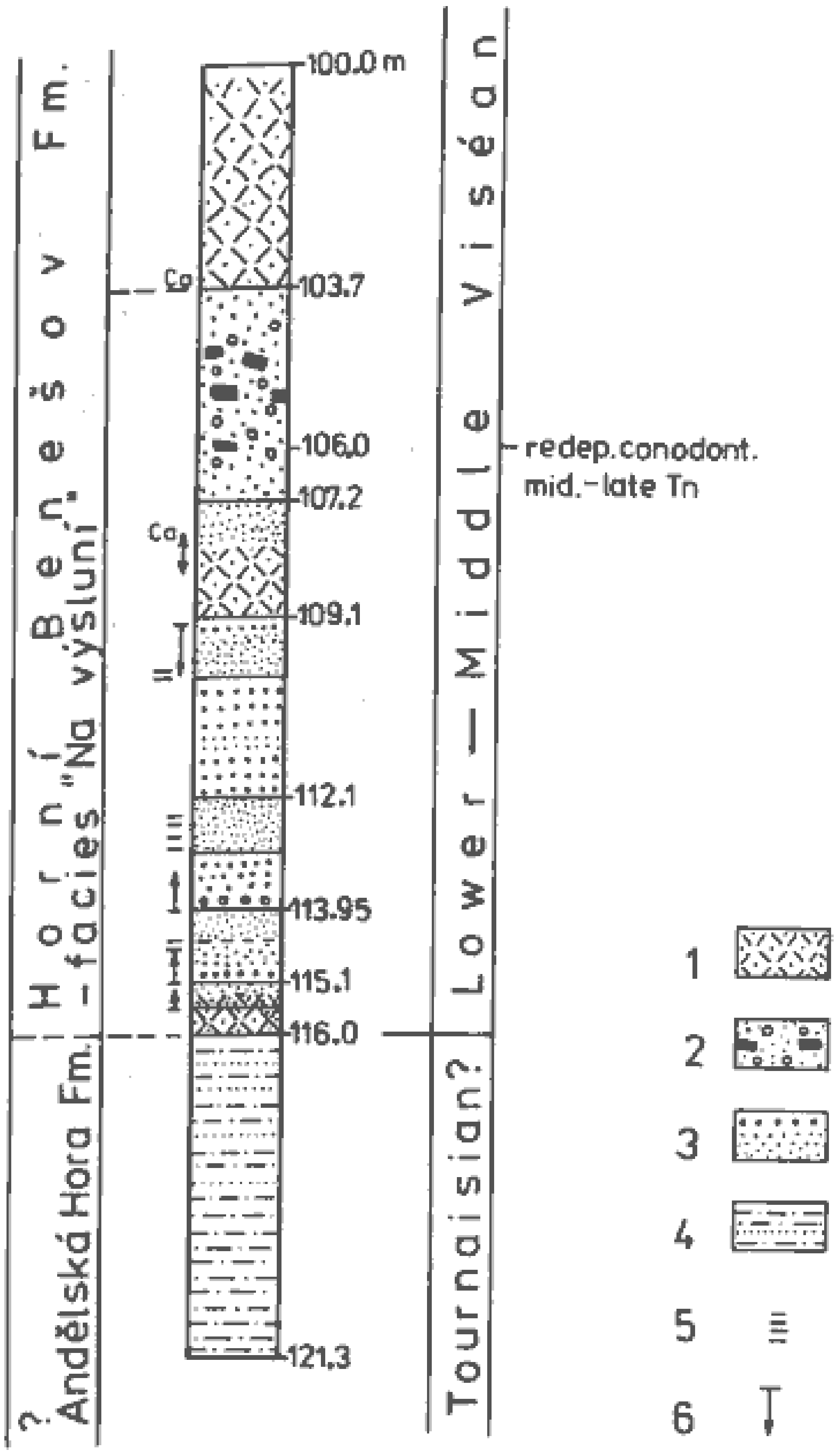
contingently even higher. The Ponikev Formation occurring S of Krnov is of Upper Tournaisian age (the Scaliognathus anchoralis Zone - Zikmundová 1967). A discordant unconformity between greywackes of the Horní Benešov Formation and sediments of the Ponikev Formation can be observed in the Moravský Beroun MV-114 borehole which is located NE of Křišťanovice. The hiatus is documented by the occurrence of breccia composed of fragments of siliceous shales, spilites and black phosphorites. The hiatus is thought to have occurred in the closest neighbourhood of the volcanic elevation.

In contrast to numerous localities of Famennian conodonts, no Tournaisian conodonts were found so far in the whole area. The sedimentation is likely to have been interrupted in the whole central part of the volcanic elevation and extremely condensed on its slopes in the form of black cherts.

Intercalations of basic tuffs to tuffites and small effusions of basic volcanics were observed in the Ponikev Formation W of Čabová, along the west slope of Železník hill. The effusions are accompanied by tuffs, tuffites and sedimentary iron ores at some localities west of Ondrášov.

The thickness of the Ponikev Formation vari considerably. It may reach as much as 200 m (W Čabová) in a depression between volcanic elevatio whereas toward the tops of the elevations it decreases ve fast. In the Moravský Beroun MV-108 borehole locat south of Nové Valteřice (Fig. 5), the Ponikev Formati was observed to be only 4 m thick. The Ponikev Formati passes laterally into the Andělská Hora Formation. T transition is manifested by a greater silty admixture shales and cherts as well as by similar chemic composition of shales (particularly by a low Al_2O_3/Na ratio). The transition appears to be the most conspicuo in the vicinity of Horní Loděnice. It is thought to ha occurred in the middle of the Famennian as demonstrated in the Loděnice-101 borehole.

Locally subordinate intercalations of fine-grain quartzose sandstones 5-15 cm thick occur in the Ponik Formation between Horní Loděnice and Ondrášov. The source area is likely to have been located toward the S in place of a hypothetical elevation built by an o Proterozoic basement which was the source of detri quartz also in later periods.



7. The Moravský Beroun MV-119 borehole log.
1 - medium-grained greywacke, 2 - strongly calcareous coarse-grained sandstones with quartz pebbles and limestone clasts, 3 - coarse- to fine-grained calcareous quartz sandstones, 4 - silty shales with lenticular laminae of siltstones and rare sandstones, 5 - lamination, 6 - gradation, Ca - calcareous.

The Moravský Beroun Formation

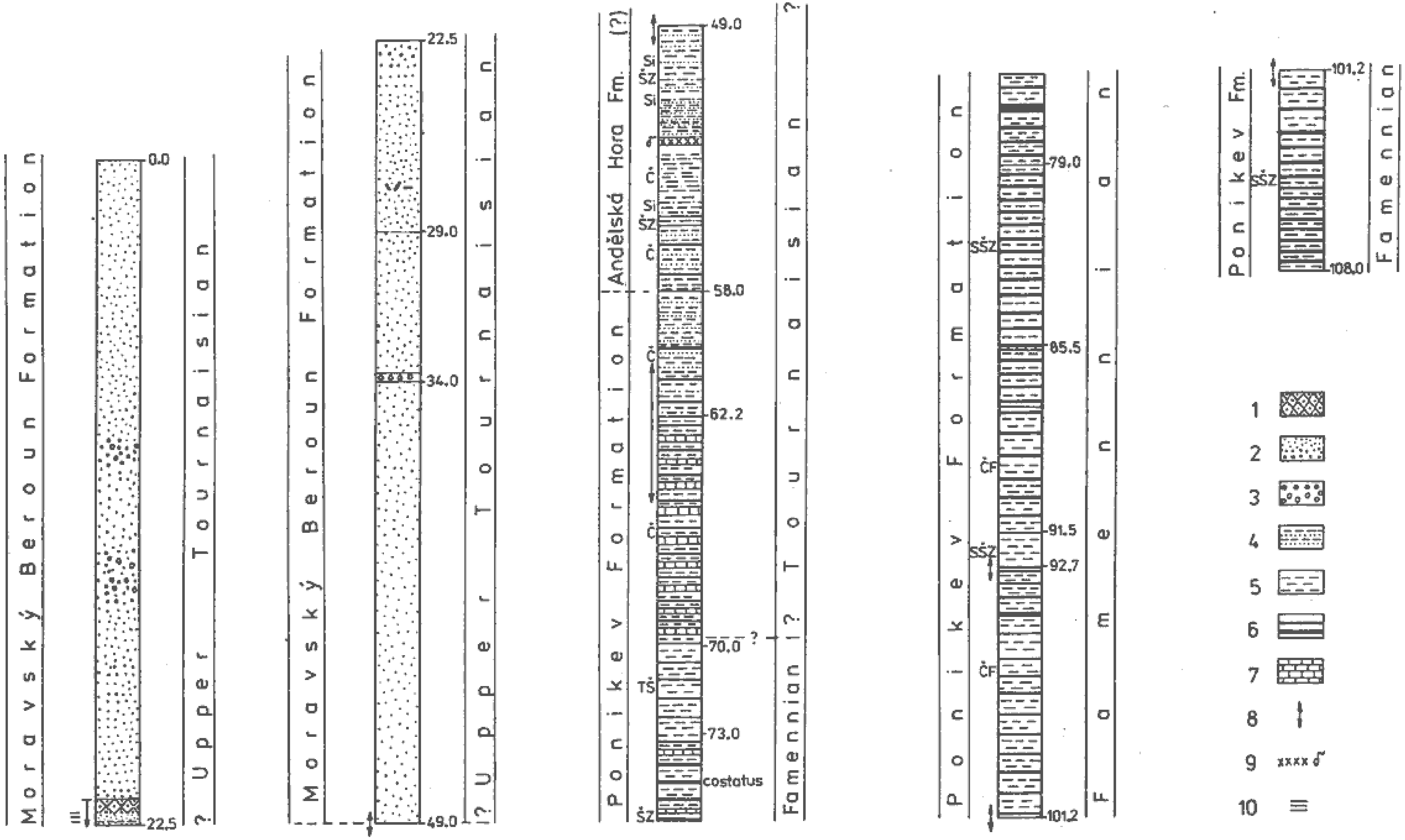
It occurs in the roof of the Ponikev Formation. In the neighbourhood of Moravský Beroun, the formation was found in a 10 km long strip trending N-S, and in a small outcrop W of Ondrášov.

Two synclines N of Moravský Beroun are filled with strongly weathered secondary decalcified quartzose sand with layers of desintegrated quartzose conglomerates. Toward the north, these synclines join each other to form a single synclinorium. They fill a depression between volcanic elevations. A less conspicuous elevation lying further to the west is covered with sediments in its north section. The MV-108 borehole, located in a sand pit S of Nové Valteřice, showed only 4 m thick Ponikev Formation to occur under 50 m thick sediments of the Moravský Beroun Formation. The borehole also penetrated a volcanic elevation with a layer of tentaculitid limestone (of perhaps Middle Devonian age) which lies under the Ponikev Formation. The top of the volcanic elevation crops out N of Nové Valteřice. Its eastern rim as well as the roof are built up by the Ponikev Formation whereas its western rim (and the roof too) are composed of the Moravský Beroun Formation. The volcanic elevation is thought to have formed there a divide which prevented clastic sediments of the Moravský Beroun formation to cross the elevation. As a result, greywackes of the Horní Benešov Formation are deposited toward the east directly on the Ponikev Formation. This sequence is manifested in the borehole MV-121.

About 1 m thick rhythms can be observed in sand pits S of Nové Valteřice. They consist of fine-grained to medium-grained quartzose conglomerates with sporadic quartz pebbles up to 5 cm large at the base. Pea gravel conglomerates alternating with coarse-grained sands in the form of tiny layers which gradually pass into each other the (20 cm) occur toward the top. Coarse- to fine-grained white sands (40 cm thick) follow further in the succession. Conglomerates exhibit partly some secondary silicification. Quartz pebbles of conglomerates were found to be mostly well rounded and rarely even perfectly rounded. Their largest size is 8 cm, on the average 1-3 cm.

A light grey tuff lamina, 0.5 cm thick, weathered into clay, was found in two sand pits 500 m apart, excavated along the N-S direction. The tuff contains 27.13 wt.% Al_2O_3, 3.4 wt.% MgO and 10.56 wt.% K_2O. The TiO_2/Al_2O_3 ratio (0.041) and a higher concentration of MgO indicate that its origin may be related to contemporaneous basic volcanic eruptions. A slightly higher content of BaO - 0.39 wt.% is worth noticing. The SiO_2/Al_2O_3 ratio (1.8) argues for an absence of free quartz. A layer of green argilllitized tuff with relics of vitric texture (altered lapilli and ash), about 45 cm thick, can be observed in the Moravský Beroun MV-108 borehole at the depth of 12.6-13.2 m. Its chemical composition corresponds to an average chemistry of basic tuffs (Přichystal 1985). The Moravský Beroun Formation is younger than the conodont fauna of the Famennian and Lower Tournaisian which was identified by Zikmundová (1966) in limestone fragments from the Volárna 1 borehole (located on the north end of the described site) - thus being of higher Tournaisian age. Layers of basic tuffs and tuffites related to contemporaneous volcanism, which is proved to be of the Upper Tournaisian in the Šternberk region, argue for the above mentioned assumption.

Another area, W of Ondrášov, is separated from the above mentioned region by a transversal elevation where the Moravský Beroun Formation was missing already at the time of deposition of the Horní Benešov Formation. The latter is deposited straight on older volcanics or on the Ponikev Formation. Layers of medium-grained conglomerates, slightly silicified, were found besides coarse-grained sandstones in abandoned sand pits. An



8. The Moravský Beroun MV-120 borehole log.

1 - medium-grained greywacke, 2 - medium- to coarse-grained sandstone, 3 - pea gravel and fine -grained quartz conglomerates , 4 - silty shales with lenticular laminae of silts tones, 5 - clay shchs, 6 - chert, 7 - limestones, 8 - gradual transition, 9 - crushed zone along a fault, 10 - lamination; TŠ - dark grey colouring, SŠZ - light grey-green colour shades, Č - black, ČF - purple, Si - silicification, ŠZ - grey-green colour shades.

average size of quartz pebbles varies between 1 and 3 cm, rarely they are as much as 5 cm large.

The formation was found to be decalcified down to the depth of 80 m at an eponymous locality near Moravský Beroun. As a result, petrographic studies could have been done only on stable compounds. The following composition was established by Kukal (1980): quartz pebbles and grains 68-82 vol.%, cherts (of the underlying Ponikev Formation) 4-9 vol.%, quartzites 3-8 vol.%, metaquartzites and metacherts 0-7 vol.%, acid aplitic granitoids 0-1 vol.%, quartz porphyries (perhaps even keratophyres) 4-12 vol.%, clay shales and phyllites 0-4 vol.%, mica shists and gneisses 0-1 vol.%, limestones locally as much as 40 vol.% (providing they are not leached out), in some places 2-3 vol.%. Large fragments of dark grey and grey micritic and crinoidal bioclastic limestones with rare corals and stromatoporoids were also observed in this formation. A pebble of muscovite-tourmaline quartzite was also reported by Zapletal (1972).

Mostly medium-grained varieties appear to prevail among sandstones (Md 0.18-1.34). They are well sorted (0.42-1.1), locally even very well sorted. Asymmetry is close to zero, locally is slightly negative, in some places slightly positive. An obvious bimodal distribution was observed by Z. Kukal: fine fraction (0.15-0.25 mm) is separated from the coarse fraction (1 mm) by a pronounced "grain-size gap". The roundness of quartz grains in fraction 0.25-1 mm is regarded as being good (0.39-0.42), in fraction over 2 mm as being very good (0.42-0.48). It is either due to recycling of clastic grains (of quartzite pebbles) from older sediments or due to multiple winnowing in shallow water. The Al_2O_3/Na_2O ratio (45) established in a single layer of shale indicates deposition of more weathered material. Poikilitic calcite matrix of conglomerates reported by Kukal (1980) in the Volárna 1 borehole argues for its secondary origin. It does not exclude a terrestrial origin of the Moravský Beroun Formation.

The formation was observed in the boreholes MV-117 (at the depth of 60.6-108.0 m) and MV-120 (22.5-49.0 m) located in the northern part of the region at the village Volárna. It forms a gentle elevation on the surface, trending N-S, and being as much as 200 m wide. The beds are mostly in vertical position. The elevation width corresponds to true thickness of the strata. It represents maximal thickness in the centre of a former depression (Fig. 10). Both boreholes showed the thickness to be decreasing down to 25 and 45 m along the depression margins. It dies away at the tops of volcanic elevations.

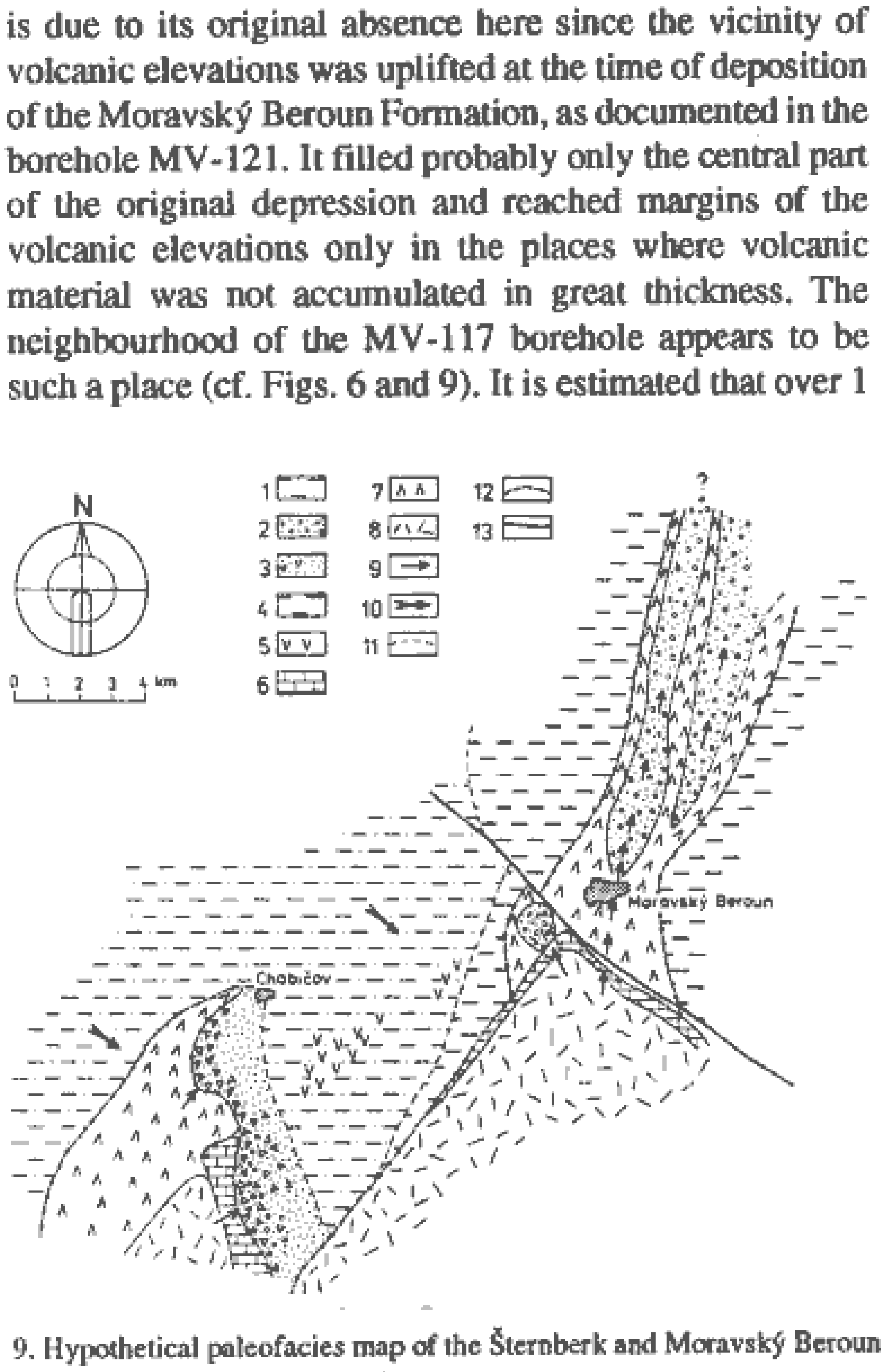
The Moravský Beroun Formation penetrated by the boreholes MV-117 and 120 was found to be strongly weathered and decalcified. Nowadays it is represented by quartzose, mostly coarse-grained sandstones and fine-grained conglomerates. Sandstones strongly prevail over conglomerates. Sporadic, perfectly rounded quartz pebbles found in the borehole MV-117 were up to 3 cm large, those found in the borehole MV-120 up to 2 cm in size. A fragment of weathered shale, 8 cm long and 1.5 cm thick was observed in the borehole MV-117. More abundant fragments of grey, fine-grained shales of the same size occur in a newly constructed roadcut W of the Volárna village. Chemical analysis indicates that we deal with redeposited fragments of the Stínava-Chabičov Formation which constitutes layers in the volcanic series. Very low SiO_2/Al_2O_3 ratio (1.86) as well as high Al_2O_3/Na_2O ratio (124) are characteristic of shales of the Stínava-Chabičov Formation.

Quartz entirely predominates in both the conglomerates and the sanstones (over 95 vol.%). Monocrystalline, polycrystalline, cataclastic and vein-type quartz occurs in the rocks. Among other rocks, the following were identified: quartzites and metaquartzites, cherts, keratophyres and basic effusives (rare), quartz porphyries and granitoid. Among minerals, the following were established: muscovite (also rare biotite), K-feldspars and plagioclases, zircon and green tourmaline.

The assemblage of transparent heavy minerals is characteristic of prevailing chemically resistant minerals (relative proportions in vol.%): idiomorphic zircon 4-13, rounded zircon 48-80.6, black-brown variety of rutile 1.5-3.9, tourmaline in several varieties (brown, green and blue) 4.2-36.7. These very resistant minerals constitute 88-98 vol. % of the transparent heavy fraction. Other heavy minerals such as garnet, amphibole and monazite, occur only locally. Typical appears to be the occurrence of pink zircon.

The source area of clastic material for the Moravský Beroun Formation is thought to have been located south of its present occurrence. It must have been strongly weathered and formed a flat island that was covered with residual gravel. It was built by a medium grade metamorphosed crystalline Proterozoic complex (pink zircon) with intrusions of granitoids. Transgressing Devonian sediments are represented by pebbles of quartzites and particularly carbonates which are believed to have constituted the rim of the elevation structure (limestones with stromatoporoids). A deep erosion during a short-lasting uplift exposed locally even fresh rocks which were the source of garnet and amphibole. Pebbles of metaquartzites, phyllites and metacherts indicate that part of the source area was built by low grade metamorphic rocks of Upper Proterozoic age. Originally, the coarse-grained clastic material was thought to have been transported from the west (Dvořák 1966, Zapletal 1972). Prevailing E-W orientation of long axes of quartz pebbles (Zapletal 1972) argues for this assumption. However, taking into consideration some sedimentological literature (Friedmann, Sanders 1978), the orientation of pebbles can be interpreted in various ways. In some cases, it may indicate a flow along N-S direction in a narrow depression between volcanic elevations.

Coarse-grained clastic material which shows no sorting from the south to the north, is believed to have been transported by a river which formed a channel between subparallel volcanic elevations from a hypothetical source located S of Moravský Beroun. There is a striking lithological similarity (rhythmic structure) with terrestrial basal clastic formation of the Devonian in the Ostrava region. However, the Moravský Beroun Formation is better sorted (Dvořák 1985) and more extended toward the north. Based upon results obtained from the borehole MV-117, the Moravský Beroun Formation is expected to occur also eastwards, in a depression between the above described N-S structure Moravský Beroun-Volárna and the elevation of the Šternberk-Horní Benešov structure, running from Moravský Beroun toward the NE to Leskovec. The Moravský Beroun Formation, occurring along the contact of the Horní Benešov and Ponikev Formations, has never been exposed on the surface. This is due to its original absence here since the vicinity of volcanic elevations was uplifted at the time of deposition of the Moravský Beroun Formation, as documented in the borehole MV-121. It filled probably only the central part of the original depression and reached margins of the volcanic elevations only in the places where volcanic material was not accumulated in great thickness. The neighbourhood of the MV-117 borehole appears to be such a place (cf. Figs. 6 and 9). It is estimated that over 1 km^3 of sediments was deposited here in total. Quartz is th most frequent constituent.



9. Hypothetical paleofacies map of the Šternberk and Moravský Beroun vicinity in the Upper Tournaisian.
1 - Andělská Hora Formation (shales, siltstones and minor fine-grained greywackes), 2 - quartz conglomerates and coarse-grained sandstones, 3 - sandy limestone breccias and sandstones, 4 - siliceous shales with cherts, 5 - contemporaneous volcanism, 6 - limestones, 7 - basic volcanics and siliceous shales, 8 - Proterozoic metamorphites (6-8 - part of the dry land), 9 - direction of movement of clastic material, 10 - direction of sea transgression, 11 - approximate facies boundary, 12 - approximate shoreline, 13 - synsedimentary dislocation.

The Andělská Hora Formation

The formation is represented by black-grey silty shale with laminae and thin layers of siltstones an intercalations of fine-grained greywackes. It exhibits pronounced rhythmic structure with graded bedding. Th thickness of individual rhythms varies betwee centimetres and decimetres. Its major occurrence located in the vicinity of Horní Loděnice where it show maximal thickness (in several hundred m) and envelope a large basic volcanic body accompanied by tuffs and iro ores. Alternating volcanic tuffs and shales were found an outcrop behind a house near the church. A simil occurrence of volcanics with iron ores inside the Andělsk Hora Formation was observed along the western margi of Ondrášov.

Black-grey shales with laminae of siltstones an sporadically even fine-grained quartzose sandstones a also tentatively regarded as the Andělská Hora Formatio They were penetrated by the boreholes MV-119 (116-13 m) and MV-120 (49-55.7 m) in the northern part of th area under study (Figs. 7 and 8). These sediments occ only on the west slope of the entire elevated structure. Du to its position in the roof of the Ponikev Formation as we as under the Moravský Beroun Formation, it is assum to be of Middle Tournaisian age. Transition of silty shal from the underlying Ponikev Formation is manifested b a very slow disappearance of cherts and by an increase silty laminae. Surprising is the occurrence of layers whic consist of fine-grained quartzose sandstones.

Bioturbation was found to be abundant. Dark colo and the presence of pyrite point to a reducing environme during the deposition. The Al_2O_3/Na_2O ratio (1 indicates deposition of fresh fine clastic materia Consequently, the source of detrital quartz of th quartzose sandstones has to be sought elsewhere (in loc elevation of high grade metamorphic rocks of Proterozo age).

Northward and eastward the Andělská Hora Formati passes laterally and gradually into the Ponikev Formati of Famennian and Tournaisian age. The uppermost pa passes into the "Na výsluní" facies which is of Lower a Middle Viséan age (see below).

The Horní Benešov Formation
The "Na výsluní" facies

This new term is proposed for a variegated rock sequen which locally resembles the Moravský Beroun Formati and in some places looks like the Andělská Ho Formation when observed with the naked eye. Howeve a detailed investigation showed this formation to diff from those mentioned above in many respects. It consists of dark grey sandy limestones, black-grey shales with laminae and thin layers of quartzose siltstones showing graded bedding and breccias composed of fragments of various shales and even sandstone pebbles in a sandstone matrix. The name was selected according to the Moravský Beroun MV-109borehole which penetrated this facies for the first time. The borehole was situated in the local railroad which bears the above mentioned name. This facies in its characteristic development has never been found exposed on the surface. It is known only from boreholes MV-102A, 102B, 109, 113 and 115.

Underlying weathered and decalcified rocks, about 30 m thick, were reached by the Moravský Beroun MV-109 borehole (Fig. 5). They consist of dark grey, coarse- to fine-grained sandy limestones which pass into calcareous sandstones. Layers showing sharp contacts and various grain size were found to alternate. Relatively abundant are thin intercalations of black-grey shales with laminae of siltstones, but in general, these rocks are subordinate. About 2 cm thick layers of breccia with fragments of shales and limestones occur in the facies. Sandstones become more fine-grained and shales more frequent toward the basement. Clastic limestones contain abundant volcanic quartz, biotite and K-feldspars (as acid tuffite admixture), quartz grains with undulatory extinction (which come from an old crystalline complex, most likely from granitoids), fragments of cherts, limestones and shales (from underlying Devonian sediments), fragments of basic rocks as well as calcified volcanic glass which gives evidence of denudation of Devonian basic volcanics, and also argues for contemporaneous basic volcanism. Pellets and mainly bioclasts are abundant in addition to limestone extraclasts (also with tentaculitids). Fragments of crinoidal segments, algae, bryozoans and brachiopods are most abundant. A rare fragment of the tabulate coral *Sinopora polonica* was also identified (J. Hladil). Foraminifers were found to be abundant. The following genera of foraminifers were identified by R. Conil (Belgium) in samples from the depth of 33.7 m: *Eostaffela, Endothyra, Archaediscus, Earlandia minor* and *Brunsia*. Among algae, the genera Koninckopora and Girvanella were identified. Foraminifers of the genera *Beasiella* and *Glomodiscus* were found in limestone fragments. They seem to be of the Lower Viséan age and are thought to have been redeposited together with limestone fragments. Autochthonous foraminifers appear to be most likely of Middle Viséan age. Bioclasts are often micritized and phosphatized. Well preserved ooliths are rare. About a 2 m thick horizon of clay shales was penetrated by the borehole MV 109 (94.0-96.4 m) underneath a 60 m thick layer composed mostly of quartzose sandstones and siltstones which do not differ from siliceous material of overlying sandstones. The lowermost part of the borehole (96.4-100.0 m) reached fine- to coarse-grained breccia consisting of compressed shreds of shales with rare siltstone laminae, as much as 6 cm large fragments of greenish shales and up to 5 cm large fragments of shales with siltstone laminae showing graded bedding. Pebbles of grey, slightly calcareous, medium-grained quartzose sandstones up to 3 cm large are rare. A rather minor matrix is composed mostly of slightly calcareous sandstone. Bipyramidal grains of volcanic quartz are common in addition to quartz exhibiting wavy extinction. Sediments exposed in the MV-109 borehole are thought to be in a reverse position but no proof is available.

The boreholes MV-102A (the lowermost section of the borehole - the base of the strata sequence), MV-102B (weathered central part) and particularly MV-112 penetrated apparently the major part of the whole facies "Na výsluní" at the second locality. The sediments are again in a reverse position (Fig. 5).

An excellent example of a contact between the Ponikev Formation and "Na výsluní" facies can be seen at the depth of 92.5-136.0 m of the borehole MV-102A. Black cherts appear to prevail over shales at depth interval of 92.6-118.7 m. This interval is not paleontologically dated because conodonts are missing. It may belong to the Tournaisian according to its position between the proved Famennian in the underlying rocks and the proved Lower to Middle Viséan in its stratigraphic roof. Sedimentation during the Tournaisian must have been considerably condensed. A similar situation is known in the borehole Horní Benešov HB-SV-3. The borehole Moravský Beroun MV-102A penetrated at the depth interval of 118.7-125.0 m dark grey to black-grey shales with numerous siltstone lamiane and rare cherts which argues for gradual transition from the Ponikev Formation. Abundant intercalations of bioclastic limestones and particularly fine-grained breccia composed of fragments of cherts, limestones, black shales, aphanites and basic volcanics begin to appear in shales and siltstones in lower parts of the section. Limestone fragments are usually silicified. Abundant monocrystals of quartz and K-feldspar indicate their volcanic origin. Tentaculitids found in limestone clasts argue for a denudation of the Devonian basement (most likely the Eifelian-uppermost Emsian). Among bioclasts, fragments of crinoids and algae are most abundant. At the depth of 135 m O. Friáková identified a redeposited conodont fauna with *Bispathodus aculeatus anteposicornis*. Coarser-grained layers of breccia and sandstones give evidence of a renewed marine transgression which followed after gradual regression and stagnation during the Tournaisian. The thickness of sediments increased during the Lower and Middle Viséan due to faster subsidence as documented in the borehole MV-112. This borehole is located 60 m west of the borehole MV-102A (Figs. 4, 5). A transition of the Ponikev Formation into the "Na výsluní" facies was penetrated by this borehole (its uppermost part). This transition zone was found weathered and decalcified which corresponds to the situation at the base of the MV-102A borehole. The strata seem to be also in a reverse position in the borehole MV-112. A layer composed mostly of shales and siltstones which occur in the stratigraphic roof of the Ponikev Formation was found to be 17 m thick in the borehole MV-112 whereas the same layer penetrated by the MV-102A borehole is only 8 m thick. It is followed by a 3 m thick layer in which calcareous siltstones alternate with shales and siltstones. A stratigraphic equivalent of sandy limestones which was penetrated by the borehole MV-109 is represented by about a 40 m thick layer found in the borehole MV-112. It consists of fine- and medium-grained quartzose calcareous sandstone. Its stratigraphically lower part, being 16 m thick, contains rare beds of black-grey shales with laminae and layers of siltstones. This suite of sediments is abundant in the stratigraphically higher section of the quartzose calcareous sandstones mentioned above. Rhythms showing graded bedding and being a few mm up to 3 cm thick with widespread shales were found to occur in shales and siltstones. Sandstones exhibit conspicuous bedding and lamination but no graded bedding. Abundant volcanic quartz is similar to that found in the borehole MV-109. Sandstones seem to be better sorted. Sandy limestones are missing. Bioclasts are common; they are often phosphatized. Rounded zoned (often pink) zircons, green and blue tourmalines and locally even rutiles are common accessory minerals found in all thin sections. Larger quartz grains are usually well rounded. Shreds of black-grey shales with embedded quartz grains are rather sporadic. Ooliths are also rare. Coarser-grained bases of rhythms with graded bedding consist of the same siliceous material and similar assemblage of accessory heavy minerals which were found to occur in relatively coarser sandstones. This characteristics makes them obviously different from siltstones occurring in rhythms of the Andělská Hora Formation where siltstones show higher admixture of greywackes. Small fragments of carbonified floral tissue were found in shales. These shales are geochemically different from those in the Andělská Hora Formation. The Andělská Hora shales exhibit the Al_2O_3/Na_2O ratio to be on average around 8.2 which argues for deposition of chemically not weathered clastic material (Kukal 1980). On the other hand, the shales from MV-109 and 112 boreholes indicate that the source of the clay material was in a flysch facies (Al_2O_3/Na_2O ratio = 13.3 to 18.1) but at the same time point to a deposition of chemically weathered material (having Al_2O_3/Na_2O ratio 62.5 and 65.06) which comes from the same source as sorted quartz material. The "Na výsluní" facies shows some higher concentrations of $C_{org.}$ (1-1.5 wt.%).

There is a considerable decrease of calcareous sandstone layers in the lowermost section of the borehole MV-112 (from 134.0 m downward). Rhythms exhibiting graded bedding are as much as 5 cm thick. Shales and siltstones exhibit rather frequent bioturbation in th section of the borehole. Even burrows after borin activities of organisms (worms ?) can be observed. Tw such parallel burrows 0.5 cm wide and 2 cm deep we found at the depth of 149.0 m. They occur in shales, in position perpendicular to the bedding plane, and are fill with grey sandstone. A slump structure resulting fro immersion of sandstone layers into shales was observ at the depth of 136.2-136.5 m. Two rhythms about 8 c thick were affected by slump deformation (an evidence deposition on the slope). Layers of fine-grained original calcareous sandstones, 3-10 cm thick, were found in shallow borehole MV-102B which is located 30 m NW the borehole MV-112. The layers occur in shales a siltstones showing graded bedding and rhythms 2 mm 3 cm thick. Shales are abundant.

Contemporaneous sedimentation of sandstones fou in the borehole MV-112 and associated with limeston in the borehole MV-109 is indicated by a foraminif fauna from the depth of 79.8 m (MV-112 borehole). T following species were indentified by R. Conil: *Endothy* sp. (Viséan type), *Paraendothyra* sp., *Tournayellid* *Fusulinacea, Eoastaffella* sp., *Bessiella* sp., *Dainella* s *Tetrataxis* sp., *Archaediscus* sp. (rather primitive for *Earlandia moderata* ?, *Valvulinella* sp., *Diploshaeri* *inaequalis*, *Bisphaera* sp., and *Selebra* sp. Algae of t *Dasycladacea* group were found to accompa foraminifers. This fauna is regarded to belong to the upp part of the Lower and to the lower part of the Mid Viséan.

Mineralogical investigation of transparent hea mineral fraction of the sandstones (Otava, 1981) show that the mineral assemblage in general is almost identi with that found in the Moravský Beroun Formation a even with that of Emsian sandstones in remote baseme This may argue for the same source of sorted detri material. A part of extremely resistant heavy minerals m come straight from the Moravský Beroun Formati However, two specimens quite different from Moravský Beroun Formation were found. Th composition indicates that chemically less weathe detritus could have been occasionally washed down fr the source area. The mineral assemblage gives evide of the occurrence of high-grade metamorphic rocks Proterozoic age. Identified minerals show the follow relative proportions (in vol.%) found in two specim mentioned above: colourless garnet (6.4 and 9.8 spectively), brownish garnet (62.1 and 28.5), idiomorp zircon (6.8 and 11.5), rounded zircon (9.6 and 30 apatite (2.1 and 0.5), rutile (2.9 and 1.8), tourmaline (and 17.0 - brown variety prevails over green var., b tourmaline is rare), titanite (1.2), amphibole (0 staurolite (2.0), kyanite (0.6), epidote (0.2), mona (0.2), alterites (0.5).

In the north, the "Na výsluní" facies occurred only al the west margin of the structure. Thin bedd fine-grained quartzose sandstones, often strongly calcareous and passing even into sandy limestones, were found in the borehole MV-115. Clastic fraction consists almost entirely of monocrystalline quartz. Rare are muscovite and phosphate grains. Crinoidal segments seem to prevail among bioclasts. Lithological development is identical with that found in the southern localities of this facies. Only foraminifers are missing. Heavy mineral assemblage from the depth of 76.5 m (borehole MV-115) also points to the above mentioned parallel development. The assemblage consists of extremely resistant minerals with garnet which was found only in rocks of this facies.

A slightly younger part of the "Na výsluní" facies was encountered by boreholes MV-119 and partly by MV-120 (Figs. 7 and 8). It differs from the above described part in being laterally replaced by greywackes of the Horní Benešov Formation. It actually represents a "basal transgressive horizon" of the Horní Benešov Formation over the west anticline of the Šternberk-Horní Benešov elevation structure. A fresh sequence of this facies was penetrated by the borehole MV-119. The sequence is 10 m thick. Strongly calcareous fine- to coarse-grained quartzose sandstones were found to be alternating in the lower part of the sequence. Locally feldspathic sandstones with calcareous as well as non-calcareous feldspathic and lithic fine- to medium-grained greywackes occur in layers about 0.5 to 2 m thick. The sandstones pass in some places into sandy limestones with abundant micritized bioclasts, particularly segments of crinoids. Coral fragments are rare. Carbonified flora appears to be accumulated in thinly bedded to laminated greywackes. Composite assemblages of heavy minerals from these greywackes (i.e. lower ZTR index, shape of zircons, high concentration of tourmaline) indicate not only vertical alternation of greywackes and sandstones but also mixing of clastic material within single layers (no tectonic alternation).

The character of weathering in the source area can be derived from the occurrence of as much as 10 vol.% of kaolinized K-feldspars in feldspathic sandstones. The assemblage of ultrastable heavy minerals rich in tourmaline also indicates the character of weathering. Locally increased number of idiomorphic zircon appears to be a sign of volcanic admixture.

The upper part of the sequence which in the MV-119 borehole belongs to the "Na výsluní" facies is composed of limestone breccia with limestone clasts up to 5 cm in size and with quartz pebbles 1-2 cm large. Abundant matrix consists of sandy limestone to calcareous feldspathic sandstone. It contains up to 1 cm large black phosphorite nodules, small pebbles of strongly weathered granitoids, quartzites, cherts and as much as 10 vol.% of K-feldspars. Quartz grains are both monocrystalline and polycrystalline. Limestone matrix contains abundant micritized fragments of crinoidal segments and fragments of brachiopod valves. Large limestone fragments consist of grey and dark grey micrites and biomicrites. Z. Krejčí identified in limestone fragments the following conodont fauna: *Gnathodus delicatus* and *Pseudopolygnathus* cf. *vogesi* of the Middle to Upper Tournaisian. Consequetly, the "Na výsluní" facies is regarded as Viséan. Quartz pebbles were found to be perfectly rounded whereas limestone pebbles are semirounded. Assemblages of ultra stable heavy minerals, together with quartz pebbles, indicate that the source of detrital material comes from the redeposited Moravský Beroun Formation. Altered pebbles of granitoids and K-feldspars are thought to have come from weathered rocks of the Proterozoic basement whereas limestone clasts come from limestones rimming the elevation.

The sedimentary environment during the deposition of the "Na výsluní" facies is believed to have been changing considerably. Sandy limestones and sandstones represent a shallow marine sediment of carbonate platforms exhibiting a considerable dynamics of the aqueous environment. They were transported into the place of deposition by occasional stronger currents whereas coarser sediments were washed to the slopes not reached by currents. The depositional area was located in a close neighbourhood of the platform where the sediments originated and where also the majority of fauna used to live (i.e. massive layers of sandstones and limestones with almost no shales). The sea is thought to have had a transgressional character at that time. Fragments of Devonian and Tournaisian limestones, cherts and basic volcanics were washed down in the basin. Their parent rocks were on shore during the sea transgression. The sedimentation was affected by simultaneous basic (calcified glass) as well as acid volcanism. The source of quartz appears to be the same as that for the Moravský Beroun Formation. It was partly recycled from the fine-grained fraction of this formation. Clastic material seems to be better sorted south of here, in the vicinity of the borehole MV-112. Abundant, very stable heavy minerals were found to be locally accumulated in addition to quartz.

The rate of sedimentation is thought to have been changing considerably. The deposition of black-grey and black shales in a quiet reducing environment high in organic C prevails in the lower and upper parts of the facies (e.g. borehole MV-112). Very fine grained sand and silt have been transported in here through local muddy currents from the east, from a shallow water platform during occasional storms (graded bedding and bioturbation - tempestites). The majority of shales come from western sources and represent here the flysch facies which fills a basin located further to the west (the Horní Benešov Formation sensu stricto). Clay material was deposited from a suspension whereas coarser polymict clastic material was difficult to be carried by sea currents as far as the margins of the elevation.

Marine transgression could have been locally replaced by regression. The occurrence of shale breccia with sandstone pebbles (found at the base of the MV-109 borehole) may argue for such an event. Clasts of this breccia are thought to have come mostly from sediments constituting the "Na výsluní" facies.

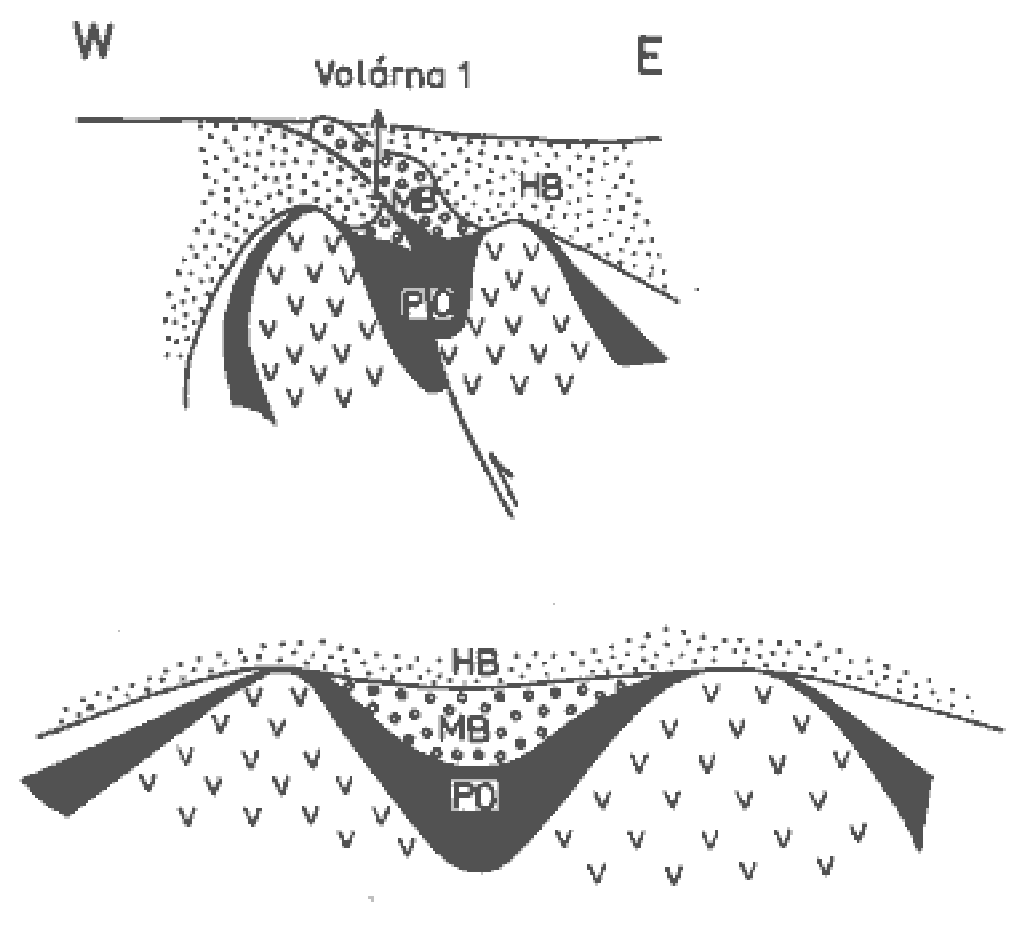
Abundant volcanic quartz of sand size makes the "Na výsluní" facies different from the Moravský Beroun Formation which is older. This relatively coarse-grained acid tuffaceous admixture enables a certain stratigraphic correlation (tephrochronology). Tuffites are known to be spread over a large distance and seem to be isochronous. Acid tuffs are assumed to have come from eruptions of terrestrial volcanoes active in the Variscan median mass. They are thought to have been located in the places where Variscan granitoids crop out nowadays. Thin layers of very fine-grained tuffites are reported from the Upper Tournaisian in Moravia, for instance from upper parts of the Andělská Hora Formation near Chabičov (Dvořák et al. 1983). Thicker and relatively coarser tuffites are known from the boundary of the Ponikev and Horní Benešov Formations in the northern vicinity of Horní Benešov (younger than the Upper Tournaisian). The best stratigraphically dated sections with tuffites occur toward the east in the vicinity of Hranice. Rare tuffaceous laminae were found in the Upper Tournaisian in the Choryně-9 borehole. However, more abundant and thicker laminae begin to appear as late as the Lower Viséan. In the borehole Opatovice-1 (Dvořák et al. 1981), they occur in the Lower Viséan. Abundant coarser admixture of volcanic quartz (including other compounds of tuffites such as biotite, K-feldspars and idiomorphic zircons) occur at the base of the Horní Benešov Formation at many localities along the west margin of the present occurrence (Kukal 1980). A similar correlation exists for siliceous shales with abundant tuffs and tuffites found in the borehole Horní Benešov HB-SV-3 (Dvořák et al. 1983). Greater accumulation of acid tuffites in the Lower Viséan is also known from the Góry Świętokrzyskie Mts. in Poland (Żakowa et al. 1983) and from the Rhenish Slate Mts. and from Harz (Hoss 1957). A very conspicuous layer of acid tuffs, 3.8 m thick, occurs in the Lower Viséan of the Nepasice-1 borehole near Hradec Králové (Z. Kukal). This locality with a large thickness of tuffs may serve as an example where to look for the source of acid volcanic material. Tephrochronological correlation indicates that the "Na výsluní" facies represents a chronological equivalent of greywackes at the base of the Horní Benešov Formation which occur at the west margin of the present outcrop of the above mentioned formation. Lateral transition of massive thick greywackes of the Horní Benešov Formation eastward into rhythmites with graded bedding is known from the broader vicinity of Šternberk. Layers of massive greywackes alternating with layers of rhythmites occur already east of the volcanic elevation. Consequently, rhythmites with graded bedding are likely to be regarded as a transition facies between contemporaneous massive greywackes at the west margin of the basin and the "Na výsluní" facies in the east. Very fine-grained greywackes occur at the base of a few deci- and centimetres thick rhythms. These are difficult to distinguish with the naked eye from distal facies of the Andělská Hora Formation and impossible to plot on a map separately (see Pl. 1). A similar development is documented by identical character of sandstone to siltstone intercalations showing typical heavy mineral assemblage inside the uppermost layers of the Andělská Hora Formation south of Horní Loděnice.

Studies of sediments in the boreholes Moravský Beroun MV-109A, 109 and 112 showed two very different facies to substitute each other laterally. One of them is represented by fine rhythmic shales with graded bedding which are characteristic of completely distal flysch sediments. The other facies consists of sandy limestones to sorted quartz sandstones with ooliths, algae and other shallow water organisms which represent shallow water flowing environment of carbonate platforms. Transition from sandy limestones (borehole MV-109) to calcareous sandstones (borehole MV-112) and further to greywackes exposed in abandoned quarries at Horní Loděnice can be observed parallel to strike from the NNE to the SSW. All types of rocks described above alternate with shales and siltstones which exhibit conspicuous graded bedding. The described course of lateral facies transition is demonstrated in the NNE by a slope of volcanic elevation whereas in the SSW there is a transversal axial depression which occurs between two volcanic elevations - the Chabičov elevation in the SSW and the Moravský Beroun elevation in the NNE. Polymict clastic material could have been transported in the axial depression from the west because there was no barrier in the form of a volcanic elevation. A facies of sorted quartzose sandstones with accumulated stable heavy minerals seems to prevail in the central part between carbonate facies in the NNE and rhythmite facies with greywackes in the SSW. This facies is located NW of a hypothetical elevation of the Proterozoic crystalline complex which is thought to have been a source of detritus for the Moravský Beroun Formation (S of Moravský Beroun).

The following evolution of sedimentary processes can be established according to the data gathered so far in the broader vicinity of Moravský Beroun from the Tournaisian to the Upper Viséan: a condensed sedimentation of the Ponikev Formation prevailed during the Lower and Middle Tournaisian in the whole area except Horní Loděnice where shales and siltstones of the Andělská Hora Formation were deposited.

The situation appears to have changed in the Upper Tournaisian (Fig. 9). A hypothetical elevation south of Moravský Beroun, composed of strongly weathered higher metamorphosed rocks is believed to have been rising fast together with basic volcanics in the northern foreland. Coarse quartz clastic material together with rare fragments of limestones, iron ore, basic volcanics and shales were transported by a river from the weathered surface. The detritus has filled relatively narrow depressions between volcanic elevations more than 10 km long. These depressions become slightly wider and deeper toward the north. Deposition of the Ponikev Formation continued east of here (unless the sedimentation was interrupted). Shales and siltstones of the Andělská Hora Formation were deposited west of the Šternberk-Horní Benešov Zone. Around the turn of the Tournaisian and Viséan, the vertical movement of blocks became reverse. Hypothetical crystalline and volcanic elevations began to sink gradually and were flooded by the sea. Sandy limestone platforms were formed along the coast and covered by sediments which were deposited in flowing very shallow water environment. Toward the NW (perpendicularly to the shoreline) and SSW, the sandy limestones and calcareous sandstones gradually passed into shales and siltstones with intercalations of greywackes. Later, during the upper part of the Middle Viséan, the sea transgressed over central parts of volcanic elevations. The "Na výsluní" facies found in the MV-119 borehole represents a typical littoral sediment of transgressing sea. Very heterogeneous clastic material (stable together with completely unstable) from close as well as from more distant neighbourhood was deposited in strongly moving shallow water environment. At that time, greywackes of the Horní Benešov Formation were deposited straight on basic volcanics of the Middle and Lower Devonian. The anticlinorial structure submerged under the sea level.

Volcanic elevations were sticking out of the sea level till the Middle Viséan and locally they were deeply denuded as low as the level of the Upper Emsian. The position of the Horní Benešov Formation north of Čabová indicates that a considerable discordance must have occurred during the sea transgression. An anticlinal structure near Čabová overturned toward the NW has originated already in a synsedimentary environment. It was uplifted and then denuded already prior to the sea transgression in the Middle Viséan. The anticline is thought to have been broken in its top in the Upper Viséan during the deposition of the Moravice Formation. The east part of the anticline has sunk (Fig. 4).



10. A scheme of structural development at the Volárna lodge north of Moravský Beroun.
V - basic volcanics, PO - Ponikev Formation, MB - Moravský Beroun Formation, HB - Horní Benešov Formation. The sedimentary filling between volcanic elevations is "squeezed out" due to compression.

The Horní Benešov Formation sensu stricto

The roof of the "Na výsluní" facies is composed of mostly massive, dark, blue-grey, medium-grained greywackes with very rare intercalations of rhythmites showing graded bedding which consists of fine-grained greywackes, siltstones and shales. This facies appears to be abundant W and NW of outcrops of the Devonian and lower part of the Lower Carboniferous, including a synclinorium between Nové Valteřice and Křišťanovice (Pl. 1).

Thick layers of rhythmites begin to alternate with greywackes in the area between Moravský Beroun and Ondrášov, SE of an anticlinorium which is mostly composed of Devonian volcanics. About 1-1.5 m thick layers of medium-grained greywackes alternate with rhythmites showing graded bedding which exhibit rhythms about 40 cm thick (consisting of fine-grained greywackes, siltstones and shales showing ratio 4:1:1) and with rhythms as much as 2-8 cm thick in which siltstones and shales prevail. These sediments also fill a synclinorium extending between the west margin of Ondrášov and the last houses of the town Moravský Beroun along the highway leading to Nové Valteřice. They are deposited on the Ponikev Formation and even straight on the Middle Devonian volcanics, following a hiatus. Complex folded greywackes as well as flyschoid alternation of greywackes, siltstones and shales lying on volcanics were discovered in pits and adits north of Čabová during an exploration program searching for iron ores in the fifties. Here, the Horní Benešov Formation occurring in local depressions in volcanics was found to be close to intercalations of the Stínava-Chabičov Formation of the Emsian. Similar situation occurs in the vicinity of Chabičov where the upper part of the Andělská Hora Formation and locally also the Horní Benešov Formation are deposited on volcanics with shale intercalations of Upper Emsian age.

Lithic greywackes are most abundant. They contain over 40 % of unstable compounds, particularly tiny fragments of acid volcanics and altered rocks. As much as 10 vol.% of feldspars were found to occur there. Among them K-feldspars strongly predominate over plagioclases. Quartz shreds and idiomorphic zircons indicate a tuffaceous admixture. Quartz aggregates showing wavy extiction seem to come from metagranitoids crushed to various degree.

Occurrence of a layer consisting of sandy limestone to calcareous sandstone found in the borehole MV-122 at the depth of 32.3 m gives evidence of lateral substitution of clastic greywacke facies of the Horní Benešov Formation with the "Na výslunť" facies, as described earlier. The latter facies, on the contrary, contains intercalations of fine-grained distal greywackes.

Some characteristic intercalation is represented by a kaolinitic, weathered, white acid tuff which passes upward in tuffaceous shale. It occurs in the borehole MV-119 (see Fig. 7).

Greywackes of the Horní Benešov Formation were discovered even east of the anticlinal structure that was NE of Křišťanovice, already during the sedimentation, plunging into a transversal depression. This is also manifested by a typical heavy mineral assemblage found in the borehole MV-114. Here, the Horní Benešov Formation was deposited on the Ponikev Formation, following a longer hiatus - as indicated by numerous breccias with abundant phosphorites.

Greywackes and rhythmites of the Horní Benešov Formation in the neighbourhood of Moravský Beroun, due to their position in the roof of the "Na výslunť" facies, can be regarded as belonging to the upper part of the Middle Viséan and/or to the boundary of the Middle and Upper Viséan.

The Moravice Formation

Lithologically, there is almost no difference between this formation and that of Horní Benešov, particularly of its distal facies where greywackes alternate with siltstones and shales. Only analysis of heavy minerals allowed to identify the base of the Moravice Formation in a strip E of Čabová which is parallel with the east margin of the Šternberk-Horní Benešov Zone. Due to a steep overthrust of Lower Devonian rocks toward the east on the flysch formation just near Čabová, the base of the Moravice Formation approaches the Šternberk-Horní Benešov Zone (the Čabová MV-101 borehole). Some heavy mineral concentrates show very abundant idiomorphic zircon which may indicate a stronger tuffaceous admixture at the base of the Moravice Formation.

The base of the Moravice Formation, due to its position, most likely belongs to the Upper Viséan (its lowest part).

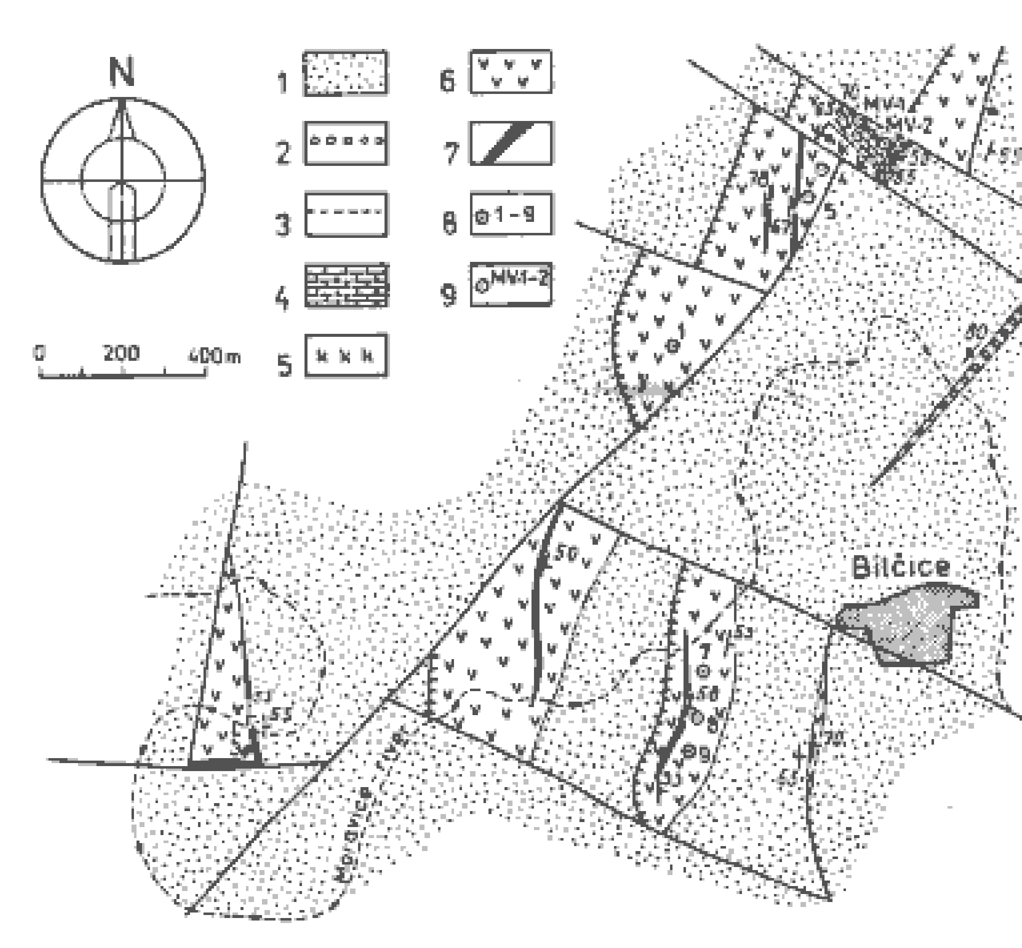
The vicinity of Leskovec

The following authors participated in the investigation of this locality: J. Hladil (coral and stromatoporoid fauna), O. Friáková and J. Zikmundová (conodont fauna), Z. Kukal (petrography of sediments), A. Přichystal (petrography of volcanics), J. Horák (mineralogy of keratophyres), J. Otava (heavy minerals) and P. Müller (reflectance of finely dispersed organic matter) - cf. Dvořák et al. (1989).

The west vicinity of Leskovec nad Moravicí belongs to the southern margin of the north part of the Šternberk-Horní Benešov Zone. Devonian rocks are exposed on the surface in the form of tectonically confined blocks which are mostly thrust on greywackes of the Horní Benešov Formation (Fig. 11). Volcanics, which are most abundant, were studied by A. Přichystal. Mostly sediments from outcrops and from two boreholes (MV-1 and 2) are discussed in this paper.

Stratigraphic and facies development
Layers of limestones and shales in volcanics

Layers of shales and rare limestones were found to be enveloped by mostly basic effusives and tuffs. They were described already by Skácel (1952, 1955) who identified sections of tentaculitids (in thin sections), coral fragments, crinoidal segments and orthocone nautiloids. The number of these layers is not known exactly. At least two of them are assumed to exist. Non economic iron ores of the Lahn-Dill type are confined to these layers. They were mined in the past. Shales are black, fine-grained, rarely calcareous, locally tuffaceous. They are also silicified (SiO_2/Al_2O_3



11. Map of bedrock geology of the west vicinity of Leskovec n[a] Moravicí.
1 - greywackes, 2 - petromict conglomerates, 3 - pebble shales (1-3 - Ho[rní] Benešov Formation, Lower and Middle Viséan), 4 - limeston[es] (Givetian-Famennian), 5 - quartz keratophyres, 6 - basic volcanics, 7 [-] clay shales, locally accompanied by limestones (Stínava-Chabič[ov] Formation, Eifelian), 8 - boreholes of the fifties, 9 - new survey borin[gs]

3.82 and 4.25) and slightly rich in Fe_2O_3 (8.6 and 7.82 wt.%) and FeO (11.97 and 1.96 wt.%). The Al_2O_3/Na_2O ratio (115 and 87) argues for deposition of a chemically very mature material. Although the shales are black in colour, no higher contents of $C_{org.}$ were found. Their thickness varies between 1.7 and 2 m. Limestones are locally accompanied by intercalations of shales (which supposedly form lenses). They are max. 30 cm thick, blue-grey and micritic. A conodont fauna was identified in only one specimen from an old pit in a small valley NW of Leskovec. It gives Upper Eifelian age. A macrofauna, discovered earlier, seems to be of the same age.

Vicinity of a quarry near old lime works

Completely different setting was found in an abandoned quarry near old lime works in the northern part of the area. Two shallow boreholes (MV-1,2) drilled there brought a lot of new data (fig. 12).

Keratophyres

The oldest rocks penetrated by the borehole MV-2 are silicified rocks resembling keratophyres (for details see A. Přichystal). Tuffs and tuffites are most abundant whereas lavas are minor. Acidic rocks corresponding to quartz keratophyres are rare. Abundant silicified and ferruginous organic structures which probably correspond to algae were found in tuffites. Changing conditions during the sedimentation are reflected in the occurrence of pyrite, hematite and magnetite. Framboidal and colomorph pyrite was also found beside pyrite hexahedrons (J. Horák). Small clasts of quartzose sandstones and rocks which can be classified as tuffaceous limestone were found in tuffaceous rocks. Original environment is thought to have been of reducing character as manifested by pyrite which is rarely accompanied by chalcopyrite in vugs of tuffs and tuffites. Remaining pores were filled with hematite and magnetite that originated in an oxidizing environment. Oxidizing and reducing conditions seem to have been alternating during the whole deposition of tuffs and tuffites which are over 55 m thick. Pyritization and hematitization were accompanied by silicification of rocks. High concentration of K_2O (being as much as 9.72 wt.%) which prevails over Na_2O appears to be significant from the viewpoint of the origin of a stratabound base metal deposit. From the transition of keratophyres into the overlying Lažánky Limestones which are of Middle and Lower Eifelian age (10 m above the base of limestones), it follows that they are likely of Lower Eifelian and/or Upper Emsian age. Abundant algal structures, sandstone clasts, hematite and magnetite indicate that the deposition of tuffs took place in very shallow water environment, most likely on the slope of an elevation.

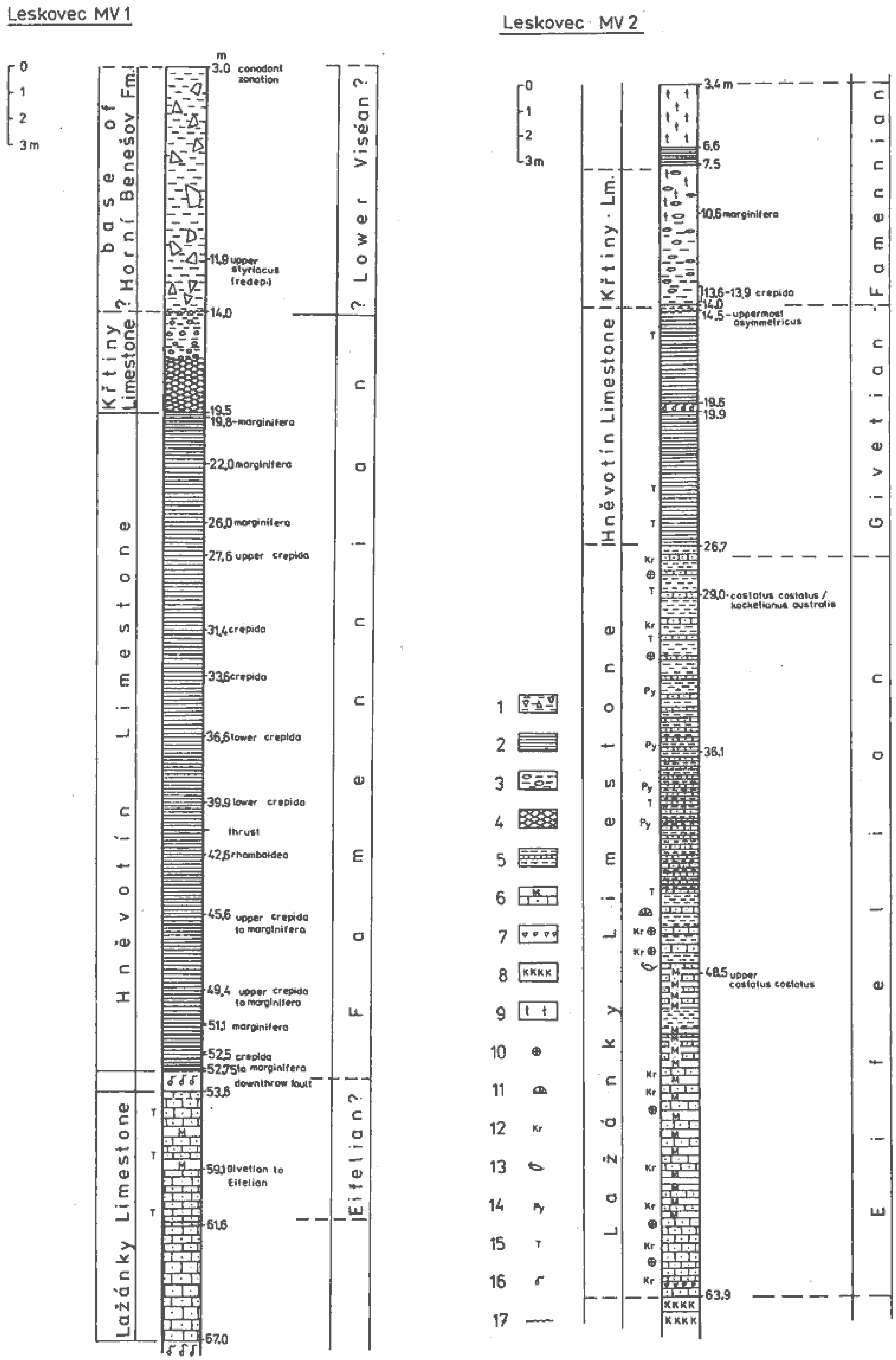
The Lažánky Limestones

The overlying Lažánky Limestones which are 2.9 m thick, are represented by grey, dark grey to black-grey bioclastic micritic limestones which alternate with subordinate layers of black calcareous and clay shales. Bioclastic limestones with fragments of crinoidal stems and corals seem to prevail at the base. Biomicritic limestones and shales appear to increase upward. Pyrite nodules begin to appear more frequently in shales. Large fragments of globular stromatoporoids, rugose and tabulate corals, bryozoans, brachiopods and crinoidal segments were found in layers of bioclastic limestones. Sections of styliolina and ostracodes are more frequent in micritic limestones. At the base of limestones (59.10 and 62.70 m) a small admixture of clastic quartz was found on the boundary of keratophyre tuffs and limestones in addition to layers of keratophyre tuffs. Clastic quartz also occurs in a shale intercalation at the depth of 51.9 m and in limestone at 49.20 m. Bioclastic limestones in their central part envelope small intraclasts of micritic limestones which are thought to have been partly transported in plastic state. In the uppermost third of the whole section, the black, highly calcareous as well as clay shales seem to prevail over layers (3-10 cm thick) of dark grey, fine- to coarse-grained bioclastic limestones. A pulp of crinoidal stems and styliolina is most abundant besides fragments of rugose corals. Pyrite is frequent but silicification occurs in the uppermost parts of the section. (The SiO_2/Al_2O_3 ratio is over 3.) Higher content of $C_{org.}$ (being around 1 wt. %) was also observed there.

The occurrence of tabulate corals proves Eifelian age to be applied for the whole section of the Lažánky Limestones. Conodont microfauna allows these limestones to be classified in the Middle Eifelian. A specimen from the depth of 28.30-29.00 m represents a transition between the Polygnathus costatus costatus and Tortodus kockelianus australis Zones whereas a specimen from 48.30-48.50 m contains some genera which are characteristic of the upper part of the Polygnathus costatus costatus Zone. Representatives of the genus *Polygnathus* seem to be most abundant among the conodont assemblages. As the first specimen comes from the uppermost part and the second one from the middle of the Lažánky Limestones, it seems to be likely that both the Middle and the Lower Eifelian occur there.

Limestones and shales appear to have been deposited in strongly reducing environment. A flowing environment along the slope of submarine elevation is thought to occur during deposition of older limestones. Younger limestones appear to have originated in a protected quiet bay where unsorted detritus of shallow water fauna (typical of wave motion) was occasionally washed in during storms. There were no currents near the sea bottom.

Organic matter was accumulating in the bay to form pyrite during its decay. Silicification of the uppermost


Leskovec MV 1
0
1
2
3 m
m
3.0 conodont zonation
11.9 upper styriacus (redep.)
14.0
19.5
19.8 marginifera
22.0 marginifera
26.0 marginifera
27.6 upper crepida
31.4 crepida
33.6 crepida
36.6 lower crepida
39.9 lower crepida
thrust
42.6 rhomboidea
45.6 upper crepida to marginifera
49.4 upper crepida to marginifera
51.1 marginifera
52.5 crepida
52.75 to marginifera
downthrow fault
53.8
59.1 Givetian to Eifelian
61.6
67.0
base of ? Horní Benešov Fm.
Křtiny ? Limestone
Hněvotín Limestone
Lažánky Limestone
? Lower Viséan ?
Famennian
Eifelian?
Leskovec MV 2
0
1
2
3 m
3.4 m
6.6
7.5
10.6 marginifera
13.6–13.9 crepida
14.0
14.5 – uppermost asymmetricus
19.6
19.9
26.7
29.0 – costatus costatus / kockelianus australis
36.1
48.5 upper costatus costatus
63.9
Křtiny Lm.
Hněvotín Limestone
Lažánky Limestone
Famennian
Givetian
Eifelian
T
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1
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17

parts of the sequence may indicate shallowing of the basin and a surface wash of chemically weathered rocks (keratophyres?) into depression. The Lažánky Limestones were also penetrated by the borehole MV-1 at the depth interval of 53.60-67.00 m. They show identical character (Fig. 12).

The Hněvotín Limestones

They were found in boreholes MV-2 and MV-1 as well as in an abandoned quarry near old lime works. The oldest section was penetrated by the borehole MV-2 at the depth of 14.50 and 26.70 m. Here, the rocks are represented by grey, at the base also dark grey, micritic, laminated limestones with abundant tiny layers of grey-greenish calcareous shales. Some lenticular stromatactis were found to occur locally in limestones. Limestones are represented by biomicrites with locally accumulated tentaculitid shells and other shell pulp. Sections of conodonts are rare. The original thickness is thought to have been reduced due to a downfault dislocation. The thickness preserved today is less than 10 m. Stratigraphic dating was done in the uppermost part of the Hněvotín Limestones penetrated by the borehole MV-2 at the depth of 14.20 m using conodont fauna. The age corresponds to the uppermost Givetian (the lowest part of the Polygnathus asymmetricus Zone). Not exactly identified conodont fragments from the depth of 25.50 m do not exclude Lower Givetian age. The occurrence of tentaculitids also corresponds to Givetian age of the limestones. They are thought to have been deposited in a quiet bay having an open circulation and normal salinity. Currents were transporting tentaculitid shells from open sea to be later deposited at the bottom. Reducing environment (pyrite is reported from the lowest section) was gradually changing upward into oxidizing environment. A hiatus (at 14.50 m of the borehole MV-2) is assumed to occur and last during the whole Frasnian including the base of the Famennian. Reduction of strata (penetrated by the borehole) due to a downfault dislocation is rather unlikely. The sea in the vicinity of the MV-2 borehole is believed to have regressed on the turn of the Givetian and Frasnian.

About a 7 m thick sequence of grey and light grey laminated limestones with coatings and upward even with laminae of grey-greenish shales is exposed in an abandoned quarry SE of the borehole MV-2. The limestones contain conodont fauna of Famennian age extending from the Palmatolepis crepida Zone as high as the upper part of the Polygnathus styriacus Zone. Underlying rocks are not exposed. The described sequence (with questionable Frasnian) is linked lithologically with the Hněvotín Limestones of the borehole MV-2.

The Hněvotín Limestones were also penetrated by the borehole MV-1 at the depth of 19.50-52.75 m. There is an overthrust fault at the depth of 41 m which is proved by conodont fauna. The fault divides the sequence of the described limestones into two parts. Lithologically, the whole sequence is represented by light grey, rarely pinkish micritic limestones with minor laminae of greenish clay shales. Small lenticular stromatactis, a few centimetres in size, begin to appear in limestones of the lower half of the sequence. Rare silty admixture of clastic quartz occurs only locally in the limestones. Secondary silicification and conodont fauna are more abundant. The majority of the depth interval of 41.00-52.70 m belongs to the Palmatolepis marginifera Zone, and the uppermost part to the Palmatolepis rhomboidea Zone. The age of the Hněvotín Limestone is well supported by evidence: the base corresponds to the Palmatolepis crepida Zone (both the lower and the upper parts of the zone are proved) which is about 10 m thick; the Palmatolepis marginifera Zone (being about 5 m thick) is confined to a higher situated horizon. Existence of the P. rhomboidea Zone remains problematic. It is either missing locally or its thickness does not exceed 1 m.

Lithologically identical Hněvotín Limestones were observed in an abandoned quarry located in close SW vicinity of the borehole MV-1. Limestones with more abundant intercalations of dark grey clay shales are exposed in the opposite wall of the quarry. The limestones contain conodont fauna of the "Middle" Frasnian: the upper part of the Polygnathus asymmetricus Zone and the Ancyrognathus triangularis Zone. The Hněvotín Limestones, showing a small thickness, are exposed in the wall which is closer to the borehole MV-1. They contain conodont fauna of the Scaphignathus velifer Zone (the lower part of this zone shows redeposited conodont fauna of the upper part of the Palmatolepis crepida Zone). The purest thin bedded light grey limestones are likely to have been mined out. Their fragments and pieces can be found in neighbouring fields. They contain no conodont fauna. Assuming from their position, they seem to belong to the higher Frasnian and to the lowermost Famennian.

The Hněvotín Limestones are thought to have been deposited in an oxidizing environment of intertidal

←

12. The Leskovec MV-1 borehole log and the Leskovec MV-2 borehole log (upper parts). Transferred to true thickness

1 - shales (partly tuffaceous) with clasts of limestones and shales, 2 - laminated limestones, 3 - shales with limestone nodules, 4 - nodular limestones, 5 - biodetrital limestones alternating with shales, 6 - micritic limestones alternating with biodetrital limestones, 7 - tuffaceous breccias, 8 - keratophyre tuffs, 9 - keratophyre tuffites, 10 - rugose corals, 11 - stromatoporoids, 12 - crinoidal segments, 13 - brachiopods, 14 - pyrite, 15 - tentaculitids, 16 - fault, 17 - break in sedimentation.

platforms. Small lenticular stromatactis can be interpreted as "bird's-eye-structures". Total thickness is not known but it is believed to be a few tens of metres. They were deposited during a long period of time, since the Givetian till the Upper Famennian. The Al_2O_3/Na_2O ratio of calcareous shale laminae indicates deposition of chemically weathered material.

The Křtiny Limestones

These limestones are partly equivalent to the Hněvotín Limestones, as far as the time of their deposition is concerned. They were found in the borehole MV-2 at the depth of 10.50-14.00 m (and/or 7.50-14.00 m). They are underlain by a 0.5 m thick layer of grey-greenish calcareous shales which transgressively lie on the Hněvotín Limestones of the Givetian, following a long-lasting hiatus. The Křtiny Limestones are represented by grey micritic nodular limestones. Limestone nodules seem to be "immersed" in a grey-greenish calcareous shale. The Křtiny Limestones pass upward in tuffaceous shales and then in tuffites. The latter also contain nodules of the same limestones which occur in the Křtiny Limestones. Only the character of the matrix is changing. Regarding biostratigraphy, the Palmatolepis crepida Zone was proved to occur at the base of the Křtiny Limestones whereas the Palmatolepis marginifera Zone was found at the transition to tuffites.

The Křtiny Limestones were found in the borehole MV-1 at the depth interval of 14.00-19.50 m. They are represented in the lower part by light grey micritic nodular limestones with relatively abundant grey-greenish clay matrix which disappears toward underlying rocks. In contrast to that, the matrix consisting of shale increases upward to become dominant in the interval of 14.00-15.50 m. The thickness of the Křtiny Limestones does not exceed 4 m. No conodont fauna was found in the borehole MV-1. The limestones are believed to be certainly younger than the Palmatolepis marginifera Zone which was identified in the underlying Hněvotín Limestones.

Identical, about 2 m thick, Křtiny Limestones containing conodont fauna of the Polygnathus styriacus Zone were found to occur in the vicinity of the borehole MV-1. This paleontological evidence applies also to the Křtiny Limestones which were observed in the borehole MV-1. The Křtiny Limestones gradually develop from the underlying Hněvotín Limestones. Nodular texture is believed to have resulted from precipitation of $CaCO_3$ from a calcareous clayey sediment in which $CaCO_3$ and a clastic clay compound show certain proportions (Z. Kukal). Lithofacies of the Křtiny Limestones is typical of increasing deposition of clastic clay material in contrast to sedimentation of micrite. Clay (and/or tuffaceous) matrix within the Křtiny Limestones appears to increase upward. Limestone sedimentation is thought to have been completely terminated in the Upper Famennian around the boundary of the Polygnathus styriacus and Bispathodus costatus Zones. Only a thin layer of shales (max. 1 m thick) or intermediate (keratophyre?) tuffites were then deposited (in the vicinity of the borehole MV-2) during the uppermost Famennian. Thus, the Upper Famennian period can be characterized by uplifting of the adjacent volcanic elevation and by very slow sea retreat from its slopes. The drift of weathered material (Al_2O_3/Na_2O - 40) from the shore was increasing. An intermediate volcanism is likely to have been linked with the above described uplift. Some tuffs were deposited only locally. The sea retreated from the elevation slopes around the turn of the Devonian and Carboniferous.

The Horní Benešov Formation

The only outcrop exposing the contact of the Horn Benešov Formation with the underlying Devonian strata occurs in an abandoned quarry near the old lime works. The contact is sharp. The Horní Benešov Formation is following a long lasting hiatus (during at least the whol Tournaisian), deposited transgressively, thus showing an obvious unconformity. The unconformity is als manifested by the occurrence of about a 10 m thick laye of basal slump conglomerates with abundan tuffaceous-clayey matrix in which are "immersed completely unsorted, up to 50 cm large, sharp o semirounded fragments of underlying limestones weathered volcanics, iron ores and black shales. One clas of laminated limestone found in the borehole MV-1 (at th depth of 3-14 m) showed a conodont fauna correspondin to the Polygnathus styriacus Zone whereas another clas of bioclastic limestone with crinoids showed in thi section a strong sandy admixture forming lenses. Th matrix confined to this horizon is close to intermediat tuffites from the uppermost section of the borehole MV-2 Only in the roof, there are fine-grained greywackes wit 20-40 cm thick laminae of shales and further upwar coarse-grained greywackes as a typical representative c the Horní Benešov Formation. Medium- an coarse-grained massive greywackes occur in the broa vicinity of Leskovec. Isolated blocks of Devonian rock should form a natural boundary between the Hor Benešov Formation in the west and the Moravic Formation in the east. According to Zapletal (1983), layer of petromictic fine-grained conglomerates as muc as 10 m thick, near Bílčice is regarded as a proof of t Moravice Formation. Similarly, a brief investigation heavy minerals confined to greywackes (J. Otava) at t foot of the borehole MV-2 showed these greywackes belong rather to the base of the Moravice Formation tha to the Horní Benešov Formation. However, greywack of neither formation can be distinguished with the nak eye.

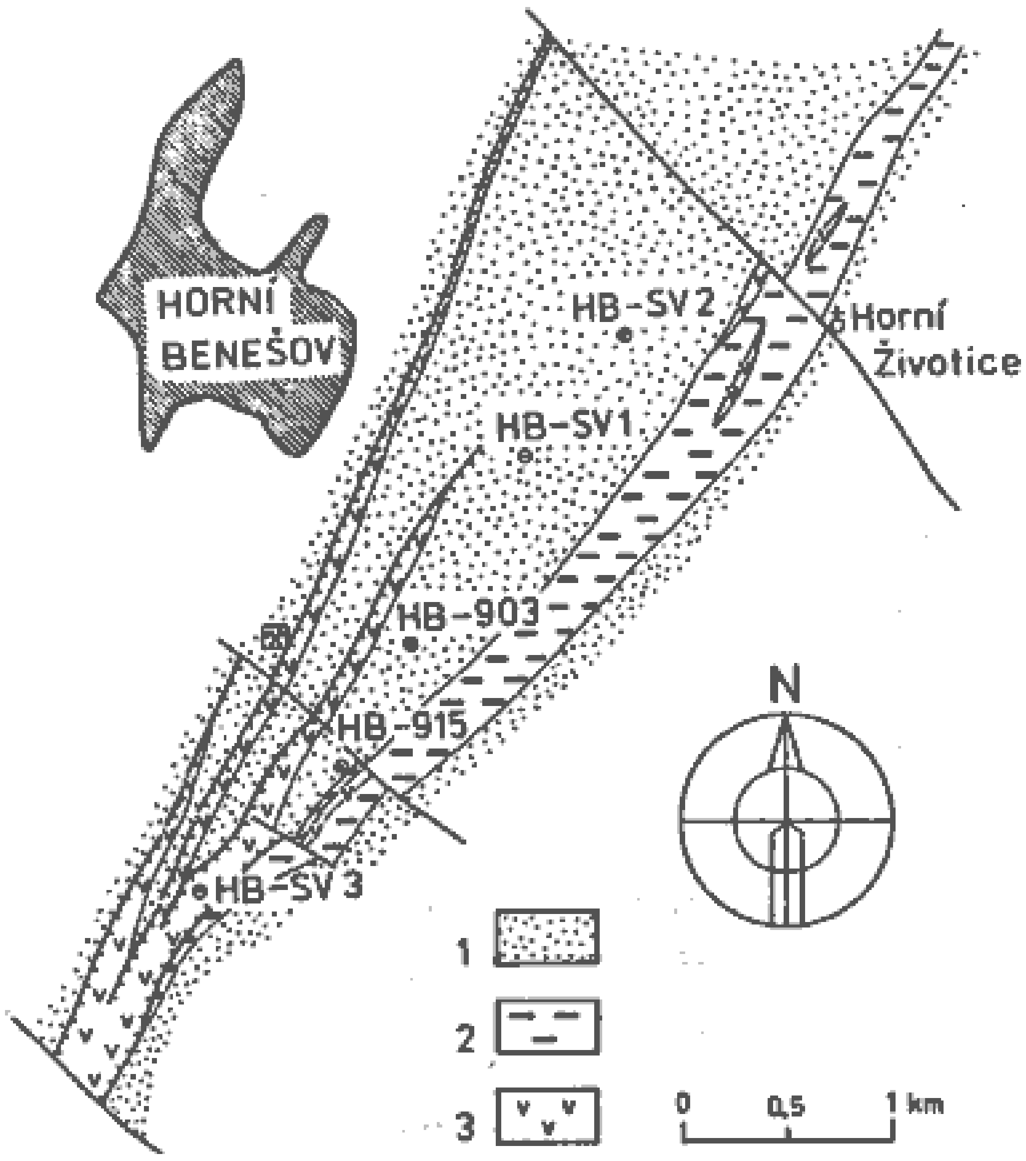
Metamorphism and tectonic style

Reflectance of finely disseminated organic matter was measured by P. Müller only in specimens from the borehole MV-2. Two samples come from Eifelian shales (from the depth interval 30.7 and 50.0 m) and three samples were obtained from shale intercalations in greywackes which represent a transition from the Horní Benešov Formation. The grade of metamorphism corresponds to a higher degree of anchimetamorphism (meta-anthracite). However, measured values of reflectance were found to be lower (3.7-5.8 $R_{max.}$) when compared with those measured in the east and west neighbourhood. Taking into account the values measured in the Horní Benešov Formation in the borehole Dětřichov-1 (7-9 $R_{max.}$), those obtained from Eifelian shales are low. Only a few kilometres eastward from here, the Upper Viséan shales of the Moravice Formation observed in the borehole Slezská Harta J-104-D at the depth of 34 m showed reflectance 5.15 R_{max}. Judging from correlation of specimens of similar age, it seems obvious that Devonian rocks of the Šternberk-Horní Benešov Zone were never submerged to a few kilometres depth and later uplifted by tectonic movements.

Geological map (Fig. 11) shows almost monoclinal inclination of beds toward the east. All structures exhibit vergency toward the west due to the measured cleavage which shows identical strike as well as inclination (50-70°). The only exception is represented by a small block near the old lime works where the strike of beds and cleavage turn to the NW-SE and dip to the NE. It seems obvious that the block rotated to its present position during the late movements along faults. Almost all earlier boreholes (drilled to explore iron ores - Skácel 1952) as well as our present mapping boreholes reached greywackes of the Horní Benešov Formation at relatively shallow depths of max. 150 m underneath Devonian rocks. Only boreholes Nos. 4 and 5 did not penetrate Devonian rocks even at depths of 170 and 200 m, respectively. Consequently, Devonian rocks seem to form larger or smaller slices thrust over greywackes of the Horní Benešov Formation toward the west. Boreholes Nos. 7,8 and 9 are arranged along a N-S line. Judging from the position of Devonian volcanics thrust over the greywackes exposed in these three boreholes, the thrust plane seems to be dipping at 20-25° to the north.

The vicinity of Horní Benešov (Figs. 2, 13)

The interpretation of a complex stratigraphy is based on data obtained from boreholes HB-903, HB-915, HB-SV-1, HB-SV-2, HB-SV-3 as well as from some other boreholes, from exposures near a mine working out a stratabound base metal deposit and from underground workings (Urbánek 1974). All conodont fauna was studied by O. Friáková unless referred otherwise.



13. Map of bedrock geology of the Horní Benešov vicinity. Compiled by J. Dvořák using maps of J. Urbánek.
1 - mostly greywackes of the Horní Benešov Formation, 2 - siliceous shales with cherts (Ponikev Formation, Upper Frasnian to Middle Viséan), 3 - basic, to a lesser extent intermediate and acid volcanics with intercalations of shales and limestones.

Borehole HB-903 (Fig. 16)

It was drilled from the 9th level of the shaft in the central part of the deposit. It reached the Devonian of the central and particularly of the mineralized slice at a relatively great depth along the dip (toward the ESE).

Central slice

The uppermost part (3 m thick) penetrated by the borehole consists of strongly crushed basic tuffs which are separated from underlying limestones by a thrust fault (tuffs were thrust over limestones). Then grey and light grey micritic limestones, thinly bedded, locally nodular and with clay admixture follow in the sequence. The clay admixture is more abundant at the base. The nodular limestones are 7.2 m thick. Conodont fauna of the Scaphignathus velifer Zone was identified in the uppermost part. Next 4.4 m downward, a single specimen showed two assemblages of conodonts: base of the Palmatolepis marginifera and Palmatolepis rhomboidea Zones which correspond to the "Middle" Famennian. Conodont fauna of the middle P. crepida Zone was found at the depth of 5.2 m from the limestone surface. Further 0.8 m downward, a fauna of the Palmatolepis gigas Zone was identified. Conodont fauna of the P. gigas Zone including redeposited fauna of the Polygnathus platforms. Small lenticular stromatactis can be interpreted as "bird's-eye-structures". Total thickness is not known but it is believed to be a few tens of metres. They were deposited during a long period of time, since the Givetian till the Upper Famennian. The Al_2O_3/Na_2O ratio of calcareous shale laminae indicates deposition of chemically weathered material.

The Křtiny Limestones

These limestones are partly equivalent to the Hněvotín Limestones, as far as the time of their deposition is concerned. They were found in the borehole MV-2 at the depth of 10.50-14.00 m (and/or 7.50-14.00 m). They are underlain by a 0.5 m thick layer of grey-greenish calcareous shales which transgressively lie on the Hněvotín Limestones of the Givetian, following a long-lasting hiatus. The Křtiny Limestones are represented by grey micritic nodular limestones. Limestone nodules seem to be "immersed" in a grey-greenish calcareous shale. The Křtiny Limestones pass upward in tuffaceous shales and then in tuffites. The latter also contain nodules of the same limestones which occur in the Křtiny Limestones. Only the character of the matrix is changing. Regarding biostratigraphy, the Palmatolepis crepida Zone was proved to occur at the base of the Křtiny Limestones whereas the Palmatolepis marginifera Zone was found at the transition to tuffites.

The Křtiny Limestones were found in the borehole MV-1 at the depth interval of 14.00-19.50 m. They are represented in the lower part by light grey micritic nodular limestones with relatively abundant grey-greenish clay matrix which disappears toward underlying rocks. In contrast to that, the matrix consisting of shale increases upward to become dominant in the interval of 14.00-15.50 m. The thickness of the Křtiny Limestones does not exceed 4 m. No conodont fauna was found in the borehole MV-1. The limestones are believed to be certainly younger than the Palmatolepis marginifera Zone which was identified in the underlying Hněvotín Limestones.

Identical, about 2 m thick, Křtiny Limestones containing conodont fauna of the Polygnathus styriacus Zone were found to occur in the vicinity of the borehole MV-1. This paleontological evidence applies also to the Křtiny Limestones which were observed in the borehole MV-1. The Křtiny Limestones gradually develop from the underlying Hněvotín Limestones. Nodular texture is believed to have resulted from precipitation of $CaCO_3$ from a calcareous clayey sediment in which $CaCO_3$ and a clastic clay compound show certain proportions (Z. Kukal). Lithofacies of the Křtiny Limestones is typical of increasing deposition of clastic clay material in contrast to sedimentation of micrite. Clay (and/or tuffaceous) matrix within the Křtiny Limestones appears to increase upward. Limestone sedimentation is thought to have been completely terminated in the Upper Famennian around th boundary of the Polygnathus styriacus and Bispathodu costatus Zones. Only a thin layer of shales (max. 1 m thick or intermediate (keratophyre?) tuffites were the deposited (in the vicinity of the borehole MV-2) durin the uppermost Famennian. Thus, the Upper Famennian period can be characterized by uplifting of the adjacen volcanic elevation and by very slow sea retreat from its slopes. The drift of weathered material (Al_2O_3/Na_2O - 40) from the shore was increasing. An intermediate volcanism is likely to have been linked with the above described uplift. Some tuffs were deposited only locally. The sea retreated from the elevation slopes around the turn of the Devonian and Carboniferous.

The Horní Benešov Formation

The only outcrop exposing the contact of the Horní Benešov Formation with the underlying Devonian strata occurs in an abandoned quarry near the old lime works. The contact is sharp. The Horní Benešov Formation is, following a long lasting hiatus (during at least the whole Tournaisian), deposited transgressively, thus showing an obvious unconformity. The unconformity is also manifested by the occurrence of about a 10 m thick layer of basal slump conglomerates with abundant tuffaceous-clayey matrix in which are "immersed" completely unsorted, up to 50 cm large, sharp or semirounded fragments of underlying limestones, weathered volcanics, iron ores and black shales. One clast of laminated limestone found in the borehole MV-1 (at the depth of 3-14 m) showed a conodont fauna corresponding to the Polygnathus styriacus Zone whereas another clast of bioclastic limestone with crinoids showed in thin section a strong sandy admixture forming lenses. The matrix confined to this horizon is close to intermediate tuffites from the uppermost section of the borehole MV-2. Only in the roof, there are fine-grained greywackes with 20-40 cm thick laminae of shales and further upward coarse-grained greywackes as a typical representative of the Horní Benešov Formation. Medium- and coarse-grained massive greywackes occur in the broad vicinity of Leskovec. Isolated blocks of Devonian rocks should form a natural boundary between the Horní Benešov Formation in the west and the Moravice Formation in the east. According to Zapletal (1983), a layer of petromictic fine-grained conglomerates as much as 10 m thick, near Bílčice is regarded as a proof of the Moravice Formation. Similarly, a brief investigation of heavy minerals confined to greywackes (J. Otava) at the foot of the borehole MV-2 showed these greywackes to belong rather to the base of the Moravice Formation than to the Horní Benešov Formation. However, greywackes of neither formation can be distinguished with the naked eye.

admixture which slowly disappears with depth. About 5.5 m below the base of the tuffs, the limestones contain conodont fauna of the zone Ancyrognathus triangularis. The limestones are 9 m thick and thrust over the Horní Benešov Formation. They show isoclinal folding at the base and are disturbed by thrust faults. Some small limestone blocks are thought to have been moved in here along a large thrust fault as follows from the occurrence of conodont fauna of the Palmatolepis rhomboidea Zone (lower Famennian). At that time, the sedimentation in the thrust block was locally interrupted.

Mineralized slice

A 1.8 m thick layer of black-grey silty shales with laminae of siltstones and rare intercalations of fine-grained greywackes underlie the greywackes of the Horní Benešov Formation. They lie on grey laminated micritic limestones with laminae of dark grey shales, forming a sharp contact. Only one conodont corresponding to the Lower Famennian was identified in the uppermost parts of limestones. Richer fauna was found about 4.5 m deeper. It is equivalent to the upper part of the Palmatolepis marginifera Zone as far as the base of the Scaphignathus velifer Zone. The limestones are 8.8 m thick, thrust over crushed shales and greywackes showing in the borehole a thickness of 1.6 m. They are underlain by lithologically identical and contemporaneous limestones being 9.6 m thick. Some conodont fauna was found about 4.5 m below crushed shales and greywackes. It corresponds to the Lower Famennian, specifically to the middle up to the upper parts of the Palmatolepis crepida Zone. Other specimens were found to be sterile. These limestones are equivalent to those occurring in central "slice" which are of Famennian age. The sedimentation between the Scaphignathus velifer and Palmatolepis crepida Zones is thought to have been continuing in mineralized "slice" but could have been interrupted during another period of time. About 1 m thick black calcareous clay shales with limestone laminae, which gradually pass into underlying rocks, were found to occur lower in the section. They are followed by 26.2 m thick calcareous grey-greenish hyaloclastites which are locally reddish in colour due to iron oxides. Black shales being 0.8 m thick occur again at the base of hyaloclastites, showing transition into overlying rocks. Underlying rocks are again represented by light grey, fine-grained, partly laminated limestones which are 14.3 m thick. They slowly pass downward into grey crinoidal limestones with greenish tuffaceous admixture. They are 7.5 m thick. Conodont fauna of the Palmatolepis gigas Zone was identified in the middle of this layer. Hyaloclastites of this slice are likely to belong to the lowest Famennian and/or to the Frasnian/Famennian boundary (the Palmatolepis triangularis Zone ?).

Lower in the section, a 5.2 m thick layer of tuffs separates some limestones which are similar to those described above. They are of micritic character, showing nodular texture and locally high volcanic admixture. These limestones, being 5.5 m thick, pass downward in tuffs of silimar thickness which lower in the section alternate with grey limestones. These limestones can be put to the Jesenec Limestones.

The limestones are dark grey in their lowermost part and locally envelope layers of black shales or are strongly mineralized with galena and sphalerite. Relatively rich fauna was found at the base. It consists of rugose corals of *Digonophyllum* type and particularly of the following tabulate corals: *Alveolites fornicatus*, *Crassialveolites* cf. *crassus*, *Crassialveolites* cf. *levis*, *Gracilopora vermicularis* and *Thamnopora* ex gr. *micropora* or *Thamnopora* ex gr. *polyforata* (according to J. Hladil). A cluster of globular stromatoporoid *Actinostroma* cf. *clathratum* (identified by V. Zukalová), then stems of algae and primitive foraminifers were also found there. The whole fauna assemblage indicates to be of uppermost Eifelian age. They belong to the Lažánky Limestones.

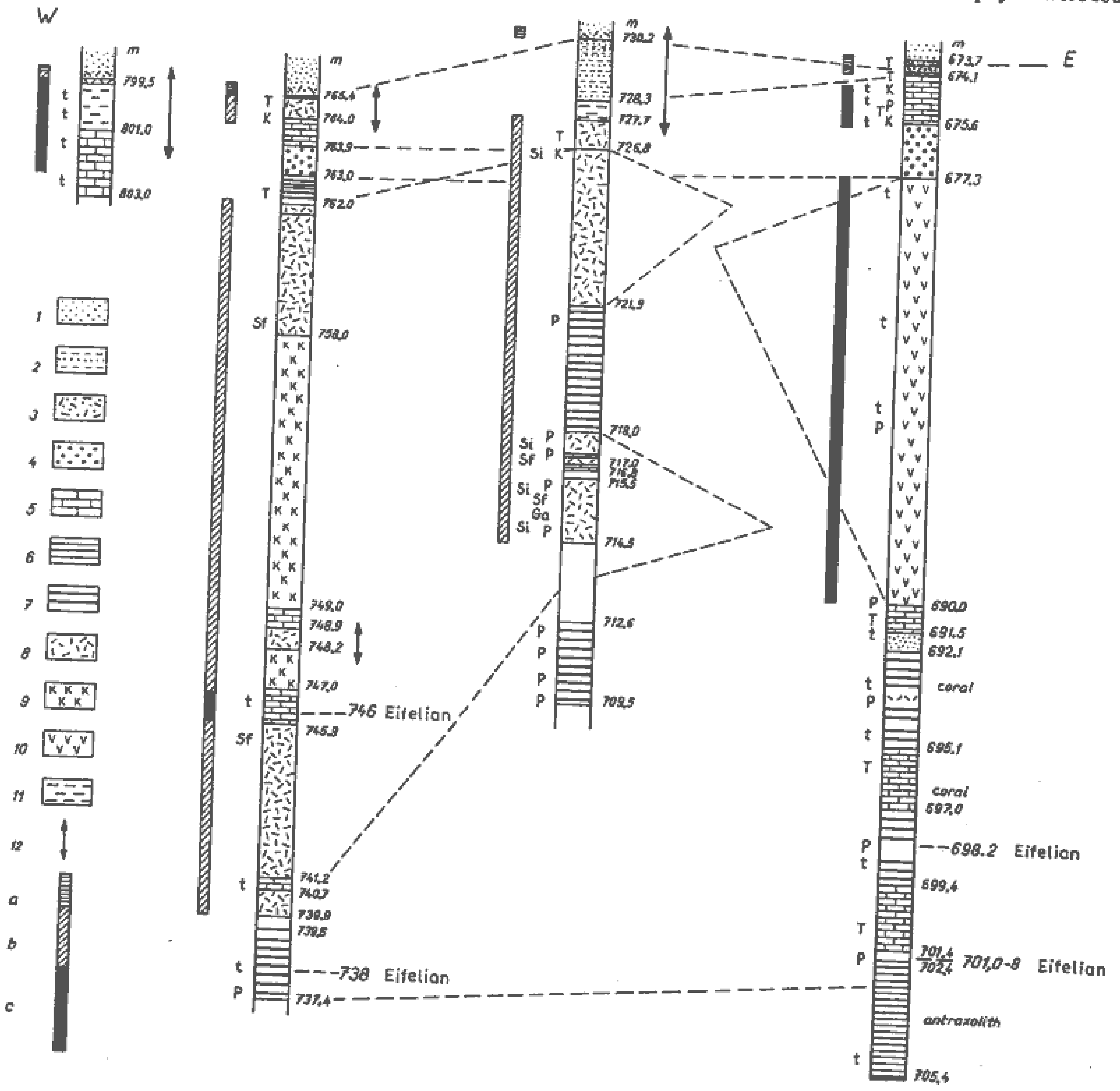
A 2.4 m thick layer of siliceous sericite schist strongly mineralized with galena and sphalerite occurs close to underlying strata. A thrust fault separates this schist from slices of light grey micritic limestones with laminae of shales and dark grey limestones with mineralized shreds of sericite schists. Conodont fauna of central part of the Palmatolepis crepida Zone (of the Lower Famennian) was found to be confined to light grey limestones. Slices of these limestones are thought to have been moved inhere along a large thrust fault, judging from their tectonic contact with greywackes of the Horní Benešov Formation.

Borehole HB-SV-1
(Dvořák et al. 1981, Figs. 13, 15 and Pl. 2)

It was drilled N of the mineral deposit which is being mined. The borehole did not penetrate the central slice but reached some other slices located underneath the mineralized slice. These slices seem to differ from each other. Tuffaceous greywackes and laminae of acid tuffites enveloped in a layer of shale occur at the base of the Horní Benešov Formation. A gradual lithological transition into pre-flysch facies was observed in sediments underlying the Horní Benešov Formation. A long hiatus which includes the Famennian and Tournaisian is expected to occur at the depth of 674.1 m, judging from analogy with the borehole HB-903. Tentaculitids in limestones below a 674.1 m horizon are likely to be of Frasnian age already. Different setting was found to occur in lower lying slices (located west of here): some gradual transition of dark grey silty shales rich in siltstones passing into light green tuffaceous shales can be observed at the depth interval of 730.2-727.7 m. Both facies form laminae which alternate in a transition zone. Similar setting was also found at the depth interval of 765.3-765.5 m. These sediments may correspond to the late Famennian and Tournaisian and seem to be strongly condensed.

No conodont or other stratigraphically significant fauna occurs in lower parts of the strata sequence of single slices. The only exception are four specimens found in lower parts. These specimens indicate Eifelian age of limestones. Lithostratigraphic correlation appears to be also very difficult due to the occurrence of various facies including volcanics. Light green tuffaceous shales with laminae of litho- to crystalloclastic tuffs to tuffites (727.6 and 765.0 m) can be correlated due to conodont fauna observed in thin sections. Similarly iron ores from the depth of 676 and 763 m can be also correlated. They are mostly of Upper Frasnian age in the neighbouring boreholes. Hyaloclastites (677.3-690.0 m) were found to occur only in the uppermost slice. They correspond to hyaloclastites of the same age which are confined to the mineralized slice observed in the borehole HB-903.

Only keratophyre tuffs exist in both lower and westward located slices whereas keratophyres were found



15. Correlation scheme of Devonian and Lower Carboniferous rocks founds in individual tectonic slices, part of the Horní Benešov HB-SV-1 borehole. 1 - greywackes of the Horní Benešov Formation, 2 - silty shales and siltstones (Andělská Hora Formation?), 3 - tuffaceous greywackes at the base of the Horní Benešov Formation, 4 - calcareous iron ores, 5 - grey and light grey limestones, 6 - laminated limestones, 7 - dark limestones with intercalations and laminae of black shales (5-7 - Jesenec Limestones), 8 - keratophyre tuffs and tuffites, 9 - keratophyres, 10 - hyaloclastites, 11 - light green tuffaceous shales (Ponikev Formation, Famennian? - Tournaisian), 12 - gradual lithological transition, a - acid, b - intermediate, c - basic volcanism, K - conodonts, P - pyrite, Ga - galena, Sf - sphalerite, Si - silicification, T - tuffaceous admixture (lamina), t - tentaculitids.

in the lowermost slice. Their base in this slice is of Eifelian age assuming from conodont fauna from limestone intercalations. However, the highest stratigraphic position of keratophyres is difficult to establish. Mostly dark grey to black-grey, very fine-grained limestones with laminae and intercalations of black shales occur in all three slices. They contain relatively abundant stems of crinoids, tentaculitids and rare (695-697 m) fragments of corals. Less abundant are grey, rarely light grey, lenticular and laminated limestones. The limestones always occur in lower parts of the strata sequence in all slices. Pyrite accumulations are confined to limestones and particularly to intercalations of black shales which occur in the central slice in the vicinity of the base metal (Pb-Zn) deposit (712-715 m).

If we project unfolded slices in the original space, it becomes obvious that the centre of keratophyre volcanism was located in the west whereas the centre of basic volcanism was in the east. Both types of volcanism thin away in opposite direction. There is a keratophyre in the west slice (737.4-765.4 m) which is accompanied in both the overlying and underlying strata by crystalloclastic feldspar tuffs. Noneconomic sphalerite occurs in over- and underlying tuffs, close to the keratophyre body. Keratophyres are missing in the central slice (709.5-728.3 m) and their tuffs are strongly silicified and thinner relative to the western slice. A mineral deposit composed of galena and sphalerite is confined to this slice which is characteristic of the presence of intermediate tuffs and black shales with layers of limestones with pyrite. As mentioned before, keratophyre and basic volcanics are missing here. The deposit is likely to be of Middle Devonian age.

Borehole HB-SV-2 (Fig. 18 and Pl. 3)

Of all the pilot boreholes, this one has the northernmost location (Dvořák et al. 1985).

Biostratigraphy

Not very well preserved conodont microfauna found in limestones at the depth interval of 1073.0-1077.3 m corresponds to the lower part of the P. marginifera Zone. As a specimen from the depth of 1078.0-1078.2 m contained conodonts of the P. gigas Zone (Upper Frasnian), a redeposition of Frasnian fauna or a hiatus at the turn of the Frasnian/Famennian are thought to have occurred (3 conodont zones are missing). Fauna from the depth of 1091.5-1092.3 m (Frasnian) is badly preserved. However, this fauna together with abundant tentaculitids in limestone layers (which form on fragments in breccias) give evidence that the section between 1078.0 and 1091.7 m of the borehole is likely to be of the Upper and/or Middle Frasnian. Deeper, down to 1116.1 m, there is no data for dating. This strata sequence may belong to the early Frasnian but may be even older.

The interval between 1044.0-1072.9 m is difficult to classify. It is obviously younger than the lower part of the P. marginifera Zone since it lies on limestones of that age, following a hiatus. It may be younger than the Upper Famennian, judging from badly preserved, most likely redeposited, conodont fauna from the depth interval 1050.2-1050.5 m. Consequently, the borehole section between 1044.0-1072.9 m is regarded tentatively as Tournaisian. It contains fragments of earlier volcanics, limestones and shales of the Frasnian or even older period. As there are already a proved redeposited conodont fauna and limestone clasts with Frasnian and Lower Famennian tentaculitids from underlying limestones, it cannot be excluded that the overlying section began to deposit during the Upper Famennian.

A gradual transition into the roof around the depth of 1044.0 m (indicated even by chemical analyses), shows Tournaisian (or maybe even Viséan) age of this part of the borehole.

The Horní Benešov Formation was impossible to classify biostratigraphically. It is assumed that the lower sliced part with volcanics below the large thrust fault at the depth of 1116.1 m is relatively older than the upper part of the strata sequence of the Horní Benešov Formation penetrated at the interval of 0-1039.8 m. The heavy mineral analysis indicates that the interval between 973.6 and 1039.8 m can be correlated with the slices underlying the thrust fault at the depth of 1116.1 m.

Lithofacies development

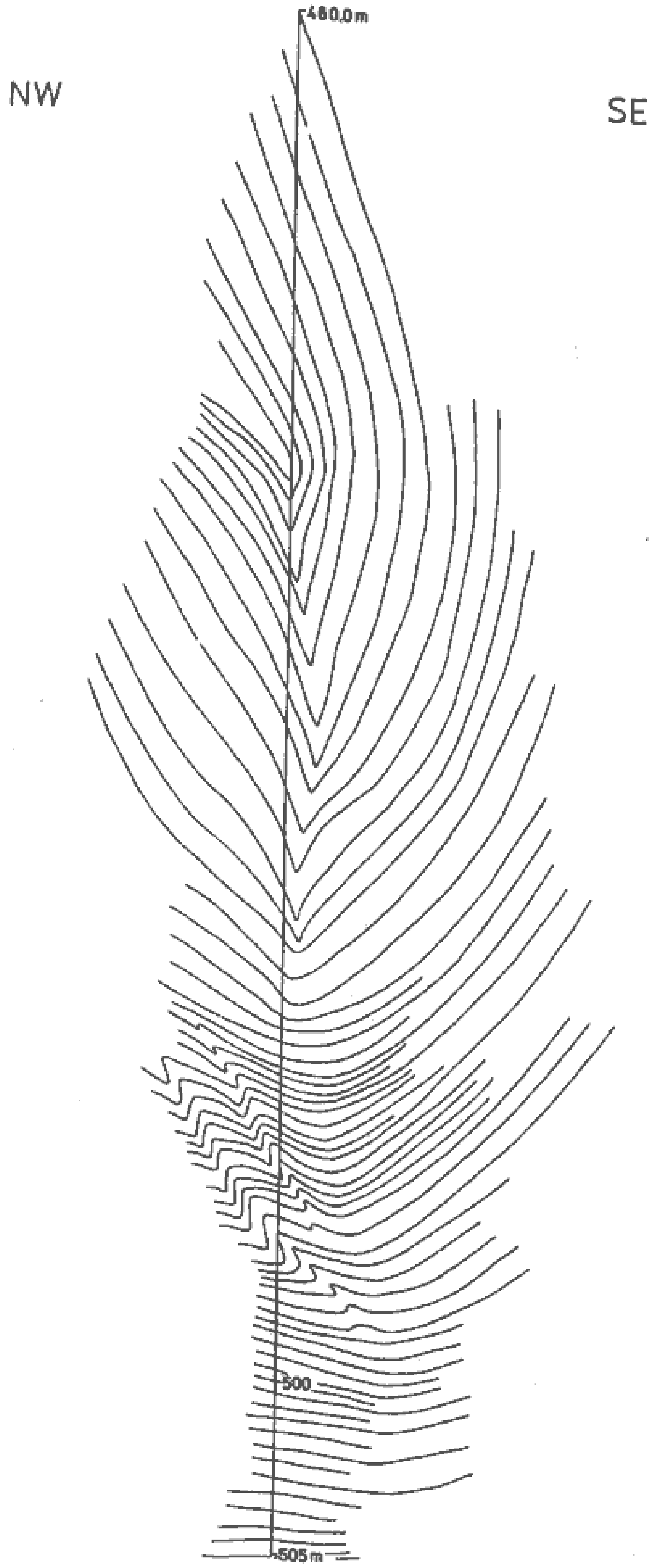
The earliest part can be delineated by depths of 1072.9 and 1116.1 m. The following sediments were found to alternate in the lower section:

a) mostly dark coloured, originally biomicritic limestones with tentaculitids (styliolina), locally also with crinoids, nowadays strongly recrystallized,

b) mostly black clay shales, often passing into tuffites on one side and into limestones on the other side,

c) mostly silicified but locally also strongly calcareous vitroclastic sandy tuffs and litho- and crystalloclastic keratophyres and/or quartz keratophyres. Tuffs pass in tuffites, tuffaceous shales and tuffaceous limestones.

As mentioned before, this interval is thought to be most likely of Frasnian (or even earlier) age. The uppermost part of this horizon consists of grey biomicritic limestones (1073.2 - 1078.4 m) of the "Middle" Famennian age which contain rare layers of acid tuffs to tuffites and in its lower part there is also a 20 cm thick intercalation of sedimentary breccia. The latter contains fragments of bioclastic limestones with tentaculitids (of Frasnian or even earlier age), carbonatized green acid tuffs and shales. Tuffs are silicified. Famennian limestones in the roof of the breccia layer enclose a redeposited fauna of the Frasnian-Famennian boundary, the earliest Famennian and/or Frasnian.



16. Detail of tectonic style based on the interpretation of drill core of the Horní Benešov HB-SV-2 borehole from the depth of 460-505 m. Alternation of shales, siltstones and fine-grained greywackes of the Horní Benešov Formation.

The dark colour of sediments and their lithological character (micritic limestones and shales) indicate that they have been deposited in a protected bay with reducing environment under the wave base level. Small thickness of silicified acidic tuffs and their fast alternation with other sediments argue for a relatively long lasting volcanic activity whose centre is thought to have been located at a greater distance. A thin layer at the depth of 1086.4 m consisting of siliceous rock with stilpnomelane and carbonate seems to indicate some hydrothermal activity close to the present drill site. Micritic limestones appear to increase upward which may argue for a shallowing of the basin, emergence of neighbouring areas and redeposition of earlier volcanic but mostly sedimentary material of the Upper Frasnian and Lower Famennian. As the Famennian limestones contain single redeposited earlier conodonts, it is obvious that some weathering and dissolution of earlier limestones must have occurred onshore following an emergence.

The upper section (1044.0-1072.9 m) is likely to be of Tournaisian age. It can be divided into lower part (1054.3-1072.9 m) where locally silicified, sericitized crystalloclastic tuffs and tuffites occur in some places whereas in other places lithoclastic and even sandy tuffs and tuffites prevail. They correspond to keratophyres and quartz keratophyres which are difficult to distinguish from each other (grainsize and alteration). The contact at the base of the described horizon at the depth of 1072.9 m is sharp. Coarse-grained breccia consisting of mostly black phosphate nodules in chaotic arrangement (70 % of the whole rock) lies on a lamina of tuffaceous shale. The largest phosphate nodules are as much as 5 cm long and max. 3 cm wide, having calcareous core. A light green tuffaceous matrix exhibits breccia texture with locally accumulated conodonts. The grain size of breccia becomes finer in upward direction and phosphate nodules gradually disappear. Similar "sharp bases" with phosphate nodules were found at depths of 1071.0 and 1068.5 m. Only at the depth of 1068.6 m, there is a layer of black clay shale which is 2 cm thick. Fragments of pinkish micritic and biosparitic limestones occur in higher position (1067.1 and 1064.5 m).

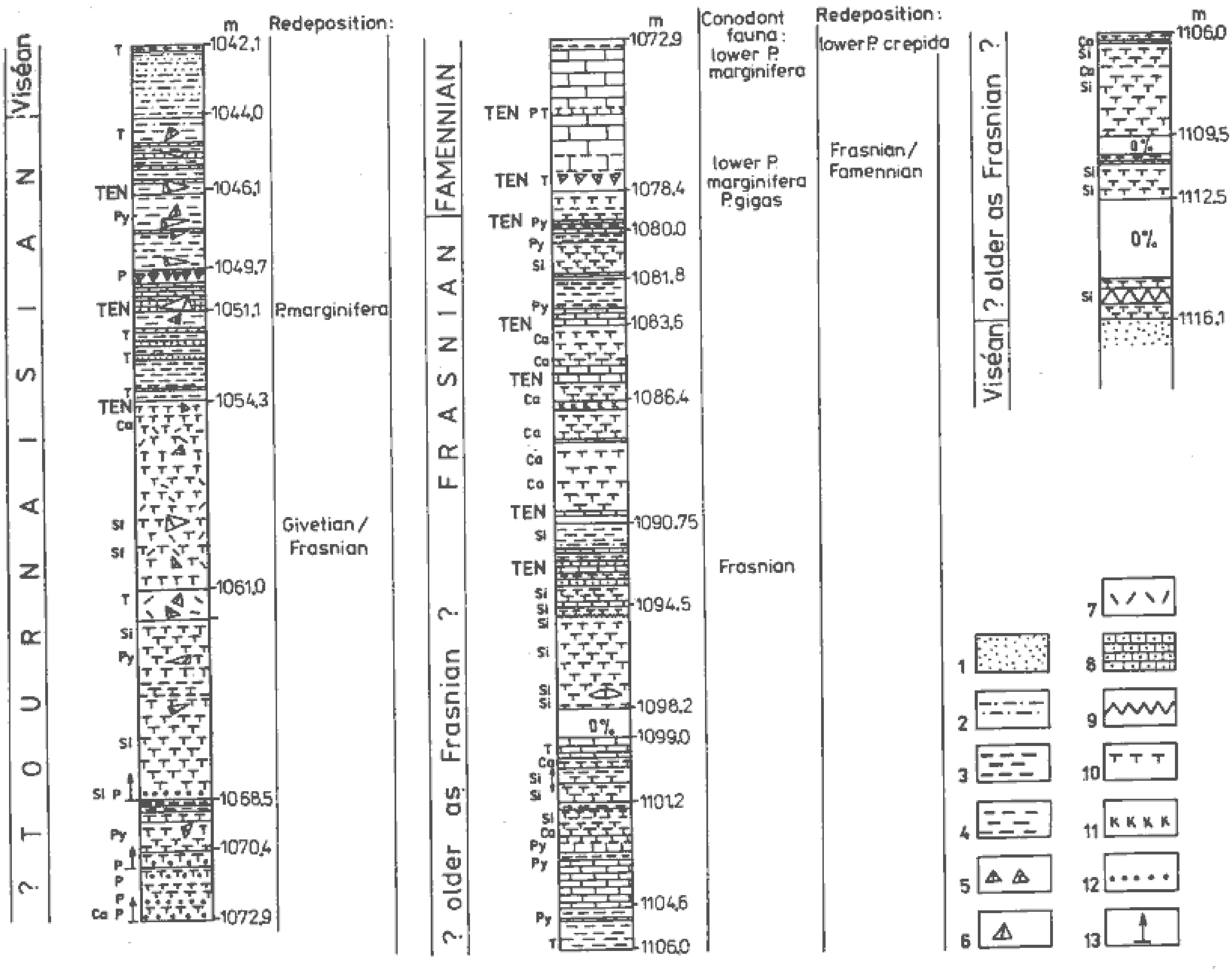
Clearly tuffaceous sedimentation was interrupted at the depth of 1061.0-1062.0 m when breccia was deposited. It is composed of shreds of black shales, tuffites and rare grey limestones. The matrix is again tuffaceous.

The uppermost part of the tuffaceous section (1054.3-1061.0 m) is characterised by abundant limestone fragments (dark grey with styliolina, light grey to grey with crinoids) which are of Frasnian and/or Givetian age, a few centimetres to decimetres in size. One of these limestone fragments was rimmed by a sphalerite lamina (at the depth of 1058.6-1058.8 m). Single sphalerite grains are also scattered in lower lying tuffs and tuffites of quartz keratophyres.

A strata sequence gradually transiting from the underlying tuffs and tuffites occurs at the depth of 1044.0-1054.3 m; it is characteristic of abundant dark shales which enclose layers and laminae of the same tuffs and tuffites that occur in the underlying rocks. Fragments of grey micritic and dark grey bioclastic limestones are common. The assemblage of biosparrudite limestone with tabulate corals, crinoids, bryozoans and styliolina is of typically shallow water character and probably of Frasnian age. The limestone also contains fragments of volcanics and foamy volcanic glass. It cannot be excluded that some laminated limestones with no fossils constitute common intercalations in shales. The majority of samples which were collected to study conodonts turned out to be fossil free. Only one sample from the depth of 1050.2-1050.5 m showed most likely redeposited Famennian fauna which is, however, younger than the P. marginifera Zone.

Intercalations of breccia were also found to occur there. The breccia consists of shreds of black shales, pebbles of silicified tuffites, basic volcanics, black phosphorites, limestones and just one pebble of feldspathic greywacke. The matrix is composed of dark grey shale. A thin layer of tuffitic greywacke also occurs at the depth of 1052.6 m. The uppermost part (1044.0-1049.7 m) is built by black shales which are locally calcareous. In some places they also contain fragments of strongly compressed limestones with styliolina which are difficult to distinguish with the naked eye from adjacent shales. Large shreds of basic hyaloclastites were also found beside limestone fragments. This is likely to indicate deeper denudation of the neighbouring volcanic island.

Consequently, the tuffitic layer with phosphorites at the base is thought to have been deposited quickly on "Middle Famennian" limestones following a longer or shorter hiatus. The deposition is believed to have occurred on the slope of a volcanic elevation. Phosphatic nodules and individual conodonts seem to come from top of the elevation due to an emergence of older limestones with



17. Detail of the Horní Benešov HB-SV-2 borehole log, depth interval 1 042.1-1 116.1 m. Transferred to true thickness.
1 - greywackes, 2 - siltstones, 3 - black shales, 4 - dark grey shales, 5 - clasts of volcanic rocks, 6 - limestone clasts, 7 - shale clasts, 8 - limestones, 9 - cherts, 10 - acid tuffs and tuffites, 11 - siliceous rock with stilpnomelane, 12 - phosphorite nodules, 13 - graded bedding, TEN - tentaculitids, P - phosphorite, Py - pyrite, Sf - sphalerite, Ca - calcification, Si. silicification, T - laminae of an acid tuff or tuffite.

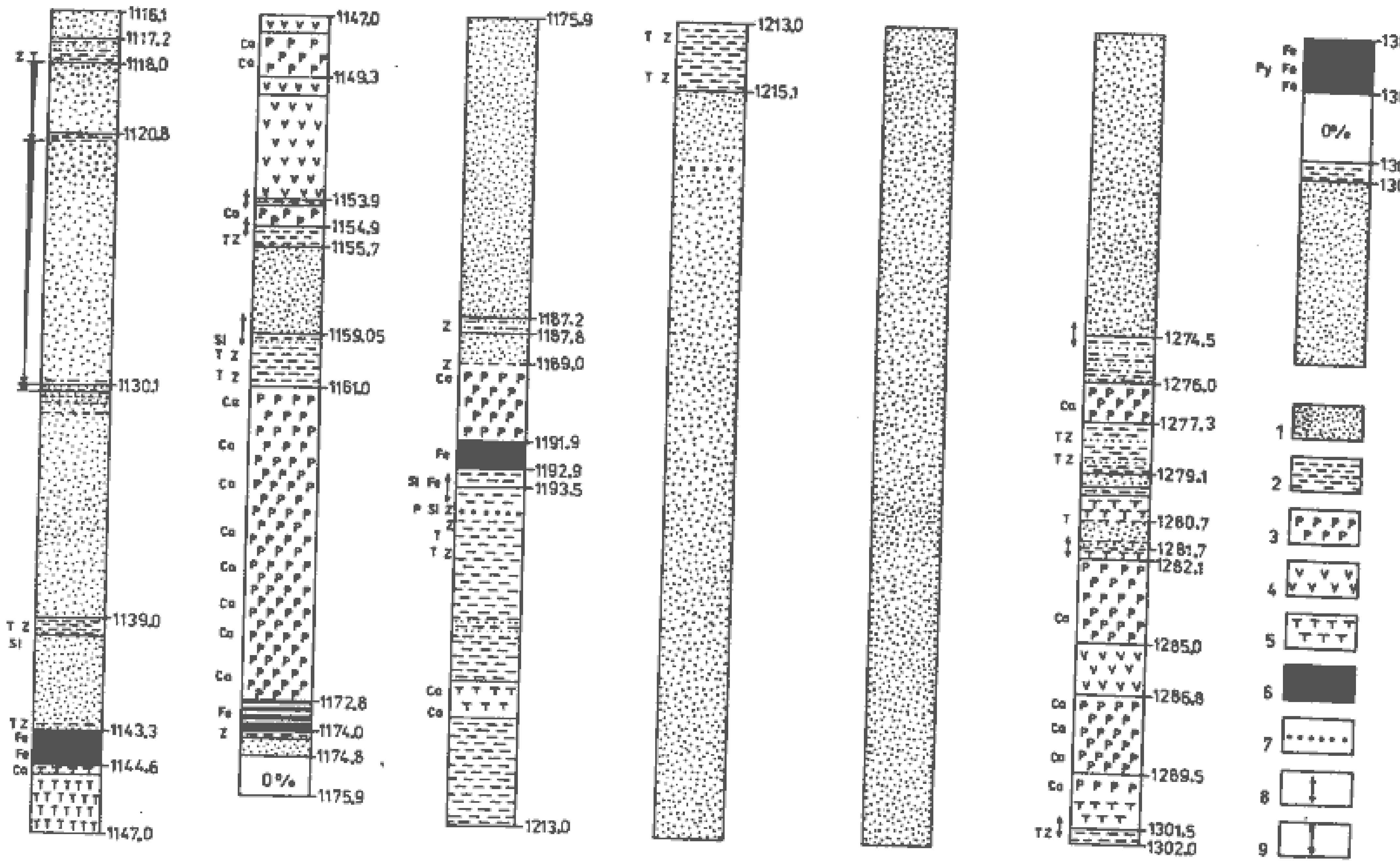
conodonts which were weathered and dissolved and phosphatic nodules accumulated in the littoral zone along the slope of the volcanic elevation. A volcano eruption producing acid tuffaceous material together with earth tremors are thought to be responsible for short distance transport of phosphatic nodules, conodonts and tuffs and their fast deposition on a sunken block. The established thickness, being approx. 18 m, considerably exceeds that of similar tuffitic horizons found elsewhere in a similar position (e.g. in borehole HB-SV-1 where their thickness was less than 1 m and their grain size considerably finer - tuffaceous shales with conodonts). Chemical analysis of phosphorite from the depth of 1072.9 m showed higher contents of P_2O_5, MnO and Na_2O, and that of tuffaceous shale (1072.9 m) gave high FeO (10 wt.%) which may indicate formation of hardground along the original shore. Higher concentrations of CaO and MgO are characteristic of tuffaceous shale whereas K_2O is low, probably washed away.

Volcanic acitivity seems to cease gradually during deposition of the upper part of the described section. Pelitic sedimentation in a quiet reducing environment under the wave base level appears to prevail in the basin in which some coarse detritus (consisting of limestones, acid silicified tuffs and basic peperites) was brought in during occasional storms or earth tremors. Silicified tuffs may indicate some hydrothermal alteration. An exotic material is represented by a layer and a single pebble of greywacke in breccia at the depths of 1049.95 and 1052.6 metres. It may indicate a contemporaneous greywacke sedimentation in the basin, west of today's drilling site.

Chemical composition of calcareous shales from the depth of 1047.5 m points to a deposition of chemically weathered clay. The SiO_2/Al_2O_3 ratio indicates a weak silicification. In contrast to that, the chemical composition of shales from the depth of 1045.95 m shows already some affinity with typical shales which occur inside the Horní Benešov Formation. This gives an evidence of both lateral and vertical transition into coarser clastic flysch sedimentation.

The Horní Benešov Formation

It occurs in two forms. One of them is represented by a gradual transition from pre-flysch formations from the surface down to 1044.0 m. The other form of different facies development occurs in slices under a large thrust fault from the depth of 1116.1 m down to the borehole bottom at 1362.0 m. The interval 0.0-1044.0 m together with Devonian strata were thrust from the east to the west



18. Detail of the Horní Benešov HB-SV-2 borehole log, depth interval 1 116.1-1 310.0 m. Transferred to true thickness.
1 - coarse- to fine-grained greywacke, 2 - dark grey to black shale (Z - green), 3 - hyaloclastites, 4 - basic vitreous rock, 5 - basic tuff, 6 - iron ore, 7 - siliceous-phosphatic nodules, 8 - gradual transition, 9 - graded bedding, Ca - calcification, Fe - ferric sediments and tuffites, Si - silicification, P - phosphatic nodules and grains, Py - pyrite, T - tuffites. All rocks belong to the Horní Benešov Formation, to its lower part (Lower Viséan).

over the Horní Benešov Formation under the thrust fault at the depth of 1116.1 m. Consequently, this "upper" Horní Benešov Formation is assumed to have been originally deposited east of the formation found at the borehole bottom.

The Horní Benešov Formation in the roof of pre-flysch formations starts at the depth of 1039.8-1044.0 m with a rather thin layer of black-grey silty shales with siltstone laminae and with thin intercalations of greywackes at the depth of 1039.8-1044.0 m. A thin layer of greenish tuffaceous shales with laminae of acid tuffites occurs at the base. A shred of this shale was found in a higher position.

Overlying rocks are folded into hundreds of metre large overturned folds which are most likely broken along thrust faults. Consequently, overturned fold limbs cannot be correlated (based upon detailed description) with not overturned limbs. Fast lateral transitions are unlikely. Fine- to medium-grained greywackes prevail over coarse-grained greywackes with rare pebbles of acid granitoids which suffered dynamic metamorphism, acid and/or intermediate volcanics, anchimetamorphosed sediments (slates, feldspathic sandstones, greywackes, silicified quartz sandstones, cherts and even limestones) and metamorphic rocks (phyllites, mica schists and rare gneisses).

The greywackes show a heavy mineral assemblage which is characteristic of the Horní Benešov Formation (Otava 1981). However, the assemblage which comes from the base of greywackes (1039.6 m) is typical of sediments passing into greywackes of the Andělská Hora Formation. Similar appears to be a specimen from the depth of 629.4 m which may give evidence that greywackes penetrated here belong to the base of the Horní Benešov Formation.

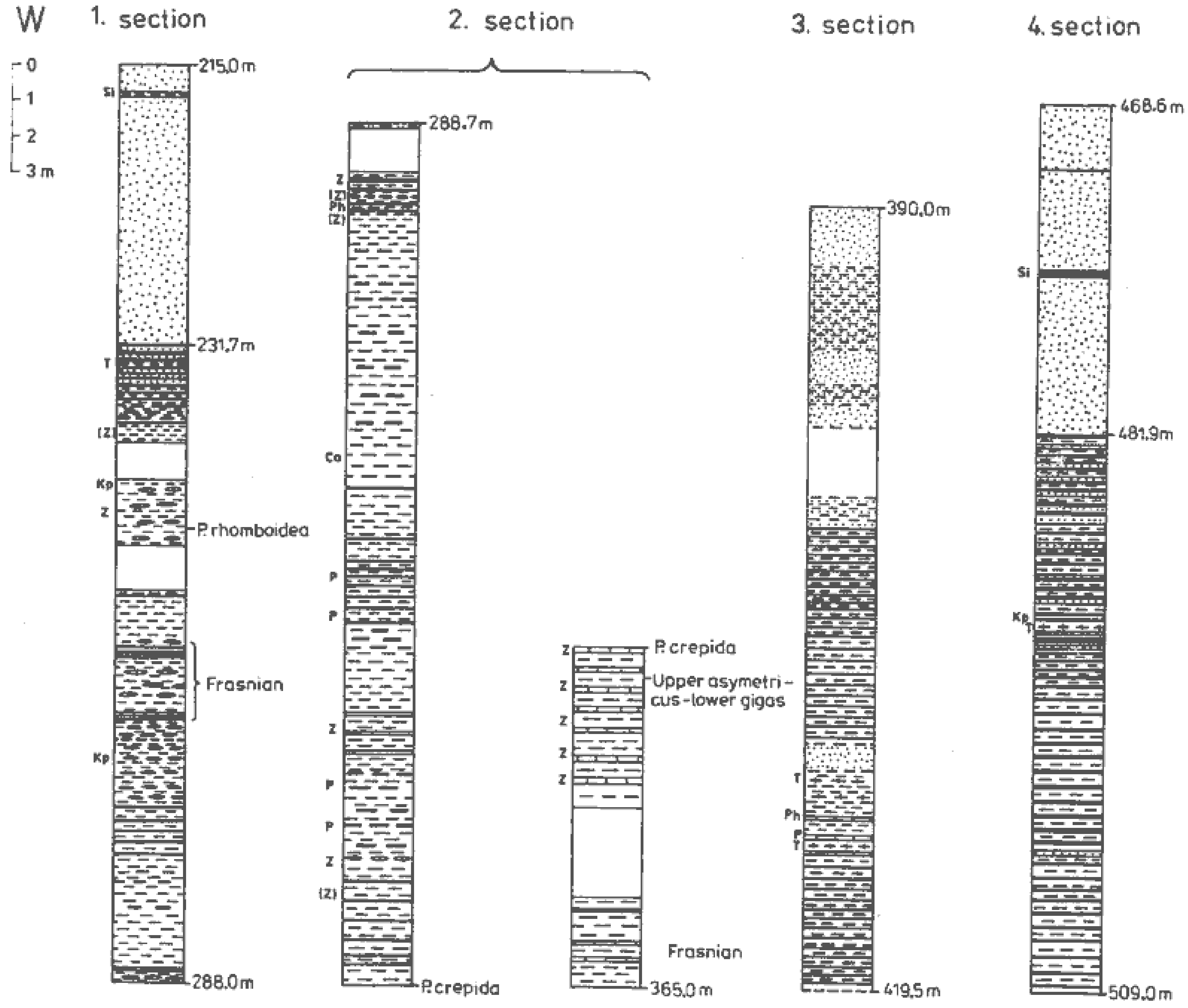
The greywackes are locally black-grey, slightly calcareous, enriched with plant organic matter (abundant plant debris). Intercalations of unsorted black sediments rich in clay-silty matrix containing larger clastic grains are abundant. Pyrite nodules or crystals were often found in the rocks. Flattened shreds of shales are abundant in greywackes.

Rhythmites showing graded bedding appear to be an important constituent of the Horní Benešov Formation even though they represent by volume only 1/4 of the total thickness of the formation penetrated by the borehole. The thickness of rhythms composed of fine-grained greywackes, siltstones and shales (usually showing ratios 3:1:1 to 5:2:1) varies mostly between 1 and 6 cm, exceptionally even 7-30 cm. There are locally also some rhythms much thicker (at the depth of 580.25-580.8 m) which are built at the base by coarser-grained greywacke (20 cm), followed by medium-grained (15 cm), fine-grained greywacke (12 cm), then siltstone (5 cm) and by shale (2 cm). Laminated fine-grained greywackes often suffered from convolute deformation which occasionally passed into slumps. Locally a relatively abundant bioturbation can be observed. Vertical and oblique burrows of various diameter which occur in shales and siltstones are usually filled with greywackes. The burrows seem to be "folded" due to a shrinkage of original clay during diagenetic processes to form shale.

Two types of black and black-grey clay shales were distinguished: the first type (black-grey) is silty with SiO_2/Al_2O_3 ratio over 3 and Al_2O_3/Na_2O ratio usually about 10. This ratio is typical of all shales related to flysch formations; it indicates deposition of chemically not weathered clay material. The other type is represented by black, very fine-grained shales with SiO_2/Al_2O_3 ratio below 2 (free SiO_2 is missing) and Al_2O_3/Na_2O ratio over 100 (e.g. at depths of 844.0 m, 968.8 m). They are high in Al_2O_3 (over 25 wt.%) and K_2O (7-9 wt.%) and low in Na_2O. These shales are regarded to be tuffaceous (Dvořák 1986) and enriched with organic matter (1.5-2.4 wt.% $C_{org.}$). They represent an autochthonous sediment in the basin which was deposited from a suspension during a long period of time when clastic sedimentation was interrupted. Fine volcanic (vitreous) material is thought to have been windblown from volcanic eruptions located most likely in the central part of the Bohemian Massif (Variscan median mass). This volcanic activity is indicated by a thin layer of sandy litho-crystalloclastic tuff to tuffite at the depth of 857.2 m and by an admixture of volcanic material in sediments (e.g. volcanic quartz) at depths of 467.8 m, 639.5 m, 696.4 m, 881.9 m and 965.6 m. This seems to represent just a fragment of the real volcanic admixture because greywackes were not sampled in detail. Decomposition of volcanic glass gave origin to montmorillonite which influenced the organic matter on the basin bottom (due to its absorptive and catalytic capacity). Consequently, the sediments are black in colour. The occurrence of some trace elements is connected with organic matter (cf. Dvořák 1986). A gradual transition can be observed between the above mentioned two types of shales.

The lower part of the Horní Benešov Formation under the thrust fault at 1116.1 m shows some similarities with the overlying part only in some places. Greywackes also contain assemblages of heavy minerals which are partly not characteristic of the Horní Benešov Formation. The uppermost located samples under the thrust fault at 1116.7 m could correspond to the Andělská Hora Formation. Two rhythms showing graded bedding were found very close under the thrust fault. The first one is 2 m thick whereas the other is almost 7 m thick. They are mostly composed of coarse-, medium- and fine-grained greywackes whereas siltstones and shales are minor.

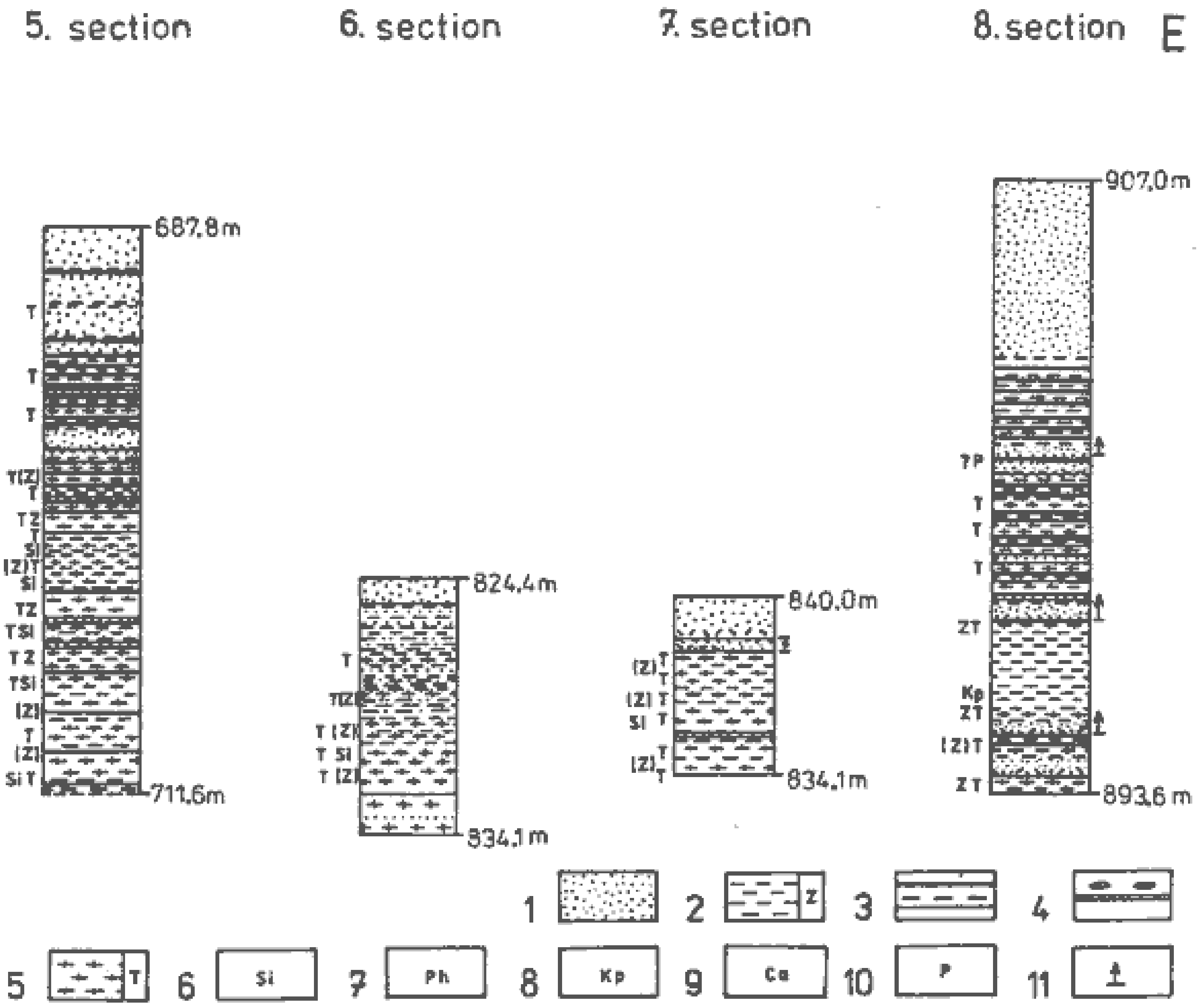
The basic difference consists in the character of rocks constituting intercalations although they represent only approximately one fifth of the whole strata sequence. In addition to layers of typical shales and siltstones, the following sediments were observed: laminae of siliceous



shales and cherts, siliceous phosphorites (which form nodules in siliceous and tuffaceous shales) and mostly greenish tuffaceous shales with laminae and thin layers of acid tuffs and tuffites related to quartz keratophyres.

Newly discovered rocks within this strata sequence are represented by effusives of basic vitreous magma accompanied by strongly calcareous hyaloclastites, tuffs and iron ores. The latter are composed of magnetite and thuringite-stilpnomelane. These basic effusions represent the latest period of initial volcanism known in the Šternberk-Horní Benešov Zone. They constitute intercalations in the basal part of the Horní Benešov Formation. Acid tuffs and tuffites correspond to quartz keratophyre volcanism of this zone. Volcanic products could have been spread by sea currents or transported and distributed during eruptions of volcanoes. Some volcanoes were located onshore. The whole described sequence of greywackes, basic and acid volcanics with layers of siliceous shales was discovered by boreholes drilled earlier in the footwall of the "mineralized slice". For example, some phosphorite nodules in siliceous shale with tuffite laminae and acid keratophyre tuffs and tuffites occurring in the Horní Benešov Formation between the central and mineralized slices were found in the borehole HB-903.

Consequently, volcanic activity in the north part of the Šternberk-Horní Benešov Zone is believed to have migrated in time from its Lower and Middle Devonian centre toward the margins of the whole structure, i.e. toward the NW. It is doubtful whether we deal here with the Andělská Hora Formation because of the rather coarse-grained facies of massive greywackes. Accumulation of the lower part of the Horní Benešov Formation is more likely to occur in places where greywackes were partly sorted by sea currents. A zone of subsidence at the foot of the tectonically ejected volcanic elevation of the Šternberk-Horní Benešov Zone is thought to have been sinking fast. It was filled with coarse detrital material, basic effusions and acid tuffs and tuffites of keratophyre chemistry. Some iron ores, siliceous shales



19. Reconstructed sections of individual tectonic slices penetrated by the Horní Benešov HB-SV-3 borehole. Transferred to true thickness.
1 - greywackes, 2 - shales: Z - green, (z) - greenish, 3 - cherts, 4 - limestones, 5 - tuffs and tuffites, 6 - silicification, 7 - phosphorite nodules, 8 - admixture of quartz silt, 9 - carbonate admixture, 10 - pyrite, 11 - graded bedding.

and black tuffaceous shales (at depths of 1204.5 m and 1321.4 m) were deposited in breaks. They are almost identical with the Horní Benešov Formation overlying the Devonian (only $C_{org.}$ is lower).

Borehole HB-915

It is located in the central part of the mineral deposit, about 150 m south of the main cross adit. The borehole was drilled from the 9th level of the central slice at 40° inclination to the east. Consequently, the contact with the Horní Benešov Formation is missing. The central slice was found to be strongly disturbed by thrust faults. The importance of this borehole consists in the penetration of a facies (in tectonic footwall of the central slice) which is very similar to that found in the borehole HB-SV-3. The contact with the Horní Benešov Formation is broken by disjunctive folding. The whole strata sequence is inclined at 55-70° with respect to the borehole.

Dark grey shales with laminae of siltstones and very fine-grained greywackes, about 1.5 m thick occur in the uppermost part of the section. The thickness is assumed to be structurally reduced. They gradually pass downward into olive green shales containing single thin layers of grey micritic limestones. Conodont fauna of the lower part of the Palmatolepis crepida Zone was found here at two depths (100.7 and 119.0 m). Thin lenses of grey cherts begin to appear in the lowermost part of this 20 m thick strata sequence. Cherts seem to increase downward at the expense of limestones which gradually disappear. Green shales very slowly pass into black-grey shales with black radiolarian cherts over 30 m thick. About 8 m thick layer of green hyaloclastites occurs in their lower part. This layer very slowly passes into underlying clay shales with abundant grey cherts. Their colour becomes black-grey with depth. Their contact with underlying greywackes of the Horní Benešov Formation is of tectonic character which resulted in dragging of cherts into greywackes and vice versa. The Horní Benešov Formation is in a normal position (not overturned). Consequently, the overlying Devonian strata represented by the Ponikev Formation are thought to be also in a normal position. The lower part consisting of radiolarian cherts and hyaloclastites is likely to be of the Upper Frasnian. It can be correlated with shales associated with cherts in the borehole HB-SV-3 in which they are paleontologically proved. The strata sequence within the Middle and Upper Famennian is either strongly condensed or contains some hidden hiatuses. Some tectonic reduction cannot be excluded either.

Borehole HB-SV-3 (Dvořák et al. 1984, Fig. 19 and Pl. 2)

It was drilled south of the shaft into the "main" (east) zone at a place where mineralized and central slices join the "main" zone. The borehole penetrated several larger and numerous small tectonic slices which are steeply thrust over each other (east vergency). A layer of dark shales with abundant bombs of basic volcanics and thin layers of grey limestones was found in the uppermost slice in addition to the uppermost green hyaloclastites with layers of tuffs and red and grey limestones (which are likely to be of the Frasnian). Limestones contain sections of tentaculitids which allow this layer to be classified as Frasnian (or earlier). Greywackes of the Horní Benešov Formation seem to occupy always the uppermost positions within the lower slices. However, greywacke layers of various thickness usually occur also in the underlying Ponikev Formation. Thus, a gradual vertical transition seems to be indicated. A lateral transition is likely to occur too. Abundant thin layers and nodules of micritic limestones and minor cherts were found in two higher lying slices. On the other hand, limestones are missing in the lower part of the borehole. They are replaced by abundant grey and black radiolarian cherts. The lowermost part consists of relatively abundant olive green shales alternating with dark grey and black cherts.

Only the lower parts of two higher lying slices rich in limestones can be paleontologically dated using conodont fauna. The lower part corresponds to the higher Frasnian and some 2-3 m upward there is the Lower Famennian. Specifically, the Palmatolepis rhomboidea Zone was identified at the depth of 243.6 m whereas fauna of the late Frasnian was found at depths of 249.7 m, 250.3 m and 258.5 m. It corresponds to the upper part of the Polygnathus asymmetricus Zone to the lower part of the Palmatolepis triangularis Zone.

A conodont fauna confined to the base of the Palmatolepis crepida Zone was identified by O. Friáková in the lower slice at the depth of 349.5 m. A fauna corresponding to the upper part of the Polygnathus asymmetricus Zone to the lower part of the Palmatolepis gigas Zone was found at the depth of 351.6 and 352.0 m respectively.

Dating of the period when greywackes began to deposit in the studied area remains tentative unless some fauna from the upper layers of the Ponikev Formation becomes available. When correlating the strata sequence in single slices from the roof to the bottom, originally from the west to the east, it can be seen that thin layers of greywackes, sharply separated from adjacent rocks, start to appear increasingly deeper inside the Ponikev Formation. This may either indicate an extension of the Ponikev Formation into stratigraphically higher position within the lower (more easterly located) slices, or an accelerated subsidence of this part of the original basin. As a result, the lowermost greywacke layers in the east should correspond to the lowermost greywacke layers in condensed strata sequence in the west. The greywackes belong to the Horní Benešov Formation. Their deposition began during the Middle Viséan. The Ponikev Formation under the greywackes of the uppermost slice shows a true thickness of about 15 m which corresponds to the Upper Frasnian, Famennian, Tournaisian and the base of the Viséan. Its equivalent in the lower slice is about 20 m thick. In lower slices, there is no paleontological evidence of trends leading to an increase of thickness toward the east.

The greatest condensation in the uppermost slice is thought to have occurred shortly before the sedimentation of greywackes. About 2-3 m thick black laminated cherts with black shale laminae and with several greywacke layers, 0.5-4.0 cm thick were deposited there. Green (or grey-green) shales become more abundant in lower slices but stratigraphically slightly lower in the sequence. They seem to represent redeposited weathered volcanics (showing 3-4 wt.% MgO).

Tephrochronology and paleogeography may help to decipher the correlation of the strata sequence. Abundant acid tuffites were found only in the lowermost, originally easternmost cross-sections through the Ponikev Formation. Tuffites are usually spread over large areas. They are mostly preserved in rather thin fine-grained sediments (micritic limestones, cherts, shales) where the tuffites were difficult to be spread by sea currents. This problem has been discussed in the paragraph dealing with the "Na výsluní" facies near Moravský Beroun. The boundary between the Ponikev and Horní Benešov Formations within the uppermost slice is likely to occur above the Tournaisian-Viséan boundary. On the other hand, the Ponikev Formation within originally more easterly lying sedimentation space extended as high as the Middle Viséan. Its boundary with the Horní Benešov Formation may run as high as the Middle-Upper Viséan boundary and/or along the base of the Upper Viséan, prior to the Goα goniatite Zone.

Siliceous shales with limestone layers were deposited east of the Šternberk-Horní Benešov Zone near Horní Benešov during the Upper Frasnian. The sedimentation is thought to have been strongly condensed in the Upper

Devonian and particularly in the Tournaisian. Dark cherts were mostly deposited there, particularly farther away from the centre of basic volcanism. On the other hand, agglomerate tuffs, laminae and thin layers of mostly Frasnian and Famennian limestones occur close to volcanic elevations. They disappear toward the east being replaced by cherts. Sedimentations of dark and grey, mostly radiolarian, cherts seem to prevail during the Tournaisian and Lower Viséan. The first thin layers of greywackes in shales and cherts begin to occur in the Middle Viséan. At this time, the sedimentation of the Horní Benešov Formation was moving eastward to push the Ponikev Formation away from the basin. Consequently, greywacke layers become more abundant in siliceous shales whereas overlying greywackes of the Horní Benešov Formation contain layers of siliceous shales and cherts. Typical are abundant layers and laminae of acid tuffs and tuffites. Layers of greywackes exhibiting graded bedding occur only in the lowermost (and easternmost) section. Remaining greywacke intercalations show sharp contacts with over and underlying rocks. They exhibit no graded bedding. They were deposited by regular laminar currents bringing occasionally coarse clastic material from the west into a basin which was certainly not deeper than the sedimentation space of the Horní Benešov Formation in the west. The substitution of the Horní Benešov Formation for the Ponikev Formation is manifested by layers of greywackes whereas the substitution of the Andělská Hora Formation for the Ponikev Formation is indicated by layers of silty shales and siltstones (vicinity of Šternberk).

Biostratigraphically proved finds from the mine and outcrops in the vicinity of Horní Benešov

The oldest find refers to Eifelian fauna (mostly trilobites) in dark shales (Chlupáč 1969). This fauna was first discovered when sinking the Anna shaft, later in the Jánská shaft and most recently in a trench south of the shaft. No fauna was found in boreholes. Shales of the Stínava-Chabičov Formation probably occur only as a tectonic lens at the base of the central slice but confined to its easternmost part. They thin out along the dip. The fauna itself is compressed but the shales seem to be only slightly altered. According to Chlupáč (1969), the trilobite fauna in particular is almost identical with that of the Barrandian. Tabulate and rugose corals, brachiopods and tentaculitids are most abundant in addition to trilobites. Rare are cephalopods, hyoliths, gastropods and pelecypods. The whole assemblage argues for well oxidized, shallow, protected marine environment adjacent to local volcanic elevations. Limestones are likely to be stratigraphic equivalents. This idea is supported by the occurrence of Eifelian conodont fauna which is locked in dark and light limestones at the base of the mineralized slice in block No. 6105. The fauna corresponds to the Taphrognathus kockelianus up to Polygnathus xylus ensensis Zones.

A very important find of conodont fauna is located 200 m north of Glammersberg hill in the eastern major zone in shales of the Ponikev Formation. Fauna of the Scaphignathus velifer and Polygnathus styriacus Zones was identified by Zikmundová (1964) in samples from a 5 m thick layer of siliceous shales with no cherts (which occur in both the under and overlying rocks). It proves Upper Famennian age of the Ponikev Formation confined to the major eastern zone as found for instance in the borehole HB-SV 3. However, only the Frasnian and Lower Famennian were paleontologically established in the above mentioned borehole. Consequently, it supports the idea about Upper Famennian and Tournaisian age of the upper part of the Ponikev Formation in the borehole HB-SV 3. Zikmundová (1966) mentions conodont fauna of the Palmatolepis gigas Zone to the lower part of the P. triangularis Zone (Frasnian/Famennian boundary - the Ponikev Formation) from the northern surroundings of Horní Životice (NNE of the town Horní Benešov).

Summary of stratigraphy in the vicinity of Horní Benešov (Fig. 25)

The basement of the discussed stratigraphic sequences is not known. Lower Devonian basic volcanics are likely to represent the basement which is similar to the vicinity of Moravský Beroun and Šternberk. A strongly condensed volcano-sedimentary sequence of Middle to Upper Devonian age is thought to have been torn off from the above mentioned volcanics along thrust faults showing west oriented vergency. The original sedimentation space was strongly reduced. No detrital quartz was found in sediments. A shallow water character of sedimentation accompanied by facies variations and hiatuses, particularly during the Famennian and Tournaisian, are other typical features of this period. The sedimentation during the Famennian and Tournaisian is believed to have been condensed to such a degree that it ceased completely in some places. These conditions lasted for the longest period (Upper Famennian and Tournaisian) in the eastern part of the mineralized slice and in the central slice as a whole. Hiatus is likely to have been extended toward the east, to the centre of basic volcanism. The thickness of basic agglomerate tuffs appears to be increasing very fast to reach several hundred metres in the central slice (Urbánek 1974).

While W of the inferred centre of basic volcanism, there is a few metres thick layer of dark shales with laminae and intercalations of siltstones representing perhaps the easternmost extension of the Andělská Hora Formation occurring straight under the Horní Benešov Formation, east of that centre only layers of greywackes were found to be enclosed straight in the Ponikev Formation. So far, they are difficult to be dated in more detail. They are likely to be equivalent to the upper part of the Horní Benešov Formation reported west of the volcanic elevation which supposedly represents a volcanic centre. Consequently, they are of Middle Viséan age and accompanied by acid tuffs and tuffites.

A biofacies analysis of limestones from boreholes in the vicinity of Horní Benešov (J. Hladil 1984) showed that light grey but mostly dark grey limestones with clay admixture were deposited during the Upper Eifelian and Lower Givetian. Their deposition is thought to have occurred in lagoons with Coenites and also on open shelf. Coral reefs of rather small dimensions grew along some volcanic elevations. Eifelian bioherms were locally destroyed during the Upper Givetian but some small bioherms used to grow in some other places even during the same period (stromatoporoids, corals). Clastic reworked limestones were deposited on slopes of volcanic elevations. Very sporadic micritic limestones with cephalopods and tentaculitids occur in open but protected parts of the shelf.

Some algae laminites with locally accumulated shells of tentaculitids were deposited in a tidal zone of limestone platforms during the Frasnian. Barriers of crinoidal light grey limestones, usually tuffaceous, originated often in flowing environment along platform margins. Condensed strata sequences of nodular biomicrites and laminated limestones with more abundant conodonts were deposited during a slow sea regression, locally in the Upper Frasnian or in some other places as late as the Lower Famennian. Sediments of several conodont zones are often missing. They locally contain a redeposited Lower Frasnian conodont fauna. Clastic limestones to breccias with clasts of reef limestones of Eifelian and Givetian age were found to occur in some other places.

The area of today mineralized and central slices is thought to have emerged during the Upper Famennian and in the Tournaisian. Olive green tuffaceous shales, locally with sections of conodonts, were deposited only in marginal areas. They indicate termination of limestone sedimentation. A very condensed sequence of greenish or black shales with cherts was deposited in some other places. These rocks in the neighbourhood of volcanic centres tend to enclose nodules of micritic limestones (which were deposited during the Upper Frasnian and Lower Famennian). Over a 1000 m thick sequence of the Horní Benešov Formation was deposited west of the volcanic elevation during the Lower and Middle Viséan. On the other hand, a condensed sequence of siliceous shales continued to be deposited east of the elevation.

Sediments of all studied sections which are confined to the time span Upper Eifelian-Lower Famennian and/or Tournaisian show generally a small thickness, not exceeding 100 m.

Tectonic setting

All boreholes drilled within the mineral deposit, including the boreholes HB-SV 1 and 2 showed a west oriented vergency of folded structure accompanied by large thrust faults at the base of the Devonian "slices". The boundary between pre-flysch and flysch formations is usually not disturbed by tectonics. The above mentioned thrust faults are of listric character; their inclination becomes steeper toward the east and finally the thrust planes become vertical. There is evidence that pre-flysch sediments and volcanics are often disturbed by partial thrust faults (Pls. 2 and 3).

In contrast to that, the borehole HB-SV 3 showed that the major eastern belt, represented on the surface mostly by the Ponikev Formation, is strongly sliced with an east vergency. This limb of strongly disturbed fan-shaped anticlinorium is only partially developed. Its structure developed later than that of the west limb (Pl. 2).

The region between Krnov and Horní Životice

Pre-flysch sediments of this region plunge gradually under the flysch formations. They emerge on the surface as narrow apexes of anticlines accompanied by thrust faults. Only rocks of the Ponikev Formation were found to crop out, except for the vicinity of Lichnov.

In addition, some basic volcanics accompanied by tuffs emerge on the surface in the middle of the Ponikev Formation near Horní Životice. Siliceous shales with cherts also contain sporadic thin layers of micritic limestones which can be observed only in boreholes. Upper Frasnian conodonts from outcrops were described by Zikmundová just from the vicinity of Horní Životice. O. Friáková identified some fauna of the P. marginifera Zone which occurs in a limestone layer in the borehole HB-SV-2p (at the depth of 350 m).

A contact between the Ponikev and Horní Benešov Formations was found in a single outcrop north of Sosnová. The uppermost horizon of the Ponikev Formation is represented by grey cherts with laminae of grey shales that become brown when weathered. They enclose laminae and lenticular intercalations of acid tuffites and fine-grained tuffs. Greywackes of the Horní Benešov Formation are deposited on shales in the form of a sharp contact consisting of a few centimetres thick horizon with shreds of shales. This horizon is likely to be of transgressive character following a break in sedimentation.

Another facies of pre-flysch formations occurs in the core of an overturned anticline near Lichnov. This anticline deflects to the west from the "major" strip of the Šternberk-Horní Benešov Zone. Trench No.31 was described from here by Hettler et al. (1965). Amygdaloidal spilites with sporadic layers of tuffs and black shales constitute the oldest rocks in the anticline axis. Shales envelope lenses and laminae of blue-grey fine-grained limestones. Dark grey shales with layers of dark grey fine-grained limestones occur in the roof of volcanics. Limestones in the middle of the shale horizon tend to form a body (about 1 m thick) in which they strongly prevail. The limestones contain crinoidal segments. Limestone layers again tend to decrease upward. Some completely weathered rocks and lenses of supposedly acid tuffs and tuffites begin to appear in shales straight above the uppermost limestone layer. Shales also enclose laminae and intercalations of siltstones which upward slowly pass into medium-grained greywackes of the Horní Benešov Formation. The thickness of shales with limestone layers does not exceed 4 m. The age of limestones is not known. Their transition into the Horní Benešov Formation may be only apparent. A hiatus cannot be excluded either. However, the section indicates that the sedimentation must have been strongly condensed (with hiatuses ?) near volcanic elevations. The centre of basic volcanism is believed to have been located more to the west of the "major" belt of the northernmost part of the Horní Benešov Zone.

A contact of the Ponikev and Horní Benešov Formations was exposed south of Krnov in a roadcut of the highway to Laryšov constructed in the years 1965-1966. So far, the latest conodont fauna of the Ponikev Formation has been described by Zikmundová (1967) in samples from the upper horizons of this formation. It belongs to the Upper Tournaisian (Scaliognathus anchoralis Zone). Judging from outcrops not well preserved today, we may be dealing with tectonically not disturbed contact between the Ponikev and Horní Benešov Formations. Thin layers of greywackes, similar to those found in the borehole HB-SV 3, occur in the uppermost parts of the Ponikev Formation.

Tectogenesis

A detailed, not yet completed investigation of the Šternberk-Horní Benešov Zone revealed a strong influence of volcanism on the deposition of Devonian and Carboniferous sediments (Pl. 4).

Volcanism is biostratigraphically proved to exist since the lower part of the Upper Emsian through to the Lower and/or Middle Viséan. It affected the sedimentation even later till volcanic elevations were not completely covered with flysch formations. Biofacies studies, particularly those of limestones, show that the sedimentation occurred in a shallow water environment. Some strong influx of detrital quartz into the Šternberk-Horní Benešov region was deposited in fluvial or shallow marine environment. It was noted in the Emsian and Eifelian basements as well as in the Tournaisian roof of the major volcanic mass. Similar to limestones, this indicates a shallow water sedimentation and the occurrence of granitic layer of the Earth's crust in the basement of the whole sedimentation space of the geosyncline. There is no evidence of the occurrence of an ocean floor, not even within a narrow space (rift zone) because deep water sediments are missing. In contrast to that, the rise of volcanic elevations prior to the flysch sedimentation (denudation of anticlinorial volcanic tops down to the Lower Devonian level) clearly shows a squeezing of volcanics as well as sediments out of a mobile zone which was fast sinking earlier (cf. Quade et al. 1981). A considerably condensed sequence of Upper Devonian and Tournaisian sediments, accompanied often by hiatuses and by biostratigraphically established redeposition of Middle Devonian sediments (including Lower Frasnian) in Upper Devonian and Tournaisian strata. This setting seems to support the assumption mentioned above.

The ascent of volcanism was made possible due to a fault zone in Proterozoic basement trending NNE-SSW. The greatest accumulation of volcanics occurs near an intersection of this zone with transversal faults of mostly NW-SE strike. The ascent was locally also controlled by N-S and E-W faults. Fault zones in the old basement are believed to have been mobile and therefore flooded by the sea already in the Devonian (and possibly even in the Silurian). The majority of Lower Devonian sediments (as high as the uppermost Emsian) were deposited in a mooving shallow water environment of the Rhenish bio- and lithofacies. At that time, volcanic activity must have been so strong that accumulations of ejecta started to prevent free flow on the basin's bottom. The sedimentary facies changed from the Rhenish to Hercynian facies. The sedimentary intercalations in volcanics became thinner. The Middle Devonian seems to represent the peek of volcanic activity (at least locally). In other places, there is a trend to strong condensation (inversion) which also led to the formation of stratabound deposits of base metals which are confined to black shales with pyrite and thin limestone bodies with reef fauna (Dvořák 1987).

Volcanic activity in the Upper Devonian appears to be of much lower intensity. Rather thin layers of siliceous shales and cherts, related to post volcanic activity, were mostly deposited (Mísař 1957). In some places they passed laterally into condensed sedimentation of micritic limestones which are locally nodular, in places laminated but generally confined to the margins of volcanic elevations. This kind of sedimentation extended locally till the Tournaisian whereas some other places were already affected by the approaching face of the flysch facies. Some volcanic elevations kept rising, judging from a hiatus which occurred between the Upper Frasnian and Viséan. Their slopes were covered with a thin layer of cherts. Flysch sedimentation of the Andělská Hora Formation transgressed depressions located in the southern part of the zone already since the Famennian. This kind of sedimentation during the Tournaisian seems to have replaced the sedimentation of cherts and even limestones. The flysch sediments often lie on deeply denuded Lower and Middle Devonian volcanics, following a long lasting hiatus.

Old elevations of Proterozoic crystalline basement are thought to have been rising fast for a short period of time during the Upper Tournaisian. Coarse-grained detrital quartz, derived from these elevations, was transported from the south to the north in continental and shallow marine environment. This kind of sedimentation also indicates a shallow water deposition of underlying siliceous shales and cherts (a find of an arthropod of the genus *Angustidontus!*).

The Lower and Middle Viséan are already characteristic of the beginning of the flysch sedimentation confined to the Horní Benešov Formation. The sea is thought to have gradually flooded the tops of volcanic elevations which is most clearly manifested by the occurrence of the "Na výsluní" facies near Moravský Beroun. Elevations of Proterozoic crystalline rocks are thought to have been sinking to considerable depths during deposition of flysch formations. In contrast to that, initial volcanics became a base for a synsedimentary anticlinorium (inversion structure) which during the whole period of Variscan tectogenesis continued to occur in a high position with respect to the west and east adjacent structures that were sinking fast to depths exceeding 3 km. Lower grade metamorphism of Devonian sediments confined to the Šternberk-Horní Benešov inversion structure relative to the grade of metamorphism of Viséan sediments in its neighbourhood may argue for the above mentioned assumption.

Maximum reflectivity measured on finely dispersed organic matter in Devonian and Lower Carboniferous shales in the Šternberk (16 samples), Moravský Beroun (14 samples) and Horní Benešov (47 samples) regions gave on average 4.5 $R_{max.}$, 5.0 $R_{max.}$ and 5.9 $R_{max.}$ respectively. The majority of measurements were performed by P. Müller.

Volcanic elevations of the Šternberk-Horní Benešov Zone were gradually stretched out into higher positions from the south to the north. The "stretching out" near Šternberk is believed to have been about 1-1.5 km whereas that near Moravský Beroun was about 3 km, based upon drilling results of the Dětřichov 1 borehole. The "stretching out" in the vicinity of Horní Benešov is thought to be 4 km and even more. The width of pre-flysch formations and volcanics along the today's denudation level is gradually narrowing toward the north (Fig. 1). Listric overthrust faults seem to have played an increasing role. The "tear-off" plane usually follows the clay shales of the Stínava-Chabičov Formation which are enveloped by volcanics instead of following the boundary between the flysch and pre-flysch formations. Even in the north (south of Krnov), siliceous shales were not "torn off" from the Horní Benešov Formation but the crushed zone occurs inside the Ponikev Formation. The fold structure in the western vicinity of Horní Benešov is rather open in its higher levels (slightly reversed folds) whereas reversed folds at the depth of about 1000 m are strongly pinched or almost isoclinal.

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Geologie paleozoika šternbersko-hornobenešovské zóny (Nízký Jeseník, severní Morava)

(Resumé anglického textu)

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Šternbersko-hornobenešovská zóna zaujímá důležitou pozici uprostřed paleozoika Nízkého Jeseníku. Bazické vulkanity vystupovaly podél predisponované drcené zóny (směru SSV-JJZ) od svrchního emsu do spodního visé. Vulkanická činnost silně ovlivňovala sedimentaci: uprostřed svrchního emsu se změnila rýnská lito- i biofacie na hercynskou. Pelitická sedimentace přetrvala do eifelu, kdy postupně začala převládat mělkovodní vápencová sedimentace. Od svrchního frasnu byla zčásti vystřídána depozicí křemitých břidlic se silicity. Před nástupem flyšového vývoje se místy u Šternberka a Moravského Berouna uložilo moravskoberounské souvrství - křemenné slepence, pískovce a vápencové brekcie. Na Šternbersku nastoupila flyšová sedimentace během famenu a tournai. V severnějších územích začala až během spodního a středního visé. Antiklinoriální vějířovitá struktura šternbersko-hornobenešovské zóny se vyvíjela hlavně během depozice hornobenešovského souvrství (spodní a střední visé), kdy byla "vytlačována" do výšky 3 až 4 km vlivem kolize rulových ker proterozoického podkladu. O tom též svědčí relativně nízký stupeň metamorfních přeměn hornin proti východnímu a západnímu okolí.

Vysvětlivky k obrázkům

1. Přehledná geologická mapa Nízkého Jeseníku.
   1 - vulkanity a sedimenty šternbersko-hornobenešovské a vrbenské zóny, 2 - převážně vápence devonského a spodnokarbonského stáří u Hranic a v okolí, 3 - andělskohorské souvrství (famen a tournai), 4 - hornobenešovské souvrství (spodní a střední visé), 5 - moravické souvrství (svrchní visé - zóny Go α a β), 6 - převážně droby, 7 - převážně břidlice a prachovce (6 a 7 - hradecko-kyjovické souvrství - svrchní visé, zóna Go χ a báze namuru A), 8 - ostravské souvrství (spodní polovina namuru A).
2. Stratigraf. schematické profily šternbersko-hornobenešovské zóny.

1 - tmavě šedé jílovité břidlice (stínavsko-chabičovské souvrství - svrchní ems a eifel), 2 - vápence (vápence jesenecké - eifel až tournai), 3 - písčité vápence a vápnité pískovce, místy s vložkami břidlic (facie "Na výsluní", spodní visé - báze středního visé), 4 - laminované šedé a světle šedé vápence (vápence hněvotínské - frasn a famen), 5 - křemité břidlice se silicity (ponikevské souvrství - svrchní frasn až střední visé), 6 - prachovité břidlice a prachovce (andělskohorské souvrství - famen a tournai, místy touto šrafurou vyznačeny též vložky břidlic v hornobenešovském souvrství), 7 - vápencové brekcie, křemenné slepence a pískovce, 8 - křemenné slepence a hrubozrnné pískovce (7 a 8 - moravskoberounské souvrství - svrchní tournai), 9 - droby (hornobenešovské souvrství - spodní a střední visé), 10 - jemnozrnné křemenné pískovce v různých stratigrafických úrovních, 11 - bazické vulkanity, 12 - bazické tufy, 13 - keratofyry, 14 - hiát.

3. Odkrytá geologická mapa okolí Šternberka.
   1 - pliocén, 2 - břidlice, prachovce a jemnozrnné droby, 3 - droby (2 a 3 - hornobenešovské souvrství, spodní a střední visé), 4 - břidlice s laminami prachovců, lokálně valounovité břidlice a droby v místech transgrese přes spodnodevonské vulkanity, 5 - prachovité břidlice s vložkami drob (4 a 5 - andělskohorské souvrství, famen a tournai), 6 - vápencové brekcie s valouny křemene, křemenné pískovce (moravskoberounské souvrství, svrchní tournai), 7 - křemité břidlice se silicity, u Babic s vložkami křemenných pískovců (ponikevské souvrství, svrchní frasn až tournai), 8 - vápence (vápence jesenecké, svrchní frasn a tournai), 9 - bazické vulkanity, 10 - jílovité břidlice, místy písčité, místy s čočkami vápenců (stínavsko-chabičovské souvrství, svrchní ems a eifel).
4. Geologické řezy s. okolím Moravského Berouna (viz příl. 1).
   1 - droby s podřízenými vložkami prachovců a břidlic, 2 - vápnité pískovce a písčité vápence, místy s vložkami břidlic - facie "Na výsluní" (1 a 2 - hornobenešovské souvrství), 3 - křemenné slepence a hrubozrnné pískovce (moravskoberounské souvrství), 4 - křemité břidlice se silicity (ponikevské souvrství), 5 - bazické vulkanity s vložkami tmavých jílovitých břidlic souvrství stínavsko-chabičovského.
5. Profily mapovacích vrtů z okolí Moravského Berouna (přepočítáno na pravé mocnosti; u překocených sledů otočeno do normální polohy).
   1 - silicity, 2 - jílovité břidlice, 3 - prachovité břidlice s laminami prachovců, 4 - jemno- až hrubozrnné pískovce, 5 - vápence, 6 - písčité vápence, 7 - vápencové brekcie, 8 - brekcie tvořená úlomky břidlic a pískovců, 9 - bazické tufity, 10 - bazické tufy, 11 - spility, 12 - čočky vápenců, 13 - rugózní korál, 14 - fosforitové konkrece, 15 - brekcie tvořená úlomky bazických vulkanitů a břidlic.
6. Profil vrtu Moravský Beroun MV-117. Přepočítáno na pravé mocnosti.
   1 - černé silicity, 2 - křemité břidlice, 3 - jílovité břidlice, 4 - prachovité břidlice a prachovce, 5 - jemno- až hrubozrnné droby, 6 - jemno- až středozrnné křemenné pískovce, 7 - hrubozrnné křemenné pískovce, 8 - drobnozrnné, místy až středozrnné křemenné slepence, 9 - klasty břidlic a silicitů, 10 - gradační zvrstvení, 11 - sedimentace po hiátu..
7. Profil vrtu Moravský Beroun MV-119.
   1 - středozrnná droba, 2 - silně vápnité hrubozrnné pískovce s valouny křemene a klasty vápenců, 3 - hrubozrnné až jemnozrnné vápnité křemenné pískovce, 4 - prachovité břidlice s čočkovitými laminami prachovců a vzácně i pískovců, 5 - laminace, 6 - gradace, Ca - vápnitost.
8. Profil vrtu Moravský Beroun MV-120.
   1 - středozrnná droba, 2 - středo- až hrubozrnný pískovec, 3 - štěrčíkové a drobnozrnné křemenné slepence, 4 - prachovité břidlice s čočkovitými laminami prachovců, 5 - jílovité břidlice, 6 - silicity, 7 - vápence, 8 - pozvolný přechod, 9 - drcená partie v blízkosti dislokace, 10 - laminace; TŠ - tmavě šedé zbarvení, SŠZ - světle šedozelené zbarvení, Č - černé zbarvení, ČF - červenofialové zbarvení, Si - silicifikace, ŠZ - šedozelené zbarvení.
9. Hypotetická paleofaciální mapa okolí Šternberka a Moravského Berouna ve svrchním tournai.
   1 - andělskohorské souvrství (břidlice, prachovce a podřízeně jemnozrnné droby), 2 - křemenné slepence a hrubozrnné pískovce, 3 - písčité vápencové brekcie a pískovce, 4 - křemité břidlice se silicity, 5 - současný bazický vulkanismus, 6 - vápence, 7 - bazické vulkanity a křemité břidlice, 8 - proterozoické metamorfity (6 až 8 - součást souše), 9 - směr pohybu klastického materiálu, 10 - směr transgrese moře, 11 - přibližné rozhraní facií, 12 - přibližný průběh pobřeží, 13 - synsedimentárně fungující dislokace.
10. Schéma vývoje struktury u samoty Volárna s. od Moravského Berouna.
    V - bazické vulkanity, PO - ponikevské souvrství, MB - moravskoberounské souvrství, HB - hornobenešovské souvrství. Sedimentární výplň mezi vulkanickými prahy je v důsledku stlačení "vytlačována" vzhůru.
11. Odkrytá geologická mapa západního okolí Leskovce nad Moravicí.
    1 - droby, 2 - petromiktní slepence, 3 - valounové břidlice (1 až 3 - hornobenešovské souvrství, spodní a střední visé, 4 - vápence (givet-famen), 5 - křemenné keratofyry, 6 - bazické vulkanity, 7 - jílovité břidlice, místy doprovázené vápenci (stínavsko-chabičovské souvrství, eifel), 8 - vrty z padesátých let, 9 - nové mapovací vrty.
12. Profil svrchních částí vrtů Leskovec MV-1 a MV-2 (přepočítáno na pravé mocnosti).
    1 - břidlice (zčásti tufitické) s klasty vápenců a břidlic, 2 - laminované vápence, 3 - břidlice s hlízami vápenců, 4 - hlíznaté vápence, 5 - biodetritové vápence se střídají s břidlicemi, 6 - mikritové vápence se střídají s biodetritovými, 7 - tufitické brekcie, 8 - keratofyrové tufy, 9 - keratofyrové tufity, 10 - rugózní koráli, 11 - stromatopory, 12 - krinoidové články, 13 - brachiopodi, 14 - pyrit, 15 - tentakuliti, 16 - dislokace, 17 - přerušení sedimentace.
13. Odkrytá geologická mapa okolí Horního Benešova. Na základě mapování J. Urbánka sestavil J. Dvořák.
    1 - převážně droby hornobenešovského souvrství, 2 - křemité břidlice se silicity (ponikevské souvrství, svrchní frasn až střední visé), 3 - bazické, méně intermediární a kyselé vulkanity s vložkami břidlic a vápenců).
14. Profily dvěma šupinami předflyšových souvrství, zastižených vrtem Horní Benešov HB-903 a jejich korelace (vrt vrtán z devátého patra dolu).
    1 - droby, 2 - střídání prachovitých břidlic, prachovců a jemnozrnných drob, 3 - černé břidlice s konkrecemi fosforitů, laminami šedých kyselých tufitů a úlomky stonků flóry (1 až 3 - hornobenešovské souvrství, spodní a střední visé), 4 - šedé laminované a hlíznaté mikritové vápence s laminkami břidlice (vápence křtinské, svrchní frasn a famen), 5 - červeně zbarvená brekcie s úlomky vápnitých železných rud a šedých krinoidových vápenců v tufitické mezerní hmotě (frasn), 6 - tmavé leptochloritové železné rudy (frasn), 7 - šedé laminované vápence (frasn), 8 - černé břidlice (frasn), 9 - tmavé vápence s vložkami černých břidlic (frasn-givet?), 10 - šedé i světle šedé krinoidové vápence (frasn), 11 - vápence se zelenou tufitickou příměsí (frasn-givet), 12 - tmavé vápence se stromatoporoidovou a korálovou faunou (spodní givet-svrchní eifel), 13 - hyaloklastity (rozhraní frasn-famen), 14 - bazické tufy (svrchní frasn), 15 - sericitické břidlice neznámého stáří, 16 - přesmyk, 17 - pozvolný litologický přechod, 18 - zjištěný hiát, Pb - galenit, Zn - sfalerit, Fe - železitá příměs, K - krinoidové články, Ph - fosforit, T - kyselý tufit.
15. Korelační schéma hornin devonského a spodnokarbonského stáří části vrtu Horní Benešov HB-SV-1, zastižených v jednotlivých tektonických šupinách.
    1 - droby hornobenešovského souvrství, 2- prachovité břidlice a prachovce (? andělskohorské souvrství), 3 - tufitické droby na bázi hornobenešovského souvrství, 4 - vápnité železné rudy, 5 - šedé a světle šedé vápence, 6 - laminované vápence, 7 - tmavé vápence s vložkami a laminami černých břidlic (5 až 7 - vápence jesenecké), 8 - keratofyrové tufy a tufity, 9 - keratofyry, 10 - hyaloklastity, 11 - světle zelené tufitické břidlice (ponikevské souvrství,

?famen-tournai), 12 - pozvolný litologický přechod, a - kyselý, b - intermediární, c - bazický vulkanismus, K - konodonti, P - pyrit, Ga - galenit, Sf - sfalerit, Si - silicifikace, T - tufitická příměs (lamina), t - tentakuliti.

16. Detail tektonické stavby, interpretovaný na základě jader z vrtu Horní Benešov HB-SV-2 v hloubce 460-505 m. Střídání břidlic, prachovců a jemnozrnných drob hornobenešovského souvrství.

17. Detail vrtu Horní Benešov HB-SV-2 z hloubky 1 042.1-1 116.1 m (přepočítáno na pravé mocnosti).
1 - droby, 2 - prachovce, 3 - černé břidlice, 4 - tmavě šedé břidlice, 5 - klasty vulkanických hornin, 6 - klasty vápenců, 7 - klasty břidlic, 8 - vápence, 9 - silicity, 10 - kyselé tufy a tufity, 11 - křemičitá hornina se stilpnomelanem, 12 - fosforitové konkrece, 13 - gradační zvrstvení, TEN - tentakuliti, P - fosforit, Py - pyrit, Sf - sfalerit, Ca - vápnitost, Si - silicifikace, T - laminy kyselého tufu nebo tufitu.

18. Detail vrtu Horní Benešov HB-SV-2 z hloubky 1 116.1-1 310 m (přepočítáno na pravé mocnosti).
1 - hrubozrnná až jemnozrnná droba, 2 - tmavě šedá a černá břidlice (Z - zelená), 3 - hyaloklastity, 4 - bazická sklovitá hornina, 5 - bazický tuf, 6 - železná ruda, 7 - křemitofosfatické konkrece, 8 - pozvolný přechod, 9 - gradační zvrstvení, Ca - vápnitost, Fe - železité sedimenty a tufity, Si - silicifikace, P - fosfatické konkrece a zrna, Py - pyrit, T - tufit. Všechny horniny náleží spodní části hornobenešovského souvrství (spodní visé).

19. Rekonstruované profily jednotlivými šupinami vrtu Horní Benešov HB-SV-3 (přepočítáno na pravé mocnosti).
1 - droby, 2 - břidlice: Z - zelené, (z) - nazelenalé, 3 - silicity, 4 - vápence, 5 - tufy a tufity, 6 - silicifikace, 7 - fosforitové hlízy, 8 - příměs křemenného prachu, 9 - karbonatická příměs, 10 - pyrit, 11 - gradační zvrstvení.

Vysvětlivky k přílohám

Příl. 1

Odkrytá geologická mapa okolí Moravského Berouna.
1 - bazalt (starý kvartér), 2 - droby, 3 - střídání břidlic, prachovců a jemnozrnných drob, 4 - vápnité pískovce a písčité vápence s vložkami břidlic facie "Na výsluní" (2-4 - hornobenešovské souvrství, spodní a střední visé), 5 - střídání břidlic, prachovců a jemnozrnných drob (andělskohorské souvrství - tournai), 6 - křemenné slepence a hrubozrnné pískovce (moravskoberounské souvrství, svrchní tournai), 7 - křemité břidlice se silicity (ponikevské souvrství, svrchní frasn až tournai), 8 - tmavé jílovité břidlice (stínavsko-chabičovské souvrství, svrchní ems a eifel), 9 - bazické a vzácně též intermediární vulkanity - střídání láv a tufů, 10 - nové mapovací vrty, 11 - vrty ze šedesátých let, 12 - vrty z padesátých let, 13 - průzkumné šachtice a štoly z padesátých let.

Příl. 2

A. Profil vrtu Horní Benešov HB-SV-1.
1 - droby, 2 - černé břidlice, 3 - břidlice, prachovce a jemnozrnné droby, 4 - tenké vložky břidlic a prachovců, 5 - petromiktní slepence, 6 - tenké vložky slepenců, 7 - tufitické droby (1-7 - hornobenešovské souvrství), 8 - vápence a břidlice, 9 - bazické vulkanity, 10 - intermediární vulkanity (8 až 10 - převážně eifel-frasn).

B. Profil vrtu Horní Benešov HB-SV-3 s interpretací tektonické stavby v okolí.
1 - hyaloklastity, 2 - bazické tufy, 3 - vložky vápenců v tufech, 4 - pumy bazického vulkanismu v břidlicích, 5 - klivář v hyaloklastitech a tufech, 6 - vápencové vložky a hlízy v břidlicích, 7 - silicity, 8 - kyselé tufy a tufity, 9 - droby, 10 - tektonické útržky drob, 11 - zelené křemité břidlice, 12 - šedé a černé břidlice, 13 - mocné křemenné žíly, 14 - dislokace. Vrt ilustruje vzájemné zastupování hornobenešovského a ponikevského souvrství.

Příl. 3

Profil vrtu Horní Benešov HB-SV-2.
1 - droby, 2 - střídání břidlic, prachovců, jemnozrnných drob většinou v gradačně zvrstvených rytmech (1 a 2 - hornobenešovské souvrství), 3 - brekcie, tvořená úlomky vápenců, bazických i kyselých vulkanitů v břidličné základní hmotě s laminami tufitů, 4 - převážně kyselé tufy a tufity, na bázi s fosforitovými konkrecemi, 5 - bazické vulkanické horniny, 6 - sedimentárně vulkanický sled, tvořený vápenci, břidlicemi a kyselými tufy (3 až 6 - frasn až tournai ?).

Příl. 4

Rekonstruovaný paleofaciální řez j. okolím Horního Benešova. Jako srovnávací úroveň je použita báze hornobenešovského souvrství (droby, na Z na bázi tufitické).
1 - droby, 2 - prachovité břidlice s laminami prachovců (?andělskohorské souvrství), 3 - černošedé křemité břidlice se silicity, 4 - zelené křemité břidlice s hlízami vápenců (3 a 4 - ponikevské souvrství, svrchní frasn až střední visé), 5 - mikritové, z části hlíznaté vápence (vápence křtinské, svrchní frasn-famen), 6 - šedé a světle šedé vápence (vápence jesenecké, eifel až frasn), 7 - tmavě šedé až černošedé vápence, místy s vložkami černých břidlic, jinde se stromatoporoidovou a korálovou faunou (vápence lažánecké, eifel,givet), 8 - černošedé jemné jílovité břidlice s trilobitovou a jinou faunou (stínavsko-chabičovské souvrství, eifel), 9 - křemičitá hornina s ložiskem barevných kovů, 10 - polštářové lávy, 11 - hyaloklastity, 12 - bazické tufy, 13 - keratofyry, 14 - intermediární a kyselé tufy, 15 - železné rudy, 16 - sedimentace po hiátu. Řez ilustruje velmi faciálně proměnlivé sedimentační prostředí v závislosti na vulkanické činnosti.