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Silurian succession of the Kosov quarry near Beroun

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Locality *- The locality comprising several stops occurs in a large abandoned quarry on north-west side of Kosov Hill, about 2.5 km south-west of Beroun railway station (Fig. 1), at coordinates: Stop A – Sheinwoodian-Homerian boundary section N 49°56'25'', 14°3'8''; Stop B – middle Homerian Mulde/Lundgreni Event N 49°56'22'', E 14°3'12''; Stop C base Pridoli section N 49°56'24'', E 14°3'29''.*
Lithostratigraphic units *- middle and upper part of Motol Fm., upper Kopanina Fm. and lower and middle Požáry Fm.*
Age *- upper Sheinwoodian, Homerian, and upper Ludfordian stages and lower and middle Přídolí Series.*
What to see *- Stop A – Sheinwoodian-Homerian boundary interval. Potential candidate section for revised GSSP of the Homerian Stage with abundant graptolites. Conodonts confined to limestone slump beds and tuffitic limestone intercalations. Stop B – Richly fossiliferous, shale-dominated succession across middle Homerian Lundgreni graptolite extinction Event (corresponding with Mulde Event of Jeppsson & Calner, 2003), survival interval and subsequent recovery. Stop C – Richly fossiliferous Ludlow-Přídolí boundary section. Rapid transition from a thick bank of cephalopod limestones to alternating limestones and shales of the Požáry Fm. Cooksonia land plants associate dendroid and graptoloid graptolites in the middle and upper part of the section. The quarry is famous paleontological locality since early 20th Century.*

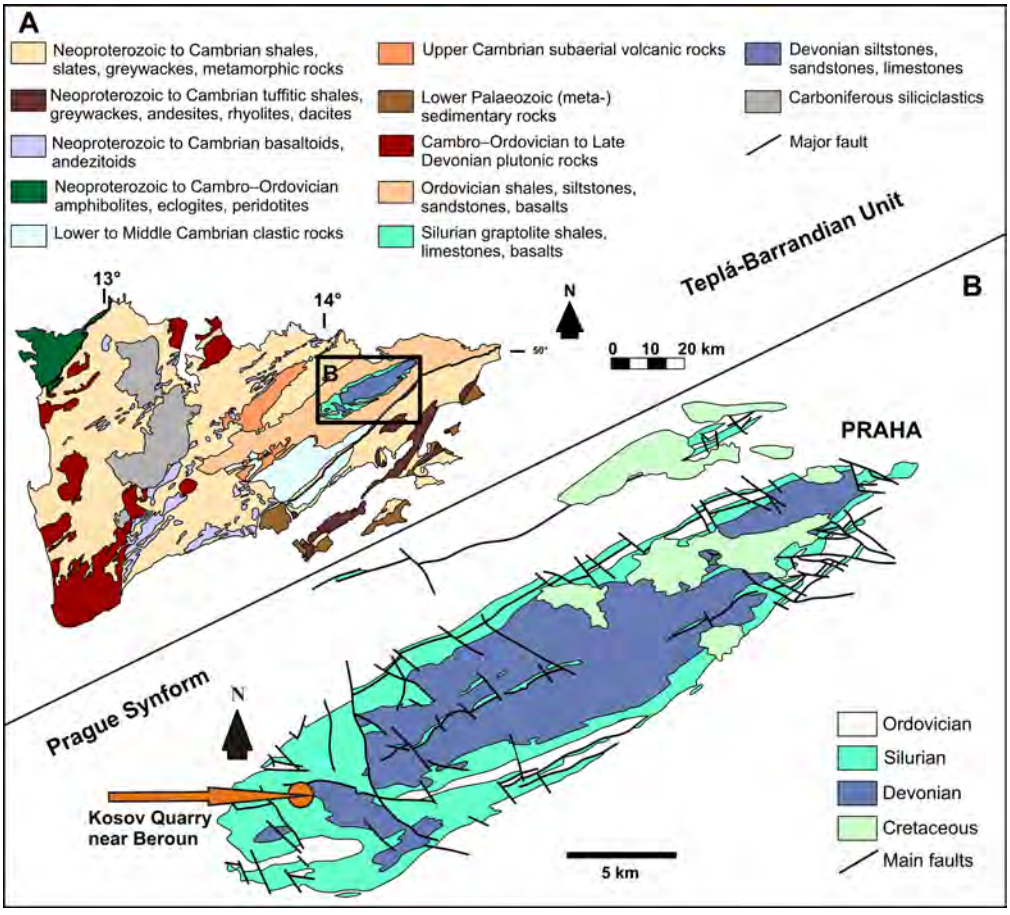

Figure 1. A location of the Kosov Quarry (near Beroun) in the Prague Synform (i.e. a part of the Teplá-Barrandian Unit).

How to get there

Section exposed in the lower part of the quarry is accessible by unpaved private road stemming from K Lomu street at western side of Beroun-Jarov. Private road is closed by two gates. Other access road, running from public road from Beroun to Koněprusy, is closed by a gate at southern entrance of the upper quarry.

Historical outline

The quarry situated near the top of the Kosov hill, west of classical Barrande' s localities at "Dlouhá Hora" ridge, exposed famous, richly fossiliferous Silurian strata comprising mid-Wenlock through to middle Přídolí sedimentary and volcanic-sedimentary succession. See Bouček (1941), Havlíček et al. (1958), Turek (1983, 1990), Chlupáč et al. (1990) and Kříž (1992) for more detail.

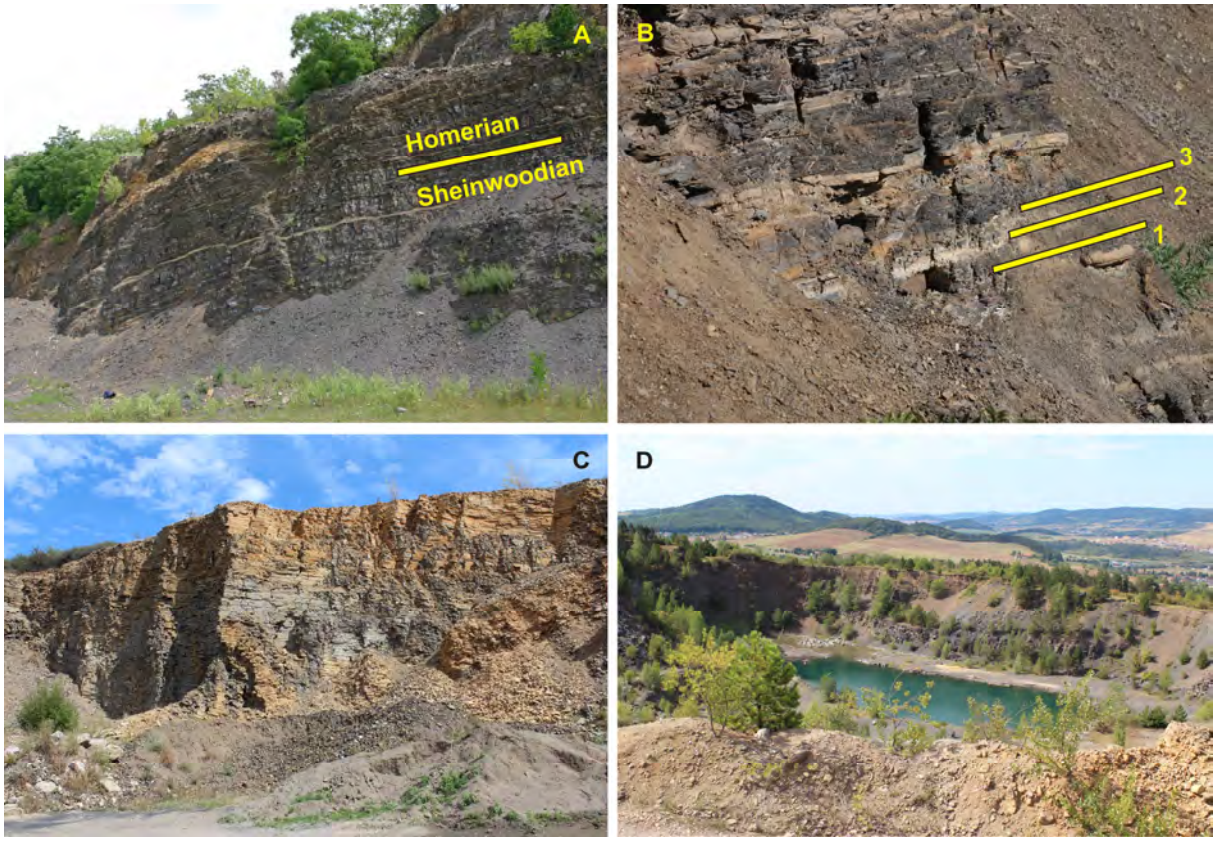

Figure 2. A. A photo of the Sheinwoodian-Homerian boundary section exposed at 6th level of the Kosov quarry (Stop A). Black shale succession is intercalated by pale-colored tuffitic-limestone gravity deposits derived from adjacent volcanic elevations. Slump-bed of tuffitic-limestone endostratic breccia was exposed in 2008 in the upper-right part of the section. Sheinwoodian-Homerian boundary is marked by yellow bar.
B. Sedimentary succession across mid-Homerian Lundgreni/Mulde Event exposed at 5th level of the Kosov quarry. This part of the exposure exhibits grey shales with numerous volcanoclastic intercalations. Base of the volcanoclastic debris-flow is exposed in the uppermost part of the photographed succession. Yellow bars indicate (1) – the base of *P. parvus* graptolite Biozone, (2) – the level with abundant shelly fauna of *Decoroproetus-Ravozetina* benthic Community and (3) – the base of *P. frequens* graptolite Biozone.
C. The Požáry Formation of the Přídolí Series exposed in the Kosov Quarry.
D. A general view of the Kosov Quarry near Beroun – the lowest part with lake.

Stop A

Lithology, fossil content and stratigraphy

Stop A exhibits a 20 m thick succession of black, laminated, calcareous shales of the Motol Formation exposed in the lowermost 6th and 5th levels of the Kosov quarry (Fig. 2). Shaly succession is underlain

and overlain by doleritic basalt sills and intercalated by several thin beds of the tuffaceous limestone composed of volcanic glass fragments, various bioclasts and lithoclasts transported by turbiditic currents from sublittoral zone of neighboring volcanic elevations. A slump bed of endostratic breccia occurs in the upper part of the black shale succession, 4 m below the overlying basalt sill.

The lowermost 180 cm of the shaly succession with graptolites of the *rigidus* Biozone including *Cyrtograptus rigidus* Tullberg, *Streptograptus retroflexus* (Tullberg), *Pristiograptus dubius* (Suess), *Monograptus flemingii* (Salter), and *Monoclimacis flumendosae* (Gortani) are no longer accessible at present.

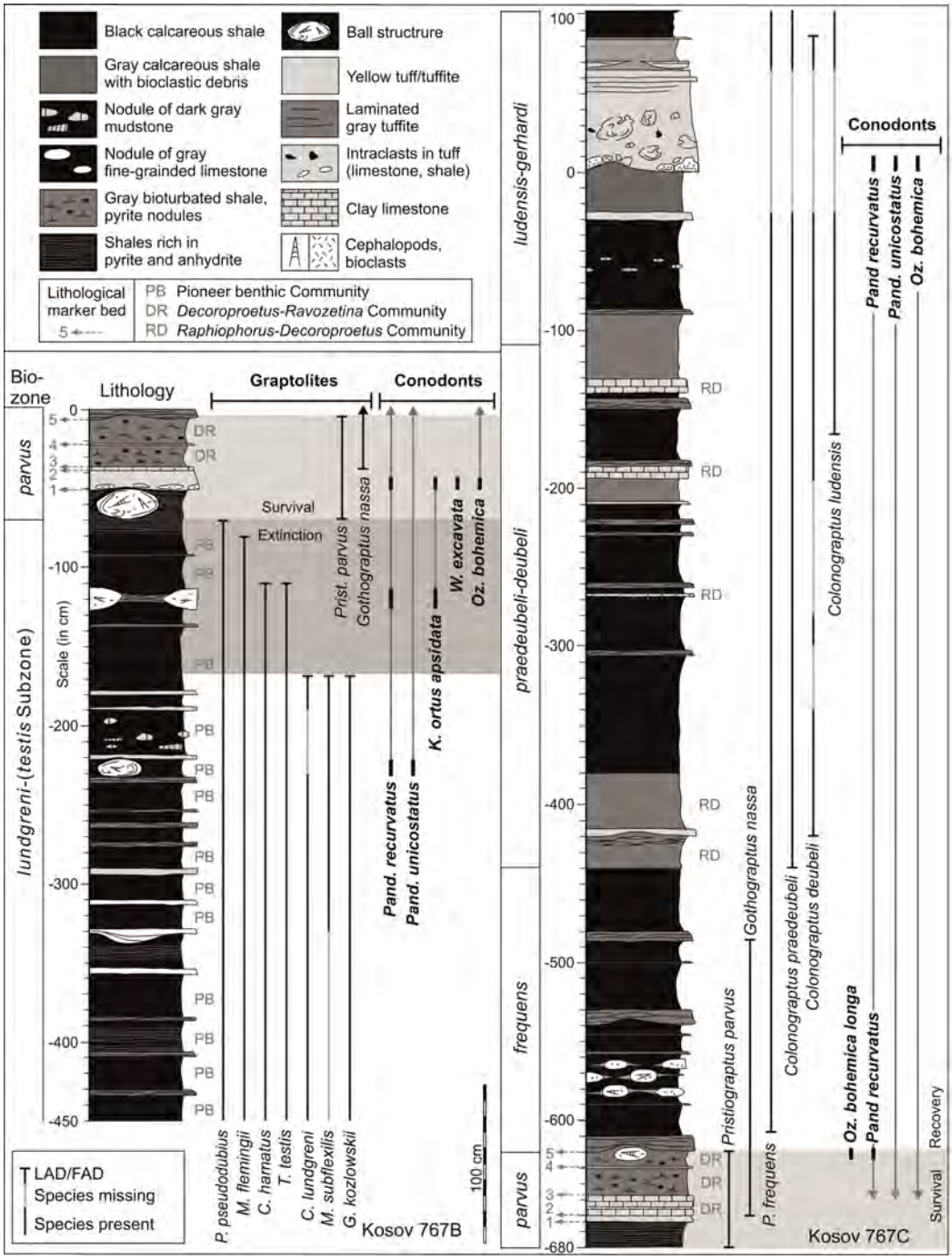

Figure 3. Middle and upper Homerian section at 5th level of the Kosov quarry (Stop B). Log, biostratigraphy, graptolite-range chart and non-graptolite fossil record across the Lundgreni/Mulde Event and subsequent recovery interval. This exposure corresponds, in part, with Section 767B by Kříž (1992).

It is succeeded by well exposed c. 6.5 m thick *ramosus-perneri* Biozone with *Cyrtograptus ramosus* Bouček, *Cyrtograptus perneri* Bouček, *Cyrtograptus multiramis* Törnquist (in the upper part), *Streptograptus retroflexus* (Tullberg) - (in the lower part), *Streptograptus*? cf. *antennularius* (Meneghini), *Pristiograptus dubius* (Suess) *s.l.*, *Pristiograptus pseudodubius* Bouček, *Monograptus flemingii* (Salter), and *Monoclimacis flumendosae* (Gortani) associated with flattened orthoconic nautiloids, rare dendroid graptolites, brachiopods *Valdaria budili*, worms *Kolihaia eremita* and cardiolid bivalves.

Remaining *c.* 11.5 m thick interval, below the overlying sill, belongs to the *lundgreni* Biozone. This biozone is subdivided in the lower *Cyrtograptus radians* Subzone (c. 2 m thick in this section), 5 m thick interval without specific subzonal status, and the upper subzone of *Testograptus testis* that further continues above the basalt sill in the section visited at Stop B. Graptolite assemblages consist of *Cyrtograptus perneri* Bouček (lower and middle part of the biozone), *Cyrtograptus lundgreni* Tullberg*, Cyrtograptus radians* Törnquist (lower subzone), *Cyrtograptus hamatus* (Baily) - (upper subzone), *Diversograptus* cf. *gracilis* Bouček (upper subzone), *Testograptus testis* (Barrande) - (upper subzone), *P. dubius* (Suess) *s.l.*, *P. pseudodubius* Bouček, *M. flemingii* (Salter) and *Mcl. flumendosae* (Gortani). Graptoloid fauna occurs together with common orthoconic nautiloid shells, occasionally colonized by epibyssate benthic elements (crinoids of the *Flexibilia* group, bivalves *Cardiola* and *Butovicella*, brachiopods *Lissatrypa*, annellid worms, gastropods, and bryozoans).

Middle part of the *lundgreni* Biozone is particularly well-exposed at the floor of the lowermost (6th) level, 40 m north of the pool.

Palaeoenvironment

The general lithology and fauna indicate a low-energy, oxygen deficient environment with a soft, muddy, largely anoxic but temporarily oxygenated bottom inhabited by epibenthic bivalves and crinoids attached to empty cephalopod shells.

Conodonts

Conodont elements were isolated from tuffitic-limestone intercalations and tuffitic-limestone debree flow (*Cyrtograptus rigidus, Cy. ramosus-Cy. perneri* and *Cy. lundgreni* graptolite Biozone). All samples contained conodonts that are refered to *O. s. rhenana*, *K. walliseri*, *K. ortus ortus* and *O. s. sagitta* conodont Biozones and thus confirming the Sheinwoodian-Homerian boundary interval. At same levels the conodont elements in samples were relatively abundant including zonally diagnostic platform elements and hundreds of coniform elements.

Stop B

Lithology, fossil content and stratigraphy

Lower part of the section visited at 5th level of the quarry begins with black-shale succession of the upper *lundgreni* Biozone exposed above stratigraphically highest basalt sill (Fig. 3). Black shales of the upper Motol Formation are intercalated by numerous subordinate tuffitic beds and occasional nodules of black muddy limestone. Much of the uppermost 5 m of *Cyrtograptus lundgreni* Biozone (*testis* Subzone) hosts rich graptolite assemblage of *Paraplectograptus eiseli* (Manck), *Pseudoplectograptus praemacilentus* (Bouček & Münch), *Gothograptus kozlowskii* Kozlowska-Dawidziuk, *Pristiograptus pseudodubius* Bouček, *Monograptus flemingii* (Salter), *Monograptus subflexilis* Přibyl, *Monoclimacis flumendosae* (Gortani), *Testograptus testis* (Barrande), *Cyrtograptus lundgreni* Tullberg, *Cyrtograptus mancki* Bouček and *Cyrtograptus hamatus* (Baily). Final 1.2 m of this interval, however, recorded accelerating impoverishment of the flourishing fauna as a result of global extinction termed “big crisis” by Jaeger (1992). Nowadays, the latter is known as *lundgreni* extinction Event (Štorch 1995). First victims among graptolites were large and specialized cyrtograptids, plectograptines and some monograptids. Brief occurrence in the extinction interval qualified *Monograptus ambiguus* Jaeger and *Cyrtograptus hemmanni* Bouček for disaster taxa (see Gräfenwarth Section in Thüringen for comparison). Latest survivors *M. flemingii* and *Pr. pseudodubius*

recorded from 0.4 cm thick interval assigned to *Monograptus flemingii* Biozone belong in ubiquitous, ecologically tolerant taxa. Both species vanished after all.
Next, 0.7 m thick interval witnessed period of survival, when planktic graptoloids as a whole balanced on the edge of imminent extinction. Minute rhabdosomes of the only monograptid survivor – *Pristiograptus parvus* Ulst may serve as a text-book example of Liliput Syndrom. Dwarf pristiograptids were soon accompanied by plectograptid *Gothograptus nassa* (Holm). Abundant, but small shelly fauna of *Decoroproetus-Ravozetina* Community account for weakened anoxy in the *Pristiograptus parvus* Biozone. Slow recovery of the graptolite fauna begun with subsequent immigration of standard-sized *Pristiograptus frequens* Jaekel, still accompanied by *G. nassa*. Morphological experimentation with sicula and initial thecae heralding subsequent appearance of early colonograptids has been observed in about the middle of 1.9 m thick *Pristiograptus frequens* Biozone. Subsequent *Colonograptus praedeubeli-Colonograptus deubeli* Biozone is characterized by abundant *C. praedeubeli*, associated with *P. frequens* and *C. deubeli* which became more common in the upper part of 3.3 m thick biozone. In several beds graptolites are accompanied by uncommon elements of *Raphiophorus-Decoroproetus* trilobite Community of Chlupáč (1987) and rare brachiopods.
Remaining, 3.2 m of the measured section is represented by dark grey shales of *Colonograptus ludensis-Colonograptus gerhardi* Biozone with prominent 0.7 mm thick volcanic debris flow in the middle of this interval. Note strikingly erosional base of the debris flow. Graptolite diversity increased gradually. *C. deubeli* (Jaeger) and *C. praedeubeli* (Jaeger) vanished while *Colonograptus ludensis* (Murchison), *Spinograptus munchi* (Eisenack), *Pristiograptus auctus* Rickards and first neogothograptids (*Neogothograptus eximinassa* Maletz) made their lowest occurrences. *Colonograptus gerhardi* (Kühne) typical of the upper part of the biozone is missing which suggests that only lower part of the *ludensis-gerhardi* Biozone is preserved in the section terminated by heavily tectonized interval below large complex of basaltic pillow-lavas, hyaloclastites and volcanoclastics exposed on 5th and 4th levels of the quarry.

Palaeoenvironment
The general lithology and fauna indicate a low energy oxygen deficient environment with a soft muddy, largely anoxic bottom with periodic influx of basalt volcaniclastics. Graptolite mass extinction and appearance of rich, small-size benthic fauna with some anachronistic elements indicate profound environmental and biotic perturbations.

Conodonts
Total of seven samples from limestone lenses and slump balls were processed for conodonts. Some levels were quite rich in platform elements including zonal indexes: *Ozarkodina bohemica* (Walliser) *Ozarkodina bohemica longa* Calner & Jeppsson and *Kockelella ortus absidata* Barrick & Klapper. The two latter represent the indexes of the respective subzones within the late Homerian *Oz. bohemica* Interval Zone (Slavík, 2014).

Stop C

Lithology, fossil content and stratigraphy
Higher part of the Silurian sequence exposed on the eastern face of the upper Kosov Quarry described by Kříž et al. (1986) and Kříž (1992) comprises upper Ludfordian part of the Kopanina Formation and lower and middle part of Požáry Formation of Přídolí age. The uppermost Kopanina Formation is developed as thick-bedded, about 5 m thick bioclastic limestone with characteristic brachiopod-trilobite *Prionopeltis archiaci-Atrypoidea modesta* Community (Havlíček & Štorch, 1990). Abundant brachiopods and trilobites associate other benthic fauna and large shells of nektobenthic cephalopods. Abrupt change in lithology at the top of the bioclastic limestone indicating the base of Požáry Formation is coincident with the base of the Přídolí Series in this section. Joint occurrence of the lowermost Přídolian zonal index graptolite *Neocolonograptus parultimus* (Jaeger) and trilobite *Prionopeltis striata* (Barrande) in grey micritic limestone bed overlying the last bed of biodetritic

limestone indicate the lowermost Přídolí age of this limestone. The sequence continues with 0.1 m thick, grey-brown calcareous shale overlain by 0.16-0.17 m thick micritic and sparitic limestone with bivalves *Cardiolinka bohemica* Kříž, cephalopods and brachiopods. Higher beds of the Požáry Formation comprise ca. 28 m thick succession of almost regularly alternating dark laminated micritic limestones and grey-brown calcareous shales. Subordinate shelly fauna is sorted and accumulated in thin layers. In the lower part of the Požáry Fm. Havlíček and Štorch (1990) recognized *Gracianella graciosa* benthic Community composed by small brachiopods and trilobites. Planktic and nektonic fauna is more common in the Požáry Fm., being represented by graptolites of *Neocolonograptus parultimus-Neocolonograptus ultimus*, *Neocolonograptus lochkovensis* and *"Monograptus" bouceki* biozones. Graptoloid graptolites are associated by diverse dendroid graptolites and uncommon early vascular plants *Cooksonia*. Biostratigraphic value of the section is further reinforced by chitinozoans.

Palaeonvironment

Lithology and fauna of the cephalopod limestone bank of the uppermost Kopanina Fm. indicate a well oxygenated, high energy environment and firm bottom whereas dark-grey micritic limestones of the Požáry Fm., alternating with graptolite-bearing calcareous shale, account for deeper, less well-oxygenated and quiet water bottom environment.

Conodonts

The conodonts from the Ludlow-Přídolí boundary have been reported by Schönlaub (in Kříž et al., 1986). The conodont elements were relatively scarce, only one index taxon for the latest Ludlow has been recorded: *Ozarkodina crispa* (Walliser) has its last occurrence in bed No. 19, i.e. just below the base of the Přídolí with *Monograptus parultimus*. Further study is necessary to prove the occurrence of other zones, especially the basal Přídolí *Z. zellmeri* conodont biozone in the sense of Slavík & Carls (2012).

References

BOUČEK, B. (1941): Geologické výlety do okolí pražského, 201 p. Melantrich, Praha. [in Czech]

CHLUPÁČ, I. (1987): Ecostratigraphy of Silurian trilobite assemblages of the Barrandian area. - Newsletters in Stratigraphy, 17: 169-186.

CHLUPÁČ, I., HAVLÍČEK, V., KŘÍŽ, J., KUKAL, Z., & ŠTORCH, P. (1998): Palaeozoic of the Barrandian (Cambrian to Devonian). 183p. - Czech Geological Survey, Prague.

HAVLÍČEK, V. & ŠTORCH, P. (1990): Silurian brachiopods and benthic communities in the Prague Basin, Czechoslovakia). - Rozpravy Ústředního ústavu geologického, Praha, 48: 1-275.

HAVLÍČEK, C., HORNÝ, R., CHLUPÁČ, I. & ŠNAJDR, M. (1958): Průvodce ke geologickým exkursím do Barrandienu. - Sbírka geologických průvodců 1: 157 p. Nakladatelství ČSAV, Praha. [in Czech]

JEPPSSON, L. & CALNER, M., (2003): The Silurian Mulde Event and a scenario for secundo-secundo events. - Transactions of the Royal Society of Edinburgh: Earth Sciences, 93*:* 135-154.

KŘÍŽ, J. (1992): Silurian Field Excursions: Prague Basin (Barrandian), Bohemia. - National Museum of Wales, Geological Series, No 13: 1-111.

KŘÍŽ, J., JAEGER, H., PARIS, F. & SCHÖNLAUB, H.P. (1986): Přídolí – the Fourth Subdivision of the Silurian. - Jahrbuch der Geologischen Bundesanstalt, 129: 291-360.

JAEGER, H. (1992): Neue Standard-Graptolithenzonenfolge nach der "Grossen Krise" an der Wenlock/Ludlow – Grenze (Silur). - Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 182, 3: 303-354.

SLAVÍK, L. & CARLS, P. (2012): Post-Lau Event (late Ludfordian, Silurian) recovery of conodont faunas of Bohemia. - Bulletin of Geosciences, 87: 815-832.

SLAVÍK, L. (2014): Revision of the conodont zonation of the Wenlock-Ludlow boundary in the Prague Synform. - Estonian Journal of Earth Sciences, 63(4): 305-311.

ŠTORCH, P. (1995): Biotic crises and post-crisis recoveries recorded by Silurian planktonic graptolite faunas of the Barrandian area (Czech Republic). - In: Čejchan, P., Hladil, J. & Štorch, P. (eds): Evolution and extinctions. - Geolines, 3: 59-70.

TUREK, V. (1983): Hydrodynamic conditions and the benthic community of upper Wenlockian calcareous shales in the western part of the Barrandian (Kosov Quarry). - Časopis pro Mineralogii a Geologii, 28(3): 245-260.

TUREK, V. (1990): Comments to upper Wenlock zonal subdivisions in the Silurian of Central Bohemia. - Časopis pro Mineralogii a Geologii, 35(4): 337-353.