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Middle Ordovician at Praha – Červený vrch Hill (Barrandian area, Czech Republic)

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Abstract. A large temporary excavation in the Middle Ordovician in the NE part of the Barrandian at Praha-Vokovice (Červený vrch Hill) was studied. Volcanic products forming the lower part of the exposed Ordovician sequence are represented mostly by basalts and basaltic tuffs. The lowermost parts of the Šárka Formation contain very rich graptolite and phyllocarid fauna, whilst benthic organisms are very rare. This faunal association contrasts with the younger "Euorthisina-Placoparia Community" sensu Havlíček and Vaněk (1990) and enables comparison with other localities in the lower part of the Šárka Formation in the Prague Basin.

Key words: Middle Ordovician, Prague Basin, Šárka Formation, measured section, lithology

Introduction

The city of Prague lies mostly on Ordovician rocks. These rocks belong to the NE part of the so-called Prague Basin – the area of sedimentation of Ordovician to Devonian formations in central Bohemia (sensu Havlíček 1980, 1981) within the major unit – the Barrandian. Good outcrops of the Middle and Upper Ordovician rocks are rare in the whole area, now strongly urbanized. Particularly the soft Ordovician shale sequences are covered by younger sediments, and no more accessible for study.

The NW part of Prague has a particular importance for Ordovician stratigraphy and palaeontology because it features the famous localities of Middle Ordovician fossils contained in shales and concretions of the Šárka and Dobrotivá formations. The localities at Praha-Vokovice and in area of the Šárka Valley were known to geologists and fossil collectors already in Barrande's times, and the first palaeontological finds date to around 1860 (Krejčí 1863), though geological observations were published yet earlier (Zippe 1845).

The classic fossil sites were mostly situated on fields, where fossiliferous concretions were concentrated in regolith. Concretions with fossils were sampled by many collectors, among whom particularly C. Klouček and F. Hanuš markedly contributed to the general knowledge of Middle Ordovician faunas in the first half of the 20th century (they also published topographic data on localities – see Klouček 1916, Hanuš 1923). The most important source of stratigraphical information on Llanvirnian faunas was the outcrop of the so-called Pulkrábek or Vokovice brickyard, carefully investigated by Bouček (1927). This locality was the only biostratigraphically well documented outcrop in the Šárka Formation in the NE part of the Barrandian, and permitted to draw conclusions on zonal subdivision which was later studied and documented particularly in the western part of the Barrandian, i.e., in the area of Rokycany (see review in Kraft and Kraft 1995, a.o.).

Owing to all this, the new temporary exposure in Middle Ordovician rocks created within the construction activities at Praha-Vokovice, near Červený vrch Hill (geographical coordinates: x = 5552166.53 and y = 3454166.81 in the Gauss-Krüger System), was of a particular importance. The excavation exposed Ordovician volcanic products in the lowermost part of the sequence (incomplete thickness about 60 m), and the overlying shales of the lower part of the Šárka Formation in accessible thickness of around 40 m (for topographical and geological situation see Figs. 1 and 2).

Geological setting

Geological situation in the NW part of Prague and the wider area of the studied locality is shown on geological map 1 : 25,000 with explanatory text, sheet 12-243 Praha-sever (Králík et al. 1984).

The succession exposed in the studied excavation consists of two stratigraphical units – the older, volcanic sequence which may be regarded as the NE extension of the volcanic Komárov Complex (cf. facies maps in Havlíček and Štorch in Chlupáč et al. 1998), and the overlying shale sequence demonstrably representing the lower part of the Šárka Formation.

Results

Volcanic Complex

Volcanic products, forming the lower part of the exposed Ordovician rocks, are represented by strongly weathered basalts and basaltic tuffs. The rocks are yellow, red to violet, less coherent rocks or residues with common oxyhydroxides. These form thin laminae and lens-like bodies and (together with secondary carbonates) also matrix and fil-

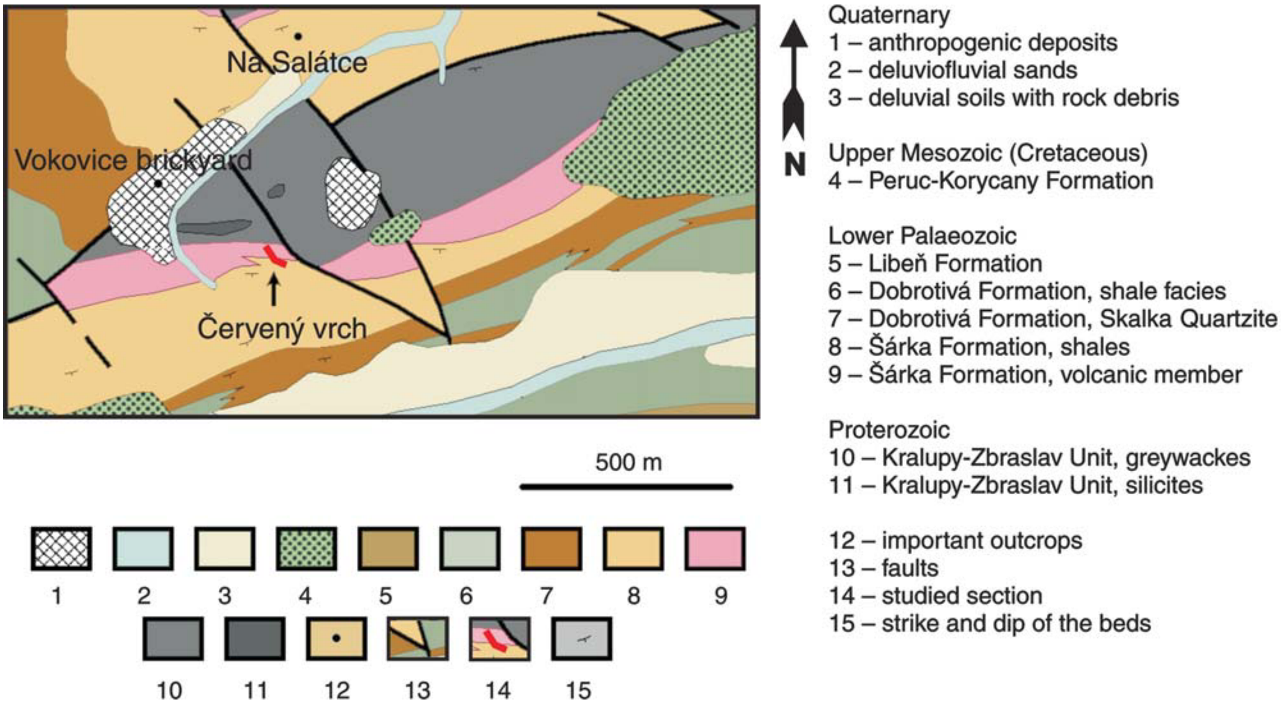

Fig. 1. Geological sketch-map of the Červený vrch Hill and Šárka area in Prague. Red line shows the geographical position of the studied section; black dots show two important palaeontological localities in the neighbourhood – former "Pulkrábek" or "Vokovice" brickyard and former "Na Salátce" brickyard at Praha-Jenerálka.

lings of small veinlets surrounding or replacing the primary minerals decomposed by weathering. Reddish-brown, iron-rich altered tuffs predominate; effusions of vesicular basalt with secondary carbonate fillings were occasionally described earlier. In the exposed sequence, it was possible to distinguish eight layers of alternating tuffs and altered volcanics (see Fig. 2).

Volcanic member of the Šárka Formation reveals two associations which manifest different compositional and genetical properties, hence also different stage and nature of alteration and weathering. Nevertheless, the correct determination of volcanological and depositional conditions is difficult due to the age of the deposits, subjected to severe modification in the past. The evaluation of the origin of the sequence is therefore rather speculative, based on stratigraphically younger materials.

Two representative rock types were sampled and analysed in the section (Tab. 1).

1 – Red and brownish-coloured volcaniclastic – hyaloclastic volcanics below the upper part of the slope edge,

2 – White-grey, finely laminated, pseudo-fluidally structured volcanics, which overlie the preceding type.

Type 1

The original vitroclastic structure of the rock was almost completely obliterated by secondary recrystallization and alteration processes. Red colour, resulting from intensive Fe-pigmentation, is a typical feature. Oxyhydroxides are dispersed throughout the rock, which obscures its pyroclastic nature. Basaltic glass is markedly altered. The presence of abundant radially orientated aggregates of microcrystalline quartz can be explained by recrystallization of either pyroclastic or hyaloclastic particles, which served as authigenic minerals centres. Secondary quartz occurs in the mesostasis of the rock and fills abundant minute fissures.

Secondary carbonate accumulates in patches. In spite of silicification of the rock, the SiO_2 content is relatively low. On the contrary, the contents of TiO_2 and Fe^{3+} are higher, which can be explained by subaquatic alteration. The contents of CaO, MgO and CO^2 are relatively low, their presence attests for newly formed carbonate minerals.

Type 2

Solid volcanic rock shows macroscopically pseudofluidal structure, and disintegrates into angular cubes. Microcrystalline quartz dominates in the mesostasis; its origin can be attributed to the devitrification of original glass and subsequent recrystallization. Few remnants of crystalloclasts can be observed, represented by fragments and grains of quartz and perhaps also strongly kaolinized feldspar grains. Abundant chlorite and kaolinite are dispersed throughout the rock. Vitro- and crystallo-clastic structure can be recognized, which may indicate the ignimbrite (welded tuff) nature of the original volcanic rock. Chemical composition (see Tab. 1) shows enrichment in SiO_2 and lower contents of CaO, MgO, MnO, and especially Fe_2O_3. Higher contents can be seen for Ti and Al. Considering that the whole rock was modified by alteration and weathering processes, unambiguous conclusions about the volcanological origin and magma character are difficult. The rock can be tentatively defined as strongly altered and silicified ignimbrite. The degree of weathering and alteration in both studied specimens can be also documented by the high content of water (8 wt.% and over 9 wt.%).

Basaltic calc-alkaline volcanism dominates with both effusive and explosive facies documented. The earlier described pyroclastic deposits include grey-greenish tuffs together with above-mentioned red-brownish Fe-rich tuffs (and tuffites?), in some cases in association with shales (Králík et al. 1984). Red-coloured tuffs correspond most probably to hyaloclastites, with brownish clay material being a product of subaquatic disintegration of sideromelane fragments, i.e., altered basaltic glass.

Röhlich (1960) reported the presence of acid volcanic rocks, which occupy the lower part of the Šárka Formation in the Troja-Kobylisy area. Although he called them "quartz porphyrites", they represent dacites and dacitic tuffs. Evidence of acid volcanic tuffs together with basaltic agglomerates is very interesting and can be interpreted as ignimbrite flows produced by fissure eruptions. This idea is also supported by relics of the original vitroclastic structure of the rock, pseudofluidal nature as well as strong silicification, as a result of devitrification and recrystallization of original glassy shards.

In the wider vicinity of the studied exposure, volcanic rocks represent the basal member of the Ordovician succession. They directly overlie, with clear angular unconformity, the Proterozoic rocks of the Kralupy-Zbraslav Group formed by shales, siltstones, greywackes and large lens-like bodies of silicites (e.g., Králík et al. 1984, see Pouba and Skoček 2000, Kovanda et al. 2001). According to the observations made by I. Chlupáč in the past, these weathered varicoloured volcanic and volcaniclastic rocks are as much as 100 m thick in the eastern vicinity of the studied exposure, i.e., in the former highway cutting between Bořislavka and the Šárka Valley. However, the development and thickness are highly variable.

The stratigraphic assignment is doubtful, as no intercalation of fossiliferous sediments were found: some authors regarded them as belonging to the Komárov (now Klabava) Formation – e.g. Slavíková and Slavík (1917) or Kettner (1919), other were inclined to range the volcanic sequence in this part of Prague to the overlying Šárka Formation (Woldřich in Čermák et al. 1914), or directly assigned it as

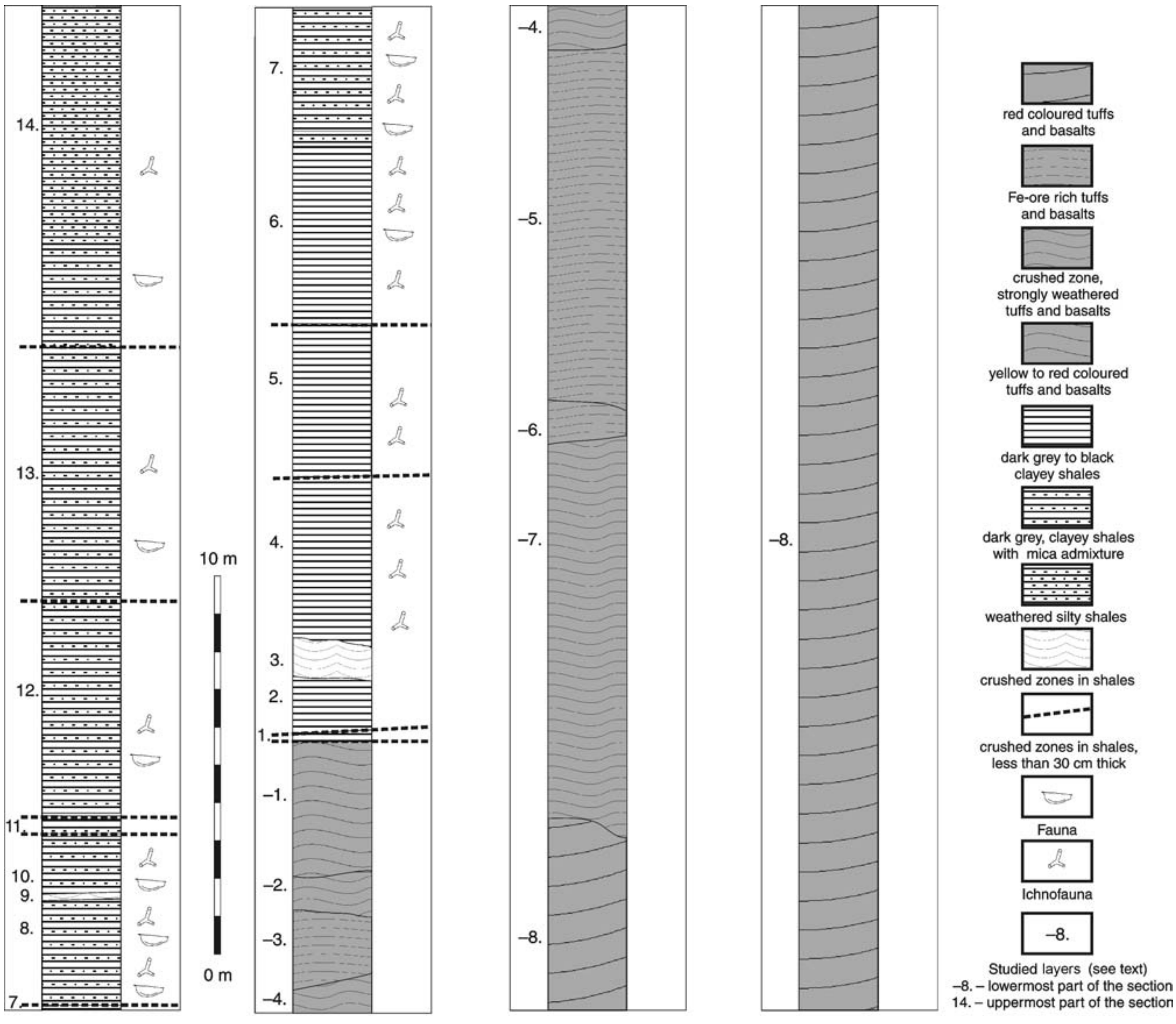

Fig. 2. Schematic section of the temporary outcrop across the Červený vrch Hill.

a facies of the Šárka Formation of Llanvirnian age (Havlíček in Králík et al. 1984).

Ordovician ferrolites were mined in the western proximity of the studied exposure in the past (cf. Krejčí and Helmhacker 1885, Slavíková and Slavík 1917). The ferrolites, formed by hematite-rich tuffs, hematite-rich quartz, limonite and some other minerals (pyrite, chamosite etc.), form local lens-like bodies within the volcanic complex. The ferrolites were not found in the studied exposure but a loose block of ferruginous quartz of red colour with typical features of similar rocks occurring at other localities of Ordovician ferrolites may be considered their analogue (see Chvátal 2003, this volume).

Iron-rich quartz of probably sedimentary chemogenic origin was reported from the Červený vrch Hill area especially by Slavíková and Slavík (1917), but the first report, however, refers already to Peithner (1768).

Sedimentary sequence of the Šárka Formation

The boundary between the volcanic or volcaniclastic rocks with the overlying shales is relatively sharp and may be affected by tectonics (a few cm thick layer of crushed shale is developed above the contact with the volcanics).

The shale sequence belongs to the lower part of the Šárka Formation and is exposed in a thickness of around 38 m. It consists of black to dark grey shales and silty shales with common clastic mica. The amount of silt component and mica seems to increase upwards. Based on lithological contrast and tectonic features (possibly faults), the exposed, relatively monotonous shale succession was subdivided into 14 layers, among which shales with only very fine mica admixture occur in the lowermost one, while grey silty and micaceous shales form the uppermost layer. The content of mica and silt component strongly fluctuates within the individual layers, forming laminae of millimetre thickness. Some laminae are distinctly enriched in organic remains, especially the dominant fragments and carapace valves of phyllocarid crustaceans, *Caryocaris*. Other fossils are less frequent, though not expressively rare: dendroid graptolites (*Ptilograptus, Acanthograptus, Dendrograptus, Dictyonema*, etc.), graptolites (*Undulograptus, Aulograptus, Corymbograptus, Didymograptus*, a.o. – see Kraft and Kraft 2003, this volume).

Other faunal components are represented by inarticulate brachiopods (compiled by M. Mergl), namely their lingulate forms. Plastic deformations of the valves and traces of dissolution are visible. These taphonomic effects cause difficulties in the determination of fossil taxa. However, the following taxa were identified: *Paterula incognita* Mergl, 1999; *Cyrtonotreta osekensis* Mergl, 2002 and *Spodyloglossella* sp. The collected material also contains several indeterminable fragments of large lingulate brachiopods. The whole brachiopod assemblage is featured by a low diversity and deep-water character. The absence of taxa common and abundant in the Šárka Formation such as *Mytoella* and *Wosekella* is remarkable. Comparatively rare are the remains of trilobites (probably including even representatives of naraoids – the first finds of this group from the Barrandian area), orthocone nautiloids, conulariids etc. (see also Kraft and Kraft 2003 and Kraft et al. 2003, this volume). Ichnofossils are common but their assemblage is monotonous (*Pilichnus, Planolites, Nereites, Palaeophycus*, a.o. – see Mikuláš 2003, this volume).

Dark siliceous (primary carbonate, see Kukal 1962) concretions, characteristic for some fossil-rich localities of the Šárka Formation, are rare. In the eastern part of the studied outcrop, concretions were not found at all. In the western part, only one layer contained concretions; it may correspond to layer No. 7 (see Fig. 2) in the measured section. These concretions yielded only few remains of *Placoparia*, *Ectillaenus*, Asaphidae gen. et sp. indet., *Caryocaris*, articulate brachiopods *Eodalmanella*, Modiomorphidae indet., "*Orthoceras*" *bisignatum*, echinoderms *Lagynocystites* cf. *pyramidalis* and ichnofossils (*Pilichnus* a.o.).

Comparison with near sections

The most similar development and fossil content, easily comparable with the studied exposure, is known from the quarry of the former "Na Salátce" brickyard in the Šárka Valley near the settlement of Jenerálka, about 800 m N of the studied excavation. These two sites are, however, separated by an important longitudinal fault striking NE–SW (see Fig. 1), which caused a relative subsidence of the block with Proterozoic and Ordovician rocks in the north. Also normal faults of NW–SE strike may obscure the primary distance, which was obviously longer.

The former "Na Salátce" quarry was studied by the second author at the occasion of collecting phyllocarids (Chlupáč 1970). The lithological analogy, including rare occurrence of larger concretions, is almost perfect and also the fossil content and mode of occurrence are analogous: the dominant fossils are phyllocarids of the genus *Caryocaris* represented by *C. wrighti* Salter and *C. subula* Chlupáč (see also Chlupáč 2003, this volume), followed in frequency (but markedly less common than *Caryocaris*) by large graptolites *Corymbograptus retroflexus* (Perner) and biserial "*Pseudoclimacograptus"* cf. *scharenbergi* (Larworth), followed by inarticulate brachiopods. Other fossils are rare: dendroids (among them also *Acanthograptus* regarded as a plant *Bojophyton pragense* Obrhel at that time), sporadic remains of asaphid, pliomerid (*Placoparia*) and dalmanitid trilobites, conulariids, articulate brachiopods (*Euorthisina*), sponge spicules (*Pyritonema*) etc. The mode of occurrence is almost similar: carapace valves (often articulated) and diverse fragments of *Caryocaris* were very frequently found as clusters of several or even numerous individuals, accompanied by disseminated dark organic matter. The rare presence of other fossils, monotonous ichnofossil assemblage and identical lithology were other features supporting the correlation – the two localities belong to the lower (maybe lowermost) part of the Šárka Formation at a distance of less than 50 m from the base of the shale sequence above the volcanics.

Differences in the non-graptolite fauna seem to be only quantitative: in the presently studied excavation, *Caryocaris subula* is by far the most frequent and markedly dominant fossil, while at Jenerálka *Caryocaris wrighti* was more common and its frequency was comparable with that of *C. subula*. Graptolite faunas of both localities contain the index species *Corymbograptus retroflexus* that documents the assignment to the lower part of the Šárka Formation (cf. discussion on zonal subdivisions in Kraft and Kraft 2000). However, the stratigraphically important graptolite and dendroid fauna has not been found at the Jenerálka (Na Salátce) locality yet.

Another large exposure of the Šárka Formation in the neighborhood of the studied locality was the former, now completely reclamated Pulkrábek (Vokovice) brickyard (see Fig. 1), described as a very important comparative section of Ordovician rocks for the NE part of the Barrandian area by Bouček (1927). A comparison with the outcrop at Červený vrch Hill allows to conclude that the presently studied sequence can be stratigraphically correlated (with some reservation) only with the interval, which was designated as 1 and 2 by Bouček (1927) but not characterized by sufficient faunal content. All the other intervals exposed at that classic outcrop show marked differences in fauna and are obviously younger.

Tab. 1. Analyses of representative samples from the volcanic member (values in wt.%)

Whole-rock chemical analyses of major elements		
	Sample No.	
Component	1	2
SiO_2	69.68	50.40
TiO_2	1.27	2.31
Al_2O_3	19.70	14.04
Fe_2O_3	0.227	17.85
FeO	0.119	0.260
MnO	0.021	0.193
MgO	0.090	1.16
CaO	0.090	1.46
SrO	0.043	0.016
BaO	0.031	0.022
Li_2O	0.045	0.034
Na_2O	0.020	0.040
ntblK_2O	0.050	1.24
P_2O_5	0.113	0.073
CO_2	0.040	1.66
lt1C_{nekarb}	0.063	0.043
F	0.027	0.042
S	0.017	0.054
H_2O^+	7.41	7.45
H_2O^-	0.290	0.990
F_{ekv}	0.011	0.018
S_{ekv}	0.004	0.013
Σ	99.33	99.30

Other smaller, temporary outcrops of shales of the Šárka Formation in the NW part of Prague, i.e., at Praha-Vokovice, yielded either only poor faunas not allowing a well-based comparison, or are evidently younger, corresponding to layer No. 3 and higher portions of the sequence of the Šárka Formation described by Bouček (1927).

Conclusion

The lowermost part of the Šárka Formation in the NE part of the Barrandian, developed in the shale facies, shows fauna comparable with the near, but surprisingly also with distant localities (see discussion in Kraft and Kraft 2003, this volume). As suggested by the dominance of pelagic organisms (graptolites, phyllocarids) and the absence or very rare occurrence of benthic organisms (e.g. echinoderms and articulate brachiopods), this fauna sufficiently documents the lower (including the lowest) part of the Šárka Formation. The described faunal assemblage is well distinguishable from younger faunas, assigned by Havlíček and Vaněk (1990) to their "Euorthisina--Placoparia Community".

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Plate I
A photographic documentation of the temporary excavation on Červený vrch Hill in Prague.

1 – An orange-coloured uppermost part of the volcanic horizon (layers Nos. –2 and –1) and lowermost parts of the dark grey shale sequence (layers Nos. 1–3).

2 – A separate outcrop with common siliceous concretions, a detail of the bedding plane.

3 – A detail of the strongly weathered, red-coloured volcanics.

Plate II

1 – The most fossiliferous part of the shale sequence (layer No. 8) with rich graptolite and dendroid fauna.

2 – The most fossiliferous part of the shale sequence (layer No. 8) with rich graptolite and dendroid fauna.

3 – Upper parts of the shale sequence (layers Nos. 11–14).