FOSSIL IMPRINT • vol. 72 • 2016 • no. 3-4 • pp. 215–224
(formerly ACTA MUSEI NATIONALIS PRAGAE, Series B – Historia Naturalis)

NATIONAL MUSEUM

FOSSIL FAUNA AND FLORA OF A RE-DISCOVERED LOCALITY IN THE LATE CARBONIFEROUS PLOUŽNICE HORIZON OF THE KRKONOŠE PIEDMONT BASIN, BOHEMIAN MASSIF

STANISLAV ŠTAMBERG[1,5,*], JÖRG W. SCHNEIDER[2,4], RALF WERNEBURG[3]

[1] Museum of Eastern Bohemia, Eliščino nábřeží 465, 500 01 Hradec Králové, the Czech Republic; e-mail: s.stamberg@muzeumhk.cz.
[2] Technische Universität Bergakademie Freiberg, Institut für Geologie, Cotta-Straße 2, D-09596 Freiberg, Germany; e-mail: Joerg.Schneider@geo.tu-freiberg.de.
[3] Naturhistorisches Museum Schloss Bertholdsburg Schleusingen, Burgstraße 6, D-98553 Schleusingen, Germany; e-mail: werneburg@museum.schleusingen.de.
[4] Kazan Federal University, Kremlyovskaya str. 18, 420008 Kazan, Russia.
[5] Faculty of Arts, University of Hradec Králové, Centre of Interdisciplinary Research, Rokitanského 62, 500 03 Hradec Králové, the Czech Republic.
* corresponding author

Štamberg, S., Schneider, J. W., Werneburg, R. (2016): Fossil fauna and flora of a re-discovered locality in the Late Carboniferous Ploužnice Horizon of the Krkonoše Piedmont Basin, Bohemian Massif. – Fossil Imprint, 72(3-4): 215–224, Praha. ISSN 2533-4050 (print), ISSN 2533-4069 (on-line).

Abstract: Here we present preliminary information on the fossil content of a rediscovered fossiliferous locality in the Late Carboniferous (Stephanian; Kasimovian/Gzhelian) Ploužnice Horizon, Semily Formation, in the Krkonoše Piedmont Basin of the Bohemian Massif. Several meters thick reddish to grey tuffaceous siltstones of this lacustrine horizon contain centimetre thick bone-bed layers and sporadically distributed plant remains. Common are isolated fish remains of actinopterygians, chondrichthyans, and acanthodians as well as isolated insect wings, mainly from blattoids. The biostratigraphic age is determined by blattoid insects as Stephanian B/C (Kasimovian/Gzhelian).

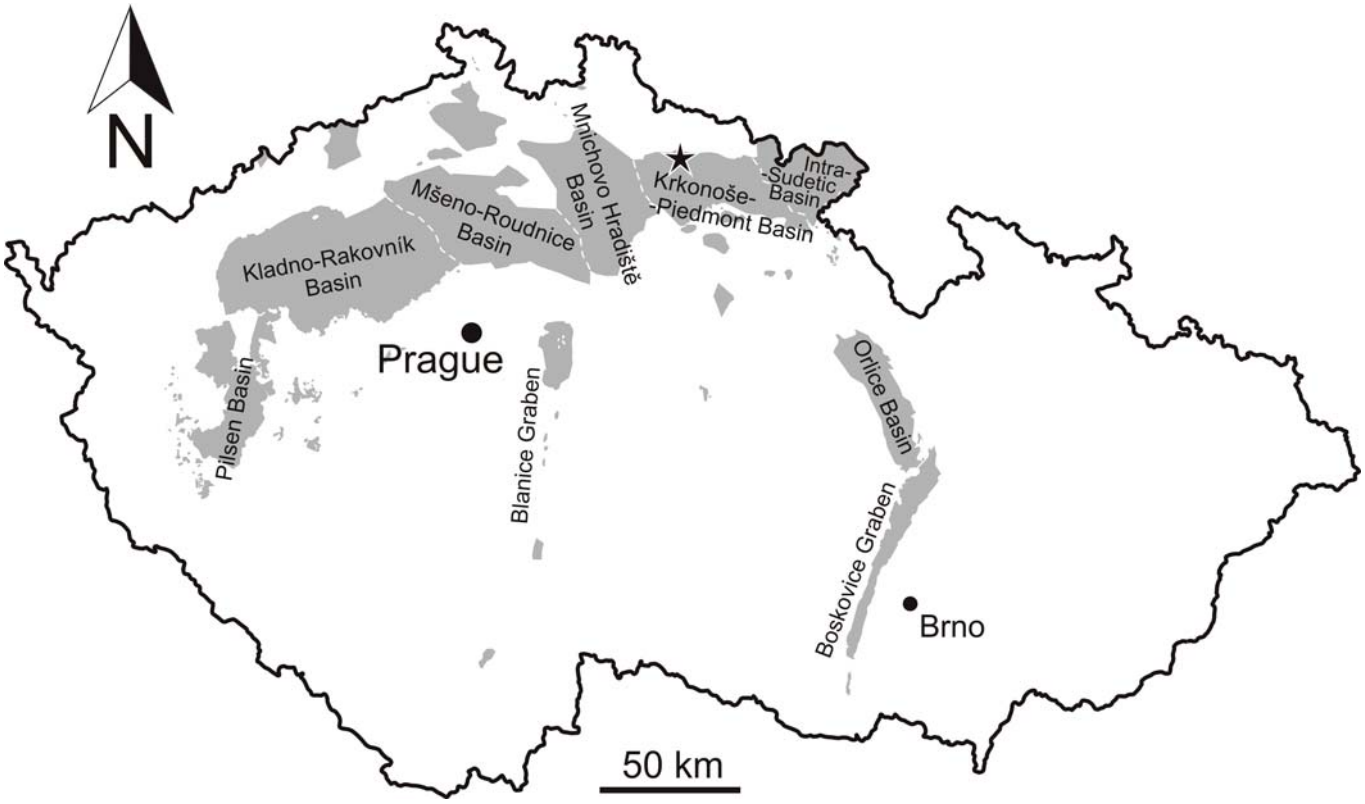
Key words: Carboniferous, Spiloblattinidae, Sphenacanthidae, Acanthodii, Actinopterygii, Krkonoše Piedmont Basin, Bohemian Massif

Received: October 4, 2016 | Accepted: November 6, 2016 | Issued: December 30, 2016

Introduction

The Late Palaeozoic Krkonoše Piedmont Basin (KPB) is up to 1100 km^2 in size, extending in an E-W direction and is situated in the north-eastern region of the Bohemian Massif in the Czech Republic (Text-fig. 1). As part of the Sudetic basins it belongs together with the Central and Western Bohemian basins to a 300 km long and more than 70 km wide system of extensional intramontane basins that originated in the early post-orogenic phase during the Middle to Late Visean (Intra-Sudetic Basin) but mainly during the Westphalian (Martínek et al. 2006, Opluštil et al. 2014, 2016a, b). The basin fill of the KPB consist of roughly 1800 m of continental sediments, discontinuously deposited from Westphalian D (late Moscovian) to the earliest Triassic (for details see Opluštil et al. 2016b).

Lists of the fossiliferous localities of Stephanian age in the KPB were published by Blecha et al. (1997), Zajíc (2007) and Štamberg and Zajíc (2008). The Ploužnice Horizon of the Stephanian Semily Formation is one of the palaeontologically and biostratigraphically important horizons in the KPB. Fauna and flora were collected from this horizon already at the end of 19th century (Frič 1912a, b). There are several, but mainly brief, descriptions and notes on the position of outcrops in the Ploužnice Horizon in the vicinity of the Ploužnice village, i.e. in the area between the villages Kyje and Žďár u Kumburku. The earliest and best descriptions were written by Frič (1912a, b) about an outcrop in the railway cut between Ploužnice and Kyje at the kilometre stone 61.2. Frič (1912a, b) published a profile of the outcrop with a layer of dark-red shale which he called the bone-bed. He mentioned a second locality with tetrapod tracks in this railway cut at the kilometre stone 60.5, close to Kyje and near the former Menzl's quarry. Further information on fossiliferous outcrops in the vicinity of Ploužnice is very limited. Kamarád (1959) reported the discovery of conchostracans and insect wings in a road cut near the hamlet of Smita between Ploužnice and Žďár u Kumburku. He collected the fossils from violet claystones in a 2–3 m high slope near the road. Blecha et al. (1997) identified several outcrops along the railway cut Ploužnice – Kyje with sporadic occurrences of isolated scales of actinopterygians and tetrapod tracks.

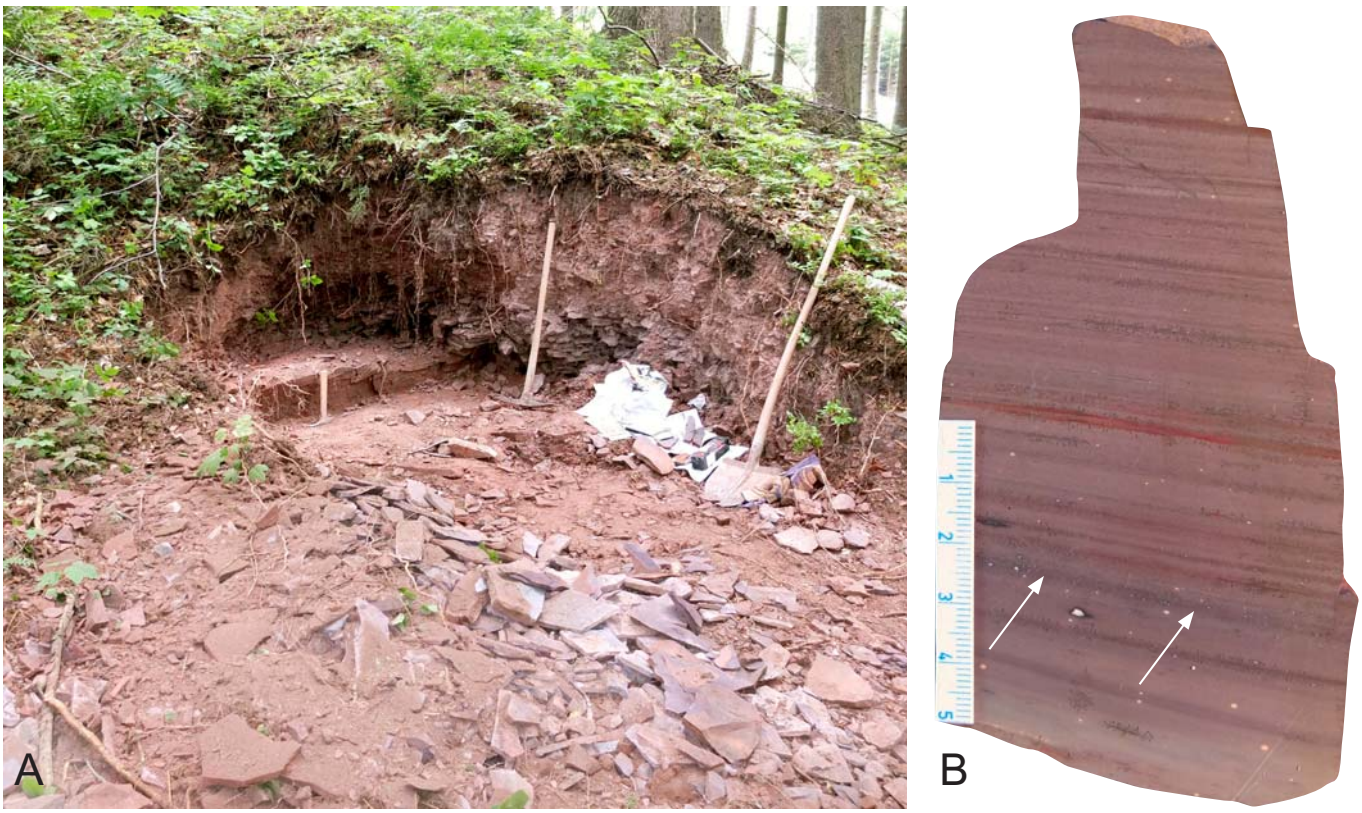


Text-fig. 1. Map of the Carboniferous-Permian non-marine basins of the Czech Republic; the star indicates roughly the position of the locality Ploužnice in the north-western part of the Krkonoše Piedmont Basin (according to Opluštil et al. 2016b).

Several museums store important insect specimens from the Ploužnice horizon labelled simply as "Kyje" without further details to the locality and information on the collector, as, e.g., the National Museum, Prague, and the Municipal Museum Nová Paka (Schneider 1982). Fish scales and other isolated vertebrate remains from the locality Žďár u Kumburku are stored in the collection of the Geologische Bundesanstalt in Vienna (Štamberg 2016). The exact outcrop position of the Kyje locality with apparently many finds of insect wing remains unknown so far. The occurrence of scales, teeth and other isolated fragments of actinopterygians in fieldstones of reddish siltstones on farmland near Žďár u Kumburku on the NE side of the road Ploužnice – Žďár u Kumburku was verified in recent years by the private collector M. Lapacík. Zajíc (2013) mentioned localities with fauna and flora in the vicinity of Ploužnice. Šimůnek and Mencl (2013) named one locality behind the last house in Ploužnice on the left side of the road leading to Jičín where K. Havlata and Z. Rieger in the sixties of the last century found isolated vertebrate remains and insect wings. During the last decades the authors of this paper sporadically tried to find Frič's (1912a, b) bone-bed horizon and the mysterious insect locality "Kyje" without any real success. Only in the late seventies of the last century one of us (JWS) re-discovered the bone bed in the railway cut between Ploužnice and Kyje and gave some samples of isolated fish remains (e.g. acanthodian spines) from that bed to be added to the collections of the Institute of Geology and Palaeontology of the Charles University, Prague. But, already 20 years later we have been unable to find that horizon again. Only in 2015 during extensive joint fieldwork by the authors, an outcrop with the typical reddish to violet tuffaceous siltstones and pyroclastics containing bone bed like layers of vertebrate remains and insect wings was discovered on the steep road slope at the southern entrance of Ploužnice. In the following a first report on this locality and its fossil content is presented.

Geological setting and taphonomy

The Krkonoše Piedmont Basin originated in the Late Westphalian (Opluštil et al. 2014, 2016b). During the deposition of the Stephanian Semily Formation it had an asymmetric halfgraben structure with a steep northern basin margin and a low gradient southern margin, which is indicated by the facies pattern of the lacustrine Ploužnice Horizon and Štěpanice-Čikvásky Horizon. Both several tens of meters thick horizons are stratigraphically equivalent but contain different types of sediments (Tásler et al. 1981, Prouza and Tásler 2001, Opluštil et al. 2013). The Štěpanice-Čikvásky Horizon extends along the northern basin margin and consists of two lacustrine intervals of mainly green to grey mudstones and greyish-black finely laminated bituminous claystones and intercalated mineable coals (Opluštil et al. 2016b). Both lacustrine levels are separated by tens of meters thick fluvial red beds. Its lithostratigraphical equivalent, the Ploužnice Horizon, is situated in the southern part of the basin and also consists of two lacustrine horizons several tens of meters thick. Typical



Text-fig. 2. A – First small excavation trench in the newly discovered fossiliferous outcrop area of the Ploužnice lake horizon, locality "Small Ravine" south of the village Ploužnice on the slope of road No. 286. Typical are the red, violet and varicoloured tuffaceous siltstones. Semily Formation, Late Stephanian, Krkonoše Piedmont Basin. B – Basal part of fossiliferous 12 cm to14 cm thick reddish to purple-red tuffaceous siltstone bed from the trench in Text-fig. 2A. Internal bedding is expressed as horizontal but with diffuse changes in grain size from fine silt to coarse, fine sandy silt. Intercalated in places are 3 to 5 mm thick layers (indicated by arrows) with patchy concentrations of isolated fish remains, especially in the first 3 centimetres of this siltstone layer. The large white spot at 2.5 cm is a coprolite fragment.

are varicoloured pale grey, violet and red siltstones and claystones with a high content of redeposited volcanic ashes, ripple bedded sandstones, intercalated red cherts and in situ pyroclastics (Prouza and Tásler 2001, Opluštil et al. 2013, 2016b, Stárková et al. 2015). The newly discovered fossiliferous locality in the Ploužnice Horizon is situated on the south-eastern border of Ploužnice village in a small ravine on a forested slope on the left side of the road leading to the village of Bradlecká Lhota. It is named here as Ploužnice "Small Ravine", the coordinates are 50°30'41.800" N; 15°23 '6.600" E. A first short trench in the middle part of the ravine in the tens of meters thick sequence of lacustrine, gray siltstones and violet and red, variegated, tuffaceous siltstones represents a typical fossiliferous section within the whole unit (Text-fig. 2A). The base of the outcrop exposes greenish sandstones without any fauna and flora remains. Above them a nodular chert of 10 to 14 cm thickness occurs. It consists internally of cm thick layers of clast-supported roundish to oval yellowish to reddish chert aggregates of 0.5 to 1 mm diameter in a matrix of pure, crystalline quartz or yellowish whitish chert. Fining up grading in a 2 to 3 cm scale could be observed from chert aggregates of mainly 1 mm to 0.5 mm diameter. The chert aggregates usually have a very fine whitish fringe. Not rare are sub-millimetre thin and 1.5 to 5 mm long, weakly bended shells (conchostracans?), in places enveloped by a chert aggregate. Rare are isolated ostracod shells of < 1 mm in size. Above the nodular chert follows a fossiliferous 12 cm to 14 cm thick reddish to purple-red tuffaceous siltstone. The internal bedding is expressed as horizontal but diffuse changes in grain size from fine silt to coarse, fine sandy silt (Text-fig. 2B). Very common are sub-millimetre long rusty brown streaks, which may be altered biotites. White mica is common. Intercalated are in places 3 to 5 mm thick layers with patchy concentrations of isolated fish remains, especially in the first three centimetres of this siltstone layer. This is similar to what Frič (1912a, b) called the "bone bed" in the Ploužnice railway cut. In addition to actinopterygian scales and teeth, fragments of acanthodians, and freshwater sharks, it contains not rarely insect wings as well as abundant *Cordaites* leaves and other plant remains. All these fossils occur also in other layers of this kind of tuffaceous siltstone but not in this frequency. A 30 cm thick reddish siltstone forms the uppermost part of the trench. Fragments of plants and rare isolated scales occur only in the lower 10 cm thick part of this bed.

Taphonomically interesting is the dark red iron-oxide preservation of plant remains and insect wings (e.g. Pl. 1, Figs 1, 2, 4). Possibly it was primary pyrite that became oxidised very early during sedimentation or in early diagenesis. The fish remains often occur in fine sandy silt layers. The quartz and feldspar grains of the fine sand are subrounded but the scales, teeth and other isolated skeletal

elements show no signs of abrasion due to longer transportation (Pl. 1, Fig. 5). Therefore, bone bed-like concentrations of ichtyolithes may be caused by low energy bottom currents only. Common phosphatic particles of 1 mm to several mm in size from fragmented coprolites support this interpretation. Even the indistinct bedding of the sediment points to deposition mainly from suspension, not from energetically higher currents.

Fossil content of the trench at the locality "Small Ravine" near Ploužnice

Flora

The plant remains from the new outcrop need to be exactly determined; here we give only a short preliminary overview. The specimens are stored in the Museum of Eastern Bohemia in Hradec Králové (MHK).

Pecopteris sp. – MHK 82648, MHK 82658, MHK 82659
?*Lepidostrobophyllum* cf. *lanceolatum* – MHK 82660
Odontopteris sp.
Walchia sp. (Pl. 1, Fig. 2) – very rare; MHK 82656, MHK 82657
Cordaites sp. (Pl. 1, Figs 1, 2) – MHK 82649 – 82655

Cordaite leaves with parallel nervation are the most abundant plant remains (MHK 82649 – MHK 82655) in the level of the bone-bed, and are less numerous in other parts of the horizon. Most leaves bear numerous small round spots (Pl. 1, Fig. 1). The same was already described by Šimůnek and Mencl (2013) from the near-by outcrop of the Ploužnice Horizon as hard fruiting bodies of the pyrenomycete fungus *Hysterites cordaitis* Grand'Eury. These spots are limited not only to *Cordaites* sp. but they are also common on other plants (*Walchia* sp., *Pecopteris* sp.). Now, they are interpreted as insect galls.

Fauna

The faunistic record is relatively diverse even though it consists of isolated fish remains and insect wings only. All specimens are housed in the Museum of Eastern Bohemia in Hradec Králové (MHK); only the better preserved specimens are designated here with their collection numbers.

Insecta Linnaeus, 1758

Most common are isolated wings of blattoid insects (cockroachoids), e.g. MHK 82638 – MHK 82644. Some of them belong to the family Spiloblattinidae (Pl. 1, Figs 1, 4), which are very important for Late Carboniferous and Early Permian biostratigraphy in the whole Euramerican realm (see below and Schneider and Werneburg 2006, 2012, Schneider et al. 2013). As known so far, the entomofauna of the Ploužnice horizon show the typical late Stephanian composition (Schneider 1983).

Chondrichthyes Huxley, 1880
Sphenacanthidae Maisey, 1982
Turnovichthys magnus Štamberg, 2001

Specimens MHK 82592 and MHK82601 represent terminal fragments of large spines. The fragments of the spines carry conspicuous, longitudinally arranged ribs that converge towards the tip of the spine (Pl. 1, Fig. 3). The spine wall is formed by trabecular dentine. The finds of these large spines suggest the presence of a large sphenacanthid elasmobranch in the Ploužnice lake as previously demonstrated by Štamberg (2001) with the *Turnovichthys magnus* spine from the Ploužnice Horizon in the locality Krsmol. Additionally, typical sphenacanthid placoid scales (Pl. 1, Fig. 5) and tooth fragments were found.

Xenacanthidae Fritsch, 1889
Orthacanthus sp.

Single fragmentary teeth, but with the typical serration on the cutting edges of the cusps, indicate the unquestionable presence of this large predator in the Ploužnice lake.

Coprolites

Coprolites are relatively abundant. Well preserved specimens MHK 82632 – MHK 82637 of 3–4.5 cm length are oval in shape and tapering at one terminal point. The spiral convolution is usually well preserved (Pl. 1, Fig. 6). The shape and the spiral convolution support their classification to sharks as type 4, heteropolar macrospiral, of Hunt and Lucas (2012).

Acanthodii Owen, 1846
Acanthodes sp.

Remnants of the acanthodians are represented by isolated scales (MHK 82616, MHK 82600) and fragments of the pectoral girdle (MHK 82600, MHK 82626).hey are much rarer than the remains of actinopterygians. The shape of the pectoral girdle with a relatively strong scapular blade (Pl. 2, Fig.1) is in agreement with the shape of these bones in *Acanthodes* sp. as described from the Bohemian Stephanian by Zajíc (1998).

Actinopterygii Cope, 1877
Elonichthyidae Aldinger, 1937
"*Elonichthys*" sp.

Isolated scales and small teeth are the most abundant fish remains. The scales (MHK 82591, 82594, 82615) possess sculptures of diagonal ridges. The longest ridge pass diagonally from the anterodorsal corner to the posteroventral corner of the scale, and it divides the outer surface of the scale into the posterodorsal and anteroventral halves. Diagonal ridges similar to the ridges above terminate in pointed processes on the posterior margin of the scale. The ridges below the diagonal ridge do not reach the posterior border of the scale. It conforms to the sculpture of scales described by Štamberg (2016) as "*Elonichthys*" sp.

The teeth are slender and sharply pointed (MHK 82591, 82616, 82625) with a distinct acrodentine apex (Pl. 2, Fig. 2). They are one or two millimetres long. Some teeth exhibit well preserved, lanceolate microtubercles on their surface (Pl. 2, Fig. 3), despite the fact that the surface of the teeth is often abraded due to transport processes. An isolated crescent shaped nasal bone with longitudinal ridges (MHK 82611) completes the set of "*Elonichthys*" sp. remains.

Pygopteridae Aldinger, 1937
Progyrolepis sp.

Only one tooth (MHK 82631) and one fragment of a scale (MHK 82620) can be considered to be from *Progyrolepis* sp. The tooth is 2.5 mm long, with a broad base and not as slender as in "*Elonichthys*" sp. The scale has strong ridges on its surface, and no diagonal ridge dividing the outer surface of the scale into dorso-posterior and ventro-anterior halves as in "*Elonichthys*" sp.

Aeduellidae Romer, 1945
Spinarichthys dispersus (Fritsch, 1895)

Abundant scales (MHK 82589, 82599, 82604, 82614, 82622) with a conspicuous dorsal projection of peg and socket articulation. Scales are posteriorly pectinated. Outer surfaces of the scales are smooth, but under high magnification regularly distributed tubercles can be identified on the outer surface of the scales (Pl. 2, Fig. 5).

Trissolepidae Fritsch, 1893
Sphaerolepis kounoviensis Frič, 1877

Remains of *Sphaerolepis kounoviensis* are represented by isolated scales and skeletal fragments. The scales show a typical cycloidal shape with circuli (MHK 82593, 82620). Numerous isolated ridge scales and fulcral scales with smooth surfaces (MHK 82605, 82608, 82627) probably also belong to *Sphaerolepis kounoviensis.* Several jaw fragments (Pl. 2, Fig. 6) also contain teeth (MHK 82589, 82610, 82628). The teeth are all of the same size, with a cylindrical shape and terminate conically, without any grooves on their surface. A cleithrum (MHK 82613, 82618) has a narrow, dorso-ventrally elongated branch and a horizontal branch that projects towards the slender, conspicuous process anteriorly. A well preserved isolated parasphenoid (MHK 82630) belongs as well to *Sphaerolepis kounoviensis*. The sample shows the parasphenoid in dorsal view (Pl. 2, Fig. 4), but an area with missing bone on the counterpart demonstrates also the ventral part of this element. The corpus of the parasphenoid has an anteriorly prolonged processus cultriformis and there is also a significantly extended posterior region of the corpus parasphenoidis, which is also typical for *Sphaerolepis kounoviensis* (Štamberg and Zajíc 2000, Štamberg 2013). The pair of processus ascendens project at an angle of 40°–50° to the axis of the corpus parasphenoidis. The large bucco-hypophysial foramen is situated in the centre of the parasphenoid. The ventral surface of the parasphenoid carries numerous sharply pointed teeth. The tooth patch extends around the bucco-hypophysial foramen.

Discussion and Conclusions

The first relatively restricted excavations in the newly discovered locality Ploužnice "Small Ravine" close to the village Ploužnice in the Ploužnice lake horizon of the Semily Formation, late Carboniferous of the Krkonoše Piedmont Basin, have produced an interesting fossil content. The flora is of mesophilous character, dominated by cordaite leaves; walchian twigs are rare but well preserved, pointing to dry stands surrounding the lake. Isolated fish remains are common, likewise wings of blattoid insects. The fish fauna is typical of the Late Carboniferous Bohemian basins (Štamberg 2016). Most common are actinopterygian fishes such as "*Elonichthys*" sp., *Progyrolepis* sp., *Spinarichthys dispersus* and *Sphaerolepis kounoviensis*, not uncommon is *Acanthodes*. The top predators of the lake were freshwater sharks such as *Turnovichthys magnus* and the larger *Orthacanthus*. The presence of both freshwater sharks points to the typical Late Carboniferous shark association of perennial lakes in the European basins consisting of *Orthacanthus*, *Bohemiacanthus*, *Xenacanthus*, *Lissodus* and sphenacanthids such as *Turnovichthys* (Schneider and Zajic 1994, Schneider 1996). This association, still incomplete due to sampling biases in the case of the Krkonoše Piedmont Basin, is proven (more or less complete) from the Puertollano Basin in Spain via the Guardia Pisano Basin of Sardinia, Italy, the Saar-Nahe Basin, the Thuringian Forest Basin, and the Saale Basin in Germany, the Western and Central Bohemian basins in the Czech Republic up to the Donetsk Basin in the Ukraine (e.g. Schneider and Zajíc 1994, Schneider 1996, Schneider et al. 2000, Fischer et al. 2010). This very wide palaeobiogeographical distribution is interpreted as being the result of changing interconnections of the dewatering (river) systems during the Late Carboniferous enabling the migration of sharks between all larger basins of the European Variscides, perhaps also including the North American Appalachian basins. After the Franconian movements at around 300 Ma, the interconnections of the Carboniferous basins became interrupted by palaeogeographical changes and basin reorganisation (e.g. Schneider et al. 1995, Fischer et al. 2010, Opluštil et al. 2016a, b). Consequently, the shark faunas were impoverished in most of these basins because of interruptions in lake development linked with local extinctions and missing river connections for re-immigrations. The restricted shark fauna of post-Franconian time consists mostly of *Xenacanthus* and *Bohemiacanthus* only (see Schneider and Zajíc 1994: fig. 29 and Schneider 1996: fig. 10). Exceptions are the Permian Saar-Nahe Basin and the French Bourbon-l´Archambault Basin (Buxières) in which beside the xenacanthids, orthacanthid sharks and the hypodontid *Lissodus* exist up into the Late Lower Rotliegend or the Artinskian, respectively. Future taxonomical studies of the actinopterygians faunas in the European basins outside the well investigated Czech basins will give more detailed and exact information on the migration pattern of fishes and thus of basin interconnections and the development of river systems in space and time (e.g. Štamberg 2010, 2016).

The age of the Ploužnice horizon is still under discussion. According to Schneider and Werneburg (2006, 2012) the Ploužnice horizon, which is the type horizon of *Sysciophlebia rubida* Schneider, 1982, belongs to the *Sysciophlebia rubida*-*Syscioblatta lawrenceana*-zone. The type horizon of *Syscioblatta lawrenceana*, which co-occurs with *S. rubida* in the Ploužnice lake horizon (Schneider and Werneburg 2012), is the Lawrence Shale of the Lawrence Formation, Douglas Group, Midcontinent basin, Kansas. This formation belongs to the Cass cyclothem at the base of the Virgilian and is assigned to the *Streptognathodus zethus* conodont-zone at the very base of the Virgilian, which corresponds to latest Kasimovian (e.g. Barrick et al. 2013; for details see

Schneider and Scholze 2016 in press). The upper range of this zone is defined by the base of the *Sysciophlebia euglyptica-Syscioblatta dohrni* zone, which has a base that is definitely older than 300 Ma and may be situated in the middle Gzhelian (Stephanian C) estimated at 302 Ma (Schneider et al. 2013: fig. 4). Opluštil et al. (2016a) correlated the Ploužnice lake horizon with the Klobuky lake horizon of the Líně Formation in the Central and Western Bohemian basins. An ash bed within the Klobuky lake horizon gives a CA-ID-TIMS age of 298.97+/–0.09 Ma, which is just at the Gzhelian/Asselian boundary of 298.9 Ma (Opluštil et al. 2016a). This age is transferred to the Ploužnice horizon by Opluštil et al. (2016a, b). The time difference between the latest Kasimovian/earliest Gzhelian age, based on insects and the assumed isotopic age of the Ploužnice lake horizon according to Opluštil et al. (2016a) is roughly 3 Ma to 4 Ma. This is too much even in continental deposits and needs to be explained. Possibly the lithostratigraphic correlation of the Ploužnice horizon of the Krkonoše Piedmont Basin with the Klobuky horizon of the Central and Western Bohemian basins (as in Opluštil et al. 2016a) is not correct as discussed in Schneider and Scholze (2016 in press). Both horizons are more than 50 km apart from one another and situated in different basins – it is a well-known fact that even within the same basin the correlation of outcrops in lake horizons could be a very difficult task. Opluštil et al. (2016b) added further arguments for the correlation of the Klobuky with the Ploužnice lake horizon based on the macroflora and fish remains, but both plants and fishes do not allow such precise correlations in the opinion of the second author of this paper (JWS). On the other hand, misidentifications of the insect zone species, especially of *S. lawrenceana* in the Ploužnice horizon, could not be excluded. Fortunately, the new locality is very rich in blattoid insects, especially in spiloblattinids, which are used for insect biostratigraphy. Further excavations will produce enough specimens for a taxonomical and thus biostratigraphical reinvestigation of the insect zone species in the Ploužnice horizon. Additionally, the pyroclastic layers in this horizon will be used for isotopic age determination which would support the chronostratigraphic calibration of the biostratigraphy and a link to the Standard Global Time Scale.

Acknowledgments

SŠ is very grateful to the private collector M. Lapacík for donating some samples for study purposes, and to L. Váchová for assistance with SEM at the Paleontological Department of the National Museum, Prague. This is a contribution to the Internal project No 160019 of the Museum of Eastern Bohemia in Hradec Králové. The authors are grateful to the reviewers Spencer G. Lucas and Stanislav Opluštil for the very careful reviews which greatly improved the manuscript. JWS thanks the German Research Foundation, grant numbers SCHN 408/21 and SCHN 408/22, for financial support of the fieldwork and further investigations. Additionally, this study was supported by the Russian Government Program of Competitive Growth of Kazan Federal University. The publication aims to contribute to the tasks of the Non-Marine – Marine Late Carboniferous – Permian – Early Triassic Working Group of the respective International Subcommissions on Stratigraphy of the IUGS. Thanks go to Stanislav Opluštil and his team for long term cooperation and extensive discussions on the correlation of European Carboniferous and Permian basins.

References

Barrick, J. E., Lambert, L. L., Heckel, P. H., Roscoe, S., Boardman, D. R. (2013): Midcontinent Pennsylvanian Conodont Zonation. – Stratigraphy, 10: 55–72.

Blecha, M., Martínek, K., Drábková, J., Šimůnek, Z., Zajíc, J. (1997): Environmental changes at the Carboniferous/Permian boundary and their impact on floral and faunal assemblages of the fossiliferous lacustrine horizons of the Krkonoše Piedmont Basin; Final Report of project GAČR 205/94/0692. – MS, Czech Geological Survey, Prague, Czech Republic, 177 pp. (copy in library of Czech Geological Survey, Prague)

Fischer, J., Schneider, J. W., Ronchi, A. (2010): *Lissodus* (Hybodontoidea) from the Permocarboniferous (Gzehlian/Asselian) of Guardia Pisano (Sardinia, Italy). – Acta Palaeontologica Polonica, 55(2): 241–264. https://doi.org/10.4202/app.2009.0019

Frič, A. (1912a): Studie v oboru českého útvaru permského [Studies of Permian Formation in Bohemia]. – Archiv pro přírodovědecký výzkum Čech, 15(2): 1–48. (in Czech)

Frič, A. (1912b): Studien im Gebiete der Permformation Böhmens. – Archiv für die naturwissenschaftliche Landesdurchforschung Böhmens, 15(2): 1–52.

Hunt, A., Lucas, S. G. (2012): Descriptive terminology of coprolites and recent feces. – New Mexico Museum of Natural History and Science, Bulletin, 57: 153–160.

Kamarád, L. (1959): Zpráva o paleontologickém výzkumu v podkrkonošském permu [Report of the Paleontological Research in Permian from Krkonoše Piedmont Basin]. – Zprávy o geologických výzkumech v roce 1957: 94. (in Czech)

Martínek, K., Blecha, M., Daněk, V., Franců, J., Hladíková, J., Johnová, R., Uličný, D. (2006): Record of palaeoenvironmental changes in a Lower Permian organic-rich lacustrine succession: Integrated sedimentological and geochemical study of the Rudník member, Krkonoše Piedmont Basin, Czech Republic. – Palaeogeography, Palaeoclimatology, Palaeoecology, 230: 85–128. https://doi.org/10.1016/j.palaeo.2005.07.009

Opluštil, S., Martínek, K., Lojka, R., Rosenau, N., Zajíc, J., Šimůnek, Z., Drábková, J., Štamberg, S. (2014): The Carboniferous – Permian basins of Central and Western Bohemia, the Krkonoše Mt. foreland and the Bohemian Massif, Czech Republic. – In: Schneider, J. W., Opluštil, S., Scholze, F. (eds), CPC-2014 Field Meeting on Carboniferous and Permian Nonmarine – Marine Correlation. July 21st–27th, Freiberg, Germany. Excursion Guide. Wissenschaftliche Mitteilungen des Institutes für Geologie 46, Technische Universität Bergakademie Freiberg, 14–54.

Opluštil, S., Schmitz, M., Cleal, C. J., Martínek, K. (2016a): A review of the Middle-Late Pennsylvanian west European regional substages and floral biozones, and their

correlation to the Global Time Scale based on new U-Pb ages. – Earth-Science Reviews, 154: 301–335. https://doi.org/10.1016/j.earscirev.2016.01.004

Opluštil, S, Schmitz, M., Kachlík, V., Štamberg, S. (2016b): Re-assessment of litostratigraphy, biostratigraphy, and volcanic activity of the Late Paleozoic Intra-Sudetic, Krkonoše-Piedmont and Mnichovo Hradiště basins (Czech Republic) based on new U-Pb CA-ID-TIMS ages. – Bulletin of Geosciences, 91(2): 399–432.

Opluštil, S., Šimůnek, Z., Zajíc, J., Mencl, V. (2013): Climatic and biotic changes around the Carboniferous/Permian boundary recorded in the continental basins of the Czech Republic. – International Journal of Coal Geology, 119: 114–151. https://doi.org/10.1016/j.coal.2013.07.014

Prouza, V., Tásler, R. (2001): Podkrkonošská pánev [Krkonoše Piedmont Basin]. – In: Pešek, J. et al. (eds), Geologie a ložiska svrchnopaleozoických limnických pánví České republiky [Geology and Deposits of Upper Palaeozoic Limnic Basins of the Czech Republic]. Český geologický ústav, Praha, pp. 128–166. (in Czech)

Schneider, J. (1982): Entwurf einer Zonengliederung für das euramerische Permokarbon mittels der Spiloblattinidae (Blattodea, Insecta). – Freiberger Forschungshefte, C, 375: 27–47.

Schneider, J. (1983): Die Blattodea (Insecta) des Paläozoikums. Teil I: Systematic, Ökologie und Biostratigraphie. – Freiberger Forschungshefte, C, 382: 106–145.

Schneider, J. (1996): Xenacanth teeth – a key for taxonomy and biostratigraphy. – Modern Geology, 20: 321–340.

Schneider, J. W., Scholze, F. (2016 in press): Late Pennsylvanian to Early Triassic conchostracan biostratigraphy – a preliminary approach. – In: Lucas, S. G., Shen, S. (eds), The Permian Timescale. Geological Society, London, Special Publication.

Schneider, J. W., Werneburg, R. (2006): Insect biostratigraphy of the European late Carboniferous and early Permian. – In: Lucas, S. G., Cassinis, G., Schneider, J. W. (eds), Non-Marine Permian Biostratigraphy and Biochronology. – Geological Society, London, Special Publications, 265: 325–336. https://doi.org/10.1144/GSL.SP.2006.265.01.15

Schneider, J. W., Werneburg, R. (2012): Stratigraphie des Rotliegend mit Insekten und Amphibien. – In: Lützner, H., Kowalczyk, G., Deutsche Stratigraphische Kommission (eds), Stratigraphie von Deutschland X: Rotliegend Teil I: Innervariscische Becken. Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften, 61: 110–142.

Schneider, J., Zajíc, J. (1994): Xenacanthiden (Pisces, Chondrichthyes) des mitteleuropäischen Oberkarbon und Perm – Revision der Originale zu Goldfuss 1847, Beyrich 1848, Kner 1867 und Fritsch 1879–1890. – Freiberger Forschungshefte, C, 452: 101–151.

Schneider, J. W., Hampe, O., Soler-Gijón, R. (2000): The Late Carboniferous and Permian: Aquatic vertebrate zonation in Southern Spain and German basins. – In: Blieck, A., Turner, S. (eds), Palaeozoic Vertebrate Biochronology and Global Marine/Non-Marine Correlation. Final Report of IGCP 328 (1991–1996). Courier Forschungsinstitut Senckenberg, 223: 543–556.

Schneider, J. W., Rössler, R., Gaitzsch, B. (1995): Time lines of the Late Variscan volcanism – a holostratigraphic synthesis. – Zentralblatt für Geologie und Paläontologie, Teil I, H. 5/6: 477–490.

Schneider, J.W., Lucas, S.G., Barrick, J.E. (2013): The Early Permian age of the Dunkard Group, Appalachian basin, U.S.A., based on spiloblattinid insect biostratigraphy. – International Journal of Coal Geology, 119: 88–92. https://doi.org/10.1016/j.coal.2013.07.019

Schneider, J. W., Opluštil, S., Scholze, F. (eds) (2014): CPC-2014 Field Meeting on Carboniferous and Permian Nonmarine – Marine Correlation. July 21st–27th, Freiberg, Germany. Excursion Guide. – Wissenschaftliche Mitteilungen des Institutes für Geologie 46, Technische Universität Bergakademie Freiberg, 121 pp.

Stárková, M., Martínek, K., Mikuláš, R., Rosenau, N. (2015): Types of soft-sediment deformation structures in a lacustrine Ploužnice member (Stephanian, Gzhelian, Pennsylvanian, Bohemian Massif), their timing, and possible trigger mechanism. – International Journal of Earth Sciences, 104(5): 1277–1298. https://doi.org/10.1007/s00531-015-1155-5

Šimůnek, Z., Mencl, V. (2013): Fytopaleontologie svrchního karbonu a permu [Phytopalaeontology of Late Carboniferous and Permian]. – In: Stárková, K. et al., Vysvětlivky k základní geologické mapě České republiky 1:25 000, 03-431 Lomnice nad Popelkou [Comments to the basic geological map of the Czech Republic 1:25 000, 03-431 Lomnice nad Popelkou]. Česká geologická služba, Praha, pp.117–122. (in Czech)

Štamberg, S. (2001): Fin spine of a ctenacanthoid shark (Elasmobranchii, Ctenacanthoidea) from the Upper Stephanian of the Krkonoše Piedmont Basin (Bohemia). – Bulletin of the Czech Geological Survey, 76(2): 141–148.

Štamberg, S. (2010): A new aeduellid actinopterygian from the Lower Permian of the Krkonoše Piedmont Basin (Bohemian Massif) and its relationships to other Aeduellidae. – Bulletin of Geosciences, 85(2): 183–198. https://doi.org/10.3140/bull.geosci.1190

Štamberg, S. (2013): Knowledge of the Carboniferous and Permian actinopterygian fishes of the Bohemian Massif – 100 years after Antonín Frič. – Acta Musei Nationalis Pragae, Series B – Historia Naturalis, 69(3-4): 159–181. https://doi.org/10.14446/AMNP.2013.159

Štamberg, S. (2016): Actinopterygians of the Stephanian sediments of the Krkonoše Piedmont Basin (Bohemian Massif) and their palaeobiogeographic relationships. – Bulletin of Geosciences, 91(1): 169–186. https://doi.org/10.3140/bull.geosci.1582

Štamberg, S., Zajíc, J. (2000): New data on the osteology of actinopterygian fish *Sphaerolepis kounoviensis*. – Věstník Českého geologického ústavu, 75(4): 455–458.

Štamberg, S., Zajíc, J. (2008): Carboniferous and Permian faunas and their occurrence in the limnic basins of the Czech Republic. – Museum of Eastern Bohemia at Hradec Králové, Hradec Králové, 224 pp.

Tásler, R., Havlena, V., Prouza, V. (1981): Nové litostratigrafické členění centrální a západní části podkrkonošské pánve [New lithostratigraphic subdivision of central and western part of Krkonoše Piedmont Basin]. – Věstník

Ústředního ústavu geologického, 56(3): 129–143. (in Czech)
Zajíc, J. (1998): Acanthodians of the Bohemian Limnic Stephanian. – Czech Geological survey Special Papers, 10: 1–45.
Zajíc, J. (2007): Carboniferous Fauna of the Krkonoše Piedmont Basin. – Acta Musei reginaehradecensis, Series A, 32: 11–16.
Zajíc, J. (2013): Zoopaleontologie svrchního karbonu [Zoopalaeontology of Late Carboniferous]. – In: Stárková, K. et al., Vysvětlivky k základní geologické mapě České republiky 1:25 000, 03-431 Lomnice nad Popelkou [Comments to the basic geological map of the Czech Republic 1:25 000, 03-431 Lomnice nad Popelkou]. Česká geologická služba, Praha, pp. 125–127. (in Czech)

Explanations of the plates

PLATE 1

1. Tuffaceous siltstone with a 3 cm wide *Cordaites* leaf and a spiloblattinid cockroach wing (upper left corner) with the typical colour pattern. The round spots on the leaf (indicated by arrows) are interpreted as insect galls. Ploužnice lake horizon, locality "Small Ravine". MHK 82641. Scale bar 10 mm.
2. Tuffaceous siltstone with common plant remains. In the centre a walchian twig, on the right a cordaitalean leaf. Ploužnice lake horizon, locality "Small Ravine". MHK 82657.
3. Terminal fragment of a large spine of *Turnovichthys magnus* Štamberg, 2001. The spine carries conspicuous longitudinally arranged ribs which converge towards the tip of the spine. Ploužnice lake horizon, locality "Small Ravine". MHK 82601. Scale bar 10 mm.
4. Basal part of a spiloblattinid cockroach forewing with the diagnostic colour pattern. These wings are used for biostratigraphy. Length of the wing fragment 8 mm. Ploužnice lake horizon, locality "Small Ravine". MHK 82641. Scale bar 1 mm.
5. Typical multicuspid placoid scale (dermal denticle) of a sphenacanthid freshwater shark, most possibly of *Turnovichthys*. Ploužnice lake horizon, locality "Small Ravine". MHK 82821. Scale bar 1 mm.
6. Coprolite of oval shape with spiral convolution supporting its classification to sharks. Ploužnice lake horizon, locality "Small Ravine". MHK 82632. Scale bar 10 mm.

PLATE 2

1. *Acanthodes* sp. The pectoral girdle with a relatively strong scapular blade. Ploužnice lake horizon, locality "Small Ravine". MHK 82600. Scale bar 1 mm.
2. "*Elonichthys*" sp. Slender and sharply pointed tooth with a distinct acrodentine apex. Ploužnice lake horizon, locality "Small Ravine". MHK 82625. Scale bar 1 mm.
3. "*Elonichthys*" sp. Lanceolate microtubercles on the surface of the tooth from the previous figure. MHK 82625. Scale bar 100 μm.
4. *Sphaerolepis kounoviensis* Frič, 1877. Parasphenoid in dorsal view with the anteriorly extended processus cultriformis and significantly extended posterior region of the corpus parasphenoidis. Ploužnice lake horizon, locality "Small Ravine". MHK 82630. Scale bar 1 mm.
5. *Spinarichthys dispersus* (Fritsch, 1895). Outer surface of the scales is smooth, but under high magnification regularly distributed tubercles on the outer surface of the scale can be seen (indicated by arrows). Ploužnice lake horizon, locality "Small Ravine". MHK 82599. Scale bar 50 μm.
6. *Sphaerolepis kounoviensis* Frič, 1877. Anterior blade of the left maxilla in lateral view with fragments of teeth. Ploužnice lake horizon, locality "Small Ravine". MHK 82589. Scale bar 1 mm.

PLATE 1

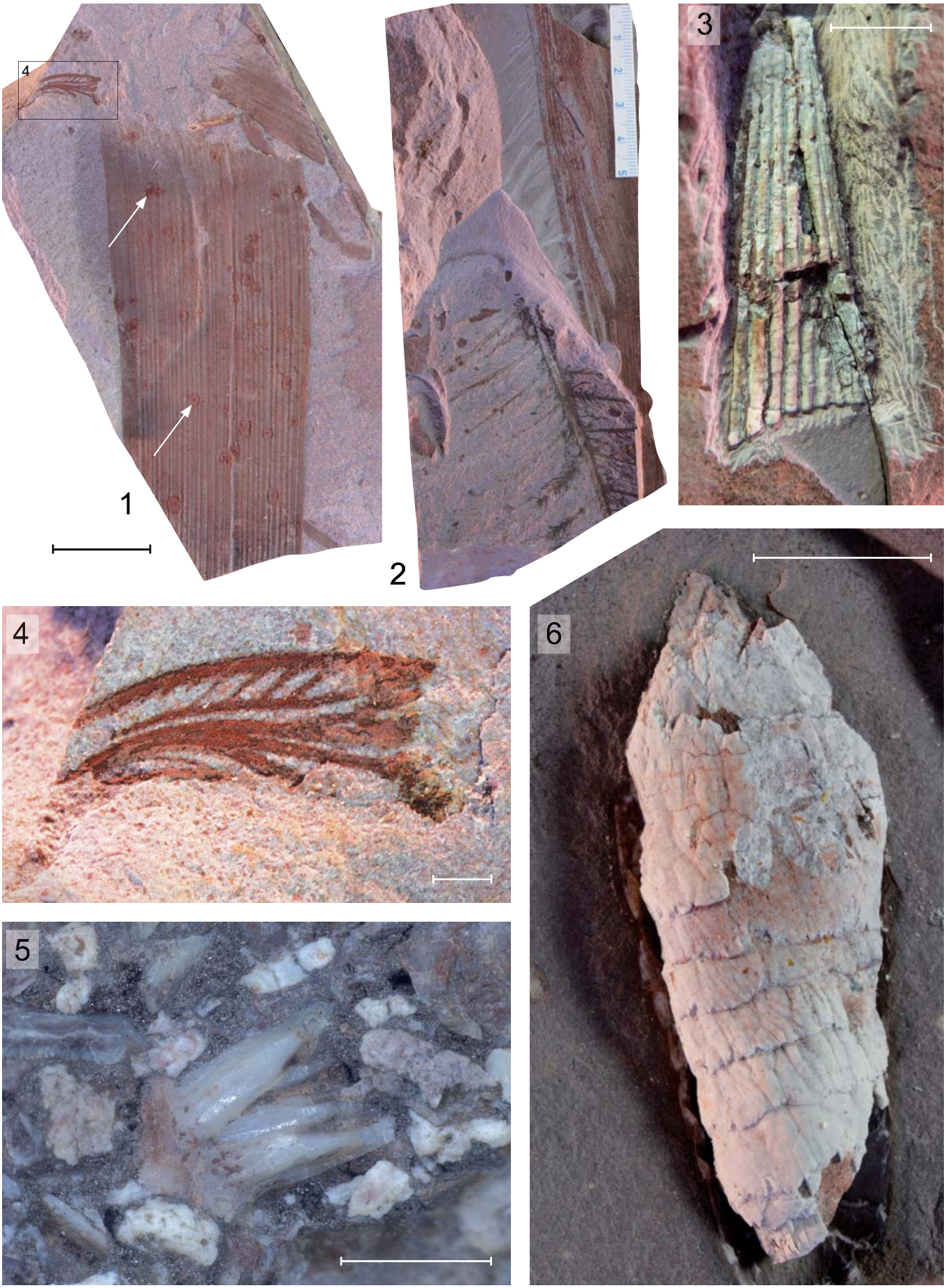


PLATE 2