VERSITA
DOI: 10.2478/fbgp-2013-0006
**Folia vol. 47, No. 1-2, 2013**

# SUMMARY OF OCCURRENCE AND TAXONOMY OF SILICIFIED *AGATHOXYLON*-TYPE OF WOOD IN LATE PALEOZOIC BASINS OF THE CZECH REPUBLIC

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**Abstract:** *The late Paleozoic deposits in several basins in the Czech Republic are well known for their abundance of silicified stems. Despite the fact they have been known since 19th century, there are few modern works of this material. The stems have been known to occur at several stratigraphic levels. During the course of recent field work such material has been found at additional levels. Most of them belong to the genus* Agathoxylon*, divided here into two types: cordaitalean plants and conifers. Based on previous data from Intra Sudetic and Pilsen Basins, and new material from Krkonoše Piedmont and Kladno-Rakovník Basins, this work compiles and compares the occurrence, anatomical features and taxonomy of silicified* Agathoxylon*-type of stems through four studied areas. The various cordaitalean – conifer ratio among all basins reflect different palaeoenvironment in each of them.*

**Key words:** silicified wood, stem anatomy, *Agathoxylon*-type of wood, cordaitaleans, conifers, late Paleozoic, Czech Republic.

## 1. INTRODUCTION

Silicified araucarioid wood is an important element of the floras from the late Paleozoic Czech basins. There are several papers which recently described this type of wood from different parts of the Bohemian Massif (e.g., Matysová, 2006; Mencl, 2007; Mencl et al., 2009; Holeček, 2011; Bureš, 2011, 2013; Opluštil et al., 2013).

The nomenclature of araucarioid wood has been often discussed, and several various names have been applied to this wood over time (e.g., *Dadoxylon* Endlicher, *Agathoxylon* Hartig, *Araucarioxylon* Kraus, and *Dammaroxylon* J. Schultze-Motel). Present palaeoxylologists generally prefer the use of term *Agathoxylon* for such wood (Rößler et al., in press) and we follow this usage herein.

## 2. HISTORICAL INSIGHT

### 2.1. Krkonoše Piedmont Basin

Silicified plant remains in area of Nová Paka (Figure 1) have been known for many years. Their occurrence was first mentioned, as far as we can ascertain, by Maloch (1844) (see Heber, 1844) who described stems in the villages of Pecka and Stupná. Goeppert (1858) presented the first scientific description of the conifer wood *Araucarites schrollianus* (= *„Dadoxylon“ saxonicum*; synonym: *„Dadoxylon“ schrollianum*), as well as calamitalean wood and stems of ferns from Kozinec, Nová Paka and Pecka. Occurrences of *Medullosa, Psaronius* and *Agathoxylon* stems and the existence of silicified peats in Nová Paka and Lázně Bělohrad were described by Frič (1912). In his work, special attention was paid to insect borings on the stem surface, and to the presence of small axes of the climbing fern *Ankyropteris brongniartii*, occasionally preserved in the root mantle of *Psaronius* stems. Vysocký (1859), Jokély (1861), Stur (1877), Makowsky (1878), Katzer (1892), Daněk (1902), Petrascheck (1924) and Hynie (1927) reported on the silicified stems from around Nová Paka. In the Nová Paka region, stems are most often found as lag on hillsides as loose pieces, less commonly they

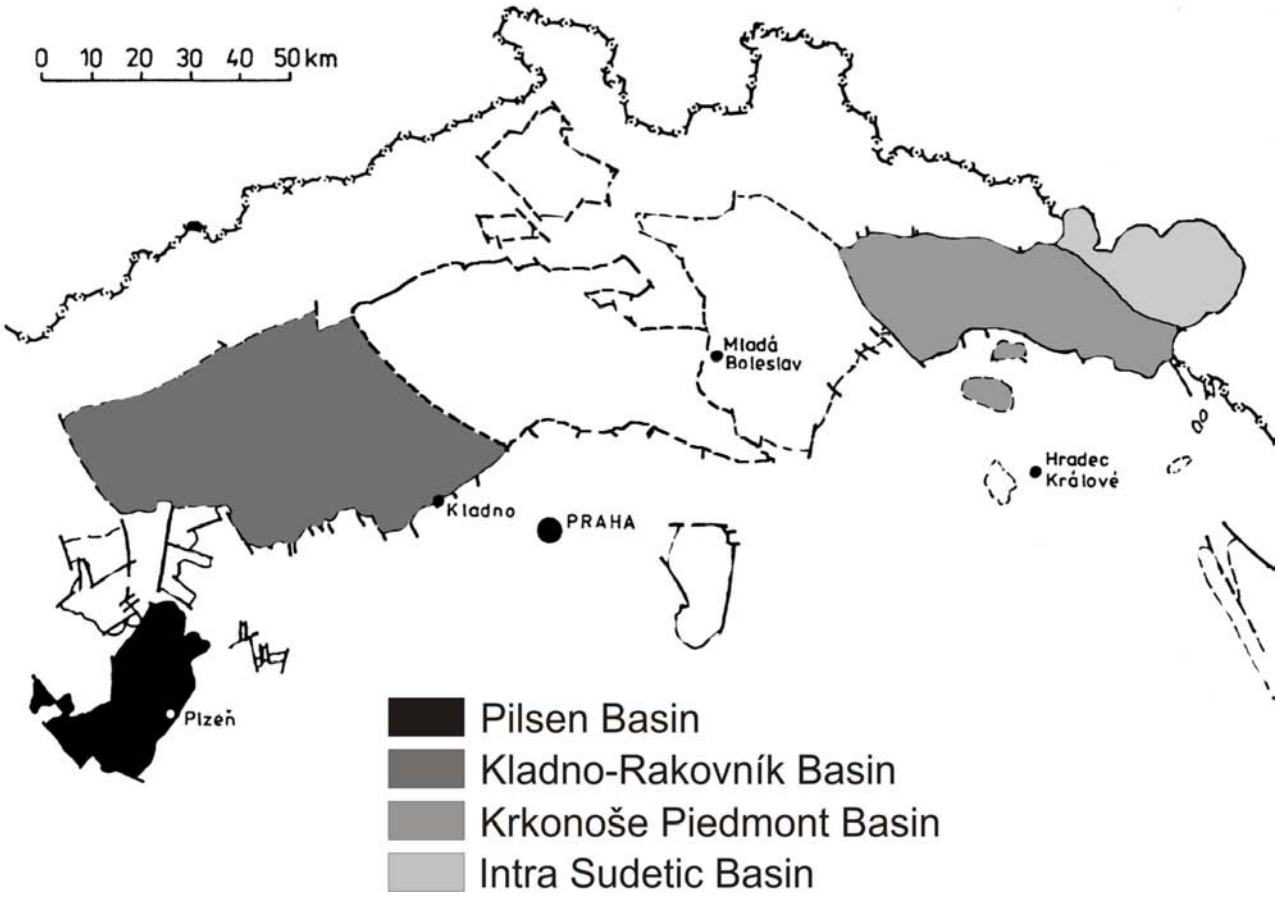



Figure 1. *Late Paleozoic basins of the Czech Republic. Studied areas are highlighted. After Pešek et al. (2001).*

have been found in outcrops, but never in upright position (Purkyně, 1927). Some specimens preserve bark and leaf scars (Renger, 1858, 1863). Feistmantel (1873a, b, c) generally considered silicified stems from the Nová Paka to be early Permian, but recent research indicates that they are of late Pennsylvanian (Kasimovian – Gzhelian) age (Pešek et al., 2001; Matysová, 2006; Mencl, 2007; Mencl et al., 2009; Mencl et al., 2013; Opluštil et al., 2013). The most recent general summary of silicified stem localities in Czech Republic was presented by Březinová (1970). Most recently short notes on the material from the Krkonoše Piedmont Basin have been published by Havlena (1955, 1958), Vítek (1986), Soukup (1997), Dernbach (1996) and Dernbach et al. (2002). Subsequent to Goeppert (1858) no detailed anatomical study of the *Agathoxylon*-type wood has been published.

## 2.2. Intra Sudetic Basin

In the Czech part of the Intra Sudetic Basin (Figure 1) silicified wood have been known for a long time. The first scientific descriptions were presented by Goeppert (1857, 1858) based on silicified wood in the Jestřebí hory region; an area about 30 x 7.5 kilometres.

The length of stems reaches up to 6 m, and diameter varies between 40 and 50 cm. Most are oval in cross-section due to compression. Some logs have preserved growth rings and knots with stubs of branches, and all lack bark (Goeppert, 1858). Systematically these fossils were interpreted as conifers and attributed to the species *Araucarites brandlingii* (Lindl. & Hutt.) Göpp. and *Araucarites schrollianus* Göpp. (Goeppert, 1857, 1858).

Occurrences of silicified stems in the Intra Sudetic Basin mentioned also many other authors,

e.g., Stur (1877), Makowsky (1878), Katzer (1892), Petrascheck (1924), Purkyně (1927), Březinová (1970) and Tásler et al. (1979). The most modern research was performed by Matysová (2006), Mencl (2007) and Mencl et al. (2009) who interpreted this material as cordaitalean wood.

### 2.3. Kladno-Rakovník Basin and Pilsen Basin

The occurrence of petrified stems in the Kladno-Rakovník and Pilsen Basins (Figure 1) has been known for about 150 years. Such fossil material is less common in this basin than in the Krkonoše Piedmont area. The first mention of such material in the Pilsen Basin was by Miksch (1853) who described stems up to 7.5 m in length from locality Chotíkov. The first anatomical studies of silicified stems were performed by Feistmantel (1873a, b, c), who described many stems from the Kladno-Rakovník Basin (localities Rakovník, Lubná, Hředle, Řevničov, Klobuky and Krušovice). He assigned different wood types to the conifer *Araucarites schrollianus* (= *„Dadoxylon“ saxonicum*; synonym: *„Dadoxylon“ schrollianum*), and fern *Psaronius* (Feismantel, 1873b). These stems are without bark, some have growth rings, knots and pith cavities (Feistmantel, 1873c). First taxonomic description of silicified stems from both basins was provided by Feistmantel (1883). He determined one well-preserved piece of wood from Mutějovice (Kladno-Rakovník Basin) to belong to *Araucarioxylon schrollianus,* several loose-pieces from Lochotín as the cordaitalean wood *Araucarioxylon brandlingi* (Lindl. & Hutt.) Göpp., and from Líně and Červený Újezd he identified wood as the conifer *Araucarites schrollianus* Göpp. (Feistmantel, 1883). Frič (1912) described silicified wood from a sandstone near Kněževes, and one stem uniquely preserved in outcrop of whitish sandstone near Klobuky. Purkyně (1927) provided a summary of petrified stems from Bohemia, including the new localities; Očihov, Kryry and Slaný; where black coloured silicified wood was found. He attempted stratigraphic correlations based on the occurrence of fossil wood (Purkyně, 1912). The possible applications of the silicified wood for stratigraphic correlations were also discussed by Němejc (1953), Pouba and Špinar (1954), and Pešek (1968). Subsequently Skoček (1970) divided petrified wood in two taphonomic types: dark which organic matter is present (deposited in swamps and partly humified), and light which lacks organic matter, which were deposited under dry climatic conditions (Skoček, 1970). Short notes about silicified stems were mentioned by several other authors, e.g., Němejc (1953), Pouba and Špinar (1954), Havlena (1964), Březinová (1970), Obrhel (1977), Řehoř and Řehoř (2005) and Svejkovský (2009). A short note about the silicified peat and fossil wood in the Kloubuky area was published by local collectors (Dvořák and Švancara, 2003). A palaeoichnological study was performed by Mikuláš and Zasadil (2008), who described silicified stems with insect boreholes and fungal traces from Kněževes, Hředle, Bílenec, Očihov a Stachov. The newest systematic work on silicified stems from the Kladno-Rakovník Basin summarised the occurrences of various types of stems and described their anatomy was done by Holeček (2011). Silicified conifer and cordaitalean stems from the Pilsen Basin and their anatomical features were described by Bureš (2011, 2013).

## 3. GEOLOGICAL SETTINGS

### 3.1. Krkonoše Piedmont Basin

The Krkonoše Piedmont Basin is situated in the northern part of the Czech Republic, at the foot of the Krkonoše-Jizerské hory crystalline complex (Figure 1) and belongs to a system of post-orogenic extensional/transtensional basins of the Bohemian Massif. Purely continental deposits in the Krkonoše Piedmont Basin are early Moscovian (Asturian) to early (or even middle) Triassic in age (Figure 2). The sediment fill of this basin reaches a maximum thickness about 1800 m (Pešek et al., 2001).

Previous geologic mapping indicates that silicified *Agathoxylon*-type stems are known from two stratigraphic levels: the Štikov Arkoses (Kumburk Formation) and the Ploužnice Horizon (Semily Formation) (Pešek et al., 2001). More recently this wood has been found in both the Brusnice Member (lower Kumburk Formation) and the lower Prosečné Formation. Stems, when found in place are horizontal on bedding planes; no upright stems have been observed.

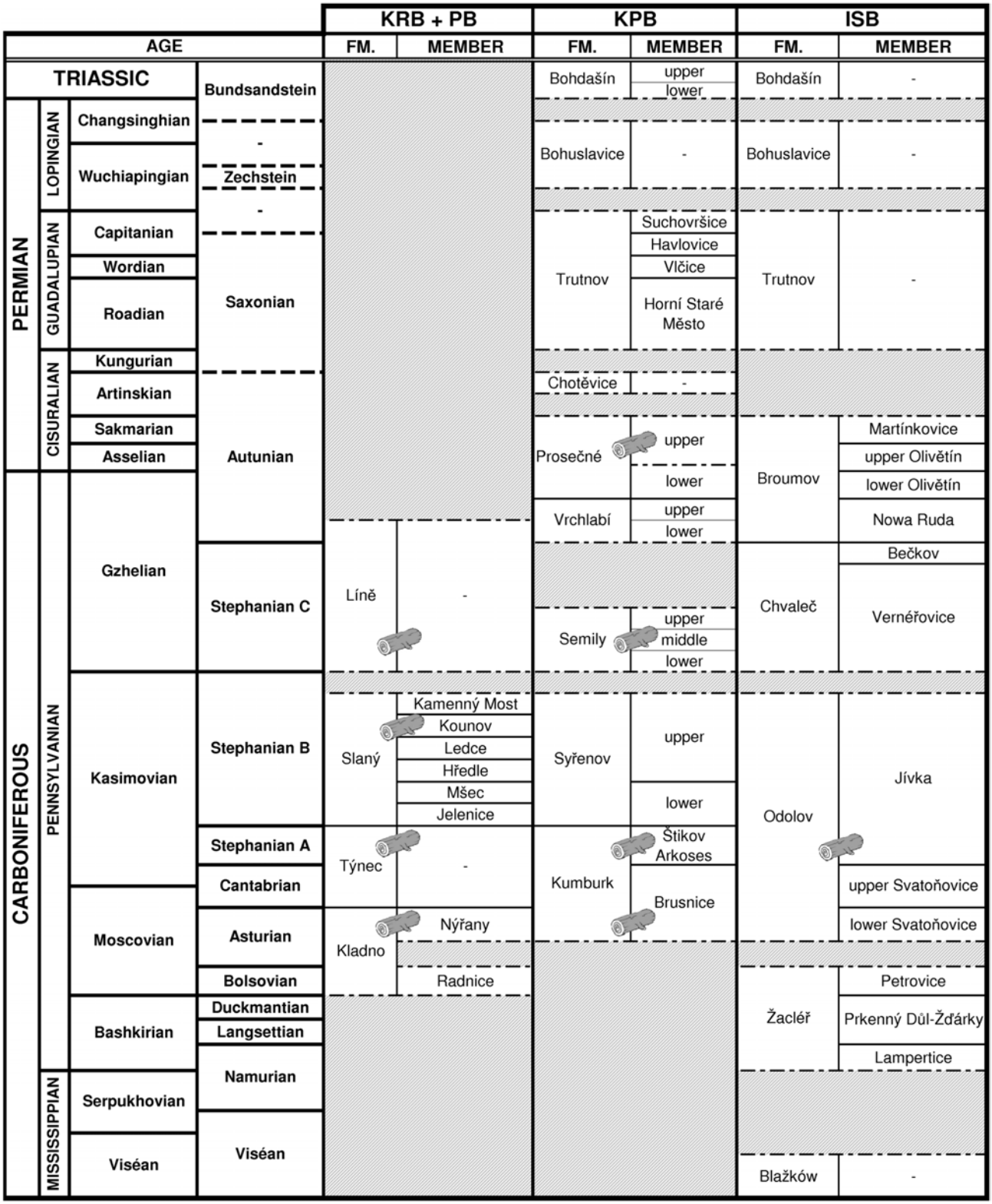



Figure 2. *Comparison of stratigraphy of the Kladno – Rakovník Basin (KRB), Pilsen Basin (PB), Krkonoše Piedmont Basin (KPB) and Intra Sudetic Basin (ISB). Stratigraphical positions of the silicified stems are illustrated by small logs. Compiled after Mencl et al. (2009), Holeček (2011) and Gradstein et al. (2012).*

### *3.1.1. Kumburk Formation*

Brusnice Member (lower Kumburk)

This unit is upper Moscovian – lower Kasimovian (Asturian – Cantabrian) in age. It consists mostly of reddish aleuropelites with common, several metre thick intercalations of greyish, middle- to coarse-grained, semi-rounded to rounded, siliciclastic conglomerates (Pešek et al., 2001). This unit is only known to occur in the southern part of the Krkonoše Piedmont Basin. It was deposited in lacustrine and fluvial environments with no volcanic component (Matysová et al., 2010). Silicified stems are rare and have not yet been described from this unit. A single silicified stem was observed in horizontal position in an outcrop of coarse-grained conglomerate by one of the present authors (V. Mencl).

Štikov Arkoses (upper Kumburk)

This unit is Kasimovian (Stephanian A) in age. Deposits are middle- to coarse-grained, light grey, reddish and pinkish sandstones that may laterally become conglomeratic with rounded cobbles up to 10 centimetres in diameter (Pešek et al., 2001), probably deposited in lacustrine and/or fluvial environment without any volcanic influence (according to Matysová et al., 2010). Silicified *Agathoxylon* stems are very abundant and often preserved in outcrops. The longest log, which has been ever found in this area, was more than 8 metres long and about 1 metre in diameter.

### *3.1.2. Semily Formation*

Ploužnice Horizon (middle Semily)

This unit is Gzhelian (Stephanian C) in age. The sediments have a mostly lacustrine character (Pešek et al., 2001). They consist of fine-grained, reddish mudstones and siltstones with thin carbonate banks, calcareous and chert concretions. There is a volcanic component represented by intercalated tuffs and tuffitic sandstones which were deposited by traction mechanisms, mostly by river streams (Stárková et al., 2009). Silicified remnants of plants are, for the most part, restricted to the lower part of the Ploužnice Horizon. This unit has yielded *Agathoxylon*-type of wood, silicified stems of the fern *Psaronius*, the calamitaleans (*Arthropitys* and *Calamitea*), and the seed-fern (*Medullosa*) as well as nodules of carnelian (Sakala et al., 2009; Mencl et al., 2013; Opluštil et al., 2013). Due to the lack of outcrops, the silicified stems are usually found as lag. This unit was deposited in a lacustrine environment with influence of volcanism (according to Matysová et al., 2010).

### *3.1.3. Prosečné Formation*

The Prosečné Formation is Asselian - Sakmarian (Autunian) in age. It is only known from the central and western part of the Krkonoše Piedmont Basin. It is a very fine-grained lacustrine deposit with numerous interbedded tuffs, tuffites and limestones. The uppermost part of the Prosečné Formation is composed of pinkish arkoses and arkosic sandstones (Pešek et al., 2001). The usually dark-coloured silicified stems are very common in some localities, but found as lag only. This unit was deposited in a lacustrine environment with influence of volcanism (according to Matysová et al., 2010).

## 3.2. Intra Sudetic Basin

The Czech part of the Intra Sudetic Basin is in the north-eastern Czech Republic (Figure 1). Its sediments have the greatest stratigraphic range among the late Paleozoic basins of the Bohemian Massif, ranging from Viséan to the Middle Triassic (Pešek et al., 2001; Opluštil and Cleal, 2007; Opluštil et al., 2013) (Figure 2). Strata are divided into eight formations (Tásler et al., 1979; Pešek et al., 2001). The Intra Sudetic Basin is separated from the Krkonoše Piedmont Basin by the Hronov-Poříčí Fault. Sediments in the Intra Sudetic Basin are continental, with the exception of the Mississippian (Viséan) deposits that are partly marine. All other deposits have fluvial, proluvial or lacustrine character. A volcanoclastic component is present in several units (Pešek et al., 2001). Silicified wood is known only from one stratigraphic level called the Žaltman Arkoses in the Odolov Formation. The presence of silicified stems in the Petrovice Member (Bolsovian) that were mentioned by Tásler et al. (1979) was not confirmed (Mencl, 2007; Mencl et al., 2009). The Žaltman Arkoses is Stephanian A in age and composed of fluvial arkosic conglomerates and sandstones (Pešek et al., 2001, Valín, 1956, 1960). Stems are very rarely found in outcrops (e.g. *Kryštofovy kameny*), they are allochthonous and never found in upright position. They lack bark, roots, branches or any other extraxylary tissue (Mencl et al., 2009). Most are found as loose pieces in the field. They are most common in the area of the Jestřebí Hory (Matysová, 2006; Mencl, 2007; Mencl et al., 2009).

### 3.3. Kladno-Rakovník Basin and Pilsen Basin

The Kladno-Rakovník and Pilsen Basins are situated in the central and south-western part of the Czech Republic (Figure 1). They were formed by an extension/transition during the Variscan orogeny in the Bohemian Massif. The oldest sediments are early Moscovian and the youngest are Gzhelian in age (Figure 2), with a maximum thickness about 1440 metres. These mostly lacustrine sediments are divided into four formations, i.e. the Kladno, Týnec, Slaný and Líně Formations. Silicified wood is known to occur in all formations (Holeček, 2011), but is most common in the Týnec and Líně Formations (Pešek et al., 2001). Exposures of these formations are extremely poor or lacking thus all fossil wood has been found as fragments in eluvium. Some however have been recovered from kaolin mines in the Pilsen Basin. Whole trunks are very rare, petrified wood is often fragmented into small pieces, knots and remnants of branches are very scarce.

#### *3.3.1. Kladno Formation*

The Kladno Formation is Moscovian (Bolsovian – Cantabrian) in age and is composed of the Radnice and Nýřany members separated by a hiatus. Both are typified by dark-coloured, greyish and reddish fluvial deposits, mostly claystones, siltstones, sandstones and conglomerates in the Radnice Member, and arkoses, arkosic sandstones and siltstones in the Nýřany Member. Both units contain coal beds and common volcanic intercalations. The very scarce silicified stems in the Kladno Formation are mostly black in colour.

#### *3.3.2. Týnec Formation*

The Týnec Formation is lower Kasimovian (Barruelian) and is typified by coarse-grained reddish sediments, without or only with little volcanic intercalations. Petrified stems are very common in this unit and usually light-coloured. Trunks, up to 10 m long, have been described from this formation by Pešek et al. (2001). Two types of wood are present: *Agathoxylon*-type and calamitalean (Mencl et al., 2013).

#### *3.3.3. Slaný Formation*

Slaný Formation is Kasimovian (Stephanian B) in age, divided into six members that are composed of mostly grey-coloured sediments. Silicified stems, known only from the Kounov Member (upper part of the Slaný Formation, Fig. 2), are quite rare and usually dark-coloured. The Kounov Member is typified by fluvial and lacustrine deposits, mostly white to greyish arkoses, arkosic sandstones and aleuropelites with coal beds and tuffitic interbeds.

#### *3.3.4. Líně Formation*

The Líně Formation is Gzhelian (Stephanian C) in age and separated from the Slaný Formation by a hiatus. It consists primarily of reddish to crimson-coloured silt and claystones. Tuffs and tuffites are more common than in the underlying Slaný Formation, and are can be distinguished within three units (horizons), i.e. the Zdětín, Klobuky and Stránka Horizons (Pešek et al., 2001). Silicified *Agathoxylon*-type stems are very common in arkosic deposits of the lower part of the Líně Formation. Stems are found there as loose pieces in the field, except one unique specimen, which was preserved in outcrop and described by Frič (1912). From this stratigraphic position were also described calamitalean stems (Mencl et al., 2013). In the Klobuky area, there are also known silicified peats (e.g., Dvořák and Švancara, 2003).

## 4. MATERIAL AND METHODS

The samples from the Krkonoše Piedmont Basin are either from the palaeontological collections of the Municipal Museum Nová Paka (signature P), the Krkonoše Museum in Jilemnice (abbreviation J), or were provided by V. Mencl and private collectors (abbreviations BA, C, HB, JA, PE, S, SH). The samples from the Kladno–Rakovník Basin were collected by J. Holeček and are now housed in the West Bohemian Museum in Pilsen (abbreviations RAK, ZAS), or provided by private collectors (abbreviation ZAJ). The samples from the Pilsen Basin were provided by the West Bohemian Museum in Pilsen (signature FP), or came from the collection of the Municipal Museum Nová Paka (signature P).

Cross sections of several tens of specimens were polished and examined in reflected light with a Leica EZ 5 and Olympus SZx12 stereomicroscopes. The best preserved were thin-sectioned in the standard transverse, tangential longitudinal and radial longitudinal sections, and studied using transmitted light under either an Olympus BX-51 or SZX12

microscope. Images were made with Olympus Camedia 3030 and 5050 digital cameras and processed with imaging software AnalySIS, NIS-Elements and Quick Photo Industrial. The data were analysed with Microsoft Excel 2007–2010.

## 5. RESULTS

The specimens from the Krkonoše Piedmont and Intra Sudetic Basins are characterised only by the structure of the secondary xylem. A few specimens have knots with stubs of branches. The wood is homoxylous pycnoxylic. Resin canals and axial parenchyma have not been observed. Radial sections rarely show alternate „araucaroid" pitting in tracheid walls. Due to a considerable amount of recrystallisation, other features can only very rarely (e.g. cross-field pitting) be seen. Samples from both basins underwent the same process of recrystallisation, but samples from the Krkonoše Piedmont Basin in much less intensive way than coeval ones from the Intra Sudetic Basin (Mencl, 2007, Mencl et al., 2009).

The specimens from the Kladno-Rakovník and Pilsen Basins show better preservation being less recrystallised. However, they also have preserved the secondary xylem only. Radial sections show alternate „araucaroid" pitting. Knots and pith are rare.

### 5.1. *Agathoxylon* sp. 1

Specimens: BA1, C1, P1760, P1786, P1793, P1831, P2697, S4, SH1, VS10, VS11, VS12, VS13, VS14, VS21, VS22, VS28, VS29, VS34, VS35, FP00066, FP00068, FP00069, FP00083, FP00098, FP00107, FP00112, FP00125, FP00126, FP00129, RAK004/1, RAK004/2, RAK004/3, RAK005/1, RAK005/2, RAK006/1, RAK008/1, RAK008/2, VS100, VS101, ZAJ002/1.

Microscopic description:
Transverse section: Growth rings not observed. Tracheids, radial diameter 20 – 162 $\mu$m (mean 60 $\mu$m), tangential diameter 23 – 149 $\mu$m (mean 65 $\mu$m) (Table 1), are mostly round to oval, organized in radial lines (Plate I/2). Axial parenchyma is not present.
Tangential longitudinal section: Tracheid pits not detected. Rays range from 2 to 45 cells in hight (Table 1), mostly uniseriate, partly biseriate, rarely triseriate. Rays cells are mostly round (Plate I/5).

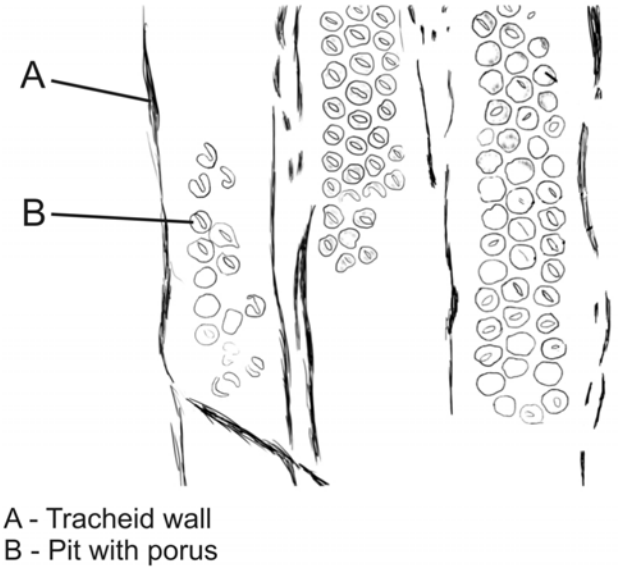



Figure 3. *Sketch of the radial longitudinal section of the specimen RAK004/1 – Agathoxylon sp. 1 (after Holeček, 2011).*

Radial longitudinal section: Tracheid pitting 1 – 4 columns usually covering the entire width of the tracheid wall and arranged in an alternating („araucarioid") pattern for maximum number of pits/cell (Plate I/6). Pits are bordered, mostly hexagonal, polygonal or oval; pores are oval or round (Figure 3). Pit diameter varies from 6 to 37 $\mu$m (Table 1). Cross-field pitting is araucarioid sensu IAWA Committee (2004) and only rarely observed. Cross-field pits are bordered, hexagonal to oval, with round to oval pores, and usually three or four in each field (Plate I/4).

Macroscopic description:
Several specimens show macroscopic features: irregular branching (solitary branches without other branches in close proximity), and an *Artisia*-type of pith (Plate I/7). These features allow them to be identified as *Agathoxylon* sp. 1. Thin sectioning of these specimens was not allowed by the keepers of the Nová Paka and Krkonoše Museums, and the private collectors.

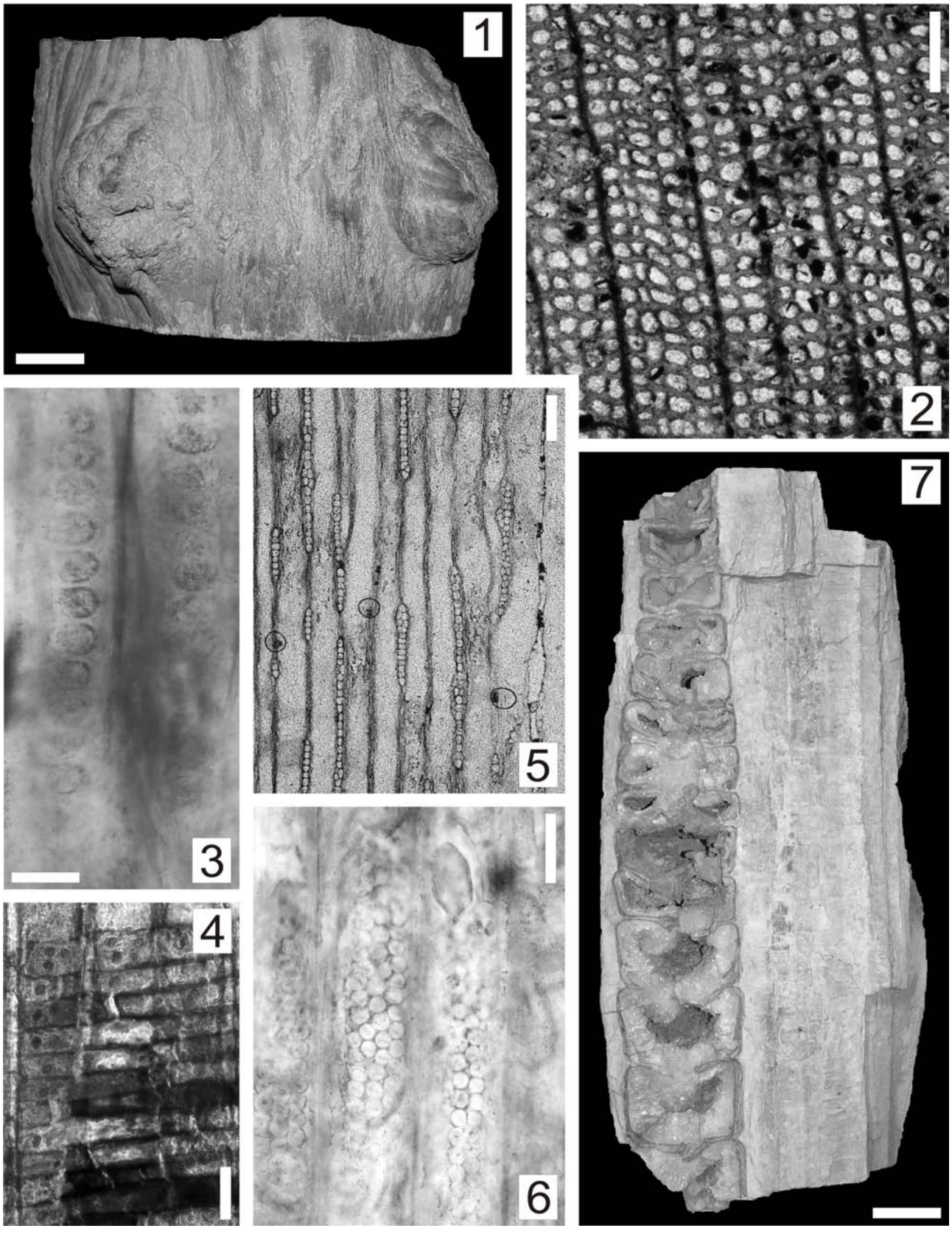
### 5.2. *Agathoxylon* sp. 2

Specimens: HB1, J8766, J8767, JA1, P302, P1478, P1798, P2960, P5113, PE1, S1, S3, S5, S6, S7, FP00067, FP00071, FP00073, FP00077, FP00093, FP00095, FP00100, FP00101, FP00103, FP00106, FP00115, FP00116, FP00118, FP00127, RAK003/2, ZAJ003/1, ZAS001/2, ZAS002/1, ZAS003/1.

Table 1. Attributes of anatomical features of studied specimens with their stratigraphical positions, and their assumed systematical affiliation. Stratigraphy: I = upper Moscovian, II = Kasimovian, III = lower Gzhelian, IV = upper Gzhelian, V = Sakmarian; 1 = Kladno-Rakovník and Pilsen basins, 2 = Krkonoše Piedmont Basin, 3 = Intra Sudetic Basin. x = attributes not detectable.

| SECTION | TRANSVERSAL | | | | | | LONGITUDINAL RADIAL | | | | | | LONGITU. TANGENTIAL | | | | STRATIGRAPHIC POSITION | *Agathoxylon* sp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FEATURE | TRACHEID DIAMETER | | | | | | PITTING | | | | | | RAYS | | | | | |
| | radial direction | | | tangential direction | | | series | | | pit diameter | | | height | | | series | | |
| SPECIMEN | min | max | mean | min | max | mean | min | max | mean | min | max | mean | min | max | mean | max | | |
| BA1 | 49 | 142 | 80,5 | 44 | 129 | 87 | 3 | 5 | 4 | 11 | 25 | 17,9 | x | x | x | x | IV/2 | 1 |
| HB1 | 72 | 121 | 92,3 | 54 | 148 | 84,3 | 1 | 1 | 1 | 9 | 31 | 16 | x | x | x | x | V/1 | 2 |
| JA1 | 36 | 60 | 45 | 34 | 55 | 43 | x | x | x | x | x | x | 4 | 26 | 14 | 2 | II/2 | 2 |
| P1760 | 34 | 84 | 57,4 | 47 | 90 | 62,1 | 2 | 3 | 2 | 8 | 16 | 11,5 | x | x | x | x | II/2 | 1 |
| P2697 | 45 | 162 | 97,4 | 34 | 149 | 98,2 | 2 | 4 | 4 | 6 | 12 | 8 | 10 | 23 | 19 | 2 | IV/2 | 1 |
| P2960 | x | x | x | x | x | x | 1 | 1 | 1 | 10 | 14 | 11,6 | x | x | x | x | V/1 | 2 |
| PE1 | x | x | x | x | x | x | 1 | 1 | 1 | 8 | 14 | 10 | x | x | x | x | II/2 | 2 |
| S1 | x | x | x | x | x | x | 1 | 1 | 1 | 11 | 25 | 16,7 | 5 | 22 | 8 | 2 | V/1 | 2 |
| S3 | 18 | 41 | 26,8 | 21 | 40 | 29,9 | 1 | 1 | 1 | 8 | 12 | 10 | 4 | 14 | 9 | 2 | V/1 | 2 |
| S4 | x | x | x | x | x | x | 1 | 2 | 1,2 | 9 | 15 | 12,8 | x | x | x | x | V/1 | 1 |
| S5 | x | x | x | x | x | x | 1 | 1 | 1 | 6 | 12 | 8,3 | 5 | 20 | 11 | 2 | V/1 | 2 |
| S6 | x | x | x | x | x | x | 1 | 2 | 1,1 | 12 | 20 | 16,3 | x | x | x | x | V/1 | 2 |
| S7 | 33 | 73 | 49 | 38 | 109 | 72,7 | 1 | 1 | 1 | 8 | 34 | 23 | x | x | x | x | V/1 | 2 |
| SH1 | 20 | 58 | 38,8 | 27 | 52 | 37,3 | 2 | 2 | 2 | 16 | 37 | 21,8 | x | x | x | x | I/2 | 1 |
| VS10 | 60 | 90 | 70 | 60 | 100 | 72,5 | 2 | 3 | 2 | 18 | 25 | 23 | 5 | 21 | 16 | 3 | II/3 | 1 |
| VS11 | 60 | 100 | 71 | 70 | 110 | 78,5 | x | x | x | x | x | x | 2 | 9 | 6 | 2 | II/3 | 1 |
| VS12 | x | x | x | x | x | x | 3 | 4 | 3,8 | 7 | 13 | 9,6 | 8 | 23 | 19 | 2 | II/3 | 1 |
| VS13 | x | x | x | x | x | x | 2 | 3 | 2,2 | 10 | 20 | 15 | 7 | 16 | 10 | 2 | II/3 | 1 |
| VS14 | 50 | 80 | 64,5 | 55 | 80 | 66 | x | x | x | x | x | x | 4 | 28 | 10 | 2 | II/3 | 1 |
| VS21 | 40 | 60 | 54,5 | 40 | 75 | 61,5 | x | x | x | x | x | x | x | x | x | x | II/3 | 1 |
| VS22 | 40 | 70 | 55,5 | 50 | 80 | 65 | x | x | x | x | x | x | 3 | 11 | 7 | 2 | II/3 | 1 |
| VS28 | 60 | 90 | 71 | 60 | 100 | 78 | x | x | x | x | x | x | x | x | x | x | II/3 | 1 |
| VS29 | 60 | 100 | 78,5 | 60 | 100 | 85 | x | x | x | x | x | x | 4 | 16 | 8 | 2 | II/3 | 1 |
| VS34 | 40 | 70 | 52 | 50 | 90 | 75 | 2 | 3 | 2,3 | 12 | 21 | 17 | 6 | 30 | 13 | 2 | II/3 | 1 |
| VS35 | 40 | 70 | 51,5 | 40 | 80 | 58,5 | 1 | 3 | 2,5 | 11 | 25 | 14 | 3 | 18 | 8 | 1 | II/3 | 1 |
| P5113 | 13 | 30 | 21,2 | 16 | 38 | 27,3 | 1 | 2 | 1,2 | 11 | 16 | 13,3 | x | x | x | x | IV/1 | 2 |
| FP00071 | 45 | 50 | 47,5 | x | x | x | 1 | 2 | 1,1 | 18 | 18 | 18 | 6 | 6 | 6 | 1 | IV/1 | 2 |
| FP00073 | 30 | 35 | 32,5 | x | x | x | 1 | 1 | 1 | 12 | 15 | 13 | x | x | x | x | IV/1 | 2 |
| FP00077 | 40 | 50 | 44,7 | x | x | x | 1 | 1 | 1 | 15 | 20 | 18 | 6 | 14 | 9 | 1 | IV/1 | 2 |
| FP00083 | 70 | 80 | 73,3 | x | x | x | 2 | 4 | 3,1 | 10 | 12 | 11 | 7 | 7 | 7 | 1 | IV/1 | 1 |
| FP00093 | 45 | 50 | 46,7 | x | x | x | 1 | 2 | 1,1 | 12 | 15 | 13 | x | x | x | x | IV/1 | 2 |
| FP00095 | 40 | 50 | 46,7 | x | x | x | 1 | 1 | 1 | 17 | 18 | 17,3 | 16 | 16 | 16 | 1 | IV/1 | 2 |
| FP00098 | 55 | 65 | 60 | x | x | x | 1 | 2 | 1,7 | 12 | 12 | 12 | 6 | 29 | 18 | 1 | IV/1 | 1 |
| FP00100 | 40 | 40 | 40 | x | x | x | 1 | 2 | 1,1 | 15 | 15 | 15 | x | x | x | x | IV/1 | 2 |
| FP00101 | 40 | 50 | 46,7 | x | x | x | 2 | 4 | 2,9 | 15 | 15 | 15 | 4 | 5 | 5 | 1 | IV/1 | 2 |
| FP00103 | 30 | 40 | 33,3 | x | x | x | 1 | 2 | 1,8 | 10 | 15 | 13 | x | x | x | x | IV/1 | 2 |
| FP00106 | 40 | 50 | 45 | x | x | x | 1 | 2 | 1 | 15 | 15 | 15 | x | x | x | x | IV/1 | 2 |
| FP00107 | 50 | 50 | 50 | x | x | x | 1 | 1 | 1 | 18 | 18 | 18 | 7 | 10 | 9 | 1 | IV/1 | 1 |
| FP00112 | 40 | 50 | 45 | x | x | x | 1 | 2 | 1,7 | 12 | 12 | 12 | x | x | x | x | IV/1 | 1 |
| FP00115 | 50 | 60 | 55 | x | x | x | 1 | 3 | 1,8 | 15 | 15 | 15 | 7 | 9 | 8 | 1 | IV/1 | 2 |
| FP00116 | 50 | 50 | 50 | x | x | x | 1 | 3 | 2 | 15 | 15 | 15 | 15 | 25 | 20 | 1 | IV/1 | 2 |
| FP00118 | 40 | 40 | 40 | x | x | x | 1 | 1 | 1 | 15 | 18 | 17 | 7 | 7 | 7 | 1 | IV/1 | 2 |
| FP00125 | 50 | 50 | 50 | x | x | x | 2 | 3 | 2,4 | 10 | 10 | 10 | x | x | x | x | IV/1 | 1 |
| FP00126 | 45 | 50 | 48,3 | x | x | x | 2 | 4 | 2,4 | 10 | 10 | 10 | 7 | 12 | 9 | 1 | IV/1 | 1 |
| FP00127 | 40 | 50 | 43,3 | x | x | x | 1 | 1 | 1 | 12 | 12 | 12 | x | x | x | x | IV/1 | 2 |
| FP00129 | 50 | 50 | 50 | x | x | x | 1 | 3 | 2 | 12 | 12 | 12 | 9 | 12 | 10 | 1 | IV/1 | 1 |
| RAK003/2 | 42 | 65 | 51,3 | 34 | 69 | 50,8 | 2 | 2 | 2 | 14 | 16 | 15,6 | x | x | x | x | III/1 | 2 |
| RAK004/1 | 36 | 85 | 59,7 | 40 | 75 | 56,5 | 1 | 4 | 3 | 10 | 12 | 10,9 | 2 | 23 | 9 | 2 | II/1 | 1 |
| RAK004/2 | 32 | 61 | 48,7 | 30 | 59 | 44,4 | 1 | 3 | 2 | 10 | 13 | 11,4 | 2 | 30 | 9 | 3 | II/1 | 1 |
| RAK004/3 | 28 | 61 | 42,9 | 23 | 52 | 39 | 1 | 3 | 2 | 10 | 13 | 12 | 3 | 22 | 7 | 2 | II/1 | 1 |
| RAK005/1 | 41 | 79 | 63,6 | 39 | 71 | 54,1 | 1 | 3 | 3 | 15 | 16 | 15,7 | 2 | 35 | 11 | 2 | II/1 | 1 |
| RAK005/2 | 56 | 79 | 65,6 | 52 | 87 | 72,2 | 2 | 4 | 3 | 13 | 16 | 14 | 3 | 45 | 13 | 2 | II/1 | 1 |
| RAK006/1 | 40 | 72 | 53,8 | 38 | 80 | 59,1 | 1 | 2 | 2 | 12 | 17 | 14 | 3 | 22 | 11 | 2 | II/1 | 1 |
| RAK008/1 | 51 | 90 | 66,2 | 40 | 67 | 55,4 | 2 | 3 | 2 | 10 | 15 | 13,4 | 3 | 27 | 14 | 3 | II/1 | 1 |
| RAK008/2 | 30 | 61 | 47,1 | 32 | 71 | 49,3 | 1 | 2 | 1 | 13 | 14 | 13,7 | 2 | 30 | 14 | 1 | II/1 | 1 |
| ZAJ002/1 | x | x | x | x | x | x | x | x | x | x | x | x | 4 | 26 | 12 | 2 | IV/1 | 1 |
| ZAJ003/1 | x | x | x | x | x | x | 1 | 2 | 1 | 15 | 23 | 19 | 2 | 26 | 9 | 2 | IV/1 | 2 |
| ZAS001/2 | x | x | x | x | x | x | 1 | 2 | 1 | 12 | 20 | 15,7 | x | x | x | x | IV/1 | 2 |
| ZAS002/1 | x | x | x | x | x | x | 1 | 2 | 1 | 11 | 14 | 13,4 | x | x | x | 1 | IV/1 | 2 |
| ZAS003/1 | x | x | x | x | x | x | 1 | 2 | 1 | 9 | 14 | 11,1 | x | x | x | x | IV/1 | 2 |

**Plate I.**



Microscopic description:
Transverse section: Growth rings were not observed. Tracheids are round or oval, rarely irregular, arranged in radial lines, radial diameter 13 – 121 $\mu$m (mean 44 $\mu$m), tangential diameter 16 – 148 $\mu$m (mean 51 $\mu$m) (Table 1). Axial parenchyma was not observed.
Tangential longitudinal section: Tracheid pits were not detected. Rays are uni- to biseriate, 2 – 26 cells in height (Table 1). Ray cells are round to slightly oval.
Radial longitudinal section: Tracheid pitting is mostly uniseriate, locally biseriate. Pits are bordered, round, diameters 6 – 37 $\mu$m (Table 1), and do not cover the total width of a tracheid wall (Table 1). Pores are round or slightly oval. Cross-field pitting not observed.

Macroscopic description:
Some of specimens of group *Agathoxylon* sp. 2 have preserved knots with the bases of branches. Branching pseudo-verticillate; with the branches arranged round the stem in the same orthogonal plane (Plate I/1).

# 6. DISCUSSION

## 6.1. Taxonomy

Only the characters of the secondary xylem are known for all specimens studied, the primary xylem and other tissues are lacking. Wood is homoxylous pycnoxylic without resin canals and axial parenchyma. Regular growth rings were not observed. Based on the known general characters (alternate pitting, lack of axial parenchyma) is possible to classify all the wood from the four basins as *Agathoxylon* sp. (Rößler et al., in press). However, due to strong recrystallisation of the quartz and the effect that has on the details visible in the wood it is not possible to make a more precise determination. Two groups (*Agathoxylon* sp. 1 and *Agathoxylon* sp. 2) are recognized based on the nature of the pitting in radial walls of the tracheids. All other features of the secondary xylem were either not discernable due to recrystallisation of the quartz or only hardly visible because of the poor preservation.

There is however a few well-preserved macroscopic features that permit the assignment, with reservations, of the two groups of *Agathoxylon* to higher levels of classification. *Agathoxylon* sp. 1 is probably assignable to the cordaitaleans, and *Agathoxylon* sp. 2 can possibly be assigned to the conifers (sensu Doubinger and Marguerier, 1975 and Noll et al., 2005).

## 6.2. Summary of stratigraphic and geographic occurrence

Using available palaeobotanical data and the occurrence of silicified stems we are able to partially reconstruct floral assemblages at various stratigraphic levels in the four studied basins.

### *6.2.1. Upper Moscovian (Asturian)*

The Nýřany Member of the Kladno Formation (Kladno-Rakovník and Pilsen Basins) and the Brusnice Member of the Kumburk Formation (Krkonoše Piedmont Basin) were deposited during this time interval. Silicified stems of this age are not known from the Intra Sudetic Basin. Specimens from the Kladno-Rakovník and Pilsen Basins were collected in the Lišany and Lužná as loose pieces in fields (Holeček, 2011). Unfortunately, their preservation is very poor and any further classification of them is not possible. Two specimens are known from the Krkonoše Piedmont Basin near Šárovcova Lhota. Both of them were collected from outcrops and have been classified as cordaitalean wood (see Table 1).

**Plate I.**
1. Part of a stem with pseudo-verticillate branching (specimen J8766, Krkonoše Piedmont Basin). Scale bar = 30 mm; 2. General view of tracheids of secondary xylem, transversal section (specimen P2697, Krkonoše Piedmont Basin). Scale bar = 1 mm; 3. Detail of tracheid pitting of *Agathoxylon* sp. 2, radial longitudinal section (specimen S1, Krkonoše Piedmont Basin). Scale bar = 30 $\mu$m; 4. Detail of cross-field pitting of *Agathoxylon* sp. 1, radial longitudinal section (specimen RAK006/1, Kladno-Rakovník Basin). Scale bar = 50 $\mu$m; 5. Detail of tangential longitudinal section showing mostly uniseriate but locally biseriate rays (specimen RAK005/2, Kladno-Rakovník Basin). Scale bar = 0.1 mm; 6. Detail of tracheid pitting of *Agathoxylon* sp. 1, radial longitudinal section; note crowded hexagonal pits (specimen FP00098, Pilsen Basin). Scale bar = 50 $\mu$m; 7. General view of the unique specimen with preserved pith of *Artisia*-type (specimen C1, Kladno-Rakovník Basin). Scale bar = 20 mm.

#### *6.2.2. Kasimovian (Stephanian A)*

Silicified stems of this age are very common and are known from all four studied basins. Most of the specimens from the Kladno-Rakovník and Pilsen Basins (Týnec Formation) are cordaitaleans (Holeček, 2011). Specimens from the Krkonoše Piedmont Basin (Štikov Arkoses, Kumburk Formation) are mostly conifers. From the Intra Sudetic Basin (Žaltman Arkoses, Odolov Formation) seven, well preserved specimen can be assigned to the cordaitaleans (Mencl, 2007, Mencl et al., 2009).

#### *6.2.3. Upper Kasimovian (Stephanian B)*

Specimens of this age are known only from the Kladno-Rakovník Basin. The only identifiable specimen is possibly cordaitalean (Holeček, 2011).

#### *6.2.4. Lower Gzhelian (Stephanian C)*

The Kladno-Rakovník, Pilsen and Krkonoše Piedmont Basins have a rich stem flora of this age, while lacking in the Intra Sudetic Basin. The Líně Formation, localities of Zbůch, Tlučná and Chotíkov, stems are 2/3 conifers and 1/3 cordaitaleans (Bureš, 2011). In the Krkonoše Piedmont Basin, the Ploužnice Horizon (Semily Formation) is well known for occurrence of several types of silicified stems, e.g., calamitaleans, ferns, pteridosperms and gymnosperms (Matysová, 2006; Matysová et al., 2008; Matysová et al., 2010; Mencl et al., 2013). All studied specimens from the Balka and Lísek localities are cordaitaleans.

#### *6.2.5. Asselian - Sakmarian (Autunian)*

Specimens from the Krkonoše Piedmont Basin are the only ones know from this age, with most probably assignable to the conifers.

## CONCLUSIONS

During our research we studied several dozen of silicified *Agathoxylon*-type of stems from the Kladno-Rakovník, Pilsen, Krkonoše Piedmont and Intra Sudetic late Paleozoic basins. Based on previous studies and new field research, silicified stems are now known to be present at five stratigraphic levels. All of them are always decorticated with secondary xylem only. They are rarely preserved in outcrops, but never in upright position. More often are found in alluvial deposits or as loose pieces in fields. Because of lack of outcrops, the assigning of these specimens to their stratigraphic positions can be done according to a detailed fieldwork in combination with the previous geological mapping data. The preservation of anatomical features is generally poor due to high recrystallisation of the quartz and destruction of the organic matter. The best preserved specimens are from the Kladno-Rakovník and Pilsen Basins, and the most poorly preserved from the Intra Sudetic Basin. Our studies of the secondary xylem resulted in the assignment of the specimens into two groups, *Agathoxylon* sp. 1 and *Agathoxylon* sp. 2. *Agathoxylon* sp. 1 exhibits features indicative of the cordaitaleans, while the homologous features in *Agathoxylon* sp. 2 are indicative of the conifers. The most significant contribution to the understanding of the floras of this time is that the cordaitaleans – conifer ratio in Western Bohemia basins is obviously different that in the Krkonoše Piedmont Basin. This fact is probably a reflection of differing palaeoenvironments.

## ACKNOWLEDGEMENTS

We would like to thank J. Luštinec and other employees of the Krkonoše Museum in Jilemnice, J. Šimurda (Krkonoše Museum in Vrchlabí) and T. Řídkošil (Czech Paradise Museum Turnov) as well as private collectors J. Červenka, J. Svejkovský, J. Zajíček and B. Zasadil for kind provide samples of their collections. Many thanks to V. Prouza (Czech Geological Survey) and J. Holeček (Radioactive Waste Repository) for their help with field works and fruitful discussion, and F. Tichávek for thin-sectioning. The manuscript was improved by the thorough reviews of S. Opluštil and Z. Kvaček, and detailed linguistic and scientific correction by D. Chaney. The research was supported by the project MSM0021620855, PRVOUK P44, SVV261203, UU09/2011 and FRL 2013.

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