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NEW FOSSIL WOODS FROM THE PALEOGENE OF DOUPOVSKÉ HORY AND ČESKÉ STŘEDOHOŘÍ MTS. (BOHEMIAN MASSIF, CZECH REPUBLIC)

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Abstract. New fossil woods are described from the Paleogene volcanoclastic sediments of Doupovské hory (localities Vrbice and Nechranice) and České středohoří Mts. (localities Bečov and Divoká rokle). Three types of conifer woods were identified (two stem woods and one root wood of Cupressaceae s.l.) and six types of angiosperm woods (families Lauraceae, Betulaceae, Ulmaceae, Malvaceae, Sapotaceae and one problematic sample). Two fossil conifer species encompassing the three conifer wood types (stem of *Glyptostroboxylon rudolphii* and stem and root of *Taxodioxylon gypsaceum*) were already known from the Tertiary of northwestern Bohemia. Five angiosperm species (*Cinnamomoxylon seemannianum*, *Alnus tschemrylica*, *Ulmoxylon* cf. *kersonianum*, *Grewioxylon ortenburgense*, *Manilkaroxylon* sp.) are documented for the first time in the studied area by our material; the sixth type of angiosperm wood we labelled only as "Xylotype Nechranice 1", since its poor preservation made precise identification impossible.

■ fossil conifer wood, fossil angiosperm wood, systematic palaeobotany, volcanoclastic sediments, Doupovské hory Mts., České středohoří Mts., Oligocene, Czech Republic

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Introduction

The Paleogene volcanoclastic sediments of Doupovské hory and České středohoří Mts. are known for their abundant fossil woods (e.g., Prakash et al. 1971, Sakala et al. 2010). In a recently defended Master thesis by Koutecký (2014), 37 new specimens of fossil wood from 4 localities (Vrbice, Nechranice, Bečov, Divoká rokle) were described. Even though some results have already been presented (Koutecký and Sakala 2014 a, b, c), the present contribution, a slightly modified English version of the Master thesis by Koutecký (2014) presents the first complete piece of published information about the new woods.

Material and methods

The fossil wood specimens were collected mainly by the first author, with additional contributions by Z. Dvořák (localities Nechranice and Bečov) and J. Svejkovský (locality Vrbice). Subsequently, the samples were cleaned, preliminarily examined with a Leica E25 binocular magnifying glass, and documented with an Olympus Fe 45 camera. Finally, selected thin sections of fossil wood were prepared following standard techniques, and studied and photographed using an Olympus BX-51 optical microscope in normal transmitted light, paired with an Olympus DP 73 camera. The photos were adjusted with Zoner Photo Studio 8, and scales added in QuickPHOTO MICRO 3.0. All anatomical descriptions are in accordance with the IAWA Softwood and Hardwood Lists (IAWA Committee 1989, 2004; InsideWood 2004 – onwards: http://insidewood.lib.ncsu.edu/search [checked February 20, 2014]). The specimens, as well as the corresponding thin slides, are housed in the Chlupáč Museum of Earth History, in the Faculty of Science of Charles University in Prague.

Geological setting

The Tertiary of north-western Bohemia is spread in the north-western part of the Czech Republic as a continuous zone of magmatic and sedimentary complexes, parallel to the Czech – German boundary. This zone, which is linked to the so-called Ohře Rift (e.g., Ulrych et al. 2002), is formed, from west to east, of the Cheb and Sokolov Basins, Doupovské hory Mts., Most Basin, České středohoří Mts. and Žitava Basin. The present contribution is limited to the two volcanic regions: Doupovské hory (DH) and České středohoří (CS) Mts. (Text-fig. 1).

The volcanic activity of both complexes is dated to the late Eocene – early Miocene (e.g., Rapprich and Holub 2008, Cajz et al. 2009), and their current morphology is the product of considerable denudation. Both are formed not only of lavas, but also lahars and other volcanic rocks, which can often be fossiliferous (e.g., Kvaček and Walther 2003), including a rich fossil wood record. An overview of the fossil wood types described so far has been progressively presented by Březinová (1970), Sakala (2004) and most recently by Koutecký (2014). In the present paper, we describe fossil woods from four localities: Vrbice and Nechranice (both

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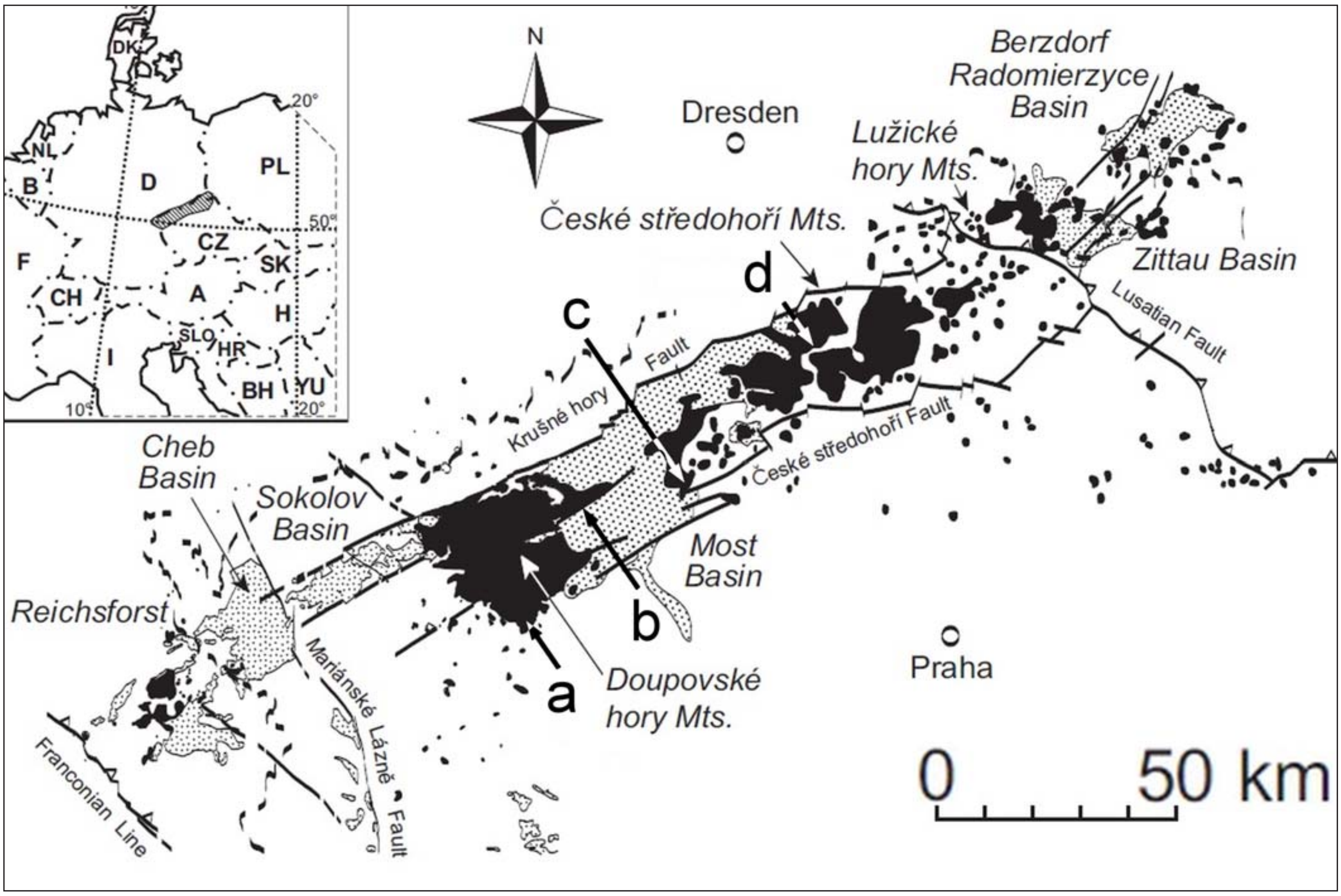


Text-fig. 1. Ohře rift fault zone with location of our localities (adapted Rapprich et al. 2007). a – Vrbice, b – Nechranice, c – Bečov, d – Divoká rokle.

DH), and Bečov and Divoká rokle (both CS). All four localities are described in detail by Koutecký (2014), so we present here only a kind of summary.

Vrbice (Pl. 6, Fig. 1)

This locality is situated in the southern slopes of DH, near the famous site of Valeč (the lowermost Oligocene: mammal zone MP21: Fejfar and Kaiser 2005), with which it can be stratigraphically correlated (V. Rapprich pers. comm. 2015). The fossiliferous rocks are tuff, with small fragments of basaltic rocks, leaves and wood. Hradecký et al. (2012) also estimated its age to Oliogocene.

Nechranice (Pl. 6, Fig. 2)

This locality is situated on the banks of the Nechranice dam, on the southern slopes of the Čachovický vrch Hill. The basement of the profile consists of weathered gneiss overlain by a pyroclastic deposit with small pieces of fossil wood. Radiometric dating has not yet been performed, but we believe it is likely to be Oligocene, or even early Miocene in age, when considering its broader geological context (Sakala et al. 2010).

Bečov (Pl. 6, Fig. 3)

This locality is situated SE from Bečov village, in the fields between Dlouhý vrch and Verpánek. The exact geological interpretation (maar or not) and age (Oligocene or early Miocene?) of the fossiliferous site are unknown (Koutecký 2014).

Divoká rokle (Pl. 6, Fig. 4)

This locality is proposed as a parastratotype of the Ústí Formation by Cajz (2000), early Oligocene in age, and its origin interpreted as a mud-flow deposit, with numerous small pieces of fossil wood (e.g., Kratochvíl 2007).

Systematic palaeontology

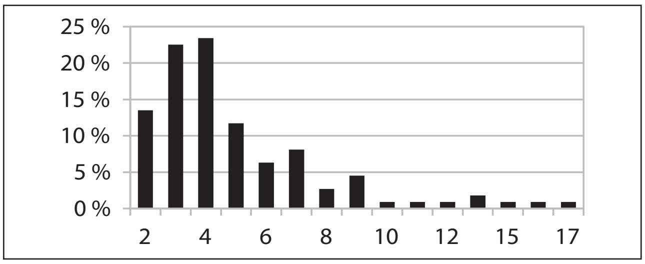
Conifers
Family: **Cupressaceae s.l.**

***Glyptostroboxylon* Conwentz emend.**
Dolezych et Van der Burgh

***Glyptostroboxylon rudolphii* Dolezych**
et Van der Burgh

Pl. 1, Fig. 4–7, Text-fig. 3

2004	*Glyptostroboxylon rudolphii* Dolezych et Van der Burgh, p. 410–411, text-fig. 6–7, p. 429, pl. II, fig. 1–9, p. 430, pl. III, fig. 1–5.
2008	*Glyptostroboxylon rudolphii* Dolezych et Van der Burgh; Teodoridis and Sakala, p. 304, fig. 5.13–5.15.



Text-fig. 2. Percentage of rays according to their height in *G. rudolphii* (samples 99/04 and 115/06 together).

Table 1. Number of tracheid rows between rays in *G. rudolphii* (samples 99/04 and 115/06 together).

value	1	2	3	4	5	6	7	8	9	10
frequency	10%	20%	18%	18%	8%	7%	5%	7%	5%	2%

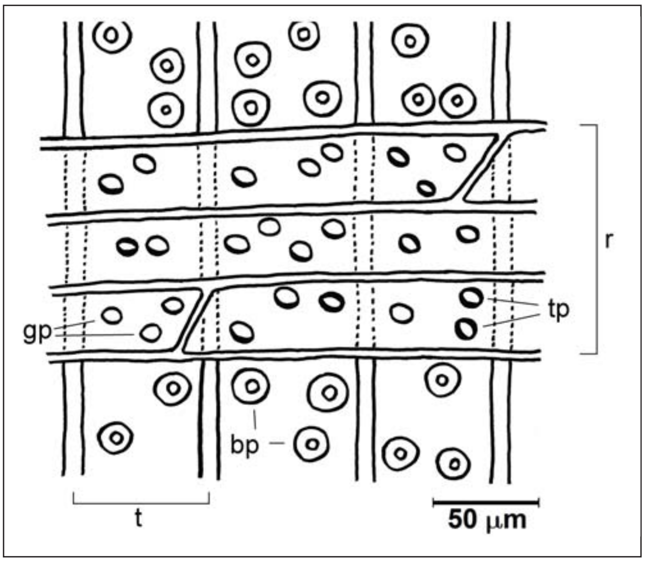
Material: Bečov 99/04, Nechranice 115/06.

Description. Growth rings distinct, 4–5 mm wide, with earlywood zone distinctly wider than latewood; transition from earlywood to latewood is gradual.

Tracheids: Outline polygonal to hexagonal. Radial diameter of earlywood tracheids 28–64–84 µm (middle value is the mean) and wall thickness 3–5 µm; radial diameter of latewood tracheids is 9–31–47 µm and wall thickness 5–7 µm; tangential diameter of tracheids ranges from 21 to 112 µm (mean 53); number of tracheids between two rays ranges from 1 to 10, most frequently 2–4 (Tab. 1). Pitting in radial tracheid walls uniseriate to biseriate (Text-fig. 3), arranged in discontinuous vertical rows; bordered pits circular in outline, 10–14 µm in diameter, with crassulae occasionally present (sample 115/06).

Rays: Mostly uniseriate, occasionally biseriate, 14–35 µm wide, very low to medium average height (4–5 cells), sensu IAWA Committee (2004). Total height range (Text-fig. 2) between 1 and 17 cells (28–392 µm); large intercellular spaces present (sample 115/06); 4–8 rays per tangential mm and 18–37 rays per square mm tangentially. Individual ray cells 14–35 µm high, horizontal and end (tangential) walls thin and smooth, with 3–6 µm thick double wall. Ray tracheids absent. Cross-field pits taxodioid to glyptostroboid (= taxodioid with much reduced borders), 7–10 µm in diameter; 2–4 pits randomly distributed per cross-field.

Axial parenchyma: Apparently in tangential bands in cross-section. Transverse walls thin and smooth.



Text-fig. 3. Schema of radial section of *G. rudolphii* (sample 99/04). t – tracheid, r – ray, bp – bordered pit, tp – taxodioid cross-field pit, gp – glyptostroboid cross-field pit.

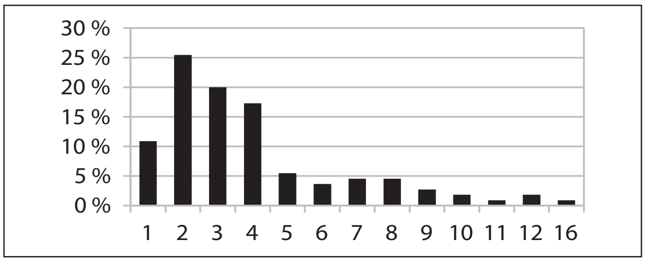
Discussion. The presence of axial parenchyma and taxodioid pits in a cross-field, as well as the absence of resin canals and spiral thickenings on tracheids place this wood in the family Cupressaceae (Teodoridis and Sakala 2008: 300). The bordered pits in radial walls of the tracheids disposed in two lateral discontinuous rows, thin and smooth transverse walls of the axial parenchyma, the homogeneous and mostly uniseriate rays, and the presence of glyptostroboid and taxodioid pits in the cross-field point more exactly to the genus *Glyptostroboxylon* CONWENTZ emend. DOLEZYCH et VAN DER BURGH (Dolezych and Van der Burgh 2004). Two species in this fossil genus have been defined so far: *G. tenerum* (KRAUS) CONWENTZ and *G. rudolphii* DOLEZYCH et VAN DER BURGH (Dolezych and Van der Burgh 2004). *G. tenerum* has typical bordered pits arranged in one, rarely two, vertical rows. Its cross-fields usually have only 1–2 (occasionally up to 4) glyptostoboid and taxodioid pits, and the rays are up to 12 cells high (Dolezych and Van der Burgh 2004). On the other hand, *G. rudolphii* has up to 3 vertical rows of bordered pits in the radial walls of the tracheids; in a cross-field, there are 1–4 predominantly glyptostroboid, but also taxodioid and cupressoid pits, and the rays are up to 20 cells high. The presence of crassulae and large intercellular spaces between cells of the rays in our wood specimens indicates this second species, which was previously described from the Most Basin by Teodoridis and Sakala (2008). Only the dimensions of tracheid and cross-field pit diameters correspond to those in *G. tenerum*. However, the quantitative divergence is not very large, and we believe can be explained as intraspecific and individual variation (e.g., Bailey and Faull 1934), which will be discussed more in detail below. Consequently, we designate our wood as *Glyptostroboxylon rudolphii* DOLEZYCH et VAN DER BURGH.

Glyptostrobus (or *Glyptostroboxylon*) is not known from the volcanic areas of Doupovské hory and České středohoří Mts. On the other hand, wood, leaves and reproductive structures are commonly present in the nearby Tertiary coal-basins (e.g., Kvaček and Teodoridis 2007).

Taxodioxylon HARTIG emend. GOTHAN
Taxodioxylon gypsaceum (GÖPPERT) KRÄUSEL
(stem wood)

Pl. 2, Fig. 1–5, Text-fig. 5

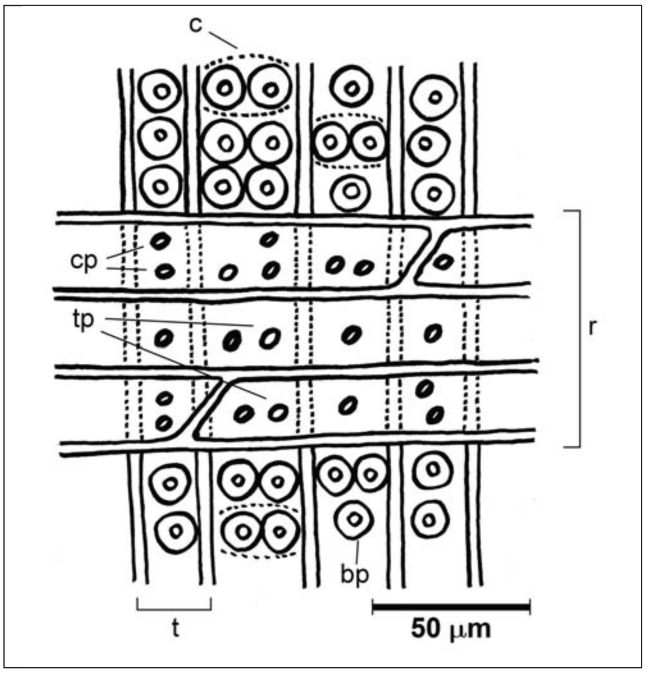
1971 *Taxodioxylon gypsaceum* (GÖPPERT) KRÄUSEL; Prakash et al., pl. 30–31, fig. 1–9.
1972 *Taxodioxylon gypsaceum* (GÖPPERT) KRÄUSEL; Selmeier, p. 123–126, pl. 1–4.
1996 *Taxodioxylon gypsaceum* (GÖPPERT) KRÄUSEL; Van der Burgh and Meijer, p. 374, fig. 1a–g.
2008 *Taxodioxylon gypsaceum* (GÖPPERT) KRÄUSEL; Teodoridis and Sakala, p. 300, fig. 5.1–5.5.



Text-fig. 4. Percentage representation of rays according to height in *T. gypsaceum* (samples Bečov 2 and 44804 together).

Table 2. Number of tracheid rows between rays in *T. gypsaceum* – stem wood (samples Bečov 2 and 44804 together).

value	5	6	3	4	5	6	7	8
frequency	5%	15%	10%	23%	15%	7%	10%	15%



Text-fig. 5. Schema of radial section of *T. gypsaceum* (sample Bečov 2). t – tracheid, r – ray, bp – bordered pit, tp – taxodioid pit, cp – cupressoid pit, c – crassulae.

2011 *Taxodioxylon gypsaceum* (Göppert) Kräusel; Dolezych, p. 28, fig. 5–6, p. 29, pl. 1/1–2.

Material: Bečov 2 and 44804.

Description. Growth rings distinct, 0.1–1.2 mm wide, with earlywood zone distinctly wider than latewood; transition from earlywood to latewood is gradual.

Tracheids: Outline polygonal to hexagonal. Radial diameter of earlywood tracheids 21–38–56 µm, wall thickness 3–6 µm; radial diameter of latewood tracheids 7–19–28 µm, wall thickness 3–7 µm; tangential diameter of tracheids ranges from 14 to 49 µm; number of tracheids between two rays ranges from 1 to 8, most frequently 4 (Tab. 2). Pitting in radial tracheid walls uniseriate to biseriate; bordered pits circular in outline, 12–17 µm in diameter, with crassulae present (Text-fig. 5).

Rays: Mostly uniseriate, occasionally biseriate, with very low average height (4 cells). Total range of height between 1 and 16 cells (Text-fig. 4); 6–8 rays per tangential mm and 42–86 rays per square mm tangentially. Individual ray cells 15–21 µm high, horizontal and end walls thin and smooth (3–6 µm). Ray tracheids absent. Cross-fields pits cupressoid to taxodioid, 7–12 µm in diameter, 1–4 pits per cross-field, arranged mainly in one horizontal row, in two rows in marginal parts.

Axial parenchyma: Diffuse. Transverse walls thin (ca 2 µm) and smooth, but in sample Bečov 2, there are probably some nodular thickenings.

Discussion. This wood, similarly to the previous wood type, shows typical features of Cupressaceae: axial parenchyma present, cupressoid to taxodioid cross-field pits, with both resin canals and spiral thickenings on tracheids absent. The bordered pits in radial walls of the tracheids are disposed in two continuous vertical rows; the presence of taxodioid pits in cross-field, and predominantly smooth horizontal and end walls of the ray parenchyma point this wood to the genus *Taxodioxylon* (Süss and Velitzelos 1997). More than three pits in the cross-field, and mostly smooth walls of the ray parenchyma are typical of *T. gypsaceum* (Kräusel 1949). Van der Burgh (1973) recognizes very thin walls of the ray parenchyma as an important feature, which differentiates *T. gypsaceum* from other species of *Taxodioxylon*, but in a later study by Van der Burgh and Meijer (1996), those authors discussed variability in this species, including wall thickness.

T. gypsaceum is described from the Doupovské hory and České středohoří Mts. by Prakash et al. (1971); from the Most Basin by Teodoridis and Sakala (2008); from Germany by Selmeier (1972), Gottwald (1992), Van der Burgh and Meijer (1996), Dolezych (2011); and from numerous additional European Tertiary sites.

As stated above, the intra-specific and individual variation in *T. gypsaceum* (Van der Burgh and Meijer 1996) is quite important.

Such variation is also evident in modern wood studies, e.g. *Sequoia sempervirens* (Bailey and Faull 1934), *Abies balsamea* (Falcon-Lang 2005) and *Larix decidua* (Denne and Gasson 2008), which all show relatively high variation of anatomical features in conifer wood, both individual and intraspecific. It therefore seems probable that some taxa were defined superfluously in the past (e.g., see discussion in Van der Burgh and Meijer 1996) on the basis of these variations, although they may well have belonged to the same species, and their differences only reflected differing habitats or parts of the same plant. Van der Burgh and Meijer (1996) point to similarity of *T. gypsaceum* and some others taxodiaceous wood, like *T. albertense*, and suggest that possibility they all belonged to the same botanical species.

Another similar species, which was described by Teodoridis and Sakala (2008) from the Tertiary Most Basin, is *T. taxodii* Gothan. Several authors (e.g., Gottwald 1992, Teodoridis and Sakala 2008 or Dolezych 2011) describe thin walls of the ray parenchyma cells for this species, similarly to *T. gypsaceum*. However. *T. taxodii* has cross-field pits whose diameter is around half the size of those in our wood, and typical nodular thickenings on the transverse walls of the axial parenchyma (Gottwald 1992, Teodoridis and Sakala 2008, Dolezych 2011). Similarly, our wood does not present pitted horizontal walls of the ray parenchyma, which are considered typical of this species by Kräusel (1949). As a result, we designate our wood as *Taxodioxylon gypsaceum* (Göppert) Kräusel. *T. gypsaceum* is generally associated with recent *Sequoia sempervirens* (D. Don) Endlicher (e.g., Selmeier 1972, Dolezych 2011) as its nearest living relative. In the Most Basin, Teodoridis and Sakala (2008) associated *T. gypsaceum* with *Quasisequoia couttsiae* Heer, on the basis of co-occurring remains of leaves or cones (*Sequoia* is missing there). Absence of *Sequoia* remains together with parallel presence of *Q. couttsiae* was pointed out by Van der Burgh and Meijer (1996). In the study area, *Q. couttsiae* is known only from several localities where the sandstone of Staré Sedlo Fm. occurs (Knobloch et al. 1996), and no other remains of *Sequoia* or *Quasisequoia* have been recorded.

Taxodioxylon gypsaceum (Göppert) Kräusel (root wood)

Pl. 1, Fig. 1, Pl. 2, Fig. 6–9, Text-fig. 7

1971 *Sequioxylon* sp.; Prakash et al., pl. 32–34, fig. 10–25.

Material: Bečov 98/04.

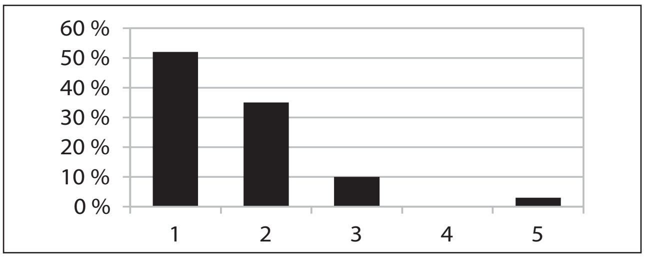
Description. Growth rings distinct, 1.5–2.3 mm wide, with earlywood zone distinctly wider than latewood; transition from earlywood to latewood is gradual.

Tracheids: Outline polygonal to hexagonal. Radial diameter of earlywood tracheids 70–87–105 µm; radial diameter of latewood tracheids is 35–49–70 µm; tangential diameter of tracheids ranges from 23 to 63 µm; number of tracheids between two rays ranges from 1 to 12, most frequently 2 (Tab. 3). Pitting in radial tracheid walls biseriate to triseriate; bordered pits circular in outline (Text-fig. 7), 10–17 µm in diameter.

Rays: Exclusively uniseriate, with very low (1–2 cells) average height. Total range of height between 1 and 5 cells (Text-fig. 6); 3–5 rays per tangential mm and 23–38 rays per square mm tangentially. Individual ray cells 21–42 µm high, horizontal and end walls thin and smooth (thickness of double wall: 3–6 µm horizontal and 3–9 tangential). Ray tracheids absent. Cross-fields pits taxodioid, occasionally cupressoid, 10–15 µm in diameter, 3–4 pits per cross-field arranged in 1–2 horizontal rows.

Axial parenchyma: Diffuse. Transverse walls not observed.

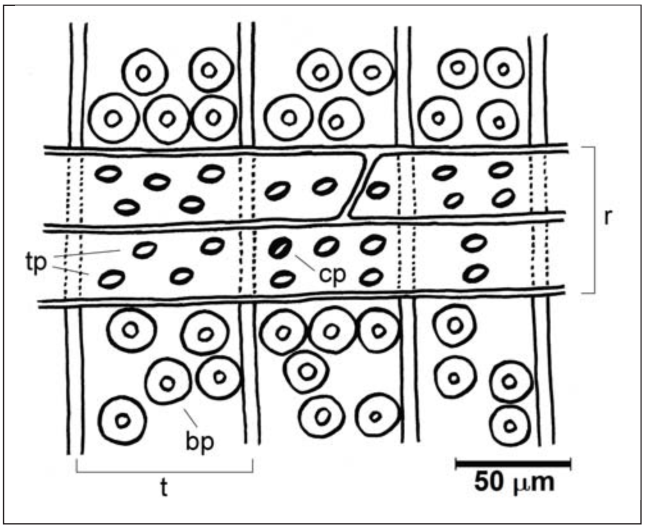
Discussion. Generally, this wood shows features that are typical of *Taxodioxylon gypsaceum* (Kräusel 1949), but it presents also several differences from the previous wood type 2, labelled *T. gypsaceum* (stem wood). Both types have opposite arrangement of bordered pits in radial tracheid walls, taxodioid and cupressoid pits in the cross-fields, similar diameter of the bordered pits, pits in cross-fields, and thin and smooth horizontal and end walls of the ray-parenchyma cells, but there is a difference in the transversal dimensions of the tracheids, and height of rays and individual ray-parenchyma cells.



Text-fig. 6. Percentage representation of rays according to height by *T. gypsaceum* (sample 98/04).

Table 3. Number of tracheid rows between rays in *T. gypsaceum* (sample 98/04).

value	1	2	3	4	5	6	7	8	9	10	11	12
frequency	15%	25%	15%	15%	3%	8%	5%	2%	2%	5%	0%	5%



Text-fig. 7. Schema of radial section of *T. gypsaceum* (sample 98/04). t – tracheid, r – ray, bp – bordered pit, tp – taxodioid pit, cp – cupressoid pit.

After comparing our fossil with those published earlier (e.g., Prakash et al. 1971, Selmeier 1972, Gottwald 1992, Van der Burgh and Meijer 1996, Teodoridis and Sakala 2008, Dolezych 2011), we think our wood is similar to Selmeier's (1972) samples from Waldkirch (Germany), except for the ray height. A similarity was also noted to *Sequoioxylon* sp. (Prakash et al. 1971): tracheids are smaller in Prakash's et al. specimen, but very low rays, bordered and cross-fields pits, and walls of the ray-parenchyma cells are similar. The authors described the tracheid outline as rounded, but the samples from Mikulovice have rather polygonal tracheid outline, as we can see in the published photos (Prakash et al. 1971: pl. 34, fig. 21 and 25). It is possible that these characteristics, which are different from the typical form *T. gypsaceum*, are related to the anatomical variation of the wood. Therefore, we think both our wood and the material described by Prakash et al. (1971) can be attributed to *T. gypsaceum*, but they probably come from a root. As demonstrated by several authors (e.g., Bailey and Faull 1934, Falcon-Lang 2005, Denne and Gasson 2008), the tracheids in root wood are up to two times larger than in stem, also the rays are generally lower, and individual ray cells higher in the root than the stem. Broadly oval outlines of ray-cells in tangential section

Table 4. Individual and intraspecific variability in wood anatomy: comparison between root, branch and stem wood anatomy, and between our wood and published descriptions of fossil woods attributed to *T. gypsaceum* (first two columns see Bailey and Faull 1934, Falcon-Lang 2005 and Denne and Gasson 2008; third column see Prakash et al. 1971, Selmeier 1972, Gottwald 1992, Van der Burgh and Meijer 1996, Teodoridis and Sakala 2008 and Dolezych 2011).

	Root	Branch	Our wood
	vs. mature stem		vs. *T. gypsaceum*
Growth ring width	--	-	+?
Ray high in cells	-	-	-
Ray parenchyma cells high	+		+
Ray parenchyma cells length	-		?
Ray – tg width	+	-	
Rays per tg mm	--	+	?
Cross-field pits number	+	+	+
Cross-field pits diameter	+		0
Vertical rows of bordered pit	++	-	+
Tracheids lenght	+	-	?
Tracheids tg diameter	+	-	+
Tracheids rd diameter	+		+

0	feature is similar
+	feature is greater
-	feature is smaller
++/--	feature is significantly greater/smaller

indicate a root as well. Unfortunately, it is not possible to verify tracheid length, due to insufficient longitudinal sections. The majority of the features, except possibly for the growth ring width point to root wood (Bailey and Faull 1934, Falcon-Lang 2005).

The poorly-observed late-wood zone, which is almost indistinct, can also indicate root wood (Bailey and Faull 1934, Denne and Gasson 2008). Low rays can also correspond to the innermost part of the stem, but there are thinner tracheids. A comparison of some features within individual variability is shown in Tab. 4. We designate our wood type 3 as *Taxodioxylon gypsaceum* (Göppert) Kräusel (root wood).

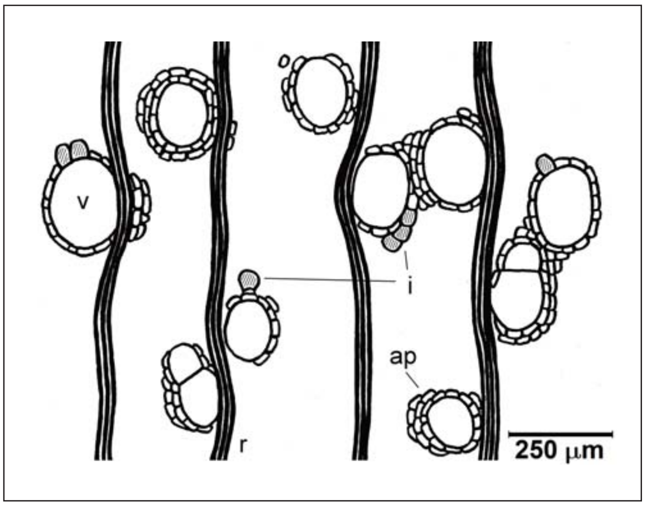
Angiosperms

Family: **Lauraceae**
Cinnamomoxylon Gottwald
Cinnamomoxylon seemannianum (Mädel) Gottwald

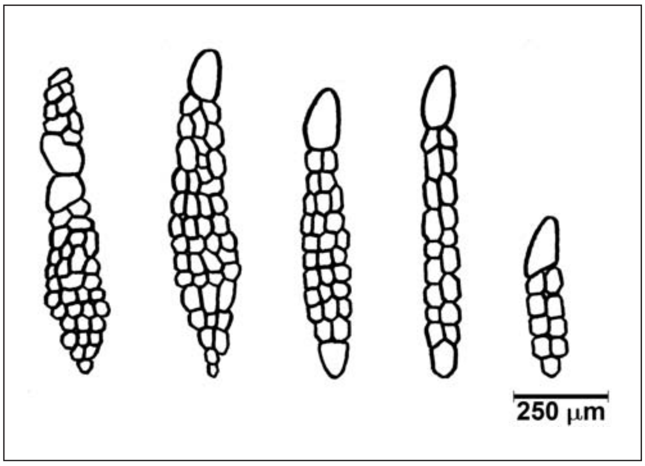
Pl. 3, Fig. 1–4, Text-fig. 8–9

1958 *Laurinoxylon seemannianum* Mädel; Mädel in Süss and Mädel, p. 82–83, text-fig. 1, 2, p. 91, pl. I, fig. 1–4, p. 93, pl. II, fig. 5–8.
1969 *Laurinoxylon* cf. *seemannianum* Mädel; Selmeier, p. 732, text-fig. 1–3, p. 735, text-fig. 5–8.
1974 *Laurinoxylon tertiarum* Prakash et Tripathi, p. 311, text-fig, pl. IV/20–25.
1984 *Laurinoxylon seemannianum* Mädel; Selmeier, p. 14–21, text-fig. 1–9
1997 *Cinnamomoxylon seemannianum* (Mädel) Gottwald; Gottwald, p. 26, text-fig. 11, p. 69, pl. IV, fig. 34–37

Material: Nechranice 69/03, 71/03, 79/04, 81/04, 111/06.



Text-fig. 8. Schema of transversal section of *C. seemanianum* (sample 81/04). v – vessel, r – ray, ap – paratracheal axial parenchyma, i – idioblast.



Text-fig. 9. Schema of typical rays in *C. seemannianum* (sample 81/04).

Description. Wood is diffuse-porous (Text-fig. 8); growth ring boundaries are indistinct.

Vessels: Mostly solitary (52–81%), occasionally in radial multiples of 2–3; solitary pores circular in outline. Tangential diameter 47–112–196 µm, radial diameter 47–274 µm; pore density ranges from 7 to 11 per square mm. Perforation plates exclusively simple; intervessel pits alternate, with polygonal outlines, 6–15 µm in diameter.

Rays: Heterocellular, 2–4 cells (29–88 µm) wide, 5–29 cells (127–525 µm) high, composed of procumbent cells and one row of upright marginal cells with idioblasts; density 6–9 rays per tangential mm. Bi- and triseriate rays common, quadriseriate rare; biseriate rays 29–49 µm wide, 5–22 cells (127–470 µm) high; triseriate rays 29–69 µm wide, 7–29 cells (147–525 µm) high; quadriseriate rays 49–88 µm wide, 16–26 cells (186–490 µm) high. A schema of typical rays is presented in Text-fig. 9.

Axial parenchyma: Paratracheal vasicentric, locally aliform, in 1–2 (occasionally 3) often incomplete layers around vessels, often confluent between two neighbouring vessels; idioblasts present.

Table 5. Comparison of *C. seemannianum* with similar fossil wood from family Lauraceae, tg – tangential.

	Laurinoxylon tertiarum **(Prakash and Tripathi 1972)**	***Cinnamomoxylon seemannianum*** **(our wood)**	***Cinnamomoxylon seemannianum*** **(Gottwald 1997)**	***Cinnamomoxylon seemannianum*** **(Selmeier 1984)**	***Cinnamomoxylon*** **cf.** ***seemannianum*** **(Selmeier 1969)**	***Cinnamomoxylon seemannianum*** **(Süss and Mädel 1958)**
Vessel arrangement	solitary and in radial multiples of 2–4	mostly solitary and in radial multiples of 2–3	solitary and in radial multiples of 2–4	especially solitary and in radial multiples of 2, less in radial multiples of 3–4 (6)	solitary and in radial multiples of 2–3	solitary and in radial multiples of 2–3
Vessels tangential diameter	60–152 µm	47–196 µm (mean 112)	mean 120 and 135 µm	45–200 µm (mean 110)	58–116 µm (mean 91)	25–150 µm (mean 99)
Vessels radial diameter	80–200 µm	47–274 µm	unknown	unknown	53–191 µm (mean 119)	45–180 µm (mean 115)
Vessels density (number per mm^2)	8–10	7–11	9 and 11	12–24	8–19	13–29
Perforation plates	simple and scalariform with 8–10 bars	simple	simple and occasionally scalariform with 4 bars	simple	simple and scalariform with 7–9 bars	simple
Axial parenchyma	vasicentric: 1–3 cells thick sheaths, occasionally aliform, rarely confluent	vasicentric: 1–2(3) cells thick sheaths, occasionally gently aliform, rarely confluent	vasicentric, often confluent	scanty paratracheal, incompletely vasicentric, in places confluent	vasicentric: 1–2 cells thick sheaths	vasicentric: 1–2 cells thick sheaths
Rays	1–3(4), mostly 2 cells wide	2–3(4) cells wide	1–4, mostly 2 and 3 cells wide	(1)2–3(4) cells wide	1–3(4) cells wide	1–3 cells wide
Rays per tg mm	6–8	6–9	unknown	6–10	14–18	5–10
Idioblasts	in rays, axial parenchyma and among fibres	in rays, axial parenchyma and among fibres	in rays, axial parenchyma and occasionally among fibres	in marginal cells of rays, occasionally isolated	in marginal cells of rays, apparently among fibres	in marginal cells of rays, axial parenchyma and among fibres
Age	late Miocene	Oligocene/Miocene	early Miocene	early-middle Miocene	late Miocene	Miocene

Idioblasts: Present in rays (in their marginal part or among two confluent rays), axial parenchyma and among fibres.

Fibres: Thin-walled, occasionally septate.

Discussion. All features, among others the presence of idioblasts, indicate that our wood belongs to the family Lauraceae (Dupéron-Laudoueneix and Dupéron 2005).

Four woods from this family were described from Tertiary of north-western Bohemia: *Laurinoxylon czechense* Prakash et al. (Prakash et al. 1971), which were also mentioned by Sakala et al. (2010); a type species of *Laurinoxylon*, *L. diluviale* (Unger) Felix, newly revised by Dupéron et al. (2008); *Sassafrasoxylon lipnicense* Březinová et Süss (Březinová and Süss 1988); and *Laurinoxylon* sp. (Březinová 1981). Our wood type is different from all of them. *L. czechense* has idioblasts associated only with rays. *L. diluviale* as newly observed by Mantzouka et al. (submitted) has idioblasts associated with ray parenchyma, and also among the fibres, not with axial parenchyma; moreover, the ray width of both species is different. *Sassafrasoxylon lipnicense* has ring porous wood (Březinová and Süss 1988), and the wood described by Březinová (1981) as *Laurinoxylon* sp. has narrower rays and distinctly wider vessels.

Our wood is most similar to the fossil species from *Laurinoxylon* Type 3 sensu Mantzouka et al. (submitted), i.e., with idioblasts in rays, in axial parenchyma, and among the fibres: *Laurinoxylon tertiarum* Prakash et Tripathi, *Laurinoxylon variabile* Privé-Gill et Pelletier, *Cinnamomoxylon limagnense* (Privé-Gill et Pelletier) Gottwald and *Cinnamomoxylon seemannianum* (Mädel) Gottwald.

However, *Cinnamomoxylon limagnense* has scalariform perforation plates (Privé-Gill and Pelletier 1981, Gottwald 1997), and very frequent idioblasts at the ray margins (Privé-Gill and Pelletier 1981). *L. tertiarum* (Prakash and Tripathi 1974) also has scalariform perforation plates, but other features are similar to our wood. *L. variabile* (Privé-Gill and Pelletier 1981) has up to 5-celled sheaths of frequently confluent vasicentric parenchyma, and thick-walled fibres. This is the only *L. seemannianum* (Mädel in Süss and Mädel 1958) that presents simple perforation plates alone, although according to Selmeier (1969), Süss (1958) observed two categories of this species: those with exclusively simple and those with exclusively scalariform perforation plates. Selmeier (1969) described *L.* cf. *seemannianum* with 4-seriate rays, and with both types of perforation plates. The new combination *Cinnamomoxylon seemannianum* was done by Gottwald (1997), and our wood fits his definition of *Cinnamomoxylon*. A comparison this wood type with similar ones can be seen in Tab. 5.

This wood shows similarity to the genus *Cinnamomum* (Richter 1981), and we designate our wood type 4 as *Cinnamomoxylon seeemanianum* (Mädel) Gottwald.

The presence of a cinnamon in the Tertiary of north-western Bohemia is independently confirmed by fossil leaves and fruits of *Daphnogene cinnamomifolia* (Brongniart) Unger from the Doupovské hory and České středohoří Mts. (e.g., Bůžek et al. 1990, Kvaček 2011).

Family: **Betulaceae**

Alnus Miller

Alnus tschemrylica Blokhina et Snezhkova

Pl. 3, Fig. 5–8, Text-fig. 10

1999 *Alnus tschemrylica* Blokhina et Snezhkova, p. 468, fig. 1a–o.

Material: Vrbice 91/04, 92/04, 93/04, 97/04.

Description. Wood is diffuse-porous (Text-Fig. 10); growth rings are distinct and 1–4.8 mm wide.

Vessels: Occasionally solitary (20–25%), mostly in radial multiples of 2–7 and clusters, rarely in tangential multiples of 2; solitary pores oval to angular, radially elongated. Tangential diameter 14–45–77 µm, radial diameter 28–119 µm;

pore density ranges from 110 to 160 per square mm. Perforation plates scalariform, with 18–24–29 bars; intervessel pits alternate and opposite.

Rays: Homocellular, two types: 1) mostly uniseriate occasionally biseriate, composed exclusively of procumbent cells, and 2) large aggregate.

Axial parenchyma: Not observed.

Fibres: Not observed.

Discussion. All features (diffuse porous wood, very small vessels, scalariform perforation plates with many bars, very thin rays as well as large aggregate rays) indicate that our wood belongs to the subfamily Betuloideae of Betulaceae (Hall 1952).

In the subfamily Betuloideae, there are two anatomically similar genera: *Betula* and *Alnus*. The difference between these genera cannot be generalized, but the presence of predominantly uniseriate rays together with aggregate rays is rather typical of *Alnus* (Hall 1952). Moreover, our wood shows small tangential diameter of vessels, and alternate arrangement of intervessel pits. All the above-mentioned features point to the genus *Alnus.*

There are only a few fossil woods attributed to *Alnus* or *Alnoxylon* so far: *Alnus latissima* Wheeler et al., *A. scalariforme* Srivastava et Suzuki, *A. tschemrylica* Blokhina et Snezhkova and *Alnoxylon vasculosum* Felix emend. Müller-Stoll et Mädel.

A. latissima (Wheeler et al. 1977) and *A. scalariforme* (Srivastava and Suzuki 2001) have fewer bars in their perforation plates, and only uniseriate rays. *Alnoxylon vasculosum* is according to Srivastava and Suzuki (2001) similar to *A. scalariforme*, but it has no scalariform perforation plates. Our wood shows the greatest similarity with *Alnus tschemrylica* (Blokhina and Snezhkova 1999). This fossil species has occasionally biseriate rays and scalariform perforation plates with up to 30 bars. We designate our wood type 5 as *Alnus tschemrylica*.

Fossil leaves and fruits of *Alnus* are described from the Tertiary of north-western Bohemia as *A. gaudinii* (Heer) E. Knobloch et Kvaček*, A. kefersteinii* (Göppert) Unger and *A. rostaniana* Saporta from the České středohoří Mts. (e.g., Kvaček and Walther 2004, Akhmetiev et al. 2009). The first author of this contribution found several fossil leaves directly at Vrbice, which were later identified by Z. Kvaček (pers. comm. 2014) as *Alnus* sp.

Family: **Ulmaceae**
***Ulmoxylon* Kaiser**
***Ulmoxylon* cf. *kersonianum* Starostin et Trelea**

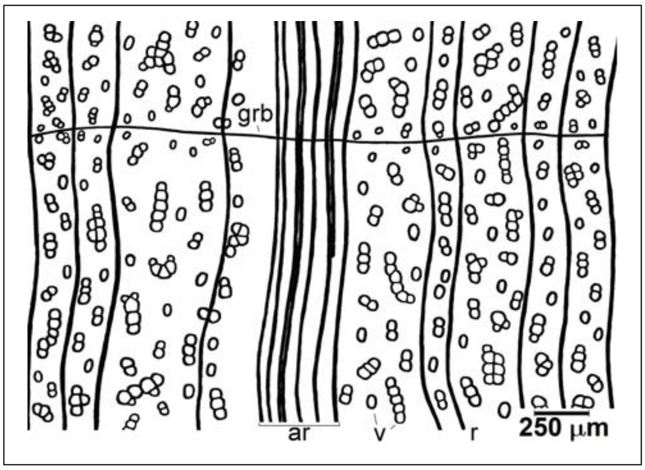
Pl. 1, Fig. 2, Pl. 4, Fig. 1–4, Text-fig. 11

?1969	*Ulmoxylon kersonianum* Starostin et Trelea, p. 450–451, fig. 1–2.
2010	*Ulmus* sp.; Sakala et al., p. 623, fig. 5C.

Material: Nechranice 75/04, Vrbice 1/3, 1/4.

Description. Wood is ring-porous (Text-fig. 11); growth rings are distinct, 0.6–(1.6)–2.9 mm wide.

Vessels: Earlywood vessels in tangential or radial multiples of 2 (occasionally 3), in 1–3 tangential rows, latewood vessels form clusters arranged in tangential to diagonal wavy bands; solitary pores circular in outline. Tangential diameter of earlywood vessels 28–87–140 µm, radial diameter 49–168 µm; tangential diameter of latewood vessels 14–33–49 µm, radial diameter 19–65 µm. Perforation plates exclusively simple; intervessel pits alternate, with polygonal outlines. Helical thickenings present.



Text-fig. 10. Schema of transversal section of *A. tschemrylica* (sample 97/04). v – vessel, r – ray, ar – aggregate ray, grb – growth-ring boundary.

Rays: Homocellular, 2–3 (occasionally 4) cells wide, 8–24 cells high, composed exclusively of procumbent cells.

Axial parenchyma: Scanty paratracheal.

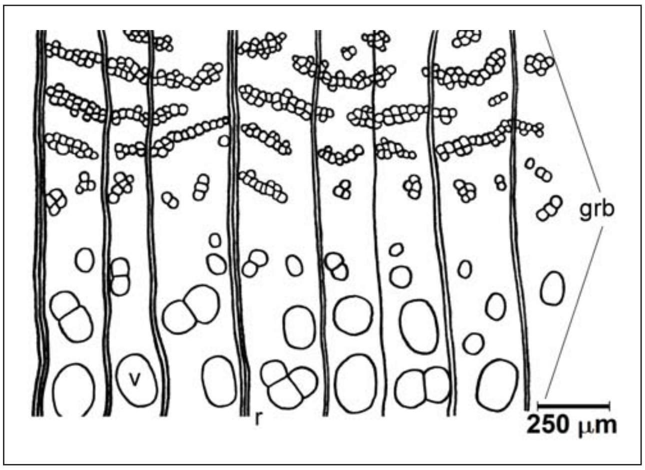
Fibres: Thin-walled.

Discussion. All features, especially the ring porosity and the typical ulmoid latewood vessels arrangement indicate that our wood belongs to the family Ulmaceae (Wheeler and Manchester 2007). A ring (or semi-ring) porous wood with latewood vessels in tangentially oriented wavy clusters is typical of deciduous specimens of this family, which are *Hemiptelea*, *Planera*, *Ulmus* and *Zelkova* (Wheeler and Manchester 2007).

Planera has diffuse to semi-ring porous wood, and its earlywood vessels do not form rows. *Zelkova* has only one row of earlywood vessels, and crystals in axial parenchyma, as well as in enlarged ray cells; *Hemiptelea* typically has very wide rays (Wheeler and Manchester 2007). All described features point to the genus *Ulmus.*

For a correct determination, it is necessary to take into account the preservation of our samples, as well as the fact they probably represent small branches. Therefore, it is possible that some of the measured dimensions are not typical.

The first specimen from the Czech Republic attributed to the Ulmaceae was identified in Bílina by Sakala (2002) as *Ulmoxylon marchesonii* Biondi. The same species was also described by Kłusek (2012) from south-eastern Poland, from the village Włoszczowice. Our wood type (see also in Sakala et al. 2010: 623) is similar to both descriptions, but has thinner rays, and no chambered crystalliferous axial parenchyma was observed. However, according to Biondi's (1981a) definition, there are most frequently tri-seriate rays. The difference of the vessel lumina dimensions can be caused by wood maturity, habitat conditions etc. Our wood is also similar to *Ulmoxylon* sp. ex aff. *Ulmus campestris* Linnaeus (Sacchi-Vialli 1958) and *Ulmoxylon* cf. *carpinifolia* (Greguss 1969), but they both have wider rays, and the latter also has cham-



Text-fig. 11. Schema of transversal section of *Ulmoxylon* cf. *kersonianum* (sample 1/3). v – vessel, r – ray, grb – one growth ring.

bered axial parenchyma with crystals. Both of them are also inadequately described, so it is not easy to present an unambiguous determination.

Ulmoxylon kersonianum (Starostin and Trelea 1969) is very similar to our fossil: it does not have chambered crystalliferous axial parenchyma; on the other hand, it also has wider rays. Although *U. marchesonii* more frequently has thinner rays, and its vessel diameter is closer to our wood than that of *U. kersonianum*, we propose, based on absence of crystalliferous chambered axial parenchyma, to designate this wood type as *Ulmoxylon* cf. *kersonianum* Starostin et Trelea. It was marked "cf." because of thinner rays and smaller vessels in our wood, possibly caused by its juvenile character.

The genus *Ulmus* is recorded in the Tertiary of north-western Bohemia both as foliage and leaves: *U. fischeri* Heer from Doupovské hory and České středohoří Mts. (e.g., Bůžek et al. 1990, Kvaček and Walther 2004) and *U. pyramidalis* Göppert from České středohoří Mts. (e.g., Akhmetiev et al. 2009). *U. pyramidalis* was associated by Sakala (2002) with the wood of *U. marchesonii*. The fossil leaves found by Kotlaba (1960) at Vrbice were later identified by. Z. Kvaček (personal communication 2014) as *U. fischeri*. It is therefore possible that the wood of *Ulmoxylon kersonianum* can be associated with the leaves of *Ulmus fischeri.*

Family: **Malvaceae s.l.**
***Grewioxylon* J. Schuster**
***Grewioxylon ortenburgense* Selmeier**

Pl. 4, Fig. 5–8, Text-fig. 12–13

1985	*Grewioxylon ortenburgense* Selmeier, p. 125–129, pl. III, fig. 4, pl. IV, fig. 1–4, pl. V, fig. 1–2.
2000	*Grewioxylon ortenburgense* Selmeier, p. 467–476, fig. 2–9 and 11–14.
2010	aff. *Craigia* sp. Sakala et al., p. 623, fig. 5D–G.

Material: Nechranice 70/03, 78/04, 84/04, 89/04, 90/04.

Description. Wood is semi-ring porous (Text-fig. 12); growth rings are distinct, 1–1.4 mm wide, clearly observed.

Vessels: Rarely solitary (11–19%). Earlywood vessels in tangential or radial multiples of 2–3 (occasionally 4), latewood vessels in radial multiples of 2–3 (occasionally 6), sporadically in clusters; solitary pores circular in outline. Tangential diameter of earlywood vessels 140–253–363 µm, radial diameter 112–372 µm; tangential diameter of latewood vessels 47–91–167 µm, radial diameter 37–149 µm; earlywood pore density 5–7–11 per square mm, latewood 8–14–18. Perforation plates exclusively simple; intervessel pits alternate, with hexagonal outlines, 12–14 µm in diameter.

Rays: Two types of rays (Text-fig. 13): 1) uniseriate rays; and 2) 4–8 cells (78–196 µm) wide, heterocellular rays, composed of procumbent cells and tile cells of *Pterospermum* type. They slightly widen tangentially at growth ring boundaries in cross-section, their height ranges from 441 to 1274 µm. Ray density 3–4 rays per tangential mm.

Axial parenchyma: Diffuse and scanty paratracheal.

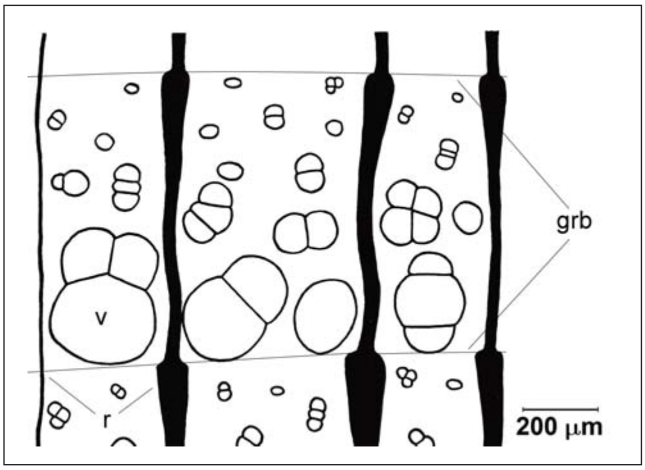
Fibres: Not observed.

Discussion. The presence of tile cells points clearly to the family Malvaceae s.l., or some species of the genus *Hopea* from the family Dipterocarpaceae (Manchester et al. 2006).

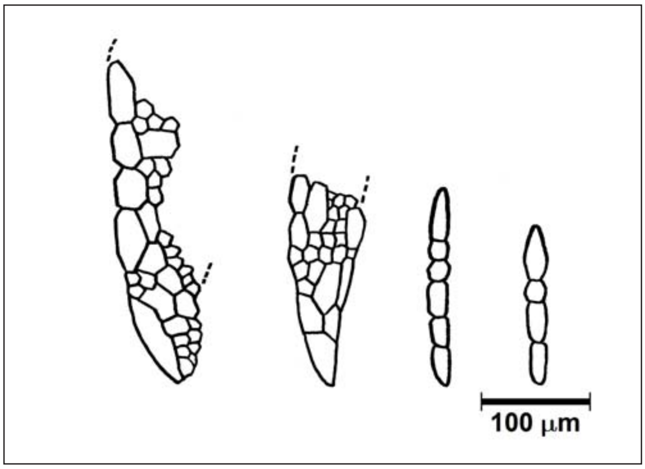
Our samples with "tile cells of *Pterospermum* type" according to Manchester and Miller (1978), together with the sample 72/03 from the locality Kadaň-Zadní vrch Hill (Doupovské hory Mts.) were attributed to the family Malvaceae s.l. by Sakala et al. (2010). The authors put the wood closer to *Craigia*, but did not observe helical thickenings in vessels (Sakala et al. 2010), which are typical of modern wood (Manchester et al. 2006).

Among the fossil representatives described so far, our wood is most similar to *Grewioxylon ortenburgense* Selmeier, *Grewioxylon auctumnalis* Gottwald, *Chattawaya paliformis* Manchester and *Triplochitioxylon oregonensis* Manchester. There is also *Wataria* Terada et Suzuki, which is rather similar to our wood, except for ring porous wood and chiefly solitary earlywood vessels (Tereda and Suzuki 1998). *G. ortenburgense* has lower tangential dimensions of vessels and more (up to twice as many) rays per tangential mm than our wood (Selmeier 1985). A possible explanation of the later difference can be due to the fact that we counted only multiseriate rays, since uniseriate rays were not well preserved. Concerning the vessel dimensions, a clue for understanding the variability in this species was presented by Selmeier (2000). On the other hand, *G. auctumnalis* has prismatic crystals, and its axial parenchyma forms discontinuous tangential bands (Gottwald 1997). Similarly, both *T. oregonensis* and *Ch. paliformis* have prismatic crystals and reticulate axial parenchyma (Manchester 1979, 1980). The anatomical comparison of our wood with similar woods is given Tab. 6. We designate it as *Grewioxylon ortenburgense* Selmeier.

According to Sakala (2007), it is possible that fossil woods of *Grewioxylon* can be associated with the fossil fruit remains of *Craigia*. In fact, numerous fossil fruit remains of *Craigia bronni* (Unger) Kvaček, Bůžek et Manchester and the accompanying leaves *Dombeyopsis lobata* Unger in many localities in the České středohoří Mts. and the Most, Sokolov and Cheb Basins (Kvaček 2004) support this hypothesis about the association of *Grewioxylon* and *Craigia.*



Text-fig. 12. Schema of transversal section of *Grewioxylon ortenburgense* (sample 89/04). v – vessel, r – ray, grb – growth ring boundary.



Text-fig. 13. Schema of typical rays in *G. ortenburgense* (sample 89/04 and 90/04).

Family: **Sapotaceae**
***Manilkaroxylon* Grambast-Fessard**
***Manilkaroxylon* sp.**

Pl. 1, Fig. 3, Pl. 5, Fig. 1–5, Text-fig. 14–15

Material: Divoká rokle: DR 2.

Description. Wood is diffuse-porous (Text-fig. 14); growth rings are distinct, and 0.5–0.6 mm wide. Vessels arranged in radial pattern (Text-fig. 14).

Vessels: Mostly solitary (ca. 76%) or in radial multiples of 2–3, tangential multiples of 2 and occasionally in clusters; solitary pores circular to angular in outline. Tangential diameter 35–89–147 µm, radial diameter 29–167 µm; pore density 18–34–43 per square mm. Perforation plates simple, horizontal or slightly inclined; intervessel pits alternate, with angular outlines, 6–9 µm in diameter; vessel element lengths 225–312–500 µm.

Rays: Heterocellular, 1–3 cells (14–42 µm) wide, 1–18 cells (56–539 µm) high, body composed only of procumbent ray cells and marginal rows of upright ray cells; ray density 5–10 rays per tangential mm. Rays with long uniseriate extremities almost as wide as multiseriate portions, rays with short extremities generally spindle-shaped (Text-fig. 15).

Axial parenchyma: Diffuse to diffuse-in-aggregates, and scanty paratracheal.

Fibres: Thin-walled, septate fibres present.

On the longitudinal sections, there are crystals, sometimes crossing the anatomical elements.

Discussion. An overall poor preservation of anatomical elements at longitudinal sections, and problematic distinction of axial parenchyma in cross section make exact determination of this wood type quite difficult. The vessel arrangement together with alternate intervessel pitting, presence of thin heterocellular rays, and prismatic crystals point to the family Sapotaceae (Wheeler et al. 2007). The problem consists of the presence of banded parenchyma typical of Sapotaceae, which was not observed in our wood. It might be that such thin bands are present, but not distinguishable from fibres. The presence of wide bands is rather improbable, as they should be observed in radial section as well. Similarly, a presence of prismatic crystals in our wood is problematic, because they can later be obscured by permineralization.

Prakash et al. (1982) showed a great similarity and consequent difficult classification of the taxa in the family Sapotaceae. Based on InsideWood database (2004 – onwards), we compared our wood with several fossil species from Sapotaceae described as *Arganioxylon sardum* Biondi, *Bumelioxylon holleisii* Selmeier, *Chrysophylloxylon pondicherriense* Awasthi, *Madhucoxylon cacharense* Prakash et Tripathi, *Manilkaroxylon crystallophora* Grambast-Fessard, *Manilkaroxylon bohemicum* Prakash et al.*, Sapotoxylon multiporosum* Prakash et al., *Sapotoxylon* sp. 1 and *Sapotoxylon* sp. 2 both described by Wheeler et al. (2007) and *Siderinium deomaliense* Prakash et Awasthi.

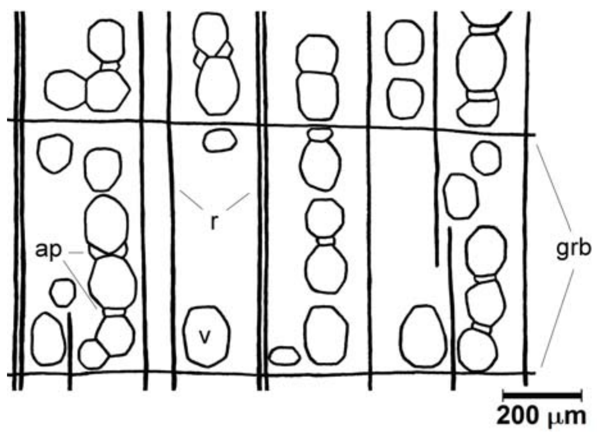
A. sardum has up to 8-cell-wide tangential bands of axial parenchyma, and long radial groups of vessels (Biondi 1981b). *B. holleisii* is the only one with polygonal vessel outlines (Selmeier 1991), but the author described spiral thickenings in vessels, distinctly smaller vessel diameters and thinner rays than in our wood. *B. holleisii* is similar to modern *Bumelia*, which was classified by Kukachka (1978a) into "*Bumelia* A". *Ch. pondicherriense* has up to 50-cell-high rays, and very long vessel elements (Awasthi 1975). The nearest modern living relative, genus *Chrysophyllum*, also has very long vessel elements, with the shortest ones (in *Ch. marginatum*) having a mean length 530 µm (Kukachka 1978b). *M. cacharense* does not have vessels arranged in radial multiples (Prakash and Tripathi 1975). *S. multiporosum* has higher (up to three times higher) pore density than our wood, and maximally biseriate rays (Prakash et al. 1982). *Sapotoxylon* sp. 1 and sp. 2 are similar to our wood, but they have wider bands of axial parenchyma (Wheeler et al. 2007). *S. deomaliense* has very high rays, up to 77 cells (Prakash and Awasthi 1969). Our wood shows the greatest similarity to *Manilkaroxylon* (Grambast-Fessard 1968). The problem consists only in the presence of banded parenchyma, which was discussed previously. Because of similarity with Sapotaceae, our wood was also compared with modern *Manilkara,* the wood of which has, according to Kukachka (1981), the following features: vessels arrange-

Table 6. Comparison of *G. ortenburgense* with similar fossil wood from family Malvaceae s.l.

	Grewioxylon auctumnalis **(Gottwald 1997)**	***Grewioxylon ortenburgense*** **(Selmeier 1985)**	***Grewioxylon ortenburgense*** **(Selmeier 2000)**	***Grewioxylon ortenburgense*** **(our wood)**	***Craigia? – 72/03*** **(Sakala et al. 2010 + new observation)**	***Chattawaya paliformis*** **(Manchester 1980)**	***Triplochitioxylon oregonensis*** **(Manchester 1979)**
Porosity	semi-ring porous	diffuse to semi-ring porous	semi-ring porous	semi-ring porous	semi-ring porous	diffuse to semi-ring porous	diffuse to semi-ring porous
Vessel arrangement	solitary and in radial multiples of 2–4	solitary; mostly in radial multiples of 2–6 (inclinations to tangential multiples)	solitary and in radial multiples of 2–7	solitary; mostly in radial uncommonly in tangential multiples of 2–3 (6); rarely in clusters	solitary; mostly in radial uncommonly in tangential multiples of 2–3(4)	solitary; in radial multiples of 2–4; occasionally in clusters	solitary and in radial multiples of 2–3
Vessels tangential diameter	190–235 µm earlywood; 80–115 µm latewood vessels	58–240 (280) µm (early and late wood)	156–299 µm earlywood; 52–143 µm latewood vessels	140–363 µm earlywood; 47–167 µm latewood vessels	149–372 µm earlywood; 56–177 µm latewood vessels	20–250 µm (early and late wood)	40–290 µm (early and late wood)
Vessels density	4–9 per square mm	6–11 per square mm in early wood; 7–16 per square mm in late wood	4–13 per square mm in early wood; 5–12 per square mm in late wood	5–11 per square mm in early wood; 8–18 per square mm in latewood	6–9 per square mm in early wood; 9–10 per square mm in late wood	average 14 per square mm	1–9 per square mm
Perforation plates	simple	simple	simple	simple	simple	simple	simple
Intervessel pits	alternate	alternate, polygonal (5–6 mm)	alternate	alternate, hexagonal	unknown	alternate	alternate
Axial parenchyma	vasicentric (locally aliform); marginal (discontinuous bands)	paratracheal, diffuse, occasionally in discontinuous bands	diffuse and vasicentric	diffuse and scanty vasicentric	diffuse to diffuse in aggregates, vasicentric	diffuse, vasicentric and reticulate in uniseriate tangential aggregates	vasicentric (1–3 cells wide sheaths) and reticulate in uni- and biseriate tangential aggregates
Rays	uniseriate and 3–4(6) cells wide, heterocellular with tile cells of *Pterospermum* type	uniseriate and 4–8(12) cells wide (wider on growth ring boundaries), heterocellular with tile cells of *Pterospermum* type	uniseriate and 3–12 cells wide with tile cells of *Pterospermum* type	uniseriate and 4–8 (widening at growth ring boundaries) cells wide, heterocellular with tile cells of *Pterospermum* type	uniseriate and 4–11 (widening at growth ring boundaries) cell wide, heterocellulas with tile cells of *Pterospermum* type	1–3 seriate and 4–14 cells wide, presence of tile cells of *Pterospermum* type	1–10 cells wide, heterocellular with tile cells *Pterospermum* type
Rays per tg mm	unknown	7–11(13)	5–9	3–4	3–6	2–6	3–7
Prismatic crystals	present	absent	absent	absent	absent	in tile cells and axial parenchyma	in tile cells

ment into parallel radial rows, eventually in combination with clusters; vessels in short radial multiples; uni- to biseriate rays sporadically 3- to 4-seriate and one- to three-cell wide tangential bands of axial parenchyma. The presence of prismatic crystals is typical only of some of species: *M. albescens* and *M. jaimiqui* have prismatic crystals even in tyloses (Kukachka 1981). On the basis of these features (wood diffuse porous, vessels arrangement in radial pattern, thin rays with low bodies and long extremities), our wood can be placed close to *Manilkara*, and designated *Manilkaroxylon.* Only two species were defined so far within this fossil genus: *M. crystallophora* and *M. bohemicum. M. crystallophora* (Grambast-Fessard 1968) has smaller vessels than our wood, and its rays contain abundant prismatic crystals. *M. bohemicum* (Prakash et al. 1974) has markedly bigger vessels, and abundant prismatic crystals in axial parenchyma. The problem with the presence of prismatic crystals in our wood was discussed earlier. Due to poor preservation of the single specimen, we leave our wood in open nomenclature as *Manilkaroxylon* sp.

In the Tertiary of north-western Bohemia, no fossil remain of *Manilkara* or *Manilkaroxylon* is known.



Text-fig. 14. Schema of transversal section of *Manilkaroxylon* sp. (sample DR2). ap – axial parenchyma, grb – growth ring boundaries, r – rays, v – vessels.

Xylotype Nechranice 1

Pl. 5, Fig. 6–9

Material: Nechranice: 112/06.

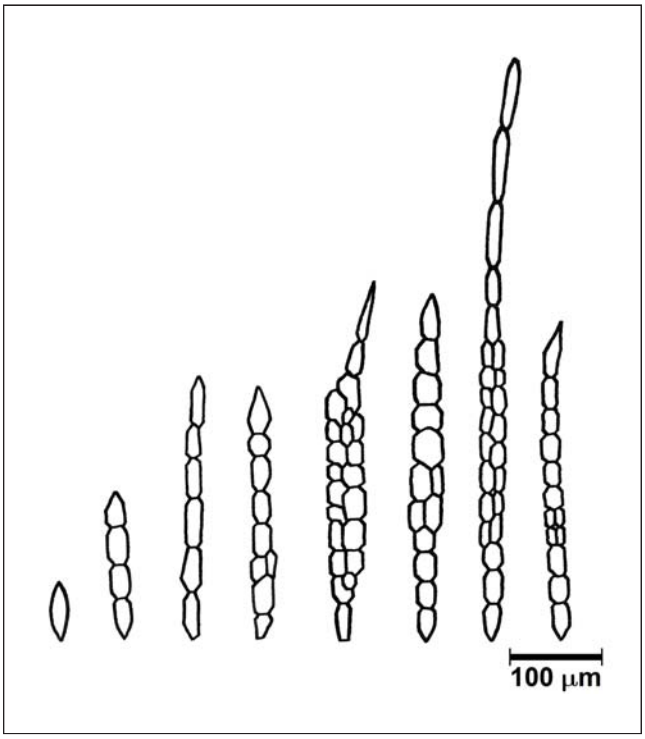
Description. Wood is diffuse-porous; growth rings are poorly observed.

Vessels: Rarely solitary (24%), more frequently in radial multiples of 2–7 and in clusters; solitary pores circular to angular in outline. Tangential diameter 42–96–149 µm, radial diameter 84–149 µm; pore density 27 per square mm.

Rays: Homocellular, 1–2 cells (14–56 µm) wide, 3–28 cells (21–196 µm) high, composed of procumbent cells; density 4–7 rays per tg mm. Biseriate rays have short uniseriate extremities, some have uniseriate portions among two biseriate bodies.

Axial parenchyma: Scanty paratracheal.

Fibres: Not observed.



Text-fig. 15. Schema of observed rays of *Manilkaroxylon* sp. (sample DR2).

Discussion. Extremely poor preservation of the material does not allow any closer systematical attribution. However, we can say that this taxon is different from all the previously described ones and we propose to designate it as "Xylotype Nechranice 1".

Conclusions

Fossil wood is both abundant and ubiquitous through geological time and space. The Tertiary of northwestern Bohemia, mainly the volcanic regions of the Doupovské hory (DH) and České středohoří (CS) Mountains are famous for their rich fossil wood record. We present here a study of thirty-seven new samples from four localities: three of them, i.e., Vrbice, Nechranice (both from DH) and Bečov (CS) represent pyroclastic deposits of the second phase of neovolcanic activity, the fourth one, Divoká rokle (CS), is a mudflow deposit of the Ústí Formation.

We have identified three types of conifers; two of them are interpreted as a stem wood, one as a root wood, and all belong to the Cupressaceae s.l., more precisely to two fossil species: *Glyptostroboxylon rudolphii* and *Taxodioxylon gypsaceum*. There are also six types of angiosperms, which belong to the families Lauraceae, Betulaceae, Ulmaceae, Malvaceae, and Sapotaceae. The last problematic angiosperm wood does not show any clear systematical affinity, and is labelled here as "Xylotype: Nechranice 1" due to its poor preservation. The two fossil conifers are known from the Tertiary of northwestern Bohemia, but the five angiosperms, *Cinnamomoxylon seemannianum*, *Alnus tschemrylica*, *Ulmoxylon* cf. *kersonianum, Grewioxylon ortenburgense* and *Manilkaroxylon* sp. are documented in the studied area for the first time.

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Explanations of the plates

PLATE 1

Fossil material from Doupovské hory Mts. and České středohoří Mts.

1. *Taxodioxylon gypsaceum* (GOEPPERT) KRÄUSEL (root wood), sample Bečov 2.
2. *Ulmoxylon* cf. *kersonianum* STAROSTIN et TRELEA, sample 1/4.
3. *Manilkaroxylon* sp., sample DR2.

Glyptostroboxylon rudolphii DOLEZYCH et VAN DER BURGH

4. Transversal section, sample 99/04. Gradual transition from earlywood to latewood.
5. Radial section, sample 99/04. Biseriate tracheid pitting in discontinous rows.
6. Radial section, sample 99/04. Cross-field with taxodioid to glyptostroboid randomly distributed pits.
7. Tangential section, sample 99/04. Uniseriate rays and partly biseriate rays.

PLATE 2

Taxodioxylon gypsaceum (GÖPPERT) KRÄUSEL, stem wood

1. Transversal section, sample Bečov 2. Gradual transition from earlywood to latewood.
2. Radial section, sample Bečov 2. Uni- to biseriate tracheid pitting.
3. Tangential section, sample Bečov 2. Very low uniseriate rays.
4. Radial section, sample Bečov 2. Axial parenchyma (arrow).
5. Radial section, sample Bečov 2. Cross-field with cupressoid pits in two horizontal rows (arrow).

Taxodioxylon gypsaceum (GÖPPERT) KRÄUSEL, root wood

6. Transversal section, sample 98/04. Diffuse axial parenchyma (arrow).
7. Radial section, sample 98/04. Triseriate tracheid pitting.
8. Tangential section, sample 98/04. Very low uniseriate rays.
9. Radial section, sample 98/04. Cross-field with taxodioid pits in two horizontal rows (arrow).

PLATE 3

Cinnamomoxylon seemannianum (MÄDEL) GOTTWALD

1. Transversal section, sample 81/04. Diffuse porous wood, vessels solitary and in radial multiples of 2.
2. Transversal section, sample 81/04. Vasicentric axial parenchyma and idioblasts associated with axial parenchyma (arrow), rays and among fibres.
3. Tangential section, sample 81/04. Multiseriate rays and idioblast associated with ray (arrow).
4. Tangential section, sample 81/04. Idioblasts among fibres (arrow).

Alnus tschemrylica BLOKHINA et SNEZHKOVA

5. Transversal section, sample 97/04. Diffuse porous wood, vessels in radial multiples and clusters, aggregate ray (arrow).
6. Radial section, sample 97/04. Scalariform perforation plate with 29 bars.
7. Radial section, sample 97/04. Homocellular ray composed of procumbent cells.
8. Tangential section, sample 97/04. Aggregate ray (arrow).

PLATE 4

Ulmoxylon cf. *kersonianum* STAROSTIN et TRELEA

1. Transversal section, sample 1/3. Ring porous wood, latewood vessels in clusters arranged in tangential to diagonal wavy bands.
2. Tangential section, sample 75/04. Helical thickening in vessel (arrow).
3. Tangential section, sample 75/04. Triseriate ray.
4. Radial section, sample 75/04. Homocellular ray composed of procumbent cells.

Grewioxylon ortenburgense SELMEIER

5. Transversal section, sample 89/04. Semi-ring porous wood, vessels in radial multiples and clusters.
6. Transversal section, sample 89/04. Tangential widening of ray at growth ring boundary (arrow).
7. Tangential section, sample 89/04. Heterocellular ray with tile cells of *Pterospermum* type (arrows).
8. Radial section, sample 89/04. Heterocellular composition of ray with tile cells of *Pterospermum* type.

PLATE 5

Manilkaroxylon sp.

1. Transversal section, sample DR2. Diffuse porous wood, vessels arrangement in radial pattern.
2. Transversal section, sample DR2. Vessels circular to polygonal in outlines.
3. Tangential section, sample DR2. Rays with uniseriate extremities almost as wide as multiseriate portions.
4. Radial section, sample DR2. Heterocellular ray composed of procumbent cells and marginal rows of upright cells.
5. Tangential section, sample DR2. Presence of crystals.

Xylotype Nechranice 1

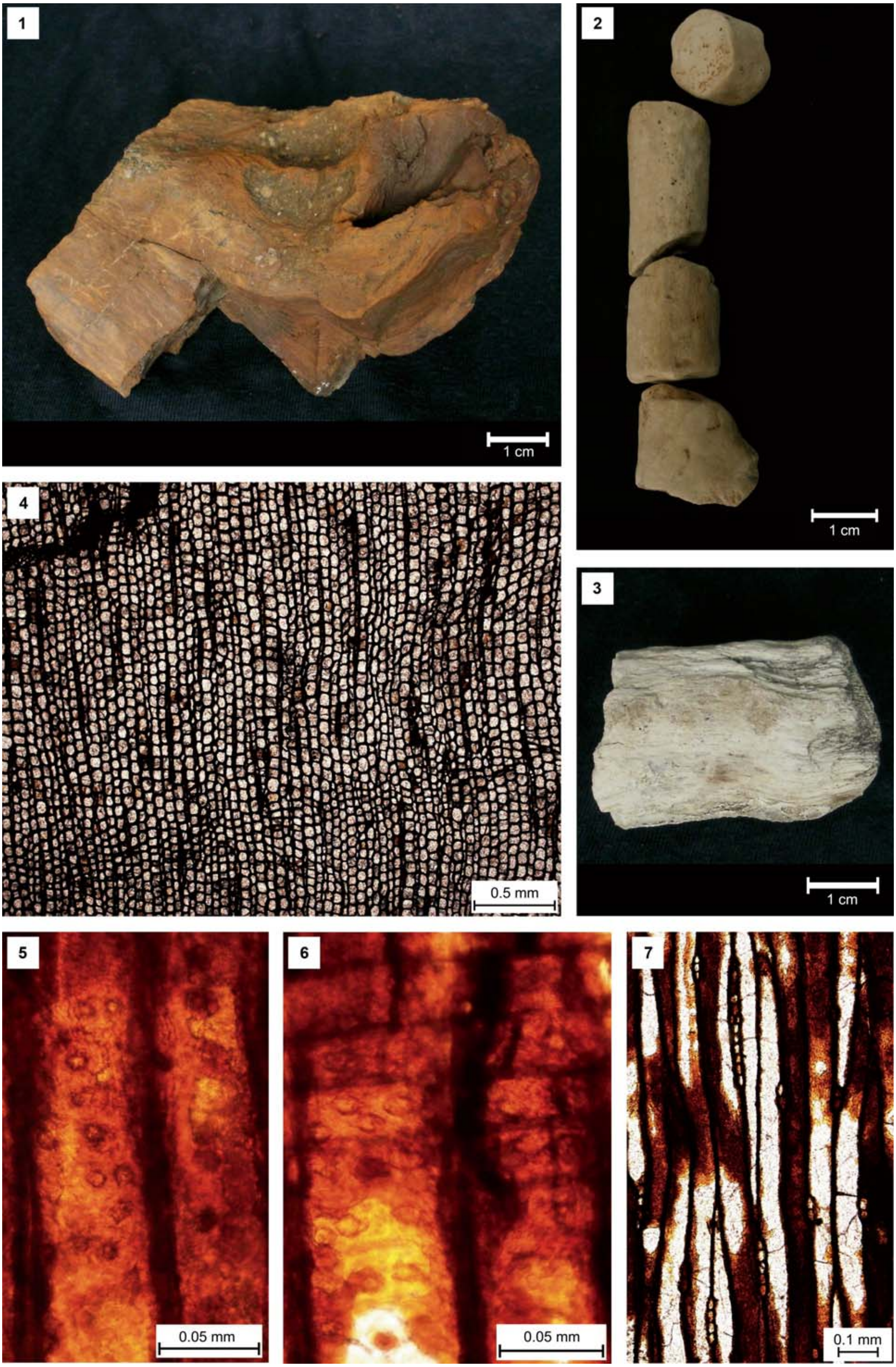
6. Transversal section, sample 112/06. Diffuse porous wood, vessels in radial multiples.
7. Radial section, sample 112/06. Homocellular ray composed of procumbent cells.
8. Tangential section, sample 112/06. Uniseriate portion of ray (arrow) between two biseriate portions.
9. Tangential section, sample 112/06. Uniseriate rays.

PLATE 6

Fossil wood localities

1. Vrbice (photo by V. Koutecký 2012)
2. Nechranice (photo by M. Řehoř 2012)
3. Bečov (photo by V. Koutecký 2013)
4. Divoká rokle (photo by J. Brendl 2014)

PLATE 1



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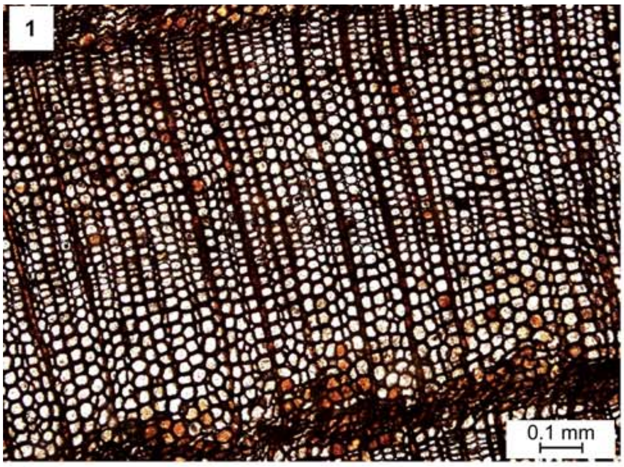
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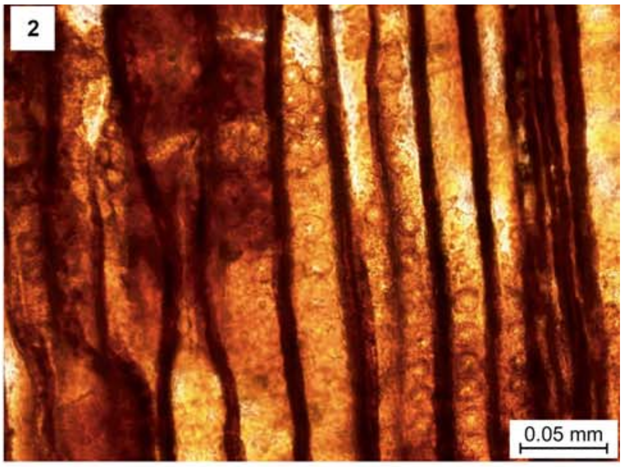
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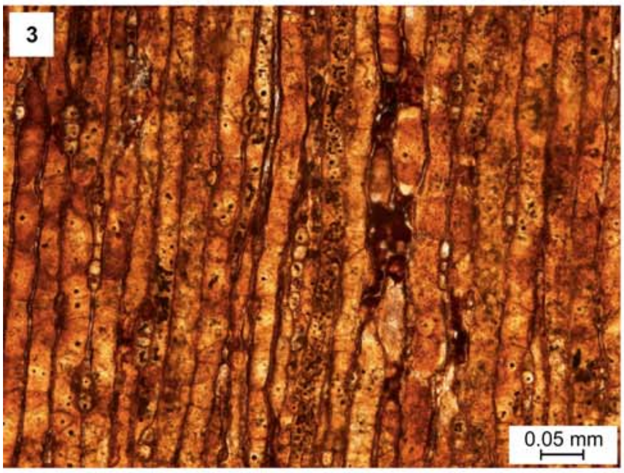
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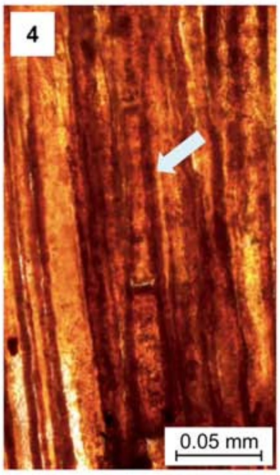
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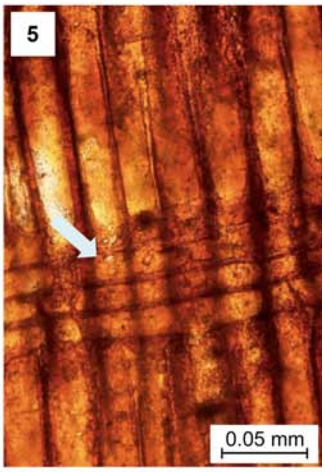
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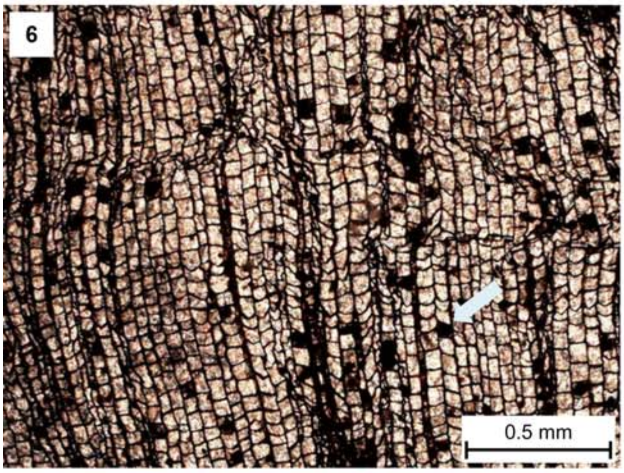
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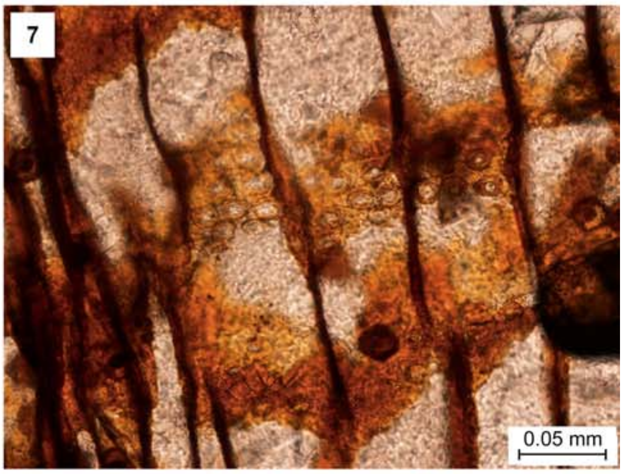
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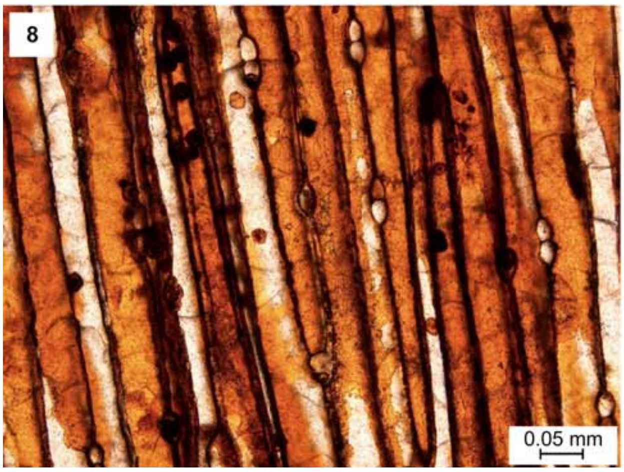
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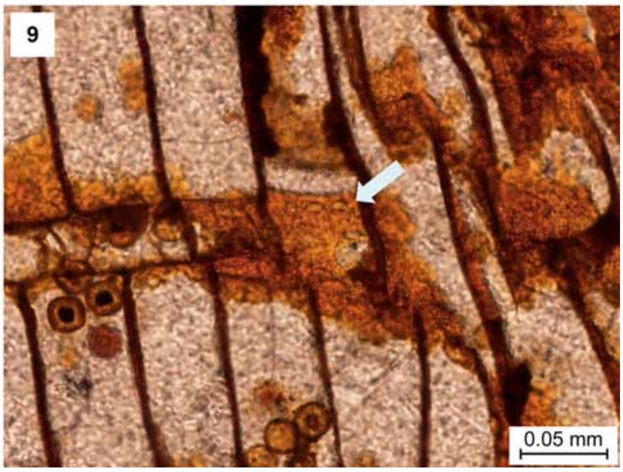
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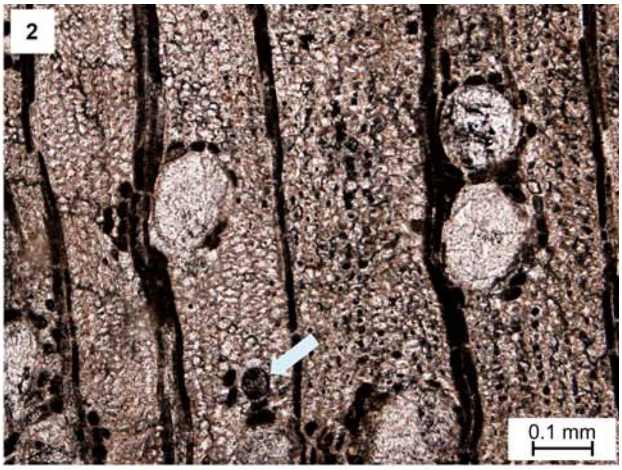

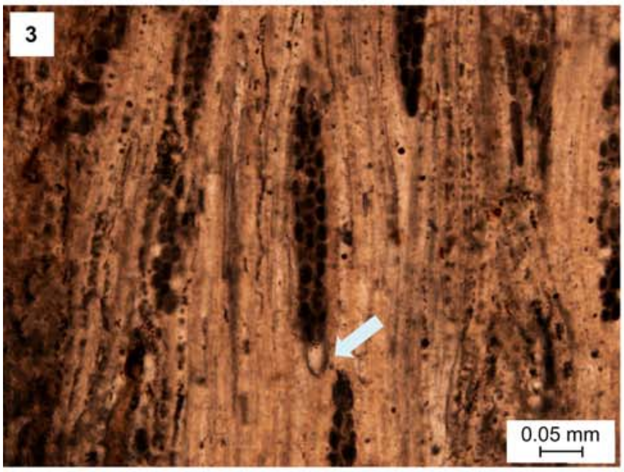

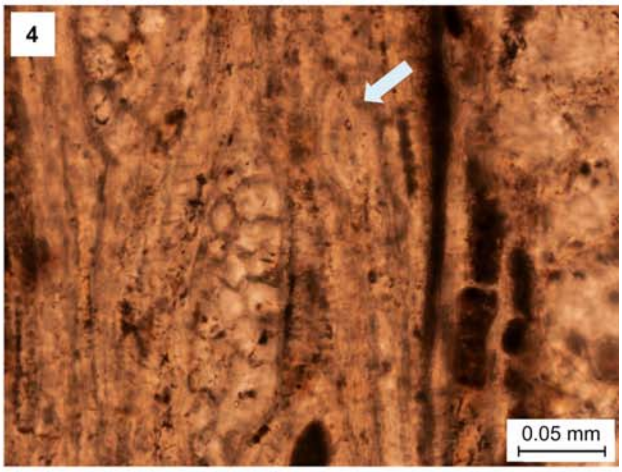

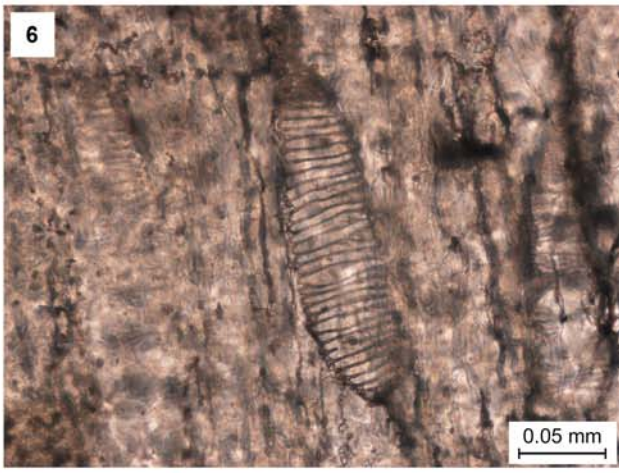

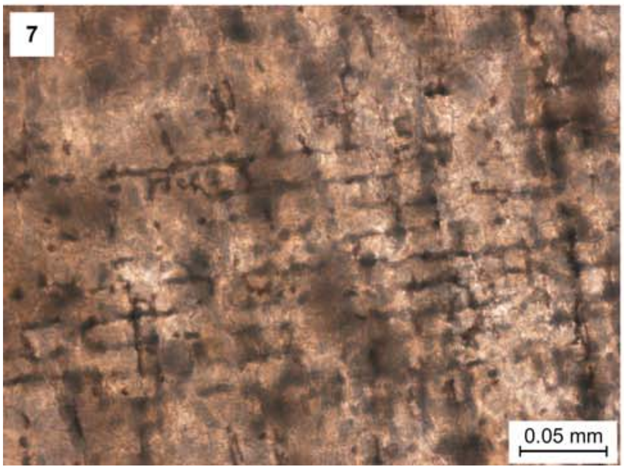

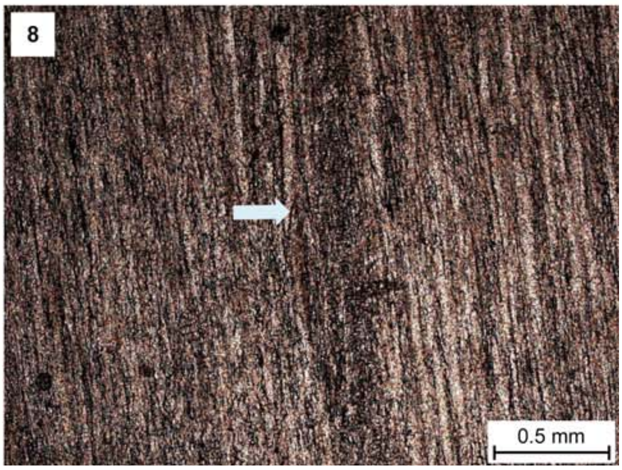

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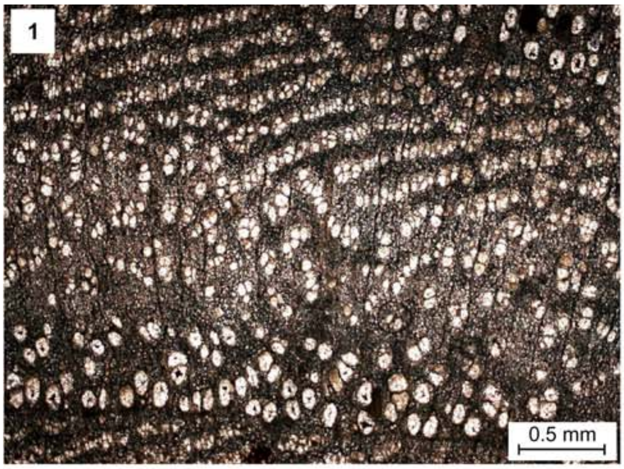

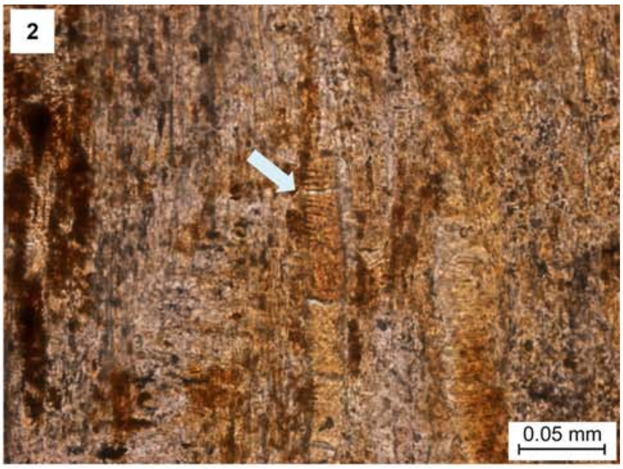

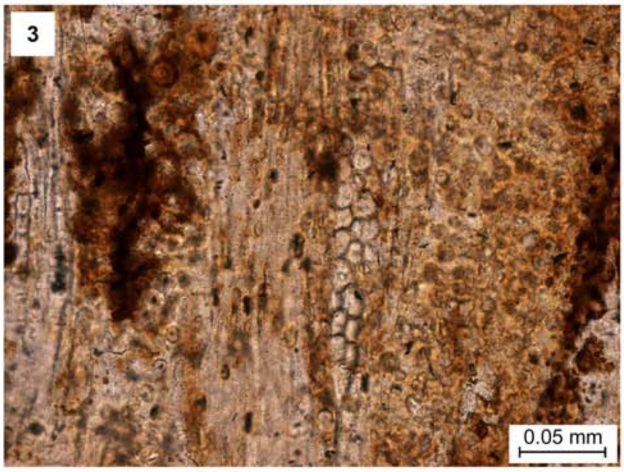

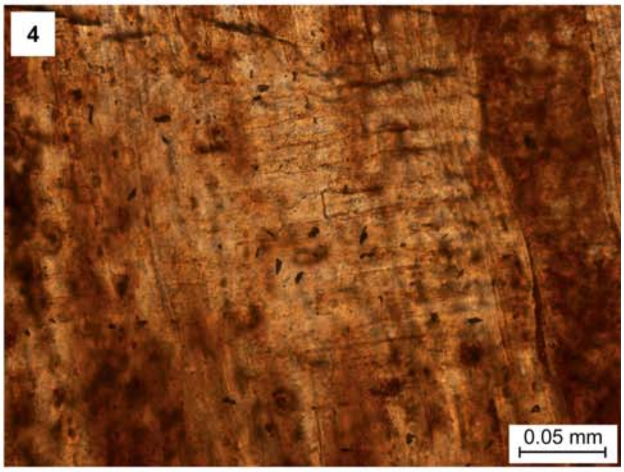

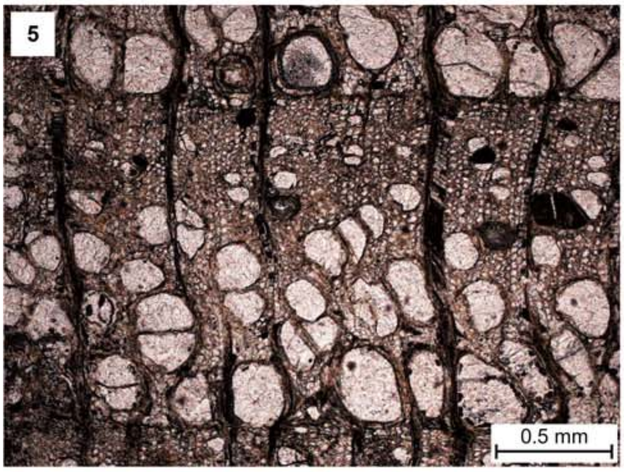

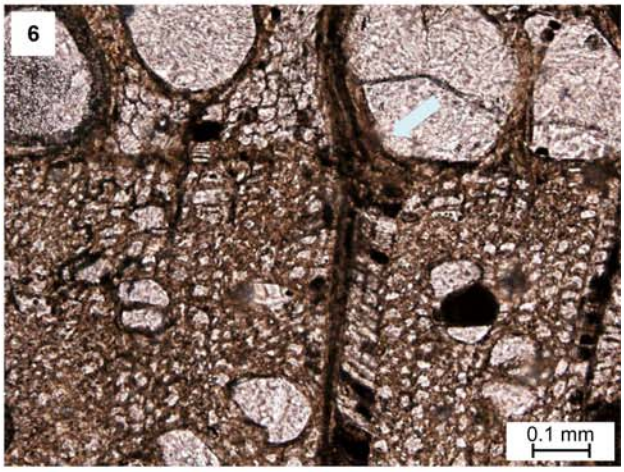

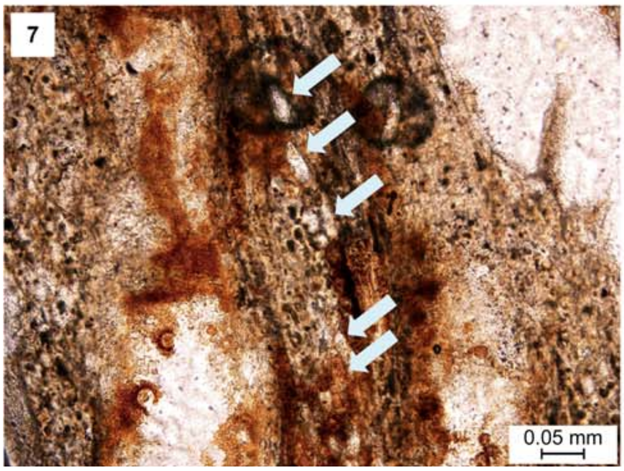

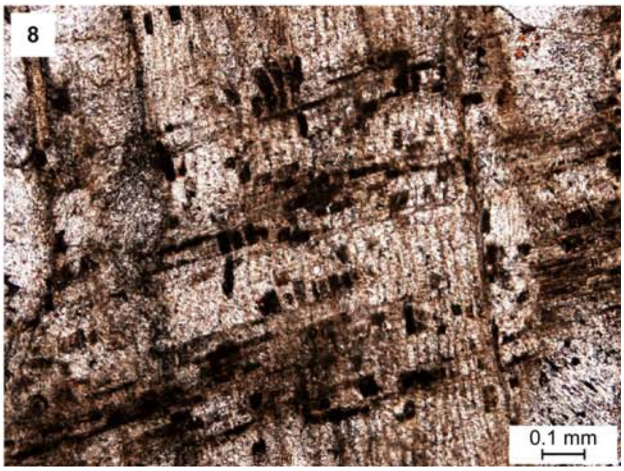

PLATE 5


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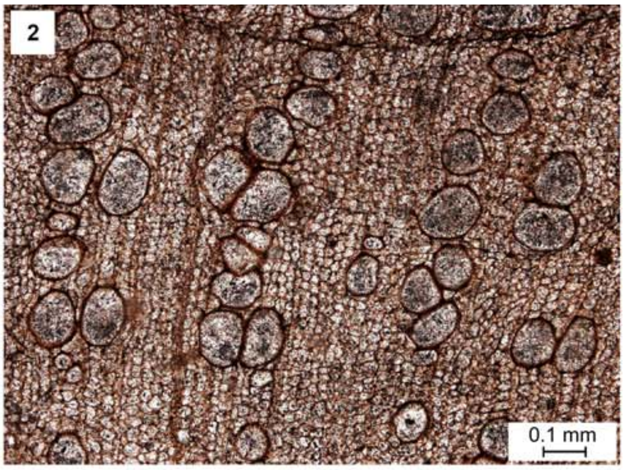
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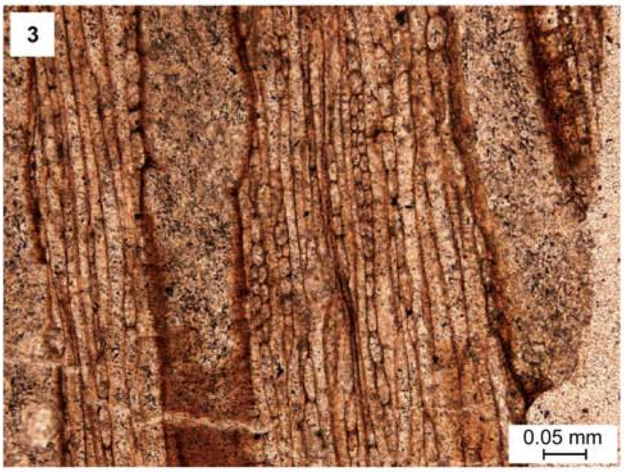
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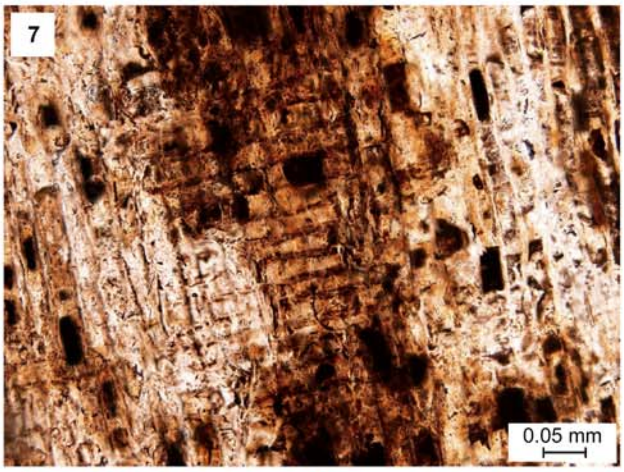
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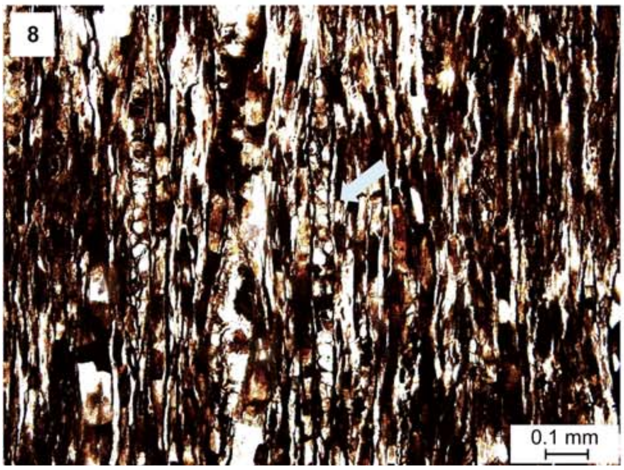
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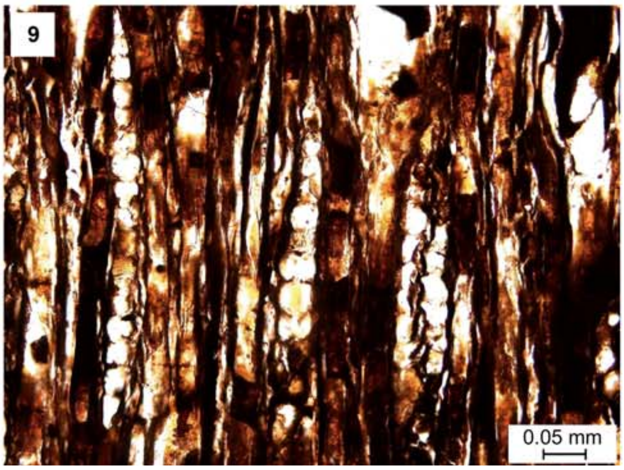
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PLATE 6


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