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Dispersed conducting tissue from the Gzhelian (Saberian) of the Kounov Coal in the Kladno-Rakovník Basin, Czech Republic

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Abstract

The late Pennsylvanian Kounov coal seam yielded exceptionally well-preserved vascular elements. Their determination is questionable due to their fragmentary nature. Scalariform, reticulated and pitted tracheids prevail. They are comparable with the sphenopsid plants *Arthropitys* and *Sphenophyllum.* Some scalariform and reticulated tracheids also resemble those of ferns. However, their precise determination is not possible. Some uniseriate pitted tracheids resemble some conifers. Because conifers do not occur in coal, they might belong to secondary wood of some calamitaleans. Dispersed vascular tissues are correlated with dispersed cuticles and macrofossils.

1. INTRODUCTION

Conducting tissues from the Upper Palaeozoic are known mostly from petrified wood (e.g. MENCL et al., 2013a, b; TRÜMPER et al., 2020; TOSAL et al., 2023). Descriptions of conducting tissues prepared during coal maceration are less common (ŠIMŮNEK & BUREŠ, 2015, 2019). Well-preserved conducting tissues have been prepared here from the Kounov Coal, exposed during construction of the highway D6, between the villages of Děkov and Hokov in the Kladno-Rakovník Basin. This paper is focussed on the description of different types of conducting tissues and reconstruction of the original flora that comprised the coal seams.

2. GEOLOGICAL SETTING

The conducting tissues in this study originated from Stephanian-age deposits in the Central and Western Bohemian regions of the Bohemian Massif, Czech Republic (Fig. 1). During late Carboniferous (Pennsylvanian) times, this area was part of an intra-montane basin complex formed within the Variscan Orogen (PEŠEK, 1994; PEŠEK et al., 1998; PEŠEK & SIVEK, 2016). In Westphalian (late Bashkirian and Moscovian) times, the sedimentation in this basin complex was represented by conglomerates, sandstones, mudstones, claystones and coal seams (Kladno Formation). Thick tuff and tuffaceous layers are also known. The lower Stephanian (Kasimovian) deposits are represented by mostly red deposits without a coal seam (the Týnec Formation). Coal deposition recommenced in the Slaný Formation (Saberian, Gzhelian). The Mělník Group of Coals is developed in the Jelenice Member at the base of the Slaný Formation. The deposition continues with grey fine-grained sandstones and mudstones, with lacustrine dark grey, laminated claystones and upwards a transition into gradationally stratified and laminated deltaic sandstones. The next member is the Kounov Member containing the Kounov coal seam that is the subject of this study (Fig. 2). The volcano-sedimentary layer (tonstein) within the Kounov coal seam called "kamínek" was dated to 301.50±0.11 Ma (OPLUŠTIL et al., 2016). This tonstein does not occur particularly in the Hořesedly locality, but in the eastern part of the Kladno-Rakovník Basin. The sandy Kamenný Most Member continues upwards, and deposition ends with red deposits of the Líně Formation, its upper part already belonging to the Permian.

3. MATERIALS AND METHODS

The samples from benches 1 and 2 of the Kounov coal were macerated to obtain dispersed conducting plant tissues. About 5 g of coal was macerated in 35 ml of concentrated (65%) nitric acid (HNO_3) for 30 minutes to 1 hour. The black residue was thoroughly washed under running water in a sieve and then treated with 10% potassium hydroxide (KOH) for up to one hour. During this process, the "coal matter" was completely dissolved and only the cuticles and conducting tissue remained. The isolated conducting tissues were either mounted in Glycerine Jelly slides, or were attached to an SEM stub for observation under a scanning electron microscope (SEM).

Two samples from the lower bench (slides 751/1-4 and 753/1-12) and two samples from the middle bench (slides 752/1-7 and 754/1-5) were used to describe the dispersed conducting tissues. Dispersed conducting tissues for each sample were stuck to the SEM stub Nos.: 162, 163, 164 and 165 for observationing in the electron microscope. The conducting tissues have been studied under light microscopes Nikon Eclipse 80i and LV100N POL, and under the electron microscope Tescan Mira3 GMU FEG-SEM.

4. RESULTS

Conducting tissues of the studied specimens can only be seen in small fragments, so the total length of tracheids is generally unknown. The structures of the wall thickening mostly correspond to the alternate pitting surface type. Due to this form of preservation, the options for further determination are

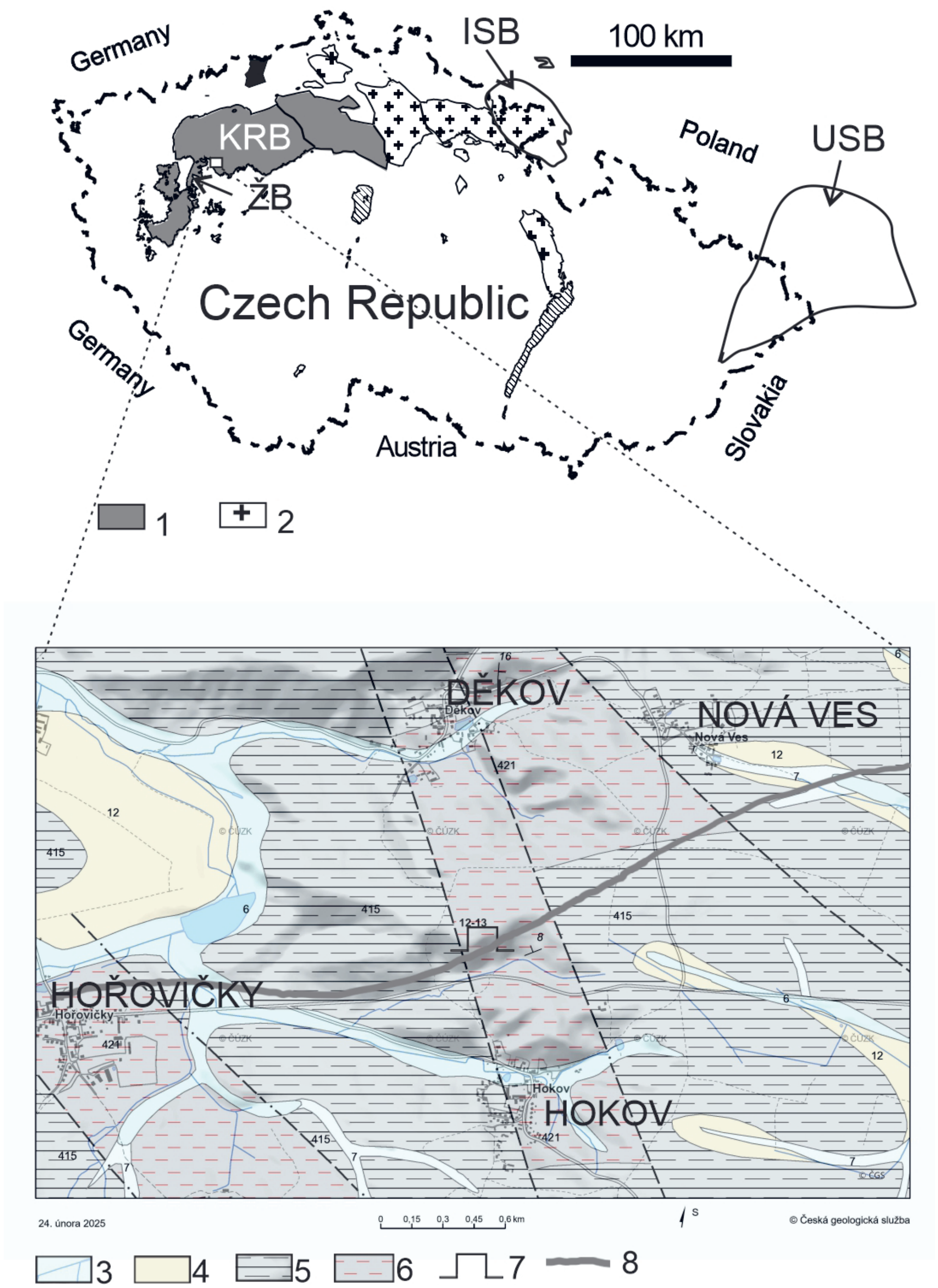

Figure 1. a A map of the Czech Republic with the Permo-Carboniferous basins and location of the studied outcrop. KRB – Kladno-Rakovník Basin, ŽB – Žihle Basin, ISB – Intrasudetic Basin, USB – Upper Silesian Basin; 1 – Central and Western Bohemian basins; 2 – Lugicau Region; **b** A geological map of the vicinity of the studied locality with villages: Hořovičky, Děkov, Hokov and Nová Ves: 3 – Quaternary fluvial deposits; 4 – Quaternary deluvial deposits. 5 – 6 Carboniferous, Stephanian. 5 – Slaný Formation, 6 – Líně Formation, 7 – Abandoned quarry (place of the studied locality), 8 – Highway route.

quite limited. We distinguished three types of conducting tissues described below.

4.1. Tracheid type 1

Conducting elements show tracheids 20 – 60 µm in diameter with uni- to multiseriate bordered pits with reticular or scalariform wall thickening. Pits are circular or oval, usually up to 5 µm in diameter (Pl. 1, figs a, b). Type 1 was often found in the lower bench of the Kounov coal seam, as well as in the middle bench of the latter.

Slides: 751/1, 2; 754/2, 4; Lower and middle bench.

4.2. Tracheid type 2

Tracheids of this conducting tissue are 100 – 200 µm wide. Bordered pits are circular or oval, usually arranged in 2 – 5 rows, and they are 2 – 10 µm in diameter. Some tracheids have reticulate wall thickening (Pl. 1, figs c, d).

Slides: 753/1–3, 5–7, 9, 11 and 12; Lower bench.

4.3. Tracheid type 3

Type 3 includes tracheids 20 – 70 µm wide with uni- to multiseriate bordered, oval-circular pits of 5 – 10 µm in diameter.

Global scale		Regional scale		Lithostratigraphy		
Subperiod	Stage	Stage	Substage	Formation	Member	Coal seams
Pennsylvanian	Gzhelian	Stephanian	Stephanian C Stephanian B	Líně		
			Saberian	Slaný	Kamenný Most	
					Kounov	Kounov coals
					Ledce	
					Hředle	
					Mšec	
					Jelenice	Mělník coals
	Kasimovian		Barruelian (A)	Týnec		
			Cantabrian	Kladno	Nýřany	Nevřeň coals
	Moscovian	Westphalian	Asturian (D)			Chotíkov coals Nýřany coals
			Duckmantian-Bolsovian (B-C)		Radnice	Lubná coals Radnice coals

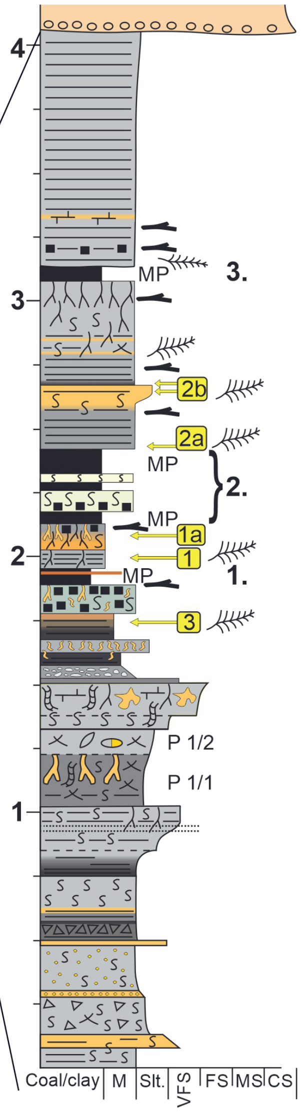

Figure 2. Stratigraphic table of the Kladno-Rakovník Basin and the log with the Kounov coal seam split into benches. Stratigraphic table simplified according to OPLUŠTIL et al., 2024. Stratigraphic and lithostratigraphic units not to scale, log of the section R. Lojka.

In some tracheids, reticular thickening developed (Pl. 1, fig. e). These structures may represent the metaxylem tracheids of ferns.

Slide 751/1; Lower bench.

5. DISCUSSION

The defined types do not have taxonomic value. We decided to describe them to register the principal differences between the studied vascular tissues. The possible affinity of the studied tissues are further discussed.

5.1. Tracheid type 1

This structure with tracheids 20 – 60 µm wide corresponds to *Sphenophyllum speciosum* ZEILLER (PANT & MEHRA) presented by BATENBURG (1982). Moreover, some samples with a large proportion of thick-walled tracheids with uniseriate bordered pits could correspond to the secondary tissues of coniferoid plants (*Agathoxylon*-type of wood) also mentioned from local coeval basins in e.g. MENCL et al. (2009) and MENCL et al. (2013a). The newest research from the early Permian Chemnitz Fossil Lagerstätte presents secondary tissue of the new calamitalean species *Arthropitys raimundii,* composed of tracheids with one to three rows of bordered pits (RÖSSLER et al., 2025). Similar scalariform wall thickening is also described in *Arthropitys* (cf.) *bistriata* from Germany (RÖSSLER & NOLL, 2007), and from coeval basins of the Czech Republic (MENCL et al., 2013b) as well.

5.2. Tracheid type 2

These 100 – 200 µm wide tracheids could correspond to *Sphenophyllum* sp. (e.g. BOUREAU, 1964; BATENBURG, 1982; TAYLOR et al., 2009; BUREŠ et al., 2013 and ŠIMŮNEK & BUREŠ, 2015).

5.3. Tracheid type 3

This type shows tracheids 20 – 70 µm wide that resemble the metaxylem tracheids of some coeval ferns (e.g. HERNÁNDEZ-HERNÁNDEZ et al., 2012; PŠENIČKA, 2005).

6. CONCLUSION

Well-preserved conducting tissue has been obtained only from the lower and middle benches of the Kounov coal seam.

Taxonomic identification is problematic due to their fragmentary nature.

The lower bench contains tracheids comparable to the sphenopsid fossil-genus *Arthropitys* and also to *Sphenophyllum*. Indeed, sphenopsid *Calamites* pith casts often occur above this bench.

The tissue from the middle bench resembles *Sphenophyllum* tissue and also the vascular tissue of some ferns. The exact identification is problematic, because different fern groups may have very similar anatomy.

Some uniseriate pitting of tracheids is reminiscent of the conifers. However, since conifers should not occur in coal, they might belong to calamitalean plants related to *Arthropitys raimundii*.

Wood of lycopsids, medullosans and cordaitaleans was not identified. Lycopsids and medullosans as compressions are extremely rare; however, cordaitalean macrofossils are the dominant group in the Hokov-Děkov outcrop.

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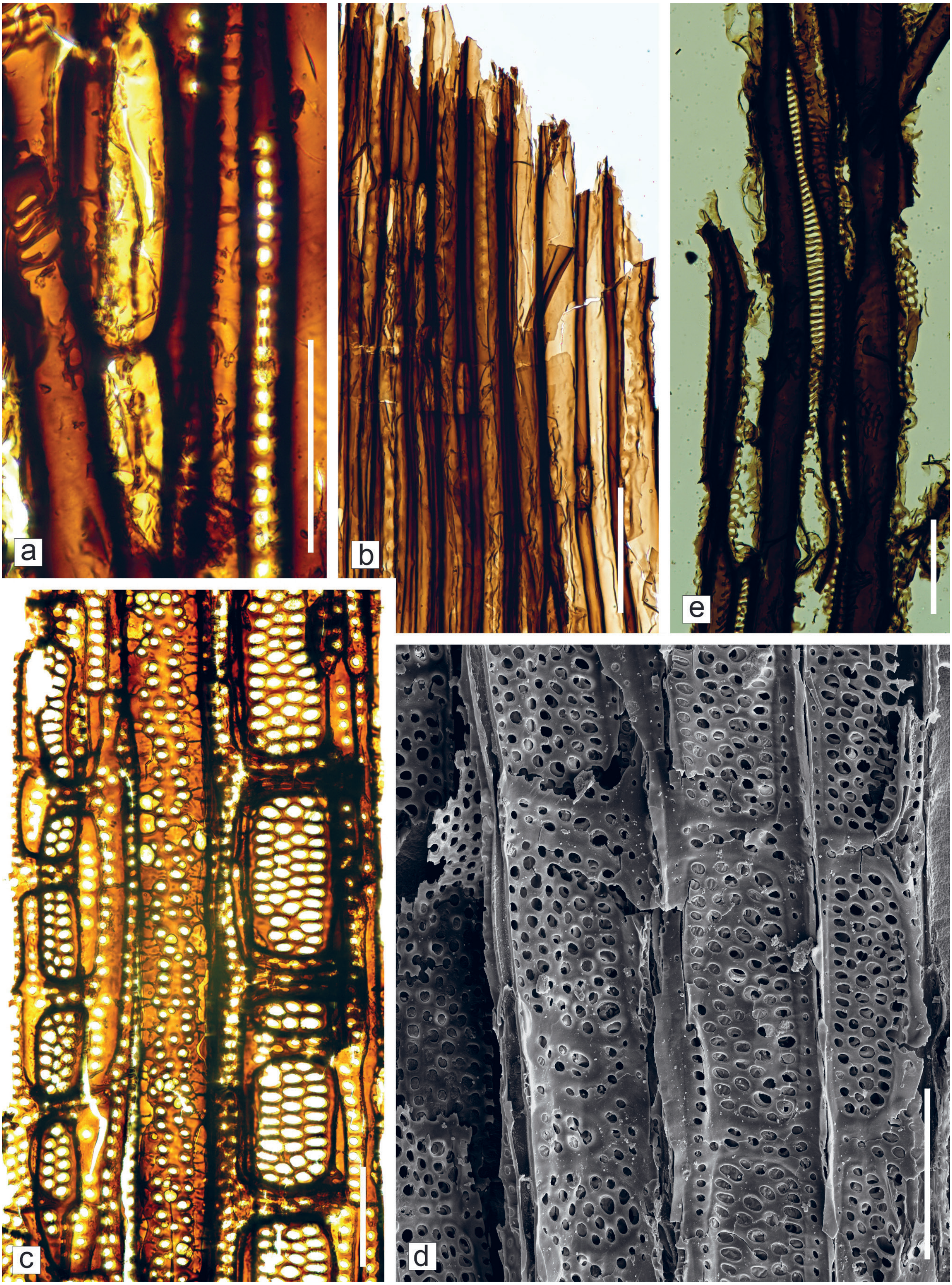

Plate 1. Dispersed conducting tissues from the Hořesedly locality. All scale bars = 100 μm.

a, b Conducting tissue of the Tracheid type 1. Tracheids with uni- to biseriate bordered pits. In some places, scalariform and reticulate wall thickenings occur. **a** – Slide 751/2, **b** – Slide 754/4; **c, d** Conducting tissue of the Tracheid type 2. Tracheids with typical wall structure of sphenophylls with multiseriate bordered pits and frequent reticulate wall thickening. **c** – Slide 753/1, **d** – tissue in the electron microscope, SEM stub 164. **e** Conducting tissue of the Tracheid type 3. Reticulate and scalariform wall thickening in tracheids probably corresponding to fern-like tissues. Slide 751/1.