The Asturian and Cantabrian floral assemblages with *Cordaites* from the Plzeň Basin (Czech Republic)* 

(Figs 1–17; Tabs 1–3)

Abstract. The macrofloras of the Nýřany Member (late Asturian–early Cantabrian age) were studied at five localities and two boreholes in the Plzeň Basin (Western Bohemia). The floras were mostly dominated by *Cordaites*, and seven species were recognised based mainly on cuticular evidence. *Cordaites dobranensis* Šimůnek was the most common species and occurred in most of the Asturian-age localities. In addition, an outcrop near Řehmanova Huť yielded *C. blazkovicensis* Šimůnek, *C. wilkischensis* Šimůnek and *C. pilsensis* Šimůnek; and borehole Krašovice Kš 1 yielded *C. krasovicensis* Šimůnek and *C. touskoviensis* Šimůnek. *Cordaites radicensis* nov. sp. was only found in the Cantabrian part of the succession, at the Raděice locality, and shows characters suggesting adaptation to somewhat drier conditions, namely thick cutinisation and proximally oriented projection of the anticlinal cell walls.

The most diversified assemblage with 29 species was found at the Dobřany locality, but most other localities yielded only 12 to 18 species. The species-spectrum of individual localities varied according to type of locality, sedimentology and method of collecting. In most localities, cordaitaleans made up 40 to 67% of the macroflora, the only notable exception being the Krimich II mine at Tučná that yielded only 5% cordaitaleans. The next important plant group was the sphenopsids, which usually comprised about 30% of the macrofloras, with the exception of Řehmanova Huť locality where there were only 3% sphenopsids. The proportion of fern remains varied between localities from 8 to 35%. Lycopsids were usually very rare, except at the Řehmanova Huť locality where 30% of the flora consisted of allochthonous lycopsid fragments. Pteridosperms were very rare and never exceeded 10% of the macroflora. The Westphalian rain forest was not monotonous, but was diversified into several floral assemblages.

My work supports the conclusion of previous workers in the area (Šetlík, 1980), that the five most common species in the Nýřany Member of the Plzeň Basin are *Pecopteris polypodioides* (Presl in Sternberg) Němejc, *Sphenophyllum emarginatum* (Brongniart) Brongniart, *Pecopteris unita*, Dicksontites pluknetii and *Annularia stellata* (Schlothoheim) Wood.

Key words: Carboniferous, cordaitaleans, plant assemblages, cuticular analysis, Plzeň Basin.
INTRODUCTION

Palaeobotanical research in the Plzeň Basin (Fig. 1) started during the second half of the 19th century (Feistmantel, 1870), and significant progress was made during the early and middle of the 20th century (Purkyně, 1913; Němejc, 1933, 1937, 1941, 1953, 1958). However, these papers only gave lists of species for individual localities; no details were given of the proportion of individual species in each floral assemblage, and the correlation between the plants and the sediment in which they were found was rarely discussed. After World War II, significant new palaeobotanical data were added from boreholes (Šetlík, 1968). Although each

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Fig. 1. Geological map of the Plzeň Basin with studied localities. 1 – Pre-Carboniferous deposits (mostly Upper Proterozoic); 2 – Kladno Formation (Bolsovian, Asturian and Cantabrian); 3 – Týnce Formation (Barruelian); 4 – Slaný Formation (Stephanian B); 5 – Líně Formation (Stephanian C); 6 – localities (Adopted from Mergl and Vohradský, 2000)
borehole yielded a limited number of species and specimens, Šetlík was able to investigate 127 boreholes allowing him to identify 48 plant species from the Nýřany Member in the Plzeň Basin. He subsequently (Šetlík, 1980) undertook a semi-quantitative analysis of the floras, and identified the most dominant species of the Nýřany Member as being *Pecopteris polypodioïdes* (Presl in Sternberg) Němejc, *Sphenophyllum emarginatum* (Bronniiart) Brongniart, *Pecopteris unita* Brongniart, *Dicksonites plukenetii* (Schlotheim) and *Annularia stellata* (Schlotheim) Wood (this was the same in both the Plzeň and the Kladno-Rakovník basins).

This paper reviews the floras of the Nýřany Member of the Plzeň Basin (Asturian and Cantabrian substages), based on investigations made by the author between the 1980s and the present (Šimůnek, 1994). During that time, about 1,500 plant fossil samples were collected from the Nýřany Member, sometimes in conjunction with colleagues B. Čtveráček (1984), J. Drábková et al. (2004), especially at Radčice. This study was undertaken to document composition and palaeoecological preferences of floral assemblages that occur at several lithostratigraphic horizons within the Asturian-Cantabrian part of the section. The stratigraphic evaluation of some of this material is problematic, as it originated from spoil tips of coal mines that worked both the Radnice and Nýřany members (e.g. the Krimich II Mine at Tlučná). Where the stratigraphical position of such samples could not be determined for certain, they were excluded from the investigation as the quantitative evaluation might not be accurate.

Forty-nine species were recorded from the five studied localities (Tab. 1), bringing the total for the Nýřany Member to more than 80 plant species. Individual assemblages were typically of low diversity, with high percentages of sphenopsids and cordaitaleans. Němejc (1958) determined the cordaitalean foliage all as *Cordaites palmaeformis* (Goeppert) Geinitz, and Šetlík (1968) recorded them only as *Cordaites* sp., regarding them as stratigraphically unimportant elements. However, this foliage is well preserved here and can be studied by means of cuticular analysis, which revealed that cordaitaleans were in fact very diverse in the Plzeň Basin. This paper brings new information about cordaitalean cuticles and some quantitative evaluation of studied plant assemblages from the Nýřany Member.

**GEOLOGICAL SETTING**

The Nýřany Member (Upper Asturian to Cantabrian substages) is the younger part of the Kladno Formation (Fig. 2). It reaches a maximum thickness of 300 m in the Plzeň Basin, where the following facies can be distinguished (Pešek, 1994): (1) a fluvial facies represented by whitish, massive, granular arkoses to arkosic sandstones; (2) a peat-forming-lacustrine facies consisting of mudstones and claystones and locally thin coal seams; and (3) an alluvial fan facies distinguished by non-grey sediments of the Komberk Horizon.

There are up to 20 coal seams and other root-horizons, mostly a few decimetres thick, but some 1–2 m thick or more. In the Plzeň Basin, four groups of coal seams are recognised (Fig. 3):
The Touškov group of coal seams. This is at the base of the member and usually consists of between one and four seams, each attaining a thickness of a few decimetres;

2. The Nýřany group of coal seams. This is known only from the Plzeň Basin and usually consists of two seams, mostly about 1 m or thicker;

3. The Chotíkov group of coal seams. This incorporates all of the seams between the Nýřany and Nevřeň group of coal seams. They are usually a few decimetres thick and are locally accompanied by tuffaceous horizons;

4. The Nevřeň group of coal seams. These seams are at the very top of the member and are interpreted as Cantabrian in age. They have been divided into the lower and upper Nevřeň seams based on megaspore content (Kalibová-Kaiserová, 1964).
Fig. 3. Nyřany Member in the northern part of the Plzeň Basin (Borehole Kš 1 Krašovice). Names of localities to the right from the stratigraphical column represent the relative level of the studied localities; 1 – coal seam; 2 – coaly claystone; 3 – claystone; 4 – siltstone; 5 – sandstone (mostly arkosic); 6 – sandstone with boulders; 7 – conglomerate; 8 – tuffite and tuffitic admixture; Bols. – Bolsovian (Section simplified from Opekár et al., 1994)
METHODS AND MATERIALS

Most of the identifications recorded in this paper were based on traditional features of gross-morphology. However, leaf morphology alone does not provide sufficient characters to identify cordaitalean leaves in a taxonomically meaningful way, and so the epidermal structure preserved in their cuticles was investigated. Detailed descriptions of six of these species can be found in Šimůnek (2007); that of a seventh species is presented in this paper. Well-preserved coalified leaf fragments were separated from the rock by means of a needle or hydrofluoric acid (HF). These leaf fragments were then bleached in Schulze’s reagent (40% HN\(_3\) with crystals of KClO\(_3\)) for usually between 20 and 40 hours. They were then washed in 10% potassium hydroxide (KOH) solution and finally rinsed in distilled water. Some cuticles were stained with safranin for several hours to accentuate the anticlinal walls and stomata. Before embedding in glycerine gelatine slides, the cuticles were dehydrated in pure glycerine. The glycerine gelatine slides were examined using an Olympus 50 compound microscope, Nomarski Interference Contrast usually offering the best results. The stomatal index, SI, was calculated according to the formula: SI = 100 × S/(B + S), where B is the number of cells in a given area, and S the number of stomata in the same area (Salisbury, 1928; Kerp, 1990).

Material for this study comes from five localities: three coalmines – Krimich II Mine, Tlučná near Nýřany, Hugo Mine near Dobřany and old Dobře štěstí Mine near Nová Ves; two outcrops have been studied – a temporary outcrop near Heřmanova Hut’ – Vlkýš exposed during high way construction, and a section near Radčeice. In addition, flora from two boreholes has been studied with respect to cordaitalean remains: Nýřany-Tesla HJ 3/1 and Krašovice Kš 1. Together, more than 1500 samples have been obtained from individual localities: Radčeice (about 100), Nová Ves (124), Dobřany (993), Heřmanova Hut’ (220) and Tlučná near Nýřany (about 100).

All determinable plant remains were collected from each locality. The exact provenance of plant fossils collected from pit tips of coal mines is not known. The possible area from which a fossil might have originated could be several km\(^2\) (3 km\(^2\) in Krimich II mine in Tlučná). The relative position to the coal seam is usually “Floznah” in the sense of Gastaldo (1996), which implies flora preserved above coal seams or in its interbeds (i.e., it is a typical roof-shale flora). A different situation was found in outcrops and boreholes. These floral assemblages are “Flozfern” according to Gastaldo (1996), which means flora stratigraphically distant from coal seams. The plant assemblages from the two boreholes were very rare and therefore a quantitative evaluation of these assemblages is not possible. Besides these localities, 2 outcrops have been studied. The plant fossils from Heřmanova Hut’ were collected from a single mudstone horizon 0.6 m thick, whereas those from the Radčeice outcrop locality were collected from at least 2 vertically separated horizons exposed at several places along a nearly 800 m long outcrop.

All of the samples for this study, together with the 82 microscopic slides containing the cuticles prepared from 18 cordaitalean specimens, are now housed at the Czech Geological Survey, Prague.
CORDAITALEAN PLANTS

Cordaitalean remains dominated most of the assemblages examined in this study. In the past, they have been determined simply as Cordaites sp., or Cordaites principalis (Germar) Geinitz. However, cuticular analysis has allowed seven distinct species to be recognised in the Nýøany Member of the Plzeò Basin. Six species have been described elsewhere (Šimùnek, 2007), but a seventh species is new and is being described in this paper. The species can be divided into three groups based on features of their abaxial cuticles (Tab. 2):

1. Species with single or double stomatal rows on the abaxial cuticle: Cordaites krasovicensis Šimùnek (Figs 4.1; 5.1–4); Cordaites pilsensis Šimùnek (Figs 4.2; 5.5–7); Cordaites blazkovicensis Šimùnek (Figs 4.3; 6.1);
2. Species with stomata arranged in double or multiple stomatal rows connected to stomatiferous bands: Cordaites dobranensis Šimùnek (Figs 4.4–5; 7.1–5); Cordaites wilkischensis Šimùnek (Figs 4.6; 6.2–4); Cordaites touskovensis Šimùnek (Figs 7.5–7; 8.8);
3. Species with stomata irregularly dispersed in stomatiferous bands on the abaxial cuticle.

Cordaites radcicensis nov. sp.

(Figs 7.6–9; 8.1–7)

Holotype: Czech Geological Survey, Prague, inv. No. ZŠ 300, slides Nos 423/1–11.

Name derivation: After the type locality Radčice village.

Type locality: Radčice section, Plzeñ Basin.

Type horizon: Kladno Formation; Nýøany Member, equivalent to Nevřeñ group of coal seams, Cantabrian.

Diagnosis: Medium wide leaves with relatively infrequent venation, 1–2 thin veins occurring between pairs of thick veins. Stomata of adaxial cuticle occur in dark stomatiferous bands; stomata of abaxial cuticle occur in stomatiferous bands. Stomatal subsidiary cells oval, similar to ordinary cells. Anticlinal walls strongly cutinised, with proximally oriented projections. There is a great difference between the stomatiferous and non-stomatiferous bands.

Description of the holotype (Fig. 8.7): The holotype represents a leaf fragment 110 mm long and 25 mm wide, with near-parallel lateral margins. The venation is prominent, with 10–14 veins per cm; there are 1–2 thinner veins between two thick veins.

Description of adaxial cuticle (Fig. 7.6–9): Near the margin, cutinisation is comparatively weaker, and cells are more elongate than in the central parts of leaves (Fig. 8.1), 60–100 µm long and only 10–18 µm wide. Towards the centre of the leaf, the cells become oblong, hexagonal to nearly isodiametric in shape, and are 22–50 µm long and 18–32 µm wide.
The stomatal complexes, rare in dark stomatiferous bands, are composed of pairs of guard cells that are about 20 µm long and 8 µm wide, two polygonal or round polar subsidiary cells 20–30 µm long and 12–16 µm wide, and two bean-shaped lateral subsidiary cells 30–36 µm long and 12–20 µm wide. The stoma, including subsidiary cells is 56 µm long and 52 µm wide, and anticlinal walls are bent. The non-stomatiferous bands are 200 µm wide, and the constituent ordinary cells are oblong to square with bent anticlinal walls, 24–68 µm long and 20–32 µm wide. The stomatal density is 8–11 stomata per 1 mm², and SI about 1.

**Description of abaxial cuticle** (Fig. 8.1–6): The cells of the abaxial cuticle are also differentiated into stomatiferous and non-stomatiferous bands. Near the leaf margin (Fig. 8.1), the abaxial epidermis was formed by elongate, oblong cells, 40–80 µm long and 10–20 µm wide. Stomatiferous bands are discernible at a greater distance from the leaf margin. They are 100–140 µm wide and formed by round, oval to oblong cells with bent, thick and prominent anticlinal walls having strongly cutinised incisions, and are oriented proximally. These cells are 20–50 µm long and 15–20 µm wide. The stomatal complexes are discreet, because subsidiary cells resemble the ordinary cells of the stomatiferous band. The guard cells are sunken, partly covered and surrounded by a thicker cutinisation of the anticlinal walls of the subsidiary cells. The pairs of guard cells are 14–18 µm long and 6–8 µm wide. The cells of the non-stomatiferous bands are mostly oblong, with slightly bent anticlinal walls, 36–64 µm long and 16–24 µm wide. The stomatal density is 180–240 stomata per 1 mm², and SI is 8–14.

**Comparison:** This species is very similar to *Cordaites principalis* (cuticular morphotype 5 of Zodrow et al., 2000) from the Bay St. George sub-basin, Newfoundland, Canada (late Bolsovian age). Both species have stomata on the abaxial surface arranged in stomatiferous bands. The anticlinal cell walls are strongly cutinised; and numerous prominent projections are oriented proximally. The stomata are not very distinct. The adaxial cuticle of *Cordaites radicicensis* nov. sp. has stomata in dark bands, whereas the adaxial cuticle of the Canadian morphotype 5, resembles the abaxial cuticle. The synonymy of these two species has not been proved yet.
PLANT ASSEMBLAGES FROM THE TOUŠKOV GROUP OF COAL SEAMS

Krašovice Kš 1 Borehole. The Touškov group of coal seams usually lie just above the base of the Nýřany Member (Fig. 3) and are known mostly from boreholes. The Krašovice Kš 1 Borehole (Fig. 9) passed through the basal part of the Nýřany Member, including the lower Touškov coal seam.

There are two possibilities as to where to place the boundary between the Radnice and Nýřany members. Traditionally, it has been placed at the base of the brown tuffite, in the Krašovice Kš 1 Borehole at a depth of 363.7 m (Fig. 9). However, a Nýřany-like flora [e.g., *Annularia stellata* (Schlotheim) Wood, *Pecopteris polypodioides* (Presl in Sternberg) Němejc] occurs in a mudstone at a depth of 368.7 m, suggesting that the boundary must be below this brown tuffite.

The second possibility is to place the boundary at the base of a conglomerate body at a depth of 379.7 m (Fig. 9). This conglomerate body is 3.6 m thick, and consists of an arkosic matrix with pebbles up to 40 mm long. The fossiliferous mudstone layer (371–366.5 m; Fig. 9) is grey with rare bands of coaly claystone. One of these bands, nearly 0.1 m thick, in depth 368.6 m, is followed by the flora mentioned in Tab. 1. Other plant remains have also been found near the top of this mudstone layer (Fig. 9).

The section continues with pebble conglomerate, followed by light-grey sandy siltstone and a 1 m thick layer of brown tuffite. The lower Touškov coal seam is developed just above this tuffite. The overlying dark grey silty claystone is rich in plant fossils. This claystone is followed by grey siltstones with occasional plant remains.

*Cordaites touskovensis* Šimůnek and *C. krasovicensis* Šimůnek have been found together here with *Annularia stellata* (Schlotheim) Wood and *Pecopteris polypodioides* (Presl in Sternberg) Němejc. They came from one layer of the borehole Krašovice Kš 1 (Figs. 3 and 9).

**Interpretation.** The plant remains are well preserved in claystone to mudstone just above coaly claystone. They had undergone only a short transport. We do not know, whether they are autochthonous or paraautochthonous in the sense of Gastaldo et al. (1995).
PLANT ASSEMBLAGES FROM THE NÝŘANY GROUP OF COAL SEAMS

Krimich II Mine. The Krimich II Mine in Tlučná, near Nýřany, used to be one of the most productive mines in this region. It worked both the Radnice and Nýřany groups of coal seams, although it focused mainly on the former. The Nýřany Member here has only very thin and uneconomic coals, workable only over a restricted area (Fig. 10), and only the Main and partly the Roof Nýřany coal seams were exploited here. The Main Nýřany coal seam typical splits into benches. Either mudstone or sandstone overlies the coal seams (borehole 239b; Fig. 10). The mudstone roof rocks contain plant remains representing a typical roof-shale “Floznah” flora (*sensu* Gastaldo, 1996).

The district of workable Nýřany group of coal seams of this coal mine was spread over an area of about three km$^2$. Its spoil tip contained plant fossils from both the Nýřany and Radnice members, and it was sometimes difficult to recognize from which member the plant remains came from. Except for the sedimentology of the rocks, this could only be determined by the presence of certain index species. About 100 samples from this locality could be confidently assigned to the Nýřany Member, and these yielded only a limited number of species.

The assemblage from Tlučná, Krimich II Mine is typified by the presence of *Lepidodendron subdichotomum* Sterzel (Fig. 11.6), *Sphenophyllum emarginatum* (Brongniart) Brongniart (Fig. 11.8), *Annularia sphenophylloides* (Zenker) Gubi
er, *Pecopteris polypodioides* (Presl in Sternberg) Němejc (Fig. 11.7) and *Dicksonites plueckenetii* (Schlotheim). Cordaitaleans are rare and they are represented by *Cordaites dobranensis* Šimůnek.

**Interpretation.** The collected floras were preserved almost entirely in mudstones. Sphenopsids (*Sphenophyllum emarginatum* and *Annularia sphenophylloidoides*) and ferns (*Pecopteris polypodioides*) are the most common groups in the assemblage. Sphenopsids colonised wet parts of flood basins and tree ferns lowland environments including peat-forming environment (Behrensmeyer *et al.*, 1992). Also lycopsids (*Lepidodendron subdichotomum* Sterzel) are relatively common. According to (Behrensmeyer *et al.*, 1992), they preferred peat and mineral sub-

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**Fig. 6.** *Cordaites blazkovicensis* Šimůnek (1), Heřmanova Huť – Vlkýš locality, Nýřany group of coal seams. 1 – Adaxial cuticle with two stomatal rows, slide 328/3, ×100. Scale bar = 100 µm; *Cordaites wilkischensis* Šimůnek (2–4), Heřmanova Huť – Vlkýš locality, Nýřany group of coal seams. 2 – Adaxial cuticle, slide 327/3, ×150. Scale bar = 100 µm; 3 – Abaxial cuticle with stomatal rows connected into stomatiferous bands, s – stomatiferous bands, slide 327/4, ×100. Scale bar = 100 µm; 4 – Detail from Fig. 4.3. with stomata (s) from the stomatiferous band, ×300. Scale bar = 100 µm. *Cordaites touskovensis* Šimůnek (5–7), Krašovice locality, borehole Kš 1, depth 368.65 m, Touškov group of coal seams. 5 – Adaxial cuticle, poorly preserved, slide 260/2, ×300. Scale bar = 100 µm; 6 – Abaxial cuticle with stomatal rows, (s – stomata), slide 260/2, ×150. Scale bar = 100 µm; 7 – Detail of a stomatal row from Fig. 6.6. (s – stoma), ×300. Scale bar = 100 µm
strate swamps. It is presumed that this assemblage is mixed from different habitats. The evidence of Stigmaria roots has been found in the spoil pile of Krimich II mine, however, it is not certain, whether these roots are of Nýøany or Radnice origin. Cordaitaleans and pteridosperms occur here very rarely. As this assemblage is from the pit tip, there is little evidence to allow a palaeoecological interpretation. According to the fragmentary preservation of the assemblage, it is supposed, that this assemblage is parautochthonous.

Heømanova Hut. This flora was obtained from an outcrop exposed during highway construction, and was several hundred metres long. The outcrop was formed mostly by sandstones and arkosic sandstones, but also including a layer of finer-grained deposits with rooted intervals and intervals yielding plant macro-fossils (Fig. 12). The fossiliferous strata are about 0.6 m thick and could be sampled over an area of 2 m². The resulting 1 m³ of rock yielded 220 samples.

At Heømanova Hut (Tab. 1), 48% of the plant assemblage was dominated by large fragments or complete leaves of four species of cordaitaleans: Cordaites wilkischensis Šimùnek (Fig. 4.6), C. pilsensis Šimùnek (Fig. 4.2), C. blazkovicensis Šimùnek (Fig. 4.3) and C. dobranensis Šimùnek. Also abundant were isolated pinnules of Linopteris neuropteroides Gutbier f. major Potonié (Fig. 11.5). Surprisingly, also relatively common were representatives of wet habitat vegetation – Lepidocarpon hofmannii (Nìmejc) (Fig. 11.2) and Lepidophyllum sp.

Interpretation. The sandstones are surely of fluviatile origin and are unfossiliferous. The original environment of the mudstones layers was probably a flood plain or alluvial plain, and the presence of several rooted horizons supports the existence of a periodically vegetated environment. The soil was probably well-drained and no coal seams originated here. The flora collected here is typically “Flozfern” sensu Gastaldo (1996), and includes the large and nearly complete cordaitalean leaves that indicate minimal transport from their site of growth and, therefore, they are probably parautochthonous. The small and fragmentary remains of lycopsids, sphenopsids and pteridosperm debris indicates a further distance of transport and, therefore, are probably parautochthonous or allochthonous sensu Gastaldo et al. (1995).

Fig. 7. Cordaites dobranensis Šimùnek (1–5), Dobøany, Dobré štìstí Mine locality, Chotìkov group of coal seams. 1 – Adaxial cuticle with a stomatal row, slide 283/3, ×100. Scale bar = 100 µm; 2 – Detail of the stomatal row from Fig. 7.1, ×300. Scale bar = 100 µm; 3 – Adaxial cuticle with stomata of a stomatiferous band with poorly developed crypt, slide 243/3, ×300. Scale bar = 100 µm; 4 – Abaxial cuticle with stomatal rows arranged into stomatiferous bands, slide 164/4, ×100. Scale bar = 100 µm; 5 – Detail of a stomatiferous band from Fig. 7.4, showing stomata with well developed crypt (c), ×300. Scale bar = 100 µm. Cordaites radicicen sis nov. sp. (6–9), Radìce locality, Nevøeò group of coal seams. 6–9 – Adaxial cuticle with dark (stomatiferous) bands; 6 – Cuticle with two dark bands, slide 423/3, ×100. Scale bar = 100 µm; 7 – Detail of a dark band, slide 423/4, ×250. Scale bar = 100 µm; 8 – Cuticle with two dark bands with stomata (s), slide 423/4, ×100. Scale bar = 100 µm; 9 – Detail from Fig. 7.8. with a stoma (s) in the dark band, ×300. Scale bar = 100 µm
Nýřany-Tesla Borehole HJ 3/1. This borehole was drilled by the Building Geology Company; the description of it lacks detail. It was only 102 m deep and did not reach the coal seam (in the nearby Ziegler Mine that operated between 1872 and 1917, the Nýřany coal seams occurred at depths of 120 and 130 m – Purkyně, 1913). The borehole section consisted mainly of beige-grey to grey arkosic sandstones of varying grain-size (Fig. 13). However, there was also a 1.9 m thick greyish-black mudstone (92.8 – 94.7 m depth) yielding only *Calamostachys tuberculata* (Sternberg) Jongmans and *Cordaites dobranensis* Šimůnek leaves.

**Interpretation.** There is not enough information available to propose an interpretation.

**PLANT ASSEMBLAGES FROM THE CHOTÍKOV GROUP OF COAL SEAMS**

Nová Ves and Dobřany. These localities are described together because they belong to the same mining district which is situated in the eastern part of the Plzeň Basin southwest of Plzeň. The Dobré štěstí Mine (near Nová Ves) and the Hugo Mine (near Dobřany) operated during the years between World Wars I and II. After World War II, the Dobré štěstí Mine was abandoned and the Hugo Mine was renamed Dobré štěstí Mine which inevitably led to confusion.

Figure 14 shows sections through the shaft of the abandoned Dobré štěstí Mine near Nová Ves. The Nýřany Member is represented here by coarse-grained strata, mainly sandstones (partly arkosic). The coal seams are usually less than 1 m thick, their roofs are often formed by fossiliferous mudstone. The two Chotíkov coal seams are present at depths of 80 and 88 m. The (upper) Radnice coal seam at 160 m in depth is very thin and mineable only locally. The Proterozoic basement is usually just below this coal seam.

The Chotíkov coal seams are exposed in the neighbourhood of the former Hugo Mine where they are dipping very gently towards the WNW. The depth of these coal seams increases to nearly 200 m in the western parts of the working coalfields.

Figure 15 shows sections through the upper Chotíkov coal seam (46/63) and lower Chotíkov coal seam (Ch 17) according to Pešek (1975). Both sections are

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**Fig. 8.** *Cordaites radcicensis* sp. nov. (6–9), Radčice locality, Nevřeň group of coal seams. 1 – Cuticle near the leaf margin. Adaxial cuticle on the right and abaxial cuticle on the left, slide 423/1, ×100. Scale bar = 100 μm; 2 – Abaxial cuticle with stomatiferous bands with stomata (s) and non-stomatiferous band, slide 423/9, ×300. Scale bar = 100 μm; 3 – Detail from Fig. 8.2. with stomata (s), note strongly cutinised anticlinal cell walls. ×600. Scale bar = 50 μm; 4 – Abaxial cuticle with stomatiferous bands showing stomata (s), slide 423/6, ×300. Scale bar = 100 μm; 5 – Detail from Fig. 8.2. with a stoma (s), ×600. Scale bar = 50 μm; 6 – Abaxial cuticle with two distinct stomatiferous bands. ×150. Scale bar = 100 μm; 7 – A fragment of the leaf (holotype), from which the cuticular slides Nos 423/1-11 have been prepared. Coll. No. ZŠ 324, ×1. Scale bar = 1 cm; 8 – *Cordaites touškovensis* Šimůnek, Krašovice locality, borehole Kš 1, depth 368.65 m, Touškov group of coal seams. Coll. No. ZŠ 242, ×1. Scale bar = 1 cm
from the northern part of the working field of the Hugo Mine. The flora was obtained mainly from the interbeds and roof rock of these coal seams. Whitish tuffaceous claystone with fossils occur in the roof of the lower Chotíkov coal seam, and the overlying claystone or mudstone is also fossiliferous (Šimůnek, 1994; Opluštil et al., 2007).

The best-known flora comes from mudstones exposed over an area of 0.7 km² at the former Hugo Mine (Šimůnek, 1994). During decades of collecting, a total of 993 specimens belonging to 29 species have been found in the mudstones (see Tab. 2), with Sphenophyllum emarginatum (Brongniart) Brongniart, Calamites cisti Brongniart, C. suckowii Brongniart, Annularia stellata (Schlotheim) Wood (Fig. 16.1), Calamostachys tuberculata (Sternberg) Jongmans, Pecopteris polypodioides (Presl in Sternberg) Němejc, P. unita Brongniart and Cordaites dobranensis Šimůnek being dominant. The last named species represented 45% of this assemblage and was probably a peat-forming representative of cordaitaleans. This assemblage is similar to the Tlučná, Krimich II Mine assemblage, which was also dominated by Sphenophyllum emarginatum (Brongniart) Brongniart, Annularia stellata (Schlotheim) Wood and Pecopteris polypodioides (Presl in Sternberg) Němejc. The only significant difference between these assemblages is the lack of cordaitaleans at the Tlučná, Krimich II Mine locality.

Collecting at the old Dobré štěstí mine (near Nová Ves) was not as intensive and thus far

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Fig. 9. Section through the basal part of the Touškov Group of coal seams in the borehole Kš 1 Krašovice. 1 – Lower Touškov Coal seam; 2 – dark grey silty claystone; 3 – clayey siltstone; 4 – grey siltstone; 5 – sandy siltstone; 6 – light grey fine-grained sandstone; 7 – medium-grained arkosic sandstone; 8 – coarse-grained arkosic sandstone; 9 – conglomerate; 10 – brown-grey tuffite; 11 – plant remains; 12 – plant remain mentioned in this article (After Opekar et al., 1994)
### Table 1: Occurrence of the species in studied localities of the Plzeň Basin

| Group of Coal Seams | Locality                        | Ascolurus camptotetia | Ascolurus subpyramidatum | Calamites suckowii | Calamites sp. | Calamites cistii | Calamites linearifolium | Calamites plicatellus | Calamites plicatellus | Calamites lineatus | Calamites plumosus | Calamites polypodioides | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Calamites plumosus | Cala...
<table>
<thead>
<tr>
<th>Species</th>
<th>Cordaites plasicaenis</th>
<th>Cordaites krasovicensis</th>
<th>Cordaites blazkovicensis</th>
<th>Cordaites toskovicensis</th>
<th>Cordaites dobranensis</th>
<th>Cordaites wilkischensis</th>
<th>Cordaites pilsensis</th>
<th>Cordaites touskovensis</th>
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<tbody>
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<td>Leaves</td>
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<td>Amphiomorphic</td>
<td>Amphiomorphic</td>
<td>Amphiomorphic</td>
<td>Amphiomorphic</td>
<td>Amphiomorphic</td>
<td>Amphiomorphic</td>
<td>Isodiametric</td>
</tr>
<tr>
<td>Venation</td>
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<td>3-7</td>
<td>2-3</td>
<td>2-3</td>
<td>2-3</td>
<td>2-3</td>
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<td>2-3</td>
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<td>Thin veins between 2 thick veins</td>
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<td>1-2</td>
<td>1-2</td>
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<td>1-2</td>
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<td>Difference between stomatiferous (or intercostal) and non-stomatiferous bands</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cell shape of stomatiferous bands</td>
<td>Oblong to irregularly hexagonal</td>
<td>Mostly oblong</td>
<td>Telomeric (oblong)</td>
<td>Telomeric, pent'a-hexagonal</td>
<td>Isodiametric, polyominal</td>
<td>Dark, oblong, hexagonal, nearly isodiametric</td>
<td></td>
<td></td>
</tr>
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<td>Cell shape of non-stomatiferous bands</td>
<td>Mostly oblong</td>
<td>Mostly oblong</td>
<td>Telomeric (oblong)</td>
<td>Telomeric, oblong</td>
<td>Longitudinally oblong</td>
<td>Oblong</td>
<td>Oblong</td>
<td></td>
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<tr>
<td>Size of non-stomatiferous cells (µm)</td>
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<td>(40-160) x (15-30)</td>
<td>(40-150) x (15-30)</td>
<td>(35-150) x (15-20)</td>
<td>(25-60) x (12-25)</td>
<td>(24-60) x (12-25)</td>
<td>(28-40) x (15-20)</td>
<td>(24-60) x (12-32)</td>
</tr>
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<td>Distribution</td>
<td>Dark rare stomatal rows</td>
<td>Single or double well-defined stomatal rows</td>
<td>Well-defined single to double stomatal rows</td>
<td>Dispersed (dark spots)</td>
<td>Rare stomatal rows</td>
<td>Rarely in dark stomatiferous bands</td>
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<td>Density per 1 mm²</td>
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<td>140</td>
<td>40</td>
<td>15</td>
<td>0.14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stomatal index</td>
<td>3.5</td>
<td>13</td>
<td>1.8</td>
<td>0.75</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Length and width of guard cells (µm)</td>
<td>(28-30) x (16-20)</td>
<td>(18-25) x (15-22)</td>
<td>(32-45) x (22-35)</td>
<td>(22-25) x (29-30)</td>
<td>(20) x (8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subordinate cells</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number and shape</td>
<td>2; polynomial to oval (hexagonal)</td>
<td>2; polynomial, pentagonal to oval</td>
<td>2; oblong, square</td>
<td>2; oblong, rhomboidal</td>
<td>2; polygonal or rounded</td>
<td>2; polygonal or rounded</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size (µm)</td>
<td>(25-35) x (20-25)</td>
<td>(15-20) x (12-20)</td>
<td>(20-15) x (10-20)</td>
<td>(20-40) x (15-25)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance between stomatal rows and non-stomatiferous bands</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cell shape of stomatal rows</td>
<td>Oblong to square</td>
<td>Small trapezoidal to triangular</td>
<td>Small, rounded to oblong</td>
<td>Longitudinally oblong</td>
<td>Irregular, tet’a-pentagonal, oblong, square</td>
<td>Small oblong, square to oval cells</td>
<td>Oval to oblong</td>
<td></td>
</tr>
<tr>
<td>Size of stomatiferous cells (µm)</td>
<td>(15-25) x (15-25)</td>
<td>(25-40) x (15-20)</td>
<td>(8-18) x (5-8)</td>
<td>(40-80) x (10-18)</td>
<td>(20-40) x (10-15)</td>
<td>(20-50) x (15-20)</td>
<td>(20-50) x (15-20)</td>
<td></td>
</tr>
<tr>
<td>Cell shape of non-stomatiferous bands</td>
<td>Longitudinally tetragonal</td>
<td>Mostly oblong</td>
<td>Ovate or trapezoidal</td>
<td>Longitudinally oblong</td>
<td>Oblong</td>
<td>Longitudinally tetragonal (oblong)</td>
<td>Evaginated, oblong</td>
<td></td>
</tr>
<tr>
<td>Size of non-stomatiferous cells (µm)</td>
<td>(40-60) x (15-20)</td>
<td>(35-130) x (15-20)</td>
<td>(35-80) x (10-20)</td>
<td>(40-100) x (10-18)</td>
<td>(35-120) x (25-15)</td>
<td>(25-90) x (12-20)</td>
<td>(36-80) x (16-24)</td>
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<tr>
<td>Distribution</td>
<td>Mostly well-defined single stomatal rows</td>
<td>Well-defined single to double stomatal rows</td>
<td>Well-defined single stomatal rows</td>
<td>Stomatiferous bands with 3-5 stomatal rows</td>
<td>Stomatiferous bands - up to 5 stomatal rows</td>
<td>Stomatiferous bands - 2-5 stomatal rows</td>
<td>Stomatiferous bands - rows indiscernible</td>
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</tr>
<tr>
<td>Density per 1 mm²</td>
<td>7.60</td>
<td>143</td>
<td>186</td>
<td>110</td>
<td>230-270 (in stomatal bands)</td>
<td>180-240</td>
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<tr>
<td>Stomatal index</td>
<td>12</td>
<td>7</td>
<td>7</td>
<td>10-25 (in stomatal bands)</td>
<td>8-14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape of guard cells</td>
<td>Elliptical, polar ends in trapezoid-tetral shape</td>
<td>Elliptical</td>
<td>Elliptical</td>
<td>Elliptical</td>
<td>Elliptical</td>
<td>Elliptical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length and width of guard cells (µm)</td>
<td>(30-35) x (16-24)</td>
<td>(18-20) x (12-16)</td>
<td>20 x 15</td>
<td>(20-25) x (12-18)</td>
<td>(28-40) x (18-22)</td>
<td>(14-18) x (6-8)</td>
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<td>Subordinate cells</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number and shape</td>
<td>2; rhomboidal to oval</td>
<td>2; pentagonal, hexagonal, oval, rhomboidal, trapezoidal</td>
<td>2; oval to rounded</td>
<td>2 (5); oblong or irregular</td>
<td>2; oval, rhomboidal, square to oval</td>
<td>2;oval (rhomboidal)</td>
<td>2-3; as ordinary cells</td>
<td></td>
</tr>
<tr>
<td>Size (µm)</td>
<td>(28-35) x (15-25)</td>
<td>(15-20) x (12-16)</td>
<td>(15-40) x (12-15)</td>
<td>(40-60) x (15-20)</td>
<td>(20-40) x (15-20)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number and shape</td>
<td>wide, oblong or regular trapezoid</td>
<td>2(3); ± trapezoidal, reniform</td>
<td>2; bean-shaped</td>
<td>2 (5); oblong or irregular</td>
<td>2(3); oblong to reniform</td>
<td>2; reniform</td>
<td>2-3; as ordinary cells</td>
<td></td>
</tr>
<tr>
<td>Size (µm)</td>
<td>(46-65) x (25-30)</td>
<td>(15-60) x (15-20)</td>
<td>(40-50) x (15-20)</td>
<td>(35-40) x (15-20)</td>
<td>(36-80) x (12-20)</td>
<td>(52-80) x (12-18)</td>
<td></td>
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</tr>
<tr>
<td>Shape of crypt</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td></td>
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</tr>
<tr>
<td>Subsidiary cells</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tbody>
</table>
fewer specimens (124) were obtained here. Nevertheless, it yielded a very similar assemblage, albeit not so rich in species (Tab. 1). Remarkable are the remains of *Cordaites dobranensis* Šimůnek that here form 67% of the plant assemblage (Tab. 3).

The assemblage from the tuffaceous layer at the Dobřany locality consisted of only a few species because it could only be sampled over a small area, probably representing several thousands m$^2$. However, all of the species found there also occurred in the mudstones of the same locality.

**Interpretation.** The floras collected at these localities are typically “Floznah” sensu Gastaldo (1996). The whitish tuffaceous layer lies directly above the coal seam and probably terminated the peat bog habitat here. It contains an autochthonous or paraautochthonous plant assemblage, indicating wet, peat-forming conditions. The plant assemblage from different light grey to black, thin-bedded to unbedded mudstones can represent a variety of origins from autochthonous to

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**Fig. 10.** Tlučná near Nýřany, Krimich II borehole sections from Vejprnice mining area; (coordinates 238b and 239 b) with Main Nýřany coal seam, 246b/82 with Roof Nýřany coal seam. 1 – coal; 2 – claystone, siltstone and mudstone; 3 – sandstone; 4 – plant remains (coordinates: 238b: x = 1 070 476, y = 828 936, z = 9.65 m; 239b: x = 1 070 475, y = 828 940, z = 9.4 m; 246b/82: x = 1 070 448, y = 829 292, z = 8.4 m). (Adopted from Mining Archive ZUD, Zbůch: Korous & Zelenka, 1981 unpublished)
allochthonous *sensu* Gastaldo *et al.* (1995). The mudstone was deposited some time after the tuffaceous layer, or directly above the coal seam where the tuffaceous layer was not developed (Fig. 15). This assemblage contains mostly sphenopsids that lived in wet parts of flood basins, and ferns that grew in lowland and peat-forming environments (Behrensmeyer *et al.*, 1992). Pteridosperms, as dwellers of better-drained parts of flood basins are very rare and they are of parautochthonous or allochthonous origin (Behrensmeyer *et al.*, 1992). One specimen of *Lesleya* sp. Lesquereux was found in dark mudstone with mica admixture. According to Remy and Remy (1975), *Lesleya* is meso- to xerophyte plant, also Leary and Pfefferkorn (1977) consider *Lesleya* as an upland floral element. This plant in the Chotíkov group of coal seams is surely of allochthonous origin.

### Table 3

Percentage occurrence of plant groups in individual localities of the Plzeň Basin

<table>
<thead>
<tr>
<th>Localities</th>
<th>Lycopods</th>
<th>Sphenopsids</th>
<th>Ferns</th>
<th>Pteridosperms</th>
<th>Cordaites</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radčice</td>
<td>0</td>
<td>[30]</td>
<td>[15]</td>
<td>[10]</td>
<td>[45]</td>
<td>[100]</td>
</tr>
<tr>
<td>Nová Ves, Hugo Mine</td>
<td>0</td>
<td>21</td>
<td>8</td>
<td>4</td>
<td>67</td>
<td>124</td>
</tr>
<tr>
<td>Dobřany</td>
<td>mudstones</td>
<td>7</td>
<td>30</td>
<td>12</td>
<td>45</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>tuffites</td>
<td>2</td>
<td>29</td>
<td>31</td>
<td>7</td>
<td>31</td>
</tr>
<tr>
<td>Heřmanova Huť-Vlkýš</td>
<td>30</td>
<td>3</td>
<td>10</td>
<td>9</td>
<td>48</td>
<td>220</td>
</tr>
<tr>
<td>Tlučná, Krimich II Mine</td>
<td>[20]</td>
<td>[35]</td>
<td>[35]</td>
<td>[5]</td>
<td>[5]</td>
<td>[100]</td>
</tr>
<tr>
<td>Nýřany-Tesla, HJ 3/4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Krašovice, KŠ 1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Explanation: [5] - Estimated percentage - Radčice (including semiquantitative data from Čtveráček, 1984), Tlučná, selective assemblage after omitting the Radnice species. X – present; grey – important group in the locality

PLANT ASSEMBLAGES FROM THE NEVŘEŇ GROUP OF COAL SEAMS

Radčice. This is the only section of this age studied. Overbank deposits form a relatively thick (1.5 to 3 m; Fig. 17) and laterally extensive (more than 60 m) complex with fine-grained facies. Parallel lamination and root traces are the most common features. Laterally confined basal parts of the section may reflect its abandoned channel-fill origin. Deposition of most of the facies took place in a subaqueous environment (flooded swamp or slightly deeper oxbow lake), but the presence of root traces and thin coal seams suggested periodic emergence and vegetation-cover. The mineral composition of the thin interbeds of light grey claystone to fine-grained sandstone suggests a volcanic origin. The upper part of the section is dominated by horizontal- to low-angle cross-bedded sandstone of probably crevasse splay origin indicating the increasing proximity to the fluvial channels at the end of overbank-deposition.

The youngest outcrop at Radčice represents the end of sedimentation of the Nýřany Member. It is a section about 800 m long, with coarse sandstones and conglomerates. These rocks contain several mudstone lenses, some of which yield a rare flora. Each lens contains only a few species, but each assemblage differs from the others; the assemblage from Tab. 1 was compiled from all fossiliferous lenses and represents about 100 specimens.
The plant assemblage from Raděice is rich in cordaitaleans, but only one species has been identified: *Cordaites radcicensis* nov. sp. The other dominant species – *Calamites cistii* Brongniart and *Pecopteris* sp. – are without stratigraphical significance, but a Cantabrian age is indicated by the occasional presence of *Sphenophyllum oblongifolium* (Germar) (Cleal et al., 2003). Ferns *Pecopteris “arborescens”* (Schlotheim) and *P. hemitellioides* Brongniart are also typical for the Stephanian. No lycopsid macrofossils were found, but *Lycospora* Schopf, Wilson et Bentall spores have been found very rarely in some samples (Drábková et al., 2005).

According to one of the reviewers (A. Bashforth), the *Callipteridium* samples from Raděice locality belong to *Callipteridium armasii* (Zeiller) Wagner, and not *Callipteridium rubescens* (Presl in Němec) Wagner, as I determined earlier. There are several very similar Asturian and Cantabrian species: *Alethopteris subdavreuxii* Sterzel from Zwickau (Germany), *Alethopteris costei* Zeiller from Central Bohemian and Intrasudetic basins (Czech Republic) and from Saar Basin (Ger-

**Fig. 14.** Section through the shaft of Dobré štětí Mine near Nová Ves. 1 – Quaternary; 2 – claystones; 3 – siltstones; 4 – coal seams and their representatives; 5 – sandstones; NY – the coals belonging to Nýřany Member (Chotíkov Group of coal seams); RA – the Upper Radnice coal seam (After Pešek, 1975)

**Fig. 15.** Schematic sections of the coal seams of the Northern working field of Hugo mine near Dobřany. 46/63 – Upper Coal; CH 17 – Lower Coal; 1 – bituminous coal; 2 – banded coal with high ash content; 3 – claystone and siltstone; 4 – claystone with appendices of *Stigmaria*; 5 – volcanogenetic layer; 6 – fine-grained sandstone; 7 – plant remains (After Pešek, 1975)
many). They are, maybe, younger synonyms of *Callipteridium* (*Praecallipteridium*) *rubescens* (Presl in Sternberg) Wagner, which was also described by Němejc (1929) as *Alethopteris rubescens*. Another younger synonym of *Callipteridium rubescens* is *C. jongmansii* (Bertrand) Wagner from France (A. Bashforth, pers. comm.). The venation density (approximately 30 veins/cm of the pinnule margin) of *Callipteridium armasii* is not as high as venation density *C. rubescens* (45–50 veins/cm of the pinnule margin). *Callipteridium armasii* has been described from Asia Minor by Zeiller (1899) and also from Saar Basin, North France and Great Britain (Franke, 1912). Wagner (1969) reported the species *Callipteridium armasii* as an important element of the Cantabrian in Spain. In the subsequent paper, Wagner and Winkler Prins (1985) reported *Callipteridium armasii* from both Asturian and Cantabrian substages. Except for the Radčice locality (Fig. 16.4), this species has not been reported from the Czech Republic yet. These discussed species deserve detailed revision.

**Interpretation.** The fossiliferous rocks of the Radčice section show a sedimentology indicating oxbow lake or abandoned channel-fill environments. The presence of several rooted horizons shows the existence of fossil soils and slow deposition of mudstone layers (Fig. 17). The flora is usually fragmentary and not very well preserved (with some exceptions). It is partly parautochthonous and partly allochthonous, transported by a river and deposited in the above-mentioned abandoned river channels. According to Opluštil et al. (2005), the climatic setting was generally humid with increasing seasonality. Although the flora is relatively rare and typical hygrophilous forms lack, only mesophilous and xerophilous floral elements have been found at Radčice.

### VEGETATIONAL ANALYSIS

Apart from in the boreholes, the most common plant groups represented in the studied localities of the Plzeň Basin are cordaitaleans and sphenopsids (Tab. 1). Remains of *Cordaites* Unger were found at all of the localities, being most common in Nová Ves (67%), Dobřany and Radčice (45%) and Heřmanova Hut (48%). Only one locality (the Krimich II mine at Tlučná) was poor in cordaitalean remains. The species *Cordaites dobranensis* Šimůnek, which occurred in nearly all of the localities (except Radčice), was the most common species. There is no evidence about its habitat. The most probable is that it grew on large areas close to mires, or in the dryer parts of mires.

![Fig. 16. Flora from the Nýøany Member, Chotíkov group of coal seams, Asturian. Nová Ves, Dobré štětí Mine locality. 1 – *Annularia stellata* (Schlotheim) Wood, Coll. No. ZŠ 317, ×0.5. Scale bar = 2 cm; 2 – *Dicksonites plukenetii* (Schlotheim), Coll. No. ZŠ 318, ×0.5. Scale bar = 2 cm. Flora from the Nýøany Member, Nevøeò Group of coal seams, Cantabrian. Radčice locality. 3 – *Calamites cistii* Brongniart, Coll. No. ZŠ 319, ×1. Scale bar = 1 cm; 4 – *Callipteridium* (*Praecallipteridium*) cf. *armasii* (Zeiller) Wagner, Coll. No. ZŠ 320, ×3. Scale bar = 1 cm; 5 – *Sphenophyllum oblongifolium* (Germar), Coll. No. ZŠ 321, ×2. Scale bar = 1 cm]
The greatest diversity of *Cordaites* species was at Heřmanova Hut', where four species were found (Tab. 1). *C. dobranensis* Šimůnek was not very common at this locality (although it was also found in the Nýřany-Tesla borehole HVJ 3/1) but the other three species were relatively abundant. However, *C. tounkovensis* and *C. krasovicensis* were both absent from the Nýřany and Chotíkov group of coal seams despite being abundant in the underlying Touškov group of coal seams. It is not clear whether this is because these species favoured habitats not developed in the interval associated with the Nýřany and Chotíkov groups of coal seams, or if stratigraphy played a role. It seems that *Cordaites radcicensis* nov. sp., which was only found associated with the topmost Nevřen group of coal seams, was better adapted to a drier climate (thick cutinisation and proximally oriented projection of the anticlinal cell walls).

Sphenopsids represented about 30% of the assemblages at the Radčice, Dobřany and Tlučná localities. The most common sphenopsid from Radčice was *Calamites cistii* Brongniart (Fig. 16.3); from Nová Ves *Calamites cistii* Brongniart and *Annularia stellata* (Schlotheim) Wood (Fig. 16.1); and from Dobřany *Sphenophyllum emarginatum* (Brongniart) Brongniart, *Calamites cistii* Brongniart, *C. suckowii* Brongniart, *Annularia stellata* (Schlotheim) Wood and *Calamostachys tuberculata* (Sternberg) Jongmans. *Sphenophyllum emarginatum* (Brongniart) Bron-
gniart, Annularia stellata (Schlotheim) Wood and Annularia sphenophylloides (Zenker) Gutbier were the most common sphenopsids from the Tlučná locality. Sphenopsids were extremely rare in the Heřmanova Hut’ locality (Tabs 1, 3).

Ferns were rare in most localities, which is surprising as they are usually important Asturian floral elements. They were relatively abundant in only two localities—in the tuffaceous layer at the Dobřany and Tlučná localities (31% and 35%, respectively). The fern assemblages were essentially similar in both localities, differing only in the proportion of species. The most common species were Pecopteris polyendioides (Presl in Sternberg) Němejc and P. unita Brongniart (Tabs 1, 3).

Lycopsids have not been found so far at the Radčice and Nová Ves localities, and they were very rare at the Dobřany locality. They were a little more abundant at the Tlučná locality, where the dominant lycopsid was Lepidodendron sub-dichotomum Sterzel, a species that probably favoured peat forming habitats. At the Heřmanova Hut’ locality, lycopsid remains were also relatively common (30%) but here represented mostly by isolated sporophylls of Lepidocarpon hofmannii (Němějc) and leaves Lepidophyllum sp. These small plant remains could have been easily transported from a long distance away, and also could have belonged to one or a few trees. Only four fragments of stems or bark of Lepidodendron sub-dichotomum Sterzel (Fig. 11.1) were found at this locality. The environmental conditions at the Heřmanova Hut’ locality were probably not arid, but neither were they wet enough for the formation of peat mires.

Pteridosperms were very rare in most of the communities of the Nýřany Member. The most common representative of the callistophytes was Dicksonites plukenetii (Schlotheim), found at the Tlučná locality. Among the medulosaleans, abundant isolated pinnules of Linopteris neuropteroides Gutbier f. major Potonié were found at the Heřmanova Hut’ locality. The stratigraphically important species for the Nýřany Member is Callipteridium (Praecallipteridium) rubescens (Presl in Sternberg) Wagner that was found at the Radčice and Dobřany localities. Other species occur very rarely (see Tabs 1, 3).

CONCLUSIONS

Fifty species from the Nýřany Member of the Plzeň Basin were recorded in this study. One new species Cordaites radcicensis nov. sp. is described and the species Callipteridium (Praecallipteridium) armasii is new for the Bohemian Carboniferous. The five most common species in the Nýřany Member—Pecopteris polyendioides (Presl in Sternberg) Němejc, Sphenophyllum emarginatum (Brongniart) Brongniart, Pecopteris unita Brongniart, Dicksonites plukenetii (Schlotheim) and Annularia stellata (Schlotheim) Wood are in concordance with Šetlík’s (1980) observation.

Most of the studied localities yielded between 10 and 20 species. However, the most diverse and representative assemblage for the Nýřany Member floras came from mudstones at the Hugo Mine at Dobřany with 32 species described.
The Nýřany and Chotíkov groups of coal seams were biostratigraphically indistinguishable based on the associated floras, and appear to be Late Asturian in age. Sphenopsids and cordaitaleans dominated. Four species of *Cordaites* were identified using cuticular evidence. Ferns as the Asturian and Cantabrian characteristic elements were abundant only in Tlučná and in the Dobřany tuffites. Pteridosperms were rare in all of the localities studied. Lycopsids were also rare, except at the Tlučná locality. The quantity of lycopsids at Heřmanova Hut is caused by numerous leaves and sporophylls.

The youngest plant assemblage studied, from the Radčice section, yielded *Sphenophyllum oblongifolium*, which indicates a Cantabrian age (Cleal *et al.*, 2003). Also cordaitaleans and sphenopsids dominated, ferns and pteridosperms were rare, lycopsids were absent. A new species *C. radcicensis* nov. sp. was described with its epidermal characters. Thick cutinisation and proximally oriented projection of the anticlinal cell walls suggest a more seasonal climate (Opluštil *et al.*, 2005).

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