

Revision of the genus *Cordaites* UNGER from the Permian of the Intrasudetic Basin (Broumov Formation, Olivětín Member, Czech Republic)

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Abstract

Cordaitalean remains are not very common in the Permian of the Intrasudetic Basin (Czech Republic and Poland) and have usually been classified simply as *Cordaites* sp. Based on leaf morphology, venation and cuticles (where possible), five cordaitalean species are recognised: *Cordaites* cf. *beinertianus*, *C. cf. affinis*, *C. cf. roesslerianus*, *C. cf. foliolatus* and *Cordaites* sp. A. The determination of *Cordaites* leaves is difficult because of the variability and similarities between several species. The biggest leaf was determined as *Cordaites* cf. *beinertianus*. The cuticles of *Cordaites* cf. *affinis* resemble the cuticles of *C. palmaeformis* and *C. radvanicensis*, however, the latter is known only in a fragmentary state. *Cordaites beinertianus* and *C. palmaeformis* are very similar and are considered as conspecific by some authors. *Cordaites affinis* has generally smaller leaves. *Cordaites* cf. *roesslerianus* is comparable with *C. principalis* with which it is sometimes synonymised. *C. cf. foliolatus* is represented by a much narrower leaf than is typical for cordaitalean leaves from France. *Cordaites* sp. A is a relatively small leaf-form and differs from all other forms previously described.

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1. INTRODUCTION

Cordaitalean remains from the Bohemian part of the Intrasudetic Basin have been known to palaeobotanists since the 19th century [e.g. *Cordaites platynervis* (GÖPPERT, 1864) GRAND'EURY, 1877]. Since then, tens of *Cordaites* species have been described based on leaf morphology and venation. However, it has been shown that venation can be strongly influenced by both taphonomic and preservation conditions (CROOKALL, 1970). Moreover, many species have been described based on incomplete specimens, without their base, or apex, and such specimens are difficult to compare with other specimens only by the means of venation.

In reality, the situation is more complicated, because both leaf morphology and venation have some natural variability caused by the edaphic and climatic conditions in which the plant grew. The most stable feature seems to be the cuticle. Cordaitalean cuticles have been studied by FLORIN (1931), and more systematically by BARTHEL (1962, 1964, 1976), LEDRAN (1960, 1966), and RABITZ (1966). BARTHEL (1962, 1964, 1976) found that one species [e.g. *Cordaites principalis* (GERMAR) GEINITZ] can have different cuticles, that he named Type 1 to Type 8. BARTHEL (1976) was aware of the problem of the correct determination of *Cordaites* species and came to the conclusion that it is not possible to distinguish three long-leaved *Cordaites* species – *C. borassifolius* (STERNBERG) UNGER, *C. palmaeformis* (GÖPPERT) WEISS and *C. principalis* (GERMAR) GEINITZ, and he suggested calling them “*Cordaites* sp.” This interpretation helps to avoid problems in the determination of *Cordaites* species, but it does not enable recognition of the diversity of this group and/or the specification of the number of *Cordaites* species per locality. BARTHEL (2009, 2016) did not change his mind and classified all samples as *Cordaites* sp.

From the quantity of *Cordaites* names, only *Cordaites borassifolius*, *C. palmaeformis* and *C. principalis* dominate in the

palaeobotanical literature. As shown above, these species are understood by different authors in different ways, and only cuticles from the type material will help to solve the problem of the accurate determination of these species. Cuticles of *Cordaites borassifolius* were described as amphistomatic with dispersed stomata on the adaxial cuticle, and stomatiferous and non-stomatiferous bands on the abaxial cuticle (ŠIMŮNEK et al., 2009). Studying cuticles of *Cordaites palmaeformis* was difficult due to poor preservation, but eventually the stomata were shown to be arranged in stomatal rows on both cuticles (ŠIMŮNEK, 2015). A problem remains with *Cordaites principalis*, because its holotype is preserved as an impression in fine-grained sandstone that does not allow cuticular study (ŠIMŮNEK, 2015).

Some cordaitalean remains were discovered during the study of flora from the Olivětín Member in the Intrasudetic Basin. Because some of these remains were large and some contain coal matter suitable for cuticular study, description of these specimens by the author was possible.

2. MATERIAL AND METHODS

The specimens are stored in the collections of the National Museum in Prague and the Museum of Eastern Bohemia in Hradec Králové (No. 74574 and 74575). All specimens came from the Otovice locality (National Museum), and Otovice, Černý potok (Black Creek) limestone (Museum of Eastern Bohemia). All were from the Permian (latest Asselian) Broumov Formation, Olivětín Member (OPLUŠTIL et al. 2016, Table 1). Three *Cordaites* specimens were macerated and slides No. 698/1-16, 699/1 and 700/1-4 prepared.

The method used involved maceration in Schulze's reagent, as described previously by KERP (1990), KRINGS & KERP (1997) and KERP & KRINGS (1999). Coalified fragments of

Table 1. Stratigraphic table of the youngest part of the Intrasudetic Basin. Adopted according to OPLUŠTIL et al. (2016). Remark: Time intervals of gaps between younger units are not known.

Global scale		Regional scale		Formation	Member	Group of Coal seams		
Tri.	Middle			Bohdašín				
	Hiatus						246	
Permian	?Lopingian?	Zechstein		Bohuslavice				
	Hiatus							
	Guadalupian			Trutnov				
	Hiatus						295	
Permian	Cisuralian	Rotliegend	Asselian*	Broumov	Martínkovice			
					Olivětín	●		
					Nowa Ruda			
Pennsylvanian	Gzhelian	Stephanian	C	Chvaleč	Bečkov			
			B	Hiatus				300
			Saberian	Odolov	Jívka	Radvanice		
			Barruelian		"Žaltman arkoses"			

Key: Tri. Triassic * Stage of Global scale ● studied interval

leaves were separated from the rock by needle or by hydrofluoric acid (HF) digestion. These fragments were bleached in Schulze's reagent (40% HNO₃ with crystals of KClO₃) for 3–7 hours. After the treatment in Schulze's reagent, cuticles were washed in water, subsequently immersed in 2% or 10% potassium hydroxide (KOH) and finally rinsed in distilled water. Some cuticles were stained with safranin, Bismarck brown, malachite green or neutral red (KRINGS, 2000) for 1 to 2 hours to accentuate the anticlinal walls and stomata. Before embedding in glycerine-gelatine slides, the cuticles were dehydrated in pure glycerine.

3. GEOLOGICAL SETTING

The Intrasudetic Basin, which is situated along the eastern margin of a suite of Late Palaeozoic Bohemian continental basins (Fig. 1), is the most important among the Sudetic basins. Structurally, the Intra-Sudetic Basin is a complicated NW–SE-elongated syncline with up to 5 km of infill that occupies an approximately 1800 km² area, of which about one third is located in the territory of the Czech Republic (formerly Czechoslovakia). Deposition spans a wide stratigraphic interval from the middle Viséan to the Triassic and includes several hiatuses. Continental deposits unconformably overlie Saxo-Thuringian crystalline complexes

of Pre-Cambrian to Early Palaeozoic age (TÁSLER et al., 1979, BOSSOWSKI, 1995). Viséan sediments in Poland consist of a few kilometres of fluvial to alluvial-fan strata with intercalated marine to deltaic deposits. They are followed in Poland by Serpukhovian (early Namurian) fluvial and coal-rich deposits of the Wałbrzych Formation. In Bashkirian times, the depositional center enlarged further to the south along a tectonically active western basin margin. This resulted in deposition of the Late Bashkirian–Early Moscovian Žacléř Formation (Yeadonian–Bolssovian), with about 60–80 coal seams in three members. Locally important coal seams of Kasimovian – Gzhelian (Cantabrian to Saberian) age occur only in the Czech part of the basin in the Odolov Formation (Svatoňovice and Jívka members) (Table 1).

The Stephanian/Permian Chvaleč Formation is mostly composed of coal-barren fluvial red beds and contains only one thin coal seam in the Vernéřovice Member. Lacustrine horizons a few tens of metres thick, with bituminous limestones and shales are rarely intercalated in red beds (Bečkov Horizon). The overlying Broumov Formation contains the Nowa Ruda, Olivětín and Martínkovice members that correspond mostly to the Asselian (OPLUŠTIL et al. 2016). The Nowa Ruda Member is formed mostly by thick complexes of rhyolite tuffs and tuffites, The Olivětín Member contains fossiliferous "Walchia" shales several tens of metres thick and thin bituminous shales and Ruprechtice and Otovice limestones. The Martínkovice Member also contains limestone horizons, but only animal fossils have been discovered so far. The Upper Permian Trutnov and Bohuslavice formations are composed of red and brown mudstone and sandstone deposits; and the Middle Triassic Bohdašín Formation is represented mostly by white sandstones.

4. SYSTEMATICS

Order Cordaitanthales MEYEN, 1984

Family Cordaitanthaceae MEYEN, 1984

Genus *Cordaites* UNGER, 1850

Type species *Cordaites borassifolius* (STERNBERG) UNGER, 1850

As mentioned in the Introduction, there are difficulties with the systematics of *Cordaites* leaves. More than 40 cordaitalean species have been described based on leaf adpressions from Europe,



Figure 1. Map of the Czech Republic with Permo-Carboniferous basins and the studied locality.

defined on the shape, dimensions and venation type. Even with complete, or nearly complete leaves, there can still be difficulties in classifying specimens to particular species, because the venation is often poorly preserved due to taphonomic processes (CROOKALL, 1970).

About 15 species of *Cordaites* UNGER and *Poa-Cordaites* GRAND'EURY ex BRONGNIART have been described from the Stephanian and Permian, or reported from these strata. These species were compared with specimens found in the Otovice localities but the latter are problematic because their cuticles are poorly preserved and so cannot be used in species determination.

In both museums, seven fragments, probably belonging to four or five species, were selected for study. CROOKALL (1970) only described five species from Great Britain. The last comprehensive paper on cordaitaleans was published by LEDRAN (1966) who described 22 species from France. She also tried to describe the cuticles but they were usually poorly preserved and only in a few cases did they add significant information to supplement the morphological description. BARTHEL (1962, 1964) distinguished in *Cordaites principalis* several types of cuticles and considered *Cordaites borassifolius*, *C. palmaeformis* and *C. principalis* as indistinguishable from each other (BARTHEL, 1976, 2009, 2016).

Specimens from the Otovice locality demonstrate the variability in leaf shape, dimension and venation. Here, comparison of these specimens will be made with other specimens described from the uppermost Stephanian and Permian.

***Cordaites* cf. *beinertianus* (GÖPPERT, 1841)
GRAND'EURY, 1877**

(Fig. 2a, h, i; Pl. 1, Figs. a, b)

1841 *Noeggerathia beinertiana* GÖPPERT, Vol. 5-6, p.108, pl. 12, fig. 3.

1877 *Cordaites beinertianus* GÖPPERT; GRAND'EURY, p. 215.

1914 *Dorycordaites beinertianus* (GÖPPERT) GRAND'EURY; Bureau, p. 304, Atlas, 1913, pl. 66, fig. 1.

Description: The leaf is lanceolate with a bluntly pointed apex. The fragment is 565 mm long and 97 mm wide. The venation is very fine and dense, 45–60 veins per cm in different parts of the leaf (Fig. 2a, h, i; Pl. 1, Figs. a, b).

Remarks: The complete leaf may have been more than 600 mm long, and because its right margin is enrolled (Fig. 2a), it could be 110–120 mm wide. The holotype of *Cordaites beinertianus* (GÖPPERT, 1842) represents the basal half of a leaf. It is wedge-shaped, widening from 3 mm (base) to 55 mm (in the middle) along its length of 170 mm. The veins are very thin, and it seems from the picture that there are about 30 veins per cm. As the apex is not preserved, determination by means of venation only is uncertain. The type locality of *Cordaites beinertianus* is the Charlottenbrunn (nowadays Jedlina Zdrój), of Poland and is probably Bolsovian in age. This combination was used for the first time by GRAND'EURY (1877) in comparison with *Cordaites affinis*, but *C. beinertianus* was not formally transferred to the genus *Cordaites*. GRAND'EURY (1877) used this name without description, only with reference to (GÖPPERT, 1842). *C. beinertianus* was also reported from the Upper Stephanian (BUREAU, 1914), though it is not known that these young specimens are of the same species as the holotype.

This specimen is also similar to *Cordaites palmaeformis*, however the lectotype represents several leaf fragments 160–180

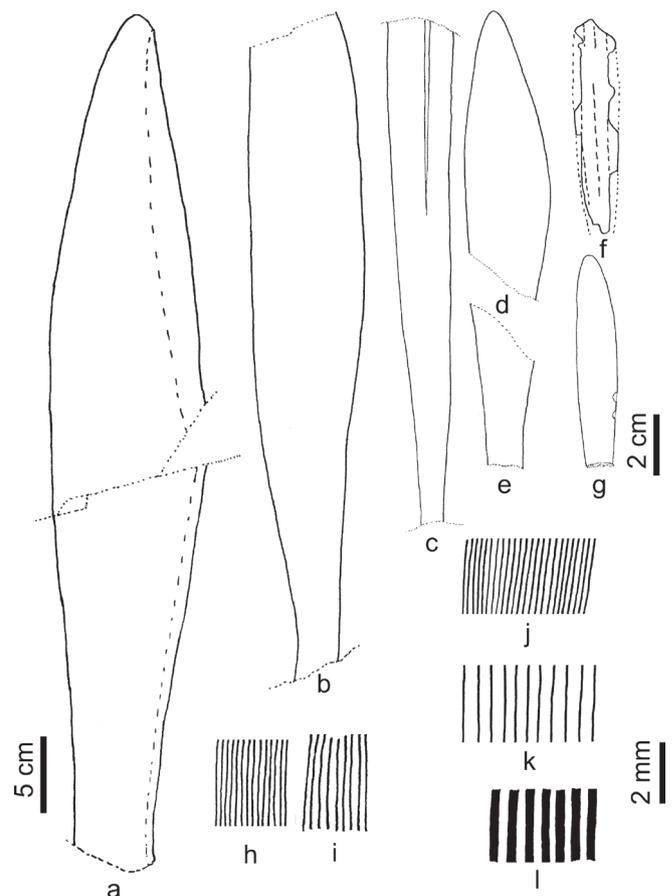


Figure 2. Shapes and venations of *Cordaites* leaves: a. – *Cordaites* cf. *beinertianus*, b. and c. – *Cordaites* cf. *affinis*, d. and e. – *Cordaites* sp. A; f. – *Cordaites* cf. *roesslerianus*, g. – *Cordaites* cf. *foliolatus*; Scale bars: a = 5 cm; b–g = 2 cm. Venations of leaves: h, i – *Cordaites* cf. *beinertianus* (fig. a), j – *Cordaites* cf. *affinis* (fig. b), k – *Cordaites* sp. a (fig. d), l – *Cordaites* cf. *roesslerianus* (fig. f). (Left scale bar is only for a; right upper scale bar is for b–g and left lower scale is for h–l).

mm long and 12–20 mm wide (ŠIMŮNEK, 2015). Other specimens figured by GÖPPERT (1852) also do not have a preserved apex, which is an important diagnostic feature, but the leaves are wider, up to 50 mm wide. GÖPPERT (1852) did not specify the venation density; he only noted that the venation was fine and dense. Only subsequent authors more precisely defined the venation density: GEINITZ (1855) – 3–4; WEISS (1871) – 3–5 and ZEILLER (1886–1888) – 8–12 veins per mm. CROOKALL (1970) mentioned 35–50 veins per mm. This confusion may be because each specimen came from a different country and stratigraphy. The lectotype of *Cordaites palmaeformis* came from the Langsetian of Wałbrzych in the Intrasudetic Basin (ŠIMŮNEK, 2015), however the other syntype (GÖPPERT, 1852, pl. 16, fig. 2) is from the Upper Silesian Basin. The leaves of *Cordaites palmaeformis* are amphistomatic (ŠIMŮNEK, 2015), with stomata on both cuticles arranged in rows. One cuticle (probably adaxial) has 5–6 rows per mm, whilst the second cuticle (probably abaxial) has 12–16 rows per mm. These densities correspond to the densities of fine veins in the adpressions, and also correspond to the specimen from Otovice. However, there is a large stratigraphic distance between these specimens, and cuticles from this specimen from Otovice are not known. GÖPPERT (1852) compared *Cordaites palmaeformis* with *C. beinertianus*.

***Cordaites cf. affinis* GRAND'EURY, 1877**

(Fig. 2b, c, j; Pl. 1, Fig. c–e; Pl. 2)

1877 *Cordaites affinis* GRAND'EURY; GRAND'EURY: p. 215–216, pl. XVIII, figs 6, 7.1896 *Cordaites (Dorycordaites) affinis* GRAND'EURY; RENAULT: p. 344, pl. LXXXVI, fig. 17.

Material: Two specimens. National Museum and Museum of East Bohemia (No. 74574). Cuticle slides 698/1–16 have been prepared from specimen 74574.

Description: Two incomplete leaves. The larger (Pl. 1, Fig. c) is 215 mm long and 36.5 mm wide. Maximum leaf width is below its middle. The second specimen (Pl. 1, fig. e) is a leaf fragment 165.5 mm long and 20.5 mm wide in its upper part. This leaf was probably thin and lacerated in its upper part. The venation is the same in both specimens, formed by very thin veins with density of 55 veins per cm.

Cuticles are very poorly preserved with details only visible by staining with safranin, malachite green or neutral red. It is difficult to distinguish adaxial and abaxial cuticles as both probably have stomatal rows and non-stomatiferous bands. Cuticles on Pl. 2, Figs a, b come from the same leaf fragment and were stained in malachite green. Pl. 2, Fig. a probably represents an adaxial cuticle. Dark bands 120–170 μm wide are distinguishable from light bands around 60 μm wide. Pl. 2 Fig. b probably belongs to an abaxial cuticle. The lighter bands on the adaxial cuticle probably correspond to stomatal rows on the abaxial cuticle and darker bands to non-stomatiferous bands (costal fields).

Abaxial cuticle (Pl. 2, Figs b–h). The cells are differentiated into 90–160 μm wide non-stomatiferous bands and 50–60 μm wide stomatal rows. In contrast to the adaxial cuticles, the stomatal rows are darker than the non-stomatiferous bands. The cells of the non-stomatiferous bands are oblong with straight or slightly bent walls, 15–22 μm wide and 45–80 μm long. The structure of the stomatal rows is difficult to observe. Usually, there are 2 guard cells, 2 polar and 2 lateral subsidiary cells per stomatal complex. The stomatal complexes were probably collapsed and it is impossible to distinguish cell walls from folds on the periclinal walls. In a few cases, guard cells have been preserved. They have a crescent shape, are 28–40 μm long and 12–14 μm wide (Pl. 2, Figs. e, f).

Remarks: GRAND'EURY (1877) described similar specimens with fine venation as *Cordaites affinis*. They are narrow, lanceolate leaves with sharp apices, about 200–300 μm long and 18–30 μm wide. The widest part of the leaf is also approximately in the middle of the leaf. The dimensions of the leaves described here fit to this description, only they (Pl. 1, fig. 3) are a little wider – 36.5 mm. The vein density is comparable with data from LEDRAN (1966): 50–60 per mm. Leaves of *Cordaites affinis* start gradually to widen from their base, the leaf on Pl. 1, fig. c widens more and thus resembles more closely *Cordaites palmaeformis* that is compared closely with previous species.

Cuticles prepared from the specimen on Pl. 1, fig. c resemble the cuticles of *Cordaites palmaeformis* (ŠIMŮNEK, 2015) with stomatal rows on both the abaxial and adaxial cuticles. Cuticles from the type material of *Cordaites palmaeformis* were also poorly preserved, however, the structure of the stomatal complexes of adaxial and abaxial cuticles has eventually been resolved. *Cordaites cf. affinis* from Otovice and *Cordaites palmaeformis* from Walbrzych are both amphistomatic leaves with stomata arranged in stomatal rows on both cuticles. However, it is still not possible to demonstrate that the specimen on Pl. 1, fig. c is *Cordaites affinis*, or if it belongs to *Cordaites palmaeformis*, because cells of the sto-

matal rows are poorly preserved and a comparison is not possible, therefore these specimens are named as *Cordaites cf. affinis*.

LEDRAN (1960, 1966) studied cuticles from cordaitaleans from France which were also poorly preserved. Her drawings of the cuticles show that the stomatal complexes are drawn as cyclocytic complexes with 4 or 5 equal subsidiary cells around the stomatal pore. Such a stomatal type is not known from cordaitaleans. Abaxial cuticles of *Cordaites angulosostriatus* also have stomatal rows (LEDRAN, 1960, 1966). Its reconstruction by RABITZ (1966) is more realistic. The adaxial cuticle of *Cordaites angulosostriatus* has dispersed stomatal complexes.

BARTHEL (1964) published *Cordaites* sp. type 4 from the Asturian of Zwickau that also has dark stomatal rows on abaxial cuticles and dispersed stomata on adaxial cuticles. *Cordaites regularis* described by LEDRAN (1966) has stomatal rows on the abaxial cuticle and dispersed stomata on the adaxial cuticle. Cuticles from the other nine cordaitalean species described by LEDRAN (1966) have either stomatiferous bands or irregular stomatal rows on the abaxial cuticles.

Several cordaitalean species have been described that have stomatal rows on the abaxial and adaxial cuticles: e.g. *Cordaites principalis* type 2 ZODROW et al. (2000) from the Bolsavian of Bay St. George, Newfoundland, Canada (see also ŠIMŮNEK, 2007). Similar cuticles are also known from the Bolsavian of the Czech Republic – *Cordaites verichensis* (ŠIMŮNEK, 2007) and from the Asturian of the Heřmanova Hut' locality – *Cordaites pilensis* (ŠIMŮNEK, 2007, 2008) and from the Blažkovic locality – *Cordaites blazkovicensis* ŠIMŮNEK, 2007; however, these species have a “*Cordaites principalis*-type” venation (ŠIMŮNEK, 2007, 2008). The Stephanian species *Cordaites risutensis* ŠIMŮNEK, 2007 is similar to *Cordaites cf. affinis* having fine venation with 50–60 veins per cm, however the stomatal densities within the stomatal rows are not so high and individual stomatal complexes are separated by ordinary epidermal cells. The last comparable species is *Cordaites radvanicensis* ŠIMŮNEK, 2007 from the Stephanian of the Intrasudetic Basin, Czech Republic. The type material consists of leaves less than 30 mm wide with a venation consisting of 30 thick veins per mm and 2–3 thin sclerotic bundles between each of the two thick veins. However, the “thick” veins are not as thick as those in *Cordaites principalis*. When we count all the veins, there are 90 veins per cm. A comparison of the cuticles is interesting: it was demonstrated in *Cordaites radvanicensis* that on the adaxial cuticle there are dark stomatiferous bands 120–160 mm wide, separated by light non-stomatiferous bands 60–80 mm wide. The dark stomatal rows of the abaxial cuticles are 50–70 mm wide and are separated by 50–80 mm wide non-stomatiferous bands. The data from the abaxial cuticle do not fully compare with *Cordaites cf. affinis*, but dark bands on the adaxial and abaxial cuticles are common for both species. It is possible that the specimen from Otovice, Černý potok, belongs to *Cordaites radvanicensis* ŠIMŮNEK, 2007. The guard cells of *Cordaites cf. affinis* are 28–40 mm long and the guard cells of *Cordaites radvanicensis* are 25–38 mm long (ŠIMŮNEK, 2007).

***Cordaites cf. roesslerianus* GEINITZ, 1862**

(Fig. 2f, l; Pl. 3, Figs. d–f)

1862 *Cordaites roesslerianus* n. sp.; GEINITZ: p. 149, pl. 35, fig. 5.

Material: Museum of East Bohemia, Hradec Králové, specimen No. 74575.

Description: The leaf fragment is 71.5 mm long and 15 mm wide; the margins are non-parallel, but the base and apex not preserved.

The venation differs from all previously mentioned species. The leaf relief is three-dimensional with prominent ribs and grooves that make prominent veins in oblique light; vein density 20 per cm of the leaf (Pl. 3, Fig. e). Thin veins were not observed.

Remarks: The incomplete nature of the specimen renders the correct determination problematical. *Cordaites roesslerianus* GEINITZ are also preserved in fragments up to 120 mm long and 15–20 mm wide is similar. According to GEINITZ (1862), the vein density is 20–22 veins per cm. Cuticle macerations of *Cordaites* cf. *roesslerianus* were unsuccessful, with only the dark and light bands being discernible (Pl. 3, Fig. f). Further maceration resulted in destruction of the cuticles. The dark bands that probably reflect vascular bundles are 370–500 mm wide and the light bands are only 170–300 mm wide. No sclerotic (thin) bundles were observed.

The other comparable species is *Cordaites principalis* (GERMAR) GEINITZ. Its holotype is preserved as a bunch of 32 leaves, 350–410 mm long and 15–36 mm wide. The leaf margins are slightly bent, as in the currently described specimen. The vein density of *Cordaites principalis* is 20–25 veins per cm (ŠIMŮNEK, 2015), which is also in concordance with the presently described specimen. However, the ridges in *Cordaites principalis* are more prominent and the places between the ridges are flatter. Perhaps *C. roesslerianus* is conspecific with *C. principalis*, however it is difficult to prove because the base and apex of *C. roesslerianus* is not preserved.

LIPPS (1927) described *Cordaites principalis* from the Lower Permian of the Intrasudetic Basin (Unislav Šlaski locality). It has 18–24 veins per cm and 3–4 sclerotic bundles between 2 veins.

***Cordaites* cf. *foliolatus* GRAND'EURY**

(Fig. 2g; Pl. 3, Fig. g)

1877 *Cordaites foliolatus* GRAND'EURY; GRAND'EURY: p. 219, pl. XXI, fig. 3

Material: A single specimen from the Otovice locality is stored in the National Museum, Prague.

Description: The leaf is small, narrow, 69.5 mm long and 13 mm wide. The base is 9 mm wide. The apex is blunt. The venation is not prominent, fine, about 40 veins per cm.

Remarks: This specimen to some extent resembles *Cordaites foliolatus* GRAND'EURY. Proportionally, the specimen from the Otovice is much more slender than the GRAND'EURY type specimens of *Cordaites foliolatus*, which have a narrower base (5–7 mm) and wider leaves (10–25 mm). Length/width ratio of this specimen is 5.4, whereas in GRAND'EURY's specimens it is around 4, and the apex is blunt to rounded, and the venation is prominent with 30 veins per cm and 4–6 sclerotic bundles between each pair of veins. It is also possible that the described specimen represents a juvenile leaf of some long-leaved form, therefore it is described here as *Cordaites* cf. *foliolatus* GRAND'EURY.

***Cordaites* sp. A**

(Fig. 2d, e; Pl. 3, Figs. a–c)

Material: Two fragments, stored in the National Museum, Prague. One represents the basal part and the other an apical part. They probably come from different leaves but may belong to one species.

Description: The fragment from the basal part of a leaf is 51 mm long and only 12 mm wide near the base. The leaf widens relatively progressively from the base. The second fragment represents a terminal part of a leaf. It is widest in the middle – about

28 mm and suddenly narrowed to the bluntly pointed apex. The venation is fine, but not dense, about 25 veins per cm of the leaf.

Remarks: These specimens are difficult to compare with European *Cordaites* species. The estimated length of this leaf is 120–130 mm. The small-leaved forms described by GRAND'EURY (1877) and LEDRAN (1966) are usually wider and have a blunt or rounded apex. MEYEN (1966) described some similar forms as *Ruffloria* MEYEN. Some species have a large variability, mostly also with rounded apices, but there were other forms with nearly bluntly pointed apices. However, the venation of *Ruffloria* is quite different from *Cordaites* species. The shape of the leaf is to some extent similar to *Cordaites laevis* (GRAND'EURY, 1877, pl. 25, fig. 2), which represents a drawing of a twig with leaves and fructifications. Some leaves have blunt apices but others have bluntly pointed apices. *Cordaites laevis* is maybe a nomen nudum, because GRAND'EURY (1877) wrote only that the twig is with *Cordaites laevis* leaves and *Antholithes* fructifications. There was no description of the holotype, but the drawing of GRAND'EURY (1877) was illustrated many times in subsequent publications and also on the internet.

5. DISCUSSION

It is difficult to classify Euramerican cordaitaleans only by macromorphological characteristics because of the variability of the leaves; e.g. IGNATIEV & MEYEN (1989, fig. 6) showed great variability of *Ruffloria synensis*. Similar leaves in the Euramerican Realm could be classified to several species, if we only take into account leaf shape. However, when studying cordaitaleans from one locality, we do not have such variability, e.g. in the case of *Cordaites borassifolius* (ŠIMŮNEK et al, 2009): the length of complete leaves is about 400–700 mm and width 35–90 cm, but the leaf shape remains practically the same.

Unfortunately, the localities near Otovice yielded specimens, where cuticular study was mostly not possible, so we are reliant on morphological features of cordaitalean leaves only. Still, it is not clear, if four or five *Cordaites* species are present in the Otovice localities. In this paper, five species are described, but it cannot be excluded that the specimens described here as *Cordaites* cf. *beinertianus* and *C. cf. affinis* do not belong to one species. The other species have different types of venation and *Cordaites* cf. *foliolatus* is small with a somewhat different leaf shape.

CROOKALL (1970) and BARTHEL (1976) realised the difficulty in the determination of *Cordaites* species. CROOKALL (1970) used the names of species, but BARTHEL (1976) considered all species (e.g. *Cordaites borassifolius*, *C. principalis* and *C. palmaeformis*) as “one” species, even if diversity of the cuticles was much higher, and BARTHEL (1976) and in subsequent papers (e.g. BARTHEL, 2009, 2016) preferred using “*Cordaites* sp.”. RAGOT (1966) studied many French species of Stephanian and Permian age, but *Cordaites* cuticles were poorly preserved and did not contribute to the identification of individual species. Due to their variability in leaves and venation all species in this paper are determined with some uncertainty as “cf.”, even if it is evident that more *Cordaites* species also occur in the Euramerican Permian (Asselian).

6. FLORAL ASSEMBLAGE WITH *Cordaites*

The flora of the Olivětín Member has been neglected in the palaeobotanical literature. Except for museum collections, there are unpublished works by RIEGER (1966) and BORS (1988). A taxonomic list compiled from these works and museum collections consists of: *Sigillaria brardii* BRONGNIART, *Calamites gigas*

BRONGNIART, *Palaeostachya thuringiaca* (WEISS) BARTHEL, *Cyathocarpus cyatheus* (BRONGNIART) MOSBRUGGER, "*Pecopteris*" *thuringiaca* NĚMEJC, *Autunia conferta* (STERNBERG) KERP, *A. naumannii* (GUTBIER) KERP, *Arnhardtia scheibei* (GOTHAN) HAUBOLD et KERP, *Sphenopteris germanica* WEISS, *Odontopteris lingulata* (GÖPPERT) SCHIMPER, *O. subcrenulata* ROST, *Neurodopteris auriculata* (BRONGNIART) POTONIÉ, *Barthelopteris germarii* (GIEBEL) ZODROW & CLEAL, *Taeniopteris coriacea* GÖPPERT, *T. cf. multinervia* WEISS, *Ernestiodendron filiciforme* (SCHLOTHEIM ex STERNBERG) FLORIN, *Culmitzschia angustifolia* (FLORIN) CLEMENT-WESTERHOF, *C. parvifolia* (FLORIN) CLEMENT-WESTERHOF, *C. intermedia* (FLORIN) CLEMENT-WESTERHOF, *C. speciosa* (FLORIN) CLEMENT-WESTERHOF, *Hermitia goeppertiana* (FLORIN) CLEMENT-WESTERHOF, *H. hirmeri* (FLORIN) CLEMENT-WESTERHOF, *Otovicia hypnoides* (BRONGNIART) KERP et al., *Walchia piniformis* SCHLOTHEIM ex STERNBERG and *Gomphostrobus bifidus* GEINITZ.

This assemblage, which has been collected for more than 100 years, consists mainly of mesophilous to xerophilous elements. The hygrophilous species are practically limited to *Sigillaria brardii* and pecopteroids, which occur only very rarely. Walchian conifers dominate in the "walchia shales" and *Autunia conferta* is the most common species in the limestone facies. The other species occur partly in limestone and partly in the "walchia shales".

7. CONCLUSION

Cordaitaleans are not very common in the Permian of the Intrasudetic Basin. Seven specimens studied from the museum collections represent four or five species.

The first specimen has been classified as *Cordaites cf. beinertianus*. The type material of *Cordaites beinertianus* has a similar leaf shape, but the veins are sparser than in *C. cf. beinertianus*. The leaves of *C. cf. beinertianus* also resemble *Cordaites palmaeformis*, which has slightly narrower leaves but a comparable vein density.

A further two specimens were classified as *Cordaites cf. affinis*. They have a comparable shape and venation with the type material of *Cordaites affinis* GRAND'EURY. However, the apex is not preserved, so a comparison of this feature is not possible. One specimen, from which the cuticles have been studied, is wider than typical *C. affinis* and could also be compared with *C. beinertianus*. The cuticles of *Cordaites cf. affinis* are poorly preserved, but stomatal rows and non-stomatiferous bands are distinguishable on both cuticles. The same cuticular type also occurs in *Cordaites palmaeformis*, and also *C. radvanicensis*, which is known from the Stephanian of the Intrasudetic Basin, but unfortunately only as fragments. The second specimen of *Cordaites cf. affinis* is narrow and compares well with the variability of *Cordaites affinis*. On the other hand, *Cordaites palmaeformis* can also have narrow leaves and all specimens mentioned here could represent the variability of one species similar to *Cordaites palmaeformis* or *C. beinertianus*.

The next specimen has been classified as *Cordaites cf. roesslerianus*. The determination is difficult because the base and apex are not preserved, however, the venation is very typical with wide and sparse veins. Such a venation is known from *Cordaites roesslerianus* and *C. principalis*.

Another specimen has been classified as *Cordaites cf. foliolatus*. It resembles the type specimens of that species, however, it has somewhat narrower leaves. It is the smallest cordaitalean leaf from the Otovice locality and could simply represent a juvenile leaf of one of the other species.

The final species is represented by two fragments: a basal and an apical part. It is a relatively short and wide leaf that is difficult to compare with any figured specimens, therefore it is named here as *Cordaites* sp. A. It resembles some leaves drawn by GRAND'EURY (1877) as *Cordaites laevis*, but there is neither description nor diagnosis for this species, so it must be considered as a *nomen nudum*. The venation of *Cordaites* sp. A differs from the venation of the previously mentioned specimens and therefore must belong to a different species.

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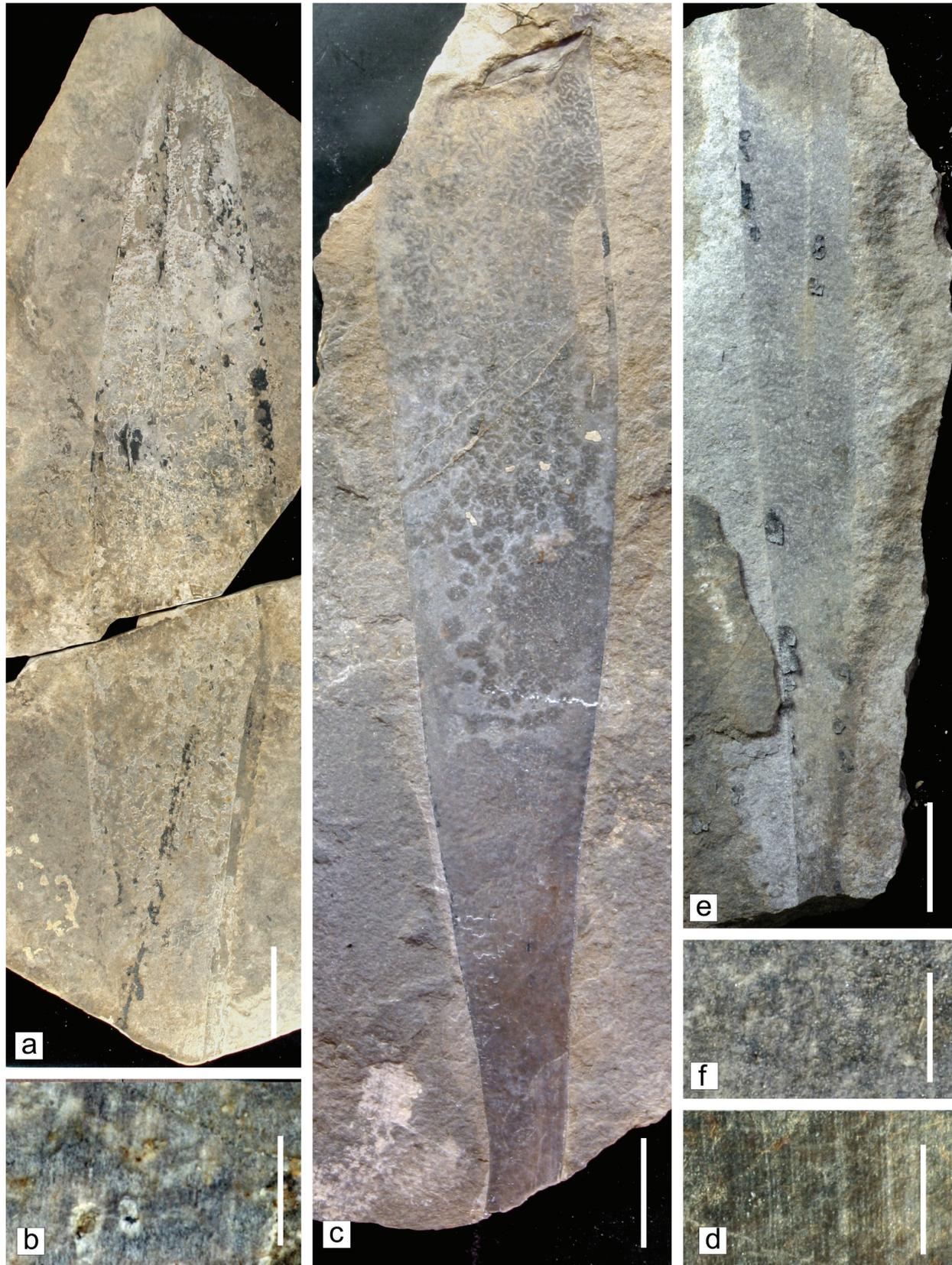


Plate 1

a – *Cordaites cf. beinertianus* (GÖPPERT) GRAND'EURY, coll. National Museum, Prague, no. E 7601, scale bar = 5 cm.

b – Venation of the leaf from Fig. a., scale bar = 2 mm

c – A leaf of *Cordaites cf. affinis* GRAND'EURY, coll. Museum of Eastern Bohemia, HRADEC KRÁLOVÉ, no. 74574, scale bar = 2 cm

d – Venation of the leaf from Fig. c., scale bar = 2 mm

e – A leaf of *Cordaites cf. affinis* GRAND'EURY, coll. National Museum, Prague, no. E 7601, scale bar = 2 cm

f – Venation of the leaf from Fig. e., scale bar = 2 mm

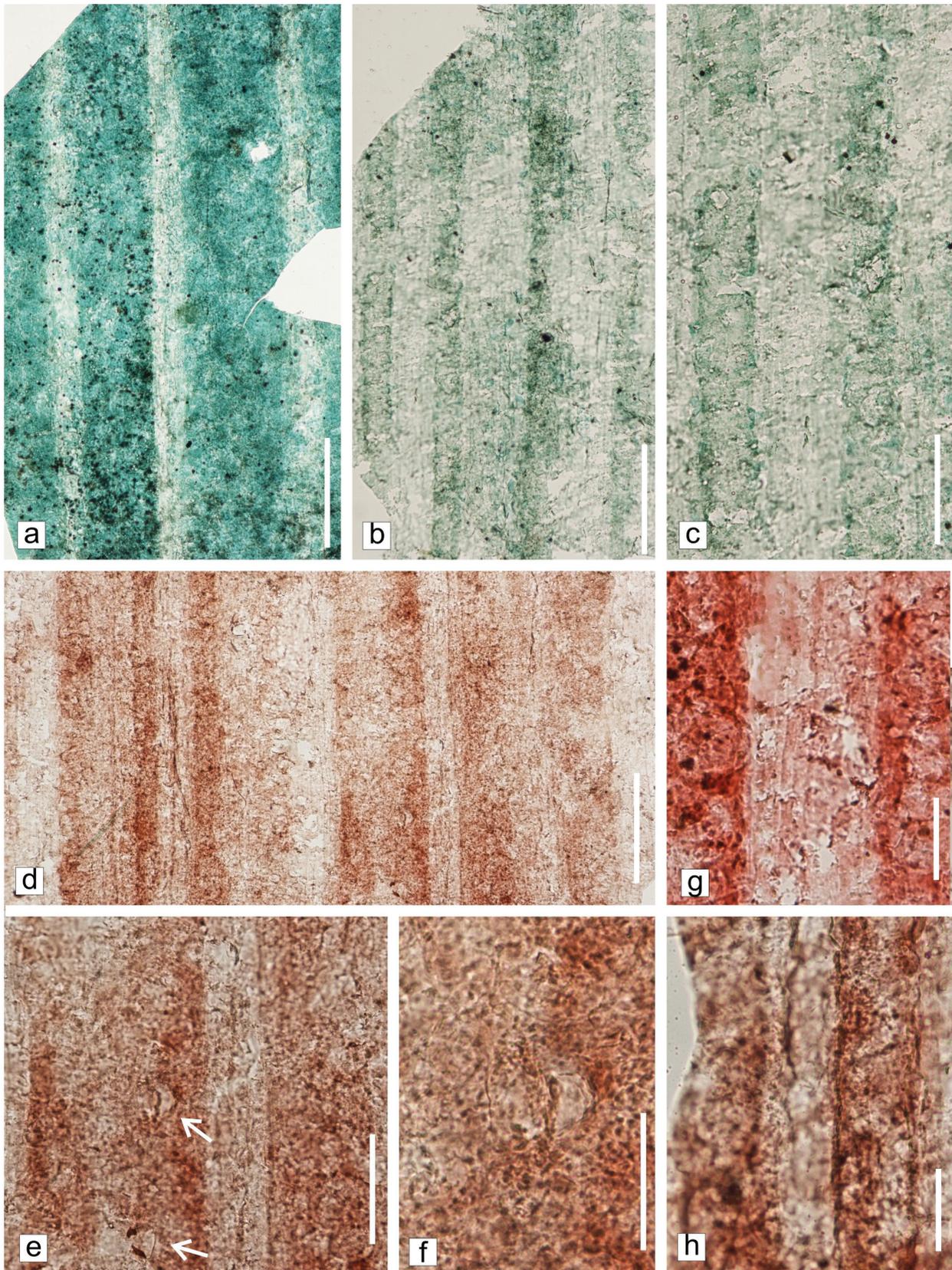


Plate 2

Cuticles of *Cordaites cf. affinis* GRAND'EURY from the leaf figured on Pl. 1, Fig. c.

a – b Adaxial and abaxial cuticle from the same leaf fragment. Slide 698/13, scale bar = 200 μ m.

c – h Abaxial cuticles. c. Detail from Fig. b. with two stomatal rows and non-stomatiferous bands. Scale bar = 100 μ m. d. Abaxial cuticle with many stomatal rows. Slide 698/15, scale bar = 200 μ m. e. Close up of Fig. d. with guard cells (arrow). Scale bar = 100 μ m. f. Close up of two guard cells from Fig. e. Scale bar = 50 μ m.

g – h Two stomatal rows and a non-stomatiferous band, Slides. g. 698/7; h. 698/14, scale bar = 50 μ m.

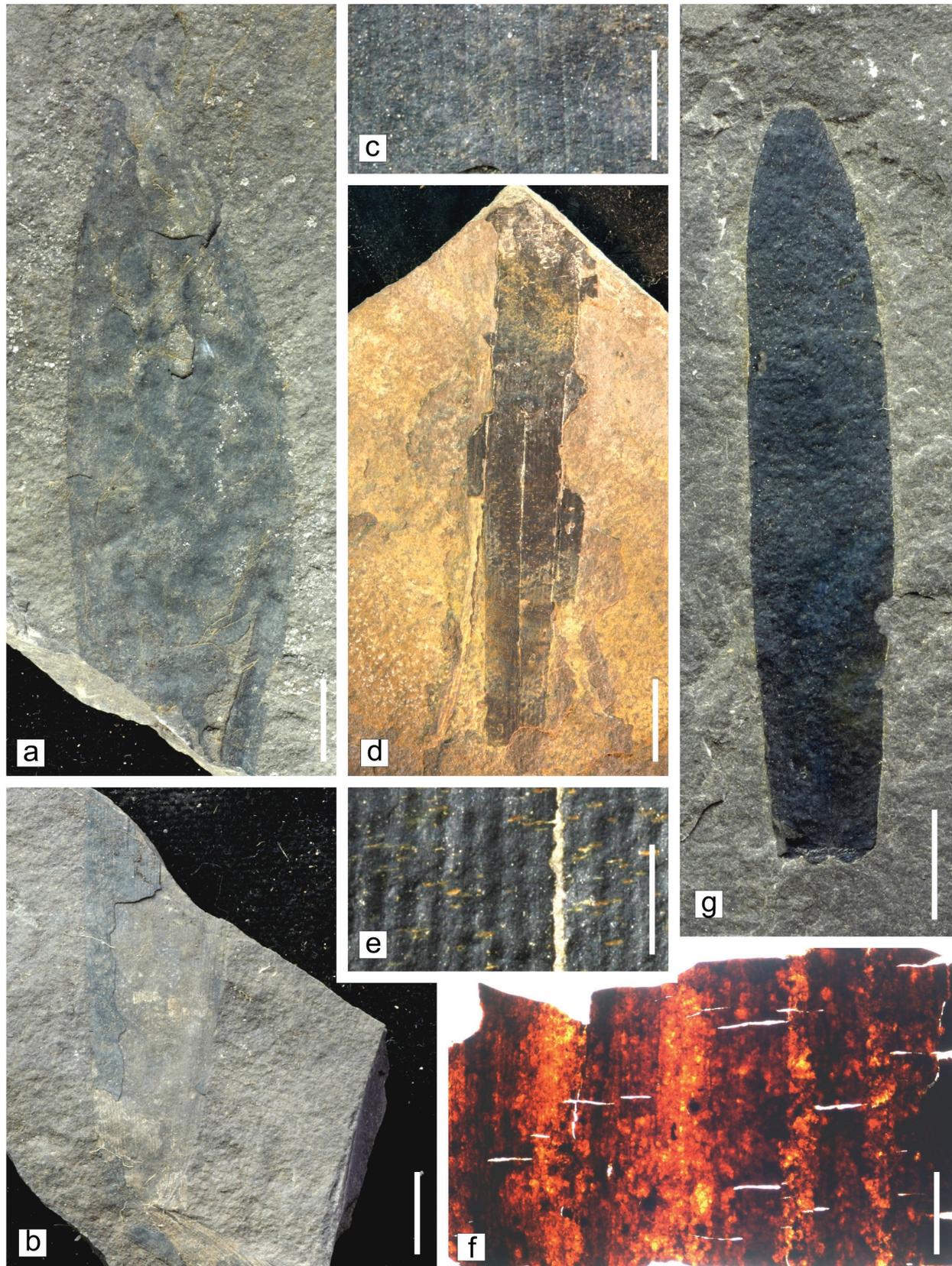


Plate 3

a – c *Cordaites* sp. A; **a**. Terminal part of the leaf, **b**. Basal part of the leaf, coll. National Museum, Prague, no. E 7602 and E 7603, (**a** and **b** – scale bar = 1 cm), **c**. Close up of the venation, scale bar = 2 mm.

d – f *Cordaites* cf. *roesslerianus* GEINITZ. **d**. Fragment of the leaf, coll. Museum of Eastern Bohemia, HRADEC KRÁLOVÉ, no. 74575, scale bar = 1 cm, **e**. Close up of the venation, scale bar = 2 mm, **f**. Macerated leaf fragment with veins (vascular bundles) and tissue between them. Slide 700/3, scale bar = 500 μ m.

g *Cordaites* cf. *foliolatus* GRAND'EURY, coll. National Museum, Prague, no. E 7599, scale bar = 1 cm.