

Fossil flora of Middle Jurassic Grojec clays (southern Poland). Raciborski's original material reinvestigated and supplemented. I. Sphenophytes

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ABSTRACT. Sphenopsid remains from Grojec clays (Grojec, Poreba, Mirów) collected and described by Raciborski in 1894 are re-examined for the first time and supplemented by Raciborski's unpublished material housed at the Jagiellonian University (Institute of Botany) and by Stur's preliminarily described material stored at the Geological Survey of Austria. Three species of *Equisetum* created by Raciborski (*Equisetum renaulti*, *E. remotum*, *E. blandum*) are now attributed to the common Jurassic species *Equisetites lateralis*, and the earlier-undescribed *Equisetites* cf. *columnaris* is recognised. The occurrence of *Neocalamites lehmannianus* (originally described by Raciborski as *Schizoneura hoerensis*) has been confirmed from Grojec. The material that Raciborski referred to this species seems to be heterogeneous, and some specimens are now removed to the new proposed species *Neocalamites grojecensis* Jarzynka et Pacyna sp. nov. The new species is diagnosed by the following features: only a few prominent ribs present on shoot, leaf scars relatively large and ellipsoidal, numerous free leaves, vascular bundles alternate at node. Possibly the new species derives from *Neocalamites lehmannianus* or at least is closely related to it. Part of the poorly preserved remains can be determined only as *Neocalamites* sp. Another species created by Raciborski, *Phyllothea* (?) *leptoderma*, is based on poorly preserved type specimens. Some of the unpublished specimens stored at the Jagiellonian University (Institute of Botany) correspond to Raciborski's description, but considering the poor preservation of the original material and the not very realistic published illustrations of this species, they rather should be regarded as indeterminate cortical fragments of *Neocalamites lehmannianus* and/or badly preserved external cortical surfaces of the new species *Neocalamites grojecensis*. *Phyllothea* (?) *leptoderma* should be considered a *nomen dubium*.

KEYWORDS: *Equisetites*, *Neocalamites*, Sphenophyta, Grojec clays, Middle Jurassic, Poland

INTRODUCTION

The Mesozoic is an interesting era in the evolutionary history of sphenopsids (Halle 1908, Osborn et al. 2000, Bomfleur et al. 2013, Elgorriaga et al. 2015). Remnants of huge woody Carboniferous and Permian calamites persist in the form of the much smaller *Neocalamites*. On the other hand, the oldest representatives of the modern genus *Equisetum* are first encountered in the Jurassic (Halle 1908, Elgorriaga et al. 2015). Species frequently

described from Jurassic strata and referred to the extinct genus *Equisetites* are very similar to modern *Equisetum* (Harris 1961, Gould 1968). The most common Mesozoic genera of Equisetales in the Northern Hemisphere are *Equisetites* Sternberg, *Equisetum* Linnaeus, *Neocalamites* Halle, and *Schizoneura* Schimper et Mougeot (Osborn et al. 2000, Barbacka 2009). In the Triassic and Jurassic, sphenophytes were present in almost all

of Europe: the United Kingdom (e.g. Phillips 1829, Lindley & Hutton 1836, Seward 1900, Stopes 1907, Harris 1961, Morton 1965, Harris & Rest 1966, Van Konijnenburg-van Cittert & Morgans 1999, Van Konijnenburg-van Cittert 2008), Italy (e.g. Krasser 1912, 1913, 1920, Wesley 1966, Scanu et al. 2012, 2015), France (e.g. Lemoigne 1968, Philippe et al. 1998), Romania (e.g. Semaka & Georgescu 1967, Popa 2009), Norway (Bruun Christensen 1995), Poland (e.g. Raciborski 1894, Barbacka et al. 2010, Jarzynka 2012, Pacyna 2013, 2014, Barbacka et al. 2014a), Hungary (Barbacka 2009, 2011), Germany (e.g. Schenk 1867, Weber 1968), Switzerland (Van Konijnenburg-van Cittert & Meyer 1996), Sweden (e.g. Halle 1908, Johansson 1922, Lundblad 1950, Pott & McLoughlin 2011), Greenland (Harris 1926, 1931, 1937), and Serbia (Djordjević-Milutinović 2010; see also Barbacka et al. 2014b).

The sphenophytes we studied originate from the Middle Jurassic of the Grojec area (southern Poland). The most significant sites where kaolinite clays occur are Grojec, Poręba, and Mirów (Fig. 1). This flora has been investigated since the 19th century. The first preliminary description was given by Stur (1888), who discussed 10 taxa. The majority of the specimens from the Grojec clays are original fossils described by Raciborski (1894) in a monograph covering 72 taxa, which was planned as the first volume of a series. The monograph “The fossil flora of fire-proof Kraków clays. Part I Cryptogamae – Archaegoniatae” was written in Polish, while the diagnoses of new species were written in Latin. Unfortunately, further volumes never appeared. Since the taxonomy followed the 19th-century system, seed ferns and cycads were included in ferns. Also, probably due to its preservation state, a twig of *Brachyphyllum* was given as a lycophyte. Nevertheless, ferns predominate and are the group most differentiated in this assemblage (Raciborski 1894, Reymanówna 1963).

After Raciborski (1894), investigations of the Grojec flora focused on morphological and taxonomical aspects of the ferns (Harris 1977, Van Konijnenburg-van Cittert 1996), and some new taxa from other clay layers and sites were described by Reymanówna (1962, 1963, 1968, 1970, 1973, 1977, 1985), Wcisło-Luraniec (1985, 1989), and Nosova & Wcisło-Luraniec (2007). Pollen grains and megaspores were also studied (Oszast 1957, Ichas 1986, Marcinkiewicz

1980). A recent revision of macroremains from Grojec was carried out as part of PhD thesis work (Jarzynka 2012), which will be published successively as a series of papers.

Raciborski (1894) created four new equisetalean species, three of which belong to the genus *Equisetum* (*Equisetum renaulti*, *E. remotum*, and *E. blandum*) and one referred to *Phyllothea* (?) *leptoderma*. Besides those, he reported *Schizoneura hoerensis* from Grojec. The new species proposed by Raciborski were discussed later but no one examined those specimens again (Halle 1908, Harris 1931, 1961).

The aim of the present work was to re-examine Raciborski's published material. The data are supplemented by other unpublished specimens from the same locality. Plant fossils from the Grojec area are stored in three collections: 1160 specimens in the Geological Museum of the Institute of Geological Sciences (Polish Academy of Sciences, Research Centre in Kraków), collected by Marian Raciborski in 1888 from 11 sites (Raciborski 1894); 484 specimens in the Geologische Bundesanstalt (Geological Survey of Austria) in Vienna, Austria, gathered by Franciszek Bartonec and passed to Dionys Stur, who published a preliminary report in 1888 (Stur 1888); and 130 specimens in the Department of Palaeobotany and Palaeoherbarium (Institute of Botany, Jagiellonian University), probably collected by Raciborski himself but not described in his monograph (Raciborski 1894).

MATERIAL AND METHODS

The studied material consists of 103 fragments of sphenopsid shoots, diaphragms, and leaves, preserved in fine-grained light or dark grey kaolinite clay, rarely in fine-grained sandstone with a significant admixture of clay, preserved as impressions, casts and moulds; organic matter is not preserved. The fossils originate from localities where Grojec clays were mined in the 19th century (Grojec, Poręba, Mirów; Fig. 1). The collected specimens belonging to Sphenophyta include 30 fragments of *Equisetites lateralis*, 8 fragments of *Equisetites* cf. *columnaris*, 23 fragments of *Neocalamites lehmannianus*, 19 fragments of *N. grojecensis*, 17 fragments of *Neocalamites* sp., and 6 fragments of *Phyllothea* (?) *leptoderma*.

Forty-nine samples are stored in the Geological Museum of the Institute of Geological Sciences, Polish Academy of Sciences, Research Centre in Kraków, coll. acronym ZNG PAN A-III-12. Twelve samples are stored in the Geologische Bundesanstalt (Geological Survey of Austria) in Vienna, Austria, coll. acronym

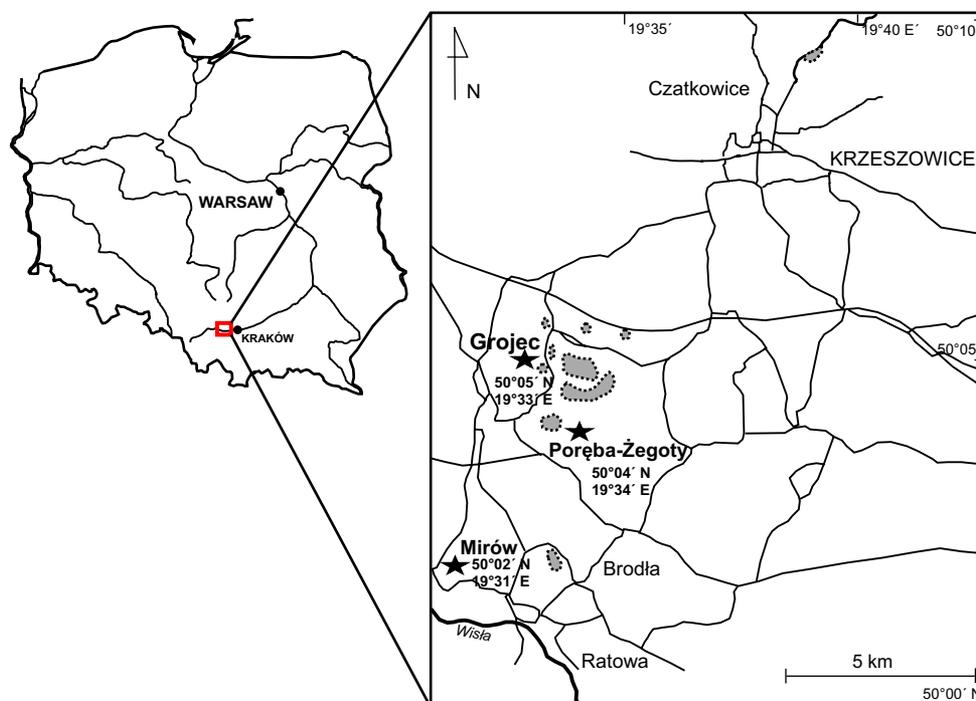


Fig. 1. Location of the investigated area and more significant sites with occurrence of fireproof clays (after Kozłowski 1957 and Nosova & Wcisło-Luranc 2007, modified)

GBA 2011/051. Forty-two samples are stored in the Department of Palaeobotany and Palaeoherbarium, Institute of Botany, Jagiellonian University, coll. acronym KRA-PALEO 105.

Specimen numbers and collection acronyms were assigned to these collections many years after Raciborski's monograph. This caused us problems in identifying which specimens had been described and illustrated in the monograph, because Raciborski did not use another system of numbering for his hand specimens. For specimens determined to have been illustrated by Raciborski, we give the original figure and plate numbers in parentheses after the coll. acronym and specimen number. For example, "ZNG PAN A-12/458 (Pl. XXVII, fig. 9)" indicates that this specimen was illustrated in Raciborski's monograph.

The specimens were examined with a Nikon SMZ 645 stereoscopic microscope and a Nikon SMZ800 microscope along with different digital cameras and NIS software.

PALAEOGEOGRAPHICAL AND GEOLOGICAL SETTING

During the Aalenian, Bajocian and almost the entire Bathonian, the Kraków area was an elevated landmass, unlike most of the territory of Poland which was covered by an epicontinental sea, an eastern extension of the Mid-European Epicontinental Basins (Dadlez 1989). The investigated area was part of Małopolska Land and bordered by the Polish Trough to the north-west, Fennosarmatia (Belarussian

High and Ukrainian Shield) to the east, the Bohemian Massif and Sudety–Silesia Land to the west, and the pre-Carpathian Landmass to the south (Fig. 2) (Dadlez 1989, Ziegler 1990). The Polish Basin or Polish Trough was formed by a transgression that started during the Early Aalenian. At this time the Kraków area was a narrow, elongated peninsula, oriented north-west to south-east and surrounded by shallow bays of the epicontinental sea (Jurkiewiczowa 1974).

During the Middle Bathonian, the Silesia-Kraków Monocline marked a clear division of two separated parts: the north area and the Kraków area. The two areas differ in their sedimentological, tectonic, and floristic characteristics, and in their fauna (Dayczak-Calikowska & Kopik 1973). In the southern part of the Kraków region, numerous lakes with calm sedimentation conditions developed. During the Upper Bathonian the Kraków area was largely flooded (Dayczak-Calikowska et al. 1997). Later the marine transgression gradually expanded, enlarging the marine basin. Thus, in the Callovian almost the entire region was under the sea. The transgression reached its maximum in the Oxfordian (Różycki 1953, Jurkiewiczowa 1974).

The most important basin where kaolinite clays accumulated was in the Grojec and Brodła area (Kozłowski 1957). Locally, clay

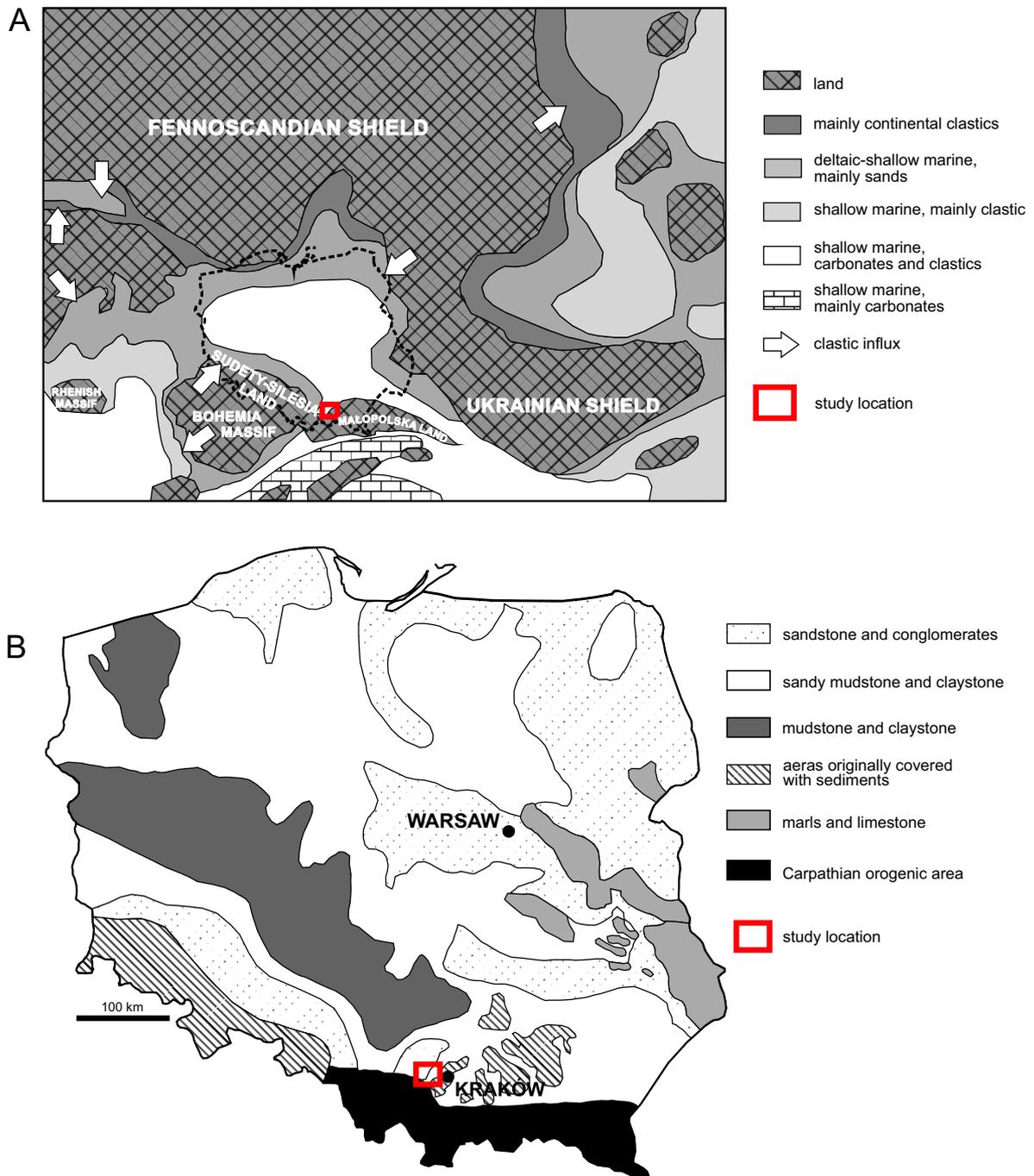


Fig. 2. (A) Palaeogeographic map of Central Europe during the Bajocian-Bathonian (after Ziegler 1988) and (B) palaeogeographic map of Poland during the Middle and Late Bathonian (after Dayczak-Calikowska 1997)

minerals, mainly kaolinite and illite, formed the layers of the Grojec clays. The clays are divided into three types depending on the mineral composition: pure clay (white, unstructured), grey clay with fossil plant remains, and clay contaminated with pyrite, carbonates and clastic deposits without plant detritus (Różycki 1953, Kozłowski 1957, Jurkiewiczowa 1974, Biała 1985).

The Grojec clays overlie deposits of different age: Triassic Gogolin and Góraźdże beds in Grojec, dolomite in Poręba-Żegoty, melaphyres in

Mirów, Lower Carboniferous shale in Głuchówki (Dżułyński 1957), limestone in Szklary (Różycki 1953), Carboniferous limestone in Podłęże and Czatkowice (Zaręczny 1894), and Kwaczała arkose in Kamień (Dżułyński 1957).

The bottom of the Grojec clays sequence is formed by white non-laminated clays without plant remains (Fig. 3). Above lie sandy deposits with beds of grey and dark grey kaolinite clays which contain numerous fossil plant fragments (Jurkiewiczowa 1974). This is the main layer from which raw material

Chronostratigraphy		Ammonite zones	Lithology
UPPER JURASSIC	OXFORDIAN		Yellow marls with fauna and phosphorites
MIDDLE JURASSIC	UPPER CALLOVIAN	<i>Kosmoceras duncani</i> <i>Kosmoceras pollux</i> <i>Kosmoceras jason</i>	Grey and yellowish limestone with numerous ammonites and sparse oolites /1 m/
	LOWER CALLOVIAN	<i>Keplerites calloviensis</i> <i>Macrocephalites typicus</i> ?!	
	? UPPER BATHONIAN		White fine-grained sands often calcareous /10 m/
	? LOWER BATHONIAN		Sandy deposits with grey clay intercalations with detritus and bigger plant remains
	? BAJOCIAN		White clay without plant remains

Fig. 3. The lithological section of the Middle and Upper Jurassic sediments of Grojec (after Różycki 1953, modified)

was exploited as refractory and ceramic clays. This part is up to 10 m thick, averaging ca 3 m in thickness, except for the bed in Poręba-Żegoty where the clays are up to 6 m thick. The upper layers, 10 m thick, consist of white fine-grained sandstone with calcareous intercalations. All of these deposits are assigned to the Bathonian. Różycki (1953) included them in the estuarine-land series. The Lower Callovian is represented by ferruginous sandstone and the Upper Callovian by grey and yellowish grey limestone with abundant ammonites and sparse oolites. The Upper Jurassic sedimentation has multicoloured marls (yellow, grey, white, reddish, or greenish) which reflect the transgression. Deposits from the coastal zone of the basin pass upwards into open-basin marls. A series of Oxfordian limestone is situated above this complex (Różycki 1953).

The age of the Grojec clays has been controversial over the years. This complex has been assigned to the Carboniferous (Zejszner 1847, 1866), Upper Triassic (Roemer 1866, 1867, Zejszner 1869, 1870), Lower Jurassic (Różycki 1953, Znosko 1955, 1959), and Middle Jurassic (Roemer 1870, Stur 1888, Samsonowicz 1929, Harris 1961, 1977, Mossoczy 1961, Reymanówna 1963, Jurkiewiczowa 1967, Rogalska 1976, Gradziński 1993, 2009). Jurkiewiczowa (1974) included the Grojec clays in the Vesulian-Bathonian, or rather the Lower Bathonian. Investigations of the development and range of the transgression in the uppermost Bathonian led by Jurkiewiczowa (1967) prompted Dayczak-Calikowska and Kopik (1973) and Dayczak-Calikowska (1976) to suggest Lower or Middle Bathonian age.

Based on the occurrence of megaspores (Marcinkiewicz 1957, 1980) and sporomorphs (Ichas 1986), Płonczyński and Łopusiński (1993) dated these sediments to the Bathonian, and Jach (2000) reached a similar conclusion.

SYSTEMATIC DESCRIPTION

Taxonomy is given according to Taylor et al. 2009.

Division: EQUISETOPHYTA Scott 1900

Order: EQUISETALES de Candolle 1804
ex von Berchtold et Presl 1820

Family: EQUISETACEAE Good 1975

Genus: *Equisetites* Sternberg 1833

Type species: *Equisetites muensteri*
Sternberg 1833

Equisetites lateralis (Phillips 1829) Gould
1968 (= *Equisetum laterale* Phillips 1829)

Pl. 1, figs 1–11.

- 1829 *Equisetum laterale* Phillips, p. 153, pl. 10, fig. 13.
1836 *Equisetum laterale* Phillips: Lindley & Hutton, p. 95, pl. 186.
1851 *Asterophyllies* ? *lateralis* (Phillips) Bunbury, p. 189.
1856 *Calamites lateralis* (Phillips) Zigno, p. 46, pl. 3, fig. 3.
1875 *Equisetites lateralis* (Phillips) Phillips, p. 196, pl. 10, fig. 13.
1894 *Equisetum renaulti* Raciborski, p. 89 (231), pl. 27, figs 1–14.

- 1894 *Equisetum remotum* Raciborski, p. 91 (233), pl. 27, figs 15–16.
- 1894 *Equisetum blandum* Raciborski, p. 91 (233), pl. 26, figs 3–4, pl. 27, figs 17–27.
- 1898 *Equisetites lateralis* (Phillips) Seward, p. 275, pl. 275, text-figs 58F, 63–64.
- 1900 *Equisetites columnaris* (Brongniart) Seward, pl. 19, figs 4–5, text-figs 3–4.
- 1905 *Equisetum Phillipsi* (Dunker) Brongniart: Ward, p. 298, pl. 72, figs 1–11.
- 1907 *Equisetites columnaris* (Brongniart) Seward: Stopes, p. 378, pl. 27, fig. 1.
- 1907 *Equisetites broraensis* Stopes, p. 379, pl. 27, fig. 2.
- 1913 *Equisetites approximatus* Nathorst: Halle, p. 6, pl. 1, figs 6–14, text-fig. 1.
- 1945 *Equisetites lateralis* (Phillips): Harris, p. 222, text-figs 3, 5–6.
- 1956 *Equisetites lateralis* (Phillips) Seward: Semaka, p. 107, text-figs 1, 10.
- 1961 *Equisetum laterale* (Phillips) Harris, p. 20, text-figs 5A–D, G.
- 1965 *Equisetites patagonica* Herbst, p. 29, pl. 1, figs 1, 3, pl. 2, figs 9–10.
- 1967 *Equisetites lateralis* (Phillips) Harris: Semaka & Georgescu, p. 734, fig. 6.
- 1968 *Equisetum laterale* (Phillips) Gould, p. 157, figs 2–3, pl. 1, figs 1–22; pl. 2, figs 1–18.
- 1989 *Equisetum laterale* (Phillips) Gould: Gee, p. 157, pl. 1, figs 3–6.
- 2004 *Equisetum laterale* (Phillips) Gould: Rees & Cleal, p. 8, pl. 2, figs 1–4.
- 2005 *Equisetum laterale* (Phillips) Gould: Cantrill & Hunter, p. 539, figs 2A–E.
- 2008 *Equisetum laterale* (Phillips) Gould: Ociepa in Birkenmajer & Ociepa, p. 21, figs 8–9, 10B.

Material. Thirty fragments of shoots, diaphragms, leaves and strobili: ZNG PAN A-III-12/58, 209, 432, 449 (Pl. XXVII, fig. 6), 450 (strobilus), 451, 452 (Pl. XXVII, fig. 1), 453 (Pl. XXVII, fig. 2), 454 (Pl. XXVII, fig. 3), 455–457, 458 (Pl. XXVII, fig. 9), 459 (diaphragm), 460–463 (Pl. XXVII, figs 15, 16), 464 (diaphragm, Pl. XXVII, fig. 26), 465, 466 (strobilus, Pl. XXVII, fig. 27), 467 (diaphragm), 468 (diaphragm), 469–471 (diaphragm, Pl. XXVII, fig. 23), from Grojec, Poreba and Mirów.

Description. Shoots have recognisable nodes and internodes and are unbranched (Pl. 1, figs 1–3), smooth or longitudinally ribbed (Pl. 1, fig. 2). Preserved fragments of shoots 17.0–65.0 mm long and 3.0–29.0 mm wide. Internodes up to 14.0–16.0 mm in length and 21.0 to 27.0 mm in width; nodes slightly wider, up to 2.0 mm long.

Ribs flat, density 3–4 ribs per 5 mm, running straight through node. Leaf sheathes

(Pl. 1, figs 4, 5) consisting of 8–14 leaves on compressed half of shoots; commissural furrows usually poorly marked, 3.0–10.0 mm long.

Leaves lanceolate with acute apices, 5.3–7.0 mm long. Free parts (above commissural furrow) 2.0–3.5 mm long.

Transversal sections of shoots visible. Diaphragms circular or elliptical in outline, 2.5–9.0 mm in diameter, preserved as cartwheel structures (Pl. 1, figs 6–8) consisting of small central hub 1.0–2.0 mm in diameter and 18–23 surrounding spokes.

Strobili (Pl. 1, figs 9–11) elliptical in outline, with rounded apices, 11.0–18.0 mm long and ca 10.0 mm wide. Sporangiohores (Pl. 1, figs 9, 10) consisting of hexagonal distal shields 1.5–2.0 × 0.7 mm (in widest part). Umbo recognisable in central part of shields (Pl. 1, fig. 10).

Discussion. The differences in fossil equisetalean plants mainly concern shoot width, leaf sheath form, and diaphragm type. The specimens from Grojec are assigned to *Equisetites* based on numerous vegetative and reproductive features: shoots having nodes and internodes, leaves forming a sheath, diaphragm type, and features of strobili.

Raciborski (1894) described three new species of *Equisetum* from the Grojec clays: *Equisetum blandum*, *E. renaulti* with slightly smaller shoots than *E. blandum*, and *E. remotum* described on the basis of only one strobilus. Close to the strobilus of *E. remotum* was an impression of an *E. renaulti* shoot.

Raciborski (1894) believed that *Equisetum blandum* and *E. remotum* could be conspecific, but the poor quality of the material prevented him from determining their variability. Raciborski considered strobilus length (*E. remotum* 18.0 mm and *E. renaulti* 13.0 mm) to be the main difference between these two species. In fact such a difference is not diagnostic; other morphological characters of the strobili of the two taxa correspond (Osborn et al. 2000).

Raciborski proposed three new species for his specimens but their shoot and diaphragm morphology, especially shoot width, internode length, number of spokes, cartwheel structure dimensions, and leaf shape correspond to *Equisetites lateralis* (Phillips) Gould (= *Equisetum laterale* Phillips), described from the Middle Jurassic of Yorkshire by Harris (1961). This species is characterised by having cartwheel

structures with a small hub in the centre and spokes around it, usually smooth shoots typically 30.0 mm wide, and usually 25 to 35 leaves arranged in leaf whorls.

Morphology similar to *Equisetites lateralis* is found in other species known from the Jurassic: *E. muensteri* Sternberg, *E. columnaris* (Brongniart) Phillips, and *E. beanii* (Bunbury) Seward.

Specimens of *E. muensteri* are similar in shoot width (ca 20.0 mm), but their diaphragm is uniform, smooth without hubs and spokes, and the number of leaves is higher (up to 50–80). The width of *E. columnaris* shoots ranges between 40.0 and 65.0 mm, wider than shoots of *E. lateralis*.

E. beani has the widest shoots (100.0–120.0 mm). The type of diaphragm of *E. beani* is similar to that of *E. columnaris*; it is smooth and uniform.

Occurrence in Mesozoic floras. *E. lateralis* is known from China, Late Triassic–Middle Jurassic (Wang 2002, Deng et al. 2006); Argentina, Triassic (Herbst 1965); Romania, Early Jurassic (Semaka 1956, Semaka & Georgescu 1967, Preda et al. 1985); Antarctica, Early Jurassic (Gee 1989, Rees & Cleal 2004, Cantrill & Hunter 2005, Birkenmajer & Ociepa 2008); the United Kingdom, Early–Middle Jurassic (e.g. Phillips 1829, Lindley & Hutton 1836, Seward 1900, Stopes 1907, Harris 1961); Kazakhstan, Middle Jurassic (Vakhrameev 1991); the United States, Late Jurassic (Tidwell 1990); and Australia, Jurassic (Gould 1968). In the Polish Mesozoic it occurred in Grojec, Middle Jurassic (= *Equisetum blandum*, *E. remotum*, *E. renaulatii*, Raciborski 1894).

Equisetites* cf. *columnaris (Brongniart
1828a) Phillips 1875

Pl. 2, figs 1–4.

- 1822 “Reed or Cane” Young & Bird, p. 184, pl. 3, fig. 3.
1828 “Reed or Cane” Young & Bird, p. 193, pl. 3, fig. 4–6.
1827 *Oncylogonatum carbonarium* Koenig in Murchison, p. 115, pl. 13.
1828a *Equisetum columnare* Brongniart, p. 115, pl. 13, figs 1–4.
1873 *Equisetum columnare* Brongniart: Saporta, p. 300, pl. 32.
1875 *Equisetites columnaris* (Brongniart) Phillips, p. 197.
1898 *Equisetites columnaris* (Brongniart) Phillips: Seward, p. 72, text-fig. 11.

- 1900 *Equisetites columnaris* (Brongniart) Phillips: Seward, p. 53, pl. 19, figs 1–3.
1913 *Equisetites columnaris* (Brongniart) Phillips: Halle, p. 3, pl. 2.
1941 *Equisetites columnaris* (Brongniart) Phillips: Harris, p. 292, text-figs 1–2.
1945 *Equisetites columnaris* (Brongniart) Phillips: Harris, p. 227, text-fig. 7.
1961 *Equisetum columnare* (Brongniart) Harris, p. 15, text-figs 4, 5E, F, I, J.
1964 *Equisetum veronense* (Zigno) Kilpper, p. 12, text-fig. 7, pl. 1, fig. 6, pl. 2, figs 1, 3.
1964 *Equisetum sarrani* Zeiller: Kilpper, p. 15, pl. 2, fig. 4.
1964 *Equisetum* sp. cf. *E. sarranii* Zeiller: Kilpper, p. 15, pl. 2, fig. 2.
1967 *Equisetum columnare* Brongniart: Lorch, pp. 132, 134, pl. 2, figs a–f.
1967 *Equisetites columnaris* Brongniart: Semaka & Georgescu, p. 732, pl. 5.
1977 *Equisetites* cf. *laevis* Halle: Corsin & Stampfli, p. 519, pl. 8, fig. 7.
1977 *Equisetites* sp.: Fakhr, p. 37, pl. 1, fig. 3.
1997 *Equisetites columnaris* (Brongniart) Phillips: Schweitzer et al., p. 135, text-fig. 15, pl. 5, figs 1–7, pl. 6, figs 1–3.
1999 *Equisetites columnaris* Brongniart: Van Konijnenburg-van Cittert & Morgans, p. 35, text-figs 13B, 14.
2009 *Equisetites columnaris* (Phillips) Brongniart: Barbacka, p. 224, pl. 1, figs 9–16.

Material. Six fragments of shoots and diaphragms: ZNG PAN A-III-12/365, 416, GBA 2011/51/0001/1, 0002, 0003, 0035, all from Grojec.

Description. Fragments of unbranched shoots smooth, 37.0–78.0 mm long and 26.0–28.0 mm wide. Whole internodes not preserved. One shoot fragment shows a well-recognisable node (Pl. 2, fig. 1) with rhomboidal leaf traces (Pl. 2, fig. 2). Traces 2.0–2.8 mm long and 0.8–1.1 mm wide. Another shoot fragment shows a leaf sheath (Pl. 2, fig. 3) with fragments of 6 leaves. Leaf sheath together with free teeth ca 10.0 mm long. Leaves not preserved entirely; without apices. Leaf width at base 2.5–3.2 mm. Leaves partly adnate along a distance of ca 2.0 mm, preserved free parts ca 2.0–3.0 mm long.

Diaphragms (Pl. 1, fig. 4) are smooth, circular, diameter 21.0–32.0 mm. They are preserved as a pitted diaphragm with a large flat central part surrounded by a peripheral ring of regularly distributed segments ca 1500 µm in diameter, which probably were vallecular canals 1.0 mm wide (diaphragm interpretation according to Elgorriaga et al. 2015).

Discussion. Raciborski (1894) collected but did not identify or describe the two specimens mentioned. Their shoot and diaphragm morphology best corresponds to *E. columnaris* (Brongniart) Phillips, but all specimens from Grojec are smaller and narrower than typical representatives of this species.

Equisetum columnare from the Middle Jurassic of Yorkshire is characterised by typical shoot width of 40.0–65.0 mm (20.0 mm near apex), a smooth diaphragm with peripheral ring, typical leaf sheath length of 20.0 mm, and free parts of leaves 2.0–5.0 mm in length (Harris 1961); the material from the Grojec clays has slightly narrower internodes (26.0–28.0 mm), shorter free parts of leaves (2.0–3.0), and rhomboidal leaf scars, but seems to fit within the range of diversity.

In the material from the Early Jurassic of Hungary, two morphotypes of *Equisetites columnaris* were recognised: large, and small; the small morphotype is more fragmented (Barbacka 2009). Some features of the Hungarian large morphotype correspond to those of material from Grojec, such as smooth internodes, shoot width up to 25.0 mm, leaf sheath length (11.0–12.0 mm), number of leaves (9–12), and type and diameter of diaphragm.

The material from Grojec shows some similarity of shoot width to *Equisetum veronense* (12.0–35.0 mm) as interpreted by Kilpper (1964). This species was described from Iran by Kilpper (1964), but Schweitzer et al. (1997) assigned these specimens to *Equisetites columnaris*.

Other material from Iran described by Schweitzer et al. (1997) and assigned to *E. columnaris* shows features corresponding to the Grojec specimens, such as an almost smooth or finely grained diaphragm and leaf width ca 1.0 mm, but the maximum shoot width of Iranian specimens is 50.0 mm and the leaves are 10.0 mm long, while the material from Grojec is 28.0 mm wide and the leaves are shorter.

Occurrence in Mesozoic floras. Iran and Afghanistan, Late Triassic – Early Jurassic (Kilpper 1964, Corsin & Stampfli 1977, Schweitzer et al. 1997); Italy, Early Jurassic (Krasser 1912, 1913, 1920, Wesley 1966); Hungary, Early Jurassic (Barbacka 2009, 2011); Romania, Early Jurassic (Semaka & Georgescu 1967); Serbia, Early Jurassic (Djordjević-Milutinović 2010); the United Kingdom, Early–Middle Jurassic (Phillips 1875, Murchison

1827, Seward 1900, Halle 1913, Harris 1941, 1945, 1961, Morton 1965, Van Konijnenburg-van Cittert & Morgans 1999); and Israel, Jurassic (Lorch 1967). Not found so far in the Polish Mesozoic.

Family: *incertae sedis*

Genus: *Neocalamites* Halle 1908
emend. Bomfleur et al. 2013

Type species: *Neocalamites lehmannianus* (Goeppert 1846) Weber 1968 (= *Neocalamites hoerensis* (Schimper 1869) Halle 1908 *sensu* Halle 1908).

Remarks. The emended diagnosis of the genus *Neocalamites* proposed by Bomfleur et al. (2013) is confirmed here.

The taxonomy of European Upper Triassic and Lower Jurassic *Neocalamites* species is confused. The commonly recognised *N. merianii* and *N. lehmannianus* are similar and lack clearly differing features (Weber 1968, Pott et al. 2008, Pott & McLoughlin 2011). The most frequently encountered specimens have few diagnostic features; they are often preserved en masse in varying states of decomposition. True taxonomic features are difficult to differentiate from taphonomic ones.

Neocalamites lehmannianus
(Goeppert 1846) Weber 1968

Pl. 2, figs 5–8.

- 1846 *Calamites lehmannianus* Goeppert, p. 143, Pl. I, figs 1–3.
1869 *Schizoneura hoerensis* Schimper, p. 283–284.
1894 *Schizoneura hoerensis* Schimper: Raciborski, p. 95–98 in part
1908 *Neocalamites hoerensis* (Schimper) Halle, p. 6–13, Taf. 1–2.
1931 *Neocalamites hoerensis* (Schimper) Halle: Harris, p. 22–25, 29, text-figs 4A, B.
1961 *Neocalamites hoerensis* (Schimper) Halle: Harris, p. 30–33, text-fig. 8.
1968 *Neocalamites lehmannianus* (Goeppert) Weber, p. 31–39, Pl. 1, figs 17–23, Pl. 2, figs 25–27, Abb. 4–5.
2010 *Neocalamites lehmannianus* (Goeppert) Weber: Barbacka et al. 2010, p. 375, pl. 1, fig. 1.
2011 *Neocalamites lehmannianus* (Goeppert) Weber: Pott & McLoughlin, p. 1027–1028, text-fig. 3C–E.

Material. Twenty-three fragments of shoots, ZNG PAN A-12/484, KRA-PALEO 105/34, 39, 54, 59, 97, 98, 101–105, 107–117, all from Grojec.

Description. Shoots consisting of nodes and internodes 17.0–35.0 mm wide and longitudinally ribbed. Ribs flat, 12–20 ribs per 10 mm shoot width (Pl. 2, figs 5–7). Delicate, dense, longitudinal striae visible on ribs. Ribs of neighbouring internodes opposite at node; only some alternate. On nodes, circular leaf scars 1.0 mm in diameter visible on every second or third rib (Pl. 2, figs 8a, b). Shoots slightly widened at nodes. Leaves not preserved.

Discussion. This species was well described and illustrated by Halle (1908) under the name *Neocalamites hoerensis* and by Weber (1968), who solved nomenclatural problems. Longstanding confusion of this species with *Calamites hoerensis* Hisinger 1840 caused by Schimper (1869) (for full discussion of this see Barbacka et al. 2014a) had not been clarified at the time of Raciborski's description of Grojec flora; thus Raciborski used the name *Schizoneura hoerensis* for material referred here to *N. lehmannianus*. The generic name *Neocalamites* was proposed by Halle in 1908 to avoid confusion with the genus *Schizoneura*, to which the species now referred to the genus *Neocalamites* were earlier incorrectly ascribed. In mature shoots, *Neocalamites* has free or only basally fused leaves, while in *Schizoneura* they are fused in groups of several leaves each.

The material described here shows dimensions and rib and leaf scar characters typical for *N. lehmannianus*. Grojec is the second locality of this species in the Middle Jurassic of Europe. This species was first described by Nathorst (1881) and Harris (1961) from Yorkshire. Roemer (1870) listed it from Grojec but without a description and illustrations.

It seems that all descriptions regarded only the decorticate inner vascular cylinder. The external cortical surface of shoots in this species is unknown. It could be smooth with wide low ribs if *Calamites hoerensis* is conspecific with *N. lehmannianus* (see discussion below).

In the present paper only part of the material originally referred by Raciborski to *Schizoneura hoerensis* is referred to *N. lehmannianus*. Some specimens show different features, and for them we propose a new species (see below).

Occurrence in Mesozoic floras. Eastern and Central Asia, Late Triassic – Middle Jurassic (Kryshtofovich 1933, Stanislavski 1971, Dobruskina 1985); Canada, Late Triassic

(Ash & Basinger 1991); Russia, Late Triassic (Volynets & Shorokhova 2007); Kyrgyzstan, Late Triassic (Shcherbakov 2008); Germany, Late Triassic – Early Jurassic (Schenk 1867, Weber 1968); Sweden, Late Triassic – Early Jurassic (Halle 1908, Johansson 1922, Lundblad 1950, Pott & McLoughlin 2011); Greenland, Late Triassic – Early Jurassic (Harris 1926, 1931, 1937); Japan, Late Triassic – Early Jurassic (Oishi 1932); China, Late Triassic – Middle Jurassic (Deng et al. 2006); Hungary, Early Jurassic (see Barbacka et al. 2014b); the United Kingdom, Middle Jurassic (Harris 1961); and Iran, Middle Jurassic (Farahimaneh et al. 2008). In Poland the species is known from Upper Silesia (type locality: Dobiercice), from where it was originally described by Goeppert (1846). It was also described (referred to *Schizoneura hoerensis*) by Raciborski (1890) from Norian-Rhaetian strata of Czerwone Żlebki in the Tatra Mts (Reymanówna 1986). Numerous specimens of it have been described and illustrated from Lower Jurassic strata of the Holy Cross Mts (Raciborski 1892, Makarewiczówna 1928, Barbacka et al. 2010, Pacyna 2013, 2014, Barbacka et al. 2014a).

Neocalamites grojecensis

Jarzynka et Pacyna sp. nov.

Pl. 3, figs 1–8, Pl. 4, figs 1–9, Pl. 5, figs 1–3.

1894 *Schizoneura hoerensis* Schimper: Raciborski, p. 95–98 in part, Pl. XXVI, fig. 9, Pl. XXVII, figs 28–31, 36–38, 40–43.

Diagnosis. Shoots consisting of nodes and internodes 4.0–70.0 mm wide. Shoots widened at nodes, slightly narrowing toward middle of internodes. External cortical surface markedly longitudinally ribbed. Ribs with longitudinal striae. Elliptical leaf scars, 2.0 mm long, 1.0 mm wide at each rib, above nodal line. Ribs alternate at nodes, rarely opposite. In vascular cylinder, bundles at least two times as numerous as ribs on external cortical surface. Vascular bundles alternate at nodes, rarely subopposite to opposite. At least 30 leaves in node. Leaves free from base, 1.5 mm wide, several cm long, finely longitudinally striated and turning towards shoot top. Shoot at node has smooth diaphragm in central part, surrounded by narrow ring of vascular bundles with carinal canals and finely pitted cortex without vallecular canals.

Type locality. Grojec.

Type horizon. Grojec clays, Bathonian, Middle Jurassic.

Derivation of name. after type locality – Grojec.

Holotype (*hic designatus*). ZNG PAN A-12/477 (Raciborski 1894: Pl. XXVI, fig. 9) – intermediate-size shoot with leaf scars preserved, Grojec; Pl. 3, figs 1, 2.

Material. Nineteen fragments of shoots, diaphragm, and leaf whorl.

Intermediate-size shoots. ZNG PAN A-12/474 (leaf whorl) (Pl. XXVII, fig. 36), 482 (Pl. XXVII, fig. 40), 483 (Pl. XXVII, fig. 28), KRA-PALEO 105/49, 70; Pl. 3, figs 1, 2, 4, 6, Pl. 5, fig. 2.

Wide shoots. ZNG PAN A-12/433, 479 (Pl. XXVII, fig. 43), 480 (diaphragm) (Pl. XXVII, fig. 42), 486 (Pl. XXVII, fig. 31), 487, KRA-PALEO 105/20, 29, 45, 55, 61; Pl. 3, figs 3, 7, 8, Pl. 4, figs 2–9, Pl. 5, figs 1, 3.

Narrow shoots. ZNG PAN A-12/481 (Pl. XXVII, fig. 30), 483 (Pl. XXVII, fig. 37), 485 (Pl. XXVII, fig. 38); Pl. 3, fig 5, Pl. 4, fig. 1. All specimens from Grojec.

Description. Shoots consisting of nodes and internodes 4.0–70.0 mm wide. Shoots widening at nodes, slightly narrowing toward middle of internodes. External cortical surface and internal cylinder of vascular bundles mostly separately preserved; only a few specimens have them in organic connection (Pl. 3, fig. 6). Prominent ribs visible on external cortical surface but not very dense (Pl. 3, figs 1, 2, 4), they are longitudinally striated (Pl. 3, fig. 4). Dense ribbing (corresponding to bundles) is typical for preserved decorticate vascular cylinders (Pl. 5, fig. 1). Vascular bundles could be visible in external ribs as longitudinal striation (Pl. 4, fig. 5).

Three categories of shoot width clearly distinguishable: narrow, intermediate (most typical), and wide. Narrow shoots (probably the youngest lateral branches) 5.0–8.0 mm wide, their internodes 12.0–47.0 mm long, 8 ribs per 4 mm to 6 ribs per 6 mm shoot width (Pl. 3, fig. 5, Pl. 4, fig. 1). Intermediate-size shoots 15.0–20.0 mm wide, 5 ribs per 10 mm. Leaf scars best preserved on this type of shoot: elliptical, 2.0 mm long, 1.0 mm wide, appearing at each rib above nodal line (Pl. 3, figs 1,

2, 4). Wide shoots (probably the main shoots) 25.0 to 70.0 mm wide, 2 ribs per 10 mm (Pl. 4, figs 2–5). Ends of ribs are rounded at nodes in these shoots. Leaf scars usually badly preserved, similar in dimensions to those in intermediate-size shoots. Ribs alternate at nodes, only a few opposite.

Bundles in vascular cylinder at least two times as numerous as ribs visible on external cortical surface in narrowest shoots, 4 bundles per cortical rib in intermediate-size shoots, 8–10 per rib in widest shoots. Vascular bundles alternate at nodes, only a few subopposite to opposite (Pl. 4, figs 6–9).

At least 30 leaves in node (incompletely preserved), free from base, 1.5 mm wide, several cm long, finely longitudinally striated, turning towards shoot top (Pl. 5, fig. 2). No leaf preserved intact, all broken, numerous isolated leaf fragments accompany narrow and intermediate-size shoots (Pl. 3, figs 1, 5, Pl. 4, fig. 1).

One shoot broken at node, its internal structure visible in cross section (Pl. 5, fig. 3). Shoot at node at least 35.0 mm wide (incompletely preserved). In central part of node, smooth nodal diaphragm visible, with narrow ring of vascular bundles next to it, each 2.0 mm long, 1.0 mm wide, with carinal canals ca 0.75 mm in diameter at bundle outer margins. Cortex finely pitted, without vallecular canals.

Probable scars of lateral shoots at nodes of two wide shoot specimens (ZNG PAN A-12/482 (Pl. 3, fig. 7) and specimen 486 (Pl. 3, fig. 8), well illustrated by Raciborski (1894, Pl. XXVII, figs 39, 40). Badly preserved, lenticular in shape, 16.0–20.0 mm long, 10.0–15.0 mm wide.

Discussion. Our examination of specimens originally referred by Raciborski (1894) to *Schizoneura hoerensis* revealed that the material is heterogenous. After separating out the specimens typical for *Neocalamites lehmannianus* we recognised a group of specimens differing from *N. lehmannianus* and from all *Neocalamites* species described so far. Since these specimens have a common set of features we propose a new species for them. It includes several specimens sharing diagnostic features among the narrow, intermediate-size and wide shoots. The fact that all of them were preserved together in clay slabs and that they show the same features suggests that this might be an accumulation of different plant parts of one sphenopsid species.

The gross morphology of these specimens corresponds with the generic diagnosis of *Neocalamites* in terms of node structure, the ribs on internodes, and free leaves.

Raciborski regarded the longitudinal ribs on shoots as a result of specimen deformation, but we suggest that this is a diagnostic character of the new species. The ribs are too regularly arranged to be only the result of shoot deformation. We recognised this feature in all shoot size categories. Also, leaf scars are connected with these ribs, so this is not an accidental feature. These ribs are gently striated. They could be real striae, as seen on *N. lehmannianus* ribs, or traces of vascular bundles. In *N. merianii*, Kräusel (1958, 1959) described and illustrated specimens in which dense, prominent, longitudinal ribbing caused by vascular bundles is overlapped by coarser ribbing of the external cortex. Probably the coaly layer remaining after cortex decomposition was very thin. Such preserved specimens have been also described from Poland (Barbacka et al. 2014a). It is worth noting that in the genus *Neocalamites*, unlike in extant sphenopsid species, the vascular bundles were not equal in number to the ribs visible on the shoot surface. The shoot surface was covered with wide ribs which were less numerous than the vascular bundles (Kelber & Hansch 1995). This feature is also confirmed by the new species described here.

The leaf scars of *N. grojecensis* are elliptical and are bigger than the circular leaf scars of *N. lehmannianus*. In *N. lehmannianus*, leaf scars are present on every second or third rib, while in *N. grojecensis* they are on each rib. Raciborski (1894) already noticed this difference in the number, size and density of leaf scars in specimens referred to *Schizoneura hoerensis*, but he could not settle whether they were of taxonomic value. *N. grojecensis* differs from *N. lehmannianus* in leaf scar number, size, and density. We think that leaf scar characters are of high diagnostic value in fossil sphenophytes, and use them as such in the description of *N. grojecensis*.

The isolated cylinder of vascular bundles of *N. grojecensis*, especially in narrower shoots, is similar to those in *N. lehmannianus*, but in wider shoots the vascular bundles are more dispersed and more protruding; most important, they alternate in the nodes and are subopposite or opposite only rarely. In *N. lehmannianus* the bundles are mainly opposite.

It is worth noting that Harris (1961) expressed doubt about the attribution of the Grojec *Neocalamites* to *N. lehmanninus* (he used the name *N. hoerensis*). He proposed to refer it to *N. nathorstii*. We examined specimens of *N. nathorstii* from Yorkshire stored in the collection of the W. Szafer Institute of Botany, Polish Academy of Sciences, and after careful comparison with that material and also with published illustrations of this species (Erdtman 1921) we conclude that Harris's suggestion was wrong. *N. nathorstii* has smaller shoots, less prominent ribbing, and not so prominent leaf scars (Erdtman 1921).

We also considered the possibility that the remains described here as *N. lehmannianus* are all decorticate shoots of *N. grojecensis*, but at least some of the specimens referred here to *N. lehmannianus* have preserved leaf scars typical for this species. They are smaller and of different shape than those of *N. grojecensis*. The available specimens do not support the suggestion that circular leaf scars typical for *N. lehmannianus*, visible on the vascular cylinder, could change their shape, crossing through the cortex and becoming visible on the cortex surface as elliptical leaf scars typical for *N. grojecensis*. Also, specimens similar to *N. grojecensis* have never been described from rich assemblages of *N. lehmannianus*, so they could not be simply a state of preservation of *N. lehmannianus*.

Based on a comparison of features (see Table 1), we suggest that this new species derives from *Neocalamites lehmannianus* or at least is closely related to it.

Neocalamites sp.

Pl. 5, fig. 4.

Material. Seventeen fragments of shoots: KRA-PALEO 105/11, 26, 38, 42, 43, 50, 75, 77, 83, 99, 100, GBA 2011/51/0004-0006/1, 00012/1, 0020, 0043/1.

Description. Fragments of shoots 107.0–161.0 mm long and 20.0–30.0 mm in width (Pl. 5, fig. 4). Internode length 76.0–122.0 mm; ornamentation hardly visible.

Discussion. The gross morphology of shoots corresponds with the general diagnostic features of *Neocalamites*. The lack of diaphragms and poor preservation of the specimens make exact identification impossible; they may

Table 1. Comparison of features of *Neocalamites grojecensis* Jarzynka et Pacyna sp. nov. and *Neocalamites lehmannianus* (Goepfert 1846) Weber 1968

Feature	<i>Neocalamites grojecensis</i> sp. nov.	<i>Neocalamites lehmannianus</i> (Weber 1968, Barbacka et al. 2010, 2014b, material described here)
Width of specimens	5–70 mm (intermediate-size shoots 15–20 mm wide)	17–35 mm
Shoot widened at nodes	Yes, distinct	Yes, not very marked
External cortical surface of shoots	With coarse ribbing	Unknown, probably smooth and/or with wide low ribs (if <i>Calamites hoerensis</i> conspecific with <i>N. lehmannianus</i>)
Number of ribs per 10 mm on external cortical surface of shoots	At least 10 (in narrow shoots), 5 (in intermediate-size shoots), 2 (in wide shoots)	Unknown
Number of ribs/vascular bundle per 10 mm on internal cortical surface of shoots	10–15	12–20
Vascular bundles arrangement at nodes	Mostly alternate, only a few subopposite to opposite	Mostly opposite, some subopposite and alternate
Longitudinal striations on ribs	Present	Present
Leaf scars	On each rib, elliptical, 2.0 mm long, 1.0 mm wide	Visible on every second or third rib, circular, 1.0 mm in diameter
Number of leaves per node	Probably ca 30	Probably ca 20
Stem cross section at node	Diaphragm smooth, ring of vascular bundles with carinal canals, wide ring of cortical tissue without vallecular canals	Diaphragm smooth, ring of vascular bundles with carinal canals

belong to *N. lehmannianus* or to *N. grojecensis* (form with coarse ribs).

The material described here as *Neocalamites* sp. comes from the Vienna and Jagiellonian University collections and was never described by Raciborski (1894).

Occurrence in Mesozoic floras. The genus *Neocalamites* is widespread in Mesozoic sediments of all continents (e.g. Flint & Gould 1975, Dobruskina 1982, Kimura et al. 1988, Bose et al. 1990, Ash 1999, Mehlqvist et al. 2009, Barbacka et al. 2014b). In Poland, *Neocalamites* sp. was noted from the Middle Triassic–Early Jurassic of the Holy Cross Mts (Raciborski 1891a, b, Pawłowska 1979, Reymanówna 1986, Wcisło-Luraniec 1987, 1991a, b, 1993, Barbacka et al. 2009, 2011, 2014a as *N. merianii*, Pacyna 2013, 2014).

***Phyllothea* (?) *leptoderma* Raciborski 1894
*nomen dubium***

Pl. 5, figs 5–11.

1894 *Phyllothea* (?) *leptoderma* Raciborski, p. 93–95, pl. 26, figs 32–35.

Material. ZNG PAN A-12/472 (Pl. XXVII, fig. 32), 473 (Pl. XXVII, fig. 34), 475 (Pl. XXVII, fig. 35), 476 (type series); KRA-PALEO 105/56 and 106, all specimens are from Grojec; the specimens from Poreba mentioned in the original description were not found in Raciborski's collection.

Original diagnosis according to Raciborski (1894, translated from Latin): Shoots elongate, rarely simply branched, articulate, to 65.0 mm thick. Nodes distinct, often swollen. Internodes cylindrical, or thickened towards apex and base, longitudinally finely striated, ca 10 striae per 1 mm width.

Leaves in whorls, linear, to 2.0 mm broad, to 8 (and more) mm long, finely striated (12–16 striae), their bases connecting. Sheath to 3.0 mm long.

Discussion. The specimens on which Raciborski (1894) based his new species are badly preserved and seem quite heterogenous. In our opinion, under this name Raciborski grouped poorly preserved equisetalean remains lacking clear diagnostic features. Some important features Raciborski emphasised in the Polish description are omitted from his Latin diagnosis of this species: among others, the opposite arrangement of the ribs at the node, and the regular square structures on some shoot surfaces. In fact, none of the specimens show characteristics of the genus *Phyllothea* Brongniart 1828 (Brongniart 1828, 1828a–1837, Rayner 1992); they could be poor remains of *Neocalamites*. The main feature of this material is the absence of clearly visible ribbing of internodes. Published sketches of this species are idealised and do not correspond to the original specimens.

Interestingly, some specimens described by Raciborski (e.g. ZNG PAN A-12/475, Pl. 5, figs

10, 11 and ZNG PAN A-12/476, Pl. 5, figs 9) and identified recently in the additional collection mentioned here (KRA-PALEO 105/56, Pl. 5, figs 7, 8 and KRA-PALEO 105/106) are similar to Hisinger's type specimens of *Calamites hoerensis* (Hisinger 1840, Pl. 38, fig. 8). That species is a source of longstanding taxonomic confusion. *Calamites hoerensis* was established by Hisinger (1840) based on two poorly preserved specimens from Scania (see Halle 1908). Their internodes possess weakly visible ribs. The ends of smaller ribs, recognisable only at the nodes, are opposite to alternate. Schimper (1869) gave an emended diagnosis of this species under the binomen *Schizoneura hoerensis* but without illustrations. Based on Schimper's diagnosis, numerous specimens not resembling Hisinger's illustrations were referred to this species by Nathorst (1878a, b) and Halle (1908). Halle (1908) created the new genus *Neocalamites*, with *Neocalamites hoerensis sensu* Schimper (1869) as its type species. What is more, Halle (1908) found and illustrated Hisinger's (1840) types but considered them indeterminable, and suggested that they might belong to the species *Equisetites scanicus* (?), but this suggestion probably is incorrect. The species *N. hoerensis*, as diagnosed by Halle (1908), was accepted and widely used by later authors (Harris 1926, 1931, 1961, Weber 1968).

The species *Calamites lehmannianus* Goepfert was established originally for two specimens from Dobiercice in Upper Silesia (Goepfert 1846). Goepfert (1846) considered that his new species was similar to *Calamites hoerensis* (Hisinger 1840), but Halle (1908) believed that the two species differed. Weber (1968) revised both species thoroughly, synonymised *Neocalamites hoerensis sensu* Halle (1908) with *Calamites lehmannianus* Goepfert, and referred it to the genus *Neocalamites*.

Since Halle's publication (1908), the type specimens of *C. hoerensis* have not been attributed to *N. hoerensis*. On the other hand, specimens very similar to Hisinger's *Calamites hoerensis* accompany the typical *N. lehmannianus* in a huge unpublished collection from the Lower Jurassic of the Holy Cross Mts assembled by Raciborski (1891a, b, 1892). An external cortical surface of *N. lehmannianus* is unknown; typical specimens of it have well visible ribbing of the vascular bundles, which means that they are decorticate. Here we suggest that Hisinger's *Calamites hoerensis* may represent the external

cortical surface of *Neocalamites hoerensis sensu* Halle, and therefore *N. lehmannianus*. However, because there are no specimens to support this proposal it remains only that.

If *Calamites hoerensis* is the external cortical surface of *Neocalamites lehmannianus*, some of the specimens described by Raciborski as *Phyllothea* (?) *leptoderma* could be connected with typical specimens of *N. lehmannianus* based on the mostly opposite arrangement of the surface ribs (Pl. 5, figs 9–11). Also note that they accompany *N. lehmannianus* on clay slabs (e.g. KRA-PALEO 105/106), so they may simply represent badly preserved cortical surfaces of *N. lehmannianus* (specimens ZNG PAN A-12/475, 476, KRA-PALEO 105/56 and 106).

The main feature on which Raciborski based his determination of *Phyllothea* was the opposite arrangement of ribs on the nodes. Such an arrangement is typical for the genus *Phyllothea*. However, this feature, clearly articulated in the Polish description, was omitted from the Latin diagnosis. Unexpectedly, our examination of original specimens illustrated by Raciborski (1894) revealed that in the best-preserved specimen with a node (ZNG PAN A-12/475) the ribs are mostly alternate; only some are opposite or subopposite (Pl. 5, figs 10, 11), thus Raciborski misinterpreted and incorrectly illustrated this feature (Pl. XXVII, fig. 35). Other type specimens have nodes insufficiently preserved for observation of the rib arrangement.

We suggest that specimens ZNG PAN A-12/472 and 473 referred by Raciborski to *Phyllothea* (?) *leptoderma*, with badly preserved ribbing similar to that of *Neocalamites grojecensis*, may be poorly preserved specimens of intermediate-size shoots of this species (Pl. 5, figs 5, 6). We observed the striae mentioned in the diagnosis only on these two shoots, but they accompany heavily deformed ribs similar to those in *N. grojecensis*.

Some specimens from the Institute of Botany (Jagiellonian University) collection (KRA-PALEO 105/56 and 106) match Raciborski's description of *Phyllothea* (?) *leptoderma*. Specimen KRA-PALEO 105/56 has an opposite arrangement of ribs at the node, but like all the others referred to this species by Raciborski, it is heavy distorted and the ribbing of the internode is difficult to interpret (Pl. 5, fig. 7). The specimen has a well-preserved rectangular cell pattern (Pl. 5, fig. 8). There is an interesting branch scar (oval, 7.0 mm diameter)

preserved at the node. Raciborski mentioned the occurrence of branch scars on his specimens of *Schizoneura hoerensis* and *Phyllothea* (?) *leptoderma*. Unfortunately, none of the preserved specimens in the collection Raciborski described has a branch scar preserved.

Some specimens (ZNG PAN A-12/475, KRA-PALEO 105/56) show small, regular, square structures on the surface (Pl. 5, figs 8, 10, 11), already noticed and illustrated by Raciborski. He interpreted them as a taphonomic feature, but they seem to be epidermal cell patterns. They are all of the same type, of similar dimensions, and very regularly arranged.

Among the specimens Raciborski referred to *P. leptoderma* is a shoot fragment with a whorl of leaves at the node (ZNG PAN A-12/474). This specimen was illustrated on Plate XXVII, fig. 36, and is still in the collection (Pl. 5, fig. 2). Part of the Latin diagnosis of *P. leptoderma* is based on this specimen; in it, Raciborski (1894) wrongly interpreted the leaves as basally fused and forming a sheath. The genus *Phyllothea* has long free leaves which spread out from a sheath formed by the fused bases of the leaves. This feature separates it from *Equisetum* and *Equisetites*, in which the leaves are short, tooth-like, and closely adpressed to the shoots. In our opinion this specimen belongs to *N. grojecensis*, since the details of its structure correspond to *N. grojecensis*. The internodes, though not very well preserved, agree with the typical average shoot dimensions of the new species, together with the observed ribbing. The leaves in the whorl are of the same size as numerous isolated ones accompanying intermediate-size shoots of *N. grojecensis*, but are smaller and more numerous than in the whorl of *N. lehmannianus*, for example in the specimen described by Barbacka et al. (2010) from Odrowąż in the Holy Cross Mts. For details about this specimen see above (*Neocalamites grojecensis* description).

To sum up: the type specimens of *Phyllothea* (?) *leptoderma* Raciborski 1894 are poorly preserved and therefore the species should be considered a *nomen dubium*. Although some specimens from the Institute of Botany (Jagiellonian University) collection conform to Raciborski's description, they can be better interpreted as cortical remains of *Neocalamites lehmannianus* rather than a new *Phyllothea* species. Judging by the bad preservation of the specimens and their unrealistic

published illustrations, we suggest that Raciborski based this species on indeterminable cortical fragments of *Neocalamites lehmannianus*; some other specimens may represent badly preserved external cortical surfaces of the new species *Neocalamites grojecensis*.

PALAEOECOLOGY OF GROJEC SPHENOPHYTES

Raciborski (1894) stated that conclusions about the palaeoecology and the geological age of the Grojec flora would be presented in the next part of his work, but unfortunately it was never published.

During the Middle Jurassic the study area was part of a vast territory with numerous rivers, ponds, and lakes, with well-vegetated marshy flood plains (Różycki 1953, Kozłowski 1957, Jurkiewiczowa 1974).

Sphenophytes represent ca 5% of the whole plant assemblage in Grojec, which is dominated by ferns. Based on species co-occurrence on the same slab and assuming that they grew more or less in the same assemblages,

Table 2. Co-occurrence of sphenopsids with other plants in flora of Grojec (+ co-occurrence, - lack of co-occurrence)

	<i>Equisetites lateralis</i>	<i>Equisetites</i> cf. <i>columnaris</i>	<i>Neocalamites lehmannianus</i>	<i>Neocalamites grojecensis</i> sp. nov.	<i>Neocalamites</i> sp.	<i>Phyllothea</i> (?) <i>leptoderma</i> *
<i>Neocalamites lehmannianus</i>	-	-		+	-	-
<i>Neocalamites grojecensis</i>	-	-	+		-	-
<i>Cladophlebis denticulata</i>	+	+	+	+	+	+
<i>Cladophlebis haiburnensis</i>	+	-	-	-	+	-
<i>Cladophlebis roesserti</i>	+	-	+	+	+	-
<i>Cladophlebis</i> sp. A	+	+	-	-	-	-
<i>Gleichenia rostafinskii</i>	+	-	-	-	-	-
<i>Klukia exilis</i>	+	+	-	+	+	-
<i>Coniopteris hymenophylloides</i>	-	-	+	+	+	-
<i>Eboracia lobifolia</i>	+	+	+	+	+	+
<i>Gonatosorus nathorstii</i>	+	-	-	-	-	-
<i>Pachypteris rhomboidalis</i>	+	-	-	-	-	-
<i>Sagenopteris</i> cf. <i>colpodes</i>	+	-	-	-	-	-

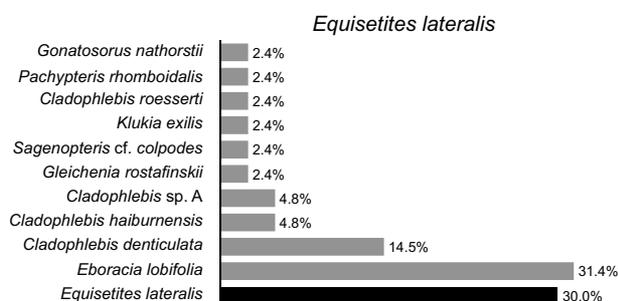


Fig. 4. Co-occurrence of *Equisetites lateralis* with other plants in the flora of Grojec clays (black bar – self-occurrence value)

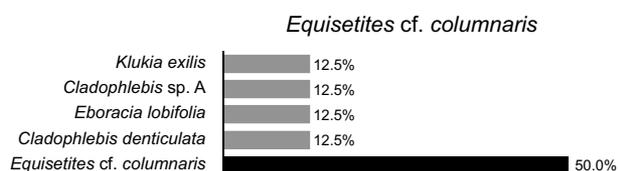


Fig. 5. Co-occurrence of *Equisetites cf. columnaris* with other plants in the flora of Grojec clays (black bar – self-occurrence value)

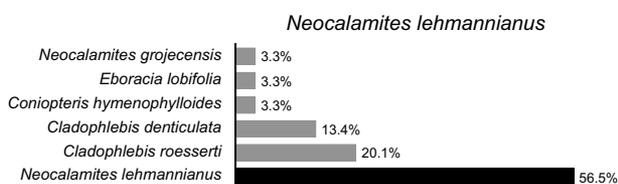


Fig. 6. Co-occurrence of *Neocalamites lehmannianus* with other plants in the flora of Grojec clays (black bar – self-occurrence value)

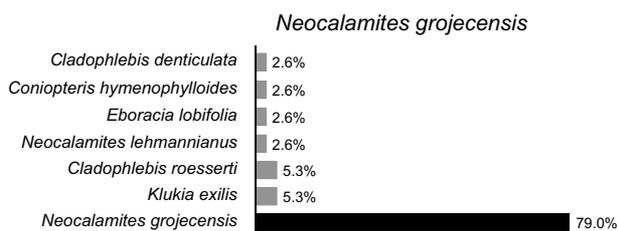


Fig. 7. Co-occurrence of *Neocalamites grojecensis* sp. nov. with other plants in the flora of Grojec clays (black bar – self-occurrence value)

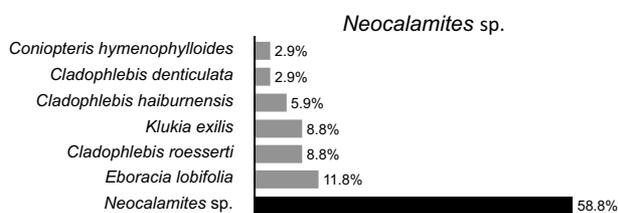


Fig. 8. Co-occurrence of *Neocalamites* sp. with other plants in the flora of Grojec clays (black bar – self-occurrence value)

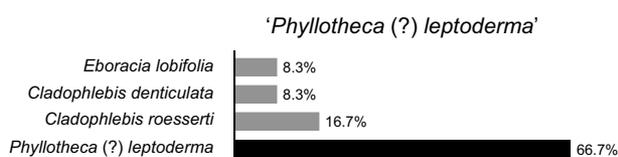


Fig. 9. Co-occurrence of “*Phyllothea (?) leptoderma*” with other plants in flora of Grojec (black bar – self-occurrence value)

the sphenophytes from Grojec (*Equisetites* spp., *Neocalamites* spp., “*Phyllothea (?) leptoderma*”) were mainly associated with ferns (Tab. 2) and can be interpreted as members of the lowermost storey of moist-forest vegetation (e.g. Vakhrameev 1991, Van Konijnenburg-van Cittert 2002, Abbink et al. 2004).

The occurrence of equisetalean plants is connected with higher-moisture habitats in the immediate vicinity of rivers and lakes (Batten 1974, Abbink et al. 2004). *Equisetites lateralis* plants could overgrow periodically flooded areas such as banks of meandering rivers and shores of lakes (Harris 1961, Preda et al. 1985, Wang 2002, Rees & Cleal 2004, Deng et al. 2006, Barbacka 2009, 2011, Popa & Meller 2009). *Equisetites cf. columnaris* occurred more frequently alone (50%) than *E. lateralis* (30%), but both usually occurred with ferns (Figs 4, 5) such as *Eboracia lobifolia*, *Klukia exilis*, *Cladophlebis denticulata*, *C. haiburnensis*, *C. roesserti*, and *Cladophlebis sp. A*. Interestingly, these two species are the only sphenophytes in Grojec occurring with seed ferns (*Pachypteris rhomboidalis*, *Sagenopteris cf. colpodes*). This may indicate that these plants could grow in the same types of habitat.

Like those *Equisetites* plants, representatives of *Neocalamites lehmannianus*, *N. grojecensis* and *Neocalamites* sp. occur with ferns (Figs 6, 7, 8), especially *Eboracia lobifolia* and *Cladophlebis roesserti*, but other ferns are also present: *Cladophlebis denticulata*, *C. haiburnensis*, *Klukia exilis*, and *Coniopteris hymenophylloides*. A narrower spectrum of taxa co-occur with “*Phyllothea (?) leptoderma*” (Fig. 9), which is accompanied by *Cladophlebis roesserti*, *C. denticulata* and *Eboracia lobifolia*. *Neocalamites lehmannianus* and *N. grojecensis* occur together on one slab; these species show a higher degree of self-occurrence, 58% and 79% respectively.

It is widely believed that sphenopsids of the genus *Neocalamites* prefer moist habitats but sometimes slightly drier than *Equisetites* (Barbacka 2009, 2011). The occurrence of *Neocalamites* spp. with ferns that usually grow in wetter habitats suggests that in the Grojec area *Equisetites* and *Neocalamites* plants grew at sites with similar moisture.

Horsetails *Equisetites* never occur with any other sphenophytes (*Neocalamites* spp., “*Phyllothea (?) leptoderma*”), indicating that they did not grow at the same sites.

CONCLUSIONS

On the basis of numerous specimens (103) from the Middle Jurassic flora of Grojec, we made a re-examination of the sphenopsids from this locality. The material consists of the originally published collection of M. Raciborski (1894; 49 specimens), D. Stur's (1888) preliminarily published collection (12 specimens), and 42 unpublished specimens stored in the Jagiellonian University. We found that three new *Equisetum* species (*E. blandum*, *E. renaulti* and *E. remotum*) created by Raciborski (1894) should be reassigned to the widespread Jurassic species *Equisetites lateralis*. We identified another representative of horse-tails, *Equisetites* cf. *columnaris*, on the basis on Stur's partly published collection and Raciborski's original material; Raciborski (1894) did not mention those specimens as belonging to the sphenopsids. Another species originally assigned by Raciborski (1894) to *Schizoneura hoerensis* is here recognised as *Neocalmites lehmannianus* (Goeppert) Weber. Numerous specimens which Raciborski referred to this species showed heterogeneity and served for our description of the new species *Neocalmites grojecensis*. It is characterised mainly by its few prominent ribs present on the shoots, relatively large ellipsoidal leaf scars, free leaves numerous at the node, and vascular bundles alternating at the node. The proposed species may be related to *N. lehmannianus* or may derive from it.

Raciborski (1894) created the new species *Phyllothea* (?) *leptoderma*, but our detailed re-examination of the poorly preserved original material and the unrealistic illustrations in Raciborski's monograph suggested that the material ascribed to this species probably consists of indeterminate cortical fragments of *Neocalmites lehmannianus* or *Neocalmites grojecensis*. These doubts are the basis for our statement that this species is a *nomen dubium*. The state of preservation of 17 specimens allows only a general referral to *Neocalmites* sp.

The sphenophytes from the Grojec clays could overgrow periodically flooded sites with higher moisture along riverbanks and near lakes. They were associated with ferns and they can be interpreted as members of the lowermost storey of moist-forest vegetation. Interestingly, *Equisetites lateralis* co-occurred with ferns and seed ferns, while other sphenopsids occurred

only with ferns. Our observation of the material has shown that representatives of *Equisetites* and *Neocalmites* never occurred together.

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PLATES

Plate 1

Figs 1–11. *Equisetites lateralis* (Phillips 1829) Gould 1968 (= *Equisetum laterale* Phillips 1829)

1. Fragment of shoot, ZNG PAN A-III-12\465
2. Shoot with ornamentation, ZNG PAN A-III-12\465
3. Fragment of shoot, ZNG PAN A-III-12\366
4. Leaf sheath with commissural furrows, ZNG PAN A-III-12\469
5. Drawing of specimen in fig. 4; **cf** – commissural furrow
- 6, 7, 8. Cartwheel structures with central hubs (**ch**) and surrounding spokes (**ss**), 6 – ZNG PAN A-III-12\466, illustrated by Raciborski on Pl. XXVII, fig. 27, 7 – ZNG PAN A-III-12\467, 8 – ZNG PAN A-III-12\462
9. Sporangioophores with hexagonal distal shields, ZNG PAN A-III-12\450
10. Fragment of strobilus with well-visible umbo (**u**), ZNG PAN A-III-12\459
11. Shoot with strobilus, ZNG PAN A-III-12\450

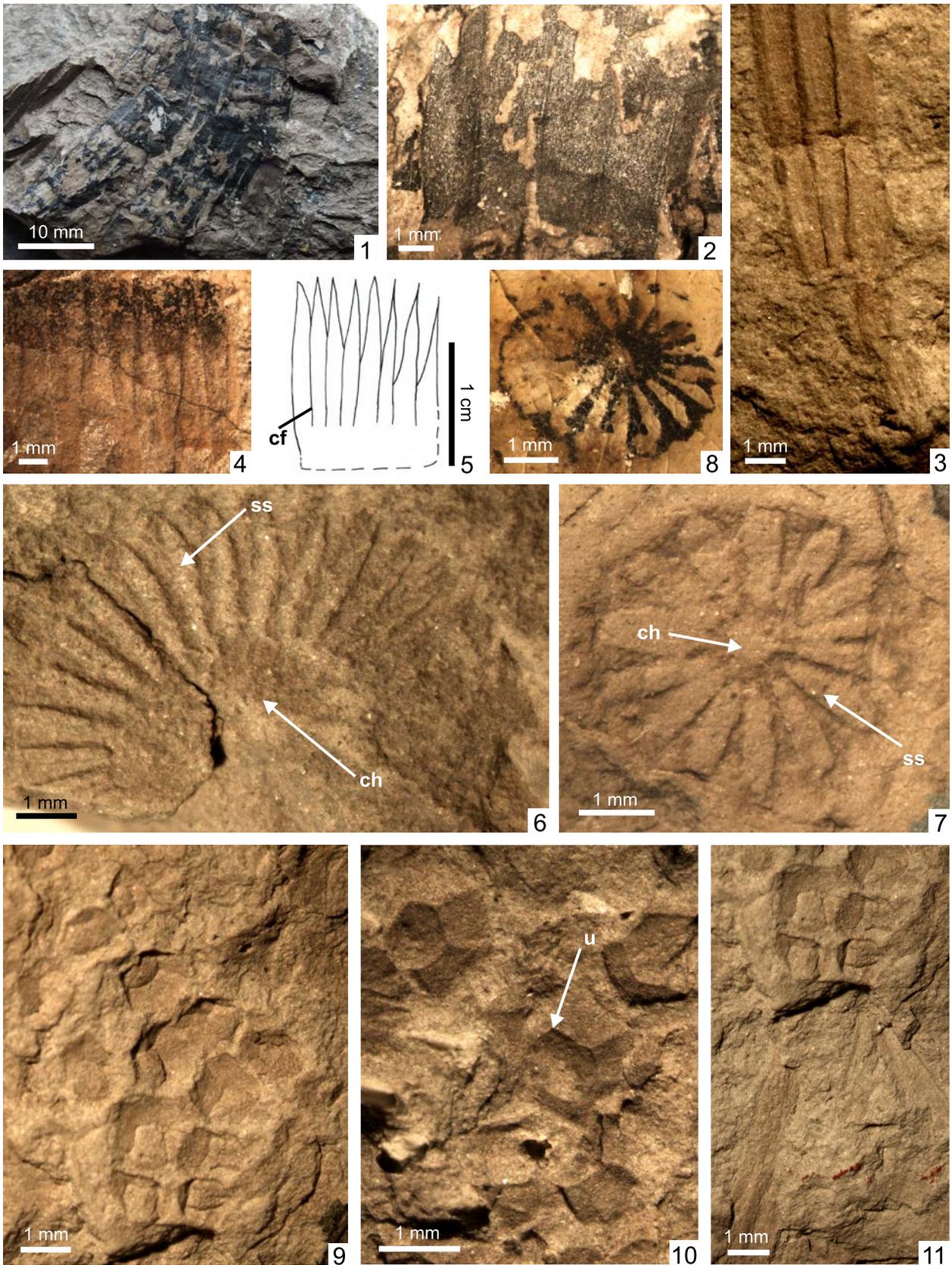


Plate 2

Figs 1–4. *Equisetites* cf. *columnaris* (Phillips 1828) Brongniart 1875

1. Node with leaf traces, GBA 2011/051/0002/1
2. Rhomboidal leaf traces, GBA 2011/051/0002/1
3. Leaf sheath with leaf fragments, GBA 2011/051/0035/2
4. Pitted diaphragm with ring of vallecular canals (**vc**), GBA 2011/051/0002/2

Figs 5–8. *Neocalamites lehmannianus* (Goeppert 1846) Weber 1968

5. Shoot fragment with one node, KRA-PALEO 105/98
6. Shoot fragment with well-visible dense flat ribs, KRA-PALEO 105/34
7. Shoot fragment with one node and poorly preserved leaf scars, ZNG PAN A-12/484
- 8a. Shoot fragment with node and leaf scars (**ls**), KRA-PALEO 105/97
- 8b. Enlargement of circular leaf scars of the same specimen

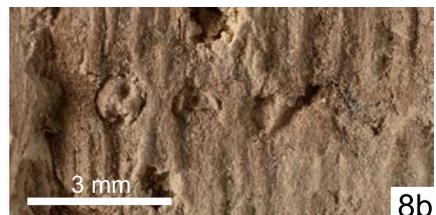
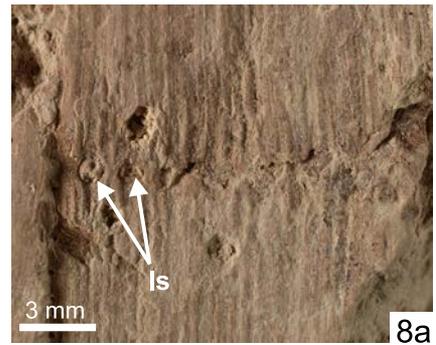
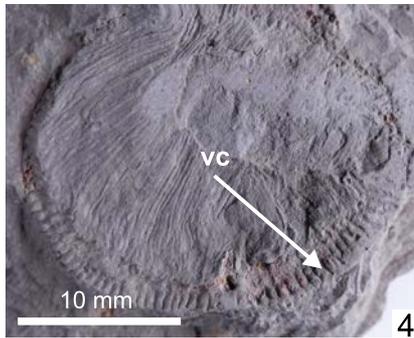
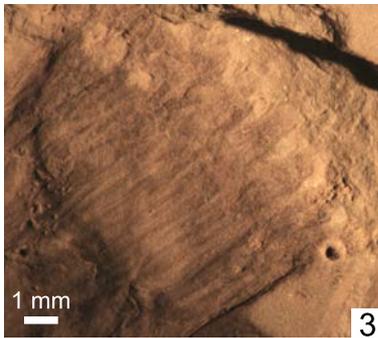
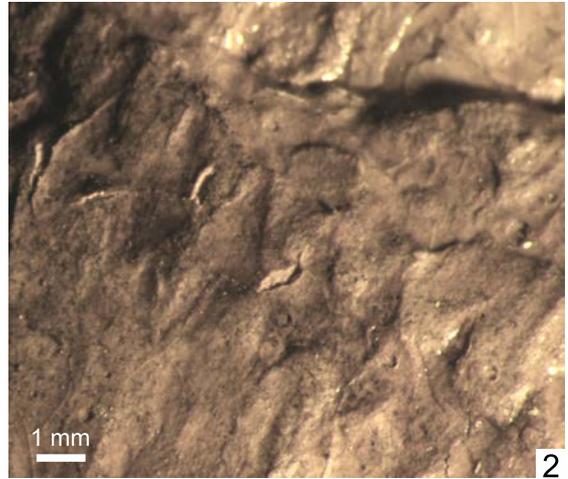
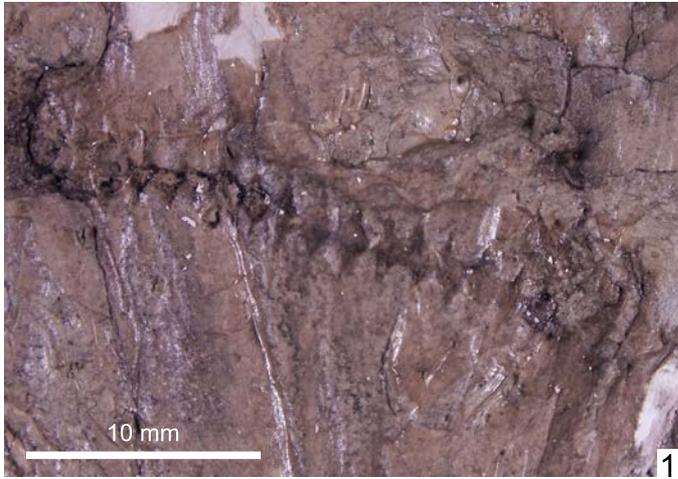


Plate 3

Figs 1–8. *Neocalamites grojecensis* Jarzynka et Pacyna sp. nov.

1. Shoot fragment with one node and leaf scars well visible, ZNG PAN A-12/477 – holotype, illustrated by Raciborski on Pl. XXVI, fig. 9
2. Enlargement of node with elliptical leaf scars of holotype
3. Wide shoot with two nodes, ZNG PAN A-12/477, illustrated by Raciborski on Pl. XXVI, fig. 9
4. Intermediate-size shoot with node and leaf scars, ZNG PAN A-12/483
5. Narrow shoot with two widened nodes preserved, ZNG PAN A-12/481, illustrated by Raciborski on Pl. XXVII, fig. 30
6. Specimen showing internal vascular cylinder (**vc**) and external cortical surface with ribs (**r**) in organic connection, KRA-PALEO 105/97
7. Wide shoot fragment with branch scar, ZNG PAN A-12/482, illustrated by Raciborski on Pl. XXVII, fig. 40
8. Wide shoot fragment with node and branch scar well visible, ZNG PAN A-12/486, illustrated by Raciborski on Pl. XXVII, fig. 31

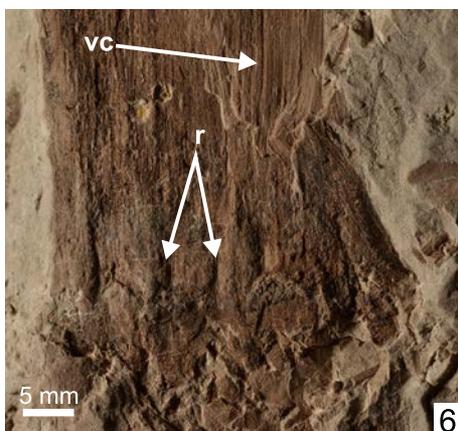
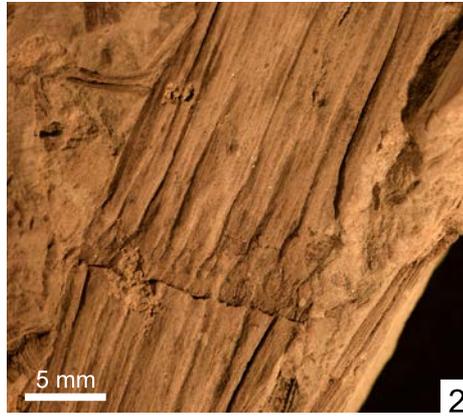


Plate 4

Figs 1–9. *Neocalamites grojecensis* Jarzynka et Pacyna sp. nov.

1. Narrow shoot with node and one leaf still attached, ZNG PAN A-12/483, illustrated by Raciborski on Pl. XXVII, fig. 37
2. Widest shoot with one node, ZNG PAN A-12/477
3. Wide shoot with one node, ZNG PAN A-12/483
4. Wide shoot with one node and badly preserved leaf scars, ZNG PAN A-12/479, illustrated by Raciborski on Pl. XXVII, fig. 43
5. Wide shoot with vascular bundles overlapped by coarser ribbing of external cortex and one node, KRA-PALEO 105/29
6. Vascular bundle arrangement at node, ZNG PAN A-12/480
7. Vascular bundle arrangement at node, ZNG PAN A-12/486
8. Vascular bundle arrangement at node, ZNG PAN A-12/487
9. Vascular bundles, at internode distorted as a result of decomposition, ZNG PAN A-12/433

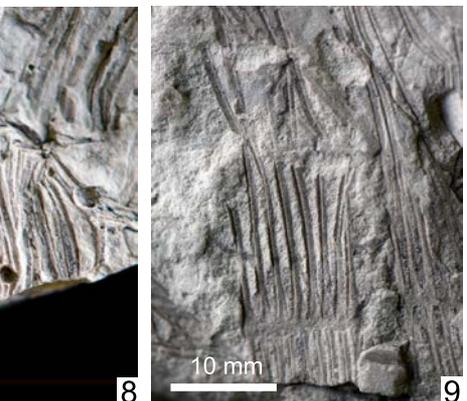
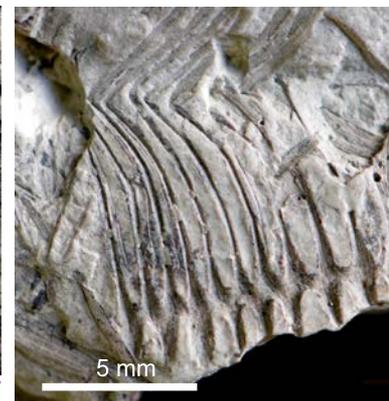
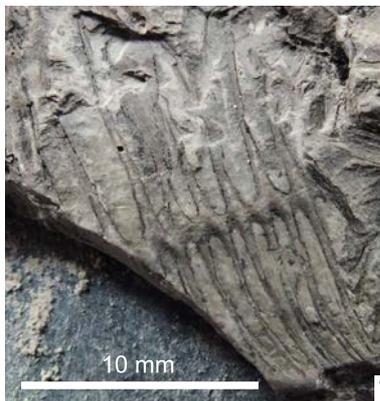


Plate 5

Figs 1–3. *Neocalamites grojecensis* Jarzynka et Pacyna sp. nov.

1. Isolated cylinder of vascular bundles, leaf scars visible beneath, ZNG PAN A-12/482
2. Shoot with node and whorl of leaves still attached, ZNG PAN A-12/474, illustrated by Raciborski on Pl. XXVII, fig. 36
3. Shoot cross section at node, with smooth diaphragm (**di**) visible, surrounded by narrow ring of vascular bundles (**vb**) with carinal canals (**cc**) and finely pitted cortex (**c**) without vallecular canals, ZNG PAN A-12/480, illustrated by Raciborski on Pl. XXVII, fig. 42

Fig. 4. *Neocalamites* sp.

4. Shoot fragment with badly preserved node, GBA 2011/051/0012

Figs 5–11. “*Phyllothea* (?) *leptoderma*” Raciborski 1894

5. Probably external cortical surface of *N. grojecensis* with node preserved, ZNG PAN A-12/473, illustrated by Raciborski on Pl. XXVII, fig. 34
6. Probably external cortical surface of *N. grojecensis* with badly preserved ribbing, ZNG PAN A-12/472, illustrated by Raciborski on Pl. XXVII, fig. 32
7. Probably external cortical surface of *N. lehmannianus*, KRA-PALEO 105/56
8. Probably external cortical surface of *N. lehmannianus*, branch scar enlarged, small regular square structures visible on internode surfaces, KRA-PALEO 105/56
9. Probably external cortical surface of *N. lehmannianus*, one node visible, ZNG PAN A-12/476
10. Probably external cortical surface of *N. lehmannianus*, ribs mostly alternate, only some are opposite or subopposite, small regular square structures also visible on surface, ZNG PAN A-12/475 positive, illustrated by Raciborski on Pl. XXVII, fig. 35
11. Probably external cortical surface of *N. lehmannianus*, ZNG PAN A-12/475 negative

