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Critical review of research on the Lower Jurassic flora of Poland

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ABSTRACT. The Lower Jurassic plant macrofossils of Poland are poorly known. Relatively rich sources of fossils are found in only a few outcrops in the Holy Cross Mountains. Other described plant remains come from drill cores taken from most areas of Poland, but as a rule these are single specimens. The only professional descriptions of Lower Jurassic macroflora are papers by Raciborski, Makarewiczówna, and a team of researchers consisting of Reymanówna, Barbacka, Ziaja, and Wcisło-Luraniec. Raciborski's fossil collection is still available for research and revision. Such work is in progress. The collection described by Makarewiczówna contained many interesting specimens but unfortunately the majority of them are now missing. Stratigraphic research by geologists has provided some new specimens from drill cores and outcrops in the Holy Cross Mountains but these have not been subjected to detailed palaeobotanical analysis. The palynology of the Lower Jurassic was focused on biostratigraphy from the outset of that research. As an outcome it provided spore-pollen and megaspore zonations for Lower Jurassic strata in Poland. The Polish Lower Jurassic flora is comprised of ferns (very numerous), lycopsids, sphenopsids, cycadaleans, bennettitaleans, gnetaleans, ginkgoaleans, and conifers. This flora is taxonomically poorer than the equally old and geographically close floras of Denmark, Sweden, and Germany. Macrofloristic data have been used by geologists as an important source of information for assessing the age of Lower Jurassic formations, particularly in the Holy Cross Mountains. Hence the need for the old collections to be taxonomically revised and for new material from outcrops and drill cores to be examined and described.

KEYWORDS: fossil plants, biostratigraphy, *Thaumatopteris* zone, Lower Jurassic, Poland

INTRODUCTION

Plant remains from Polish Lower Jurassic strata have been known since early in the 19th century (Pusch 1833, 1837, Reymanówna 1963a, Reymanówna et al. 1987) but there are few professional papers on them (Raciborski 1891a, b, 1892a, b, Makarewiczówna 1928, Ziaja 2006, Barbacka et al. 2010). Data gathered so far indicate that the taxonomic composition of these floras is similar to same-age floras from neighbouring Germany, Denmark, and Sweden (Schenk 1867, Nathorst 1878, Möller 1902, Gothan 1914, Antevs 1919, Lundblad 1950, Weber 1968, Pott & McLoughlin 2011). The Polish floras are much poorer taxonomically, however (Tabs 1–7), probably because in Poland there are fewer accessible outcrops to study (Znosko 1955, Marek & Pajchlowa 1997, Piotrowski et al. 2004), but also because of gaps in research, which are becoming increasingly evident as new data appear. The majority of localities with preserved Lower Jurassic floras are in the Holy Cross Mountains area (Siemiradzki 1891, Samsonowicz 1924, 1929, Passendorfer 1939, Karaszewski 1960, 1962, Karaszewski & Kopik 1970, Pieńkowski 1983, 1985, 1991, 2004a, Reymanówna et al. 1987). Rich dinosaur track assemblages have recently been discovered in localities where plant macrofossils had been described previously, and also in new localities (Karaszewski 1969, Pieńkowski & Gierliński 1987, Gierliński 1991, 1995, 1999, Gierliński & Pieńkowski 1999, Gierliński et al. 2001, Niedźwiedzki & Niedźwiedzki 2001, 2004, Niedźwiedzki & Pieńkowski 2004,

Gierliński & Niedźwiedzki 2005, Pieńkowski 2006, Niedźwiedzki & Remin 2008). As a result of these discoveries there is growing interest in new research and a greater understanding of the need to revise old collections. These new data will supplement our knowledge of Lower Jurassic ecosystems, one of the first to be dominated by dinosaurs. In biostratigraphy these floras are useful for estimating the age of nonmarine sequences of Lower Jurassic deposits not bearing other fossils. The lowermost Jurassic floras are well represented in Poland. Data about these floras could be useful in discussions of the Triassic-Jurassic extinction and the revival of floras after this extinction. Polish Lower Jurassic floras can also provide important new biogeographic data. Findings of numerous northern Asian floral taxa in the Polish floras of this period suggest that Poland was then a place through which northern taxa migrated from Asia to Europe during cooler climatic episodes (Vakhrameev 1991).

MAIN RESULTS OF PREVIOUS RESEARCH ON POLISH LOWER JURASSIC PLANT FOSSILS AND FUTURE PROSPECTS

Schneider (1829) was the first to note plant fossils in the Polish Lower Jurassic. Pusch (1833, 1837) gave the first descriptions and illustrations of Polish Lower Jurassic plants. He determined *Pecopteris angustissima*?, *Neuropteris scheuchzeri*, and *Cycadites nilsonii*, but only illustrated specimens of *Pecopteris angustissima?* (Pusch 1837). Pusch found these specimens in the Kamienna river valley in the Holy Cross Mountains area. Raciborski (1891a) and Samsonowicz (1929) attempted to revise Pusch's specimens, both recognizing his determinations as incorrect, but differed in their opinions as to their species affiliation. Raciborski was not able to examine Pusch's specimens. Samsonowicz, who personally examined them, was a trained geologist but not a palaeobotanist. The Pusch collection was destroyed during the Second World War (Bieda 1948). Some descriptions and illustrations of Lower Jurassic plants from the Holy Cross Mountains are to be found in Siemiradzki's papers (Siemiradzki 1887, Siemiradzki & Dunikowski 1891), but these specimens were few and badly preserved.

Raciborski (1891a, b, 1892a, b) wrote the most important papers on the Lower Jurassic flora of the Holy Cross Mountains. He described plant remains from some localities which still today are universally recognised as the most important ones in Polish Lower Jurassic stratigraphy. He correctly identified the fossil assemblage from Gromadzice as belonging to the *Thaumatopteris schenki* zone (then referred to as Rhaetian). However, he erroneously assigned the flora from the Chmielów locality to this zone, although to this day the precise stratigraphic position of this flora has not been settled (Karaszewski 1965). Raciborski established the new genus of gymnospermous male strobili *Ixostrobus*, then recognised in many floras around the world (Raciborski 1892a, b, Harris & Miller 1974, Wcisło-Luraniec 1992c, Wcisło-Luraniec & Barbacka 2000, Taylor et al. 2009, Pacyna & Zdebska 2011b).

Many new fossil plant specimens were collected by geologists during prospecting in the Holy Cross Mountains in the early 20th century. These were found at the localities described by Raciborski (1891a, b, 1892a, b) but also at many new sites (Samsonowicz 1929). Makarewiczówna (1928) described these new collections in an extensive paper. She also revised the collection described by Raciborski; this was needed owing to progress in studies of Europe's Lower Jurassic floras. Stratigraphic research on the Triassic-Jurassic boundary in Europe progressed considerably during this time. Makarewiczówna (1928) correctly assigned layers bearing plant fossils to the Lower Jurassic. The collection she described contained many specimens and was of high scientific value. It was divided between Vilnius (Stefan Batory University collection – the majority of specimens), Warsaw (the Geological Survey), and Kraków (Jagiellonian University). The current whereabouts of these collections is not known. A few specimens thought to have been saved by Makarewiczówna in Kraków have been found recently (author's unpublished data).

While seeking and documenting iron ores in the Przysucha Ore-bearing Formation, Kuźniar found specimens of flora (Kuźniar 1923, 1924, 1943). In his brief geological reports he listed only plant taxonomic determinations, without descriptions or illustrations. The new taxa he proposed are invalid (for example, *Bennettites Raciborskii* n. sp. Kuźniar 1924).

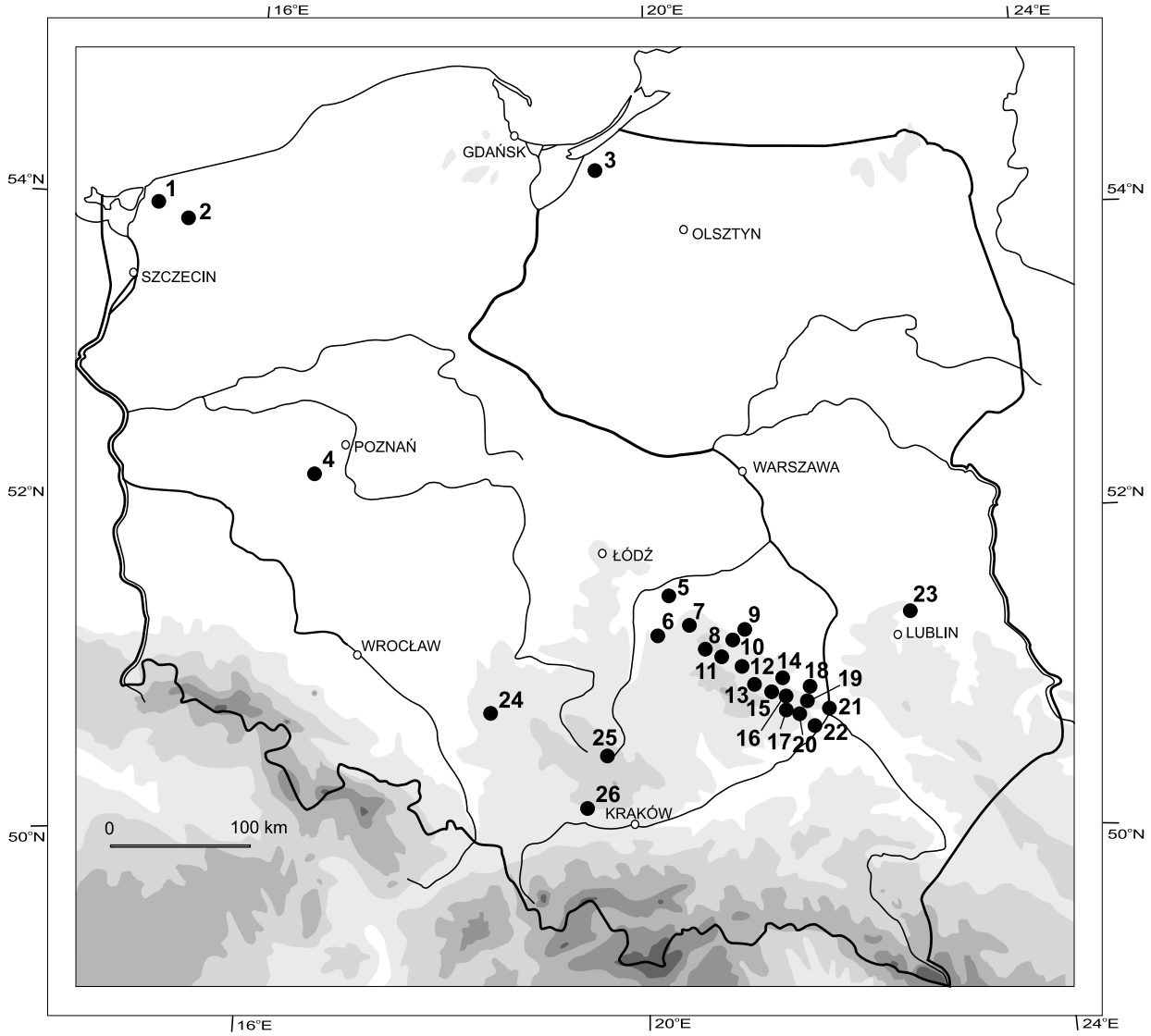

Fig. 1. Macrofossil and selected microfossil plant localities from the Polish Lower Jurassic. **1** – Kamień Pomorski IG 1 borehole, **2** – Mechowo IG 1 borehole, **3** – Borzynowo IG 1 borehole near Elbląg, **4** – Wielichowo I borehole, **5** – Studzianna borehole, **6** – Marcinkowo near Przedbórz, **7** – Mroczków-Rozwady, **8** – Dźwiertnia near Niekłań, **9** – Chlewiska area (Łazienki and Łopata mines), **10** – Huta OP-1 borehole, **11** – Odrowąż (Sołtyków), **12** – Skarżysko-Kamienna area (Barwinek, Szydłowiec, Śmiłów, Ubyszów), **13** – Brody, **14** – Chmielów, **15** – Mnichów, **16** – Jędrzejowice, **17** – Podszkodzie, **18** – Szewna, **19** – Miłków, **20** – Gromadzice, **21** – Ruda Kościelna, **22** – Wyszmontów borehole, **23** – Lublin Coal Basin (borehole L-95 and others near Łęczna), **24** – Gorzów Śląski-Praszka, **25** – Zawiercie area (Blanowice, Siewierz, Zawiercie), **26** – Tychy-Szubin

Later work led by geologists in the Holy Cross Mountains after the Second World War provided new plant specimens from drill cores and outcrops but these were only superficially determined and were not subjected to detailed palaeobotanical analysis.

Interest in these floras as biostratigraphically useful sources of information revived during detailed geological analyses of Lower Jurassic deposits in the Holy Cross Mountains led mainly by Karaszewski (Karaszewski 1960, 1962, 1965, Karaszewski & Kopik 1970). In the Polish Geological Institute an attempt to resume research on Lower Jurassic plants failed; Grabowska (1962, 1963) used cuticular analysis to examine this flora for the first time in Poland, but unfortunately the results of her research were never published, apart from a list of determined taxa (Grabowska et al. 1970).

Lower Jurassic (Upper Pliensbachian) strata also outcrop in the Zawiercie area (Upper Silesia). Coal seams of economic value in these strata were mined during the 19th and early 20th centuries (Pusch 1836, Roemer 1870, Lilpop 1917, Pieńkowski 1988). During an examination of coal geology, Rutkowski (1923) found only three specimens of plants on waste heaps there. These specimens, never properly described or illustrated, came from shale above the coal seam. He also noted plant detritus and coalified

wood fragments. According to information from miners, fossil plant specimens were discovered only rarely during coal extraction. Later, Rogalska (1954) described spores and pollen grains isolated from coal, and Domagała and Kołcon (1983) attempted to reconstruct bog plant communities based on palynological data.

Grabowska et al. (1970) collated all the data on Lower Jurassic plant macrofossil determinations from Poland up to 1970. Some of the determinations cited in that paper resulted from misinterpretation of the work of Harris (Harris 1931, 1935, 1961), so that publication should be used with caution when drawing conclusions about the taxonomic composition of the floras of the Polish Lower Jurassic.

Well-preserved remains of Lower Jurassic plants were discovered in drill cores taken to document Carboniferous coal deposits in the Lublin Coal Basin. These specimens were only preliminarily described by Szydeł and Szydeł (1981) and Migier (1978), but if properly documented these finds could yield interesting new data about the Lower Jurassic flora of Poland (Tabs 1–4).

Palynological research on Lower Jurassic strata in Poland has intensified since the 1950s (Rogalska 1954, 1956, 1962, 1976, 1980, Znosko 1955, Marcinkiewicz 1957, 1960, 1962, 1967, 1971, 1980, 1989, Orłowska-Zwolińska 1966, 1967, Marcinkiewicz et al. 1960, Fijałkowska 1989, Ziaja 2006, Ziaja & Krupnik 2010). This has been the result of an intensive drilling programme serving to document the geology of Poland. Palynological research became especially useful for age determination of nonmarine sediment sequences devoid of other index fossils. Marcinkiewicz (1971, 1980) and Rogalska (1976, 1980) attempted to use spores, pollen grains and megaspores to determine the stratigraphy of Lower Jurassic strata. The first task here was to identify the Triassic-Jurassic boundary in nonmarine sediments (Orłowska-Zwolińska 1967, Marcinkiewicz 1962, 1969). Jung's assignment of the first appearance of the *Nathorstisporites hopliticus* megaspore as the marker of the beginning of the Lower Jurassic Period in nonmarine strata was of crucial importance in this (Nathorst 1908, Jung 1958, Marcinkiewicz 1969). All these studies provided spore-pollen grains and megaspore zonations for Lower Jurassic strata in Poland (Tab. 6). The succession and evolution of floras in the Polish Lower Jurassic were outlined based on palynology, but the relations between the palynological data and the described plant macroremains have not been well studied. Only Ziaja (1989, 2006) has undertaken to analyse such a correlation, for the Odrowąż locality. Early difficulties in establishing palynological nomenclature meant that palynomorphs were referred to parent plants (if found in situ) or even to extant genera and species of plants (Rogalska 1954, 1956, 1962, 1976). As a result, the Polish palaeobotanical literature contains determinations of macrofloral remains which in fact refer to microremains. This has caused additional confusion.

The discovery in the 1970s of a locality in Odrowąż provided new impetus and new opportunities for a modern examination of the Lower Jurassic flora (Karaszewski & Kopik 1970, Karaszewski 1975, Krassilov 1982, Ichas-Ziaja 1987, Wcisło-Luraniec 1987, Reymanówna 1987, Reymanówna et al. 1987, Ziaja 2001a, b, 2004). Numerous dinosaur tracks were found there, further increasing interest and research at that site (Pieńkowski & Gierliński 1987, Gierliński 1991, 1994, Gierliński & Sawicki 1998, Gierliński & Pieńkowski 1999, Gierliński et al. 2001, 2004, Niedźwiedzki & Niedźwiedzki 2001, 2004, Pieńkowski 2004b, 2008, Niedźwiedzki 2006). Today it is a nature reserve and the fossil assemblage is the best-known Lower Jurassic ecosystem in the Holy Cross Mountains (Gierliński et al. 2000, 2004, Pieńkowski 2004b, Niedźwiedzki 2011). In Odrowąż (Sołtyków in the palaeozoological literature), dinosaur tracks, dinosaur nests, and invertebrate fossils and tracks have been found (Pieńkowski 1998, 1999, Popov 1996, Węgierek & Zherikhin 1997, Pieńkowski & Niedźwiedzki 2009). The diversified flora of this site comprises lycopsids, sphenopsids, ferns, seed ferns, cycadaleans, bennettitaleans, gnetaleans, ginkgoaleans, and conifers (Reymanówna 1987, 1991a, b, 1992, 1993, Ziaja 1989, 1991, 1992, 1993, 2004, Wcisło-Luraniec 1989, 1991a, b, 1992a, b, 1993, 2001, Ziaja & Wcisło-Luraniec 1998, 1999). The plant fossils derive from a number of ecologically distinct plant communities and represent forms ranging from herbs to bushes and low trees (Barbacka et al. 2005, 2006a, 2010). Almost all the organs of the coniferous tree *Hirmeriella muensteri* have been

found in Odrowąż: especially well preserved shoots, seed scales and male cones with pollen grains in situ (Barbacka et al. 2006b, 2007). Most cuticles from Odrowąż are not suitable for standard maceration in Schulze mixture but have been successfully examined by fluorescence microscopy (Barbacka et al. 2010). One of the main achievements of that latter work is the recognition, based on cuticle structure, that some lanceolate leaves very frequent in the Hettangian strata of the Holy Cross Mountains and already known to Pusch (he described them as grass-like) and later described as *Podozamites* (Raciborski 1891a, b, 1892a, b, Wcisło-Luraniec 1992a) are in fact fragments of bennetittalean leaves from the genus *Pterophyllum*.

Some undeterminable Lower Jurassic plant remains from the Holy Cross Mountains have been described and illustrated by Karaszewski (1962), Gierliński et al. (2006), and Pieńkowski (2006). Some plant macrofossils have also been found in drill cores from almost everywhere in Poland (Barbacka et al. 2009, Ociepa et al. 2010). Marcinkiewicz (1973) described bennettitalean leaves. Wcisło-Luraniec and Ichas-Ziaja (1990) described isolated seeds probably belonging to seed ferns.

Intensive research on plant remains from drill cores is in progress at present (Pieńkowski & Waksmundzka 2003, 2009, Barbacka et al. 2011, Krupnik et al. 2011, Pieńkowski et al. 2012). Interesting new specimens are being gathered from old localities known long ago to Raciborski, in particular the Gromadzice site (Gierliński & Pieńkowski 1999, Gierliński & Niedźwiedzki 2005, Pieńkowski 2006, Marynowski & Simoneit 2009, Zatoń et al. 2009, Pacyna & Zdebska 2011 b). Preliminary data suggest that these will provide much new information related to the taxonomic composition and palaeoecology of Lower Jurassic floras. The Raciborski collection is now under revision (Wcisło-Luraniec 1992c, Wcisło-Luraniec & Barbacka 2000, Pacyna & Zdebska 2011a, b). The discovery of dinosaur tracks in the Holy Cross Mountains, especially in locations where plant remains were described earlier, has boosted new research on this flora (Pieńkowski 2006). Full reconstructions of ecosystems are now possible for many localities (Niedźwiedzki 2011). Research on plant-animal interactions is promising (Pacyna & Zdebska 2011a).

THE SIGNIFICANCE OF PLANT FOSSILS IN THE STRATIGRAPHY OF THE LOWER JURASSIC (LIASSIC) IN POLAND

The first papers on the flora from the Polish Lower Jurassic (Raciborski 1891a, b 1892a, b, Makarewiczówna 1928) emphasised the importance of assessing the age of described floras and their application in biostratigraphy. The macrofloristic zonation of the Triassic-Jurassic boundary strata proposed by Nathorst (1910) and developed by Harris (1931, 1937) was crucial in determining the age of Polish Lower Jurassic floras. According to this zonation, the first appearance of *Thaumatopteris schenki* marks the beginning of the Jurassic. Raciborski found well preserved specimens of this species in Gromadzice (Raciborski 1892a, b). Identification of this species in Polish Lower Jurassic strata served as support for the proposed stratigraphical divisions of early Mesozoic nonmarine strata in the Holy Cross Mountains and Poland as a whole (Karaszewski 1960, 1962, 1965, Karaszewski & Kopik 1970), but Schweitzer's (1978) research on the genus *Thaumatopteris* questioned the stratigraphical importance of the species *Thaumatopteris schenki*. Based on specimens from Iran and Afghanistan and the specimens from the type locality, Schweitzer asserted that *Thaumatopteris schenki* fell within the morphological variability of *Thaumatopteris brauniana*. Schweizer also questioned the diagnostic value of the features Nathorst (1878, 1907) and Harris (1931, 1937) used to distinguish these species. He also found specimens showing morphological features intermediate between these species. Schweizer proposed that the species *Thaumatopteris schenki* and *T. brauniana* merely represented certain boundaries for the variability and states of preservation of a single species. Since *T. brauniana* is known from the Rhaetian to the Pliensbachian, the stratigraphical value of the *Thaumatopteris schenki* zone is very low. The synonymy of *T. brauniana* and *T. schenki* was confirmed by Barbacka using material from the Lower Jurassic of the Mecsek Mountains in Hungary (Barbacka personal comm. 2013) and Romania (Popa et al. 2003). Popa (1999) and Popa et al. (2003) renamed the *Thaumatopteris schenki* zone the *T. brauniana* assemblage zone, and he recognised this zone in the Hettangian strata of the Southern Carpathians. The

Table 1. Lower Jurassic lycopsids, sphenopsids and ferns described so far from Poland. Explanation of symbols used in tables 1–4: * – papers in which a given taxon is illustrated, ^ – papers in which a given taxon has been described as new for science based on specimens from Poland

Taxon, selected synonyms	Location	Horizon, age	References, comments
Cladophlebis denticulata (Brongniart 1828) Fontaine 1889	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928, Harris 1961 (according to him specimens need further study for reliable determination)
Cladophlebis haiburnensis (Lindley & Hutton 1836) Brongniart 1849	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*, Harris 1961 (noted that the specimen illustrated by Makarewiczówna is an undeterminable fragment)
Cladophlebis sp.	Studzianna borehole (Holy Cross Mts.)	Ostrowiec Formation; Sinemurian	Ociepa et al. 2010
Clathropteris meniscoides (Brongniart 1824) Brongniart 1828	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*
Dictyophyllum acutilobum (Braun 1847) Schenk 1867	Podszkodzie (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Samsonowicz 1929
	Łazienki mine – Chlewiska area (Holy Cross Mts.)	Przysucha Ore-bearing Formation; Upper Hettangian	Kuźniar 1924, 1943
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*
Dictyophyllum aff. ***dunkeri*** Nathorst 1878	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1892a*, b, Karaszewski 1965 (as *Dictyophyllum dunkeri*)
Dictyophyllum exile (Brauns 1866) Nathorst 1878	Dźwiertnia near Niekłań (Holy Cross Mts.)	Przysucha Ore-bearing Formation; Upper Hettangian	Kuźniar 1923
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a*, b
Dictyophyllum nilssoni (Brongniart 1836) Goeppert 1846	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891a*, b, Pacyna & Zdebska 2011a*
Dictyophyllum (?) ***rydzewskii*** Makarewiczówna 1928	Szewna (Holy Cross Mts.)	Skłoby Formation; Middle Hettangian	Makarewiczówna 1928^* Pterophytina, species need revision
Dictyophyllum an nova spec.?	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1892a*, b
Dictyophyllum Lindley & Hutton 1834 ***Dictyophyllum*** sp.	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Ziaja 2006
Equisetites muensteri Sternberg 1833 (=*Equisetum Münsteri* (Sternberg 1833) Schimper 1869)	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891a*, b, 1892a, b, Harris 1931
	Miłków (Holy Cross Mts.)	Skłoby Formation; Middle Hettangian	Raciborski 1891a*, 1892a, Harris 1931
Equisetites Sternberg 1833 ***Equisetites*** sp.	Barwinek near Skarżysko-Kamienna (Holy Cross Mts.)	lower Zagaje Formation; Lower Hettangian	Karaszewski 1962*
	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Ziaja 2006
	Ubyszów near Skarżysko-Kamienna (Holy Cross Mts.)	upper Skłoby Formation; Middle Hettangian	Karaszewski 1962*
Equisetum Linné 1753 ***Equisetum*** sp.	Holy Cross Mts.	Liassic	Raciborski 1891a*, b (cone fragment)
	Kamień Pomorski IG 1 borehole	Ostrowiec Formation; Upper Hettangian	Pieńkowski 2004a* (rhizome in life position)
Filicites Schlotheim 1820 ***Filicites*** sp.	Ostrowiec Świętokrzyski area (Holy Cross Mts.)	Lower Jurassic	Raciborski 1891a*
Goeppertella microloba (Schenk 1867) Oishi and Yamasita 1936 (=*Woodwardites microlobus* Schenk 1867)	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Ziaja 2006, Barbacka et al. 2010*
	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1892a*, b (as *Woodwardites microlobus*), Grabowska in Karaszewski (1965), Grabowska et al. 1970 (as *Göpertella microlobus*)

Table 1. Continued

Taxon, selected synonyms	Location	Horizon, age	References, comments
Hausmania crenata (Nathorst 1878) Möller 1902	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*
Hausmania forchhammeri Bartholin 1892	Jędrzejowice (Holy Cross Mts.)	Ostrowiec Formation; Sinemurian	Makarewiczówna 1928* (listed by Makarewiczówna as synonym of *Dictyophyllum cracoviense* Raciborski 1894, Harris (1961) listed this species as younger synonym of *Hausmania dichotoma* Dunker 1846)
Marattiopsis muensteri (Goeppert 1841) Schimper 1869 (=***Marattia muensteri*** (Goeppert 1841) Schimper 1879)	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891a*, b, Harris 1931 (Harris questioned correct species determination by Raciborski)
Marattiopsis Schimper 1874 ***Marattiopsis*** sp.	Szubin (Upper Silesia)	Lower Liassic	Jentzsch (1918)
Neocalamites lehmannianus (Goeppert 1846a) Weber 1968 (=*Schizoneura hoerensis* (Hisinger 1840) Schimper 1869) (=*Neocalamites hoerensis* (Schimper 1869) Halle 1908 *sensu* Halle 1908)	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Siemiradzki 1887 (as *Calamites lehamnnianus*), Siemiradzki & Dunikowski 1891 (as *Equisetum ungeri* Ettingshausen 1851), Samsonowicz 1929
	Huta OP-1 borehole (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Barbacka et. al 2011 (as *Neocalamites* sp.)
	Odrowąż (Holy Cross Mts.)	Zagaje Fm., Lower Hettangian	Reymanówna et al. 1987, Wcisło-Luraniec 1987, 1991a, b, 1992a*, 1993 (as *Neocalamites* sp. 1 & sp. 2), Gierliński et al. 2000*, 2004*, Pieńkowski 2006*, Ziaja 2006, Barbacka et al. 2005, 2006b, 2010*
	Miłków (Holy Cross Mts.)	Skłoby Formation; Middle Hettangian	Raciborski 1892a*, b, Makarewiczówna 1928
	Podszkodzie (Holy Cross Mts.)	Skłoby Formation; Middle Hettangian	Makarewiczówna 1928
	Dźwiertnia near Niekłań (Holy Cross Mts.)	Przysucha Ore-bearing Formation; Upper Hettangian	Kuźniar 1923, 1943 (as *Schizoneura hoerensis*), Karaszewski & Kopik 1970
	Mnichów (Holy Cross Mts.)	Przysucha Ore-bearing Formation; Upper Hettangian	Raciborski 1891a*, Makarewiczówna 1928
	Brody, Ruda Kościelna (Holy Cross Mts.)	Liassic	Makarewiczówna 1928
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a*, b, Makarewiczówna 1928
Odrolepis liassica Barbacka & Ziaja 2010	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Barbacka et al. 2010^*
Pecopteris concinna Muenster ex Presl in Sterneberg 1838 (=*Rhinipteris concinna* (Muenster ex Presl in Sterneberg 1838) Harris 1931)	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1892a*, b (as An *Pecopteris concinna* Presl 1838?)
Phlebopteris angustiloba (Presl in Sternberg 1838) Hirmer & Hörhammer 1936 (=*Laccopteris angustiloba* (Presl in Sternberg 1838) Raciborski 1891) (=*Gutbiera angustiloba* Presl in Sternberg 1838)	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Reymanówna et al. 1987, Wcisło-Luraniec 1991a, b, 1992a*, 1993, 2001, Reymanówna 1993, Gierliński et al. 2000*, 2004*, Pieńkowski 2006*, Ziaja 2006, Barbacka et al. 2005, 2010*
	Huta OP-1 borehole (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Barbacka et. al 2011
	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891a*, b, 1892a*, (as *Laccopteris (Gutbiera) angustiloba*), Harris 1931
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a*, Harris 1931, Makarewiczówna 1928 (as *Gutbiera angustiloba*), Karaszewski 1960

Table 1. Continued

Taxon, selected synonyms	Location	Horizon, age	References, comments
Phlebopteris elegans (Presl in Sternberg 1838) Gothan and Weyland 1954 (=*Laccopteris elegans* Presl in Sternberg 1838)	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891a*, b (as *Laccopteris elegans*), Harris 1931 (Harris questioned correct species determination by Raciborski), *Laccopteris elegans* Presl in Sternberg 1838 is nom. illegit., their type specimen is poorly preserved (Kvaček & Straková 1997)
	Szewna (Holy Cross Mts.)	Skłoby Formation; Middle Hettangian	Makarewiczówna 1928
	Łazienki mine – Chlewiska area (Holy Cross Mts.)	Przysucha Ore-bearing Formation; Upper Hettangian	Kuźniar 1924, 1943, Lilpop & Kostyniuk (1957) (they referred specimens of Kuźniar to *Phlebopteris brauni*)
	Dźwiertnia near Niekłań (Holy Cross Mts.)	Przysucha Ore-bearing Formation; Upper Hettangian	Kuźniar 1923
	Jędrzejowie (Holy Cross Mts.)	Ostrowiec Formation; Sinemurian	Makarewiczówna 1928
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a*, b
	Siewierz and Zawiercie area, Wysoka mine (Upper Silesia)	Blanowice Formation; Pliensbachian	Rutkowski 1923
Phlebopteris muensteri (Schenk 1867) Hirmer & Hoerhammer 1936 (=*Laccopteris Münsteri* Schenk 1867)	Dźwiertnia near Niekłań (Holy Cross Mts.)	Przysucha Ore-bearing Formation; Upper Hettangian	Kuźniar 1923, 1943
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*, Harris 1931 (as synonym of *Laccopteris brauni* Goeppert 1841)
Protorhipis integrifolia Nathorst 1879 (=*Hausmania (Protorhipis) integrifolia* (Nathorst 1879) Ôishi & Yamasita 1936)	Siewierz and Zawiercie area, Wysoka mine (Upper Silesia)	Blanowice Formation; Pliensbachian	Rutkowski 1923, Rogalska 1954 (as *Pecopteris integrifolia*)
Rhizomopteris Schimper 1869 ***Rhizomopteris*** sp.	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891a*, b, Raciborski 1892a* (as *Rhizomopteris schenkii* Nathorst 1876, fern rhizomes)
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a* (fern rhizomes)
Schizoneura Schimper & Mougeot 1844 ***Schizoneura*** (?) sp.	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891a*, b, (species indeterminate, probably *Neocalamites* sp.)
	Studzianna borehole (Holy Cross Mts.)	Ostrowiec Formation; Sinemurian	Ociepa et al. 2010
Sphenopteris (Brongniart 1822) Sternberg 1825 ***Sphenopteris*** sp.	Siewierz and Zawiercie area, Wysoka mine (Upper Silesia)	Blanowice Formation; Pliensbachian	Rutkowski 1923, Rogalska 1954
Spiropteris Schimper 1869 ***Spiropteris*** sp.	Holy Cross Mts.	Liassic	Raciborski 1891b
Thaumatopteris brauniana Popp 1863	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Barbacka et al. 2010*
	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891a*, b, 1892a*, b, Harris 1931
Thaumatopteris schenki Nathorst 1878	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Gierliński et al. 2000*, Wcisło-Luraniec 2001 (as *Thaumatopteris* sp.), Ziaja 2006
	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891a*, b, 1892a*, b, Harris 1931
Todites princeps (Presl in Sternberg 1838) Gothan 1914 (=*Todea princeps* (Presl in Sternberg 1838) Raciborski 1890)	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Wcisło-Luraniec 1992a, 2001, Ziaja 2006, Barbacka et al. 2005, 2010*
	Huta OP-1 borehole (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Barbacka et. al 2011
	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891a*, b (as *Todea princeps*), Harris 1931

Table 1. Continued

Taxon, selected synonyms	Location	Horizon, age	References, comments
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928 (*Todites* cf. *princeps*)
Todites princeps forma ***trilobata*** Barbacka & Ziaja 2010	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Barbacka et al. 2010^*
Todites williamsoni (Brongniart 1828) Seward 1900	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891a* (as *Pecopteris* sp. – figure only), 1892a*, b (as *Todea williamsonis*), Harris 1931 (referred Raciborski's specimens to *Todites goeppertianus* (Münster in Goeppert 1846) Krasser 1922)

Table 2. Lower Jurassic cycadaleans, bennettitaleans and gnetaleans described so far from Poland

Taxon, selected synonyms	Location	Horizon, age	References, comments
Allicospermum szaferi Wcisło-Luraniec & Ichas-Ziaja 1990	Borzynowo IG-1 borehole near Elbląg	Liassic (?Pliensbachian)	Wcisło-Luraniec & Ichas-Ziaja 1990^* Probably Pteridospermopsida
Anomozamites cf. ***gracilis*** Nathorst 1876	Borehole L-95 near Łęczna (Lublin Coal Basin)	Liassic	Szydeł & Szydeł 1981
Bennettites Raciborskii Kuźniar 1924	Łopata mine – Chlewiska area (Holy Cross Mts.)	Przysucha Ore-bearing Formation; Upper Hettangian	Kuźniar 1924, 1943 (Originally stated as Cycadales, *nomen nudum*; name *Bennettites* Carruthers 1870 was proposed for cycadophyte trunk)
Carpolithes Schlotheim 1820 ***Carpolithes*** sp.	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928* (Specimens need revision)
Caytonia Thomas 1925 ***Caytonia*** sp.	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Ziaja 2006
	Lublin Coal Basin	Liassic	Migier 1978
Ctenis fallax Nathorst 1879	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1892a*, b, Makarewiczówna 1928*, Karaszewski 1965, Grabowska et al. 1970 (as synonym of *Ctenis nilssonii*)
Cycadites nilsonii Sternberg 1825	Holy Cross Mts.	Liassic	Pusch 1833, Raciborski 1891a (synonym of *Nilssonia brevis* Brongniart 1824)
Lepidopteris ottonis (Goeppert 1836) Schimper 1869	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a*, b (erroneous identification), Makarewiczówna 1928, Pacyna & Zdebska 2011b
Nilssonia acuminata (Presl in Sternberg 1838) Schenk 1867	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*
Nilssonia elongata Brongniart 1828 (=***Nilssonia brevis*** f. ***elongata*** Brongniart 1828)	Dźwiertnia near Niekłań (Holy Cross Mts.)	Przysucha Ore-bearing Formation; Upper Hettangian	Kuźniar 1923, 1943, Karaszewski 1960, 1962
Nilssonia inouyei Yokoyama 1905	Podszkodzie (Holy Cross Mts.)	Skłoby Formation; Middle Hettangian	Makarewiczówna 1928
Nilssonia compta (Philips 1829) Bronn 1848	Borehole L-95 near Łęczna (Lublin Coal Basin)	Liassic	Szydeł & Szydeł 1981
Nilssonia orientalis Heer 1878	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Makarewiczówna 1928* (referred to this species' specimens determined by Raciborski (1892) as *Taeniopteris tenuinervis*)
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*
	Borehole L-95 near Łęczna (Lublin Coal Basin)	Liassic	Szydeł & Szydeł 1981

Table 2. Continued

Taxon, selected synonyms	Location	Horizon, age	References, comments
Nilssonia orientalis var. ***minor*** Fontaine 1905	Podszkodzie (Holy Cross Mts.)	Skłoby Formation; Middle Hettangian	Makarewiczówna 1928*
Nilssonia polymorpha Schenk 1867	North part of Holy Cross Mts.	Skłoby Formation; Middle Hettangian	Karaszewski 1960, Grabowska et al. 1970
	Borehole L-95 near Łęczna (Lublin Coal Basin)	Liassic	Szydeł & Szydeł 1981
Nilssonia simplex (Nathorst 1878) Makarewiczówna 1928 (=*Ctenophyllum simplex* (Nathorst 1978) Raciborski 1891) (=*Pterophyllum*? *simplex* Nathorst 1878)	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a*, b (as *Ctenophyllum simplex*), Makarewiczówna 1928*
Nilssonia Brongniart 1825 ***Nilssonia*** sp.	Skarżysko-Kamienna area (Holy Cross Mts.)	lower Skłoby Formation; Middle Hettangian	Karaszewski 1962*
	Lublin Coal Basin	Liassic	Migier 1978
Nilssoniopteris major (Lindley & Hutton 1833) Florin 1933	Borehole L-95 near Łęczna (Lublin Coal Basin)	Liassic	Szydeł & Szydeł 1981*
Nilssoniopteris vittata (Brongniart 1828) Florin 1933	Borehole L-95 and others near Łęczna (Lublin Coal Basin)	Liassic	Migier 1978, Szydeł & Szydeł 1981*
Otozamites beani (Lindley & Hutton 1832) Brongniart 1849	Borehole L-95 near Łęczna (Lublin Coal Basin)	Liassic	Szydeł & Szydeł 1981
Otozamites brevifolius Braun in Muenster 1843	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Reymanówna et al. 1987, Wcisło-Luraniec 1987, 1991a, b, 1992a*, 1993, 2001 (as *Otozamites* sp.), Ziaja 1991, 2006, Barbacka et al. 2006a, 2010*
Otozamites falsus Harris 1949	Wyszmontów borehole (eastern margin of the Holy Cross Mts.)	Borucice Beds; Upper Toarcian	Marcinkiewicz 1973*
Otozamites graphicus (Leckenby 1864) Phillips 1875	Borehole L-95 near Łęczna (Lublin Coal Basin)	Liassic	Szydeł & Szydeł 1981*
Pachypteris lanceolata Brongniart 1828	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Reymanówna et al. 1987, Wcisło-Luraniec 1987, 1991a, b, 1992a, 1993, 2001, Gierliński et al. 2000* (as *Pachypteris* sp.), Ziaja 1991, 2006, Barbacka et al. 2006a, 2010*
	Lublin Coal Basin	Liassic	Migier 1978
Pachypteris rhomboidalis (Ettinghausen 1852) Doludenko 1974	Borehole L-95 near Łęczna (Lublin Coal Basin)	Liassic	Szydeł & Szydeł 1981*
?***Pachypteris*** sp.	Studzianna borehole (Holy Cross Mts.)	Ostrowiec Formation; Sinemurian	Ociepa et al. 2010
Paracycas minuta Barbacka 2010	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Barbacka et al. 2010^*
Piroconites kuespertii Gothan 1914	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Barbacka et al. 2010*
Pseudoctenis sp.	Studzianna borehole (Holy Cross Mts.)	Ostrowiec Formation; Sinemurian	Ociepa et al. 2010
Pterophyllum alinae Barbacka 2010	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Wcisło-Luraniec 1991a, b, 1992a (as *Pterophyllum* sp.), Barbacka et al. 2006a, b, 2010^*
Pterophyllum nathorsti Schenk 1883	Podszkodzie (Holy Cross Mts.)	Skłoby Formation; Middle Hettangian	Makarewiczówna 1928*, Grabowska et al. 1970 (as *Nilssonia nathorstii* and synonym of *Pterophyllum subaequale*)
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*

Table 2. Continued

Taxon, selected synonyms	Location	Horizon, age	References, comments
Pterophyllum polonicum Makarewiczówna 1928	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928^* (species need revision), Reymanówna 1963b (as synonym of *Pterophyllum subaequale* Hartz 1896), Barbacka *et al.* 2010 (as probable synonym of *Pterophyllum alinae* Barbacka 2010)
Pterophyllum schenki Zeiller (1886) Zeiller 1903	Wielichowo I borehole (Western Poland)	Wielichowo Beds; Lower Liassic	Orłowska-Zwolińska 1966* (isolated cuticules)
Pterophyllum Brongniart 1828 ***Pterophyllum*** sp.	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Reymanówna et al. 1987, Wcisło-Luraniec 1991a, b, 1992a, 1993, 2001, Ziaja 1991, 2006
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*
	Borehole L-95 and others near Łęczna (Lublin Coal Basin)	Liassic	Migier 1978, Szydeł & Szydeł 1981*
Ptilophyllum pecten (Phillips 1829) Morris 1841	Marcinkowo near Przedborze (northwest part of Holy Cross Mts.)	Skłoby Formation; Middle Hettangian	Passendorfer 1939, Karaszewski 1960, Grabowska et al. 1970 (as *Pityophyllum pecten*)
Sagenopteris nilssoniana (Brongniart 1824) Ward 1900	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Makarewiczówna 1928*, Harris 1964 (noted that the specimen illustrated by Makarewiczówna probably also belongs to *Sagenopteris phillipsi*)
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*. Synonym of *Sagenopteris acuminata* Presl in Sternberg 1838 (Kvaček & Straková 1997)
Sagenopteris phillipsi (Brongniart 1830) Seward 1900	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928* (determination without cuticular analysis)
Sagenopteris rhoifolia Presl in Sternberg 1838 var. *pusilla* Braun ex Schenk 1867	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891a*, b Synonym of *Sagenopteris acuminata* Presl in Sternberg 1838 (Kvaček & Straková 1997)
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a*, b
Sagenopteris Presl in Sternberg 1838 ***Sagenopteris*** sp.	Borehole L-95 near Łęczna (Lublin Coal Basin)	Liassic	Szydeł & Szydeł 1981
Stenopteris Saporta 1872 ***Stenopteris*** sp.	Lublin Coal Basin	Liassic	Migier 1978
Taeniopteris superba Brongniart 1828	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Siemiradzki 1887*, Siemiradzki & Dunikowski 1891
Taeniopteris tenuinervis Brauns 1862	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1892a*, b
Thinnfeldia Ettingshausen 1852 ***Thinnfeldia*** sp.	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*
Weltrichia spectabilis (Nathorst 1909) Harris 1969	Lublin Coal Basin	Liassic	Migier 1978

Table 3. Lower Jurassic ginkgoaleans described so far from Poland

Taxon, selected synonyms	Location	Horizon, age	References, comments
Baiera muensteriana (Presl in Sternberg 1838) Heer 1876 (=*Jeanpaulia muensteriana* (Presl in Sternberg 1838) Schenk 1867)	Łazienki mine – Chlewiska area (Holy Cross Mts.)	Przysucha Ore-bearing Formation; Upper Hettangian	Kuźniar 1924, 1943, Karaszewski 1960, 1962
Baiera Braun 1843 ***Baiera*** sp.	Huta OP-1 borehole (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Barbacka et. al 2011

Table 2. Continued

Taxon, selected synonyms	Location	Horizon, age	References, comments
Baiera Braun 1843 ***Baiera*** sp.	Borehole L-95 near Łęczna (Lublin Coal Basin)	Liassic	Szydeł & Szydeł 1981*
Czekanowskia nathorsti Harris 1935	North part of Holy Cross Mts.	Lower Liassic	Grabowska 1962, 1963, Grabowska et al. 1970
Czekanowskia rigida Heer 1876	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891a*, b, 1892a*, b, Makarewiczówna 1928*, Grabowska et al. 1970 (as synonym of *Czekanowskia nathorsti* Harris)
	Chmielów (Holy Cross Mts.)	Chmielów Clays, Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a*, b, Makarewiczówna 1928*
Czekanowskia setacea Heer 1876	North part of Holy Cross Mts.	Lower Liassic	Grabowska 1962
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1892a*, b, Makarewiczówna 1928*
Czekanowskia Heer 1876 ***Czekanowskia*** sp.	North part of Holy Cross Mts.	Zagaje Formation; Lower Hettangian; Przysucha Ore-bearing Formation; Upper Hettangian	Karaszewski 1960, 1962
Ginkgo digitata (Brongniart 1828) Heer 1876	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*
Ginkgo sibirica Heer 1876 (=*Ginkgoites sibiricus* (Heer 1876) Seward 1919)	Podszkodzie (Holy Cross Mts.)	Skłoby Formation; Middle Hettangian	Makarewiczówna 1928* (leaves and seeds)
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928* (leaves and seeds)
Ginkgo whitbiensis Nathorst 1880 ex Harris 1951 (=*Ginkgoites whitbiensis*) Nathorst 1880) Seward 1900)	North part of Holy Cross Mts.	Lower Liassic	Grabowska 1962, Grabowska et al. 1970
Ginkgo aff. ***whittbyensis*** Nathorst 1880 ex Harris 1951 (=*Ginkgoites whittbyensis* (Nathorst 1880) Seward 1900)	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1891* (noted that his material could belong to a new species), Grabowska et al. 1970 corrected Raciborski *Ginkgo* aff. *whithbyensis* as *Ginkgo whitbiensis*
Ginkgo Linne 1771 ***Ginkgo*** sp.	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*
Ginkgoites marginatus (Nathorst 1878) Florin 1936	North part of Holy Cross Mts.	Lower Liassic	Grabowska 1962, 1963, Grabowska et al. 1970 (referred to this species' specimens determined by Makarewiczówna (1928) as *Ginkgo digitata* and *Ginkgo sibirica*)
Ginkgoites taeniatus (Braun 1843) Harris 1935 (=*Baiera taeniata* Braun 1843)	Podszkodzie and other locations in north-eastern part of Holy Cross Mts.	Skłoby Formation; Middle Hettangian; Liassic	Makarewiczówna 1928*, Grabowska 1962, Grabowska et al. 1970 (as *Ginkgoites taeniatus*), Karaszewski 1965, Karaszewski & Kopik 1970
Ginkgoites Seward 1919 ***Ginkgoites*** sp.	North part of Holy Cross Mts.	Zagaje Formation; Lower Hettangian	Karaszewski 1960
Ixostrobus siemiradzkii (Raciborski 1891) Raciborski 1892 (=***Taxites siemiradzkii*** Raciborski 1891) basonim (=***Stenorachis (Ixostrobus) siemiradzkii*** (Raciborski 1891) Makarewiczówna 1928)	Gromadzice (Holy Cross Mts.) – type specimen	Zagaje Formation; Lower Hettangian	Raciborski 1891a^* (description in Polish), 1891b (description in German), Raciborski 1892a*, b (description in German), Wcisło-Luraniec 1992c, Wcisło-Luraniec & Barbacka 2000*, Pacyna & Zdebska 2011b* (valid taxon, type species of genus)
	Podszkodzie (Holy Cross Mts.)	Skłoby Formation; Middle Hettangian	Makarewiczówna 1928
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928

Table 3. Continued

Taxon, selected synonyms	Location	Horizon, age	References, comments
Ixostrobus sp.	Huta OP-1 borehole (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Barbacka et. al 2011
?***Ixostrobus*** sp.	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Pacyna & Zdebska 2011b*
Schmeissneria microstachys (Presl 1833) Kirchner & van Konijnenburg-van Cittert 1994	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Reymanówna et al. 1987, Wcisło-Luraniec 1987, 1989, 1991a, b, 1992a*, b*, 1993, 2001 (described as *Stachyopitys preslii* Schenk 1867), Ziaja 2006, Barbacka et al. 2005, 2010*
Sphenobaiera leptophylla (Harris 1935) Florin 1936 (=*Baiera leptophylla* Harris 1935)	North part of Holy Cross Mts.	Lower Liassic	Grabowska 1962, 1963, Grabowska et al. 1970
Sphenobaiera cf. ***spectabilis*** (Nathorst 1906) Florin 1936	North part of Holy Cross Mts.	Lower Liassic	Grabowska 1962, 1963, Grabowska et al. 1970

Table 4. Lower Jurassic conifers described so far from Poland

Taxon, selected synonyms	Location	Horizon, age	References, comments
Cycadocarpidium erdtmanii Nathorst 1886	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a*, b
Hirmeriella muensteri (Schenk 1867) Jung 1968	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Krassilov 1982*, Reymanówna et al. 1987, Reymanówna 1987, 1991a, b, 1992*, 1993, Wcisło-Luraniec 1991a, b, 1992a, 1993, 2001, Ziaja 1991, 1992, 2006, Gierliński et al. 2000*, 2004*, Pieńkowski 2006*, Barbacka et al. 2005, 2006a, b, 2007* (description of sterile remains, female and male cones, in situ pollen grains *Classopollis*), Barbacka et al. 2010*
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928* (as *Cheirolepis Münsteri*)
Hirmeriella Hörhammer 1933 ***Hirmeriella*** sp.	Borehole L-95 near Łęczna (Lublin Coal Basin)	Liassic	Szydeł & Szydeł 1981
(cfr.) ***Palissya sphenolepis*** (Braun 1843) Nathorst 1908	Łazienki mine – Chlewiska area (Holy Cross Mts.)	Przysucha Ore-bearing Formation; Upper Hettangian	Kuźniar 1924, 1943, Karaszewski 1962
Palissya Endlicher 1847 ***Palissya*** sp.	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a*, b
Pityophyllum angustifolium (Nathorst 1878) Möller 1903	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a*, b, Makarewiczówna 1928* (she referred to this species specimens described by Raciborski (1891) as *Cycadites (?) gramineus* Heer)
Pityophyllum longifolium (Nathorst 1878) Möller 1903	Podszkodzie (Holy Cross Mts.)	Skłoby Formation; Middle Hettangian	Makarewiczówna 1928*
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a*, b; Makarewiczówna (1928) referred specimens described by Raciborski (1891) as *Cycadites* (?) *planicosta* Heer 1876 to *Pityophyllum longifolium*
Podozamites angustifolius (Eichwald 1860) Schimper 1872	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*
Podozamites distans (Presl in Sternberg 1838) Braun in Münster 1843	Podszkodzie (Holy Cross Mts.)	Skłoby Formation; Middle Hettangian	Makarewiczówna 1928* (she referred to this species' material described by Raciborski (1891, 1892) as *Podozamites lanceolatus*)
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*

Table 4. Continued

Taxon, selected synonyms	Location	Horizon, age	References, comments
Podozamites gramineus Heer 1876	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928
Podozamites lanceolatus (Lindley & Hutton 1836) Braun 1843 (=*Lindleycladus lanceolatus* (Lindley & Hutton 1836) Harris 1979)	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a*, b (he distinguished 4 forms of this species in his material: *P. l. genuinus*, *P. l. distans*, *P. l. minor* and one unnamed form), Raciborski 1892a* (*Podozamites distans* in table caption), 1892b
Podozamites cf. ***schenkii*** Heer 1876	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Barbacka et al. 2010*
	Huta OP-1 borehole (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Barbacka et. al 2011
Podozamites stobieckii Raciborski 1891	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Raciborski 1891a^*, b Makarewiczówna 1928, Harris & Miller 1974 (according to them, the species should be referred to genus *Desmiophyllum*)
Podozamites Braun 1843 ***Podozamites*** sp.	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Reymanówna et al. 1987, Reymanówna 1987, 1991b, Wcisło-Luraniec 1991a, b, 1992a, Ziaja 2006, Barbacka et al. 2005, 2006a, 2010*
Schizolepis braunii Schenk 1867	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928*
Schizolepis cf. ***moelleri*** Seward 1907	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928
Schizolepis follinii Nathorst 1876	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1892a*, b
	Chmielów (Holy Cross Mts.)	Chmielów Clays; Upper Sinemurian-Lower Pliensbachian	Makarewiczówna 1928 (as *Pityophyllum (Schizolepis) follini*)
Stachyotaxus septentrionalis (Agardh 1823) Nathorst 1886	Gromadzice (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Raciborski 1892a*, b
Swedenborgia Nathorst 1876 ***Swedenborgia*** sp.	Odrowąż (Holy Cross Mts.)	Zagaje Formation; Lower Hettangian	Reymanówna et al. 1987, Reymanówna 1987, 1991a, b, 1992*, Wcisło-Luraniec 1991a, b, 1992a, 1993, 2001, Ziaja 2006, Barbacka et al. 2005, 2010*

Thaumatopteris schenki zone is correlated with the Hettangian and at least part of the Sinemurian in Poland and Europe (Popa et al. 2003, Marcinkiewicz 1971). The upper boundary of this zone is poorly recognized (Tab. 6). It is very difficult to accurately assess the age of floras from younger stages of the Lower Jurassic. In Poland but also all across Europe, plant macrofossils have turned out to be a weak indicator of strata age in the Lower Jurassic. Plants evolved slowly during the Lower Jurassic and new taxa rarely appeared, so reliable index taxa are lacking. Only the lowermost Jurassic (particularly the Hettangian) floras are fairly easy to identify by their taxonomic composition (Tab. 5). The floras of younger stages of the Lower Jurassic become increasingly similar to the floras of the Middle Jurassic, complicating the task. The problem is well illustrated by the Chmielów flora, whose age was estimated broadly at the Sinemurian–Lower Pliensbachian from lithostratigraphy (Karaszewski 1965). The flora described by Möller (1902) probably is very similar in age but its exact age is still a matter of debate.

The palynology of the Lower Jurassic was focused on biostratigraphy from the outset of that research (Rogalska 1954, 1956, 1962, 1976, 1980, Marcinkiewicz 1957, 1960, 1967, 1971, 1980, 1989, Orłowska-Zwolińska 1966, 1967, Marcinkiewicz et al. 1960). Palynological data proved useful in identifying the Triassic-Jurassic boundary in series of nonmarine deposits lacking other fossils (Orłowska-Zwolińska 1967, Marcinkiewicz 1969). Palynological analysis became the standard

Table 5. Stratigraphical sequence of macrofloral assemblages in the Lower Jurassic of the Holy Cross Mountains

Formation (Pieńkowski 2004)	Age (Karaszewski 1960, 1962, Pieńkowski 2004)	Locality	Floral assemblage
Ostrowiec Formation-Gielniów Formation	Upper Sinemurian-Lower Pliensbachian	Chmielów	*Neocalamites lehmannianus*, *Cladophlebis denticulata*, *C. haiburnensis*, *Clathropteris meniscoides*, *Dictyophyllum acutilobum*, *D. exile*, *Hausmania crenata*, *Laccopteris elegans*, *L. muensteri*, *Phlebopteris angustiloba*, *Rhizomopteris*, *Todites princeps*, *Sagenopteris nilssoniana*, *Sagenopteris phillipsi*, *S. rhoifolia* var. *pusilla*, *Thinnfeldia* sp., *Ctenis fallax*, *Nilssonia acuminata*, *N. orientalis*, *N. simplex*, *Pterophyllum nathorsti*, *P. polonicum*, *Pterophyllum* sp., *Czekanowskia rigida*, *Cz. setacea*, *Ginkgo digitata*, *G. sibirica*, *Ginkgo* sp., *Ixostrobus siemiradzkii*, *Cycadocarpidium erdtmanii*, *Hirmeriella muensteri*, *Palissya* sp., *Pityophyllum angustifolium*, *P. longifolium*, *Podozamites angustifolius*, *P. distans*, *P. gramineus*, *P. lanceolatus*, *P. stobieckii*, *Schizolepis braunii*, *S.* cf. *moelleri*, *S. follinii*
Ostrowiec Formation	Sinemurian	Jędrzejowice	*Hausmania forchhammeri*, *Laccopteris elegans*
Przysucha Ore-bearing Formation	Upper Hettangian	Mnichów	*Neocalamites lehmannianus*
		Dźwiertnia near Niekłań	*Dictyophyllum exile*, *Laccopteris elegans*, *L. muensteri*, *Nilssonia elongata*, *Neocalamites lehmannianus*
		Chlewiska	*Laccopteris elegans*, *Dictyophyllum acutilobum*, *Baiera muensteriana*, cfr. *Palissya sphenolepis*, *Bennettites raciborskii*
Skłoby Formation	Middle Hettangian	Miłków	*Equisetites muensteri*, *Neocalamites lehmannianus*
		Szewna	*Dictyophyllum (?) rydzewskii*, *Laccopteris elegans*
		Podszkodzie	*Neocalamites lehmannianus*, *Nilssonia inouyei*, *N. orientalis* var. *minor*, *Pterophyllum nathorsti*, *Ginkgo sibirica*, *Ginkgoites taeniata*, *Ixostrobus siemiradzkii*, *Pityophyllum longifolium*, *Podozamites distans*
Zagaje Formation	Lower Hettangian (depositional sequence I b)	Gromadzice	*Neocalamites lehmannianus*, *Schizoneura (?)* sp., *Dictyophyllum* aff. *dunkeri*, *D. nilssoni*, *Dictyophyllum* an nova spec.?, *Equisetites muensteri*, *Goeppertella microloba*, *Laccopteris elegans*, *Marattiopsis muensteri*, *Pecopteris concinna*, *Phlebopteris angustiloba*, *Rhizomopteris*, *Thaumatopteris brauniana*, *T. schenki*, *Todites williamsoni*, *T. princeps*, *Sagenopteris rhoifolia* var. *pusilla*, *Nilssonia orientalis*, *Taeniopteris superba*, *T. tenuinervis*, *Czekanowskia rigida*, *Ginkgo* aff. *whittbyensis*, *Ixostrobus siemiradzkii*, *?Ixostrobus* sp., *Schizolepis follinii*, *Stachyotaxus septentrionalis*
	Lower Hettangian (depositional sequence I a)	Odrowąż (Sołtyków)	*Odrolepis liassica*, *Neocalamites lehmannianus*, *Dictyophyllum* sp., *Equisetites* sp., *Goeppertella microloba*, *Phlebopteris angustiloba*, *Thaumatopteris brauniana*, *T. schenki*, *Todites princeps*, *T. princeps* forma *trilobata*, *Pachypteris lanceolata*, *Caytonia* sp., *Sagenopteris nilssoniana*, *Paracycas minuta*, *Pterophyllum alinae*, *Pterophyllum* sp., *Otozamites brevifolius*, *Schmeissneria microstachys*, *Hirmeriella muensteri*, *Podozamites* cf. *schenkii*, *Podozamites* sp., *Swedenborgia* sp., *Piroconites kuespertii*

Table 6. Correlation of plant fossil zonation for Lower Jurassic strata in Poland

Stage	Macrofossil plant remains localities	Macrofossil plant remains zonation (Harris 1937, Marcinkiewicz 1969, 1971)	Palynological zonation (spores and pollen grains) (Rogalska 1976)	Megaspore zonation (Marcinkiewicz 1971, 1980)
Upper Toarcian			V	*Thomsonia phyllica* (=*Paxillitriletes phyllicus*)
Lower Toarcian			IV	
Upper Pliensbachian			III	
Lower Pliensbachian	Chmielów		II	*Horstisporites planatus*
Upper Sinemurian			I	
Lower Sinemurian	Jędrzejowice?	*Thaumatopteris schenki* ?		*Nathorstisporites hopliticus*
Upper Hettangian	Mnichów Dźwiertnia Chlewiska	*Thaumatopteris schenki*		
Middle Hettangian	Miłków Szewna Podszkodzie			
Lower Hettangian	Gromadzice Odrowąż			

Table 7. Main Polish Lower Jurassic macrofossil and selected microfossil plant localities with basic palaeobotanical and geological references

Fossil plant remains locality	References
Barwinek and Ubyszów near Skarżysko-Kamienna	Karaszewski 1962
Borzynowo IG-1 borehole near Elbląg	Wcisło-Luraniec & Ichas-Ziaja 1990
Chmielów	Raciborski 1891a, b, 1892a, b, Makarewiczówna 1928, Samsonowicz 1929, Karaszewski 1960, 1962, 1965, Harris & Miller 1974, Reymanówna 1963a, b, Grabowska et al. 1970
Dźwiertnia near Niekłań	Kuźniar 1923, 1943, Karaszewski 1960, 1962, Karaszewski & Kopik 1970
Gorzów Śląski-Praszka	Marcinkiewicz 1957, 1960, Marcinkiewicz et al. 1960
Gromadzice	Siemiradzki 1887, Siemiradzki & Dunikowski 1891, Raciborski 1891a, b, 1892a, b, Makarewiczówna 1928, Samsonowicz 1929, Karaszewski 1960, 1962, 1965, Grabowska et al. 1970, Gierliński & Pieńkowski 1999, Wcisło-Luraniec & Barbacka 2000, Niedźwiedzki & Niedźwiedzki 2004, Pieńkowski 2004a, 2006, Marynowski & Simoneit 2009, Zatoń et al. 2009, Ziaja & Krupnik 2010, Pacyna & Zdebska 2011a, b
Chlewiska (Łazienki mine)	Kuźniar 1924, 1943, Lilpop & Kostyniuk 1957, Karaszewski 1960, 1962, Karaszewski & Kopik 1970
Jędrzejowice	Makarewiczówna 1928, Samsonowicz 1929
Lublin Coal Basin (including borehole L-95 near Łęczna)	Migier 1978, Szydeł & Szydeł 1981
Kamień Pomorski IG 1 borehole	Pieńkowski 2004, Pieńkowski et al. 2012
Marcinkowo near Przedborze	Passendorfer 1939, Karaszewski 1960, Grabowska et al. 1970
Mechowo IG I borehole	Marcinkiewicz 1962, 1967
Miłków	Raciborski 1891a, 1892a, b, Makarewiczówna 1928, Samsonowicz 1929
Mnichów	Raciborski 1891a, Makarewiczówna 1928, Samsonowicz 1929
Mroczków-Rozwady	Rogalska 1956, Grabowska 1962, 1963, Grabowska et al. 1970
Odrowąż (Sołtyków)	Karaszewski & Kopik 1970, Karaszewski 1975, Krassilov 1982, Ichas-Ziaja 1987, Reymanówna 1987, 1991a, b, 1992, 1993, Pieńkowski & Gierliński 1987, Reymanówna et al. 1987, Wcisło-Luraniec 1987, 1991a, b, 1992a, b, Ziaja 1989, 1991, 1992, 2001, 2006, Gierliński 1991, Popov 1996, Węgierek & Zherikhin 1997, Ziaja & Wcisło-Luraniec 1998, 1999, Pieńkowski 1998, 1999, Gierliński & Pieńkowski 1999, Gierliński et al. 2000, 2001, 2004, Niedźwiedzki & Niedźwiedzki 2004, Pieńkowski 2004a, b, Barbacka et al. 2006a, b, 2007, 2010, Pieńkowski & Niedźwiedzki 2009, Niedźwiedzki 2011
Podszkodzie	Makarewiczówna 1928, Samsonowicz 1929, Grabowska et al. 1970
Zawiercie and Siewierz area (Blanowice coal)	Lilpop 1917, Rutkowski 1923, Rogalska 1954, Marcinkiewicz 1957, Domagała & Kołcon 1983, Pieńkowski 1988
Studzianna	Karaszewski 1962, Barbacka et al. 2009, Ociepa et al. 2010, Barbacka et al. in prep.
Szewna	Makarewiczówna 1928, Samsonowicz 1929
Wielichowo I borehole	Orłowska-Zwolińska 1966
Wyszmontów borehole	Marcinkiewicz 1973

method during drill core examination from older Mesozoic strata. Spore-pollen grains and megaspore zonations for the Lower Jurassic strata in Poland were proposed (Marcinkiewicz 1971, 1980, Rogalska 1976, 1980) but their stratigraphical resolution was weaker than that achieved in marine strata based on ammonites (Tab. 6).

CONCLUSIONS

Plant macrofossils are weak indicators for identification of stages in the Lower Jurassic. Plant evolution proceeded slowly and new taxa rarely appeared during that period, so reliable index taxa are lacking. Palynological data broadly confirm this conclusion (Batten & Koppelhus 1996, Koppelhus & Batten 1996). Only the lowermost Jurassic floras are easier to recognise by taxonomic composition. The floras of the younger stages of the Lower Jurassic become more and more similar to those of the Middle Jurassic, making it difficult to accurately date these floras. Many specimens of plant macrofossils from the Polish Lower Jurassic were referred to species earlier described from neighbouring Germany and Sweden, which in itself is a proper procedure. Unfortunately some very well preserved specimens were referred to species whose type specimens are badly preserved and are now deemed undeterminable. Most taxa of the Lower Jurassic plants of Europe have not been

revised since their original description, and in many genera the species are oversplit. There are similar problems with the palynological data. The generic assignment of many species is in a state of flux, especially for fern and cycadoid foliage. These species have been referred to many different genera during the development of palaeobotany, complicating the task of correlating the floras of different countries described over the decades. Most determinations of macrofossil plant remains from the Lower Jurassic in Poland are based solely on macromorphological characters. Cuticular analysis has been used only recently (Grabowska 1963, Barbacka et al. 2007, 2010). The collections described by Raciborski (1891a, b, 1892a, b) and Makarewiczówna (1928) require critical revision. The determinations of plant macrofossils made by geologists are not reliable if not accompanied by descriptions and illustrations of the specimens. Continued research on the Lower Jurassic flora of Poland should yield important new data, especially about plant evolution after the Triassic-Jurassic boundary extinction, a topic now broadly discussed. The new data could help reconstruct the first ecosystems dominated by dinosaurs. Polish floras can also be expected to provide important biogeographic data concerning plant migrations in the Jurassic.

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