Early Pennsylvanian to early Permian (Bashkirian–Asselian) miospore and pollen assemblages of the Czech part of the Intra-Sudetic Basin

Jiří Bek & Stanislav Opluštil

Unpublished data resulting from extensive palynological investigation of coal and carbonaceous rocks from more than thirty boreholes, drilled in the Czech sector of the Intra-Sudetic Basin in the second half of the 20th century, were taxonomically upgraded and analysed for stratigraphic and systematic evaluation. In total 78 genera and 322 miospore and pollen species have been recorded within a radioisotopically constrained ~21 Ma long interval from middle Bashkirian to early Asselian times, *i.e.* between 318 and 297 Ma. The miospore and pollen assemblages of coal seams are characteristic by the occurrence of stratigraphically important genera (*e.g. Waltzispora*, *Radiizonates*, *Tripartites*, *Kosankeisporites*, *Gillespieisporites*, *Cadiospora*, *Angulisporites*, *Latensina*, *Lueckisporites*, *Spinosporites*) and taxa recorded only within each member with the combination of quantitative data. Five new palynozones of the basin are recognised. All miospore and pollen taxa are divided into categories based on their plant affinity for the comparison of palynological and macrofloral records in terms of the diversity and vegetation patterns based on the combination of unpublished palynological and freshly published plant fossil records. • Key words: palynology, spores and pollen, Intra-Sudetic Basin, Pennsylvanian.

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The Intra-Sudetic Basin located along the Czech-Polish border is one of the Late Palaeozoic continental basins of Variscan Europe. It is characterised by a long depositional history ranging from late Viséan to early Triassic times. While the macrofloral record from the Czech part of the basin spans a period from the late Viséan to the Asselian (Opluštil *et al*. 2017), available palynological data cover an interval from early Bashkirian (early Pennsylvanian) to the Asselian (early Permian). The basin bears economically significant coal deposits exploited systematically since the beginning of the 19th century (Tásler *et al.* 1979) to the closure of the last coal mine in 2009. Palaeontological research was a common part of the borehole and underground mine exploration during the second half of the 20th century. However, nearly all data remained archived in the form of short unpublished reports. The only exception is a monograph on the Czech part of the basin prepared by Tásler *et al*. (1979) and later by Pešek *et al.* (2001) and Pešek (2004), where the palaeontological data are performed with a low resolution of individual members and does not include all the identified taxa. In this paper we focus on previously unpublished palynological research and attempt to assemble all existing palynological data from the Czech part of the basin to provide a complete list of taxa and their precise stratigraphic ranges. This list, in turn, serves as a base for an analysis of the diversity of palynological assemblages and their comparison with macroflora diversity in the same stratigraphic intervals (Opluštil *et al*. 2017). Available CA-ID TIMS radioisotopic ages of zircons from intercalated volcaniclastic beds in the Czech part of the basin further allow for the calibration of palynozones and biotic events marked by significant changes in palynofloras and, in turn, in macrofloras (Opluštil *et al*. 2016a, b).

History of palaeontological research of the Czech part of the Intra-Sudetic Basin

The history of palaeontological research of the basin starts in the first half of the 19th century with the onset of systematic coal mining in the area. These early research activities included geological, lithostratigraphical and palaeontological observations and focused mainly on development of basin-wide lithostratigraphy. Fossil record served as an important tool for correlation of fossiliferous strata, mostly coal groups and lacustrine horizons. The thorough overview of history of the research in the basin provided Tásler *et al*. (1979), Pešek *et al.* (2001) and Opluštil *et al*. (2017).

The first megaspore research from the Czech part of the Intra-Sudetic Basin was published by Zerndt (1937) and the last by Kaiserová (1960). The review of dispersed megaspores and a short summary of some miospore results have been published by Tásler *et al*. (1979). All other reports, *i.e.* sources of data of dispersed miospore and pollen assemblages were written by Valterová (1965, 1967a–i, 1968a–d, 1969a–d, 1970, 1972, 1974, 1976, 1977a, b, 1978, 1979a–h, 1980a–e, 1981a–c, 1982a–e, 1984a, b, 1986a–n) in the form of short manuscripts, which are parts of the unpublished well reports. A summary of dispersed miospore and pollen assemblages; however, was published by Pešek *et al*. (2001). *In situ* spores were recently described from some fructifications collected in the basin (Bek & Opluštil 2004, Bek *et al.* 2008 and Opluštil *et al.* 2009).

Geology of the Czech part of the Intra-Sudetic Basin (CPISB)

The Intra-Sudetic Basin consists of the eastern part of a large complex of Late Palaeozoic continental basins of the Bohemian Massif (Fig. 1). About two-thirds of this 1800 km^2 basin is situated in Poland, the rest is on Czech territory (Fig. 1). The sedimentation in the basin started in late Viséan and including several hiatuses continued for over 80 Ma until the Triassic (Tásler *et al*. 1979, Opluštil *et al.* 2017). Detailed overview of depositional history is described by Opluštil *et al*. (2016a, 2017). Here we will only provide a brief overview of the basin's lithostratigraphy (Fig. 1). Late Viséan to early Namurian coarse-grained alluvial deposits of the Blazkow Formation are the oldest sediments from the Czech part of the basin (Opluštil *et al*. 2017). After a short break, sedimentation resumed around late Namurian times by fluvial, bedload-dominated facies of the Žacléř Formation. This deposition would continue until middle Westphalian. These coal-bearing units (Tásler *et al.* 1979) are after another short break, followed by late Westphalian to middle Stephanian fluvial red beds of the Odolov Formation, with several embedded grey coal-bearing intervals (Fig. 1). The overlying Chvaleč Formation is also mainly a red bed complex with intercalated lacustrine strata of thin coals (Tásler *et al.* 1979) spanning the late Stephanian (late Gzhelian) and early Permian (Asselian). Succession continues with early Permian fluvial red beds of the Broumov Formation with intercalated volcanic rock (both maphic and felsic) and grey lacustrine horizons. Lacustrine strata provided rich faunas and macrofloras (Pešek *et al*. 2001, Opluštil *et al*. 2017). The remaining Permian lithostratigraphic units, the Trutnov and Bohuslavice formations, were deposited after the hiatus associated with the Saale tectonic event. Neither yielded any fossil plants (Opluštil *et al*. 2017).

Material and methods

During 2012–2015 a group of Czech palaeobotanists and palynologists created the database named the MafDat (a special software) in the West Bohemian Museum in Pilsen, and included all available palynological records and all occurrences of Carboniferous/early Permian plants from the Czech part of the Intra-Sudetic Basin (Opluštil *et al.* 2017). The bulk of palynological data presented herein is represented by 62 short unpublished manuscripts (palynological reports to boreholes) of Valterová (1965, 1967a–i, 1968a–d, 1969a–d, 1970, 1972, 1974, 1976, 1977a, b, 1978, 1979a–h, 1980a–e, 1981a–c, 1982a–e, 1984a, b, and 1986a–n) supplemented by the research of the first author (in Libertín *et al*. 2009). The samples were macerated at Geoindustria Prague, an exploration company during last few decades (1965–1986). Nearly all palynological samples were mostly taken from coal seams and associated carbonaceous mudstones. Dispersed miospores and pollen were recovered by dissolving of rocks in nitric acid for 24–48 hours and KOH for 1–2 hours and washed by water several times. Miospores and pollen were classified according to the system of dispersed fossil spores suggested by Potonié & Kremp (1954, 1955), Dettmann (1963) and Smith & Butterworth (1967) by Valterová. Species in samples without specification of their percentage, or number of specimens were recorded in the database as either present or absent. Where quantitative analyses of miospores and pollen from coal seams were made by Valterová, we counted the number of miospores/pollen as a simple average mean for each sample, *i.e.* one percent was one hundredth of total summary of all miospore and pollen specimens per sample.

The stratigraphic resolution is to the scale of individual coal seams. In case of non-coal-bearing strata, stratigraphic resolution is at the level of individual lacustrine horizon. Although macroflora was recovered from red beds (Opluštil *et al*. 2017), no miospores are known from this type of lithology.

Palynological data stored in the MafDat database have been consequently exported to two Excel spreadsheets tables. In the first one (electronic supplement 1) palynospecies are plotted against the stratigraphic column with resolution of individual fossiliferous horizons,

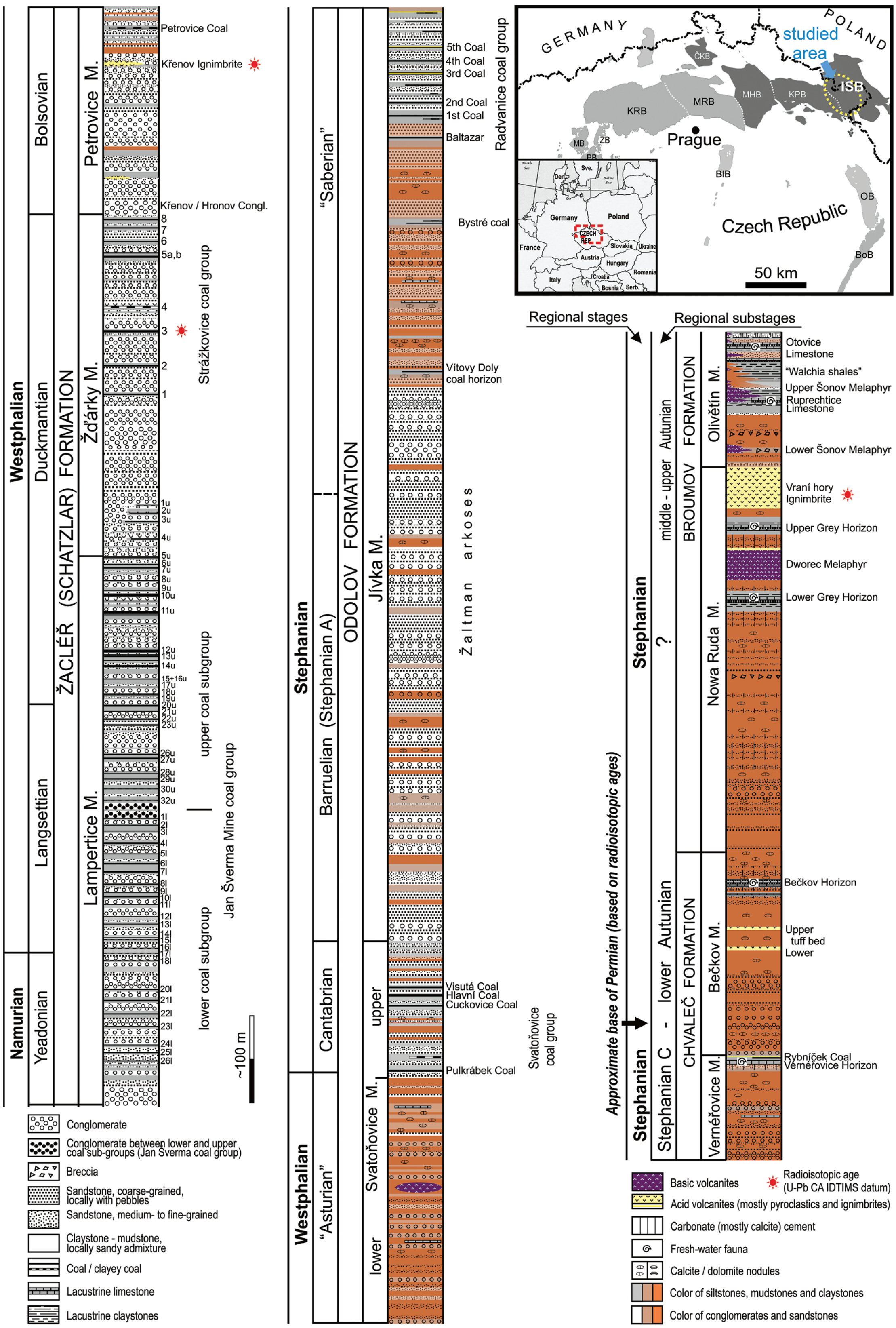

Figure 1. Lithostratigraphic subdivision of the Czech part of the Intra-Sudetic Basin. Post "Autunian" units are unfossiliferous and omited in this scheme. After Opluštil *et al*. (2016a). Abbreviation: M. – member.

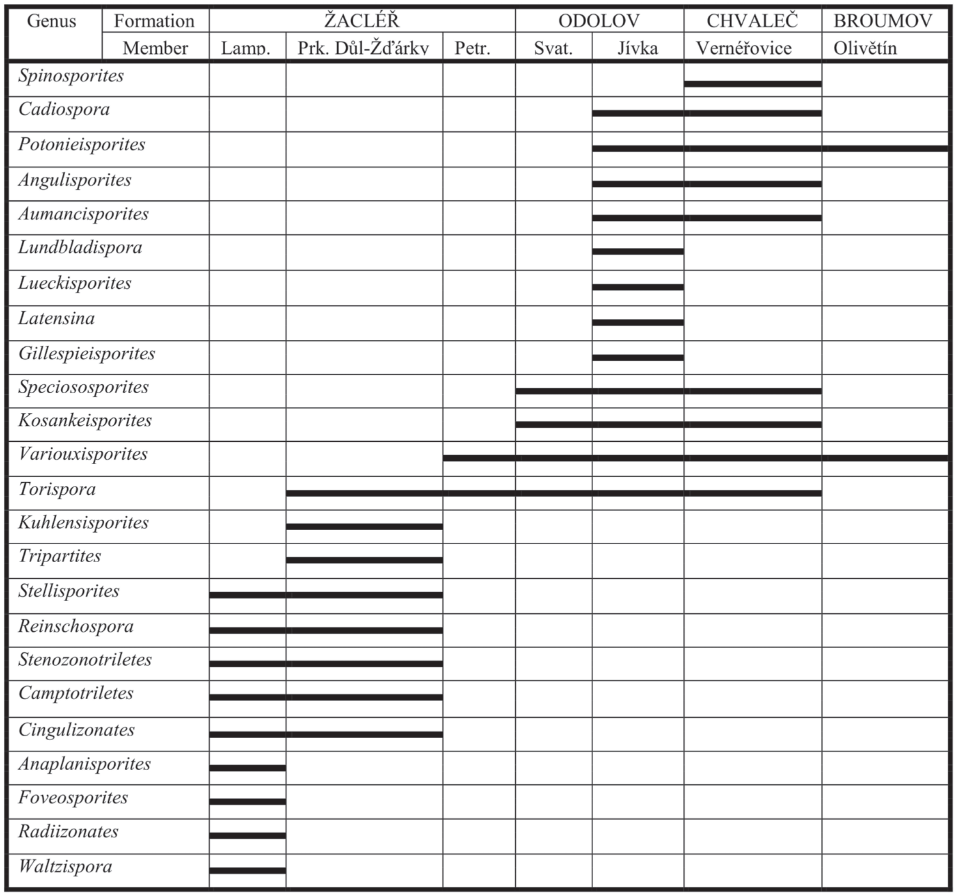

Figure 2. Gradual appearance of selected miospore and pollen genera through the profile of the Czech part of the Intra-Sudetic Basin. Abbreviations: Lamp. – Lampertice Member; Prk. Důl-Žďárky – Prkenný Důl-Žďárky Member; Petr. – Petrovice Member; Svat. – Svatoňovice Member.

usually cyclothems and lacustrine strata. This resolution is identical with that used by Opluštil *et al*. (2017) for a similar study on macroflora in the same part of the basin. The purpose is obvious – to allow palynological data to be directly comparable with similar macrofloral data (Opluštil *et al.* 2017) by individual stratigraphic intervals. Similar to the macrofloral analysis, the presence of each palynological taxon is expressed as "1" whereas its absence as "0". Empty fields between the first and last occurrences of any the taxon were subsequently filled by 1, based on assumption of continuous presence of the species in the study area, although it was not actually found at that or those levels (electronic supplement 1). To clearly distinguish between stratigraphic intervals where the taxon was found from those where its presence is only an interpretation, we marked the fields with the proved occurrence by grey colour while the fields with interpreted occurrences are white. This through-range approach to determine species richness is commonly applied in similar biostratigraphic studies and allows more reliable interpretation of biodiversities (*e.g.* Cleal 2005, Gastaldo *et al*. 2009, Cleal *et al.* 2012, Opluštil *et al*. 2017). Although such "smoothing" of the data may cause some detail in diversity change to be lost, we believe that absence of some taxa in particular level (*e.g.* coal horizon) is reflecting local-scale habitat heterogeneity, rather than the change in landscape-scale vegetation. For a further discussion on the legitimacy of using range-through data for such studies, we recommend paper of Gastaldo *et al*. (2009).

The number of species in each stratigraphic horizon was counted for larger taxonomical groups (usually families or orders and higher) based on botanical affinity to parent plants, if known. The table was consequently used for the construction of diversity curves of palynological taxa by botanical groups as well as the curve of overall diversity of palynological taxa throughout the studied interval in a similar resolution as used for macroflora (Opluštil *et al*. 2017).

The second table (electronic supplement 2) provides percentage values of individual genera plotted against stratigraphic column of the studied basin interval with the same resolution as in the electronic supplement 1. However, in this case, the fields between the first and last occurrence of the genus, where no data were available, remained empty. Data in the table has been used for the construction of graphs of percentage distribution of miospore and pollen genera throughout the studied stratigraphic interval and, in turn, for consideration of original vegetation patterns. Fig. 2 shows gradual appearance of selected miospore and pollen genera through the profile of the basin and Fig. 3 the same for miospore and pollen species.

West European regional chronostratigraphic stages and substages correlated with macrofloral biozones (Wagner 1984, Wagner & Álvarez-Vázquez 2010, Cleal 2018) are used throughout the paper instead the international chronostratigraphic stages defined dominantly on marine fauna in carbonate successions of east European Platform (Schneider *et al*. 2020). The regional ("Heerlen") stages are well defined in the Czech part of the Intra-Sudetic Basin (Opluštil *et al.* 2017) and radioisotopically constrained (Opluštil *et al*. 2016a). Their correlation to global stages is not a matter of this study, and therefore we refer readers to available summarising papers on this topic (*e.g*. Davydov *et al*. 2010, Opluštil *et al*. 2016b, Schneider *et al*. 2020).

Results

Palynological data summarised in electronic supplement 1 were obtained from 37 boreholes, several coal mines and exposures in the Czech part of the Intra-Sudetic Basin and represent 59 different stratigraphic levels. Overall diversity of palynoflora in individual stratigraphic levels varies between 8 and 158 species throughout the 21 Ma fossiliferous interval comprising Bashkirian to Asselian strata (electronic supplement; Fig. 4). Generally, high miospore and pollen diversity is typical for coal-bearing intervals with high preservation potential. In contrast, palynological record of red beds is so far absent except grey lacustrine horizons occasionally interrupting the monotonous fluvial red beds (Fig. 1). The only palynological data from these successions were obtained by interpolation between bounding fossiliferous coal-bearing or lacustrine horizons below and above.

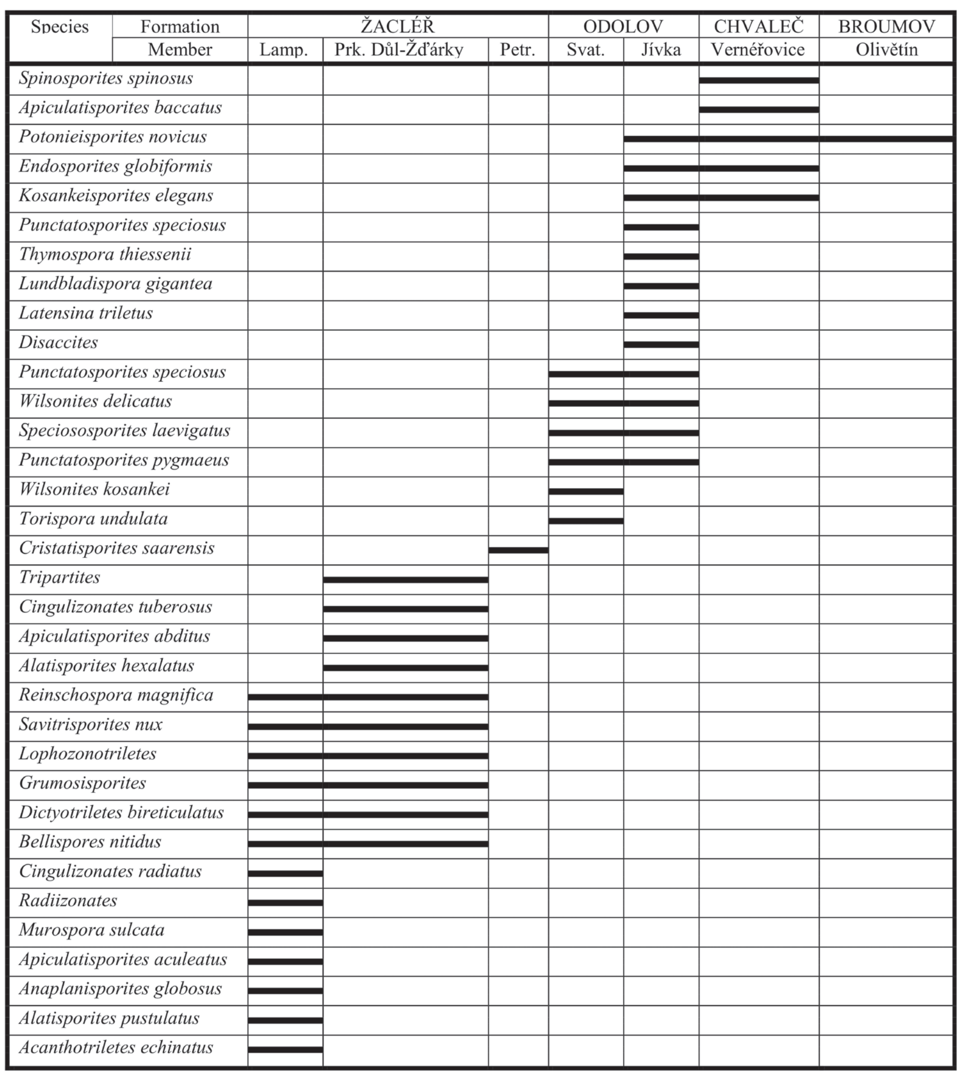

Figure 3. Gradual appearance of selected miospore and pollen species through the profile of the Czech part of the Intra-Sudetic Basin. Abbreviations: Lamp. – Lampertice Member; Prk. Důl-Žďárky – Prkenný Důl-Žďárky Member; Petr. – Petrovice Member; Svat. – Svatoňovice Member.

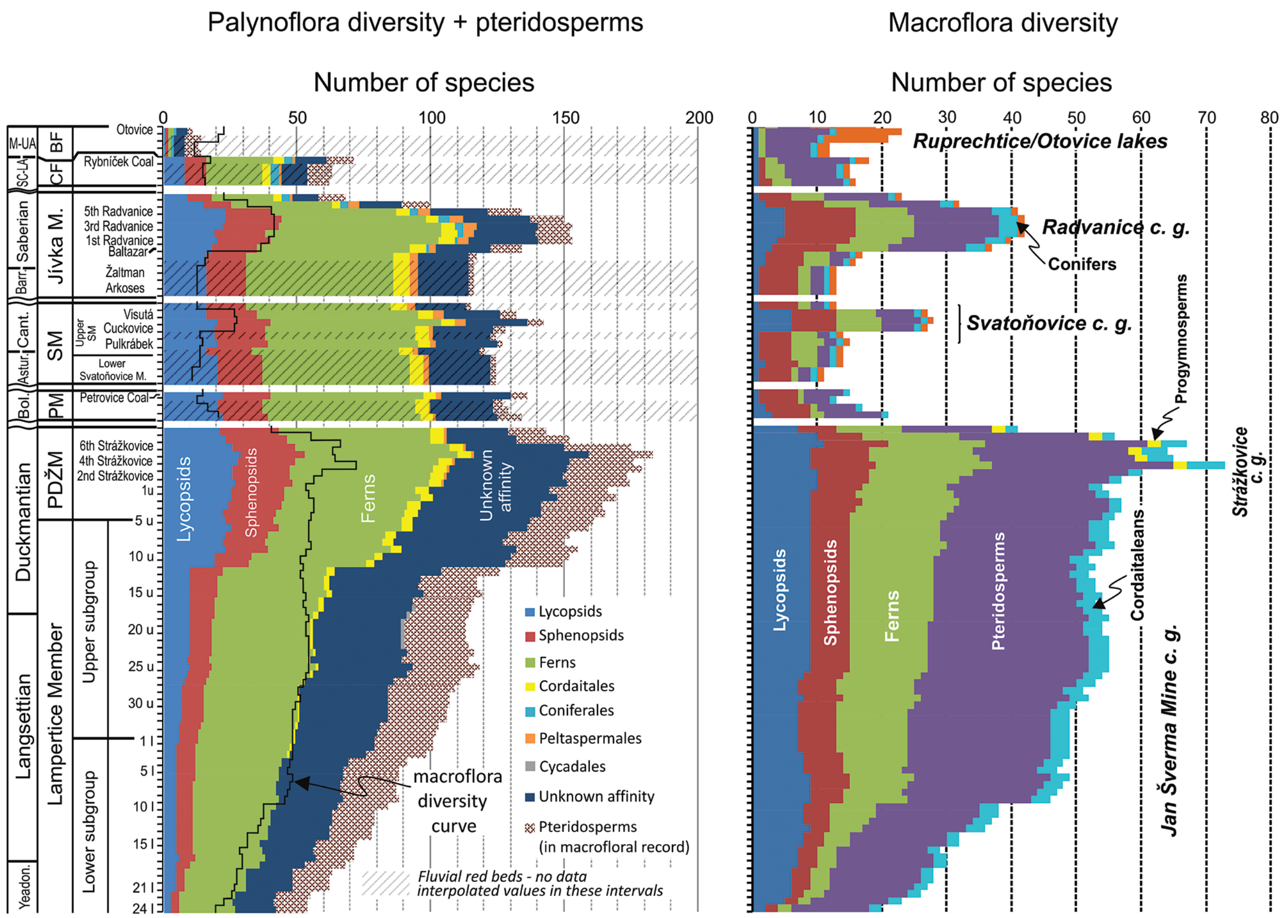

Figure 4. Comparison of diversities of miospores and macroflora in the Czech part of the Intra-Sudetic Basin. Macrofloral data adapted from Opluštil *et al.* 2017. Abbreviations: Yeadon. – Yeadonian; PDŽM – Prkenný Důl-Žďárky Member; PM – Petrovice Member; SM – Svatoňovice Member; M. – member; CF – Chvaleč Formation; BF – Broumov Formation; Bol. – Bolsovian; Astur. – Asturian; Cant. – Cantabrian; Barr. – Barruelian; SC-LA – Stephanian C–lower Autunian; M-UA – middle–upper Autunian; c. g. – coal group.

There is a gradual increase in the number of species from about 41 to 48 at the base of the Lampertice Member (= base of the studied succession), up to 103 species at the 12th coal of the upper subgroup (Fig. 4). Between the 12th and 11th coal of the upper subgroup 24 new taxa, mostly lycopsid and sphenopsid miospores, appear and the assemblage of this interval reaches 127 species (electronic supplement 1, Figs 4, 5). Above this level the overall diversity increases up to its maximum of 158 species at the 5th Strážkovice Coal in the upper part of the Prkenný Důl-Žďárky Member (upper Duckmantian). It is followed by drop to 128 species recorded between the 5th and the 8th Strážkovice coals at the top of the Prkenný Důl-Žďárky Member.

Following upwards, there is a thick fossil-barren interval up to base of the Svatoňovice coal group (Cantabrian) where only interpolated values for palynoflora diversity are available, except for the Petrovice Coal in the uppermost part of the Petrovice Member (Bolsovian). Interpolated values in red beds, however, surprisingly suggest presence of 121 palynospecies (Fig. 4), whereas in the Petrovice Coal and Svatoňovice coal group the diversity increases to 124–135 species. At the top of the coal group another drop of diversity is observed and ~113 species (interpolated values) are counted. These values are constant throughout the Barruelian to the lower Saberian red beds of the Jívka Member. The Radvanice coal group (Saberian) in the upper part of the Jívka member marks the second maximum in diversity (134–139 species). Following upwards, the diversity drastically decreases to approximately 57 species at top of this member due to unfavourable conditions for preservation (electronic supplement 1, Fig. 4). These low diversity values persist also in the Vernéřovice Member of the Chvaleč Formation (Stephanian C–lower Autunian). The Asselian strata above are poorly fossiliferous except for a few lacustrine horizons in the in the Olivětín Member, which provided about 8–9 species – the lowest values of all.

Generally, dispersed miospore and pollen assemblages from individual samples are not very rich in the number of specimens. Locally, however, palynological assemblages from some members are richer (Lampertice, Prkenný Důl-Ždárky and Jívka) than from others (Petrovice, Vernéřovice and Olivětín). Dispersed miospore and pollen assemblages from the Czech part of the Intra-Sudetic Basin can be divided into stratigraphically long-ranging of low stratigraphic value and stratigraphically important taxa. Long-ranging taxa (quantitatively variable) included genera *Calamospora* Schopf *et al.*, *Leiotriletes* (Naumova) Potonié & Kremp, *Granulatisporites* (Ibrahim) Potonié & Kremp, *Punctatisporites* (Ibrahim) Potonié & Kremp, *Apiculatisporites* (Ibrahim) Potonié & Kremp, *Florinites* Schopf *et al.*, *Laevigatosporites* (Ibrahim) Potonié & Kremp, *Latosporites* Potonié & Kremp, *Lophotriletes* (Naumova) Potonié & Kremp, *Lycospora* (Schopf *et al.*) Potonié & Kremp, *Raistrickia* (Schopf *et al.*) Potonié & Kremp, *Savitrisporites* Bharadwaj and *Triquitrites* (Wilson & Coe) Potonié & Kremp. Most of these genera are also relatively common; sometimes even abundant (*Lycospora*, *Calamospora* and *Laevigatosporites*).

Genera *Waltzispora* Staplin, *Radiizonates* Staplin & Jansonius, *Murospora* Somers, *Camptotriletes* (Naumova) Potonié & Kremp, *Anaplanisporites* Jansonius, *Reinschospora* Schopf *et al.*, *Stellisporites* Alpern, *Tripartites* (Schemel) Potonié & Kremp, *Gillespieisporites* Clendening, *Angulisporites* Bharadwaj, *Lueckisporites* (Potonié & Klaus) Jansonius, *Latensina* Alpern, *Cadiospora* (Kosanke) Turner and *Spinosporites* Alpern are the most stratigraphically important taxa. Palaeoecologically important taxa included *Lycospora*, *Densosporites* (Berry) Butterworth *et al.*, *Florinites*, smallest monolete species of genera *Laevigatosporites*, *Latosporites*, *Speciososporites* Potonié & Kremp, *Punctatosporites* Ibrahim, *Thymospora* Wilson & Venkatachala and *Torispora* Balme.

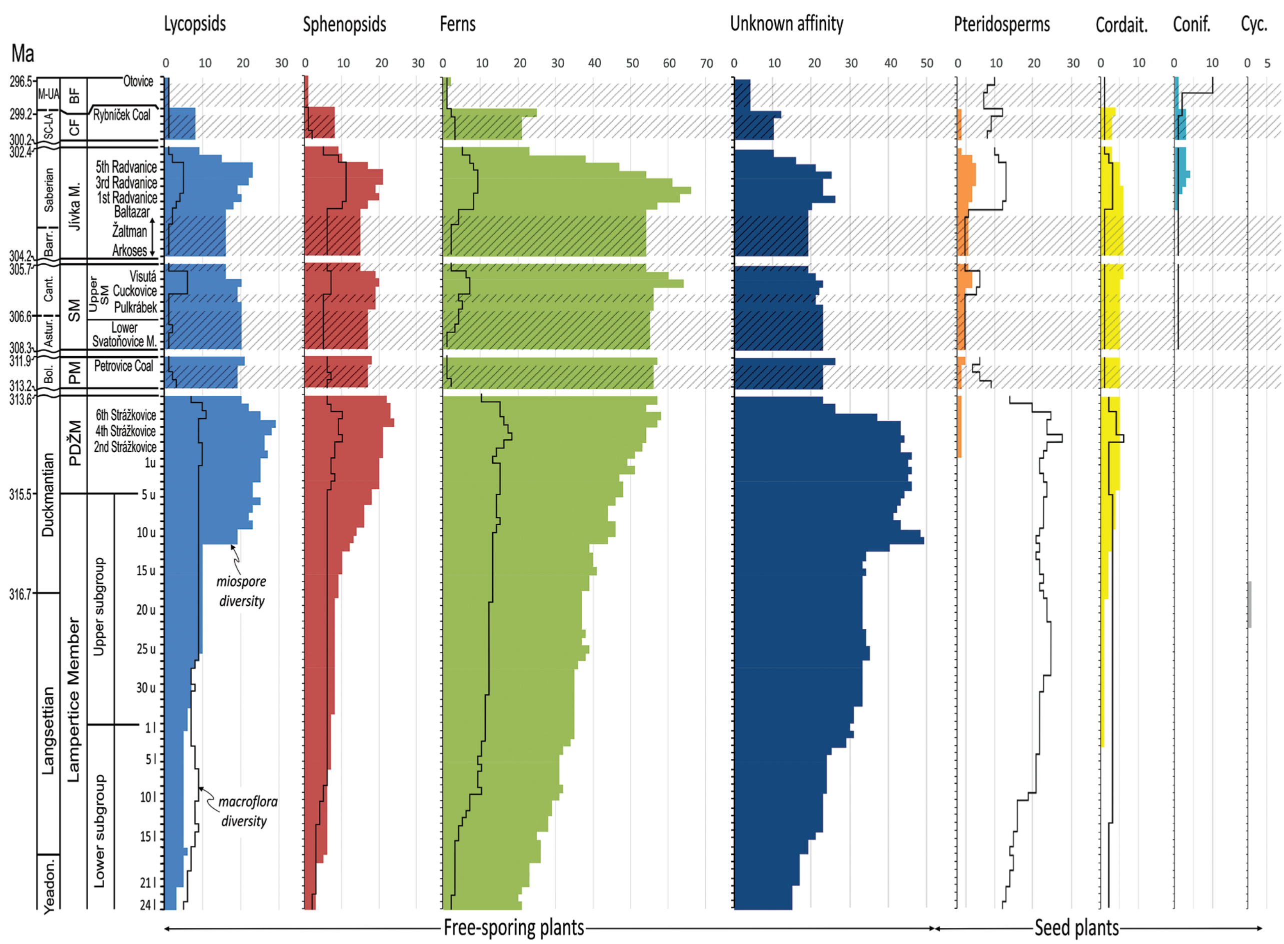

Figure 5. Miospore diversity of major plant groups and comparison with diversity of the same groups in macrofloral record (Opluštil *et al.* 2017) in the Czech part of the Intra-Sudetic Basin. Abbreviations: Yeadon. – Yeadonian; PDŽM – Prkenný Důl-Žďárky Member; PM – Petrovice Member; SM – Svatoňovice Member; M. – member; CF – Chvaleč Formation; BF – Broumov Formation; Bol. – Bolsovian; Astur. – Asturian; Cant. – Cantabrian; Barr. – Barruelian; SC-LA – Stephanian C–lower Autunian; M-UA – middle–upper Autunian; Cordait. – Cordaitales; Coniferales; Cyc. – Cycadales.

Palynology of the Czech part of the Intra-Sudetic Basin

Lampertice Member

The Lampertice Member stratigraphically covers the interval from the late Namurian (Yeadonian), the whole Langsettian and the early Duckmantian. Dispersed miospore and pollen assemblage consists of 177 species belonging to 56 genera and is the richest (together with that from the Prkenný Důl-Žďárky Member) of all members. Thirty-eight species are restricted to this interval (Tab. 1). The percentage of some genera increased from the bottom to the top of the member, *e.g.* *Densosporites* (max. 30% at the 10th upper coal seam of the Lampertice Member), *Cirratriradites* Wilson & Coe (from the 11th upper coal seam of the Lampertice Member), *Laevigatosporites* and *Latosporites* (bigger than 35 μm), *Ahrensisporites* Potonié & Kremp, *Apiculatisporites* and *Florinites*. The genera *Converrucosisporites* Potonié & Kremp, *Lophotriletes*, *Granulatisporites*, *Leiotriletes*, *Triquitrites*, *Dictyotriletes* (Naumova) Smith & Butterworth, *Pustulatisporites* Potonié & Kremp and *Savitrisporites* are the most abundant at this level (electronic supplement 2). It is interesting to note that the first appearance of the genus *Endosporites* Wilson & Coe within 7th upper coal seam is simultaneously its highest local percentage (21%) in the whole basin providing the evidence on local concentration of sub-arborescent lycopsids of the *Polysporia* type. Kalibová (in Tásler *et al*. 1979) mentioned the occurrence of only seven megaspore taxa including the species *Lagenoisporites rugosus* (Loose) Potonié & Kremp, *Cystosporites giganteus* (Zerndt) Schopf, *Tuberculatisporites mamillarius* (Bartlett) Potonié & Kremp, *Triangulatisporites triangulatus* (Zerndt) Potonié & Kremp, *Bentzisporites tricollinus* (Zerndt) Potonié & Kremp, *Spencerisporites gracilis* (Zerndt) Winslow and *Pseudovalvisisporites* spp.

Prkenný Důl-Žďárky Member

The Prkenný Důl-Žďárky Member stratigraphically belongs to the later part of Duckmantian. Its miospore and pollen assemblage is the richest of all members (together with that from the Lampertice Member) with 177 species belonging to 56 genera. The most abundant genera are *Densosporites* (16% on average), *Lycospora* (15% on average) and *Savitrisporites* (6% on average). Twenty-two

Table 1. The list of dispersed miospores and pollen from the Czech part of the Intra-Sudetic Basin that occur only in one member.

Formation	Member	Miospore and pollen species
Chvaleč	Vernéřovice	*Apiculatisporites baccatus*, *A. baccatus* f. *trebechovensis*, *Florinites piérartii*, *Punctatisporites provectus*, *Spinosporites spinosus*, *Thymospora verrucosa*
Odolov	Jívka	*Anapiculatisporites conatus*, *Apiculatisporites latigranifer*, *Aumancisporites striatus*, *Cadiospora magna* f. *maior*, *C. magna* f. *minor*, *C. magna* f. *plicata*, *C. sphaera*, *Crassispora ovalis*, *C. plicata*, *C. pergranulus*, *Disaccites* spp., *Endosporites grandisaccus*, *Gillespieisporites discoideus*, *G. spinosus*, *Guthoerlisporites magnificus*, *Illinites unicus*, *Latensina triletus*, *Lundbladispora gigantea, Lueckisporites* spp., *Punctatosporites bechlinensis*, *P. oculus*, *P. speciosus*, *Raistrickia aculeolata*, *Speciososporites plicatus*, *Thymospora thiessenii*, *Verrucosisporites donarii*, *V. grandiverrucosus*, *V. verrucosus*, *Wilsonites vesicatus*
	Svatoňovice	*Cirratriradites annulatus*, *Lycospora micrograna*, *Torispora granulata*, *T. undulata*, *Triquitrites pulvinatus*, *Wilsonites kosankei*
Žacléř	Petrovice	*Cristatisporites saarensis*
	Prkenný Důl-Ždárky	*Acanthotriletes triquetrus*, *Alatisporites hexalatus*, *Apiculatisporites abditus*, *Cingulizonates tuberosus*, *Cirratriradites flabelliformis*, *Convolutispora jugosa*, *Cristatisporites indignabundus*, *Dictyotriletes falsus*, *Florinites antiquus*, *Kuhlensisporites* spp., *Lycospora triangulata*, *Reinschospora magnifica*, *Stenozonotriletes lycosporoides*, *Tripartites* spp., *Vestispora magna*, *V. laevigata*
	Lampertice	*Acanthotriletes acerosus*, *A. falcatus*, *A. echinatus*, *A. microspinosus*, *Alatisporites pustulatus*, *A. trialatus*, *Anapiculatisporites minor*, *Anaplanisporites globulus*, *Apiculatisporites aculeatus*, *Camptotriletes juglandilis*, *Calamospora perrugosa*, *Cingulizonates loricatus*, *Cirratriradites rarus*, *Converrucosisporites armatus*, *Convolutispora varicosa*, *C. tessellata*, *Crassispora maculosa*, *Cyclogranisporites pressoides*, *Densosporites lobatus*, *D. triangularis*, *Dictyotriletes reticulocingulum*, *Endosporites magnificus*, *Foveosporites* spp., *Lycospora parva*, *Microreticulatisporites reticuloides*, *Murospora sulcata*, *Punctatisporites aerarius*, *Radiizonates* spp., *Raistrickia carbondalensis*, *R. crinita*, *R. microhorrida*, *Remysporites magnificus, Reticulatisporites adhaerens*, *Savitrisporites majus*, *Simozonotriletes majus*, *Stenozonotriletes commendatus*, *S. reticulatus*, *Waltzispora* spp.

species are restricted to this interval (Tab. 1). Some taxa make their first appearance here, *e.g. Anapiculatisporites spinosus* (Kosanke) Potonié & Kremp, *Vestispora laevigata* Wilson & Venkatachala, *V. quaesita* (Kosanke) Wilson & Venkatachala, *Punctatosporites granifer* Potonié & Kremp, *P. punctatus* (Kosanke) Alpern & Doubinger, *Torispora securis* Balme, *Endosporites formosus* Kosanke, *Cyclogranisporites jelenicensis* Kalibová, *Kuhlensisporites* spp. and *Westphalensisporites irregularis* Alpern. Interesting is the local abundance of the genus *Densosporites* in the lower part of the Strážkovice Group of coals is notable with 63% on average within 2nd and 3rd Strážkovice Coal Seams. *Endosporites, Latosporites* (smaller than 35 μm), *Vestispora* (Wilson & Hoffmeister) Wilson & Venkatachala and *Leiotriletes* are all the most abundant in the 4th Strážkovice Coal Seam with 12, 12, 13 and 10% respectively. The genus *Punctatosporites* reaches its maximum within the 8th Strážkovice Coal Seam, *i.e.* the last coal seam of the member. The percentage of the genera *Florinites* and *Savitrisporites* increases from the bottom to the top of the member while *Densosporites* and *Vestispora* decrease within the same interval. Megaspores of the Prkenný Důl-Žďárky Member (Kalibová *in* Tásler *et al*. 1979) are the same as those from the Lampertice Member except for *Triletisporites bohemicus* Kalibová that appears for the first time at this level. The most abundant megaspore species is *Lagenoisporites rugosus.*

Petrovice Member

The Petrovice Member represents strata of Bolsovian age which are mostly fossil-poor beds with dominant red beds, except the upper part where locally developed thin coal and associated grey mudstones occur. Dispersed miospore and pollen assemblage of this interval yielded a low number of taxa because only 111 species belonging to 43 genera. *Cristatisporites saarensis* Bharadwaj is recorded only at this level and *Thymospora obscura* (Kosanke) Wilson & Venkatachala, *Variouxisporites* spp. and *Vittatina* spp. make their first appearance at this level while *Knoxisporites polygonalis* (Ibrahim) Potonié & Kremp has its last occurrence. One of stratigraphically most important taxa is *Vestispora fenestrata* (Kosanke & Brokaw) Spode in Smith & Butterworth. No megaspores are described from the Petrovice Member.

Svatoňovice Member

The Svatoňovice Member stratigraphically corresponds to the Asturian and Cantabrian. Dispersed miospore and pollen assemblage consists of 130 species that belong to 45 genera. Five species are restricted to this interval including *Cirratriradites annulatus* Kosanke & Brokaw *in* Kosanke, *C. flabelliformis* Wilson & Kosanke, *Torispora granulata* Alpern, *T. undulata* Dybová & Jachowicz and *Triquitrites pulvinatus* Kosanke. Some species make their first occurrence here, *e.g. Punctatosporites granulatus* Bharadwaj, *P. pygmaeus* (Imgrund) Potonié & Kremp, *P. rotundus* (Bharadwaj) Dybová & Jachowicz, *Verrucosisporites sinensis* Imgrund, *Wilsonites delicatus* (Kosanke) Kosanke and *Variouxisporites plicatus* Alpern. Only three palynological samples from this member were quantitatively evaluated (Pulkrábek, Main and Visutá coal seams), therefore the data source is limited. The megaspore assemblage is similar to that of the Lampertice Member but four new species appear, *Laevigatisporites glabratus* (Zerndt) Potonié & Kremp, *Valvisisporites auritus* (Zerndt) Potonié & Kremp, *Cystosporites varius* (Wicher) Dijkstra and *Triletisporites tuberculatus* (Zerndt) Potonié & Kremp that make their first appearance here (Kalibová *in* Tásler *et al.* 1979).

Jívka Member

The Jívka Member stratigraphically ranges Barrualian and Saberian ages. Dispersed miospore and pollen assemblage of the Jívka Member consists of 160 species belonging to 50 genera. Thirty-nine species are restricted to this member (Tab. 1). Some species appear here for the first time, *e.g. Apiculatisporites conatus* Kalibová, *Cadiospora magna* Kosanke including forms *maior* Kalibová, *minor* Kalibová and *plicata* Kalibová. It is interesting to note the decrease of *Lycospora* from the base to the top of the member. The most abundant megaspore species are *Valvisisporites auritus* and *Lagenoisporites levis* Zerndt (Kalibová *in* Tásler *et al.* 1979). Other megaspore taxa are *Calamospora* spp., *Triangulatisporites triangulatus*, *Cystosporites giganteus*, *Spencerisporites gracilis*, *Laevigatisporites glabratus* and *Monoletes ellipsoides* Ibrahim.

Vernéřovice Member

The Vernéřovice Member is composed of red beds of the late Gzhelian (latest Stephanian to early Autunian) age. Dispersed miospore and pollen assemblages of this member consist of 29 genera with 60 species. No megaspores have been reported from the Vernéřovice Member (Kalibová *in* Tásler *et al*. 1979).

Olivětín Member

The Olivětín Member represents rocks of the late Asselian (middle–late Autunian) age. Only eleven miospore and pollen species were reported from this member: *Lycospora* spp, *Vestispora* spp., *Punctatosporites granulatus*, *Lophotriletes mosaicus* Potonié & Kremp, *Potoniei-*

Table 2. Affinity of all miospore and pollen genera recorded in the Czech part of the Intra-Sudetic Basin (based on Balme 1995 and Bek 1998, 2017).

Plant groups/parent genera		Spores and pollen genera
Lycopsids	Arborescent	*Cadiospora*, *Crassispora*, *Lycospora*
	Sub-arborescent	*Cristatisporites*, *Densosporites*, *Endosporites*
	Herbaceous	*Anapiculatisporites*, *Cingulizonates*, *Cirratriradites*, *Lundbladispora*
Sphenopsids	Calamitales	*Calamospora*
	Sphenophyllales	*Dictyotriletes muricatus*, *Laevigatosporites* and *Latosporites* (more than 35 µm), *Punctatisporites obesus*, *Reticulatasporites*, *Vestispora*
Ferns	Marratiales	*Laevigatosporites* (< 35 µm), *Latosporites* (< 35 µm), *Punctatosporites*, *Speciosporites*, *Torispora*, *Thymospora*, *Verrucosisporites*, *Cyclogranisporites*, *Punctatisporites* (except for *P. obesus*), *Tuberculatosporites*
	Zygopteridales	*Convolutispora*, *Verrucosisporites*, *Apiculatasporites*, *Apiculatisporites*, *Punctatisporites* (except for *P. obesus*), *Cyclogranisporites*
	Botryopteridales	*Verrucosisporites*, *Convolutispora*, *Camptotriletes*, *Microreticulatisporites*, *Raistrickia*, *Lophotriletes*, *Granulatisporites*, *Cyclogranisporites*
	Gleicheniales	*Triquitrites*, *Leiotriletes*
Gymnosperms	Cordaitales	*Florinites*
	Coniferales	*Lueckisporites*, *Potonieisporites*
	Cycadales	*Remysporites*
	Peltaspermales	*Vittatina*, *Wilsonites*, *Guthoerlisporites*
Unknown origin		*Acanthotriletes*, *Ahrensisporites*, *Alatisporites*, *Anaplanisporites*, *Angulisporites*, *Bellispores*, *Converrucosisporites*, *Dictyotriletes*, *Disaccites*, *Euryzonotriletes*, *Foveosporites*, *Gillespieisporites*, *Grumosisporites*, *Illinites*, *Knoxisporites*, *Kosankeisporites*, *Kuhlensisporites*, *Latensina*, *Lophozonotriletes*, *Mooreisporites*, *Murospora*, *Planisporites*, *Polymorphisporites*, *Pustulatisporites*, *Radiizonates*, *Reinschospora*, *Reticulatisporites* (except for *R. muricatus*), *Savitrisporites*, *Simozonotriletes*, *Sinuspores*, *Spinosporites*, *Stellisporites*, *Stenozonotriletes*, *Variouxisporites*, *Westphalensisporites*

Table 3. Percentage of miospores and pollen of main plants groups in all members in the Czech part of the Intra-Sudetic Basin. Abbreviations: Lamp. – Lampertice Member; Prk. Důl – Prkenný Důl Member; Petr. – Petrovice Member; Svat. – Svatoňovice Member; Vern. – Vernéřovice; Od. – Odolov Formation.

Plant group		Lamp.	Prk. Důl	Petr.	Svat.	Jívka	Vern.	Od.	Generally
Lycopsids	Arborescent	6	5	5	4	7	7	11	6.5
	Sub-arborescent	8	7	5	4	5	0	0	4.1
	Herbaceous	5	5	5	4	2	0	0	3.0
Sphenopsids	Calamites	1	2	3	2	2	3	0	1.9
	Sphenophylls	5	7	5	8	4	4	0	4.8
Ferns		31	30	40	42	34	49	22	35.4
Noeggerathiopsids		2	3	5	4	3	7	0	3.4
Gymnosperms		1	5	3	8	8	10	0	5.0
Conifers		0	0	0	0	3	3	11	2.4
Unknown origin		41	36	29	24	32	17	56	33.5

sporites novicus Bharadwaj, *Ahrensisporites angulatus* (Kosanke) Dybová & Jachowicz, *Ahrensisporites* spp., *Converrucosisporites* spp., *Gillespieisporites* spp. and *Kosankeisporites* spp. and all records represent only one specimen. No megaspores have been described from the Vernéřovice Member (Kalibová *in* Tásler *et al.* 1979).

Reconstruction of plant assemblages

It is possible to divide all dispersed miospores and pollen into several groups based on their parent plants. Table 2 shows the affinity (lycopsids, sphenopsids, ferns, gymnosperms including cordaites, conifers, cycadaleans and pteridosperms) of all miospore and pollen genera including a group with unknown producers. The percentage of miospores and pollen of main plant groups within the profile is shown in Tab. 3.

The percentage of some miospore genera produced by ferns of different groups is divided equally according to the number of groups of their producers. Fifty percent of *Convolutispora* Hoffmeister *et al.* is divided between zygopterids and botryopterids and *Punctatisporites* into marattialeans and zygopterids. Thirty-three percent of *Cyclogranisporites* Potonié & Kremp and *Verrucosisporites* (Ibrahim) Smith & Butterworth is divided among marattialeans, zygopterids and botryopterids. Monolete laevigate miospores of the *Laevigatosporites* and *Latosporites* types are divided based on their diameter that corresponds with their different plant producers. Specimens smaller than 35 µm [*Laevigatosporites minimus* (Wilson & Coe) Schopf *et al.* and *Latosporites globosus* Schemel)] belong to marattialeans (Balme 1995) all others are assigned to sphenophylls (Libertín *et al.* 2014). *Calamospora* is interpreted as sphenopsid miospore because other possible *Calamospora*-producers were not recognised in the basin.

Lycopsid spores

It is possible to divide lycopsid miospores into three main groups based on different morphological type/habit of their producers; miospores of arborescent [*Lycospora*, *Crassispora* (Bharadwaj) Sullivan and *Cadiospora*], sub-arborescent [*Densosporites*, *Endosporites* and *Cristatisporites* (Potonié & Kremp) Staplin & Jansonius] and herbaceous [*Cirratriradites*, *Cingulizonates* (Dybová & Jachowicz) Butterworth *et al.*, *Lundbladispora* (Balme) Playford) and *Anapiculatisporites* Potonié & Kremp] forms (electronic supplement 1, 2; Tab. 3). In the macrofloral record, lycopsid diversity is highest during the Langsettian and Duckmantian, where nine species of lepidodendrids and sigillarians make between 15 and 25% of the total diversity (Opluštil *et al*. 2017). It corresponds with the occurrence of *Lycospora* that makes 30% on average from all miospores of the Lampertice Member with maximum occurrences of 68 and 92% in the 26th and 33rd upper coal seams respectively (Fig. 6). Generally, *Lycospora* is more abundant in older strata of the Lampertice Member than in the Prkenný Důl-Žďárky (14%), Svatoňovice (11%) and Jívka (10%) members. It suggests a distinctive decline of their producers, *i.e.* arborescent lycopsids of the genera *Lepidodendron* Sternberg and *Lepidophloios* Sternberg from the Langsettian to the Cantabrian that is also confirmed by the macrofloral record (Opluštil *et al*. 2017). *Crassispora* and *Cadiospora* genera make their first appearance higher in the Prkenný Důl-Žďárky Member but are much rarer, especially within the Prkenný Důl-Žďárky Member. *Crassispora* produced by sigillarians (Balme 1995) has its maximum occurrence within the Jívka Member (only 3%) and *Cadiospora* – produced by sigillarians bearing cones of the *Thomasostrobus* type (Opluštil *et al*. 2009) – within the Prkenný Důl-Žďárky Member (only 2%). In the Bolsovian red bed interval of the Petrovice Member, the number of lycopsid species gradually decreases to less than five reaching ~7% of the total plant diversity and remains at similar values throughout most of the late Moscovian and late Pennsylvanian (Fig. 6). The only exceptions are coal-bearing intervals of the Svatoňovice (Cantabrian) and Radvanice (Saberian) groups, where number of taxa of arborescent lycopsids and their percentage within the entire diversity approaches Langsettian and Duckmantian values (Opluštil *et al*. 2017). However, as these authors pointed out, in these Stephanian windows of preservation, species composition of lycopsids and their small populations, expressed by general rarity of their compressions, contrast significantly with their richness and composition in Langsettian and Duckmantian macrofloras. In contrast, diversity of lycopsids in the palynological record shows an opposite trend where lowest values are typical of Langsettian to early Duckmantian times. Diversity significantly increases earlier than mid Duckmantian (Fig. 6) and reaches its maximum (~25% of all diversity) in the late Duckmantian Strážkovice coal group with subsequent minor drop to 20% at the top of that coal group. This prominent rise is due to an increase in number of miospore taxa produced by arborescent (lepidodendrids) and sub-arborescent lycopsids. Values between 15 and 20% persist throughout the most of the late Pennsylvanian. Together with macrofloral record suggests that lepidodendrid lycopsids were part of the wetland ecosystems until the latest Gzhelian (Opluštil *et al*. 2017). In palynological data, however, *Lycospora* occurs even in strata of Asselian age (electronic supplement 1, Fig. 7) and thus may indicate survival of their producers until early Permian times. Palynological record also confirms the presence of sub-arborescent and herbaceous lycopsids, the remains of which in compression record are exceptional (Bek *et al*. 2009, 2015; Opluštil *et al*. 2017). Miospores of sub-arborescent lycopsids belong to rare spore types with only 6% on average from the Lampertice to the Jívka members and maximum 18% within the Prkenný Důl-Žďárky Member. Miospores produced by herbaceous lycopsids

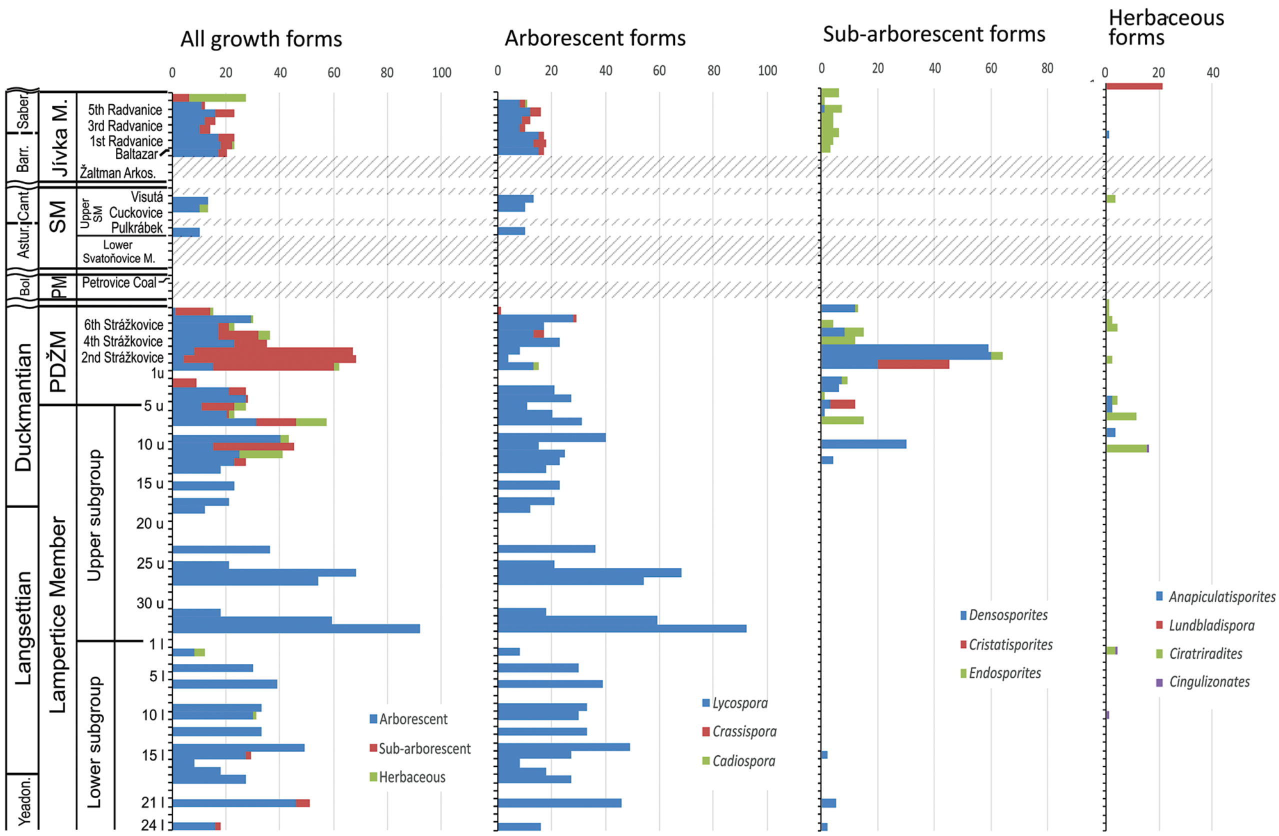

Figure 6. Percentage abundancy of lycopsid miospores in the Intra-Sudetic Basin. Abbreviations: Yeadon. – Yeadonian; PDŽM – Prkenný Důl-Žďárky Member; PM – Petrovice Member; SM – Svatoňovice Member; M. – member; CF – Chvaleč Formation; BF – Broumov Formation; Bol. – Bolsovian; Astur. – Asturian; Cant. – Cantabrian; Barr. – Barruelian; Saber. – Saberian.

are even rarer with 1.75% on average from the Lampertice to the Jívka members. A slightly increasing occurrence is recorded within the Jívka Member (3%). Miospores of lycopsids make up almost 30% on average from the Lampertice to the Jívka members with the highest occurrence within the Prkenný Důl-Žďárky members (36%).

The general pattern of lycopsid miospores is their decrease from the Lampertice (34% on average), Prkenný Důl-Žďárky (14% on average), Svatoňovice (11% on average) to the Jívka Member (10% on average). Megaspores assemblages of the Lampertice and Prkenný Důl-Žďárky members are very similar (Kalibová *in* Tásler *et al.* 1979). The most abundant are megaspores produced by flemingitacean arborescent forms that correspond with the miospore record. Seed-like megaspores of the *Cystosporites* type produced by arborescent lycopsids of the *Lepidocarpon* and *Achlamydocarpon* types occurred from the Lampertice to the Jívka members, but their "male counterparts", *i.e.* miospores of the *Cappasporites* type have never been described in the basin. The occurrence of megaspores of other groups of sigillarians is the same (*Crassispora* miospores). Miospores produced by sub-arborescent lycopsids of the *Polysporia* type occur from the upper part of the Lampertice Member but their megaspores are recoded in the Prkenný Důl-Žďárky Member for the first time. It is interesting to note that megaspores of other sub-arborescent lycopsids of the *Omphalophloios* type have never been recorded, although its miospores of the *Densosporites/Cristatisporites* types are recorded in the entire profile and reach local maximum (up to 65%) in the Prkenný Důl-Žďárky Member. Although sub-arborescent lycopsids of the *Spencerites* type are not recorded in the basin, their spores (sometimes referred to megaspores or isospores) of the *Spencerisporites* type are known from the Lampertice to the Jívka members. Megaspores of the *Triangulatisporites* and *Bentzisporites* types produced by herbaceous lycopsids of the *Selaginella* type occur from the Lampertice to the Jívka members that correspond with ranges of their miospores of the *Cirratriradites* and *Lundbladispora* types.

Sphenopsid spores

Miospores of sphenopsids are divided into two groups (electronic supplement 1; Figs 8, 9); calamitean (*Calamo-*

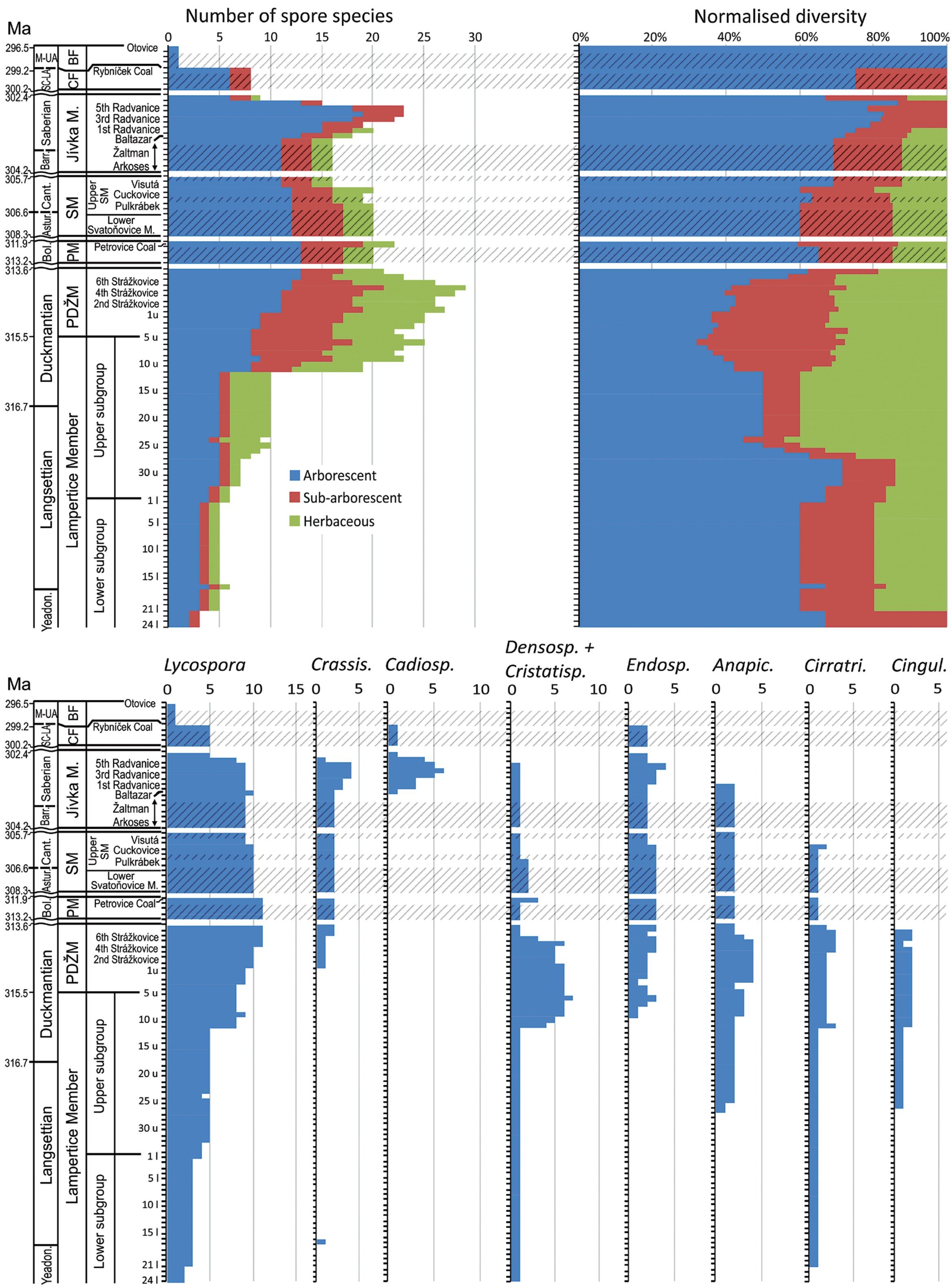

Figure 7. Species diversity of lycopsid miospores in the Czech part of the Intra-Sudetic Basin. Abbreviations: Yeadon. – Yeadonian; PDŽM – Prkenný Důl-Žďárky Member; PM – Petrovice Member; SM – Svatoňovice Member; M. – member; CF – Chvaleč Formation; BF – Broumov Formation; Bol. – Bolsovian; Astur. – Asturian; Cant. – Cantabrian; Barr. – Barruelian; Saber. – Saberian; SC-LA – Stephanian C–lower Autunian; M-UA – middle–upper Autunian; *Crassis. – Crassispora*; *Cadiosp. – Cadiospora*; *Densosp. – Densosporites*; *Cristatisp. – Cristatisporites*; *Endosp. – Endosporites*; *Anapic. – Anapiculatisporites*; *Cirratri. – Cirratriradites*; *Cingul. – Cingulizonates*.

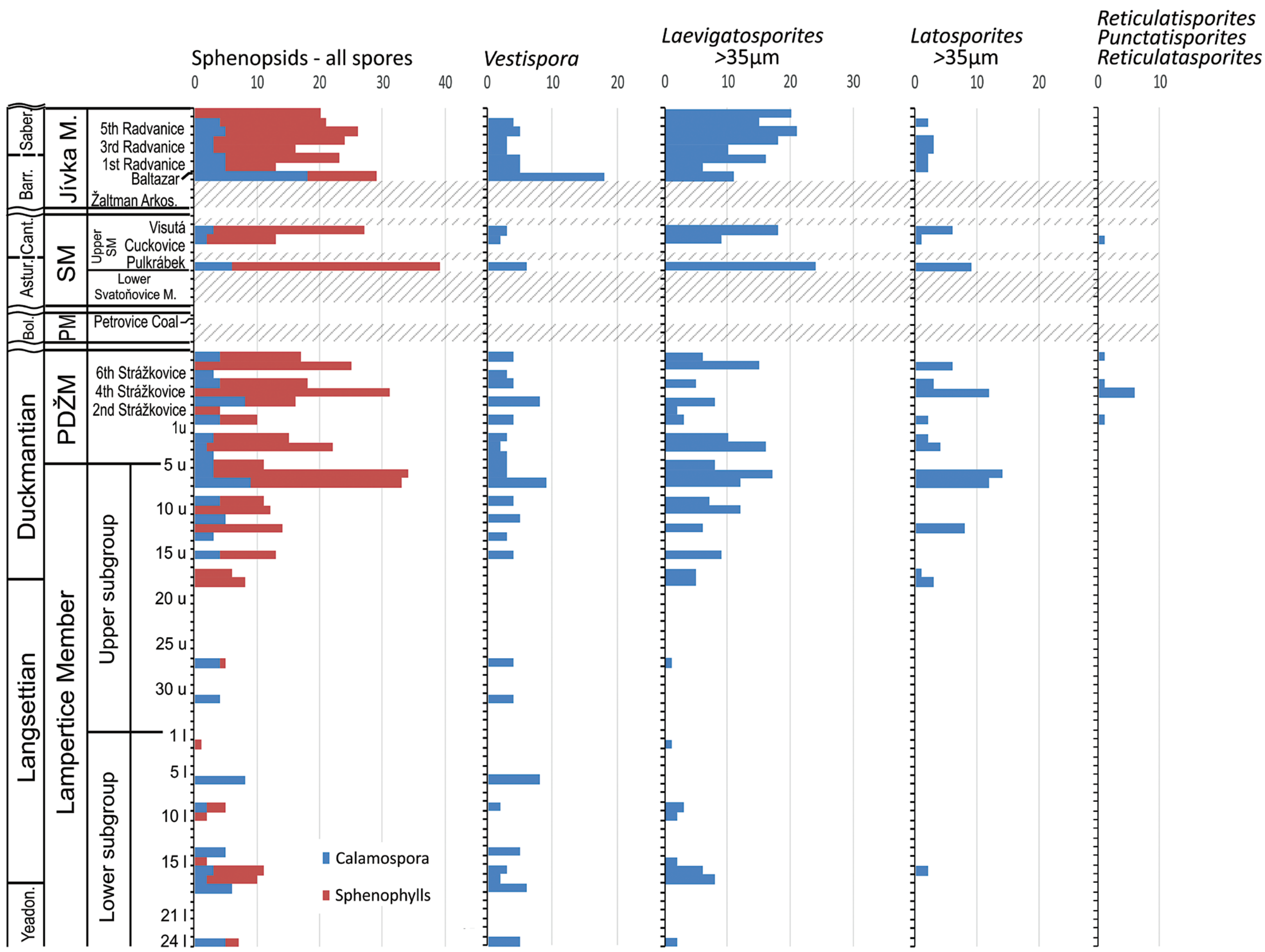

Figure 8. Percentage abundance of sphenopsid miospores in the Czech part of the Intra-Sudetic Basin. Abbreviations: Yeadon. – Yeadonian; PDŽM – Prkenný Důl-Žďárky Member; PM – Petrovice Member; SM – Svatoňovice Member; M. – member; CF – Chvaleč Formation; BF – Broumov Formation; Bol. – Bolsovian; Astur. – Asturian; Cant. – Cantabrian; Barr. – Barruelian; Saber. – Saberian.

spora) and sphenophyllalean [(*Laevigatosporites* and *Latosporites* more than 35 µm in diameter, *Vestispora*, *Dictyotriletes muricatus* Kosanke, *Punctatisporites obesus* (Loose) Potonié & Kremp and *Reticulatasporites* (Ibrahim) Potonié & Kremp (opercula of the genus *Vestispora*)]. Similar to lycopsids, also sphenopsid plants are less diverse in macrofloral record comparing to diversity of their spores (Fig. 9). There is an increase in number of sphenophyllalean miospores from the bottom to the top of the Lampertice Member, *i.e.* from the level of the 12th upper Lampertice coal seam. They reach only 2% from the 24th to 13th upper Lampertice coal seams but 12% above 11th upper Lampertice coal seam (Fig. 8). This increase continues within the Prkenný Důl-Žďárky (12% on average) Svatoňovice (16% on average) and the Jívka (14% on average) members. Sphenophyllalean miospores are rarer within the Lampertice Member with only three genera. The most abundant sphenophyllalean miospores are the species of *Laevigatosporites* and *Latosporites* bigger than 35 µm. The only recorded sphenopsid megaspores of the *Calamospora* type are described in the Jívka Member (Kalibová *in* Tásler *et al*. 1979). Changes in diversity of sphenopsid miospores is more pronounced in sphenophylls whereas diversity of *Calamospora* born by calamites remains relatively stable from the Duckmantian to Saberian (Fig. 9). It indicates a significant proportion of long-ranging taxa among calamites and *Calamospora*.

Miospores of ferns

It is possible to divide fern miospores into marattialean zygopteridalean*,* botryopteridalean and gleicheniacean types (electronic supplement 1). There is a clear contrast between diversities of ferns recorded in plant compressions and miospores, the latter being up to several times higher (Fig. 5). Their diversities, however, show similar

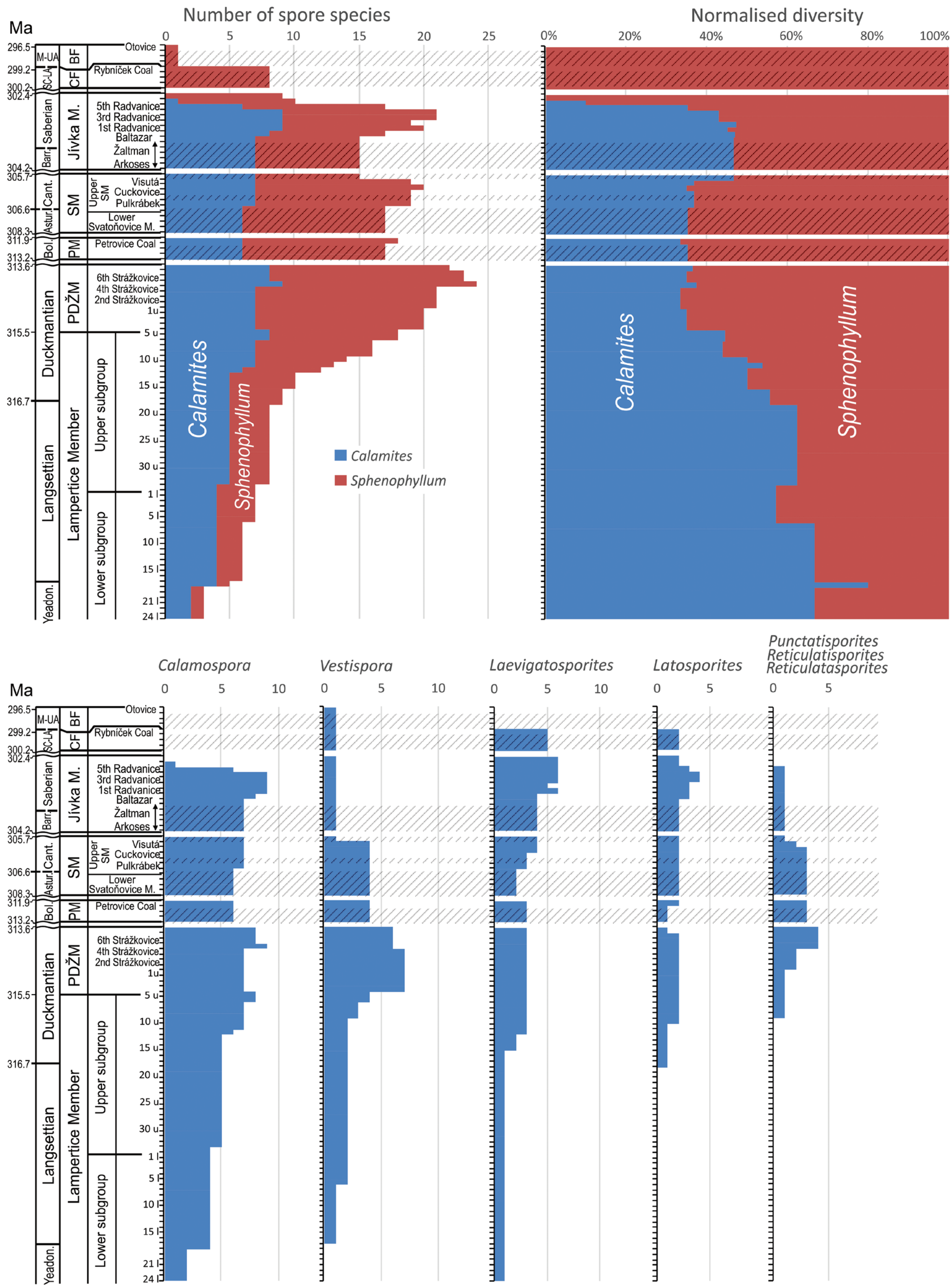

Figure 9. Species diversity of sphenopsid miospores in the Czech part of the Intra-Sudetic Basin. Abbreviations: Yeadon. – Yeadonian; PDŽM – Prkenný Důl-Žďárky Member; PM – Petrovice Member; SM – Svatoňovice Member; M. – member; CF – Chvaleč Formation; BF – Broumov Formation; Bol. – Bolsovian; Astur. – Asturian; Cant. – Cantabrian; Barr. – Barruelian; Saber. – Saberian; SC-LA – Stephanian C–lower Autunian; M-UA – middle–upper Autunian.

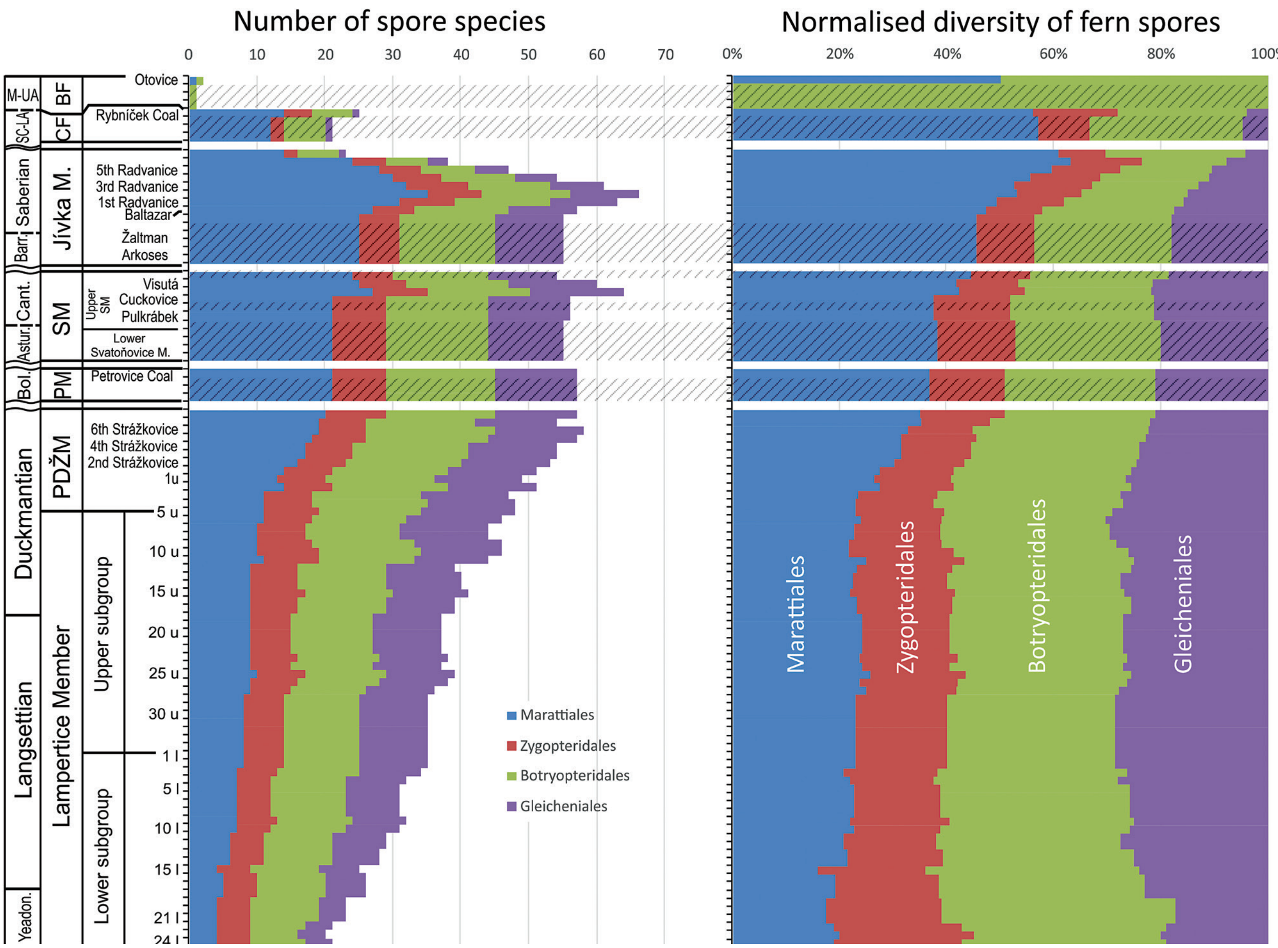

Figure 10. Species diversity of miospores produced by ferns in the Czech part of the Intra-Sudetic Basin. Abbreviations: Yeadon. – Yeadonian; PDŽM – Prkenný Důl-Žďárky Member; PM – Petrovice Member; SM – Svatoňovice Member; M. – member; CF – Chvaleč Formation; BF – Broumov Formation; Bol. – Bolsovian; Astur. – Asturian; Cant. – Cantabrian; Barr. – Barruelian; Saber. – Saberian; SC-LA – Stephanian C–lower Autunian; M-UA – middle–upper Autunian.

increase up to their maximum values in the late Duckmantian Strážkovice coal group. Above this level macrofloral diversity significantly drops and with some oscillation remains relatively low throughout the late Pennsylvanian and Asselian. In contrast, diversity of ferns in the palynological record above the Strážkovice coal group persists throughout most of Asturian and late Pennsylvanian times with further restricted increase in the Svatoňovice and Radvanice coal-bearing intervals (Figs 5, 10). This late Pennsylvanian maximum of fern diversity recorded in miospore assemblages corresponds to general dominance of ferns, especially maratiallean tree ferns, to basinal landscape in this time interval (Pfefferkorn & Thomson 1982, DiMichele 2014). The higher palynological diversity can be partly explained by the production of more than one miospore taxon produced by each species of tree fern with *Pecopteris*-type of foliage (*e.g.* Balme 1995, Bek & Opluštil 1998). It may also reflect conservatism of their foliage where different biological species produced morphologically very similar foliage hardly distinguishable in fragmentary fossil record.

The general feature of marattialean miospores is their increasing number from 2% on average in the Lampertice to the 18% in the Jívka members (Fig. 11). The most abundant are smallest (less than 35 μm in diameter) species of genera *Laevigatosporites* and *Latosporites*. It is interesting to note that local abundance (20%) of the genus *Punctatosporites* within 8th Strážkovice Coal Seam represents its maximum percentage of the whole profile. The number of miospore genera of marattialeans is more or less same through the profile of the basin (seven to eight genera). Miospores of zygopterid ferns reach 7.5% on average from the Lampertice to the Jívka members and are represented by seven genera. Generally, these miospores are the most abundant in older strata of the Lampertice Member with six genera that make up 10% on average. Zygopterid miospores reach five percent on average in the Prkenný Důl-Žďárky members and slightly increased number is recorded in the Jívka (8% on average) Member. The most abundant zygopterid miospore type is the genus *Apiculatisporites* with local abundance within the 12th lower coal seam (39%).

Botryopterid miospores are represented by six genera and make 11% on average from the Lampertice to the Jívka members (electronic supplement 1). The general pattern is similar to that of zygopterid miospores, *i.e*. the number of botryopterid miospores slightly decreases from the Lampertice (13% on average) to the Jívka (8% on average) members but the number of genera is comparable (Fig. 11). Gleicheniacean miospores are represented only by two genera, *Leiotriletes* and *Triquitrites* that reaches 4.8% along the profile and their number decreases from the Lampertice (7% on average) to the Jívka (2% on average) members. Generally, miospores of fern origin reach their maximum within the Svatoňovice Member (46%) and their minimum in the Prkenný Důl-Žďárky Member (30%).

Gymnosperm pollen

Cordaitalean pollen

Cordaitalean pollen consists of only eight *Florinites* species and makes 3.3% on average from the Lampertice to the Jívka members. Increased numbers of *Florinites* from the Lampertice (1% on average) to the Jívka members (5% on average) are observable. Local maximum of *Florinites* is recorded in the 18th upper coal seam at 8th Strážkovice Coal Seam (both of them 8%). Surprisingly, the stratigraphic range of *Florinites* is smaller than of compressions of its parent plants (Fig. 5; Opluštil *et al.* 2017). The former enters the palynological record below the mid of the Lampertice Member in early Langsettian and makes its last occurrence in the Rybníček Coal of Stephanian C–lower Autunian age (late Gzhelian). In compression floras cordaitalean remains occur throughout the entire studied section. Between late Duckmantian and Saberian times, the number of palynological taxa usually mostly exceeds macrofloral record, except the 3rd Strážkovice Coal (Duckmantian) where exceptionally high number of cordaitalean species was distinguished from cuticular analysis of their leaves (Šimůnek & Libertín 2006, Šimůnek 2007).

Coniferalean pollen

Coniferalean pollen (genera *Lueckisporites* and *Potonieisporites* Bharadwaj) occur only in the Jívka Member where they reach only 1% on average (electronic supplement 1, 2; Figs 4, 12). *Lueckisporites* occurs only in the 4th Radvanice Coal Seam where *Potonieisporites* reached

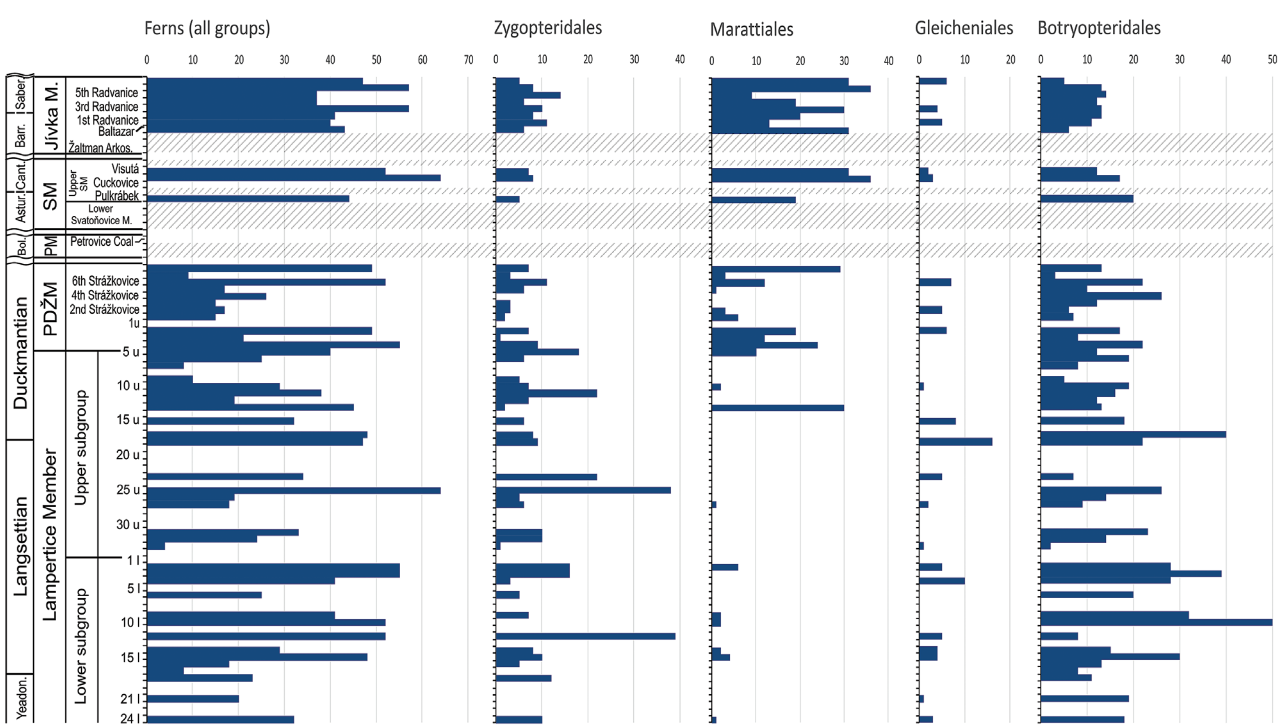

Figure 11. Percentage abundance of fern miospores in the Czech part of the Intra-Sudetic Basin. Abbreviations: Yeadon. – Yeadonian; PDŽM – Prkenný Důl-Žďárky Member; PM – Petrovice Member; SM – Svatoňovice Member; M. – member; CF – Chvaleč Formation; BF – Broumov Formation; Bol. – Bolsovian; Astur. – Asturian; Cant. – Cantabrian; Barr. – Barruelian; Saber. – Saberian.

its maximum (4%). Cumulative stratigraphic ranges of these two genera spans the interval between the Saberian and Asselian that surprisingly does not fit with the first occurrence of conifer impressions in the late Asturian red beds of the early Svatoňovice Member (Opluštil *et al*. 2017). Instead, their pollen first enters the palynological record in the Radvanice coal group of Saberian age (Figs 4, 12). This may be due to fact that palynological samples included nearly exclusively coal or carbonaceous clastics from coal-bearing intervals whereas no palynological data has been obtained from red beds. Another inconsistency between macro- and microfossil records of conifers concerns very low diversity of their pollens (one species) in the Asselian comparing to ten species identified in plant compressions (electronic supplement 1, Fig. 4).

Pollen of cycadaleans

Cycadalean pollen are represented only by the species *Remysporites magnificus* (Horst) Potonié & Kremp that rarely (three records) occurs only within the Lampertice Member.

Pollen of pteridosperms

Pollen of pteridosperms are very rarely recorded in miospore and pollen assemblages from Pennsylvanian times (Willard 1993, Peppers 1996, Eble *et al*. 2003, Willard *et al*. 2007). In the Czech part of the Intra-Sudetic Basin only very few of them have been found. They include genera *Vittatina* Luber ex Jansonius, *Guthoerlisporites* Bharadwaj and possibly *Wilsonites* Kosanke which have been reported from pollen organs possibly of peltasperm affinity (Gomankov & Meyen 1986, Poort & Kerp 1990, Balme 1995, Dimitrova *et al.* 2011) although the affinity of *Wilsonites* is only presumed (Meyen 1987). They appear for the first time in the Prkenný Důl-Žďárky Member (electronic supplement 1) but they are most abundant in the Jívka Member with 1% on average. The genus *Wilsonites* is the most common with its maximum (4%) in the 6th Radvanice Coal Seam. *Wilsonites* enters the palynological record in the upper Duckmantian Strážkovice coal group followed by *Vittatina* in the Bolsovian Petrovice Coal and by *Guthoerlisporites* in the Saberian Radvanice coal group. It is, however, not until the Cantabrian Svatoňovice coal group where this pollen becomes relatively more common and diverse (electronic supplement 1). Completely absent from palynological record is pollen of Medullosales, Lyginopteridales and Callistophytales. Very unusual but of highest importance is the occurrence of *Vittatina* that is considered to be of peltaspermales affinity (*e.g*. Poort & Kerp 1990) in the Petrovice Coal of Bolsovian age (electronic supplement 1). It is more typical for late Pennsylvanian and Permian, although in the Sydney coalfield of eastern Maritime Canada occurs in the Cantabrian (Dimitrova *et al*. 2011). The Petrovice Coal is only several tens of centimetres thick, composed of high-ash coal to carbonaceous mudstone. Its local extent suggests possible coexistence of peat swamp precursor with well-drained habitats in the basin landscape (possibly lowland) during late Bolsovian times. This coincides with the earliest dry interval of increased seasonality/aridity (Roscher & Schneider 2006). *Vittatina* is absent in the palynological record of the Svatoňovice (Cantabrian) and Radvanice (Saberian) coal groups and makes its second occurrence in the late Gzhelian Rybníček Coal of the Vernéřovice Member (electronic supplement 1).

Miospores and pollen of unknown affinity

Miospores of unknown affinity consist of 37 genera and reach 13% on average from the Lampertice to the Jívka members. Their general pattern is clearly characterised by decreasing numbers in the Lampertice (24% on average) to the Jívka (6% on average) members. The most important and abundant is the genus *Savitrisporites* that contitutes 12% in the Lampertice Member with its maximum in the 17th lower coal seam. Miospores of unknown affinity are generally more abundant in late Langsettian and Duckmantian part of the succession. We assume that most of these taxa may represent various ferns that reach their maximum diversity in plant compression record of this interval.

Palynozonation and comparison

Several Pennsylvanian palynozones have been proposed during last fifty years (*e.g*. Alpern & Liabeuf 1966, Smith & Butterworth 1967, Alpern *et al*. 1969, Grebe 1972, Coquel *et al.* 1976, Wijhe & Bless 1974, Kmiecik 1978, Górecka & Górecka-Nowak 1979, Dolby 1988, Peppers 1996, Dimitrova 2004) including the most cited western European zonation published by Clayton *et al*. (1977). The ground principle of palynozonation is the combination of first appearances and last records of one or more taxa, sometimes combined with some type of biozones, mostly acmezones. Palynozones covering more than one basin and/or country (*e.g.* Coquel *et al*. 1976, Clayton *et al.* 1977) cannot be so precise and generally valid as local ones.

Much better is detail division of only one basin or coalfield into palynozones and subzones (*e.g.* Dimitrova 2004, McLean *et al*. 2005) because characteristics of stratigraphically important data of spore and pollen species

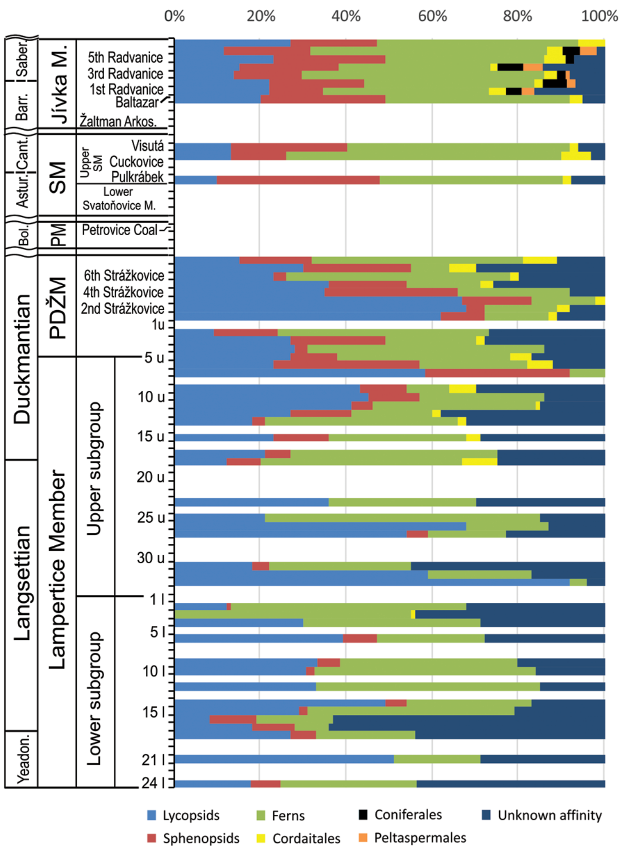

Figure 12. Percentage abundancy of major plant groups miospores in the Czech part of the Intra-Sudetic Basin. Abbreviations: Yeadon. – Yeadonian; PDŽM – Prkenný Důl-Žďárky Member; PM – Petrovice Member; SM – Svatoňovice Member; M. – member; CF – Chvaleč Formation; BF – Broumov Formation; Bol. – Bolsovian; Astur. – Asturian; Cant. – Cantabrian; Barr. – Barruelian; Saber. – Saberian.

are homogeneous. It is the reason why here we do not adopt some of existed broad international palynozones but propose a new zonation only for the Czech part of the Intra-Sudetic Basin.

Herein the proposed palynozones are based on the combination of first occurrences and last occurrences of species that occur commonly in the basin and defined by absolute age and plant zonation.

The first *Acanthotriletes echinatus-Murospora* palynozone covers the Lampertice Member sedimentation interval, *i.e.* about 320–315 Ma. This palynozone corresponds to the upper part of the *Pecopteris aspera*, the whole *Calymnotheca hoeningshausii* and lower part of the *Lochopteris rugosus* plant zones (Wagner & Alvárez-Vásques 2010). The genera *Foveosporites* Balme, *Radiizonates* and *Waltzispora* and species *Acanthotriletes echinatus* (Knox) Potonié & Kremp, *Remysporites magnificus*, *Cingulizonates loricatus* (Loose) Butterworth & Smith and *Murospora sulcata* (Waltz) Jachowicz occur only here. The increasing number of spores of *Apiculatisporites*, *Punctatisporites*, *Ahrensisporites*, *Bellispores* Artüz and *Savitrisporites* from the bottom to the top of the member is a characteristic of this palynozone. Most *Acanthotriletes* species are restricted to this interval.

Vestispora magna-Anapiculatisporites spinosus palynozone is restricted to the Prkenný Důl-Žďárky Member, *i.e.* about 315–314 Ma. This palynozone corresponds to the upper part of the *Lonchopteris rugosa* and the lowermost part of the *Paripteris linguaefolia* plant zones (Wagner & Alvárez-Vásques 2010). Some species including *Acanthotriletes triquetrus* Smith & Butterworth, *Alatisporites hexalatus* Kosanke, *Apiculatisporites abditus* (Loose) Potonié & Kremp, *Cingulizonates tuberosus* Dybová & Jachowicz, *Cristatisporites indignabundus* (Loose) Staplin & Jansonius, *Vestispora magna* (Butterworth & Williams) Wilson & Venkatachala, *V. laevigata* and the genera *Tripartites* and *Kuhlensisporites* Kruszewska are restricted to only here. Several species have their last occurrence including *Anapiculatisporites* cf. *spinosus*, *Bellispores nitidus* (Horst) Sullivan, *Dictyotriletes bireticulatus* (Ibrahim) Potonié & Kremp, *Stellisporites inflatus* Alpern, *Mooreisporites* cf. *inusitatus* Neves and *Savitrisporites nux* (Butterworth & Williams) Smith & Butterworth. The maximum of *Densosporites*, *Cristatisporites*, *Acanthotriletes* Naumova, *Punctatosporites* are characteristic, as well as the abundance of *Endosporites* and increasing number of specimens of *Planisporites* (Knox) Potonié & Kremp.

The *Wilsonites kosankei-Torispora granulata/T. undulata* palynozone corresponds to the Svatoňovice Member, *i.e.* about 308–306 Ma. This palynozone corresponds to the upper part of the *Crenulopteris acadica* and the lower part of the *Odontopteris cantabrica* plant zones (Wagner & Alvárez-Vásques 2010). The species *Cirratriradites annulatus*, *Lycospora micrograna* Hacquebard & Barss, *Triquitrites pulvinatus* Kosanke and all key taxa occur only here and *Speciososporites laevigatus* Alpern, *Punctatosporites rotundus* and *P. pygmaeus* have their first occurrence. The abundance of *Florinites* and smallest forms of *Laevigatosporites* and *Latosporites* is characteristic of this palynozone.

Cadiospora magna-Potonieisporites palynozone is restricted to the Jívka Member, *i.e.* about 304–303 Ma. This palynozone corresponds to the upper part of the *Crenulopteris lamuriana* and the lower part of the *Alethopteris zeileri* plant zones (Wagner & Alvárez-Vásques 2010). Some species including *Aumancisporites striatus* Alpern, *Cadiospora magna* f. *maior*, *C. magna* f. *minor*, *C. magna* f. *plicata*, *Gillespieisporites discoideus* (Kosanke) Kalibová, *Guthoerlisporites magnificus* Bharadwaj, *Illinites unicus* Kosanke, *Latensina triletus* Alpern, *Lundbladispora gigantea* Alpern, *Punctatosporites oculus* Smith & Butterworth, *Speciososporites plicatus* Alpern, *Thymospora thiessenii* (Kosanke)

Wilson & Venkatachala and genera *Disaccites* Cookson and *Lueckisporites* are restricted to only here. Several species make their first appearance here including *E. globiformis* (Ibrahim) Schopf *et al.*, *Kosankeisporites elegans* (Kosanke) Bharadwaj and *Potonieisporites elegans* (Wilson & Kosanke) Wilson & Venkatachala. The most prominent feature is the increasing percentage of the smallest monoletes (*Punctatosporites*, *Thymospora*, *Speciososporites*, *Torispora* and small forms of *Laevigatosporites* and *Latosporites*).

Lastly, the *Spinosporites spinosus-Potonieisporites novicus* palynozone is restricted to the Vernéřovice Member, *i.e.* 299–301 Ma. This palynozone corresponds to the lower part pf the *Autunia conferta* plant zone (Wagner & Alvárez-Vásques 2010). Both key species and *Punctatisporites baccatus* Hoffmeister *et al.* and *P. provectus* Kosanke make their first appearance here. The species *Apiculatisporites baccatus*, *A. baccatus* f. *trebechovensis* Kalibová, *Florinites piérartii* Kalibová, *Punctatisporites provectus, Spinosporites spinosus* and *Thymospora verrucosa* (Alpern) Wilson & Venkatachala are restricted to only here.

It is not possible to assign the assemblages of the Petrovice and Olivětín members to any palynozone due to very poor miospore and pollen record.

The dispersed miospore and pollen assemblages from CPISB were compared with those described from the Polish part of the same basin. This comparison included assemblages described by Górecka (1968, 1969), Górecka & Górecka-Nowak (1990). A local palynozonation framework was not proposed and these authors employed the palynozones suggested by Clayton *et al*. (1977). The Yeadonian FR palynozone is characterised by the abundance of *Crassispora kosankei*, *Stenozonotriletes triangulatus* Neves, *Schulzospora rara* Kosanke and the appearance of *Reticulatisporites reticulatus* (Ibrahim) Ibrahim. Only the genus *Laevigatosporites* and the species *Crassispora kosankei* (Potonié & Kremp) Smith & Butterworth also occur in the Czech part of the basin. The lower Langsettian RR palynozone contains the first appearance of *Cingulizonates loricatus* and *Dictyotriletes bireticulatus*, the genus *Florinites* and the species *Cirratriradites saturni* are common. Only the genus *Laevigatosporites* and the species *Dictyotriletes bireticulatus* and *Cirratriradites saturni* occur in the lower part of the Lampertice Member in the Czech part of the basin. The Langsettian RA palynozone is characterised by the appearance of the species *Endosporites globiformis* and the genus *Punctatosporites*. *Florinites mediapudens* (Loose) Potonié and Kremp, *Raistrickia fulva* Kosanke and *Radiizonates aligerens* Knox are common. *Endosporites globiformis* appears in stratigraphically younger sediments in the Czech part of the basin and *Radiizonates* has not been recorded.

The Duckmantian NJ palynozone is characterised by the appearance of *Triquitrites sculptilis* and *Punctatosporites granifer.* The character of this assemblage is similar to that in the Czech part of the basin. The Bolsovian SL palynozone contains the first occurrences of several taxa, including *Torispora securis*, *Vestispora fenestrata* and *Westphalensisporites irregularis.* Only *Vestispora fenestrata* and *Westphalensisporites irregularis* also occur in the Petrovice Member in the Czech part of the basin.

The OT palynozone includes Asturian and Barruelian strata, and the species *Triquitrites bransonii* and *T. exiguus* and the genus *Thymospora* first appearance in this zone. This assemblage also occurs in strata of the same age in the Czech part of the basin. The ST palynozone spans the latest Stephanian A and the entire Stephanian B, and is characterised by the first appearance of *Polymorphisporites* Alpern, *Spinosporites spinosus*, *Latensina*, *Cadiospora magna* and *Thymospora verrucosa.* A similar assemblage also occurs in age equivalent strata in the Czech part of the basin. The uppermost NBM palynozone of Stephanian C and D age is similar to the underlying palynozone, and can be broadly compared to both equivalents in the Czech part of the basin. On the whole, the dispersed miospore and pollen assemblages from the Polish part of the Intra-Sudetic basin are similar to those from the Czech part, particularly in stratigraphically younger members (*i.e.* from the level of the NJ palynozone, equivalent to the Prkenný Důl-Žďárky Member).

Clayton *et al.* (1977) proposed twenty-five palynozones from the Famennian to the Autunian of Western Europe. Later this scheme was slightly changed, *e.g.* by Owens *et al*. (2005). The lower part of Yeadonian FR *Raistrickia fulva-Reticulatisporites reticulatus* palynozone is marked by appearance of e.g. *Ahrensisporites beeyleyensis* Neves, *Dictyotriletes muricatus*, *Reticulatisporites reticulatus* and *Bellispores nitidus.* Other typical species are *Cirratiradites saturni*, *Mooreisporites fustis* Neves and *Spelaeotriletes arenaceus* Neves & Owens. All of these species are absent in the lower part of the Lampertice Member. SS *Triquitrites sinani-Cirratriradites saturni* palynozone covers the lower part of Langsettian and the most typical is the occurrence of genera *Ahrensisporites*, *Triquitrites* and *Cirratriradites saturni*, and increasing number of *Latosporites*. The first two genera occur in a low numbers in stratigraphically comparable strata in the Czech part of the Intra-Sudetic Basin, but higher a percentage of *Latosporites* is recorded in younger strata here. *Radiizonates aligerens* (RA) palynozone is restricted to the upper Langsettian. The key species appear for the first time here together with *Punctatosporites minutus* Ibrahim and an increased percentage of the whole genus. Other typical taxa included *Kraeuselisporites ornatus* (Neves) Owens *et al*., *Dictyotriletes bireticulatus* and the genus *Disaccites*. Only

Punctatosporites minutus is recorded in stratigraphically comparable strata in the Czech part of the Intra-Sudetic Basin. *Microreticulatisporites nobilis-Florinites junior* (NJ) palynozone covers the whole Duckmantian and lowermost Bolsovian. Both of the key species appeared here for the first time, and the most typical is abundance of *Lycospora*, *Densosporites*, *Vestispora cancellata* (Dybová & Jachowicz) Wilson & Venkatachala and maximum of *Dictyotriletes bireticulatus* and *Cirratriradites saturni*. This characteristic is similar to assemblages of the same stratigraphical level in the Czech part of the Intra-Sudetic Basin. *Torispora securis-T. laevigata* (SL) palynozone is restricted almost to the whole Bolsovian. The species *Vestispora fenestrata*, *Potonieisporites gelriaensis* Bless *et al*., *Disaccites striatiti* and *Lundbladispora gigantea* Alpern appear for the first time and *Lycospora*, *Torispora* and *Punctatosporites* are abundant. *Vestispora fenestrata* makes its first appearance in stratigraphically older strata in the Czech part of the Intra-Sudetic Basin, *Disaccites striatiti* Pant and *Potonieisporites gelriaensis* Bless *et al.* never been described here. *Thymospora obscura-T. thiessenii* (OT) palynozone is restricted to the uppermost Bolsovian, the whole Asturian and lower Barruelian strata. Typical is the increasing number of the smallest monoletes, together with a common occurrence of *Lundbladispora gigantea*, *Vestispora fenestrata* and *Westphalensisporites irregularis*. Increasing number of smallest monoletes appears in stratigraphically younger strata in the Czech part of the Intra-Sudetic Basin. *Angulisporites splendidus-Latensina trileta* (ST) palynozone covers upper part of the Barruelian and almost the whole Saberian. The smallest monoletes are still abundant together with *Lycospora* and *Densosporites*. The genera *Cheiledonites* Doubinger and *Vittatina* appear for the first time and typical are *Westphalensisporites irregularis*, *Disaccites non striatiti*, *Candidispora* spp. and *Lundbladispora gigantea*. *Cheiledonites* and *Disaccites* are not recorded in the Czech part of the Intra-Sudetic Basin but other taxa occur in the Jívka Member. *Potonieisporites novicus-bhardwajii-Cheiledonites major* (NBM) palynozone is restricted to the uppermost Saberian and to middle and upper Autunian. Smallest monoletes are again abundant and *Triquitrites*, *Lundbladispora gigantea*, *Potonieisporites*, *Cheiledonites* and *Polymorphisporites* Alpern occur regularly. The smallest monoletes are rarely recorded in stratigraphically comparable strata in the Czech part of the Intra-Sudetic Basin and generally these assemblages are not similar to that of the Vernéřovice Member because only a few of above-mentioned taxa also occur here. *Vittatina costabilis* (VC) palynozone covers lower Autunian but the number of miospore and pollen taxa in the Czech part of the Intra-Sudetic Basin at this stratigraphically level is too small to allow any useful comparison. Generally, it is possible to state that only dispersed miospore and pollen assemblages of NJ palynozone as described by Clayton *et al*. (1977) is similar to those from stratigraphically comparable strata in the Czech part of the Intra-Sudetic Basin, the characteristics of the other palynozones are different.

Generally, it is possible to conclude that dispersed miospore and pollen assemblages from Yeadonian to Autunian of Europe are not easily comparable with those in CPISB, except for assemblages from the Polish part of the basin and surprisingly those reported from the Limburg area in the Netherlands (Wijhe & Bless 1974).

Vegetation patterns estimated from quantitative palynological data

In the "grey" coal-bearing intervals the number of miospores per sample was often high enough to quantify percentages of genera (electronic supplement 2) and in turn of major plant groups which produced them. Although these quantified palynological spectra cannot be directly interpreted in term of abundancy of populations of parent plant species (Willard 1993, Willard & Phillips 1993), fluctuation of their values throughout the studied succession may reflect temporal vegetation changes of local (*e.g.* basinal) and regional scales. This, in turn provides a base for estimations of vegetation patterns and for comparison with similar data from other coalfields of tropical Pangea. Only a brief comparison is provided; a more detailed one is outside the scope of the paper.

The study by Peppers (1996) for the North American coalfields shows a prominent palynological change just above the Middle–Late Pennsylvanian boundary, expressed mainly as a change in the percentage of spores of arborescent lycopsids versus tree ferns. In Pepper's data, the *Lycospora* produced by lepidodendrid lycopsids clearly dominate the Langsettian to Duckmantian palynological assemblages (usually 70–90%), starting slowly and irregularly decreasing in the Bolsovian and especially in Asturian, and suddenly dropping nearly to zero just above the Middle–Late Pennsylvanian boundary. The decrease in *Lycospora* is mainly compensated by the increase in miospores of tree ferns that become dominant during the Late Pennsylvanian in the Appalachian and Interior coalfields (Peppers 1996, Eble 2002, Eble *et al*. 2013). This trend agrees with floral changes at this boundary as identified from plant compressions and coal balls (Pfefferkorn & Thompson 1982, Phillips *et al*. 1985, Pfefferkorn *et al*. 2008, DiMichele 2014).

A slightly different scenario shows coalfields in Europe and North Turkey. Their Langsettian to Asturian palynofloras are very similar to those in the Appalachian and Interior coalfields (Cleal *et al*. 2010). Coals of this age in the Ruhr (Jasper *et al*. 2010, Hartkopf-Fröder 2015), Saar (Peppers 1996), Pennines (Smith & Butterworth 1967), South Wales (Dimitrova *et al*. 2005), Upper Silesia (Górecka 1968, 1969; Górecka & Górecka-Nowak 1990; Bek 2008), Dobrogea (Dimitrova & Cleal 2007), Zonguldak–Amasra (Ergönül 1960, Opluštil *et al*. 2018) and Polish part of the Intra-Sudetic basins (Nowak & Górecka-Nowak 1999) are also dominated by spores of arborescent lycopsids, mainly by *Lycospora*. Although the precise percentage of palynomorphs produced by major plant groups may differ spatially and temporarily, the available data suggest an ecologically stable condition during the humid part of glacial/interglacial cycles, which supported the formation of extensive peat swamps across most of tropical Pangea (Falcon-Lang & DiMichele 2010, Cecil *et al*. 2014, DiMichele 2014, Opluštil *et al*. 2019). There is, however, a change from the Peppers (1996) scenario for the Appalachian and Interior coalfields of the USA at the Middle–Late Pennsylvanian boundary. Although an existing palynological data from European coalfields may differ in percentage of individual palynological taxa around the Middle–Late Pennsylvanian transition, they commonly show a drop in content of arborescent lycopsid spores (mainly in *Lycospora*) in spore and pollen assemblages. However, the decrease is not so drastic and *Lycospora* still remains quite a common part of palynological assemblages in many upper Pennsylvanian European coals till the end of Pennslyvanian (*e.g.* Châteauneuf *et al.* 1992, Pešek 2004). However, the main part of the palynological assemblages still consists of spores of tree ferns and in middle to late upper Pennsylvanian coals and lacustrine horizons number of conifer pollen grains increases.

Examination of our Pennsylvanian palynological data from the Intra-Sudetic Basin shows a similar trend to North American and European coalfields from Yeadonian to Asturian. Differences in the percentage of miospores between basins and within individual basins, however, exist. As an example, in the Yeadonian and Langsettian part of the succession of the Intra-Sudetic Basin the *Lycospora* content varies between 10 and 90% of the palynological assemblages of discrete coals with the common values within an interval from 20 to 40% (Fig. 6). In Duckmantian coals, the percentage of *Lycospora* varies between 5 and 40% being ~20% in average. At the Westphalian–Stephanian boundary (broadly correlated with the Middle–Late Pennsylvanian boundary in the North America) in the Svatoňovice Member, there is a decrease in the *Lycospora* content to values around 10%, but no disappearance like in the United States coalfields (Figs 7, 12). Values ~15% are typical for samples from the Saberian Radvanice coal group, our youngest quantified data. The miospores produced by marattialean tree ferns are often absent in the palynological samples through the Yeadonian to the lower Duckmantian coals, except for the 13th coal of the upper subgroup (Jan Šverma Mine coal group) where their content reaches 30% (Figs 7, 12). However, these miospores become more common in the upper Duckmantian Strážkovice coal group although most values still vary between 10 and 20%. In the upper Pennsylvanian coals of the Svatoňovice and Radvanice groups the percentage of miospores of marattialean ferns oscillates between 10 and 35% being ~24% in average. This increase is accompanied by the first appearance of conifer pollen grains in the Radvanice coal group (Saberian), although their content is in few percent only (see Fig. 12). Palynological data from the Czech part of the Intra-Sudetic Basin, therefore fit much better to similar data from European coalfields that to those in the North America, where lepidodendrid lycospid disappear from the macrofloral and microfloral records.

Temporal changes in miospores, pollen grains, and plants during Pennsylvanian and early Permian

We attempt to reconstruct temporal changes in vegetation patterns within ~21 Ma interval between 318 and 297 Ma from the middle Bashkirian to lower Asselian in the Czech part of the Intra-Sudetic Basin, based on combination of palynomorph and macrofloral data. Their comparison (Figs 4, 5) shows not only two to five times higher diversity of miospores and pollen (except the Asselian), but also reveals prominent differences in diversities between coal-bearing or lacustrine strata and coal-barren red beds. The former represents major windows of preservation when the basin landscape was colonized by flora of peat-forming wetlands populated by evolutionarily conservative plant lineages (DiMichele 2014, Looy *et al*. 2014). The latter are intervals of dominantly oxidative conditions unfavourable for fossilization of plant remains (Gastaldo & Demko 2011, Opluštil *et al*. 2017). The macroflora in the red beds is, therefore very poor, and palynomorphs are absent and only interpolated by the palynological data currently available for these intervals. However, these interpolated palynological data records implies wetland taxa surviving the period of more or less pronounced climatic seasonality between adjacent coal-bearing intervals bracketing red bed succession. It supports the idea that these wetland floras are characterised by a compositional conservatism (DiMichele & Phillips 1996). In contrast, cordaitalean leaves and conifer shoots dominate poorly preserved plant impressions found in red beds, and are accompanied only with subordinate wetland elements, mostly calamites (Opluštil *et al*. 2017). The predominance of gymnosperms in red beds suggests existence of dryland habitats in the basin lowland. However, interpolated palynological data show also an unexpectedly high diversity of free sporing plants typical of wetlands in adjacent coal-bearing windows. Therefore, we assume that during these intervals of increased climatic seasonality enhancing well-drained/dryland habitats and excluding significant peat formation, wetland flora probably survived in small refugia scattered along rivers running through basin lowland (Falcon-Lang & DiMichele 2010). This is supported by exceptional findings of lepidodendrid leafy shoots (Opluštil *et al*. 2017). In addition, occasional palynological data from similar red bed successions elsewhere in the tropical Pangea provided palynological spectra dominated by gymnosperm (cordaitalean and conifer) pollen and thus also confirming colonization of basin lowland by dryland plant biome (Dolby *et al*. 2011, Hoof *et al.* 2013).

Keeping all these facts in mind, the following model of temporal changes in composition of floras, and their vegetation patterns in the Intra-Sudetic Basin can be suggested.

Palynological data across the Yeadonian to early upper Duckmantian coal-bearing interval (Lampertice and most of the Prkenný Důl-Žďárky members except its top) shows high species stability with only minor changes between neighboring coal beds (Fig. 13). The changes in number of palynological taxa usually do not exceed 10% (<8 species) but may increase to 15% in upper part of this interval. Most of them represent origination of new species resulting in increase in diversity of palynomorphs similar to that observed in macrofloral data (Figs 13, 14). It suggests that this ~6 Ma interval is a period of ecological and species stability and highest species diversity dominated by conservative plant lineages centred to widespread wetland habitats. Arborescent lycopsids reached their highest species diversity and their populations were

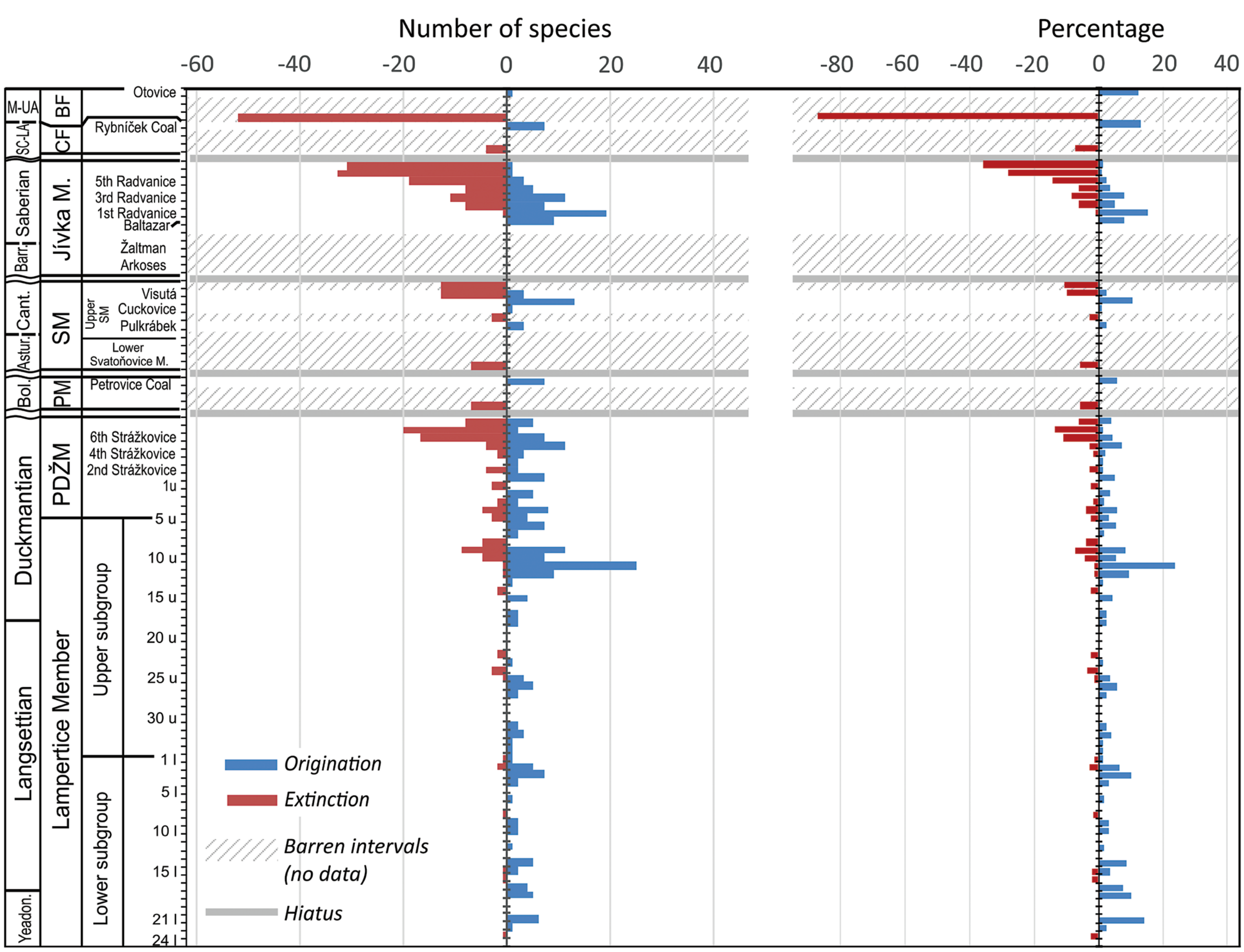

Figure 13. Origination and extinction of miospore taxa expressed in number of species (left) and in percentage of overall diversity (right) in the Czech part of the Intra-Sudetic Basin. Abbreviations: Yeadon. – Yeadonian; PDŽM – Prkenný Důl-Žďárky Member; PM – Petrovice Member; SM – Svatoňovice Member; M. – member; CF – Chvaleč Formation; BF – Broumov Formation; Bol. – Bolsovian; Astur. – Asturian; Cant. – Cantabrian; Barr. – Barruelian; Saber. – Saberian; SC-LA – Stephanian C–lower Autunian; M-UA – middle–upper Autunian.

at the maximum, as indicated by abundancy of their remains in compressions (Šetlík 1977, Libertín *et al.* 2009, Opluštil *et al*. 2017) and in quantified palynological record (Figs 7, 12). They dominated the landscape together with pteridosperms and calamites. However, the small sphenopteroid ferns and sphenophylls (Fig. 4) were also very diverse. The palynological data also indicates the presence of sub-arborescent and herbaceous, *e.g.* lycopsids either not reported (*e.g. Omphalophloios* and *Selaginella* types) or very rare (*Polysporia* Newberry) in the macrofloral record (Bek *et al.* 2008, Opluštil *et al.* 2017). This interval also hosts the highest diversity of miospores of unknown affinity (electronic supplement 1; Figs 4, 5). There is, however, no indication of conifers in this interval or other plants typical of Late Pennsylvanian and Early Permian landscape dryland biome (Looy *at al*. 2014, Opluštil *et al*. 2017).

The decline in species diversity in both, palynological and macrofloral records in upper part of the Strážkovice coal group (Figs 4, 13 and 14) suggests that this might be a natural process possibly driven by an onset of a shift to more seasonal climate (Roscher & Schneider 2006). It affected mostly populations and diversity of lycopsids (in both types of fossil records) and was less pronounced among sphenopsids, ferns and pteridosperms (Fig. 4). A similar drop in plant diversity at corresponding levels also occurs in the central Pennines (Cleal 2005). Palynological data at the top of this interval also show similar decline in diversity mainly affecting lycopsid- and fern-derived species and taxa of unknown affinity.

Following the lower Bolsovian hiatus, deposition continued in the middle Bolsovian by bedload-dominated fluvial red beds of the Petrovice Member, terminated by locally developed Petrovice Coal (Fig. 1). There are uncommon macrofloral remains throughout the member suggesting the persistence of relatively significant proportion of wetland taxa including arborescent lycopsids. Their diversity is, however, low (Opluštil *et al*. 2017). Species that continue from the Prkenný Důl-Žďárky to the Petrovice members mostly disappear in this latter unit, whereas some new taxa typical of Asturian (*e.g. Sphenophyllum emarginatum* Brongniart, *Annularia sphenophylloides* Zenker and *A. spinullosa* reported as *A. stellata* Schlotheim) appear for the first time. Mostly extrapolated palynological data (except the Petrovice Coal) show less pronounced drop in diversity comparing to macrofloral record (Figs 4, 5) and persistence of number of miospore taxa into the Cantabrian (Fig. 4). The presence of easily identifiable *Vittatina* pollen of possibly peltaspermalean origin is surprising and may indicate a stronger ecological gradient in basinal lowland during middle Bolsovian times. It allowed coexistence of scattered small-scale wetlands including peat swamps and well-drained habitats colonized by the plants typical for latest Pennsylvanian and early Permian (DiMichele *et al*. 2008, Pfefferkorn *et al*. 2008, DiMichele 2014).

Overlying interval of deposition is separated from the Petrovice Member by ~3 my long hiatus and comprises upper Asturian floodplain-dominating red beds of the lower Svatoňovice Member followed by the Cantabrian Svatoňovice coal group in the Upper Svatoňovice Member (Fig. 1). The scarce macrofloral remains from the red beds are represented by calamites, tree fern foliage, pteridosperms and exceptional findings of the earliest known walchian conifer shoots (Opluštil *et al*. 2017). The red color of strata and a mixture of dryland and wetland taxa suggest an existence of a prominent ecological gradient and a co-existence of well- and poorly-drained habitats in basin lowland, the former being probably more extensive. This landscape contrasts with the Svatoňovice coal group in top of the Svatoňovice Member, dominated by compressions of wetland plants, mostly tree ferns, calamites and medullosalen pteridosperms and subordinate lepidodendrids and sigillarian lycopsids. Similarly to macrofloral record, also palynological data show predominance of miospores produced by marattialean tree ferns, followed by calamite and lycopsid spores (Figs 11, 12). The predominance of tree ferns and subdominant calamites over arborescent lycopsids in both types of fossil records agrees with general reorganization of wetland biome in the tropical Pangea around the Middle and Late Pennsylvanian (DiMichele & Phillips 1996, Pfefferkorn *et al*. 2008, Cleal *et al.* 2010). Early Late Pennsylvanian wetlands were dominated by tree ferns, calamites, medullosalean pteridosperms with only small populations of arborescent lycopsids, the species composition of which differs from Duckmantian taxa (Němejc 1958, Opluštil *et al*. 2017).

Another interval of deposition, the Jívka Member (Fig. 1), follows the upper Cantabrian to lower Barruelian hiatus. Its major part consists of upper Barruelian coarse-grained red beds (Žaltman Arkoses) capped by the Radvanice coal group of Saberian age. The red beds provided poorly preserved plant impressions in mudstone intercalations dominated by cordaitaleans leaves, and walchian shoots, whereas in the arkoses there are rich silicified gymnosperm woods (Mencl *et al*. 2009, Opluštil *et al*. 2017). Sedimentological data and macrofloral record suggests the presence of well-drained habitats on braid plain colonised dominantly by cordaitalean or walchian conifers. However, interpolated palynological data (Fig. 4) and exceptional findings of lycopsid shoot and some sphenopsid and fern foliage suggest co-existence of poorly-drained habitats serving as refugia for wetland flora during periods of pronounced seasonality of climate. Radvanice coal group represents an interval favouring peat formation under more humid conditions. Comparing

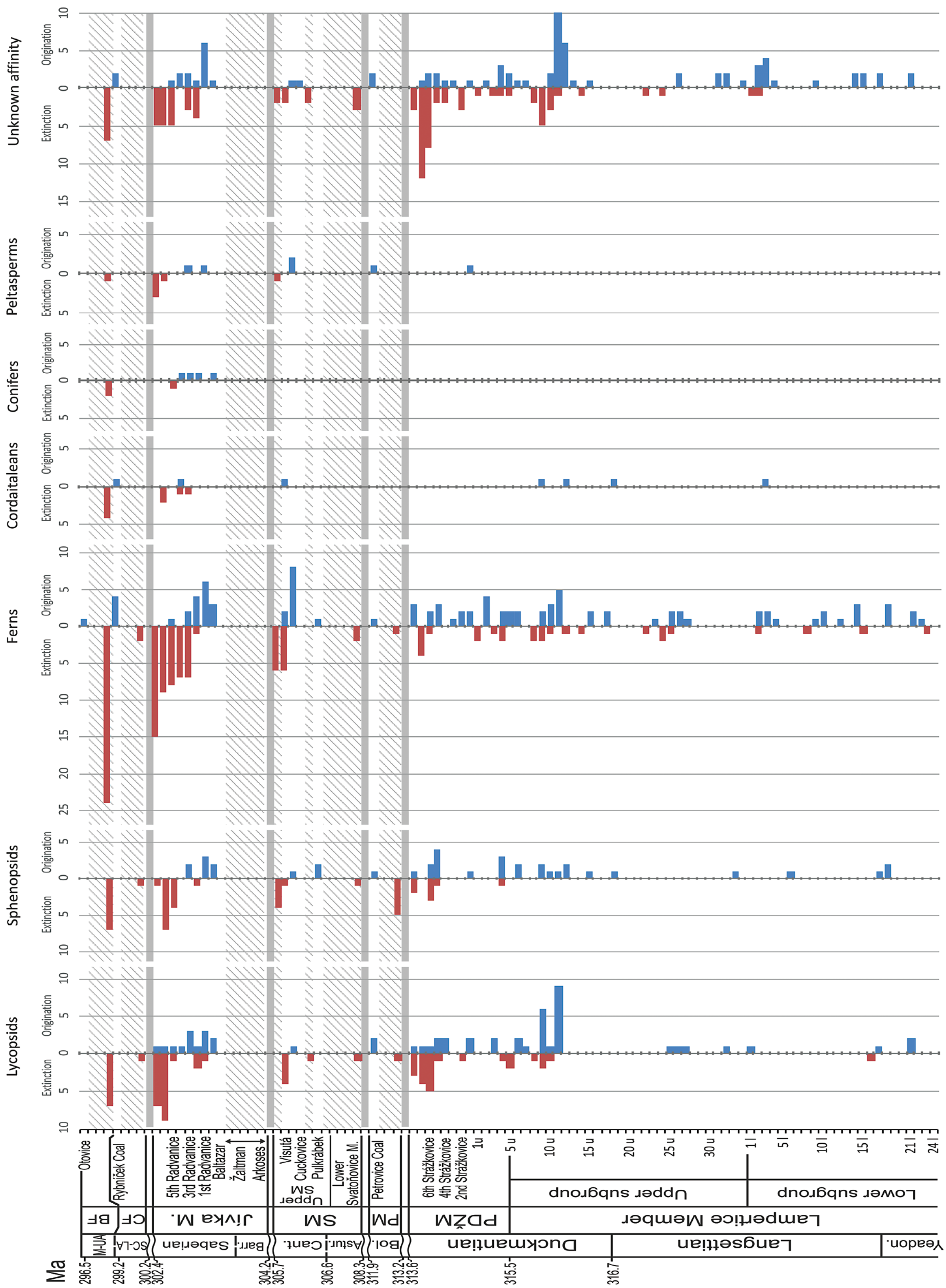

Figure 14. Origination and extinction of miospore taxa within major plant groups expressed in number of species in the Czech part of the Intra-Sudetic Basin. Abbreviations: Yeadon. – Yeadonian; PDŽM – Prkenný Důl-Žďárky Member; PM – Petrovice Member; SM – Svatoňovice Member; M. – member; CF – Chvaleč Formation; BF – Broumov Formation; Bol. – Bolsovian; Astur. – Asturian; Cant. – Cantabrian; Barr. – Barruelian; Saber. – Saberian; SC-LA – Stephanian C–lower Autunian; M-UA – middle–upper Autunian.

to earlier coal-bearing intervals, however, this is the first time when walchian conifers enter the fossil record both as pollen (electronic supplement 1; Figs 4, 12) and plant compressions in coal seams or mudstones directly associated with them (Opluštil *et al*. 2017). It indicates that even during formation of these relatively extensive peat swamps there were well-drained habitats colonized by dryland conifer flora in basinal lowland. In contrast, during formation of peat in pre-Saberian times, habitats in the basinal lowland of the Intra-Sudetic Basin were still dominated by extensive wetlands generally unfavourable for colonization by walchian conifers. However, during the deposition of the Asturian red beds the basinal lowland was a well-drained alluvial plain colonized by gymnosperms including conifers (Opluštil *et al*. 2017). The earliest palynological record of conifers in the Radvanice coal group (Saberian) coincides with the first occurrence of walchian foliage in mudstones directly associated with coal seams (Šetlík 1977, Opluštil *et al*. 2017), probably as a consequence of stronger ecological gradient in basinal lowland comparing to earlier peat-forming intervals. Present in palynological record are also peltaspermales and gingkoales pollens *Guthoerlisporites* and *Wilsonites* that extend diversity of dryland biome. However, it is assumed that wetland habitats still prevailed the basin being colonized dominantly by marattialean tree ferns, sphenopsids and subdominant arborescent lycopsids. The latter were represented by *Sigillaria brardii* Brongniart, *Asolanus camptotaenia* Wood and few lepidodendrid species (Němejc 1958, Opluštil *et al*. 2017).

Following another hiatus, deposition continued by the upper Stephanian lower Permian Chvaleč Formation, a red beds succession interrupted by two lacustrine intervals (Fig. 1). Red beds bear only rare impressions of cordaitalean and especially walchian remains (Tásler *et al*. 1979). However, the Vernéřovice Horizon with locally developed Rybníček Coal provided macroflora and about 60 miospore and pollen species, the former dominated by marattialen tree ferns with subordinate sphenopsid and even lycopsid miospores, mostly of the genus *Lycospora* (Fig. 4). Present are also pollen of cordaitalean, walchian and peltasperm seed plants. In contrast, macrofloral record provided remains of calamites and pteridosperms (Medullosales, Callystophytales and Peltaspermales) but no ferns (Šetlík in Tásler *et al*. 1979). We conclude that Rybníček coal swamp located along lake coast was dominated by wetland taxa, mostly ferns and sphenopsids with subordinate lycopsids including *Polysporia*, lepidodendrids and *Sigillaria brardii*. Common part of the peat swamp and clastic wetlands was also medullosalean and callistophytalean pteridosperms, not recorded in palynomorph assemblage. Drier habitats but probably still not far from the wetlands were possibly colonised by pteridosperms of peltaspermales affinity, whereas dryland habitats further away (not recorded in macroflora) were colonised dominantly by cordaitaleans and walchian conifers. This dryland biome predominated during deposition of the red beds part of the Chvaleč Formation.

The lower Permian red beds provided only very sparse and poorly preserved plant impressions dominated by walchian conifers. However, lacustrine horizons in the Olivětín Member bear relatively rich and diverse macrofloral record. In contrast, only few miospore taxa were obtained. Plant compressions suggest the existence of landscape dominated by conifers and pteridosperms (mostly peltasperms) with subordinate ferns, sphenopsids and cordaitalens (Opluštil *et al.* 2017). Lycopsids are represented only by *Sigillaria brardii*. However, the occurrence of *Lycospora* may indicate survival of very small populations of lepidodendrid lycopsids until Asselian times. They are, however, so far unknown in macrofloral record. This is not so unusual, in the late Autunian (= early Asselian) strata of the Autun Basin in France there also contains several *Lycospora* species (Châteauneuf *et al*. 1992).

Summary

The Intra-Sudetic Basin is a small continental basin situated along Czech-Polish border with a depositional history ranging from late Mississippian to Triassic times. Evaluation of a huge amount of previously unpublished palynological data from boreholes and coal mines provided a consistent overview on miospore and pollen diversity and stratigraphic ranges of all identified taxa from late Baskhirian to early Asselian times in a resolution of up to individual cyclothems. This, in turn, allowed the comparison of miospores and pollen ranges and diversities with recently published macrofloral record. The major results and conclusions are as follows:

(1) Palynological record is affected by the potential for preservation that varied throughout the studied interval, mainly due to shifts between more humid and drier (more seasonal) climate. These shifts controlled the groundwater table, and in turn, preservation/decomposition of plant remains and miospores and pollen. As a result, the palynological data derive from coal-bearing intervals, whereas in coal-barren red beds "data" are a mere interpolation of taxa between adjacent coal-bearing strata.

(2) Palynological samples are primarily coal and carbonaceous mudstones representing originally peat or mixed peat-clastic swamp environments, *i.e*. dominantly wetland flora composed of plant lineages, mainly of free-sporing plants.

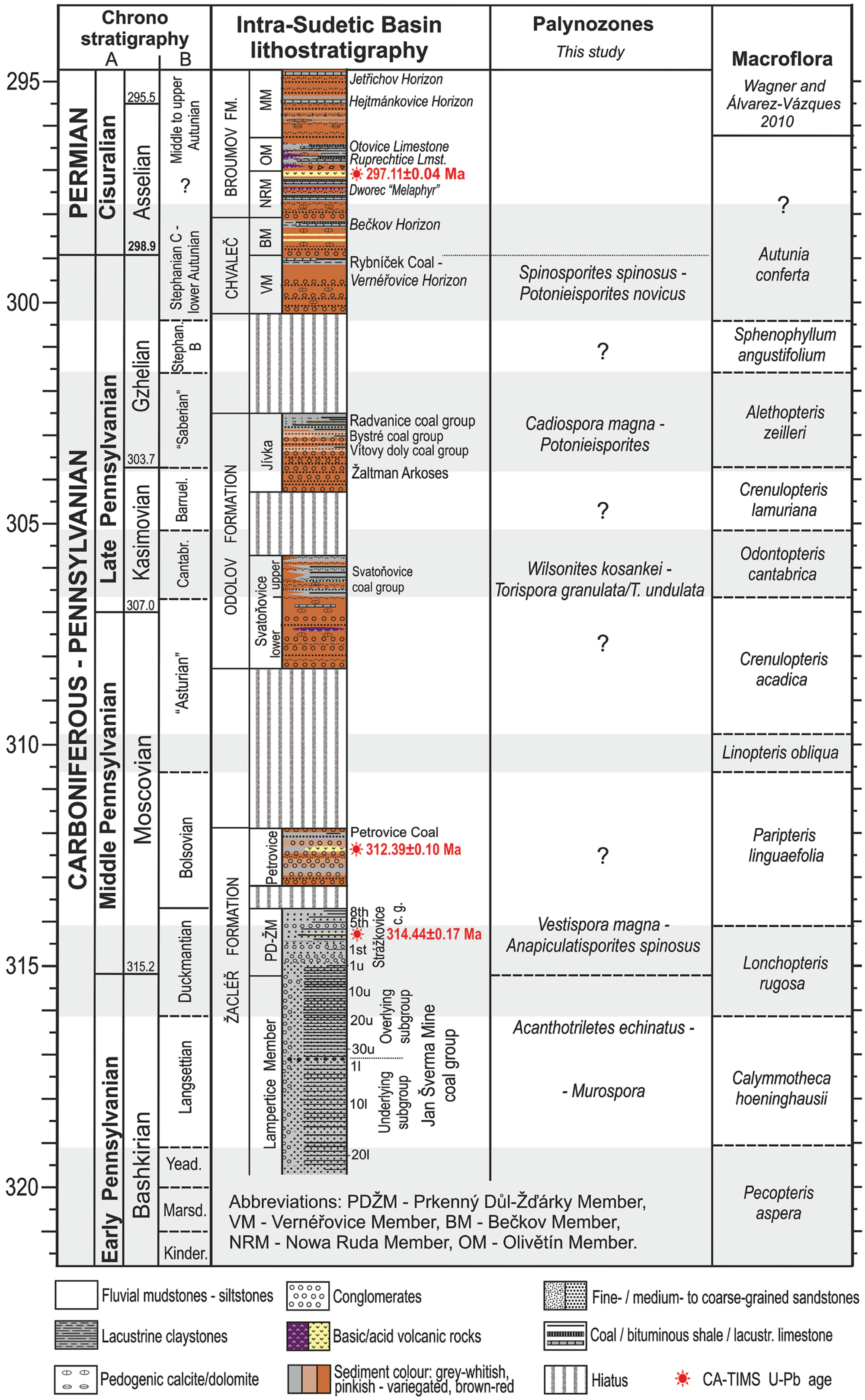

Figure 15. Palynological zones defined in this study and their comparison with macrofloral zones. Abbreviations: Kinder – Kinderscoutian; Marsd. – Marsdenian; Yead. – Yeadonian; Cantabr. – Cantabrian; Barruel. – Barruelian; Stephan. – Stephanian; FM. – formation; PD-ŽM – Prkenný Důl-Žďárky Member; VM – Verneřovice Member; BM – Bečkov Member; NRM – Nowa Ruda Member; OM – Olivětín Member; MM – Martínkovice Member.

(3) In all, 78 genera and 322 species have been identified. These are mostly miospores; pollen of seed plants is very rare, represented mainly by cordaitaleans, walchian conifers and rare peltaspermalean and/or cycadalean plant producers. Pollen of other pteridosperms (*e.g.* medullosaleans) are absent, although these plants dominate in abundance and diversity compression floras associated with coals.

(4) Five new palynozones (Fig. 15) are proposed based on first occurrences of stratigraphically important and morphologically prominent spore and pollen taxa. These taxa include *Acanthotriletes echinatus*, *Alatisporites hexalatus* Kosanke, *Cirratriradites flabelliformis*, *Vestispora magna*, *Wilsonites kosankei* Bharadwaj, *Torispora granulata*, *T. undulata*, *Cadiospora magna*, *Spinosporites spinosus* and genera *Murospora* and *Potonieisporites*. Each palynozone corresponds to one member; only for the Petrovice and Olivětín members it was not possible to suggest any palynozone due to very poor dispersed record with very low number of specimens.

(5) Two main trends through the basin succession can be recognised. The first is increased percentage of monolete (sphenophyllalean origin) miospores (more than 35 μm) and pollen from the late Baskhirian to early Asselian and the second is a prominent increased number (not first occurrence) of smallest (marratialean origin) monoletes (less than 35 μm) within the Jívka Member. The boundary between the Svatoňovice and Jívka members represented the most important change because dispersed spore and pollen assemblages significantly differ mainly in the appearance of coniferalean and gingkoalean pollen together with rapid abundance of marattialean miospores.

(6) Some groups of miospores and pollen increased from the Lampertice to the Jívka members, *i.e.* sphenopsid, marattialean, coniferalean, cordaitalean, cycadalean and unknown affinity and others have a decreasing curve, *i.e.* spores of lycopsid, zygopterid and botryopterid genera.

(7) The comparison of European dispersed miospore and pollen assemblages from late Baskhirian to early Asselian interval shows that the most similar are those from the Polish part of the Intra-Sudetic Basin. But this similarity is not absolute because some taxa described in the Polish part of the basin (*e.g. Florinites junior* Potonié & Kremp and *Radiizonates*) have never been described in the Czech part and other taxa [*e.g. Punctatosporites bechlinensis* Kalibová and *Gillespieisporites spinosus* (Kosanke) Kalibová] never described in the Polish part. Other taxa (*e.g. Endosporites globiformis*) appear later in one part of the basin than in the second one. Such differences may be influenced by the fact that almost all samples from the Czech part are from coal seams but not all samples from the Polish part are from the coal.

(8) Comparison with contemporaneous basins in Europe also shows that massively increased percentage of smallest monoletes of genera *Punctatosporites*, *Laevigatosporites*, *Latosporites*, *Torispora*, *Thymospora* and *Speciososporites* appears in several European basins and coalfields including Polish part of the Upper Silesian Basin (Górecka 1968, 1969; Górecka & Górecka-Nowak 1990) Zwickau-Oelsnitz (Hartkopf-Fröder 2005), Saxony and Saar-Nahe Basin in Germany (Hartkopf-Fröder 2005), UK (Smith & Butterworth 1967), Saar-Lorraine in France (Liabeuf *et al*. 1967, Alpern *et al*. 1969, Liabeuf & Alpern 1970, Loboziak 1971) and Portugal (Pereira 1999) and the Western Europe palynozonation (Clayton *et al*. 1977) earlier than in the Czech part of the Intra-Sudetic Basin. This prominent higher occurrence of smallest monoletes is recorded within the Asturian in these countries, but later in early Stephanian in the Czech part of the Intra-Sudetic Basin. On the other hand, *e.g.* assemblages from the Netherlands (Wijhe & Bless 1974) yielded a similar character at this stratigraphic level as those from the Czech part of the Intra-Sudetic Basin.

(9) Combined palynological and previously published macrofloral data suggest alternation of dominantly wetland and dryland floras (biomes) that follow basin-wide alternation of coal-bearing intervals and coal-barren red beds, driven by shifts between humid and drier seasonal climates.

(10) Yeadonian to Duckmantian represents a ~6 Ma coal-bearing interval of ecological and species stability when wetland habitats including peat swamps dominated basin lowlands. Changes in species composition between neighbouring cyclothems were mostly below 10 of all miospore and pollen taxa. Basin landscape was colonized by free-sporing plants. Arborescent lycopsids were at the maximum of their diversity and abundance. Pteridosperms and ferns were also diverse. There are no indications of the presence of dryland floras in this interval neither in miospores and pollen nor in plant compressions.

(11) Since the Bolsovian, ecological gradient increases allowing for the co-existence of poorly-drained wetland and well-drained dryland habitats in the basin even during coal-bearing intervals. The proportion of dryland habitats in coal-bearing intervals increases during late Pennsylvanian. Dryland flora is first recorded by the presence of *Vittatina* pollen in late Bolsovian strata. Earliest evidence of conifers is from plant impressions

in late Asturian red beds. In the Saberian coal-bearing window conifer shoots and pollens occur in sediments directly associated with coals.

(12) Palynological data indicates possible survival of lepidodendrid lycopsids into early Asselian times, although the macrofloral remains have not been found so far.

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Appendix

Alphabetical list of dispersed miospore and pollen taxa recorded in the CPISB with their maximum (max.) and average (ø) percentage. Abbreviations: L – occurrence at the Lampertice Member; PZ – Prkenný Důl-Žďárky Member; P – Petrovice Mamber; S – Svatoňovice Member; J – Jívka Member; V – Vernéřovice Member; O – Olivětín Member. Thick letters mean where the taxon is the most abundant.

Acanthotriletes acerosus Naumova, 1937. L.
Acanthotriletes echinatus (Knox) Potonié & Kremp, 1954. L. ø 4%; max. 15% – 24th upper Sub-Group of the Lampertice Coal Seam.
Acanthotriletes falcatus (Knox) Potonié & Kremp, 1954. L. ø 0.2%.
Acanthotriletes microspinosus (Ibrahim) Potonié & Kremp, 1954. L.
Acanthotriletes spp. L, PZ, P, S, J, V, O. ø 4%.
Acanthotriletes triquetrus Smith & Butterworth, 1967. PZ. ø 3%; max. 8% – 5th Žďárky Coal Seam.
Ahrensisporites angulatus (Kosanke) Dybová & Jachowicz, 1957. L, **PZ**, P, S, J, O. ø 5.3%; max. 15% – base of PZ.
Ahrensisporites guerickei (Horst) Potonié & Kremp, 1954. L, PZ, P, S.
Ahrensisporites minutus Alpern, 1959. L, PZ, P, S.
Ahrensisporites spp. L, PZ, P, S, J, O.
Alatisporites hexalatus Kosanke, 1950. PZ.
Alatisporites pustulatus Ibrahim, 1933. L.
Alatisporites spp. L, PZ, P, S.
Alatisporites trialatus Kosanke, 1950. L.
Anapiculatisporites cf. *spinosus* (Kosanke) Potonié & Kremp, 1955. L, PZ.
Anapiculatisporites minor (Butterworth & Williams) Smith & Butterworth, 1967. L, PZ, P, S, J. ø 2.5%.
Anapiculatisporites spinosus (Kosanke) Potonié & Kremp, 1955. PZ. ø 1.5%.
Anapiculatisporites spp. L, PZ, P, S, J. ø 0.5%.
Anaplanisporites globosus (Butterworth & Williams) Smith & Butterworth, 1967. L. ø 1.5%.
Angulisporites splendidus Bharadwaj, 1957. J, V. ø 2.9%, max. 5% – Radvanice coal seams.
Apiculatasporites spinulistratus (Loose) Ibrahim, 1933. **L, PZ**, P, S, J. ø 4.2%; max. 17% – Petrovice Coal Seam.
Apiculatasporites spp. L. ø 5%, max. 10% 9th underlying coal seam.
Apiculatisporites abditus (Loose) Potonié & Kremp, 1955. PZ. ø 2%.
Apiculatisporites aculeatus (Ibrahim) Smith & Butterworth, 1967. L.
Apiculatisporites baccatus Hoffmeister, Staplin & Malloy, 1955. V.
Apiculatisporites baccatus var. *trebechovensis* Kalibová, 1974. V.
Apiculatisporites conatus Kalibová, 1974. J. ø 4.1%.
Apiculatisporites latigranifer (Loose) Potonié & Kremp, 1955. PZ, P, S, J. ø 2% (only two records).
Apiculatisporites spp. L, **PZ**, P, S, J. ø 4.3%, max. 8% 1st Žďárky Coal Seam.
Aumancisporites spp. V.
Aumancisporites striatus Alpern, 1959. J. ø 1% (one record).
Bellispores nitidus (Horst) Sullivan, 1964. **L**, PZ. ø 7.4%; max. 22% – Lampertice coal seams.
Bellispores spp. **L,** PZ. ø 2.3%; max. 10% – Lampertice coal seams.
B. radiatus Dybová & Jachowicz, 1957. L, PZ.
Cadiospora spp. J, V.
Cadiospora bohemica Boháčová, 1962. J.
Cadiospora magna f. *maior* Kalibová-Kaiserová, 1972. J.
Cadiospora magna f. *minor* Kalibová-Kaiserová, 1972. J.
Cadiospora magna f. *plicata* Kalibová-Kaiserová, 1972. J.
Cadiospora magna Kosanke, 1950. J, V.
Cadiospora sphaera Butterworth & Williams, 1958. J.
Calamospora breviradiata Kosanke, 1950. S, **J**.
Calamospora cf. *laevigata* Schopf, Wilson & Bentall, 1944. J.
Calamospora hartungiana (Schopf) Schopf, Wilson & Bentall, 1944. J.
Calamospora laevigata (Ibrahim) Schopf, Wilson & Bentall, 1944. L, PZ.
Calamospora liquida Kosanke, 1950. L, **PZ**, P, S, J.
Calamospora microrugosa (Ibrahim) Schopf, Wilson & Bentall, 1944. L, PZ, P, S, J.
Calamospora minuta Bharadwaj, 1958. PZ.
Calamospora mutabilis (Loose) Schopf, Wilson & Bentall, 1944. **L**, PZ, P, S, J.
Calamospora pallida (Loose) Schopf, Wilson & Bentall, 1944. L, PZ, P, S, J.
Calamospora pedata Kosanke, 1950. L, PZ, S, J, V.

Calamospora perrugosa (Loose) Schopf, Wilson & Bentall, 1944. L, PZ.
Calamospora saariana Bharadwaj, 1957. J.
Calamospora spp. L, PZ, P, S, J, V.
Calamospora straminea Wilson & Kosanke, 1950. PZ, P, S, J, V.
Camptotriletes bucculentus (Loose) Potonié & Kremp, 1955. L, PZ.
Camptotriletes juglandilis Horst, 1955. L.
Cingulizonates loricatus (Loose) Butterworth & Williams, 1958. L.
Cingulizonates radiatus Dybová & Jachowicz, 1957. L.
Cingulizonates spp. L, PZ. ø 3.8%; max. 10% – Lampertice coal seams.
Cingulizonates tuberosus Dybová & Jachowicz, 1957. PZ.
Cirratriradites annulatus Kosanke & Brokaw in Kosanke, 1950. S.
Cirratriradites flabelliformis Wilson & Kosanke, 1944. S.
Cirratriradites rarus (Ibrahim) Schopf, Wilson & Bentall, 1944. L. Only one occurrence; 17% at the upper Lampertice Coal Seam.
Cirratriradites saturni (Ibrahim) Schopf, Wilson & Bentall, 1944. L, **PZ**, P, S. ø 4.2%; max. 10% – 11th overlying coal seam.
Cirratriradites spp. L, **PZ**. ø 2%, max. 3% PZ.
Converrucosisporites armatus (Dybová & Jachowicz) Smith & Butterworth, 1967. L. ø 2% (only two records).
Converrucosisporites spp. **L**, PZ, P, S, J, O. ø 5%; max. 35% – 9th underlying seam and 29% – 16th underlying seam.
Convolutispora florida Hoffmeister, Staplin & Malloy, 1955. L.
Convolutispora jugosa Smith & Butterworth, 1967. PZ. ø 0.5%.
Convolutispora spp. **L**, PZ, P, S, J, V. ø 2%; max. 5% – 25th and 2nd overlying coal seams.
Convolutispora tessellata Hoffmeister, Staplin & Malloy, 1955. L. ø 3% (only two records).
Convolutispora varicosa Butterworth &Williams, 1958. L, ø 1% (only one record).
Crassispora kosankei (Potonié & Kremp) Bharadwaj, 1957. L, PZ, P, S, J. ø 2%.
Crassispora maculosa (Knox) Sullivan, 1964. L. ø 1% (only one record).
Crassispora ovalis Bharadwaj, 1957. J.
Crassispora plicata Peppers, 1970. J. ø 2.5%; max. 6% – Radvanice coal seams.
Crassispora spp. PZ, P, S, J. ø 3%; max. – 11% Radvanice coal seams.
Cristatisporites indignabundus (Loose) Potonié & Kremp, 1955. PZ. ø 26%; max. 30% – 5th overlying coal seam.
Cristatisporites saarensis Bharadwaj, 1957. P.
Cristatisporites spp. L, **PZ**, ø 7.5%; max. 24% – base of PZ.
Cristatisporites solaris (Balme) Butterworth et al., 1964. L, PZ. ø 5.5%; max. 10% – 5th overlying seam.
Cyclogranisporites aureus (Loose) Potonié & Kremp, 1955. **L, PZ**, P, S, J. ø 4.5%; max. 23% – Radvanice coal seams.
Cyclogranisporites densus Bharadwaj, 1957. J, V. ø 4.2%; max. 16% – Radvanice coal seams.
Cyclogranisporites jelenicensis Kalibová, 1978. PZ, S, J, V. ø 6.5%; max. 26% – Radvanice coal seams.
Cyclogranisporites leopoldii (Kremp) Potonié & Kremp, 1955. L, PZ, S.
Cyclogranisporites minutus Bharadwaj, 1957. L, PZ, S, J.
Cyclogranisporites orbicularis (Kosanke) Potonié & Kremp, 1955. L, PZ, S, J. ø 5%; max. 30% – Radvanice coal seams.
Cyclogranisporites pergranulus Alpern, 1959. J. ø 1% (one record).
Cyclogranisporites pressoides Potonié & Kremp, 1955. L.
Cyclogranisporites spp. L, PZ, P, S. ø 4.6%; max. 16% at S.
Densosporites anulatus (Loose) Schopf, Wilson & Bentall, 1944. **L, PZ,** P. ø 5%; max. 13% – base of P.
Densosporites lobatus Kosanke, 1950. L, PZ.
Densosporites sphaerotriangularis Kosanke, 1950. P, S. ø 8%; max. 14% – base of S.
Densosporites spp. **L, PZ,** P, S, J. ø 20%; max. 100% – 3rd Žďárky Coal Seam, 97% – 1st Žďárky Coal Seam, 78% – 2nd Žďárky Coal Seam.
Densosporites triangularis Kosanke, 1950. L.
Densosporites verrucosus Dybová & Jachowicz, 1957. L, PZ.
Dictyotriletes bireticulatus (Ibrahim) Potonié & Kremp, 1955. L, PZ. ø 4.4%; max 8% – 6th Žďárky Coal Seam.
Dictyotriletes densoreticulatus Potonié & Kremp, 1955. L, **PZ**. ø 5%; max. 10% – 2nd overlying coal seam.
Dictyotriletes falsus Potonié & Kremp, 1955. PZ. ø 1% (only one record).
Dictyotriletes muricatus Kosanke, 1950. **PZ**, P, S, J. ø 2%; max. 4% – 5th Žďárky Coal Seam.
Dictyotriletes spp. L, **PZ**, P, S, J. ø 3.5%; max. 30% – Radvanice coal seams.
Dictyotriletes triangulatus Dybová & Jachowicz, 1957. L, PZ, P, S, J.
Disaccites spp. J. ø 0.1% (only one record).
Endosporites formosus Kosanke, 1950 PZ, P, S, **J,** V. ø 7.5%; max. 43% – Radvanice coal seams.
Endosporites globiformis (Ibrahim) Schopf, Wilson & Bentall, 1944. J, V. ø 2%; max. 4% – Radvanice coal seams.
Endosporites grandisaccatus Kalibová, 1978. J. ø 0.5% (only one record).
Endosporites ornatus Wilson & Coe, 1940. L, **PZ,** P, S, J. ø 7%; max. 25% – lower part of S.

Endosporites spp. PZ, P, S. ø 1.8%; max. 5%.
Endosporites zonalis Loose in Potonié, Ibrahim & Loose, 1932. L, **PZ**, ø 5%; max. 33% – PZ.
Euryzonotriletes spp. L.
Florinites antiquus Schopf in Schopf, Wilson & Bentall, 1944. L, PZ, P, S, **J**. ø 2.5%; max. 7% – Baltazar Coal Seam.
Florinites mediapudens (Loose) Potonié & Kremp, 1955. **L**, PZ, P, S, J. ø 4.2%; max. 12% – Main Svatoňovice Coal Seam.
Florinites millotii Butterworth & Williams, 1958. PZ, P, S, J.
Florinites minutus Bharadwaj, 1958. S, J. ø 3.5%; max. 5% – "Visutá" Coal Seam.
Florinites piérarti Kalibová, 1964. V.
Florinites pumicosus (Ibrahim) Schopf, Wilson & Bentall, 1944. L, PZ, P, S, J, V. ø 5% (only two measured records)
Florinites similis Kosanke, 1950. J, V.
Florinites spp. L, PZ, P, S, J, V. ø 3.9%; max. 21% – Pulkrábek Coal Seam.
Foveosporites spp. L. ø 1% (only two records).
Gillespieisporites discoideus (Kosanke) Kalibová, 1989. J. ø 3.2%; max. 10% – Radvanice coal seams.
Gillespieisporites spinosus (Kosanke) Kalibová, 1989. J.
Gillespieisporites spp. J., O. ø 2.6%; max. 29% – Baltazar Coal Seam.
Granulatisporites granulatus Ibrahim, 1933. **L**, PZ. ø 5.5%; max. 47% – 9th overlying Coal Seam.
Granulatisporites gulaferus Potonié & Kremp, 1955. **L**, PZ, P, S. ø 4.5%; max. 25% – lower part of S.
Granulatisporites microgranifer Ibrahim, 1933. **L**, PZ. ø 3.6%; max. 13% – 12th overlying coal seam.
Granulatisporites minutus Potonié & Kremp, 1955. **L, PZ**, P, S, J. ø 8%; max. 40% – Štrambach Coal Horizon.
Granulatisporites parvus (Ibrahim) Potonié & Kremp, 1955. **L, PZ,** P. ø 3%; max. 5% – Petrovice Coal Seam.
Granulatisporites piroformis (Loose) Potonié, Ibrahim & Loose, 1932. **L, PZ**, P, S, J. ø 4.5%; max. 15% – 17th overlying coal seam.
Granulatisporites spp. L, **PZ**, P, S, J. ø 5%; max. 17% – PZ.
Grumosisporites spp. **L,** PZ. ø 1.3%; max. 3% – 1st Žďárky Coal Seam.
Güthoerlisporites magnificus Bharadwaj, 1957. J.
Guthoerlisporites spp. J. ø 4%; max. 8% – Radvanice coal seams.
Illinites spp. J. ø 4% (only one record).
Illinites unicus (Kosanke) Bharadwaj, 1957. J. ø 1%.
Knoxisporites polygonalis (Ibrahim) Potonié & Kremp, 1955. **L,** PZ, P. ø 4.3%; max. 12% – between 14th and 13th Lampertice coal seams.
Knoxisporites spp. L, **PZ**. ø 1%; max. 3% – 9th overlying coal seam.
Kosankeisporites elegans (Kosanke) Bharadwaj, 1957. J, V. ø 1.4%; max. 5% – Radvanice coal seams.
Kosankeisporites spp. S, J, O. ø 2.5%; max. 4% – Na Rybníčku Coal Seam.
Kuhlensisporites spp. PZ. ø 1% (only one measured record).
Laevigatosporites costatus Alpern, 1959. J.
Laevigatosporites densus Alpern, 1959. J, V.
Laevigatosporites desmoinesensis (Wilson & Coe) Schopf, Wilson & Bentall, 1944. L, PZ, P, S, J, V. ø 17%; max. 54% – Pulkrábek Coal Seam.
Laevigatosporites maximus (Loose) Potonié & Kremp, 1955. L, PZ, P, S, J, V. ø 2.3%; max. 5% – Radvanice coal seams.
Laevigatosporites medius Kosanke, 1950. L, PZ, P, S, J, V. ø 12%; max. 82% – Radvanice coal seams.
Laevigatosporites minimus (Wilson & Coe) Schopf, Wilson & Bentall, 1944. L, PZ, S, J, V. ø 14%; max. 77% – Baltazar Coal Seam.
Laevigatosporites striatus Alpern, 1959. S, J, V. ø 0.5% (only one record).
Laevigatosporites vulgaris Ibrahim, 1933. S, J. ø 4.9%; max. 16% – Baltazar Coal Seam.
Latensina spp. J. ø 2.8%; max. 7% – Radvanice coal seams.
Latensina triletus Alpern, 1959. J. ø 3%; max. 4% – Radvanice coal seams.
Latosporites globosus Schemel, 1950. J. ø 9% (only two records); max. 16% – Radvanice coal seams.
Latosporites latus (Loose) Potonié & Kremp, 1955. L, PZ, P, S, J, V. ø 4.2%; max. 16% – 9th overlying coal seam.
Latosporites melnicensis Kalibová, 1989. J.
Latosporites robustus (Kosanke) Potonié & Kremp, 1955. P, S, **J**. ø 1.8%; max. 3% – Radvanice coal seams.
Latosporites saarensis Bharadwaj, 1955. **J,** V. ø 6.1%; max. 19% – Radvanice coal seams.
Latosporites spp. L, PZ. ø 1.8%; max. 3% – S.
Leiotriletes adnatoides Potonié & Kremp, 1955. L, PZ, P, S, J. ø 4.5%; max 20% – Petrovice Coal Seam.
Leiotriletes adnatus Kosanke, 150. **L, PZ**, P. ø 12% (only two occurrences); max. 13th–14th overlying seam.
Leiotriletes convexus (Kosanke) Potonié & Kremp, 1955. L, **PZ**, P, S. ø 5%; max. 25% at the base of P.
Leiotriletes gulaferus Potonié & Kremp, 1955. L, PZ, P, S, J. ø 4.3%; max. 25% at the base of P.
Leiotriletes minutus (Knox) Potonié & Kremp, 1955. L, PZ, P, S. ø 8%; max. 3% – 10th underlying seam.
Leiotriletes sphaerotriangulus (Loose) Potonié & Kremp, 1955. L, PZ, P, S, J. ø 4.3%; max. 11% – 2nd Žďárky Coal Seam.
Leiotriletes spp. L, PZ, P, S, J. ø 4.7%; max. 17% – P.
Lophotriletes microsaetosus (Loose) Potonié & Kremp, 1955. **L**, **PZ**, P, S, J, V. ø 4%; max. 14% – 29th upper coal Lampertice Coal Seam.

Lophotriletes cf. *microsaetosus* (Loose) Potonié & Kremp, 1955. PZ, P, S, J.
Lophotriletes commisuralis (Kosanke) Potonié & Kremp, 1955. L PZ, P, S, J. ø 3.5%; max. 6% – the "Visutá" Coal Seam.
Lophotriletes f. *gulaferus*. L, PZ, P, S. J, V.
Lophotriletes gibbosus (Ibrahim) Potonié & Kremp, 1955. **PZ, P**, S, J, V. ø 4%; max. 9% – 5th Žďárky Coal Seam.
Lophotriletes insignitus (Ibrahim) Potonié & Kremp, 1955. L, V. ø 2.5%; max. 5% – 9th Lampertice Coal Seam (only two measured records).
Lophotriletes mosaicus Potonié & Kremp, 1955. L, PZ, P, S, J, V, O. ø 3.5%; max 9% – Petrovice Coal Seam.
Lophotriletes pseudaculeatus Potonié & Kremp, 1955. PZ, P, S, J. ø 1%.
Lophotriletes spp. L, PZ, P, S, J. ø 3.5%; max. 14% – 11th Lampertice Coal Seam.
Lophozonotriletes spp. L, PZ, ø 0.5% (only one measured record).
Lueckisporites spp. J. ø 0.3% (only one record).
Lundbladispora gigantea (Alpern) Doubinger, 1961. J.
Lycospora brevijuga Kosanke, 1950. L, PZ, P, S, J. ø 9.5%; max. 36% – Radvanice coal seams.
Lycospora brevis Bharadwaj, 1957. L, PZ, P, S, J. ø 10%; max. 33% – 9th Lampertice Coal Seam.
Lycospora granulata Kosanke, 1950. **PZ**, P, S, J, V. ø 4.6%.
Lycospora microgranulata Bharadwaj, 1957. S. ø 1%.
Lycospora noctuina Butterworth & Williams, 1958. L, **PZ**, P, S, J, V. ø 4.8%; max. 2% – Jan Šverma Mine.
Lycospora parva Kosanke, 1950. L.
Lycospora pellucida (Wicher) Schopf, Wilson & Bentall, 1944. L, PZ, S. ø 1.8%; max. 10% – Jan Šverma Mine.
Lycospora pseudoannulata Kosanke, 1950. L, **PZ**, S, J, V. ø 12%; max. 31% – 1st Žďárky Coal Seam.
Lycospora punctata Kosanke, 1950. L, PZ, P, S, J, V. ø 20%; max 96% – Jan Šverma Mine.
Lycospora pusilla (Ibrahim) Potonié & Kremp, 1955. L, PZ, P, S, J. ø 18%; max. 75% – base S.
Lycospora rotunda Bharadwaj, 1957. L. ø 17% (only one record).
Lycospora spp. L, PZ, P, S, J, V, O. ø 25%, max. 91% 33rd overlying Coal Seam, 100% 2nd overlying coal seam.
Lycospora subjuga Bharadwaj, 1957. L, **PZ**, P, S, J. ø 5.5%; max. 34% – 3rd Žďárky Coal Seam.
Lycospora triangulata Bharadwaj, 1957. PZ, P. ø 3%; max. 6% – 5th Ždárky Coal Seam.
Microreticulatisporites fistulosus (Ibrahim) Potonié & Kremp, 1955. **L**, PZ, P, S, J, V. ø 3%; max. 14% – 11th Lampertice Coal Seam.
Microreticulatisporites nobilis (Wicher) Knox, 1950. **PZ**, P, S, J. ø 3%; max. 7% – Main Svatoňovice Seam.
Microreticulatisporites punctatus Knox, 1950. L. ø 2.5%; max. 12% – Jan Šverma Mine.
Microreticulatisporites reticuloides (Kosanke) Potonié & Kremp, 1955. L.
Microreticulatisporites sulcatus (Wilson & Kosanke) Smith & Butterworth, 1967. L, PZ.
Microreticulatisporites spp. **L**, PZ, P, S, J.
Mooreisporites cf. *inusitatus* (Kosanke) Neves, 1961. PZ.
Mooreisporites inusitatus (Kosanke) Neves, 1961. **L**, PZ, P, S. ø 2.7%; max. 10% – 10th overlying coal seam.
Mooreisporites spp. **L,** PZ. ø 4.9%; max. 17% – Jan Šverma Mine.
Murospora spp. L, PZ. ø 4.5%; max. 20% – 6th underlying coal seam.
Murospora sulcata (Waltz) Jachowicz, 1972. L. ø 5% (only one measured record).
Planisporites spp. **L**, PZ, P, S, J. ø 2.7%; max. 16% – upper Lampertice Coal Seam.
Polymorphisporites spp. L, PZ, P, S, J. ø 0.5%.
Potonieisporites novicus Bharadwaj, 1957. **J,** V, O. ø 1.2% max. 2% – Radvanice coal seams.
Potonieisporites spp. **J,** V. ø 2%; max 9% – Radvanice coal seams.
Potoniesporites elegans (Wilson & Kosanke) Wilson & Venkatachala, 1964. J, V. ø 0.3%.
Punctatisporites aerarius Butterworth & Williams, 1958. L. ø 1% (only one record).
Punctatisporites minutus Kosanke, 1950. **L**, PZ, P, S, J, V. ø 2%; max. 7% – 25th overlying seam.
Punctatisporites obesus (Loose) Potonié & Kremp, 1955. PZ, P, S. ø 1%.
Punctatisporites obliquus Kosanke, 1950. **L**, PZ, P, S, J, V. ø 2%; max. 5% – 2nd Žďárky Coal Seam.
Punctatisporites provectus Kosanke, 1950. V. ø 1%.
Punctatisporites punctatus Ibrahim, 1933. L, PZ, P, S. ø 2.5%; max. 4% – "Visutá" Coal Seam.
Punctatisporites spp. **L**, PZ, P, S, J, V. ø 2.3%; max. 10% – 8th overlying coal seam.
Punctatosporites bechlinensis Kalibová, 1989. J. ø 1.5%; max. 2% – Radvanice coal seams.
Punctatosporites granifer Potonié & Kremp, 1955. PZ, P, S, **J**. ø 7%; max. 23% – Main Svatoňovice Coal Seam.
Punctatosporites granulatus Bharadwaj, 1957. S, O. ø 4% (only one measured record).
Punctatosporites minutus Ibrahim, 1933. **L**, PZ, S, **J,** V. ø 6%; max. 32% – 8th Žďárky Coal Seam.
Punctatosporites oculus Smith & Butterworth, 1967. J. ø 2.5%; max. 6% – Baltazar Coal Seam.
Punctatosporites punctatus (Kosanke) Potonié & Kremp, 1955. PZ, P, S, **J**. ø 5.5%; max. 18% – 8th Žďárky Coal Seam.
Punctatosporites pygmaeus (Imgrund) Potonié & Kremp, 1955. S, J. ø 24% (only one measured record).
Punctatosporites rotundus (Bharadwaj) Dybová & Jachowicz, 1957. S, J. ø 3% (only one measured record).

Punctatosporites speciosus Kalibová, 1989. J. ø 2%; max. 4% – Radvanice coal seams.
Punctatosporites spp. L, PZ, P, S, J, V. ø 9%; max. 50% – Jan Šverma Mine.
Pustulatisporites pustulatus Potonié & Kremp, 1955. **L**, PZ, P, S, J. ø 3.8%; max. 8% – 5th Žďárky Coal Seam.
Pustulatisporites spp. L, PZ, P, S, J. ø 1.3%; max. 3% – Jan Šverma Mine.
Radiizonates spp. L.
Raistrickia aculeata Kosanke, 1950. J.
Raistrickia aculeolata Kosanke, 1950. J, V.
Raistrickia carbondalensis Peppers, 1970. L.
Raistrickia crinita Kosanke, 1950. L, PZ, P, S. ø 2.2%; max. 3% – "Visutá" Coal Seam.
Raistrickia fulva Artüz, 1957. L.
Raistrickia microhorrida (Horst) Potonié & Kremp, 1955. L.
Raistrickia saetosa (Loose) Schopf, Wilson & Bentall, 1944. **L**, PZ, P, S, J. ø 1.7%; max. 5% – 5th Žďárky Coal Seam.
Raistrickia spp. **L**, PZ, P, S, J. ø 2%; max. 12% – 2nd Žďárky Coal Seam.
Raistrickia superba (Imgrund) Schopf, Wilson & Bentall, 1944. **L,** PZ, P, S. ø 2.8%; max. 16% – upper part of L.
Reinschospora magnifica Kosanke, 1950. L, PZ.
Reinschospora spp. L, PZ. ø 0.5%.
Remysporites magnificus (Horst) Potonié & Kremp, 1955. L.
Reticulatasporites facetus Ibrahim, 1933. L, **PZ**. ø 5%; max. 11% – base of P.
Reticulatasporites spp. PZ, P, S.
Reticulatasporites taciturnus (Ibrahim) Potonié & Kremp, 1955. PZ. ø 5.5%; max 8% – 5th Žďárky Coal Seam.
Reticulatisporites adhaerens Kosanke, 1950. L, PZ. ø 2% (only one measured record).
Reticulatisporites alveolatus Knox, 1950. **L,** PZ. ø 4%; max.% – 6th Žďárky Coal Seam.
Reticulatisporites castaneaeformis (Horst) Sullivan**,** 1964. L, **PZ**. ø 4.5%; max. 14% – 2nd Žďárky Coal Seam.
Reticulatisporites reticulatus Ibrahim, 1933. PZ, P, S, J, V. ø 2% (only one measured record).
Reticulatisporites reticulocingulum (Loose) Ravn, 1986. L, PZ, P, S, J, V.
Reticulatisporites spp. **L, PZ**, P, S, J, V, O. ø 3.5%.
Savitrisporites camptotus (Alpern) Doubinger, 1974. **L,** PZ. ø 3.5 ; max. 11% – L.
Savitrisporites cingulatus (Alpern) Bharadwaj, 1962. L, **PZ**, P. ø 4.2%; max. 11% – 2nd Žďárky Coal Seam.
Savitrisporites concavus Marshall & Smith, 1965. **L,** PZ. ø 7.5%; max. 24% – 6th underlying coal seam.
Savitrisporites majus Bharadwaj, 1958. L.
Savitrisporites minor Jachowicz, 1972. **L, PZ**, P, S. ø 12%; max. 53% – 2nd overlying coal seam.
Savitrisporites nux (Butterworth & Willimas) Smith & Butterworth, 1967. **L**, PZ. ø 8.8%; max. 45% – 17th underlying coal seam.
Savitrisporites spp. **L,** PZ, P, S. ø 4.5%; max. 31% – upper part of L.
Simozonotriletes clarus Dybová & Jachowicz, 1957. PZ.
Simozonotriletes intortus (Waltz) Potonié & Kremp, 1955. L, PZ.
Simozonotriletes spp. **L**, PZ. ø 2.6%; max. 7% – between 22nd and 23rd underlying coal seams.
Sinuspores sinuatus (Artüz) Ravn, 1986. **L**, PZ. ø 3.5%; max. 20% – 18th underlying coal seam.
Speciososporites laevigatus Alpern, 1959. S, **J**. ø 3.5%; max. 16% – Radvanice coal seams.
Speciososporites minor Alpern, 1957. J, V. ø 4.5%; max. 7% – Radvanice coal seams.
Speciososporites plicatus Alpern, 1957. J. ø 2.3%; max. 3% – Radvanice coal seams.
Speciososporites spp. S, **J,** V. ø 3%; max. 14% – Radvanice coals seams.
Speciososporites triletoides Alpern, 1959. J.
Spinosporites spinosus Alpern, 1959. V. ø 4% (only one measured record).
Stellisporites cf. *inflatus* Alpern, 1959. L, PZ.
Stellisporites inflatus Alpern, 1959. L, PZ.
Stellisporites spp. L, PZ. ø 1.2%.
Stenozonotriletes commendatus Ischenko, 1956. L. ø 1%.
Stenozonotriletes lycosporoides (Butterworth & Williams) Smith & Butterworth, 1967. PZ.
Stenozonotriletes reticulatus Naumova, 1953. L. ø 1% (only one measured record).
Stenozonotriletes spp. L. ø 2%; max. 3% – 27th overlying and 21st underlying coal seams.
Thymospora obscura (Kosanke) Wilson & Venkatachala, 1964. P, S, J. ø 1% (only one measured record).
Thymospora spp. L, PZ, P, S, **J**. ø 2.4%; max. 11% – Radvanice coal seams.
Thymospora thiessenii (Kosanke) Wilson & Venkatachala, 1964. J. ø 1%.
Thymospora verrucosa (Alpern) Wilson & Venkatachala, 1964. V. ø 1% (only one measured record).
Torispora granulata Alpern, 1959. S. ø 5%.
Torispora securis Balme, 1952. PZ, P, S, **J**. ø 4%; max. 14% – lower part of the Radvanice coal seams.
Torispora spp. **S,** J. ø 9%, max. 50% lower part of S.

Torispora undulata Dybová & Jachowicz, 1957. S. ø 2%.
Tripartites spp. PZ. ø 1% (only one record).
Triquitrites auriculatus Bharadwaj, 1957. L.
Triquitrites bransonii Wilson & Hoffmeister, 1956. S, J. ø 4.6%.
Triquitrites exiquus Wilson & Kosanke, 1944. **S,** J. ø 6%; max. 14% – Main Svatoňovice Coal Seam.
Triquitrites minutus Alpern, 1959. **L, PZ**, P, S, J. ø 4.5%; max. 16% – middle of P.
Triquitrites pulvinatus Kosanke, 1950. **S**. ø 5%; max. 10% – base of S.
Triquitrites sculptilis Balme, 1952. L, PZ, P, S, J. ø 4.5%; max. 17% – Petrovice Coal Seam.
Triquitrites spp. L, PZ, P, S, J. ø 4.1% max. 50% – lower part of S.
Triquitrites tribullatus (Ibrahim) Schopf, Wilson & Bentall, 1944. PZ.
Triquitrites tricuspis (Horst) Potonié & Kremp, 1955. L, PZ. ø 4.7%; max. – 17% 16th underlying coal seam.
Triquitrites tripartitus Alpern, 1959. L, PZ, P, S. ø 4%; max. 5% – 10th overlying coal seam.
Triquitrites triturgidus (Loose) Potonié & Kremp, 1955. L, PZ, P, S, J, V. ø 2% (only one measured record).
Tuberculatosporites sp. A Kalibová, 1989. J, V.
Variouxisporites plicatus Alpern, 1959. S, J, V.
Variouxisporites spp. P, S, **J, V**. ø 3%; max. 17% – Petrovice Coal Seam.
Verrucosisporites donarii Potonié & Kremp, 1955. J. ø 3%; max. 4% – Radvanice coal seams.
Verrucosisporites grandiverrucosus (Kosanke) Smith *et al*. 1964. J. ø 3.3%.
Verrucosisporites microtuberosus (Loose) Potonié & Kremp, 1955. L, **PZ**, P, J. ø 3%; max. 11% – base of P.
Verrucosisporites sinensis Imgrund, 1960. S, J, V. ø 4%; max. 13% – Radvanice coal seams.
Verrucosisporites spp. **L, PZ**, P, S, J, V. ø 3%; max. 14% – S.
Verrucosisporites verrucosus Ibrahim, 1933. J. ø 2% (only one record).
Vestispora cancellata Dybová & Jachowicz, 1957. L, **PZ**. ø 4.6%; max. 10% – 4th Žďárky Coal Seam.
Vestispora costata (Balme) Bharadwaj, 1957. L, **PZ,** P, S. ø 4%.
Vestipora fenestrata (Kosanke & Brokaw) Spode in Smith & Butterworth, 1967. L, PZ, P, **S**. ø 9%; max. 18% – Main Svatoňovice Coal Seam.
Vestispora laevigata Wilson & Venkatachala, 1963. PZ.
Vestispora magna (Butterworth & Williams) Spode in Smith & Butterworth, 1967. PZ. ø 3% (only one measured record).
Vestispora pseudoreticulata Spode in Smith & Butterworth, 1967. L, **PZ.** ø 7%; max. 11% – 2nd Žďárky Coal Seam.
Vestispora quaesita (Kosanke & Brokaw) Wilson & Venkatachala, 1963. PZ, P, **S**. ø 4%; max. 12% – “Visutá” Coal Seam.
Vestispora spp. L, PZ, P, S, J, V, O. ø 1.3%; max. 5% – 17th underlying coal seam.
Vestispora tortuosa (Balme) Bharadwaj, 1957. PZ. ø 3% (only one measured record).
Vittatina spp. P, S, V, J.
Waltzispora spp. L. ø 1% (only one measured record).
Westphalenisporites spp. PZ, P. ø 1.8%; max. 3% – P.
Westphalensisporites irregularis Alpern, 1959. **PZ, P,** S, J. ø 8%; max. 52% – Petrovice Coal Seam.
Wilsonites delicatus Kosanke, 1950. S, **J,** V. ø 2.5%; max. 5% – Radvanice coal seams.
Wilsonites kosankei Bharadwaj, 1957. S.
Wilsonites spp. PZ, P, S, **J**. ø 2%; max. 11% – Radvanice coal seams.
Wilsonites vesicatus Kosanke, 1950. J. ø 3%; max. 5% – Radvanice coal seams.

Electronic supplement 1

The occurrence of dispersed miospores and pollen in the Czech part of the Intra-Sudetic Basin. Palynospecies are plotted against the stratigraphic column with resolution of individual fossiliferous horizons. Legend: 1 – presence of the taxon; 0 – absence of the taxon. Empty fields between the first and last occurrence of any the taxon were filled by 1, based on assumption of continuous presence of the species in the study area, although it has not been found.

Electronic supplement 2

The percentage of dispersed miospore and pollen genera in the Czech part of the Intra-Sudetic Basin. Legend: 0 – genus does not occur or reaches less than 1%.