PALYNOSTRATIGRAPHY AND PALYNOFACIES OF THE UPPER SILESIAN KEUPER (SOUTHERN POLAND)

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Abstract: The results of the palynostratigraphical studies presented in this paper come from five boreholes Patoka 1, Czarny Las, Woźniki Śląskie K1, Kobylarz 1 and Poręba as well as from four outcrops at Lipie Śląskie, Patoka, Zawiercie and Poręba, in Upper Silesia (southern Poland). The palynostratigraphical zonation presented by Or³owska-Zwoliñska (1983) for the epicontinental Upper Triassic of Poland was applied. The spore-pollen assemblage recognized in the “Chrzanów Formation” belongs to the early Carnian verrucata Subzone of the palynological longdonensis Zone. The spectrum from the Stuttgart Formation represents the Carnian astigmosus Zone. Spectra in the Patoka Marly Mudstone-Sandstone Member (Grabowa Mudstone-Carbonate Formation), with the Lisowice bone-bearing horizon, represent the middle and late Norian meyeriana b Subzone. The Rhaetian age of the bone-bearing succession in the Lisowice–Lipie Śląskie clay-pit suggested in the literature was not confirmed. The age of assemblages from the “Po³omia Formation”, which overlies the Patoka Member, was not determined, owing to the poor state of miospore preservation. Moreover, three types of palynofacies were recognized as being characteristic for a fluvial channel (1), a flood plain (2), and lacustrine and playa environments (3) as well as for an undetermined milieu. Type 1 was found in the deposits of the Stuttgart Formation, the Patoka Member and the “Po³omia Formation”, type 2 in the Patoka Member and the “Polonia Formation”, type 3 in the “Chrzanów Formation”, the Stuttgart Formation and the Patoka Member.

Key words: Miospores, palynostratigraphy, palynofacies, Upper Triassic, Upper Silesia.

INTRODUCTION

Palynostratigraphical studies, based on miospores from the Upper Triassic of Upper Silesia (Fig. 1), were initiated by Or³owska-Zwoliñska (in Grodzicka-Szymanko and Or³owska-Zwoliñska, 1972). She recognized three spore-pollen assemblages, here assigned to lithostratigraphic units that are defined below (Fig. 2): Porcellispora longdonensis in the “Chrzanów Formation”, Aulisporites astigmosus in the Stuttgart Formation, and Corollina (= Classopollis; see below) meyeriana in the lower part of the later Grabowa Formation in the Woźniki – Cynków area (E part of the Upper Silesia basin). She further studied several borehole records in the Zawiercie and Chrzanów areas (Or³owska-Zwoliñska, 1981, 1983). The results of this investigation confirmed the previous palynostratigraphy.

The next studies were carried out by Heunisch, who recognized the meyeriana b Subzone in six out of the eight samples analyzed (these results are presented in part in Szulc et al., 2006). The same age was suggested by Staneckzko (2007) for the miospore spectrum from the Lipie Śląskie clay-pit near Lubliniec, also known in the literature as the Lisowice clay-pit. Dzik et al. (2008a, b) noted the presence of the two miospore species Brachysaccus neoëmum (Leschik) Mäder and Monosulcites minimus Cookson in the Lipie Śląskie and, on the basis of their doubtful connection to the macroflora, assumed a Rhaetian age for them (see Szulc et al. 2015). Świ³o et al. (2014) presented a list of miospores also from Lipie Śląskie clay-pit, representing the uppermost meyeriana Zone (= meyeriana c Subzone). Wawrzyniak (in
Sadlok and Wawrzyniak, 2013) reported an assemblage of the probable meyeriana b Subzone at the Zawiercie-Marci-
szów outcrop. In the most recent paper on the subject, Pień-
kowski et al. (2014) assumed that the deposits at the Lipie Śląskie location represent the meyeriana c Subzone as well as the succeeding Riccisporites tuberculatus Zone.

Palynostratigraphical investigations of the Upper Trias-
sic were continued by Fijałkowska-Mader, in connection with a multidisciplinary grant to G. Racki with a focus on integrative Upper Silesian Keuper stratigraphy, and the results, complemented with unpublished material by Heu- nisch, are presented in this paper. The samples are from the complete composite middle-upper Keuper succession, de-
erved mostly from the lithologic records of four boreholes: Patoka 1, Woźniki K1, Kobylarz 1 and Poreba (Fig. 1), with an emphasis on the bone-bearing, variegated deposits of Grabowa Mudstone-Carbonate Formation (Fig. 2), a unit of Bilan (1976), recently redefined by Szulc and Racki (2015).

LITHOFACIES SUCCESSION
AND GENERAL SETTING OF THE
SEDIMENTARY ENVIRONMENTS

The Upper Triassic succession of the study area was formed in the marginal part of the Mid-Polish Basin. Therefore, its thickness is distinctly less than that at the basin centre and erosional and sedimentary gaps are more common. It is also worthy of note that the bone-bearing, alluvial facies are more frequent here than in the central part of the basin.

The lithofacies succession of the Upper Triassic in Upper Silesia is typical for the Germanic domain and reflects the main climatic fluctuations that took place across the Western Tethys domain during Carnian–Rhaetian times (Feist-Burkhardt et al., 2008). The arid phase, in early Carnian times, is recorded as evaporitic sediments of the “Chrzanów Fm” of Bilan (1976), which is correlated with the Lower Gipskeuper in other parts of Poland and the Grabfeld Formation in NW Germany (Becker et al., 2008). The unit is composed of varie-
gated mudstones and claystones containing evaporites, mostly sulphates with subordinate amounts of dolomite (Fig. 2).

The mid-Carnian was characterized by the re-establish-
ment of a humid climate, as indicated by sedimentological and palaeontological data. Pluvialisation resulted in fluvial activity, forming the braided/anastomosing river network of the Stuttgart Fm (the Schilfsandstein) in the Germanic Ba-
in. Sedimentation, typical of dry climatic conditions, char-
acterized the late Carnian and early Norian, evaporite-bear-
ing red beds of the Ozimek Member (= the Upper Gipskeu-
per) and was dominant in the Germanic Basin.

During mid- and late Norian times, the climate in the Germanic Basin underwent gradual amelioration, as indi-
cated by punctuated sedimentation of evaporite-bearing red-bed facies and their replacement by fluvial sediments, typical for the Steinmergelkeuper facies complex (= the Patoka Member, an equivalent of the Arnsztadt Formation; Szulc and Racki, 2015; see also Bilan, 1976; Szule et al., 2006). The fluvial intervals are particularly well developed at the basin margin, where they formed the alluvial complex of the Löwenstein Formation.
The gradual climatic change could be ascribed to the drift of Middle Europe into a higher palaeolatitudinal position. The Polish basin definitely migrated outside the subtropical dry belt in the latest Norian–Rhaetian times, as indicated by the complete decline of evaporitic sedimentation and by the dominance of siltstones with coal seams and abundant plant debris, typical for the uppermost part of Grabowa Fm and the fluvial quartz sandstones and gravels of the “Polonia Formation” (= Exter Formation), as noted by Grodzicka-Szymanko and Orlowska-Zwolińska (1972) Bilan (1976), Deczkowski (1997) and Szulc and Racki (2015).

MATERIAL AND METHODS

Fifty-nine samples were examined from cores of the Kobyłarz 1 (11 samples from a depth of 1.5-30.0 m), Woźniki K1 boreholes (16 samples; 68.8–99.5 m; Fig. 3) and Patak 1 (32 samples; 17.4–208.0 m; Fig. 4), but only twenty-eight yielded palynological material. This material was complemented with eight productive samples, out of the 41 elaborated by Carmen Heunisch (in Szulc et al., 2006), from the three boreholes: Woźniki (1 sample from a depth of 30.0 m), Poręba (3 samples; 7.7–11.4 m) and Czarny Las (1 sample; 9.7 m) as well as the two outcrops, at the Lipie Śląskie clay-pit, one sample from the Poręba outcrop and two samples from the clay-pit at Pawlikowice, the uppermost part of the Upper Silesian Keuper

THE UPPER TRIASSIC PALYNOLOGICAL ZONES DISTINGUISHED IN THE POLISH BASIN AND CORRELATION OF THEM

The palynostratigraphic scheme of Orlowska-Zwolińska (1983, 1985), which is the most suitable for the Polish epicontinental Triassic, was applied. Four palynological zones were distinguished in this scheme in the Upper Triassic: longdonensis (I) in the Boundary Dolomite and Lower Gipskeuper, astigmosus (a) in the Schilfsandstein; meyeriana (m) in the Upper Gipskeuper, Jarkowo and Zbashynek Beds; and tuberculatus (t) in the Wielichowo Beds. The longdonensis Zone contains two subzones, iliacoides (li) and verrucata (lv), whereas the meyeriana Zone is divided into three subzones (Fig. 6), a (ma), b (mb) and c (mc).

The base of the longdonensis Zone as well as the iliacoides Subzone is defined by the first appearances (FADs) of Porcellispora longdonensis, Echinitosporites iliacoides, Duplicisporites granulatus and Praeccirculina granifer (see the list of the miospore species in Appendix 1) and the first common occurrence of Ovalipollis. The lowermost part of the iliacoides Subzone, containing acritarchs, is found in the Boundary Dolomite, whereas its upper part, with the FAD of Camerosporites secatus, is in the lower part of Lower Gipskeuper. The last occurrences (LODs) of E. iliacoides and Eucommiidites microgranulatus determine the top of the iliacoides Subzone.

The verrucata Subzone corresponds with the acmes of the Triadispora verrucata and Ovalipollis ovalis. The top of the longdonensis Zone and verrucata Subzone is defined by the LODs of Duplicisporites granulatus, Partitisporites maliavkinae, Triadispora plicata and T. verrucata (Orłowska-Zwolińska, 1983, 1985). The verrucata Subzone is found in the upper part of the Lower Gipskeuper.

The lowermost part of the iliacoides Subzone is correlated with the top of the Heliosaccus dimorphus Zone sensu Herngreen (2005) and the top of the “Geological Time Scale” (GTS) Heliosaccus dimorphus Zone (Ogg, 2012) and its upper part and the verrucata Subzone with the Triadispora verrucata Subzone of the Camerosporites secatus Zone sensu Herngreen (2005; see e.g., Kürschner and Herngreen, 2010) as well as with the lower part of the GTS Camerosporites secatus Zone (Ogg, 2012; Fig. 6).

The astigmosus Zone corresponds with the acmes of Aulisporites astigmosus and includes the FADs of Annullispora microannulata, Apiculatisporis parvispinosus, Camarozonosporites laevigatus, C. rudis and Stereisporites caticricosus as well as the LODs of Aulisporites astigmosus, Accinctisporites ligatus, the majority of the Artrisporella species (coryliseminis, flexibilis, fimbriatus, granulatus, paraspinosus, scabratius, saturni), Illinitisporites chitonoides, Verrucosisporites morulae and V. pseudomorulae. The occurrence of the following is limited to this Zone: Apiculatisporis firmus, Gibesporites hirsutus, G. lativerrucosus, Kraeuwelisporites species: cooksonelain, dentatus, litus and ramosus, Retulatisporites distinctus, Zebrasporites corneolus and Z. fimbriatus (Orłowska-Zwolińska, 1983, 1985).

The astigmosus Zone is correlated with the Ausilisporites astigmosus Subzone of the Camerosporites secatus Zone sensu Herngreen (2005) and the middle part of the GTS Camerosporites secatus Zone (Ogg, 2012; Fig. 6).

Orłowska-Zwolińska (1983, p. 49-50) defined the meyeriana Zone as the acme zone – “...numerous and sometimes mass occurrence of Corollina meyeriana...” – in the upper part of the Upper Gipskeuper and the overlying strata. However, the base of the meyeriana Zone and the meyeriana a Subzone may be determined (see Orlowska-Zwolińska, 1983, p. 64) by the FAD of Classopollis meyeriana (previously Corollina meyeriana; see the discussion in Traverse, 2004), which correlates with the FAD of Corollina spp./Classopollis spp. This last FAD, according to Heunisch (1999, tab. 1 therein), is located in the upper part of her GTr 15 Zone in the Weser/Amstadt Formations. Kürschner and Herngreen (2010; fig. 3) placed the FAD of Classopollis spp. in the late Tuvalian (Hassberge Formation). Heunisch and Nitsch (2011) found the miospore assemblage of the meyeriana Zone in the Mainhardt Formation and opted for a Tuvalian age for the meyeriana Zone. Cirilli (2010, figs 2, 3 therein), however, located the FAD of the Classopollis meyerianus and the base of the Classopollis meyerianus Subzone in the earliest Norian. The meyeriana Subzone is correlated with the top of the Camerosporites
Fig. 5. Lithostratigraphic correlation of the profiles containing miospore assemblages.
secatus Zone sensu Herngreen (2005) and the top of the GTS C. secatus Zone (Ogg, 2012; see Fig. 6).

The base of the meyeriana b Subzone is placed at the FADs of Riccisporites tuberculatus, Carnisporites granulatus, Heliosporites altmarkensis, Monosulcites minimus and Neochomotriletes triangularis. This subzone corresponds with the acmes of Brachysaccus neomundanus, Labiisporites triassicus and Nevesisporites limatulus. Its top is placed at the LODs of Anapiculatisporites telephorus, N. limatulus and P. longdonensis. The subzone is found in the upper part of the Jarkowo Beds and the lower part of the Zbąszynek Beds (Orłowska-Zwolińska, 1983, 1985). It is correlated with the top of the Granuloperculatipollis rudis Zone sensu Herngreen (2005) and the GTS G. rudis Zone (Ogg, 2012; see Fig. 6).

The meyeriana c Subzone corresponds with the acmes of C. torosus and the last common occurrence of C. meyeriana as well as Ovalipollis and Enzasporites. Its base is placed at the FAD of Rhaetipollis germanicus and the top is defined by the LODs of many taxa common in the Upper Triassic spectra: Brachysaccus neomundanus, Carnisporites mesozoicus, Enzasporites species: manifestus, marginalis and vigens, Labisporites triassicus, Leschiisporis aduncus and Taurucospores verrucatus. The meyeriana c Subzone occurs in the upper part of the Zbąszynek Beds (Orłowska-Zwolińska, 1983, 1985) and is correlated with the lower part of the Rhaetipollis germanicus Zone sensu Kürschner and Herngreen (2010) as well as with the upper part of the GTS R. germanicus Zone (Ogg, 2012; see Fig. 6).

The base of the tuberculatus Zone is defined by the FADs of many species, the ranges of which are limited to this Zone, such as Cingulizonates rhaeticus, Cornutisporites seebergensis, Densosporites cavernatus, D. fissus, Lophotriletes verrucosus, Limbosporites lundbladii, Perinosporites thuringiacus, Semiretisporis goethae, S. ornatus, S. wielchoviensis, Triancorazaspores ancorae, T. reticulatus, or continue to the Lower Jurassic Acanthotriletes varius, Chasmatosporites apertus, C. rimatus, Concavisporites juncturn, C. juriensis, Dictyophyllidites mortoni, Lycopodiacidites rugulatus, Lycopodiumspores reticulumsporites, L. semimuris, Marattisporites semimuris, Monosulcites punctatus, Pinuspollenites minimus, Quadraeculina annelliformis, and Zebrasporites interscriptus. The Zone corresponds to the acme of Riccisporites tuberculatus. The Deltoidospora specimens as well as Concavisporites polygonalis and Monosulcites minimus are common. The top of the Zone is placed not only at the LODs of species mentioned above, but also at the LODs of Anapiculatisporites spiniger, Camarozonosporites laevigatus, G. rudis, C. zwolinskai and Lunatisporites rhaeticus. The Zone occurs in the Wielichowo Beds (Orłowska-Zwolińska, 1983, 1985) and is correlated with the Limbosporites lundbladii Subzone of the Rhaetipollis germanicus Zone sensu Kürschner and Herngreen (2010) as well as with the upper part of the GTS R. germanicus Zone (Ogg, 2012; see Fig. 6).

**DESCRIPTION OF THE MIOSPORE ASSEMBLAGES**

On the basis of more than a hundred miospore taxa, recognized in the material analyzed (a complete list is in Appendix 1 and descriptions of new taxa are given in Appendix 2), seventeen miospore assemblages representing three miospore zones were distinguished (Fig. 5).
Miospore assemblage of the longdonensis Zone (iv)

Characteristics: The two index specimens – the moss spore *Ovalipollis longdonensis* (e.g., Mader, 1977; Fig. 7A, B) and the pollen *Triadispora verrucata* (Fig. 7T, U) – occur in an assemblage, dominated by the conifer pollen *Ovalipollis*, *Triadispora* (Fig. 7P–S) and *Brachysaccus* (Fig. 7M). Monosaccate pollen, very similar to the Jurassic araucariaeacean genus *Callialasporites* (Fig. 7H, I), and conifer stratiate pollen (Fig. 7K, L), occurred sporadically. Lycopsid *Aratrisporites* specimens (Fig. 7E–G) predominated among the spores.

Occurrence: Woźniki K1, depth 88.5–89.5 m, “Chrzanów Fm” (Figs 3, 5).

Miospore assemblage of the astigmosus Zone (a)

Characteristics: The assemblage is dominated by the index pollen *Aulisporites astigmosus* (Fig. 8F, G). The pollen *Ovalipollis* (Fig. 9O–R) and *Brachysaccus* occurred less frequently. The lycopsid spores *Aratrisporites* (Fig. 9E–H) and *Kraeusellisporites* (Fig. 9B–D) were characteristic and abundant elements of this spectrum. Fern spores assigned to *Todisporites* (Fig. 8E) and the conifer pollen *Triadispora* (Fig. 10D–F) were relatively numerous. The assemblage is strongly diverse, both taxonomically and botanically. It contained, besides the specimens mentioned above, single spores of the ferns *Deltoidospora* (Fig. 8A–C), *Conosnus* (Fig. 8K), *Conbaculatisporites* (Fig. 8N), *Carnisporites* (Fig. 8I, J); the horsetail *Calamospora* (Fig. 8D); the lycopsids *Anapiculatisporites* (Fig. 8L), *Lycopodiadites* (Fig. 8R), and *Lycopodiumsporites* (Fig. 8P) as well as spores of unknown botanical affinity *Corrugatisporites* (Fig. 8O), aff. *Tauroc usurpores* (Fig. 9A) and aff. *Semiretisporites* (Fig. 8T).

They were accompanied by rare bisaccate pollen, mainly of coniferous affinity, *Illinites* (Fig. 9N), *Parillinates* (Fig. 9U), *Platysaccus* (Fig. 10A, B), *Labisporites* (Fig. 10G), *Striatohettes* (Fig. 9T) as well as the monosaccate pollen *Enzonalasporites* (Fig. 9I, K) and aff. *Callialasporites* (Fig. 9M). The fresh-water alga *Schizosporis* from the family Zygmenataceae occurred commonly (Fig. 10H). Specimens of reworked spores of the early Triassic genus *Densoisporites* (Fig. 10T), acritarchs and ?chitinozoa occurred sporadically (Fig. 10U).

Occurrence: Woźniki K1, depth 77.1–84.45 m, Stuttgart Fm (Figs 3, 5).

Miospore assemblages of the meyeriana b Subzone (mb)

Characteristics: Although there are some strong variations in composition within these assemblages (Figs 11–13), their common feature is the predominance of conifer pollen. Among them, the index species *Classopolis meyeriana* (Fig. 13K, L), *Brachysaccus neomundanus* (Fig. 13C), *Ovalipollis* sp. div. (Fig. 13B) and *Enzonalasporites* sp. div. (Fig. 13A) were the most abundant. The characteristic form is *Granulopercutalipollis rudis* (Fig. 13M, N). Less frequently the pollen *Labisporites* (Fig. 13G) occurred, accompanied by single pollen specimens of *Aulisporites*, *Parillinates* (Fig. 13D), *Platysaccus* (Fig. 13E), *Falcisporites* (Fig. 13F), aff. *Pinuspollenites*, *Protodiploxypinus* (alias *Minutosaccus*) (Fig. 13H) and *Cedrites*. Other less frequently encountered pollen included *Classopolis simplex*, *C. torosa*, *Geopollis zwołinskiae*, and *Duplicispores granulatus* (Fig. 13J). Moreover, single specimens of the cypress pollen *Monosulcites* (Fig. 13O, P) and *Cycadopites* were found. Fern spores *Todisporites* (Fig. 11R) predominated among the spores. Other spores, such as aff. *Conosmunda- sporites* (Fig. 11S), *Cyclotriletes* (Fig. 11T) and *Verrucos isporites* (Fig. 12A) as well as the lycopsid spores *Densoisporites* (Fig. 12L–P) and *Neveisporites* (Fig. 12I), occurred less frequently. They were accompanied by single occurrences of *Tauroc usurpores* (Fig. 12S, T), *Reticulatisporites* (Fig. 12H), *Deltoidospora* (Fig. 12E), *Calamospora*, *Carnisporites*, *Anapliculatisporites* (Fig. 12C, D), *Uvaespo rites*, *Foveolatritiletes* (Fig. 12G), *Corrugatisporites* (Fig. 12F), *Baculatisporites* (Fig. 11U), *Porcellispora* (Fig. 12B) and *Polycingulatisporites* (Fig. 12K, R). Specimens of *Microreticulatisporites* sp., *Neoalistrickia* sp., *Pseudoenzon alasporites summus* and *Vallasporites ignacii* seldom occurred. Single reworked acritarchs were found (Fig. 13U). The presence of fungal spores is the distinctive feature of this assemblage. The algae of the genus *Schizosporis* were relatively numerous. Single specimens of the planktonic alga *Botryococcus* were found in the Poreba borehole at a depth of 153.1 m. Charophyta specimens were recognized in a sample from the Patoka clay-pit.

Occurrence: Patoka clay-pit, uppermost part of the Patoka Mbr; Patoka 1 borehole, depth 134.6–153.1 m, Patoka Mbr (Fig. 4); Lipie Śląskie clay-pit, Patoka Mbr below the oncokite layer (see Szulc et al., 2006; fig. 5); Czarny Las borehole, depth 9.7 m, Patoka Mbr; Zawiercie outcrop, Patoka Mbr (see Szulc et al., 2006; Fig. 5); Poreba outcrop and Poreba borehole, depth 7.7–11.4 m, Patoka Mbr (Fig. 5).

Miospore assemblages of undefined palynostratigraphical position

The miospore assemblage found in the Patoka 1 borehole, at a depth of 199.00 m in the middle part of the Patoka Mbr (Figs 4, 5), did not contain any index species. It was dominated by the pollen *Ovalipollis* (Fig. 11E–G) and *Brachysaccus*. The pollen *Triadispora* (Fig. 11K, L), *Platysaccus* (Fig. 11I), *Aulisporites* (Fig. 11H) and *Enzonalasporites* (Fig. 11D) are less abundant. They were accompanied by single spores of *Calamospora*, *Anapliculatisporites* (Fig. 11B) and *Kraeuselisporites* (Fig. 11C) as well as the alga *Schizosporis* sp. (Fig. 11M). Reworked early Triassic spores (Fig. 11O) and strongly worn out specimens (Fig. 11N, P) occurred in abundance.

The miospore assemblage recognized in the Woźniki borehole, at a depth of 30.00 m, in the Patoka Mbr, contained single, poorly preserved specimens of *Enzonalasporites* sp., *Cycadopites* sp. and *Chasmatisporites* sp., as well as one specimen of the *Riccisporites tuberculosis*, accompanied by the planktonic alga *Botryococcus* sp., dinoflagellate cysts of *Dapcodinium cf. priscum* and fungal spores.

The miospore assemblage found in the Kobylarz 1 borehole, at a depth of 7.0–8.5 m, in the Lisowice bone-bearing horizon, was dominated by conifer pollen of the genera *Ova-
Fig. 10. Miospores from the Stuttgart Formation (Carnian), the Woźniki K1 borehole. Scale bar = 10 µm. I–S – stronger coalificated and wasted forms; T–U – reworked forms. A, C, E, H–K, M – depth 77.1 m; L, O, S, U – depth 84.0 m; B, D, F, G, N, P, R–T– depth 84.45 m.

Fig. 14. Miospores from the upper part of the Patoka Member (Norian) in the Kobyłarz 1 borehole (A–L) and from the “Połomia Formation” (?Rhaetian) (M–O), the upper part of the Patoka Member (P–S) and the lower part of the Patoka Member (T–U), Patoka 1 borehole. Scale bar = 10 µm. I, K – reworked forms. A–C – depth 7.5 m; D–L – depth 8.0 m; M–O – depth 18.1 m; P–S – depth 35.7 m; T, U – depth 116.7 m. A. aff. Todisporites sp. B. Anapiculatisporites spiniger (Leschik) Reinhardt. C. Anapiculatisporites telephorus (Pautsch) Klaus. D. Densosporites sp. E, F. Lunatisporites sp. G. Ovalipollis sp. H. aff. Monosulcites sp. I. Densoisporites playfordii (Balme) Dettmann. J. Densoisporites cf. playfordii (Balme) Dettmann. K. aff. Punctatisporites sp. L. Lunatisporites sp. (degraded specimen). M. aff. Accinctisporites sp. N. Calamospora sp. O. Taurocusporites verrucatus Schulz. P. Densosporites sp. R. Kraeuselisporites sp. S. Verrucosisporites sp. T. Falcisporites sp. U. Alisporites toralis (Leschik) Clarke.
lippolis (Fig. 14G), Parillinites and Brachysaccus, whereas the pollen Lunatisporites (Fig. 14E, F) and Cedripites occurred less frequently. The lycopsid spores Anapiculatisporites (Fig. 14B, C) and Densosporites are rare. Fern spores aff. Todisporites (Fig. 14A) and the pollen of cycads were infrequent. The assemblage was further characterized by a high content of reworked early Triassic miospores, mainly Densosporites (Fig. 14J) accompanied by strongly degraded, undeterminable pollen and spore grains.

Three miospore assemblages were identified in the Patoka 1 borehole (Figs 4, 5):
- the assemblage at a depth of 17.4–18.1 m, within the kaolinite interval of the “Polomia Fm”, consists of single occurrences of the spores Calamospora (Fig. 14N), Taurocuspisporites (Fig. 14O), Todisporites, Densosporites and Camarozonosporites, as well as the monosaccate pollen aff. Accinctisporites sp. (Fig. 14M) and bisaccate pollen of the genera Ovalipollis, Lunatisporites and Triadispora;
- the assemblage at 35.7–36.6 m, near the erosional top of the Patoka Mbr in this section, consists of the same taxa as described in the assemblage above at 17.4–18.1 m (Fig. 14P) and also Enzonalasporites, Falcispores (Fig. 14T) and Alisporites (Fig. 14U), as well as spores of the genera Kraeuselisporites (Fig. 14R) and Verrucosisporites (Fig. 14S). In addition, the alga Schizosporis and undeterminable, degraded spores also occur in the assemblage;
- the assemblage at 116.70–118.50 m, in the middle part of the Patoka Mbr (in the bone-bearing horizon), consists mainly of conifer pollen, assigned to Ovalipollis, Brachysaccus, Parillinites, Alisporites and Triadispora. Other pollen Striatobellitess, Platysaccusand, Falcispores and the spores of Verrucosisporites, Todisporites, Cyclotritiles, Densosporites and Corrugatisporites are rare and occur only as single specimens. Reworked early Triassic and possibly older spores are relatively abundant.

**PALYNOSTRATIGRAPHY**

Three palynological zones were recognized in the Upper Triassic deposits of Upper Silesia: longondensis within the “Chrzánów Fm”, astigmosus in the Stuttgart Fm and meyeriana in the Patoka Mbr of the Grabowa Fm (Figs 5, 15). The miospore assemblages found in the “Chrzánów Fm” represent the verrucata Subzone, whereas those in Patoka Mbr belong to the meyeriana b Subzone.

**Age of the Lisowice bone-bearing horizon**

The stratigraphical position of the Patoka Mbr interval, containing the Lisowice bone-bearing horizon (sensu Szulc and Racki, 2015; Fig. 2), is the most controversial matter in the Upper Silesian Keuper (see Szulc et al., 2015). The first determination of the early Rhaetian age of the megaspore assemblage from the Lipie Śląskie clay-pit by Fuglewicz and Śnieżek (1980) was questioned by Marcinkiewicz and Œnie¿ek (1980) was questioned by Marcinkiewicz and Œnie¿ek (1980). In support of a Rhaetian age is the presence of such megaspore species as Tasmanitriletes pedinae (Haris) Jux et Kempf, Verrutiretes utilis (Marcinkiewicz) Marcinkiewicz and V. litchii (Haris) Potonié, which have not been reported from this assemblage.

Next, Heunisch recognized the miospore meyeriana b Subzone in the Patoka Mbr at four localities, the Lipie Śląskie clay-pit, the Czarny Las borehole, and the Poręba and Zawiercie outcrops (partly published in Szulc et al., 2006; Fig. 5). The same meyeriana b Subzone was identified by Staneczko (2007) in the Lipie Śląskie clay-pit. The inventory of miospores by this author generally concurs with the palynological data obtained by Heunisch (in Szulc et al., 2006) and Fija³kowska-Mader (this paper), excluding the occurrence of Recispores tuberculatus. Neither Heunisch nor Fija³kowska-Mader found it in the spectra analyzed (with the exception of the single specimen from the Woźniki borehole, at a depth of 30 m). In addition, the photograph of the miospore presented by Staneczko (plate 1, fig. 4) is of such poor quality that the correctness of the identification of this guide species is questionable.

In the papers of Dzik et al. (2008a, b), concerning the bone-bearing strata in the Lipie Śląskie clay-pit, two miospore species of suggested Rhaetian age, Brachysaccus neomundanus and Monosulcites minimus, were mentioned. B. neomundanus is known in spore-pollen spectra occurring since the Ladinian, so combining it with the Rhaetian conifer Stachyotaxus is rather doubtful. The single gingkoalean pollen Monosulcites minimus appears already in the late Norian.

The palynozonal aspect of the Upper Triassic in the Lipie Śląskie section was again raised recently by Pieńkowskii et al. (2014). The authors, with reference to new miospore determinations quoted in Świto et al. (2014), of Carnian age. The assignation of an early Rhaetian age to Hostisporites bertelseni Fuglewicz on the basis of similarity to Hostisporites sp. is also doubtful. In addition, the index species Trileites pinguis (Harris) Potonié was determined as consmorm. The occurrence of the species T. pinguis itself does not determine the Rhaetian age of the megaspore assemblage described by Fuglewicz and Śnieżek (1980), as the pingius Zone corresponds to the late Norian and Rhaetian (see Marcinkiewicz et al., 2014).

**Fig. 15.** Palynostratigraphy of the Upper Triassic in Upper Silesia region.
made reference to only the meyeriana c Subzone and the higher tuberculatus Zone. In the description of the miospore assemblage from the Lipie Śląskie clay pit given by Świlo et al. (2014), the taxon _Rhaetipollis germanicus_ admittedly was noted, but without any illustration. Moreover, there is no information about the frequency of specimens (so important in this case), that essentially influenced the credibility of the determination of the age as meyeriana c Subzone – tuerculatus Zone (the latest Norian–Rhaetian).

An important contribution to a solution for the problem of the age of the deposits at the Lipie Śląskie locality could be the palynological studies of the adjacent boreholes and outcrops, containing the same characteristic Lisowice bone-bearing horizon, carried out by Heunisch (in Szulc et al., 2006), Wawrzyniak (in Sadowski and Wawrzyniak, 2013) and Fijalkowska-Mader (this paper). Assemblages of the meyeriana b Subzone were found in two boreholes, Patoka 1 (134.6–153.1 m) and Poręba (7.7–11.4 m) as well as in the Poręba and Zawiercie outcrops (the latter correlated with the Lipie Śląskie locality by Niedźwiecki et al., 2014).

In conclusion, there is no clear palynological evidence, either for the correlation of the Lisowice bone-bearing horizon with the meyeriana c Subzone, or for the Rhaetian age of this succession.

**Degraded and reworked palynomorphs**

The relatively large amount of degraded and reworked forms in the assemblages from the Patoka Mbr hinders the determination of its age. The most common are the early Triassic spores _Denseisporites_ (Figs 10T, 11O, 14I, J). Single specimens of the spores assigned to the early Triassic genera _Palyfordiaspora_ and _Punctatisporites_ were also found. Moreover, the Anisian spores _Perotrilites minor_ and a form resembling the Palaeozoic chitinozoans (Fig. 10U), and undetermined acritarchs (Fig. 13U) were found as well.

The co-occurrence of palynomorphs so heterochronous in the material studied confirms the intensive recycling phenomena recorded in the middle Keuper strata and may evidence the repeated cannibalistic redeposition of it (see e.g., Bilan 1976, Szulc and Racki, 2015).

**PALYNOFACIES ANALYSIS**

The definition of Powell _et al._ (1990) was applied for palynofacies: “a distinctive assemblage of palynoclasts whose composition reflects a particular sedimentary environment”. The following organic matter particles (palynoclasts), classified after APOMC (Amsterdam Palynological Organic Matter Classification) ’93 (Anonymous, 1993), occur as four groups in the studied material:

- palynomorphs – spores, pollen, prasinophytes, chlorococcales, dinocysts, acritarchs, fungal spores;
- structured organic matter – wood, cuticles, degraded organic matter (DOM);
- unstructured/amorphous organic matter (AOM; to avoid the misunderstanding, this is not amorphous matter sensu Boulter and Riddick, 1986) – homogeneous particles (particles 1–2 µm with well-defined outline and uniform appearance), heterogeneous particles (non-homogeneous particles 1–2 µm with well-defined outlines), finely dispersed matter (all particles 1–2 µm);
- indeterminate organic matter.

On the basis of the percent ratio of the particular palynoclasts groups, four types of palynofacies have been distinguished (Figs 16–18).

**Type 1**

**Characteristics:** Palynomorphs are absent, wood reaches 0–20%, DOM 5%, AOM (80–100%) is dominated by finely dispersed matter; black, opaque organic particles predominate (Fig. 18A).

**Occurrence:** Within the coarse- and variable-grained sandstones with large-scale cross-bedding, making up simple sedimentary cycles, which locally begin with a river-bed pavement [Patoka 1 borehole at 23.70 m (“Polonia Fm”), 66.40 m, 75.00 m, 81.20 m, 85.80 m, 93.50 m, 110.40 m, 113.40 m, 150.00 m, 158.90 m and 159.10 m (Patoka Mbr; Fig. 16), and Woźni K1 borehole at 68.80 and 79.50 m (Stuttgart Fm; Fig. 17)].

**Depositional environment:** Sedimentary structures and strong degradation of the palynoclasts indicate high-energy conditions, which occur in the fluvial channels of braided rivers (e.g., Fijalkowska, 1994; Tyson, 1995, p. 213).

**Type 2**

**Characteristics:** Palynomorphs, mainly pollen grains, reach 0–5%, wood – 5–15%, cuticles 1%. DOM – 2–10%, AOM (70–90%) consists of finely dispersed and heterogeneous matter; black, opaque organic particles predominate (Fig. 18B).

**Occurrence:** In the structureless sandy mudstones of the Patoka Mbr (Patoka 1 borehole at 114.70 m, 115.50 m and 116.70 m; Fig. 16).

**Depositional environment:** The character of the deposits and the palynoclasts indicates lower-energy conditions (by comparison with a fluvial channel) of the floodplain (e.g., Fijalkowska-Mader _et al._, 2015).

**Type 3**

**Characteristics:** Spores reach 10–50% in the proximal facies and several to 10% in the distal facies, pollen – several to 50% in the proximal facies and to 50–70% in the distal facies, fresh-water algae and fungal spores – less than 1%; wood – several to 40%, cuticles relatively abundant increase up to 20% in the proximal facies and several percent in the distal facies; AOM 10–50% is dominated by heterogeneous matter in the proximal facies and finely dispersed in the distal facies; black, opaque organic particles reach on average 50–60%, dark-brown, translucent – 5–10%, light brown and yellow – 10–25% (Fig. 18–E).

**Occurrence:** In the structureless siltstones of the “Polonia Fm” (Patoka 1 borehole at 17.40 m and 18.10 m); in the siltstones and mudstones with small-scale cross-lamination (Patoka 1 borehole at 35.70 m, 36.60 m, 134.60 m, 137.90 m and 140.20 m); in the horizontal-laminated mudstones (Patoka 1 borehole at 145.10 m); in the structureless mudstones (Patoka 1 borehole at 199.0 m (Patoka Mbr; Fig. 16), Patoka clay-pit, Lipie Śląskie clay-pit, Poręba outcrop; Woźni K1 borehole at 77.10 m, 77.70 m, 82.50 m, 84.00 m and
Fig. 16. Palynofacies analysis of the Upper Triassic deposits in the Patoka 1 borehole.
84.45 m (Stuttgart Fm), 88.50 and 89.50 m (“Chrzanów Fm”; Fig. 17).

Depositional environment: A large amount of spores, cuticles and wood as well as the presence of fresh-water algae are characteristic for a freshwater lacustrine basin (e.g., Heunisch, 1990; Van Bergen and Kerp, 1990; Boulter, 1994, fig. 11.2; Fijałkowska, 1994; Piekólski and Waksmundzka, 2009; Heunisch et al., 2010; Fijałkowska-Mader et al., 2015). The two samples from the evaporite-bearing “Chrzanów Fm” could represent a playa basin (e.g., Hauschke and Heunisch, 1989, 1990; Fijałkowska, 1994, Fijałkowska-Mader, 2011; Fijałkowska-Mader et al., 2015).

Type 4
Characteristics: Palynomorphs are absent, wood fragments reach 0–10%, AOM 90–100%, including heterogeneous, homogeneous and finely dispersed matter; black, opaque, organic particles 90–100% (Fig. 18F).

Occurrence: Within the structureless or streaky, laminated mudstones (Patoka 1 borehole at 50.00 m, 52.50 m, 104.70 m, 132.80 m, 205.15 m, 207.15 m and 208.00 m (Patoka Mbr; Fig. 16) and Woźniki K1 borehole at 68.80 m (Stuttgart Fm; Fig. 17).

Depositional environment: undetermined.

PALAEOENVIRONMENTAL AND PALAEOCLIMATIC INTERPRETATION

The palynofacies analysis confirms the earlier suggestions that the “Chrzanów Fm” was deposited in a playa basin (see Bilan, 1976; Deczkowski, 1997; Fig. 19).

The composition of the miospore assemblage, occurring in this formation, consisting most exclusively of conifer pollen with numerous Triadispora specimens, indicates a very dry climate in the early Carnian (see Orłowska-Zwolińska, 1983; Ziegler et al., 1994). Both conifers Volzia and Alberta producing the Triadispora pollen and lycopsids Lycostrobus and Annalespis, the parent plants of the spore Aratrisporites (see Grauvogel-Stamm, 1969; Orłowska-Zwolińska, 1979), also are known from settings of higher salinity (Mader, 1990, 1997).
Fig. 18. Types of palynofacies from the Patoka Member (Norian) in the Patoka 1 borehole (A, D, F), the Kobylarz 1 borehole (B), Stuttgart Formation (Carnian) in the Woźniki K1 borehole (C) and “Chrzanów Formation” (Carnian) in the Woźniki K1 borehole (E). A – depth 113.4 m; B – depth 9.0 m; C – depth 84.0 m; D – depth 36.6 m; E – depth 89.5 m; F – depth 205.15 m. A, C–F – scale bar 200 µm, B – scale bar 150 µm. **A. Palynofacies 1, fluvial environment – fluvial channels. B. Palynofacies 2; fluvial environment– floodplain. C. Palynofacies 3; lacustrine environment, proximal zone. D. Palynofacies 3; lacustrine environment, distal zone. E. Palynofacies 3; playa environment, proximal zone. F. Palynofacies 4; undetermined environment.**
The palynofacies occurring in the Stuttgart Fm are characteristic for fluvial and lacustrine milieu and consistent with the sedimentological interpretation (see Deczkowski, 1977). This environmental interpretation may be confirmed by abundant spores *Aulisporites astigmosus*, produced most probably by plants, which overgrew the river floodplains (e.g., Orłowska-Zwolińska, 1983). The miospore assemblage, dominated by equisetaleans (Sphaenopsida), fern spores of the Osmundaceae and Mariattiaceae families and lycopsid spores, indicates a humid climate in the middle Carnian (Julian). An increase in precipitation – the “Carnian Pluvial Event” – could be connected with volcanic activity in the Wrangellia and/or Eastern Mediterranean areas (e.g., Kozur and Bachman, 2010; Roghi et al., 2010; Dal Corso et al., 2012; Arche and López-Gómez, 2014; Fig. 19).

The deposition of the evaporite-bearing Ozimek Mbr (lower part of the Grabowa Fm) took place in a peneplained mudflat-playa basin in dry climatic conditions (Szulc and Racki, 2015). The Patoka Mbr (middle-upper part of the Grabowa Fm) was formed in a wide spectrum of environments: fluvial, lacustrine, palustrine and mud-sand flat (Środoń et al., 2014; Szulc and Racki, 2015). Both the char-
acter of sediments and the higher ratio of hygrophytic elements (lycopsid and equisetalean spores) in the miospore spectra indicate that the humidification of climatic conditions was connected with a pluvial event, which occurred in the middle-late Norian (Berra et al., 2010; Preto et al., 2010; Fig. 19). According to Vakhrameev (1981, 1987, 1991), a high frequency of the pollen Classopolis is evidence of a warm climate.

The “Polomia Fm” was deposited in fluvial environments (e.g., Szulc et al., 2006; Pięknowski et al., 2014; Środoń et al., 2014; Szulc and Rakci, 2015) and may be connected with the pluvialisation of climate in the Rhaetian (e.g., Michalik et al., 2010; Preto et al., 2010; Brański, 2011; Haas et al., 2012; Lintnerová et al., 2013; Pięknowski et al., 2014; Szulc and Rakci, 2015), even if the available palynostratigraphic dating remains equivocal.

CONCLUSIONS

1. The miospore assemblage occurring in the “Chrzanoów Fm” in the Woźniki K1 borehole represents the Carnian verrucata Subzone of the longdonensis palynological Zone.

2. The miospore assemblage recognized in the Stuttgart Fm in the Woźniki K1 borehole represents the Carnian astigmosus palynological Zone.

3. Presentation of the detailed palynostratigraphy of the Grabowa Fm is difficult, owing to the poor state of miospore preservation and redeposition phenomena, recorded in the sections studied. In the majority of the analyzed samples from the Patoka Mbr (also from the Lisowice bone-bearing horizon in the Lipie Śląskie clay-pit and the Zaświecie outcrop), miospore assemblages represent the middle Norian meyeriana b Subzone.

4. The Rhaetian age of the Grabowa Fm in the Lisowice–Lipie Śląskie clay-pit suggested in the literature is not reliably documented, as the index Rhaetian miospore species were never illustrated.

5. The results of palynofacies analysis confirm earlier environmental interpretations, based on sedimentological premises and the analysis of clay minerals (Środoń et al., 2014; Szulc et al., 2015), in which the “Polomia Fm” was deposited in fluvial environments, the Patoka Mbr in variable fluvial and lacustrine milieu, the Stuttgart Fm in fluvial and lacustrine environments, and the “Chrzanoów Fm” in a playa basin.

6. Changes in the composition of the miospore assemblages reflect changes in the palaeoclimate from dry conditions in the early Carnian, through the “Carnian Pluvial Event” in the Julian and aridization of climate at the Carnian/Norian boundary to the mid-late Norian pluvial event. Mostly coarse-grained deposition of the “Polomia Fm” could be connected with the pluvial conditions that occurred in the Rhaetian.

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REFERENCES


Appendix 1

Annotated list of sporomorph taxa
(names of the index species are in bold print)

Miospores:
aff. Acanthotriletes sp. (Fig. 8M)
Accinctisporites ligatus Leschik
Accinctisporites sp. (Fig. 9L)
aff. Accinctisporites sp. (Fig. 14M)
Alisporites toralis (Leschik) Clarke (Figs 11H, 14U)
Alisporites sp. (Fig. 10C)
Anapulculosporites spiniger (Leschik) Reinerdt (Figs 12D, 14B)
Anapulculosporites telephorus Pauwtsch (Figs 8L, 11B, 12C, 14C)
Anapulculosporites sp.
Apiculatisporis firmus (Leschik) Orlowska-Zwolinska
Apiculosporis sp.
Aratrisporites corylismenis Klaus (Fig. 9E)
Aratrisporites fimbriatus (Klaus) Playford et Dettmann
Aratrisporites flexibilis Playford et Dettmann
Aratrisporites cf. major Mader
Aratrisporites paraspinosus Klaus (Figs 7F, G, 9G, H)
Aratrisporites saturni (Thiergart) Mader (Figs 7E, 9F)
Aratrisporites scabarius Klaus
Alisporites sp.
Baculatisporites sp. (Fig. 11U)
Brachysaccus neomundanus (Leschik) Mader (Figs 7M, 13C)
Brachysaccus neomundanus (Leschik) Mader var. minor
Orlowska-Zwolinska
Brachysaccus sp.
Calamospora tener (Leschik) de Jersey (Fig. 8D)
Calamospora cf. tener (Leschik) de Jersey (Fig. 11N)
Camerosporites sp. (Figs 11A, 14N)
aff. Callialasporites sp. (Figs 7H, I, 9M)
aff. Camerosporites sp. (Fig. 7C)
Carnisporites granulatus Schulz
Carnisporites mesozoicus (Klaus) Mader
Carnisporites ornatus Mader
Carnisporites sp. (Fig. 8H)
Caytonipollenites sp.
Cedrites sp.
Classopollis meyeriana (Klaus) de Jersey (Fig. 13K, L)
Classopollis simplex (Danzet-Corsin et Laveine) Reiser et Williams
Classopollis tornus (Reissinger) Pflug
Conbaculatisporites mesozoicus Klaus (Figs 8N, 10K)
Conbaculatisporites sp. (Fig. 10L)
aff. Concentricisporites sp.
Conosmundasporites othmari Klaus (Fig. 8K)
aff. Conosmundasporites sp. (Fig. 11S)
Converrucosisporites sp.
Cortisporites scanicus Nilsson (Figs 8O, 12F)
Cortisporites sp. (Fig. 10P)
Cyclotriletes sp. (Fig. 11T)
Deloidospora minor (Couper) Pocock (Figs 8A, 12E)
Deloidospora toralis (Leschik) Lund (Fig. 8B)
Deloidospora sp. (Fig. 8C)
Densosporites aff. fissus (Reinerdt) Schulz
Densosporites silesiensis Fijalkowska-Mader sp. nov. (Fig. 12M–O) (for description see Appendix 2)
Densosporites rogaltskai Fijalkowska-Mader sp. nov. (Fig. 12P) (for description see Appendix 2)
Densosporites sp. (Figs 7D, 9A, 12L, 14D, 14P)
Duplicosporites granulatus Leschik (Fig. 13J)
Enzonalasporites manifestus Leschik (Figs 9I, 11D)
Enzonalasporites viagens Leschik (Figs 9K, 13A)
Enzonalasporites sp.
Falcisporites sp. (Figs 13F, 14T)
Foveolatirritiles sp. (Fig. 12G)
aff. Gibbosporites sp.
Geopollis zwilinskii (Lund) Brenner
Granuloperculatipollis radis Venkatatala et Goczná (Fig. 13M, N)
Illinites chitonoides Klaus
Illinites cf. chitonoides Klaus (Fig. 9N)
Inaperturopollenites sp.
Infermopollenites sulcatus (Pautsch) Scheuring (Fig. 7L)
Kraeuselisporites cf. cooksoniae (Klaus) Dettmann (Fig. 9B)
Kraeuselisporites lituus (Leschik) Scheuring (Fig. 9C)
Kraeuselisporites ramosus Leschik
Kraeuselisporites sp. (Figs 9D, 11C, 14R)
aff. Kraeuselisporites sp. (Fig. 13S)
Labisporites triassicus Orłowska-Zwolińska (Figs 10G, 13G)
Leschikisporis aduncus (Leschik) Potonié
Lophotirites sp.
Lunatisporites sp., (Fig. 14E, F, L)
Lycopodiaditacites kuepperi Klaus (Fig. 10M)
Lycopodiaditaceae cf. kuepperi Klaus (Fig. 8R)
Lycopodiaditites sp.
Lycopodiumsporites rugulatus (Couper) Schulz (Fig. 8P)
Marattisporites sp.
Microreticulatisporites opacus (Leschik) Klaus
Microreticulatisporites sp.
Monosaccites undetermined
Monsulcites minimus Cookson (Fig. 13O)
Monosulcites sp. (Fig. 13P)
aff. Monosulcites sp. (Fig. 14H)
Nevesisporites limatulus (Pautsch) Scheuring (Fig. 7L)
Nevesisporites bigranulatus (Levet-Carette) Morbey
Nevesisporites lubricus sp. (Fig. 14R)
Nevesisporites sp. (Fig. 13S)
Nevesisporites triangularis (Bolchovitina) Reinhardt (Fig. 12J)
Neochomotirites triangularis sp.
Neoviasporites sp. (Fig. 15O)
Neuralstrickia sp.
Nevesisporites bimunus (Levet-Carette) Morbey
Nevesisporites limatulus Playford (Figs 8U, 11T)
Nevesisporites lubricus Orłowska-Zwolińska
Ovaliopollis longiformis Krutzsch
Ovaliopollis luzonensis Klaus (Fig. 9O)
Ovaliopollis minimus Scheuring
Ovaliopollis cf. notabilis Scheuring (Fig. 9P)
Ovaliopollis ovalis Krutzsch (Figs 9R, 11F, G, 13B, T)
Ovaliopollis rarus Klaus (Fig. 11E)
Ovaliopollis sp. (Fig. 14G)
Palacospogonporis europea Schulz
Parillinites cf. callosus Scheuring
Parillinites vanus Scheuring (Fig. 7N)
Parillinites sp. (Figs 9U, 12D)
Partittisporites tenebrosus (Scheuring) Van der Eem
Partittisporites sp. (Fig. 13I)
aff. Pattnasporites sp.
aff. Perinopollenites sp. (Fig. 7I)
aff. Pinuspollenites sp.
Platysaccus nigre Mädler (Fig. 13E)
Platysaccus nitidus Pautsch (Fig. 10B)
Platysaccus papilionis Mädler (Fig. 13D)
Platysaccus sp. (Fig. 14I)
Polyclingulatisporites reductus (Bolchovitina) Playford et Dettmann (Fig. 12K)
Polyclingulatisporites sp. (Fig. 100)
aff. Polyposisporites sp. (Fig. 12R)
Porcellispora longdonensis (Clarke) Scheuring (Figs 7A, B, 12B) Porcellispora sp. (Fig. 12B)
Pracirecriculina granifer (Leschik) Klaus
Protodiploxypinus sp. (Fig. 13H)
aff. Protodiploxypinus sp.
Protokaploxylinus sp. (Fig. 9S)
aff. Protokaploxylinus sp. (10G)
Pseudoenzonalasporites summus Scheuring
Reticulatisporites distinctus Orłowska-Zwolińska (Fig. 12H)
Reticulatisporites sp. (Figs 8S, 13R)
Retisulcites sp. (Fig. 9I)
Ricciopollis tuberculatus Lundblad
aff. Semiretisporis sp. (Fig. 8T)
Sphagnumsporites sp.
Spiritsporites spirabilis Scheuring
Spore sp. A (Fig. 12U) (for description see Appendix 2)
Spore undetermined (10K, S)
Sriatobibiettes aytonii Visscher (Fig. 9T)
Sriatobibiettes balmei Klaus (Fig. 7K)
Sriatobibiettes sp.
Taurocosporites cf. morbeci Orłowska-Zwolińska (Fig. 12S)
Taurocosporites verrucatus Schulz (Figs 12T, 14O)
Taurocosporites sp.
aff. Taurocosporites sp. (Fig. 9A)
Todisporites cinctus (Malavikna) Orłowska-Zwolińska (Figs 8E, 11R)
Todisporites sp.
aff. Todisporites sp. (Fig. 14A)
Triadispora crassa Klaus (Figs 70, 11J)
Triadispora obscura Scheuring
Triadispora plicata Klaus (Fig. 7R)
Triadispora polonica Brugman (Figs 7S, 10D)
Tradiispora suspecta Scheuring (Figs 7P, 10E, 11K)
Triadispora verrucata (Schulz) Scheuring (Figs 7T, U)
Triadispora sp. (Figs 10F, 11L)
Uvaesporites argentaformis (Bolchovitina) Schulz
Valliasporites ignacii (Leschik) Klaus
Valliasporites sp.
Verrucosisporites cf. planus Orłowska-Zwolińska
Verrucosisporites redactus Orłowska-Zwolińska (Figs 8J, 12A)
Verrucosisporites slevecensis (Mädler) Orłowska-Zwolińska
Verrucosisporites sp. (Figs 8I, 14S)
Zebrasporites sp. (Fig. 10N)

Other palynomorphs:

Algae:
Botryococcus sp.
Schizosporis sp. (Figs 7H, 11M)
Dinoflagellata:
Dapcodinum cf. priscum Evitt
Fungal spores

Reworked miospores:
aff. Anguisulcites sp.
Densoisporites nebjargii (Schulz) Balme (Fig. 11O)
Densoisporites cf. nebjargii (Schulz) Balme (Fig. 14I)
Densoisporites playfordii (Balme) Dettmann (Fig. 14J)
Densoisporites cf. playfordii (Schulz) Balme (Fig. 14J)
Densoisporites sp. (Fig. 10T)
Peritricites minor Antonescu et Taugordeau-Lanz
aff. Playfordiaspora sp.
aff. Punctatisporites sp. (Fig. 14K)
Undetermined spore (Fig. 11P)

Reworked planktonic forms:
Acritarcha undetermined (Fig. 13U)
? Chitinozoa (Fig. 10U)
Appendix 2

Descriptions of new taxa (Anna Fija³kowska-Mader)

Descriptive terminology is after Punt et al. (1994).


Type species: Densosporites covensis Barry, 1937

Diagnosis: Trilete miospores triangular to subcircular in outline, two-layered, egzoexine on the proximal surface, evenly arched or with zona slightly raised above the central body.

Densosporites silesiensis sp. nov.

Fig. 12M, N, O

Derivation of name: Silesia – area, where the species was described for the first time.

Material: 10 specimens, Fig. 12N (holotype), housed in Polish Geological Institute – Polish Research Institute, Kielce Patoka1/137.9 (1).

Occurrence: Upper Silesia, Patoka 1 borehole, depth 137.9 m; Upper Triassic, Norian, Patoka Member of Grabowa Formation.

Description: Trilete spore with circular to subcircular outline. Outline of the central body convexly triangular to subcircular. Endoexine of central body thin, faintly roughened; laesure distinct with wide sutural ridges connected at their extremities to the zona. Ornamentation of egzoexine on the central proximal and distal areas consists of distinct regularly distributed verrucae. Verrucae are circular to irregular in shape. Sculpture of zone verrucosed.

Dimensions: Equatorial diameter 30–40 µm (10 specimens).

Remarks: The proposed species differs from other Densosporites species in the presence of verrucae on the central proximal area. It differs from D. verrucosus Dybova et Jachowicz in its circular outline.

Densosporites rogalskai sp. nov.

Fig. 12P

Derivation of name: Maria Rogalska was a Polish palynologist, who for the first time described Lower Jurassic miospores from Upper Silesia.

Material: 4 specimens, Fig. 12P (holotype), housed in Polish Geological Institute – Polish Research Institute, Kielce Patoka1/134.6 (2).

Occurrence: Upper Silesia, Patoka 1 borehole, depth 134.6 m; Upper Triassic, Norian, Patoka Member of Grabowa Formation.

Description: Trilete spore with circular outline. Outline of the central body circular. Endoexine of central body thin faintly roughened; laesure distinct with wide sutural ridges connected at their extremities to the zona. Ornamentation of egzoexine on the central proximal and distal areas consists of distinct regularly distributed verrucae. Verrucae are circular to irregular in shape. Sculpture of zone verrucosed.

Dimensions: Equatorial diameter 30–40 µm (4 specimens).

Remarks: It differs from Densosporites silesensis in the rough outline of the zone and more irregular shape of the verrucae.

Spore sp. A

Fig. 12U

Spore circular in equatorial outline. Arms of trilete mark straight, bifurcated at the ends, extends to 5/6 of the proximal surface. Wide labrum continues into ridge surrounding the areas between arms of the trilete mark. Thickening of exine on the proximal side is arranged in regular pattern consisting of three trilobate elements. Spore outline is rough. Equatorial diameter 38 (1 specimen).

The single specimen the Patoka 1 borehole (depth 153.1 m) differs from other spores in the presence of regular, trilobate-shape ornamentation on the proximal areas between the labrum and exine ridge occurring on the equator and subcircular thickening of exine in the central part of trilete mark.