The Middle Triassic limestone bedrock of the Upper Silesian-Cracow Upland, SW Poland, display numerous palaeokarstic forms, filled with a variety of internal sediments. The palaeokarst phenomena include both covered and uncovered karst forms, filled with flowstones and clastic and organic deposits (Głazek, 1989; Szulc and Worobiec, 2012). The most common palaeokarstic forms are sinkholes (dolines) developed in reefal and bioclastic carbonates of the Lower Muschelkalk. The sinkholes range from 10 to 150 m in diameter and reach 30 metres in depth. They are filled with variegated, clayey and sandy clastics, and commonly also with lignites. The latter line the bottom and sidewalls of the depression or form layered intercalations in the clastic fill (Szulc and Worobiec, 2012).

Palynological studies of the deposits from palaeosinkholes, outcropping in the Tarnów Opolski and Górażdże quarries, started in 2009. During the palynological investigation of those deposits, well preserved, rich pollen and spore assemblages and abundant freshwater algal microfossils (mainly green algae), were recorded. The taxonomical composition of the pollen and spore assemblages and the excellent state of preservation of most of the sporomorphs (pollen grains and plant spores) indicate an in situ mode of occurrence. They made it possible to date the sinkhole deposits. The composition of the assemblage (e.g., abundance of small tricolporate pollen grains of the Fagaceae family, including Cupuliferopollenites pusillus, Fususpollenites fusus, and Quercoidites microhenrici) indicates that the age of the lignites in both sinkholes is early Oligocene. Thus, the deposits at Górażdże correspond to the 5th Czempin lignite seam group. The 5th seam occurs mainly in northwestern Poland and its lignites were deposited in isolated wetland basins with marine influences. The terrestrial Górażdże palynoflora without any marine influence shows mainly local early Oligocene vegetation from the surrounding area. The results are also direct evidence of the multiphase palaeokarst of the Silesian-Cracow Upland, including the deposition of lignites of various ages.

**Key words:** Palynostratigraphy, palaeokarst, sinkhole deposits, coal, pollen grains, Palaeogene.

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**INTRODUCTION**

Worobiec, E. & Szulc, J., 2020. Palynology of Oligocene lignites in two karst palaeosinkholes at Górażdże, Upper Silesia, Poland. *Annales Societatis Geologorum Poloniae*, 90: 495–504.

**Abstract:** A palynological analysis was carried out on about 115 samples from two borehole cores, containing the infills of two palaeosinkholes at Górażdże. In both sinkholes, well preserved palynofloras were found in several lignite samples. A total of 54 fossil species, including 5 species of cryptogam spores, 7 species of gymnosperm pollen, and 42 species of angiosperm pollen, were identified. No marine palynomorphs or microremains re-deposited from older sediments have been found in these samples. The spore-pollen assemblage made it possible to date the sinkhole deposits. The composition of the assemblage (e.g., abundance of small tricolporate pollen grains of the Fagaceae family, including Cupuliferopollenites pusillus, Fususpollenites fusus, and Quercoidites microhenrici) indicates that the age of the lignites in both sinkholes is early Oligocene. Thus, the deposits at Górażdże correspond to the 5th Czempin lignite seam group. The 5th seam occurs mainly in northwestern Poland and its lignites were deposited in isolated wetland basins with marine influences. The terrestrial Górażdże palynoflora without any marine influence shows mainly local early Oligocene vegetation from the surrounding area. The results are also direct evidence of the multiphase palaeokarst of the Silesian-Cracow Upland, including the deposition of lignites of various ages.
arcto-tertiary elements, when compared with data from other pollen sites in Poland, indicate the middle Miocene age of the deposit; the lignites in that sinkhole correspond to the 1st mid-Polish lignite group (Worobiec and Szulc, 2010a). At present, similar plant communities occur in the Mississippi River Delta, Florida, Georgia, North Carolina and the Gulf of Mexico coast. There are some similarities between the middle Miocene Miocene landscape of the study area and present-day west-central Florida (USA), where numerous sinkholes and other karst features occur (Worobiec and Szulc, 2010a, b; Worobiec, 2011).

The results of pollen analysis from the sinkhole outcropping at Górażdże indicated the presence of a water body (pond), surrounded by herbaceous and riparian vegetation and mixed mesophytic forests. The climate during deposition of the sediments in the sinkhole was warm-temperate – cooler than during the middle Miocene, but still warmer than the present-day climate of Poland (Szulc and Worobiec, 2012; Worobiec, 2014b). The composition of the Górażdże palyno flora indicated a late Miocene age. Differences between the palynoflora from the Górażdże and Tarnów Opolski sinkholes were mainly quantitative. The composition of algal assemblages and that of the pollen of aquatic plants and herbs surrounding the water body, was similar in both palaeosinkholes (Worobiec, 2014a). The differences between the palynofloras from those two sinkholes were clearly visible in the compositions of the forest taxa, reflecting changes in the climate and vegetation of the surrounding area during the middle and late Miocene (Szulc and Worobiec, 2012; Worobiec, 2014b).

In recent years, palynological analysis of several dozen sediment samples from karst forms (including palaeosinkholes, caves, and fluvioglacial deposits), outcropping in the Opole region, was carried out to reconstruct the karst process phases in the study area. It seems that particularly intensive karst denudation processes took place in the Neogene, as evidenced by the taxonomically rich assemblages of well-preserved sporomorphs and microfossils of freshwater algae, found in sinkhole deposits in the western part of the Silesian Upland (Worobiec and Szulc, 2010a, b; Worobiec, 2011, 2014a, b; Szulc and Worobiec, 2012). In addition to the middle and upper Miocene palyno floras, Pliocene spore-pollen assemblages were found (unpublished data). The last phase of karstification is represented by the Quaternary karst, with very interesting forms of subglacial karst (Szulc et al., 2015).

These very interesting results were the main motivation for conducting palynological research on drill-core materials. Several boreholes were drilled at Górażdże and Tarnów Opolski in 2014 and about 200 palynological samples were studied. The results were to be published in a comprehensive summary article. Unfortunately, the untimely death of Joachim Szulc thwarted this plan. This paper presents the results of the palynological analysis of two borehole cores from Górażdże and is confined to the Palaeogene sediments, including the lignites.
of Sciences, Kraków. The portions of crushed rock were treated successively with 10% hydrochloric acid (HCl) to remove carbonates, 10% potassium hydroxide (KOH), 40% hydrofluoric acid (HF) for four days to remove silicates, and 10% hydrochloric acid (HCl) to remove silicoaluminites (Moore et al., 1991). In addition, the residuum was sieved at 5 µm on a nylon mesh. The microscope slides were made, using glycerine jelly or glycerine as a mounting medium and coverslips 24 × 24 mm. Depending on the frequency of the sporomorphs (pollen grains and spores of plants), 2–8 microscope slides from each sample were studied. The rock samples, palynological residues and slides are stored in the W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

The sporomorph taxa identified were classified according to an appropriate palaeofloristical element, mainly with reference to the Atlas of Pollen and Spores of the Polish Neogene (Stuchlik et al., 2001, 2002, 2009, 2014). In the material studied, the following palaeofloristical elements were distinguished: palaeotropical (P), including tropical (P1) and subtropical (P2); “arctotertiary” (A), including warm-temperate (A1) and temperate (A2); and cosmopolitan (P/A). Microphotographs of selected pollen grains were taken using a NIKON Eclipse microscope, fitted with a Canon digital camera.

RESULTS OF THE PALYNOLOGICAL STUDIES

Most of the samples studied were barren or yielded only sparse sporomorphs. Nevertheless, in several samples very interesting spore-pollen assemblages were recorded. One sample from the GOR-1-B borehole, taken from a depth of 2.30 m, as well as three samples from the GOR-2 borehole, taken from depths of 10.00 m, 11.20 m and 11.80 m (Figs 2, 3), yielded rich and well preserved sporomorphs. These samples were taken from dark sediment, including lignites (Fig. 4). Pollen spectra from these samples are taxonomically diversified and they are similar in composition (Tab. 1). In a few other neighbouring samples (e.g., from a sample taken from a depth of 1.90 m from the GOR-1-B borehole and from samples taken from depths of 9.60 m and 10.40 m from the GOR-2 borehole), the same taxa were found in the best four samples, but the frequencies of the sporomorphs were distinctly lower. A total of 54 fossil species, including 5 species of cryptogam spores, 7 species of gymnosperm pollen and 42 species of angiosperm pollen, were identified (Tab. 1; Fig. 5).

In all these samples pollen grains of angiosperms distinctly predominate (Tab. 1). There are mainly small tricolporate pollen grains from the Fagaceae family (mainly fossil species Cupuliferoipollenites pusillus, Fususpollenites fusus, and Quercoidites microhenricii) and Cyrilliaceae/Clethraceae (Cyrilliaceaepollenites exactus, C. megaexactus, and C. brühlensis). Other trees and shrubs are represented by Fabaceae (Tricolporopollenites liblarensis, T. fallax, and T. quisquisalis), Juglandaceae (Momipites quietus, M. punctatus, Platycaryapollenites sp., and Caryapollenites cf. triangulus), Betulaceae (mainly Alnipollenites and Trivestibulopollenites betuloides) and Aquifoliaceae (Ilexpollenites margaritatus and Ilexpollenites cf. propinquis), Sapotaceae, Platanaceae (Platanipollis ipelensis), Arecaceae (palms), Ericaceae, Malvaceae (Reevesiapollis cf. microreticulatus and Intratriporopollenites cf. microreticulatus), Oleaceae, Myricaceae, Nyssaceae, Ulmaceae, Hamamelidaceae (Tricolporopollenites staresedloensis), Salicaceae and Mastixiaceae (Cornaceaepollis satzveyensis). In addition, a few pollen grains of the fossil species Triporopollenites megagranifer, and Plicipolis sp. from the Normapolles group, plus one pollen grain of Emmapollis pseudoemmaensis were recorded.
Table 1

Results of palynological analysis (number of palynomorphs) of the samples from the GOR-1-B and GOR-2 boreholes.

| Fossil taxa                                      | Botanical affinity                          | Element | GOR-1-B 2.30 m | GOR-1-B 10.00 m | GOR-1-B 11.20 m | GOR-1-B 11.80 m | GOR-2 11.20 m | GOR-2 11.80 m | GOR-2 mean [%] |
|-------------------------------------------------|---------------------------------------------|---------|----------------|----------------|----------------|----------------|---------------|---------------|----------------|
| **Spores of cryptogams:**                       |                                             |         |                |                |                |                |               |               |                |
| Laevigatosporites sp.                           | Polypodiaceae, Davalliaceae and other ferns | P/A     | 6              | 2              | 2              | 1              | 0.89          |               |                |
| Baculatisporites sp.                            | Osmundaceae                                 | P/A     | 1              | 1              | 1              | 0.18           |               |               |                |
| Stereisporites sp. + Distancoraeasporis sp. +  | Sphagnaceae: Sphagnum                       | P/A     | 7              | 1              | 2              | 0.54           |               |               |                |
| Distverrusporis sp.                             |                                             |         |                |                |                |                |               |               |                |
| **Pollen grains of gymnosperms:**               |                                             |         |                |                |                |                |               |               |                |
| Cathayapolis sp. + Pinuspollenites sp.          | Pinaceae: Cathaya, Pinus                    | A1      | 2              | 0.50           | 2              | 4              | 1.07          |               |                |
| Cupressacites sp.                               | Cupressaceae, Taxaceae                      | A1      | 5              | 1.26           | 6              | 4              | 1.79          |               |                |
| Inaperturopollenites concedipites + I. dubius   | Cupressaceae: Taxodium, Glyptostrobus       | P2/A1   | 43             | 10.86          | 66             | 26             | 20           | 20.00         |                |
| (Potonié et Venitz) Thomson et Pflug            |                                             |         |                |                |                |                |               |               |                |
| Sciadopityspollenites sp.                       | Sciadopityaceae: Sciadopitys               | A1      | 1              | 0.25           |               |                |               |                |                |
| Sequoiapollenites sp.                           | Cupressaceae: Sequoia, Sequoiadendron,      | A1      | 4              | 1.01           | 29             | 6              | 8             | 7.68          |                |
| Metasequoia                                      |                                             |         |                |                |                |                |               |               |                |
| **Pollen grains of angiosperms:**               |                                             |         |                |                |                |                |               |               |                |
| Alnipollenites metaplasmus (Potonié) Potonié +  | Betulaceae: Alnus                          | P2/A    | 21             | 5.30           | 2              | 4              | 1             | 1.25          |                |
| Alnuspollenites sp.                             |                                             |         |                |                |                |                |               |               |                |
| Areccipites cf. convexus (Thiergari) Krutzsch   | Areccaceae                                  | P/A1    | 1              | 1              | 1              | 0.18           |               |               |                |
| Areccipites sp.                                 | Areccaceae?, Butomaceae?                   | P/A     | 2              | 0.50           | 1              | 0.18           |               |               |                |
| Carpinipites sp.                                | Betulaceae: Carpinus                       | P2/A1   | 1              | 1              | 1              | 0.18           |               |               |                |
| Caryapollenites cf. triangulus (Pflug) Krutzsch | Juglandaceae: Carya                        | P       | 2              | 2              | 0.36           |               |               |               |                |
| Cornaceaepollis satzveyensis (Pflug) Ziembińska-Tworzydlo | Mastixiaceae | P1 | 1 | 0.25 | 1 | 1 | 0.18 | | | |
| Cupuliferoipollenites oviformis (Potonié) Potonié | Fagaceae: Castanea, Castanopsis, Lithocarpus | P2/A1 | 5 | 1.26 | 8 | 1.43 | | | | |
| Cupuliferoipollenites pusillus (Potonié) Potonié | Fagaceae: Castanea, Castanopsis, Lithocarpus | P2/A1 | 93 | 23.58 | 95 | 21 | 39 | 27.68 | |
| Cyrillaceaepollenites brühlensis (Thomson) Durska | Cyrillaceae, Clethraceae | P | 2 | 2 | 1 | 0.54 | | | |
| Cyrillaceaepollenites exactus (Potonié) Potonié | Cyrillaceae, Clethraceae | P | 51 | 12.88 | 56 | 7 | 6 | 12.32 | |
| Cyrillaceaepollenites megaexactus (Potonié) Potonié | Cyrillaceae, Clethraceae | P | 6 | 1.51 | 4 | 1 | 0.89 | |
| Fossil taxa                                      | Botanical affinity  | Element | GOR-1-B 2.30 m mean [%] | GOR-2 10.00 m | GOR-2 11.20 m | GOR-2 11.80 m mean [%] |
|------------------------------------------------|---------------------|---------|--------------------------|---------------|---------------|------------------------|
| Emmapollis pseudoemmaensis Krutzsch            | Chloranthaceae?     | P1      | 1                        | 0.25          |               |                        |
| Ericipites sp.                                 | Ericaceae           | P/A     | 5                        | 1             | 1             | 1.07                   |
| Fususpollenites fuscus (Potonié) Kedves        | Fagaceae: Trigomobalanus s.l. (incl. Colombobalanus) | P1      | 42                       | 10.61         | 16            | 2                      | 3                      | 3.75                 |
| Ilxpollenites marginalitatus (Potonié) Thiergart | Aquifoliaceous: Ilex | P2      |                          |               |               |                        |
| Ilxpollenites cf. propinquus (Potonié) Potonié | Aquifoliaceous: Ilex | P/A1   | 2                        | 0.50          | 1             |                        | 0.18                   |
| Intratriporopollenites cf. microreticulatus Mai | Malvaceae: Tilioideae, Brownlowioideae | P       | 1                        | 0.25          |               |                        |
| Momipites quietus (Potonié) Nichols            | Juglandaceae: Engelhardia, Alfaroa, Oreomunnea | P       |                          |               | 4             |                        | 0.71                   |
| Momipites punctatus (Potonié) Nagy             | Juglandaceae: Engelhardia, Alfaroa, Oreomunnea | P2      | 4                        | 1.01          | 1             |                        | 0.18                   |
| Myricipites sp.                                | Myricaceae: Myrica  | P2/A1   | 4                        | 1             | 1             | 0.89                   |
| Nyssapollenites sp.                            | Nyssaceae: Nyssa    | P2/A1   | 1                        | 0.25          | 2             | 1                      | 0.54                   |
| Oleoidearumpollenites cf. microreticulatus (Pflug) Ziembska-Tworydlo | Oleaceae | P2/A1 | 3 | 0.76 | 1 | 0.18 |
| Oleoidearumpollenites sp.                      | Oleaceae            | P2/A1   | 1                        |               | 1             |                        | 0.36                   |
| Quercoidites microhenricii (Potonié) Potonié, Thomson et Thiergart | Fagaceae: Quercoideae | P2/A1 | 8 | 2.02 | 1 | 1 | 0.36 |
| Platanipollis ipelensis (Pacltová) Grabowska  | Platanaceae: Platanus | P/A1  | 3 | 0.76 | 2 | 1 | 0.54 |
| Platyctaryapollenites sp.                      | Juglandaceae: Platycarya | P2/A1 | 12 | 3.03 | 1 | 1 | 0.36 |
| Reevesiapolles cf. microreticulatus Krutzsch   | Malvaceae: Reevesia | P       | 2                        | 0.50          | 1             | 1                      | 0.36                   |
| Salixipollenites sp.                           | Salicaceae          | A       |                          |               |               |                        | 0.18                   |
| Sapotaceoidaeapollenites sp.                   | Sapotaceae          | P       | 6                        | 1.51          | 1             | 2                      | 0.54                   |
| Sparganiaceaeapollenites sp.                   | Sparganiaceae, Typhaceae | P/A |               |               |               |                        | 1 | 0.18 |
| Tricolporopollenites fallax (Potonié) Krutzsch | Fabaceae            | P/A     | 6                        | 1.51          | 2             | 2                      | 0.71                   |
| Tricolporopollenites liblarensis (Thomson) Hochuli | Fabaceae            | P/A     | 14                       | 3.53          | 9             | 1                      | 1.79                   |
| Tricolporopollenites quisqualis (Potonié) Krutzsch | Fabaceae            | P/A     | 7                        | 1.77          | 4             | 1                      | 0.71                   |
| Tricolporopollenites staresedloensis Krutzsch et Pacltová | Hamamelidaceae: Parrotia, Distylum | P2 | 3 | 0.76 | |
| Tricolporopollenites cf. villensis (Thomson) Thomson et Pflug | Fagaceae? unknown | | 4 | 2 | 1.07 |
Among the gymnosperms, pollen grains of the Cupressaceae family, including *Taxodium/Glyptostrobus* (fossil genus *Inaperturopollenites*), *Sequoia/Sequoiadendron/Metasequoia* and other Cupressaceae/Taxaceae are the most frequent. Other conifers are represented by the rare pollen grains of the Pinaceae family and *Sciadopitys*. Cryptogams are represented only by the rare spores of ferns (fossil genera *Laevigatosporites* and *Baculatisporites*) and *Sphagnum*. Non-pollen palynomorphs are very rare; only several fungal spores were recorded in most samples. No marine
palynomorphs or microremains re-deposited from older sediments have been found in these samples. Several small fragments of plant tissues were encountered.

The composition of the sporomorph association from the samples studied shows an apparent dominance of palaeotropical (including tropical and subtropical) and palaeotropical/warm-temperate palaeofloristical elements (Tab. 1; Fig. 6). These elements are represented, for example, by pollen grains of *Inaperturopollenites concedipites, I. dubius, Arecipites cf. convexus, Cupuliferoipollenites pusillus, Cyrillaceaepollenites brühlensis, C. exactus, C. megaeactus, Fususpollenites fusus, Ilexpollenites margaritatus, Ilexpollenites cf. propinquus, Intratriporopollenites cf. microreticulatus, Mopipites quietus, M. punctatus, Myricipites sp., Nyssapollenites sp., Oleoidearumpollenites cf. microreticulatus, Oleoidearumpollenites sp., Quercoidites microhenricii, Platanipollis ipelensis, Platycaryapollenites sp., Reevesiapollis cf. microreticulatus, Sapotaceoidaepollenites sp., Tricolporopollenites starestedloensis, Triporopollenites megagranifer, and Plicapollis sp.*
Conversely, the palynoflora is most similar in its composition to the Palaeogene assemblages that are younger than the Paleocene (Grabowska, 1996). Changes in the composition of the Palaeogene palynofloras in Europe were related to significant changes in the Earth’s climate. The warm and humid greenhouse climate of the early and middle Eocene changed to an icehouse climate through the late Eocene (Zachos et al., 2001; Roth-Nebelsick et al., 2004). Consequently, the late Paleocene to middle Eocene paratropical evergreen forest vegetation, characteristic for a tropical climate, changed in a stepwise manner to broad-leaved, mixed deciduous and evergreen forests in the late Eocene. In the Oligocene, the vegetation changed to mixed mesophytic forests with a significant admixture of thermophilous taxa (Collinson and Hooker, 2003; Kvaček, 2010; Worobiec et al., 2015; Kowalski et al., 2020).

The Górażdże palynoflora is rich in tropical and subtropical elements but contains only a few Normapolles pollen grains. This is the main difference between the palynoflora studied here and the Paleocene and Eocene palynofloras, characterised by, for example, the presence and richness of pollen grains from the so-called Normapolles group. Pollen grains referable to the Normapolles were most numerous in a province which extended from what is now West Siberia across Europe to eastern North America. They first appeared during the Cenomanian, diversified rapidly through the remainder of the Cretaceous and during the early Palaeogene, but by the end of the Eocene they were almost extinct (Batten, 1981). In the early Oligocene, the Normapolles group was represented by rare specimens of Plicapollis only (Grabowska, 1996). Fususpollenites fuscus and Quercoidites microhenricii are other taxa that are characteristic for the Oligocene palynofloras, as they are abundant in lower Oligocene deposits and sparse in the lower Miocene sediments. As a contrast, Miocene lignites are rich in Quercoidites henricii, Tricolporopollenites pseudocingulum, Edmundipollis and other taxa (Kasiński and Słodkowska, 2016). In addition, the stratigraphic range of Emmapolis pseudoemmmaensis is confined to the early Oligocene–early Eocene (Grabowska, 1996). The composition of the palynological spectra, including the predominance of small tricolporate pollen grains from the Fabaceae family, the occurrence of other palaeotropical taxa and the presence of rare specimens of Normapolles pollen and Emmapolis pseudoemmmaensis, clearly indicate an early Oligocene age of the palynoflora.

The lower Oligocene deposits (Czempień/Rupel Formation) are widespread throughout the Polish Lowlands (Piwocki, 2004), and form an important correlation horizon. The Rupelian marine and brackish-water deposits are usually synchronous with brackish-lacustrine sediments, containing lignite interbeds of the 5th Czempień lignite seam. The Czempień seam is correlated with the 5th Lusatian seam in the southeastern territory of Germany (Widera, 2016). Lower Oligocene (Rupelian) strata have relatively rich palynological documentation from the numerous sections in the Polish Lowlands (Grabowska, 1996; Słodkowska, 2004a, b; 2009; Kasiński and Słodkowska, 2016), due to the presence of lignites of the 5th group, but the results of most of these studies are unpublished (Grabowska and Słodkowska, 1993).
The formation of the 5th Czempin lignite seam marked the beginning of extensive lignite deposition in the Polish Lowlands. This seam has a limited extent and occurs mainly in northwestern Poland (Fig. 1), occupying a total area of ca. 7,700 km². Its thickness is usually small and does not exceed 1 m, but it reaches a considerable thickness in depressions in the salt dome caps. In extreme cases (e.g., in the Rogóźno and Wapno salt domes), its thickness may exceed 40 m. Lignites of the 5th seam originated within isolated wetland basins, surrounded by very lush and mostly mesophilous vegetation. In northern and central Poland, marine phytoplankton (dinoflagellate cysts) indicates the paralic character of the swamp basins, with a marine influence (Grabowska, 1996; Słodkowska, 2004a, b). In the mixed mesophilous forests, plants with highly thermophilous requirements predominated. The climate at that time was very warm, almost subtropical, with the mean annual temperature in the range of 17.2–23.9 °C. The palaeoclimate corresponded to a humid, subtropical climate (Cfa type) in the sub-division of Köppen (Kottek et al., 2006), characterised by hot, usually humid, summers and mild winters (Kasiński et al., 2006), and the Warmia and Mazury areas (Słodkowska, 2009).

The Górażdże palynoflora is very similar to the spore-pollen assemblages from the 5th Czempin seam in the Warszycy 19 borehole, central Poland (Grabowska, 1969 in Kasiński and Słodkowska, 2016) and to the lower Oligocene strata at localities in the Middle Vistula River valley (Słodkowska, 2004b), Pomeranian Lakeland area (Słodkowska, 2004a), and the Warmia and Mazury areas (Słodkowska, 2009). The main differences between the Górażdże assemblage and the lower Oligocene assemblages from northern Poland are the lack of marine palynomorphs and the very low frequency of bisaccate pollen grains in the Górażdże samples (Tab. 1). The presence of only sparse pollen grains of the Pinaceae family could have been caused by dense vegetation, composed of other taxa, covering the vicinity of the sinkholes. In addition, bisaccate pollen grains are always over-represented in marine sediments and the deposits at Górażdże were formed in terrestrial conditions.

The Górażdże palynoflora also shows a similarity to the assemblage from brown coal in the upper section of the Łukowa-4 borehole, SE Poland (Gedl et al., 2016). In contrast to the marine/brackish lower Oligocene strata mentioned above, coal beds from Łukowa were deposited in a freshwater environment. Unfortunately, the Łukowa samples contained a poor palynological assemblage and, therefore, detailed comparisons between these palynofloras are impossible.

CONCLUSIONS

A palynological analysis was carried out on two borehole cores from Górażdże, containing the infills of two palaeosinkholes. Of the 115 samples analysed, only 7 contained pollen grains and spores. Nevertheless, the well preserved palynoflora in these samples made it possible to date the sinkhole deposits. The presence of Emmapollis pseudoeommaensis and rare specimens of Plicapollis, together with the overall composition of the assemblage (e.g., rich in small tricolporate pollen grains of the Fagaceae family), indicate that the age of the lignites in both sinkholes is early Oligocene. Thus, the deposits from Górażdże can be correlated with the 5th Czempin seam group and they are the most south-westerly occurrence of lower Oligocene lignite in Poland. Moreover, this palynoflora is free from marine influences and, therefore, shows the local and zonal vegetation better, because the over-representation of bisaccate pollen (mainly Pinus) in marine samples often hides other elements of palynofloras. The results are also direct evidence of the multiphase palaeokarst of the Silesian-Cracow Upland, including the deposition of lignites of various ages (Oligocene and Miocene). Like the Miocene infills, the sediments analysed were formed during a warm and humid climatic phase, which favoured the processes of karstification.

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