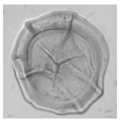
New interpretations of the Carboniferous stratigraphy of SW Poland based on miospore data

Anna Górecka-Nowak



New palynostratigraphical studies have been undertaken to elucidate the complex stratigraphy of the Carboniferous succession of the southwestern Poland. Rocks from wells Paproć 29, Katarzynin 2, Marcinki IG 1, Siciny IG 1, Dymek IG 1, Dankowice IG 1, Kalisz IG 1, Września IG 1 and Objezierze IG 1 were studied. Results of these studies facilitate a new interpretation of the stratigraphy and partly clarify timing of Carboniferous deposition and deformation. Stratigraphical interpretation of miospore assemblages proves the presence of Namurian-Westphalian (Pendleian-Alportian and Duckmantian-Asturian) or even younger rocks in the investigated intervals. During that time older rocks, the source of abundant contained miospores and faunal macrofossils, were subject of erosion and the fossils became reworked components in the studied rocks. Repetition of both dated sequences in some sections indicates that inversion of this foreland basin took place after the Bolsovian. • Key words: Carboniferous, Poland, palynostratigraphy, reworked fossils, repetition of stratigraphic sequences.

Górecka-Nowak, A. 2008. New interpretations of the Carboniferous stratigraphy of SW Poland based on miospore data. *Bulletin of Geosciences 83(1)*, 101–116 (9 figures, 1 table). Czech Geological Survey, Prague. ISSN 1214-1119. Manuscript received June 15, 2007; accepted in revised form November 30, 2007; issued March 31, 2008.

Anna Górecka-Nowak, Institute of Geological Sciences, University of Wrocław, ul. Cybulskiego 30, 50 205 Wrocław, Poland; agor@ing.uni.wroc.pl

The Carboniferous succession of SW Poland is considered as an infill in the Variscan foreland basin. It is buried under a thick cover of Permo-Mesozoic and Cenozoic rocks of the Polish Basin (Fig. 1), which in the southwestern part is called the Fore-Sudetic Monocline. Carboniferous sediments have been recorded in more than 250 wells since the early 1960s, but their recognition is still not satisfactory. The sequence is rather monotonous and consists mainly of mudstones and sandstones with intercalations of claystones and conglomerates, interpreted as turbidites. They represent a succession of a wide spectrum of sediment gravity flows with associated fine-grained hemipelagites (Mazur *et al*. 2003, 2006). The thickness of the sequence is unknown, but is not less than 2500 m.

These Carboniferous sediments are considered as syntectonic and contain records of the final events of the Variscan orogeny in the Polish part of the European Variscan belt. Recognition of the stratigraphy is necessary to understand this record. Late Viséan (and sometimes earliest Namurian[1]) goniatites and other marine faunas were considered as the most important biostratigraphic indicators occurring in the succession. Results of palynostratigraphical studies, however, seemed to indicate that the whole Carboniferous occurs here. A critical overview of previous biostratigraphical results revealed that the stratigraphy of the succession was still far from being adequately understood and that new biostratigraphical studies are required.

Here the results of recent palynostratigraphical studies of sediments from nine wells are presented. The biostratigraphical analysis permits a new interpretation of the stratigraphy of this succession and partly elucidates the timing of its deposition and deformation. The usually poorly preserved miospore assemblages occurring in the succession are commonly of mixed character. Stratigraphical interpretation of these assemblages is extremely difficult. However, the assemblages indicate that the investigated samples were deposited in the Pendleian-Alportian (early Namurian) and Duckmantian-Asturian (Westphalian B-D) intervals or even longer. Repetition of the stratigraphic intervals, palynologically documented in the Siciny IG 1 section and less convincingly so in the Marcinki IG 1, prove that tectonic deformation took place after the Bolsovian (Westphalian C).

[1] The recent Carboniferous subdivision (Henckel & Clayton 2006) is applied in this paper with regard to the new stratigraphical conclusions. In those parts of the text dealing with previous results, the traditional names of the stratigraphical units are used.

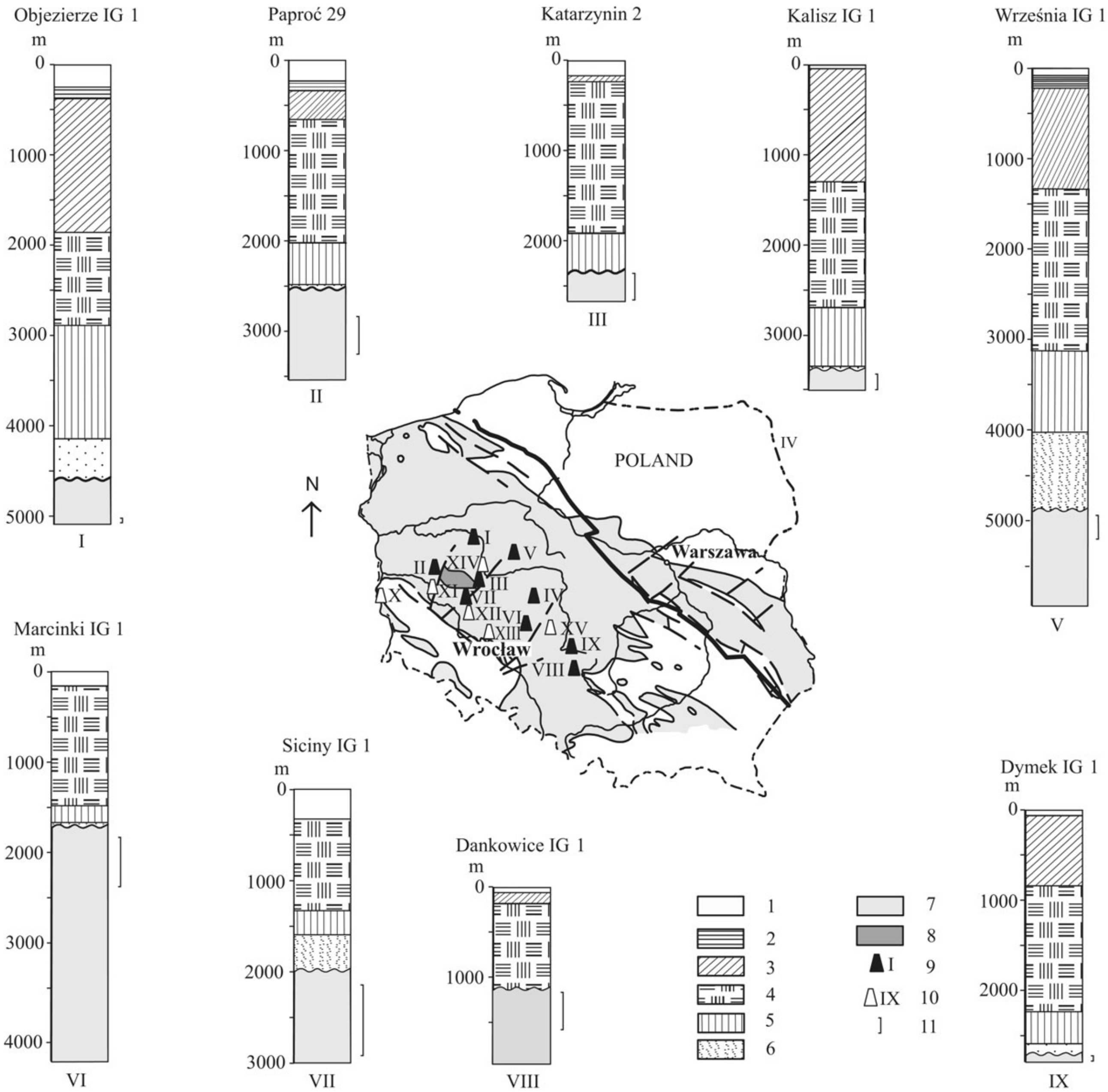


Figure 1. Location of selected wells in SW Poland (I – Objezierze IG 1, II – Paproć 29, III – Katarzynin 2, IV – Kalisz IG 1, V – Września IG 1, VI – Marcinki IG 1, VII – Siciny IG 1, VIII – Dankowice IG 1, IX – Dymek IG 1, X – Przewóz 1, XI – Ługowo 2, XII – Kowalowo 1, XIII – Czerńczyce IG 1, XIV – Donatowo 1, XV – Wierzchowice 4) and geological sections of palynologically studied wells: 1 – Cenozoic rocks, 2 – Cretaceous, 3 – Jurassic, 4 – Triassic, 5 – Zechstein, 6 – Rotliegend, 7 – Carboniferous, 8 – Leszno-Wolsztyn High, 9 – palynologically studied well, 10 – other well mentioned in text, 11 – palynologically studied interval.

Stratigraphy – previous studies

Lateral diversity of lithofacies and poor recognition of the studied Carboniferous succession, together with the poor core recovery in the wells, did not allow the establishment of a lithostratigraphical division. The rocks have yielded marine faunas, poorly preserved macrofloral remnants and usually poorly preserved miospore assemblages. Studies of this palaeontological material have provided abundant detailed information, but the recognition and biostratigraphical evidence of particular parts of the Carboniferous section remained inconclusive.

The oldest rocks in this succession are usually considered to be Tournaisian. Their occurrence was suggested by Parka & Ślusarczyk (1988), Wierzchowska-Kicułowa (1984), Kühn & Paprocka (1979) and Żelichowski (1984,

1995) mainly on the basis of superposition and lithological correlation. The only section with palynological documentation is well Przewóz 1 (Fig. 1), about which Krawczyńska-Grocholska (1978) suggested a stratigraphical age for the anchimetamorphic mudstone-greywacke slates as Upper Devonian-Tournaisian. However, this well is located to the south of the Middle Odra fault and the penetrated succession, which displays a strong affinity to the Görlitz Slate Belt (Görlitzer Schiefer Gebierge), belongs to the Lausitz Massif. Tournaisian miospores were also found among taxa of different stratigraphical ages from Devonian up to Late Carboniferous in mudstones from wells Donatowo 1 and Kowalewo 1 (Karnkowski & Rdzanek 1982a, b; Krawczyńska-Grocholska 1975, 1978). In these mixed miospore assemblages Tournaisian miospores are considered as reworked and cannot be reliably used for stratigraphical purposes. These facts suggest that the presence of the Tournaisian rocks in the succession is suspect.

On the contrary, Upper Viséan rocks seem to be documented from many wells with the highest level of certainty on the basis of marine faunas, mainly goniatites (Bojkowski 1973; Korejwo & Teller 1966, 1973; Muszer 1999; Kühn & Paprocka 1979; Żelichowski 1964b, 1995) and floral remnants (Kłapciński & Muszer 1987, 1995; Haydukiewicz *et al.* 1999). Comparison of these results with miospore data of Górecka & Parka (1980), Górecka *et al.* (1994, 2000), Parka & Ślusarczyk (1988) reveals that in many wells in rocks containing late Viséan macrofossils and considered as Upper Viséan, younger miospore assemblages were also found.

Lower Viséan deposits have been considered to occur below horizons dated as late Viséan (Kühn & Paprocka 1979, Żelichowski 1995) but no confirmatory biostratigraphic data is available to support this conclusion. Miospore documentation of the Viséan is poor and uncertain. In many wells the palynostratigraphical position of the rocks was interpreted as Upper Viséan-Lower Namurian (Górecka 1991; Górecka & Parka 1980; Górecka *et al.* 1994, 1998; Krawczyńska-Grocholska 1975, 1978; Krawczyńska-Grocholska & Grocholski 1976; Parka & Ślusarczyk 1988), but only in the Wierzchowice 4 well it was limited to the Viséan. In some other wells, the original dating of Viséan (Krawczyńska-Grocholska 1975, Krawczyńska-Grocholska & Grocholski 1976, Górecka & Parka 1980) was changed or extended to Viséan-Namurian (Karnkowski & Rdzanek 1982a, b; Parka & Ślusarczyk 1988). In the light of above reservations, the occurrence of Viséan rocks in this Carboniferous succession should also be treated as suspect and certainly in need of further studies.

Documentation of a rich palynological assemblage derived from many wells has given a Namurian A age to deposits (Górecka 1991, Górecka *et al.* 1977b, Górecka & Parka 1980, Krawczyńska-Grocholska 1975, Krawczyńska-Grocholska & Grocholski 1976). Rocks containing macrofossils also supported a Namurian A age (Kłapciński & Muszer 1987, 1995; Żelichowski 1964a, b). Górecka (1972) dated deposits from Czerńczyce IG 1 and some other wells as Namurian B and C (Górecka *et al.* 1978, Parka & Ślusarczyk 1988).

Deposits from many wells are considered to be Westphalian supported only by palynological evidence (Górecka 1991; Górecka *et al.* 1977a, b, 1994, 1998, 2000; Górecka & Parka 1978; Krawczyńska-Grocholska 1978; Parka & Ślusarczyk 1988). A review of these papers indicates that the evidence is most convincing for Upper Westphalian, when compared with Westphalian A and B. Stephanian rocks have been recognized on palynological data by Jerzykiewicz (1977), Ślusarczyk (1980), Karnkowski & Rdzanek (1982a, b) and Parka & Ślusarczyk (1988), and some of miospore assemblages from these rocks were considered to be mixed. Unclassified rocks of general latest Carboniferous age, which were recorded from a number of wells (Górecka *et al.* 1977a, b, 2000; Kłapciński & Muszer 1995), were also determined as Stephanian on the basis of macrofloral and bivalve evidence.

The above review of previous results shows that biostratigraphical studies of this Carboniferous succession resulted in a number of ambiguities and often contradictory interpretations. It should be emphasized that the biostratigraphical results from many sections presented by different authors are contradictory. This problem has already been mentioned for the comparison of results based on macrofossils and miospores, but it also exists for results from duplicated palynostratigraphical studies undertaken by various authors for the same rocks (Górecka 1991; Górecka *et al.* 1977b; Krawczyńska-Grocholska & Grocholski 1976; Krawczyńska-Grocholska 1978; Karnkowski & Rdzanek 1982a, b; Parka & Ślusarczyk 1988). The application of unreliable methods of lithological correlation, in the case of palaeontologically barren rocks (Wierzchowska-Kicułowa 1984, Żelichowski 1995), has additionally complicated opinions on stratigraphy. Summarising the overall stratigraphical results is difficult. Wierzchowska-Kicułowa (1984) and Parka & Ślusarczyk (1988) suggested that analysis of all available published data indicated that the entire section of the Carboniferous (from Tournaisian to Stephanian) is present. Żelichowski (1984, 1995) and Kmiecik (1995, 2001), partly omitting or questioning results of palynostratigraphic studies, concluded that two rock units of different age could be distinguished; the older one is Lower Carboniferous-lowermost Namurian and the younger is Upper Westphalian-Stephanian. All this reveals that the stratigraphy of the Carboniferous succession of SW Poland is still far from being sufficiently understood and indicates the necessity for new biostratigraphical studies.

New palynostratigraphical studies

Scope

The recent palynological studies involve miospores recorded from samples from nine wells: Dymek IG 1, Dankowice IG 1, Kalisz IG 1, Objezierze IG 1, Września IG 1, Paproć 29, Katarzynin 2, Marcinki IG 1 and Siciny IG 1, and the work was undertaken primarily for stratigraphic purposes (Fig. 1). In each of the wells the Carboniferous rocks occur at a depth of a few thousand metres below the Permo-Mesozoic strata, which are in turn covered by Cenozoic rocks. The majority of the studied sections had previously been investigated using biostratigraphical methods, but, at least in some cases, the results yielded mutually- or self-contradictory information.

Results

Rich miospore assemblages were obtained from the investigated samples with the most diverse found from wells Katarzynin 2, Paproć 29 and Siciny IG 1. Poorer assemblages were recorded in sections from Marcinki IG 1, Września IG and Objezierze IG 1, whereas in wells Dymek IG 1, Dankowice IG 1 and Kalisz IG 1 only a few taxa were determined. More than 400 miospore taxa were recognized in total from the studied sections.

Miospores recovered from the investigated samples are generally poorly preserved; mechanical destruction is common but the main destructive factor is thermal alteration. Miospore colours are diverse and represent all stages of thermal maturity from mature to metamorphosed. Thermal maturity varies on a regional scale. Additionally, in each miospore assemblage, specimens of different thermal maturities are observed.

Palynostratigraphy

Analysis of all the sufficiently well preserved miospore assemblages reveals their mixed character, visible in the coexistence of taxa from different stratigraphic ages and different thermal maturity. Taxa characteristic of long time intervals, from late Devonian up to Pennsylvanian occur but the stratigraphical conclusions presented below are supported only on the appearance of the youngest miospore taxa. Lists of miospores found in the studied samples are presented in Table 1, divided into groups of stratigraphically important taxa and reworked miospores. The precision of the stratigraphical interpretation was limited by the state of miospore preservation. Miospores from the Paproć 29, Katarzynin 2 and Siciny IG 1 are in the majority quite well preserved and those from the Września IG 1 and Marcinki IG 1 sections are at least in part adequately preserved to be determined precisely. Some stratigraphically important taxa were recorded, which allowed the application of the standard European miospore zonation for the Pennsylvanian (Clayton *et al*. 1977, Owens *et al*. 2004). The poor preservation of miospores from the remaining wells allows only very general interpretations.

All miospore taxa, which the tops of stratigraphical ranges are located below the base of a defined biozone, were considered as reworked and they were not taken into account during the stratigraphical interpretation. The common poor preservation of the miospores and the mixed character of their assemblages requires the presence of numerous specimens for a correct stratigraphical interpretation.

Paproć 29. – The Carboniferous strata from this well occur at depth interval 2511–3522 m and dip at a high angle of 70–90° (Fig. 2). There is no published data concerning their biostratigraphy. Rich and diverse miospore assemblages came from depth interval 2969–3522 m; all are mixed, consisting of Late Devonian to Serpukhovian (Namurian A) taxa and contain an abundance of *Lycospora*, *Densosporites*, *Pseudoannulatisporites*, *Cingulizonates*, *Radiizonates* and *Cristatisporites.* Numerous specimens of *Cingulizonates* cf. *capistratus* and the presence of *Crassispora kosankei* that appear at the base of the Serpukhovian, in association with other taxa (see Tab. 1) suggest an assignment to the *Verrucosisporites morulatus* (Vm) Sub-Biozone, according to Owens *et al*. (2004), corresponding to Pendleian (lowermost Namurian A).

Two associations of miospore taxa were distinguished among reworked miospores recorded in the studied interval (Tab. 1). The older one contains taxa typical of Late Devonian-Tournaisian and the younger is characterized by Viséan miospores.

Katarzynin 2. – Carboniferous rocks occurring at depth interval 2376.5–2650 m were considered to be Namurian based on macrofloral fossils (Kłapciński & Muszer 1995) (Fig. 2). Palynological studies of these rocks, dipping at a high angle, from depth interval 2434–2650 m provided diverse miospore assemblages, which consist of taxa of different stratigraphic ranges from Late Devonian to early Bashkirian and therefore they are considered as mixed. There are no vertical changes in the composition of miospore assemblages within the interval so all of them have been assigned to the same biozone. The occurrence of *Camptotriletes superbus, Stenozonotriletes triangulus, Crassispora kosankei*, *Lycospora subtriquetra* and *Kraeuselisporites ornatus* in association with many other taxa (Tab. 1) indicate an assignment to the *Lycospora subtriquetra-Kraeuselisporites ornatus* (SO) Biozone, corresponding to late Arnsbergian-Alportian (late Namurian A) (Clayton *et al*. 1977). Because of the mixed charac-

Table 1. Composition of Carboniferous miospore assemblages from SW Poland and their stratigraphical interpretation

Borehole Depth	Miospore assemblages	Dating
Paproć 29 2969–3522 m	Stratigraphically important taxa: *Crassispora kosankei*, *Microreticulatisporites concavus, Bellispores nitidus, Rotaspora knoxi, Crassispora maculosa*, *Triquitrites marginatus, Tripartites vetustus, Reticulatisporites carnosus, Remysporites magnificus, Leiotriletes tumidus*, *Microreticulatisporites punctatus*, *Cingulizonates* cf. *capistratus, Schulzospora* spp.*, Rugospora corporata*, *Kraeuselisporites echinatus, Secarisporites remotes, Triquitrites piramidalis*. Reworked taxa (older): *Retusotriletes incohatus, R. famenensis, Convolutispora vermiformis, Tumulispora malevkensis T. rarituberculata, Crassispora trychera, Kraeuselisporites hibernicus, K. mitratus*, *Vallatisporites verrucosus, Auroraspora macra, A. evanida, Grandispora famenensis* var. *minuta*. Reworked taxa (younger): *Dictyotriletes pactilis, Rotaspora ergonulii, Murospora aurita, Densosporites regalis, Vallatisporites ciliaris, Cribrosporites cribellatus.*	Pendleian (lowermost Namurian A)
Katarzynin 2 2434.5–2650 m	Stratigraphically important taxa: *Leiotriletes tumidus*, *Camptotriletes superbus, Anaplanisporites baccatus, Neoraistrickia inconstans, Secarisporites remotus, Knoxisporites seniradiatus, Stenozonotriletes triangulus, Ahrensisporites guerickei, Savitrisporites nux, Crassispora kosankei*, *Lycospora subtriquetra, Kraeuselisporites echinatus, K. ornatus, Discernisporites irregularis, Laevigatosporites vulgaris, Schulzospora* spp.*, Rugospora corporata*. Reworked taxa (older): *Retusotriletes incohatus, Emphanisporites* sp.*, Cyclogranisporites palaeophytus, Apiculiretusispora multiseta, Tumulispora rarituberculata, Prolycospora claytonii, Lophozonotriletes concentricus, Radiizonates mirabilis, Kraeuselisporites hibernicus, K. mitratus, Vallatisporites verrucosus, Velamisporites caperatus, Spelaeotriletes microspinosus, Auroraspora macra, Grandispora acuta, G.* cf. *distincta, G. echinata, Rugospora minuta, R. polyptycha, Diducites mucronatus*. Reworked taxa (younger): *Verrucosisporites baccatus, Dictyotriletes flavus, Ahrensisporites duplicatus, Tripartites distinctus, Potoniespores delicatus, Cingulizonates* cf. *capistratus*, *Discernisporites micromanifestus*.	Arnsbergian – Alportian (late Namurian A)
Września IG 1 4922.5–5187.3 m	Stratigraphically important taxa: *Crassispora kosankei, Punctatosporites granifer, Torispora securis, Thymospora pseudothiessenii, Florinites pumicosus, F. mediapudens*. Reworked taxa: *Acanthotriletes baculatus, Cingulizonates bialatus, Kraeuselisporites echinatus, Leiotriletes tumidus, Microreticulatisporites concavus, Retialetes radforthii, Rotaspora knoxi, Schulzospora* spp., *Spinozonotriletes uncatus, Stenozonotriletes coronatus, Triquitrites comptus*.	not older than Asturian (Westphalian D)
Siciny IG 1 2594.5–2939 m 2310.5–2319.5 m	Stratigraphically important taxa: *Leiotriletes tumidus*, *Verrucosisporites cerosus*, *Microreticulatisporites punctatus, Anaplanisporites baccatus, Neoraistrickia inconstans, Bascaudaspora variabilis, Dictyotriletes vitilis, Stenozonotriletes triangulus, Bellispores nitidus, Savitrisporites nux*, *Crassispora kosankei, Lycospora subtriquetra, Cirratriradites rarus, Kraeuselisporites ornatus*, *Schulzospora rara, Kraeuselisporites ornatus*, *Cirratriradites rarus*. Reworked taxa (older): *Retusotriletes incohatus, R. communis, Cyclogranisporites palaeophytus, Apiculiretusispora fructicosa*, *A. multiseta*, *Pustulatisporites dolbii, Prolycospora claytonii, Radiizonates mirabilis, Kraeuselisporites hibernicus, Vallatisporites verrucosus, Auroraspora macra, A. asperella, A. panda, Grandispora lupata, G. cornuta, Rugospora minuta, R. polyptycha*. Reworked taxa (younger): *Verrucosisporites baccatus*, *V. morulatus*, *Raistrickia nigra*, *Microreticulatisporites concavus, Dictyotriletes pactilis, Ahrensisporites duplicatus, Knoxisporites triradiatus, Lophozonotriletes tuberosus, Lophozonotriletes dentatus, Tricidarisporites balteolus*, *Rotaspora fracta*, *R. knoxi*, *Crassispora maculosa, Vallatisporites ciliaris, Cribrosporites cribellatus*, *Discernisporites micromanifestus*, *Perotrilites tessellatus*.	late Arnsbergian – Alportian (late Namurian A)
Siciny IG 1 2179.2–2255.5 m 2450–2546.7 m	Stratigraphically important taxa: *Cyclogranisporites aureus, Verrucosisporites donarii, Converrucosisporites armatus, Apiculatisporis aculeatus, A. variocorneus, Microreticulatisporites nobilis, M. sulcatus, Triquitrites sculptilis, Westphalensisporites irregularis, Radiizonates tenuis, Laevigatosporites perminutus, Punctatosporites* spp.*, Torispora securis, Vestispora* sp. Reworked taxa (older): *Tumulispora malevkensis, Auroraspora macra, A. panda, Grandispora cornuta, Tetraporina* sp. Reworked taxa (younger): *Leiotriletes tumidus, Verrucosisporites cerosus, V. nodosus, Waltzispora planiangulata, Anaplanisporites denticulatus, A. globulus, Procoronaspora serrata, Microreticulatisporites concavus, M. punctatus, M. microreticulatus, Raistrickia nigra, Dictyotriletes equigranulatus, Convolutispora tessellata, C. jugosa, Stenozonotriletes bracteolus, S. lycosporoides, Bascaudaspora canipa, Bellispores nitidus, Rotaspora knoxi, Murospora margodentata, Potoniespores delicatus, Triquitrites marginatus, Tripartites trilinguis, Cingulizonates* cf. *capistratus, Densosporites simplex, D. variomarginatus, Vallatisporites ciliaris, Schulzospora* spp.	Bolsovian (Westphalian C)
Marcinki IG 1 1832.8–1839 m 2393.3–2401.1 m	Stratigraphically important taxa: *Waltzispora polita, Anaplanisporites baccatus, Anaplanisporites globulus, Microreticulatisporites punctatus, Savitrisporites* sp.*, Stenozonotriletes* cf. *coronatus, Stenozonotriletes lycosporoides*, *Crassispora kosankei, Kraeuselisporites ornatus*, *Schulzospora* sp. Reworked taxa: *Triquitrites marginatus*.	late Arnsbergian – Alportian (late Namurian A)
Marcinki IG 1 2135.1–2141.5 m 2348.4–2352.8 m	Stratigraphically important taxa: *Microreticulatisporites nobilis, Verrucosisporites donarii, Westphalensisporites irregularis*, *Converrucosisporites armatus*. Reworked taxa: *Microreticulatisporites concavus*, *Rotaspora* sp.	Duckmantian (Westphalian B)

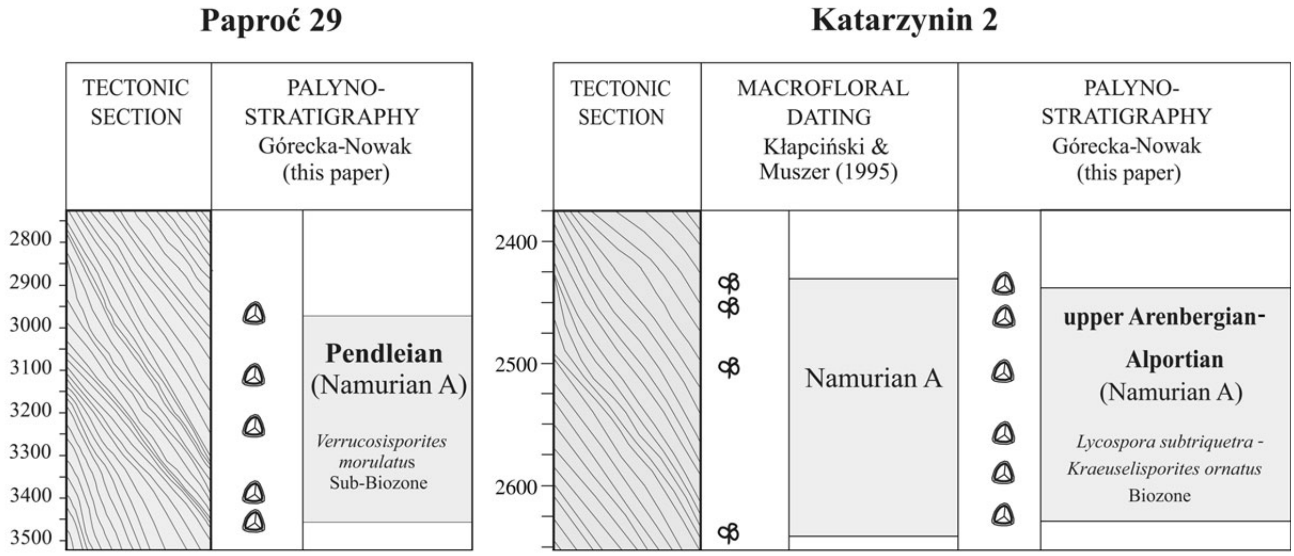


Figure 2. Stratigraphy of Carboniferous rocks in the wells Paproć 29 and Katarzynin 2.

ter and absence of *Cirratriradites rarus,* there is no evidence to justify the application of the recent subdivision of this biozone (Owens *et al.* 2004).

Abundant reworked miospores from the investigated samples comprise Late Devonian–Tournaisian taxa, considered to be the older association as well as late Viséan-early Arnsbergian (Viséan-earliest Namurian) taxa, considered to be the younger association (Tab. 1).

Września IG 1. – The Carboniferous succession was recorded at a depth of 4889.5–5904.2 m with the beds dipping at a low angle in the entire section (Fig. 3). Earlier opinions on the stratigraphy were mutually contradictory. Żelichowski (1995) dated these rocks as Upper Viséan on the basis of marine fossils. Later, Parka & Ślusarczyk (1988) on the basis of palynological data from depth 4897–5791 m divided this interval into three parts and interpreted the ages as Late Viséan-Namurian (depth 5139–5791 m), Westphalian A (depth 5035 m), and as not older than Late Westphalian A (depth 4897 m) (Fig. 3).

During the present study assemblages of very dark and poorly preserved (over-mature) miospores have been recovered from the upper part of the section (depth 4922.5–5187.3 m). This assemblage is formed of infrequent specimens, many of which identified only to generic level. Taking into account the poor quality of the palynological data, the stratigraphical position of the investigated interval can only be defined generally. Many late Viséan and Serpukhovian species are found, but this association is considered to be reworked because of its occurrence with some younger taxa (Tab. 1). The most important component from this assemblage is *Thymospora*, which indicates that the samples investigated are not older than Asturian (Westphalian D) (Clayton *et al.* 1977).

Siciny IG 1. – Carboniferous rocks occur in depth interval 2004.5–3000 m and their base was not penetrated. In the lower and upper parts of the log Carboniferous rocks lie nearly horizontally or dip at a low angle (up to 25°) whereas within the depth interval 2408.5–2665.1 m there occurs a limited tectonically deformed zone with strata dipping at high angles (up to 90°) and cut by three thrust surfaces (Fig. 4). In the upper part of the section (depth 2037–2545 m), Late Viséan marine faunas were found, and thus this part was dated as Upper Viséan. Underlying barren rocks were considered to be Lower Viséan or even Tournaisian (Kühn & Paprocka 1979, Żelichowski 1995). Palynological studies of the uppermost part of the section (Parka & Ślusarczyk 1988), in contrast, provided important data indicating a Westphalian age (Fig. 4).

Recent palynostratigraphical studies of samples from the depth interval 2179.2–2939 m provided two rich and diverse miospore assemblages of different ages, each of which is mixed, consisting of taxa with different stratigraphical ranges. In the older assemblage, Serpukhovian-early Bashkirian taxa are the youngest and they are considered as stratigraphically important. The presence of *Kraeuselisporites ornatus*, *Cirratriradites rarus* and *Lycospora subtriquetra* among others (Tab. 1) indicates that this assemblage represents the *Lycospora subtriquetra-Kraeuselisporites ornatus* (SO) Biozone (Clayton *et al.* 1977, Owens *et al.* 1977) of late Arnsbergian-Alportian (late Namurian A) age. The mixed character of this assemblage and the very low frequency of *Cirratriradites rarus* do not allow any further subdivision or recognition of any sub-biozone (Owens *et al.* 2004). Many Late Devonian-Tournaisian and late Viséan-early Serpukhovian reworked taxa were recorded in the assemblage (Tab. 1).

The younger miospore assemblage consists of many taxa (Tab. 1) but most important are: *Torispora securis*, *Microreticulatisporites sulcatus, Triquitrites sculptilis* and *Westphalensisporites* sp., an association typical of the *Torispora securis-Torispora laevigata* (SL) Biozone (Clayton *et al*. 1977), which has been correlated with Bolsovian (Westphalian C). Among the reworked miospores recorded within this younger association, Late Devonian-Tournaisian and late Viséan-Serpukhovian groups can be distinguished (Tab. 1).

Both recognized miospore assemblages duplicate in this section. The late Arnsbergian-Alportian (late Namurian A) miospore assemblage is recorded in two depth intervals: 2594.5–2939 m and 2310.5–2319.5 m. The younger, Bolsovian (Westphalian C) miospore assemblage was documented in two depth intervals: 2179.2–2255.5 m and 2450–2546.7 m. This palynological record indicates a repetition of stratigraphical sequences in the studied section, which is clearly connected with the tectonic deformation (Fig. 4).

Marcinki IG 1. – The Marcinki IG 1 section is famous because the maximum known thickness of the Carboniferous succession exceeds 2500 m and occurs in the depth range 1715–4237 m (Fig. 1). These sediments are palaeontologically well documented with marine faunas, which were recorded throughout the entire section. Korejwo & Teller (1973), Bojkowski (1973) and Żelichowski (1995) defined their stratigraphic position as Upper Viséan. According to the former, the uppermost part of the section is slightly younger and might belong to the Namurian (Fig. 5).

The previous palynostratigraphical studies of Górecka & Parka (1980) indicated that rocks in the lower part of the section (depth intervals 3584.9–3593.9 m, 3667.7–3680.6 m and 4164.5–4186 m) belong to the Viséan. Overlying beds (depths 2141.5–2148.3 m, 2559.4–2564.7 m and 2939–2945 m) were considered to be Westphalian. Later, Parka & Ślusarczyk (1988) suggested that the lower part of the log (depth 3584.9–4186 m) should be assigned to the Viséan-Namurian while still considering the upper part (depth 1734.1–2945 m) as Westphalian (Fig. 5). The contradiction in conclusions based on different fossil groups was explained by Górecka & Parka (1980), who suggested that the late Viséan marine macrofaunas occurring in rocks palynologically dated as Westphalian had to be reworked.

Recent palynostratigraphical studies were limited to the upper part of the section (depth interval of 1832.8–2401.1 m). This part contains a zone of the tectonically deformed rocks (depth 2154–2323 m) and rock sequences dipping at low to medium angles, occurring below and above this zone (Fig. 5). The investigated samples contain very poorly preserved miospores. The majority of specimens found were not positively identified, but 67 miospore taxa were determined, most of them only to generic level. The stratigraphical conclusions based on these miospore data are sometimes rather imprecise but some samples provided data to prove the presence of two miospore assemblages of different ages. Both these assemblages are mixed.

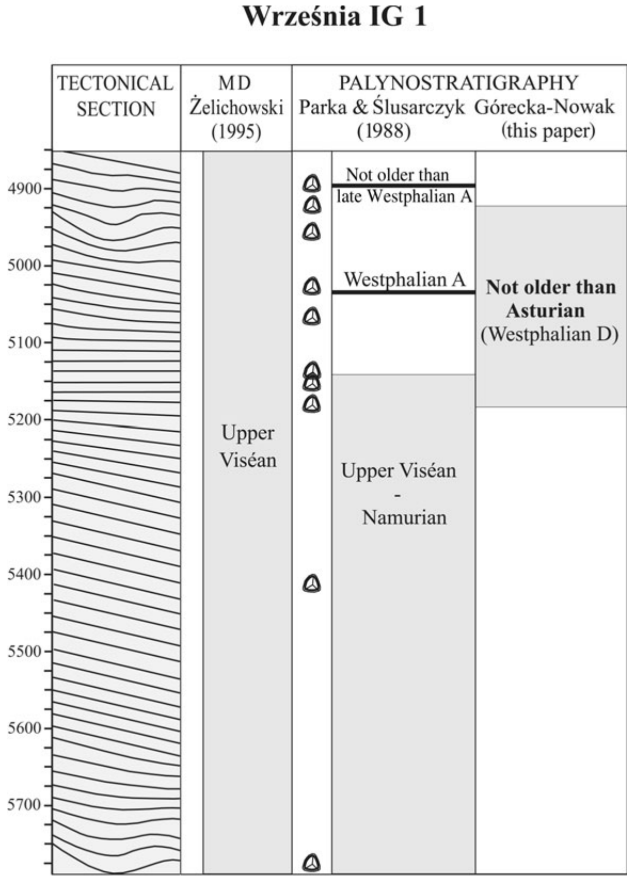


Figure 3. Stratigraphy of Carboniferous rocks in the Września IG 1 well. MD – macrofaunal dating.

The stratigraphic position of rocks containing the older miospore assemblage (Tab. 1), is defined by *Crassispora kosankei* and *Kraeuselisporites ornatus* as the *L. subriquetra-K. ornatus* (SO) Biozone (Clayton *et al*. 1977), correlated with the late Arnsbergian-Alportian (late Namurian A). There is no evidence to allow recognition of a sub-biozone according to criteria of Owens *et al*. (2004). *Triquitrites marginatus* is considered to be a reworked miospore in this assemblage.

The younger miospore assemblage is also limited in content and consists of poorly preserved miospores. The presence of *Microreticulatisporites nobilis, Verrucosisporites donarii, Westphalensisporites irregularis* and *Converrucosisporites armatus* suggest that the studied interval should probably be assigned to the *M. nobilis-F. junior* (NJ) Biozone (Clayton *et al*. 1977), corresponding to the Duckmantian (Westphalian B). In this assemblage

Microreticulatisporites concavus and *Rotaspora* spp. were found and are considered as reworked (Tab. 1).

The Arnsbergian-Alportian miospore assemblage is recorded from depth intervals 1832.8–1839 m and 2393.3–2401.1 m. Rocks dated as Duckmantian occur at depths 2135.1–2141.5 and 2348.4–2352.8 m in the top and bottom parts of the tectonically deformed zone of the well. As well the Arnsbergian-Alportian strata as the Duckmantian rocks also appear twice in the section; beds with less precisely defined stratigraphical positions occur in between. Comparison of these biostratigraphical data with the tectonic observations indicate that in the upper part of the log (1832.8–2141.5 m) the Arnsbergian-Alportian rocks are underlain by Duckmantian strata. Below them, within the depth interval 2348.4–2401.1 m, the Duckmantian rocks occur above the Arnsbergian-Alportian. Both these rock sequences are separated by tectonically deformed Viséan-Namurian rocks (Fig. 5).

Remaining sections. – Miospores found in rocks from all remaining sections were extremely poorly preserved, so only general stratigraphical conclusions can be made. Assessment of these miospore assemblages could not detect whether they contain reworked miospores. In well Objezierze IG 1, where late Viséan marine faunas had been recognized earlier (Żelichowski 1995), the thermally over-mature miospores indicate that the rocks investigated are Upper Viséan and/or Serpukhovian. In rocks from Kalisz IG 1 and Objezierze IG 1 there were even worse preserved miospores, dark brown to very dark brown in colour. Rocks from well Kalisz IG 1 were interpreted as Viséan-Serpukhovian but since there is no evidence of younger, Pennsylvanian miospore taxa, there is no basis to confirm the conclusion of Parka & Ślusarczyk (1988) on the Namurian-Westphalian age of these rocks. In wells Dymek IG 1 and Dankowice IG 1 the stratigraphical position of the studied rocks can be defined as not older then Viséan.

Discussion

The new palynological studies of the Carboniferous succession from SW Poland have provided new data and enabled a new look at the stratigraphy, which, despite over 40 years of study, had been difficult to describe and understand. Miospores found in rocks from nine deep wells were generally poorly preserved and their preservation has thus limited the possible interpretation of their stratigraphical position. They proved that two rock sequences of different ages occur in the Carboniferous complex being investigated. The older succession is Pendleian-Alportian (Namurian A), whereas the younger one is Duckmantian-Asturian (Westphalian B–D) or even younger (Fig. 6).

The stratigraphically older rocks were recorded from the Paproć 29, Katarzynin 2, Siciny IG 1 and Marcinki IG 1 wells. The Carboniferous rocks from the Paproć 29 section represent the *Verrucosisporites morulatus* (Vm) Sub-Biozone (Owens *et al*. 2004), corresponding to the Pendleian. Strata documented in Katarzynin 2, Siciny IG 1 and Marcinki IG 1 are slightly younger and represent the *Lycospora subtriquetra-Kraeuselisporites ornatus* (SO) Biozone (Clayton *et al*. 1977, Owens *et al*. 1977), correlated with the late Arnsbergian-Alportian (Fig. 6).

The younger rock succession was identified in three sections – the Marcinki IG 1, Siciny IG 1 and Września IG 1. The oldest rocks from this series were documented in the Marcinki IG 1 well and they probably belong to the *Microreticulatisporites nobilis-Florinites junior* (NJ) Biozone (Clayton *et al*. 1977), corresponding to the Duckmantian (Westphalian B), although the miospore data from this section are of rather poor quality. In the Siciny IG 1 section, the *Torispora securis-Torispora laevigata* (SL) Biozone (Clayton *et al*. 1977) was identified and it allows inclusion of the sample in the Bolsovian. The stratigraphic position of sediments from the Września IG 1 well was defined as not older than Asturian, although their miospore evidence is also poor (Fig. 6).

Both documented sedimentary sequences were recorded in two sections: Siciny IG 1 and Marcinki IG 1. In the first repetition of the Arnsbergian-Alportian and Bolsovian rock intervals was ascertained and the documentation of this stratigraphical duplication of miospores is of quite good quality. In the Marcinki IG 1 section repetition of these sequences probably also occurs but miospore documentation is much poorer and not so reliable. The comparison of stratigraphical and tectonic data from these two sections indicates that duplication of stratigraphical intervals probably has an underlying tectonic cause and the conclusion that tectonic deformation in this basin was post-Bolsovian is supported.

Miospores from the four remaining wells (Objezierze IG 1, Kalisz IG 1, Dankowice IG 1 and Dymek IG 1) were so poorly preserved that their identification is very difficult and consequently, the stratigraphical conclusions are very general.

Results of recent palynological studies of rocks from the Siciny IG 1, Marcinki IG 1 and Września IG 1 wells enabled a new stratigraphical interpretation. In all these sections late Viséan macrofossils had been found earlier (Korejwo & Teller 1973, Kühn & Paprocka 1979, Żelichowski 1995) and were considered as a reliable documentation of the Upper Viséan. The Marcinki IG 1 well was particularly important because the Carboniferous succession there has a maximum known thickness exceeding 2500 m and was referred to the Upper Viséan on the basis of the macrofauna, which had been found throughout the whole section (Żelichowski 1995). Palynostratigraphical

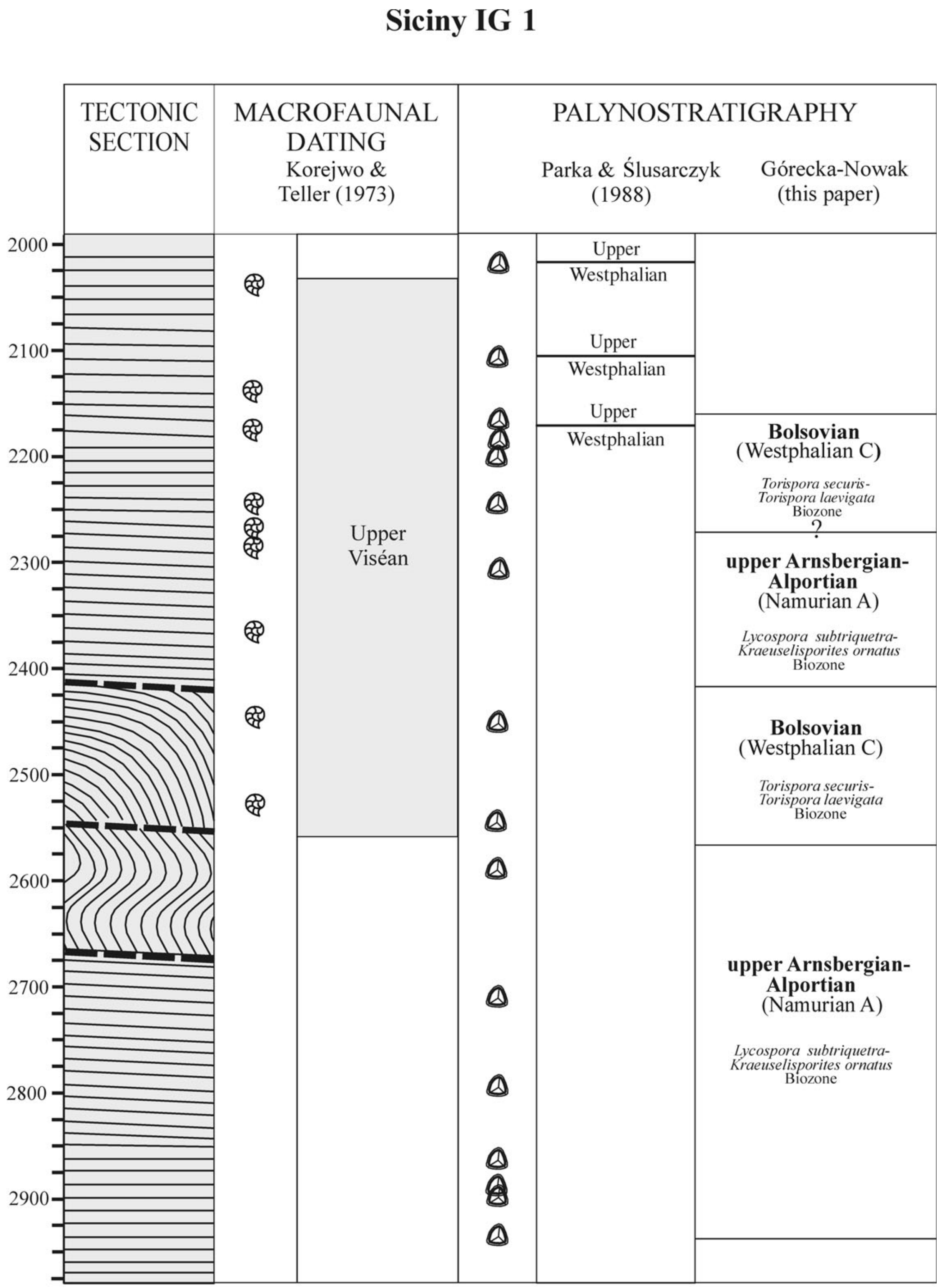


Figure 4. Stratigraphy of Carboniferous rocks in the Siciny IG 1 well.

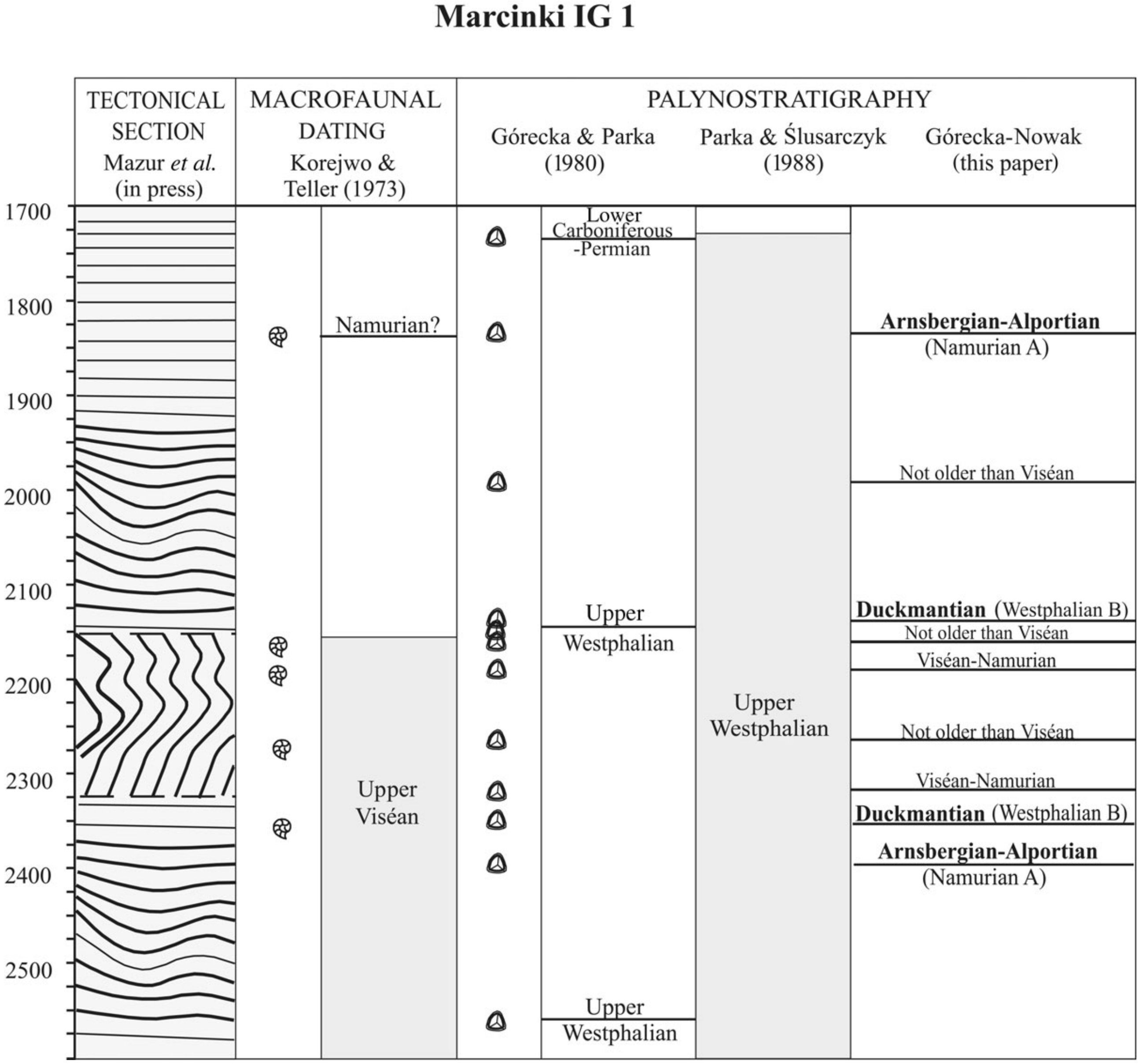


Figure 5. Stratigraphy of Carboniferous rocks in the upper part of the Marcinki IG 1 well.

studies of rocks from these three sections (Górecka & Parka 1980, Parka & Ślusarczyk 1988) proved that younger than late Viséan miospores occur in rocks that had been included to the Upper Viséan. These results were considered as less reliable in comparison to results based on macrofaunal data and thus were left out of accounts in later papers (Żelichowski 1995). Results of the recent palynostratigraphical studies confirmed previous opinions, based on palynological data, that the studied samples contain miospores younger than late Viséan, although their stratigraphical interpretation sometimes differs. It means that late Viséan macrofossils have been found in younger than Upper Viséan rocks. Similar situations were recorded in the Mąkoszyce 1, Lamki 1 and Ostrzeszów 1 wells, where Korejwo & Teller (1966) had assigned rocks to the Upper Viséan on the basis of late Viséan goniatites; later Parka & Ślusarczyk (1988) found much younger miospores there and reinterpreted the stratigraphic position as Pennsylvanian. The latter authors did not comment on this phenomena. Górecka & Parka (1980) expressed the opinion that late Viséan goniatites in the Marcinki IG 1 section, which occur in rocks containing younger miospores, have to be reworked. According to this interpretation, the presence of macrofaunas cannot be applied for stratigraphical purposes. This interpretation clarified all contradictory opinions on the stratigraphy of the stud-

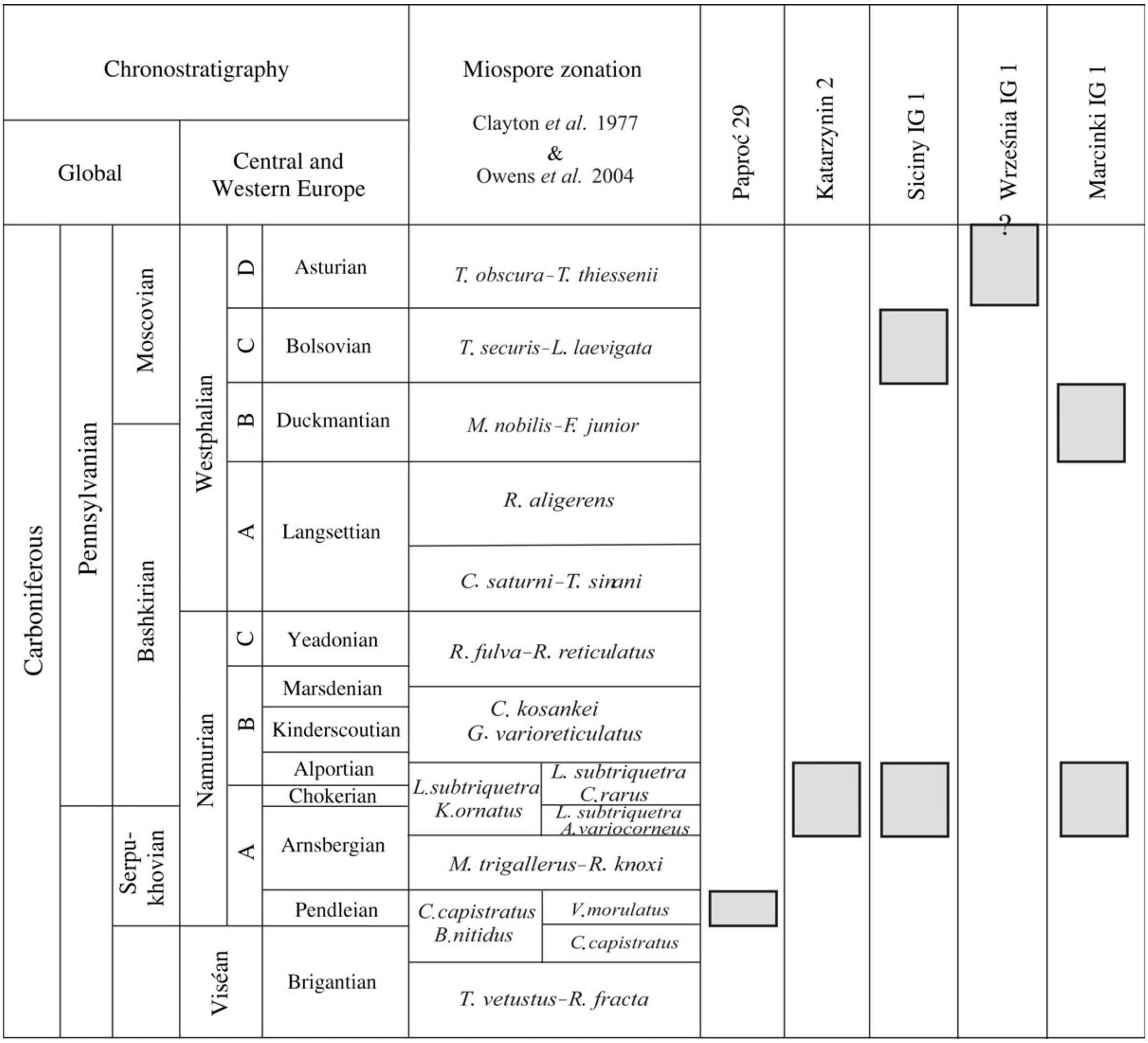


Figure 6. Miospore zonation of Carboniferous (based on Clayton *et al*. 1977 and Owens *et al*. 2004) and stratigraphical position of the studied rocks.

ied rock succession based on macrofaunal and miospore data.

Although miospore assemblages found in the studied rocks were usually poorly preserved, the occurrence of reworked miospores was observed in all of them, where preservation was well enough to determine miospore specimens precisely. The colours are diverse but usually darker compared to the youngest miospore colours. This group is very abundant and taxonomically diverse. Reworked miospores had been recorded earlier solely in rocks from three wells: Donatowo 1 (Krawczyńska-Grocholska 1975) and Kowalewo 1 (Karnkowski & Rdzanek 1982a, b, Krawczyńska-Grocholska 1978) as well as Ługowo 2 (Ślusarczyk 1980).

The new palynological data indicate that all miospore assemblages occurring in the studied succession are probably of mixed character. Stratigraphical ranges of miospore taxa considered as reworked are different and belong to long time interval from the Late Devonian to the early Namurian. In the majority of assemblages two groups of taxa of different stratigraphical ranges were recognized. The older one is typical of the Late Devonian-Tournaisian and the younger consists of taxa typical of the late Viséan-early Arnsbergian. During the deposition of the studied succession erosion of the Upper Devonian-Tournaisian and Upper Viséan-Arnsbergian rocks took place. The latter rocks were probably also the source of late Viséan (and sometimes early Serpukhovian) marine faunas, which had been found earlier in rocks in which mixed miospore assemblages have been found subsequently. It means that studied rocks contain mixed fossil assemblages, consisting of a mixed miospore association and reworked macrofossils.

In such a situation the marine faunas, considered as reworked, cannot be applied for biostratigraphy. Age determination of these mixed fossil assemblages is possible solely on the basis of the youngest fossils, which in this study meant the youngest miospore taxa. The palynostratigraphical interpretation of these miospore data is also not easy, taking into account poor preservation of mixed miospore assemblages. Difficulties connected with this interpretation are discussed by Górecka-Nowak (2007). Despite these problems the use of palynological data seems to be the only applicable method to supply reliable stratigraphical results in this monotonous Carboniferous succession.

The results presented here therefore partly elucidate the timing of deposition and deformation of the studied Carboniferous succession but some important questions still remain open. The timing of the onset of sedimentation is still unknown, especially in the light of the doubtful palaeontological documentation of the Tournaisian and Viséan. The tectonic observations indicate that the oldest part of this succession probably occurs is the northern slope of the Wolsztyn-Leszno High (Mazur 2007, oral information). Further palynostratigraphical studies of rocks from this area should solve this problem. Another important and still open question is presence of Bashkirian rocks in this succession. Although results of previous palynostratigraphical studies indicate that a complete profile of the Carboniferous is present, Żelichowski (1984, 1995) postulated a stratigraphical gap during the Bashkirian. Palynological documentation of the former upper Namurian and lower Westphalian rocks originated mainly from the Czerńczyce IG 1 (Górecka 1972). In a few other sections, strata of a similar stratigraphical position were also recorded but the palynological documentation is much poorer (Górecka *et al*. 1978, Parka & Ślusarczyk 1988). To elucidate this problem new palynostratigraphical studies of the Czerńczyce IG 1 section are needed.

Conclusions

1. Two sedimentary sequences of different age are proven in the Carboniferous complex of SW Poland. The older succession belongs to the Pendleian-Alportian, and is documented in the Paproć 29 [the *Verrucosisporites morulatus* (Vm) Sub-Biozone], Katarzynin 2, Siciny IG 1 and Marcinki IG 1 sections [the *Lycospora subtriquetra-Kraeuselisporites ornatus* (SO) Biozone according to Clayton *et al*. 1977]. The younger succession represents the Duckmantian-Asturian. The older Duckmantian rocks, are documented in the Marcinki IG 1 well [the *Microreticulatisporites nobilis-Florinites junior* (NJ) Biozone]. In the Siciny IG 1 section the *Torispora secures-Torispora laevigata* (SL) Biozone, correlated with the Bolsovian (Clayton *et al*. 1977) was recognized. The stratigraphic position of rocks from the Września IG 1 well is defined as not older than Asturian even though the miospore documentation is rather poor.

2. Both of the proven sequences are duplicated in the Siciny IG 1 and probably in the Marcinki IG 1 wells. In the first, repetition of the upper Arnsbergian-Alportian and Bolsovian rock intervals was ascertained. Palynological data from Siciny IG 1 section is of quite good quality, so documentation of the stratigraphical duplication in this section is reliable. In the Marcinki IG 1 section, the repetition of upper Arnsbergian-Alportian and Duckmantian rocks probably also occurs but miospores are much poorer in preservation and not so abundant. Comparison of stratigraphical and tectonic data from these two sections indicates that duplication of stratigraphical intervals probably has a tectonic cause and supports the conclusion that tectonic deformation was post-Bolsovian.

3. Probably all fossil assemblages occurring in the studied rocks are of mixed character, consisting of mixed miospore assemblages and sometimes reworked marine macrofossils. These reworked fossils originate from the Upper Devonian-Tournaisian and Upper Viséan-Serpukhovian rocks, which were eroded during the sedimentation of studied rocks.

4. Age determination of these mixed fossil assemblages is possible solely on the basis of the youngest fossils found, which in this study meant the youngest miospore taxa. Palynological analysis seems to be the only method, which in this monotonous Carboniferous succession may supply us with reliable stratigraphical results.

5. Although palynostratigraphical studies have already given answers on some important questions concerning the geological history of the studied basin, some of them are still open. Further palynostratigraphical studies should be focused on answering questions on the age of the oldest parts of this Carboniferous succession, as well as on the potential presence of rocks of the intermediate stratigraphical position between the Alportian and Duckmantian.

Acknowledgements

The author is grateful to Bernard Owens and Jiří Bek for helpful comments, which have improved the manuscript, and to Stanisław Mazur for discussion and tectonic sections. This research was supported by the Polish Committee for Scientific Research and Ministry of the Environment (project PCZ-007-21 'Palaeozoic Accretion of Poland').

References

BOJKOWSKI, K. 1973. Das Oberkarbon (Silesium) in Polen in Lichte faunistischer Unterschuchungen. *C. R. 7th International Congress of Stratigraphy and Geology of Carboniferous, Krefeld, IV*, 159–165.

CLAYTON, G., COQUEL, R., DOUBINGER, J., GUEINN, K.J., LOBOZIAK, S., OWENS, B. & STREEL, M. 1977. Carboniferous miospores of Western Europe: illustration and zonation. *Mededelingen Rijks Geologische Dienst 29*, 1–71.

GÓRECKA, T. 1972. Wstępne wiadomości o występowaniu górnego karbonu na monoklinie przedsudeckiej. *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej 8, Studia i Materiały 8*, 35–51.

GÓRECKA, T. 1991. Osady silezu Sudetów i Niżu Polskiego w świetle badań palinologicznych. *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej 61, Monografie 28*, 1–112.

GÓRECKA, T., CYGAN, J. & CZERSKI, K. 1994. Palinostratygraficzna analiza skał karbońskich z otworów wiertniczych Zbąszyń 3, Zbąszyń 5 i Zbąszyń 6. *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej 76, Studia i Materiały 24*, 87–94.

GÓRECKA, T., CZERSKI, K. & CYGAN, J. 1998. Palinostratygraficzne badania skał karbońskich z otworu wiertniczego Sadlno 1. *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej 85, Studia i Materiały 27*, 33–37.

GÓRECKA, T., CZERSKI, K. & CYGAN, J. 2000. Niektóre wyniki badań palinologicznych złoża gazu ziemnego „Paproć" (monoklina przedsudecka). *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej 87, Studia i Materiały 28*, 13–18.

GÓRECKA, T., JUROSZEK, C., KARWOWSKI, L., KŁAPCIŃSKI, J., LORENC, S., MIERZEJEWSKI, M., SACHANBIŃSKI, M. & ŚLUSARCZYK, S. 1977a. Utwory skalne podłoża permu zachodniej części monokliny przedsudeckiej i perykliny Żar oraz przyległej części bloku przedsudeckiego. *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej 22, Monografie 9*, 1–92.

GÓRECKA, T. & PARKA, Z. 1978. Stratygrafia warstw karbońskich w otworze wiertniczym Kowalowo 1. *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej 32, Studia i Materiały 15*, 84–88.

GÓRECKA, T. & PARKA, Z. 1980. Stratigraphy of the Carboniferous deposits taken from the drill-hole elaborated on the basis of palynological tests. (Sum.) *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej 35, Studia i Materiały 16*, 3–35.

GÓRECKA, T., PARKA, Z., ŚLUSARCZYK, S. & TEMPLIN, L. 1977b. Wyniki badań palinologicznych osadów podpermskich południowo-wschodniej części monokliny przedsudeckiej. *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej 24, Studia i Materiały 12*, 29–55.

GÓRECKA, T., PARKA, Z., ŚLUSARCZYK, S. & TEMPLIN, L. 1978. Wiek osadów podpermskich na podstawie badań palinologicznych. *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej 25, Monografie 11*, 3–147.

GÓRECKA-NOWAK, A. 2007. Palynological constraints on the age of Carboniferous clastic succession of SW Poland based on miospore data. *Geological Quarterly 51(1)*, 39–56.

HAYDUKIEWICZ, J., MUSZER, J. & KŁAPCIŃSKI, J. 1999. Dokumentacja paleontologiczna osadów podpermskich w rejonie Zbąszynia (monoklina przedsudecka). *Materiały Konferencji Naukowej Wybrane zagadnienia stratygrafii, tektoniki i okruszcowania Dolnego Śląska. Instytut Nauk Geologicznych Uniwersytetu Wrocławskiego*, 7–18.

HENCKEL, P.H. & CLAYTON, G. 2006. The Carboniferous System. Use of the new official names for the subsystems, series and stages. *Geologica Acta 4(3)*, 403–407.

JERZYKIEWICZ, J. 1977. Wyniki badań palinologicznych osadów karbonu i permu na monoklinie przedsudeckiej. *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej 24, Studia i Materiały 12*, 3–27.

KARNKOWSKI, P.H. & RDZANEK, K. 1982a. Górny karbon (stefan) w wierceniu Donatowo 1. *Przegląd Geologiczny 30(1)*, 32.

KARNKOWSKI, P.H. & RDZANEK, K. 1982b. Uwagi o podłożu permu w Wielkopolsce. *Kwartalnik Geologiczny 26(2)*, 327–339.

KŁAPCIŃSKI, J. & MUSZER, J. 1987. Wiek utworów podpermskich z wybranych otworów wiertniczych wschodniej części monokliny przedsudeckiej. *Geologia Sudetica 22*, 91–100.

KŁAPCIŃSKI, J. & MUSZER, J. 1995. Wiek osadów starszego podłoża wybranych otworów wiertniczych środkowej części monokliny przedsudeckiej. *Acta Universitatis Wratislaviensis 1607, Prace Geologiczno-Mineralogiczne 44*, 29–46.

KMIECIK, H. 1995. Miospores, 70–85. *In* ZDANOWSKI, A. & ŻAKOWA, H. (eds) The Carboniferous system in Poland. *Prace Państwowego Instytutu Geologicznego 148*.

KMIECIK, H. 2001. Miospory, 572–582. *In* PAJCHLOWA, M. (ed.) *Atlas skamieniałości przewodnich i charakterystycznych, part 1c – vol. 2. Młodszy paleozoik. Karbon. Flora. Budowa geologiczna Polski III.*

KOREJWO, K. & TELLER, L. 1966. Lower Carboniferous of the Eastern Part of the Fore-Sudetic Monocline. *Bulletin de L'Académie Polonaise des Science. Série des Sciences Chimiques, Géologiques et Géographiques 14(4)*, 243–245.

KOREJWO, K. & TELLER, L. 1973. Stratygrafia serii karbonu, 35–37. *In* GAJEWSKA, I. (ed.) Marcinki IG 1. *Profile głębokich otworów wiertniczych Instytutu Geologicznego 8*.

KRAWCZYŃSKA-GROCHOLSKA, H. 1975. Z badań palinologicznych karbonu północno-zachodniej Polski. *Przegląd Geologiczny 1*, 34–35.

KRAWCZYŃSKA-GROCHOLSKA, H. 1978. Karbon w podłożu zachodniej części monokliny przedsudeckiej. *Przewodnik 50 Zjazdu Polskiego Towarzystwa Geologicznego, Zielona Góra*, 113–118.

KRAWCZYŃSKA-GROCHOLSKA, H. & GROCHOLSKI, W. 1976. Głębsze podłoże geologiczne okolicy Poznania w świetle badań z lat 1973–1975. *Przegląd Geologiczny 9*, 520–525.

KÜHN, D. & PAPROCKA, I. 1979. *Dokumentacja wynikowa otworu wiertniczego Siciny IG-1*. Unpublished manuscript. Archive of Polish Geological Institute, Warszawa.

MAZUR, S., KUROWSKI, L., ALEKSANDROWSKI, P. & ŻELAŹNIEWICZ, A. 2003. Variscan Fold-Thrust Belt of Wielkopolska (W Poland): New structural and sedimentological data. *Geolines 16*, 71–73.

MAZUR, S., DUNLAP, W.J., TURNIAK, K. & OBERC-DZIEDZIC, T. 2006. Age constraints for the thermal evolution and erosional history of the central European Variscan belt: new data from sediments and basement of the Carboniferous foreland basin in western Poland. *Journal of the Geological Society of London 163*, 1011–1024. DOI 10.1144/0016-76492004-170

MUSZER, J. 1999. Nowa dokumentacja faunistyczna wizenu w podłożu monokliny przedsudeckiej (Jezierzyce 1). *Materiały Konferencji Naukowej Wybrane zagadnienia stratygrafii, tektoniki i okruszcowania Dolnego Śląska. Instytut Nauk Geologicznych Uniwersytetu Wrocławskiego,* 120–121.

OWENS, B., MC LEAN, D. & BODMAN, D. 2004. A revised palynozonation of British Namurian deposits and comparisons with eastern Europe. *Micropaleontology 50*, 89–103.

OWENS, B., NEVES, R. GUEINN, K.J., MISHELL, D.R.F., SARBY, H. & WILLIAMS, J.E. 1977. Palynological division of the Namurian of Northern England and Scotland. *Proceedings Yorkshire Geological Society 41*, 381–398.

PARKA, Z. & ŚLUSARCZYK, S. 1988. Stratygrafia osadów karbońskich podłoża monokliny przedsudeckiej. *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej 43, Monografie 20*, 1–47.

ŚLUSARCZYK, S. 1980. Wyniki badań palinologicznych prób z wybranych otworów wiertniczych rejonu wyniesienia wolsztyńsko-pogorzelskiego. *Prace Naukowe Instytutu Górnictaw Politechniki Wrocławskiej 35, Studia i Materiały 16*, 47–73.

WIERZCHOWSKA-KICUŁOWA, K. 1984. Budowa geologiczna utworów podpermskich monokliny przedsudeckiej. *Geologia Sudetica 19(1)*, 121–139.

ŻELICHOWSKI, A.M. 1964a. Wstępne opracowanie profilu karbonu z Ostrzeszowa. *Kwartalnik Geologiczny 8(1)*, 102–109.

ŻELICHOWSKI, A.M. 1964b. Utwory karbonu w podłożu monokliny przedsudeckiej. *Przegląd Geologiczny 5*, 224–227.

ŻELICHOWSKI, A.M. 1984. Charakterystyka utworów karbońskich, 1–8. Przedpole Sudetów. *In* POŻARYSKI, W. & DEMBOWSKI, Z. (eds) Mapa geologiczna Polski i krajów ościennych bez utworów kenozoicznych, mezozoicznych i permskich. Część tekstowa.

ŻELICHOWSKI, A.M. 1995. Wielkopolska region, 148–151. *In* ZDANOWSKI, A. & ŻAKOWA, H. (eds) The Carboniferous system in Poland. *Prace Państwowego Instytutu Geologicznego 148*.

Appendix 1. List of species recovered and referred to in the text

Acanthotriletes baculatus Neves, 1961
Ahrensisporites duplicatus Neville, 1973
Ahrensisporites guerickei (Horst) Potonié & Kremp, 1954
Anaplanisporites baccatus (Hoffmeister, Staplin & Malloy) Smith & Butterworth, 1967
Anaplanisporites denticulatus Sullivan, 1964
Anaplanisporites globulus (Butterworth & Williams) Smith & Butterworth, 1967
Apiculatisporis variocorneus Sullivan, 1964
Apiculiretusispora fructicosa Higgs, 1975
Apiculiretusispora multiseta (Luber) Butterworth & Spinner, 1967
Apiculatisporis aculeatus (Ibrahim) Smith & Butterworth, 1967
Auroraspora asperella (Kedo) Van der Zwan, 1980
Auroraspora evanida (Kedo) Avchimovitch, 1988
Auroraspora macra Sullivan, 1968
Auroraspora panda Turnau, 1978
Bascaudaspora canipa Owens, 1983
Bascaudaspora variabilis Owens, 1983
Bellispores nitidus (Artüz) Sullivan, 1964
Camptotriletes superbus Neves, 1961
Cingulizonates bialatus (Waltz) Smith & Butterworth, 1967
Cingulizonates cf. *capistratus* (Hoffmeister, Staplin & Malloy) Staplin & Jansonius, 1964
Cirratriradites rarus (Ibrahim) Schopf, Wilson & Bentall, 1944
Converrucosisporites armatus (Dybova & Jachowicz) Smith & Butterworth, 1967
Convolutispora jugosa Smith & Butterworth, 1967
Convolutispora tessellata Hoffmeister, Staplin & Malloy, 1955
Convolutispora vermiformis Hughes & Playford, 1961
Crassispora kosankei Bharadwaj, 1957
Crassispora maculosa (Knox) Sullivan, 1964
Crassispora trychera Neves & Ioannides, 1974
Cribrosporites cribellatus Sullivan, 1964
Cyclogranisporites aureus (Loose) Potonié & Kremp, 1955
Cyclogranisporites palaeophytus Neves & Ioannides, 1974
Densosporites regalis (Bharadwaj & Venkatachala) Smith & Butterworth, 1967
Densosporites simplex Staplin, 1960
Densosporites variomarginatus Playford, 1963
Dictyotriletes equigranulatus Neville, 1968
Dictyotriletes flavus Keegan, 1977
Dictyotriletes pactilis Sullivan & Marshall, 1966
Dictyotriletes vitilis Sullivan & Marshall, 1966
Diducites mucronatus (Kedo) Van Veen, 1981
Discernisporites irregularis Neves, 1958
Discernisporites micromanifestus (Hacquebard) Sabry & Neves, 1971
Emphanisporites sp.
Florinites mediapudens (Loose) Potonié & Kremp, 1956
Florinites pumicosus (Ibrahim) Schopf, Wilson & Bentall, 1944
Gorgonispora crassa (Wilsow) Higgs, Clayton & Keegan, 1988
Grandispora acuta (Kedo) Byvscheva, 1980
Grandispora cf. *distincta* (Naumova) Avchimovitch, 1993
Grandispora cornuta Higgs, 1975
Grandispora echinata Hacquebard, 1957
Grandispora famenensis (Naumova) Streel, 1974 var. *minuta* Nekriata, 1974
Grandispora lupata Turnau, 1975
Knoxisporites seniradiatus Neves, 1961
Knoxisporites triradiatus Hoffmeister, Staplin & Malloy, 1955
Kraeuselisporites echinatus Owens, Mishell & Marshall, 1976
Kraeuselisporites hibernicus Higgs, 1975
Kraeuselisporites mitratus Higgs, 1975
Kraeuselisporites ornatus (Neves) Owens, Mishell & Marshall, 1976
Laevigatosporites perminutus Alpern, 1958
Laevigatosporites vulgaris (Ibrahim) Potonié & Kremp, 1956
Leiotriletes tumidus Butterworth & Williams, 1958
Lophozonotriletes concentricus (Byvscheva) Higgs, Clayton & Keegan, 1988
Lophozonotriletes dentatus Hughes & Playford, 1961
Lophozonotriletes tuberosus Sullivan, 1964
Lycospora subtriquetra (Luber) Potonié & Kremp, 1956
Microreticulatisporites microreticulatus Knox, 1950
Microreticulatisporites nobilis (Wicher) Knox, 1950
Microreticulatisporites punctatus Knox, 1950
Microreticulatisporites sulcatus (Wilson & Kosanke) Smith & Butterworth, 1967
Microreticulatisporites concavus Butterworth & Williams, 1958
Murospora aurita (Waltz) Playford, 1962
Murospora margodentata Beju, 1970
Neoraistrickia inconstans Neves, 1961
Perotrilites tessellatus (Staplin) Neville, 1973
Potoniespores delicatus Playford, 1963
Procoronaspora serrata (Playford) Smith & Butterworth, 1967
Prolycospora claytonii Turnau, 1978
Punctatosporites granifer (Potonié & Kremp) Alpern & Doubinger, 1973
Punctatosporites sp.
Pustulatisporites dolbii Higgs, Clayton & Keegan, 1988
Radiizonates mirabilis Phillips & Clayton, 1980
Radiizonates tenuis (Loose) Butterworth & Smith, 1964
Raistrickia nigra Love, 1960
Remysporites magnificus (Horst) Butterworth & Williams, 1958
Retialetes radforthii Staplin, 1960
Reticulatisporites carnosus (Knox) Neves, 1964
Retusotriletes communis Naumova, 1953
Retusotriletes famenensis Naumova, 1953
Retusotriletes incohatus Sullivan, 1964
Rotaspora ergonuli (Agrali) Sullivan & Marshall, 1966
Rotaspora fracta (Schemel) Smith & Butterworth, 1967
Rotaspora knoxi Butterworth & Williams, 1958
Rotaspora sp.
Rugospora corporata Neves & Owens, 1966
Rugospora minuta Neves & Ioannides, 1974
Rugospora polyptycha Neves & Ioannides, 1974
Savitrisporites nux (Butterworth & Williams) Smith & Butterworth, 1967
Savitrisporites sp.
Schulzospora rara Kosanke, 1950
Schulzospora sp.
Secarisporites remotus Neves, 1961
Spelaeotriletes arenaceus Neves & Owens, 1966

Spelaeotriletes microspinosus Neves & Ioannides, 1974
Spinozonotriletes uncatus Hacquebard, 1957
Stenozonotriletes bracteolus (Butterworth & Williams) Smith & Butterworth, 1967
Stenozonotriletes cf. *coronatus* Sullivan & Marshall, 1966
Stenozonotriletes coronatus Sullivan & Marshall, 1966
Stenozonotriletes lycosporoides (Butterworth & Williams) Smith & Butterworth, 1967
Stenozonotriletes triangulus Neves, 1961
Tetraporina sp.
Thymospora pseudothiessenii (Kosanke) Wilson & Venkatachala, 1963
Torispora securis (Balme) Alpern & Doubinger, 1973
Tricidarisporites balteolus Sullivan & Marshall, 1966
Tripartites trilinguis (Horst) Smith & Butterworth, 1967
Tripartites distinctus Williams, 1973
Tripartites vetustus Schemel, 1950
Triquitrites marginatus Hoffmeister, Staplin & Malloy, 1955
Triquitrites comptus Williams, 1973
Triquitrites piramidalis (Kedo & Jushko) Stempień & Turnau, 1988
Triquitrites sculptilis (Balme) Smith & Butterworth, 1967
Tumulispora malevkensis (Kedo) Turnau, 1975
Tumulispora rarituberculata (Luber) Potonié, 1966
Vallatisporites ciliaris (Luber) Sullivan, 1964
Vallatisporites verrucosus Hacquebard, 1957
Velamisporites caperatus (Higgs) Higgs, Clayton & Keegan, 1988
Verrucosisporites nodosus Sullivan & Marshall, 1966
Verrucosisporites baccatus Staplin, 1960
Verrucosisporites cerosus (Hoffmeister, Staplin & Malloy) Butterworth & Williams, 1958
Verrucosisporites donarii Potonié & Kremp, 1955
Verrucosisporites morulatus (Knox) Smith & Butterworth, 1967
Vestispora sp.
Waltzispora planiangulata Sullivan, 1964
Waltzispora polita (Hoffmeister, Staplin & Malloy) Smith & Butterworth, 1967
Westphalensisporites irregularis Alpern, 1958