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LOWER CARBONIFEROUS (MISSISSIPPIAN) STRATIGRAPHY OF NORTHWESTERN POLAND: CONODONT, MIOSPORE AND OSTRACOD ZONES COMPARED

Hanna MATYJA[1], Elżbieta TURNAU[2] & Barbara ŻBIKOWSKA[1]

[1] *Polish Geological Institute, Rakowiecka 4, 00-975 Warszawa, Poland*
[2] *Institute of Geological Sciences, Polish Academy of Sciences, Kraków Research Center, Kraków, Senacka 1, 31-002 Kraków, Poland*

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Abstract: Detailed stratigraphy of the Tournaisian and Visėan in western Pomerania has been established on conodonts, miospores and ostracods recovered from 25 boreholes. Miospore associations from the Tournaisian and Visėan are assigned to nine biostratigraphic units (zones and subzones) erected earlier. Three successive benthic ostracod assemblages and two sub-assemblages are distinguished for the Tournaisian. The miospore zones/subzones and the ostracod assemblages/subassemblages are correlated with the Tournaisian *sandbergi*, Lower *crenulata*, *isosticha*-Upper *crenulata*, and *typicus* conodont zones. Stratigraphic gap has been demonstrated at the Devonian/Carboniferous boundary, using the results of both conodont and miospore studies. The Tournaisian/Visėan boundary has been established approximately on the first appearance of the miospore species *Lycospora pusilla* Somers.

Abstrakt: Przedstawiono szczegółową stratygrafię turneju i wizenu Pomorza Zachodniego w oparciu o konodonty, miospory i małżoraczki. Materiał do badań biostratygraficznych pochodził z 25 otworów wiertniczych. Zespoły miospor z badanych utworów zaliczono do dziewięciu wcześniej wyróżnionych jednostek biostratygraficznych (zon i podzon). Dla turneju wyróżniono trzy kolejne zespoły i dwa podzespoły małżoraczków bentonicznych. Zony/podzony miosporowe i zespoły/podzespoły małżoraczkowe skorelowano z turnejskimi zonami konodontowymi *sandbergi*, dolna *crenulata*, *isosticha*–górna *crenulata* i *typicus*. Obecność luki stratygraficznej na granicy dewon/karbon udokumentowano na podstawie konodontów i miospor. Granica turnej/wizen została ustalona jedynie w przybliżeniu, na podstawie pierwszego pojawienia się gatunku miosporowego *Lycospora pusilla* Somers.

Key words: Tournaisian, Visėan, biostratigraphy, conodonts, miospores, ostracods, western Pomerania.

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INTRODUCTION

Lower Carboniferous strata have been recorded in a number of wells drilled in the coastal part of western Pomerania and in the Koszalin–Chojnice area (Fig. 1). These strata were also encountered, but not pierced through, in several wells located southwest of the latter area (Żelichowski, 1983; Żelichowski & Łoszewska, 1987).

In the study area, the lowermost Tournaisian is developed as the Sąpolno Calcareous Shale Formation, the base of which is Famennian in age (Matyja, 1993). It is likely that sedimentation was continuous across the Devonian–Carboniferous boundary, although a distinct stratigraphic gap has been noted in some sections (Matyja & Stempień-Sałek, 1994). In a few sections, however, different units of the Tournaisian rest unconformably either on the lower Famennian (especially in the sections located in the Gozd area), or even on folded lower Palaeozoic rocks (e.g., the Brda 2 borehole). This is due to a local tectonic and erosional episode, which took place at the end of the Devonian and during the Tournaisian. The Tournaisian strata are, in most cases, discordantly overlain by Permian sediments but in several sections near Sarbinowo, Karsina and Gozd, it is the lower Visėan which underlies the Permian rocks. Younger strata have been penetrated only in the Sarbinowo 1 section where the middle and upper Visėan deposits rest unconformably on the Ordovician (Bednarczyk, 1974), and are discordantly overlain by the Westphalian.

So far, the uppermost Visėan and Namurian deposits have not been recorded in western Pomerania. The top of the Lower Carboniferous strata is probably of erosional character and the documented gap spans the topmost

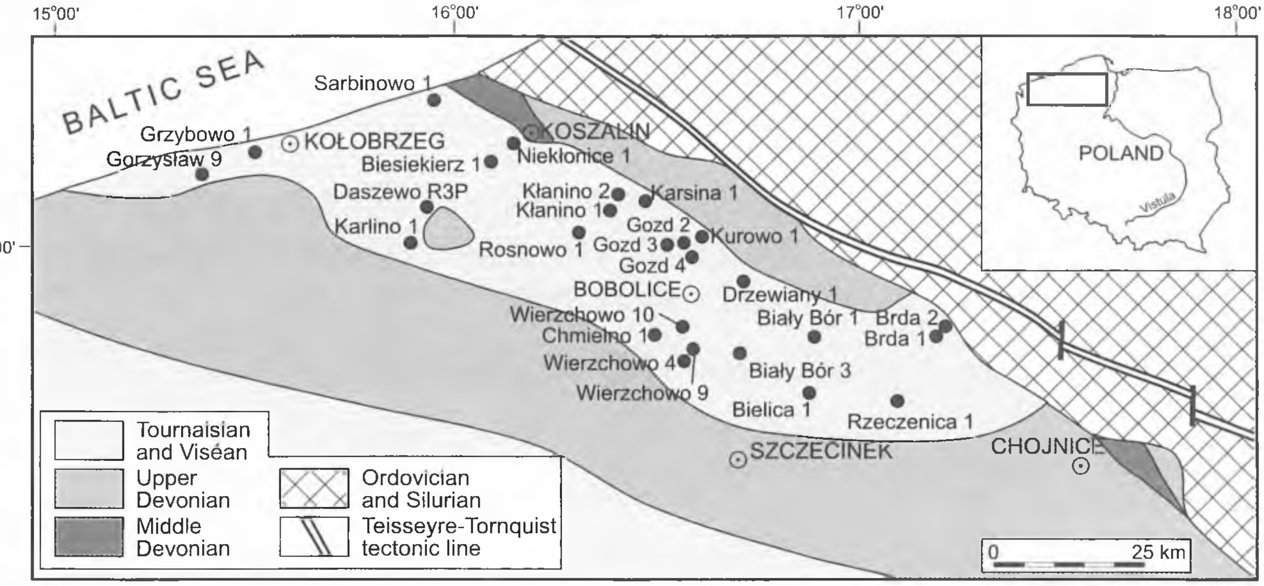

Fig. 1. Location of discussed boreholes against the geological map of pre-Permian deposits in western Pomerania. Geology after Matyja, 1993, Lipiec & Matyja, 1998, modified. Insert – position of study area

Viséan, Namurian and lower part of Westphalian.

Tournaisian and Viséan deposits in the Kołobrzeg–Chojnice area show a great lithological variability. Incomplete coring coupled with insufficient biostratigraphical data have been the main obstacles in reconstructing the pattern of development of the Devonian–Carboniferous succession. The first attempt to present the arrangement of the Carboniferous lithological bodies and their general depositional environments, was that by Dadlez (1978). Żelichowski (1983, 1995; in Żelichowski & Łoszewska, 1987) revised Dadlez's lithostraphical division and subdivided Lower Carboniferous strata into several informal units called complexes. For prospecting purposes more detailed division into units called "series" has been introduced by Lech (1986). Recently, Lipiec (in Lipiec & Matyja, 1998) modified the division of Żelichowski.

Early biostratigraphic investigations of the Carboniferous deposits in the studied area centered on macro- and microfauna (Błaszyk & Natusiewicz, 1973; Korejwo, 1976, 1979; Matyja, 1976), and spores (Krawczyńska-Grocholska, 1975; Turnau, 1975, 1978, 1979; Górecka & Parka, 1980). A generalized summary of the biostratigraphic division based both on published and unpublished data, was presented by Żelichowski & Łoszewska (1987). Some opinions on age assignements expressed in the earliest papers, were later revised (Matyja & Turnau, 1989; Clayton & Turnau, 1990; Avkhimovitch *et al.*, 1993; Matyja, 1993; Matyja & Stempień-Sałek, 1994), and the miospore zonal scheme proposed by Turnau (1978, 1979) was partly redefined by Avkhimovitch & Turnau (1994) and upgraded by Stempień-Sałek (in Matyja & Stempień-Sałek, 1994).

The details of the conodont and ostracod stratigraphy discussed in this paper are new. On the other hand, the miospore part involves only the sample material interpreted earlier by Turnau (1975, 1978, 1979), and Avkhimovitch & Turnau (1994). Recently, all previously completed palynological logs as well as some old palynological slides have been reexamined. The here presented interpretation uses the upgraded miospore zonal scheme (see Subsection *Zonal schemes*) and the results of recent miospore studies in Poland and elsewhere.

Because our faunal and palynological samples are derived from the same boreholes, we were able to calibrate the conodont, ostracod and miospore zonation schemes used. In this respect, we also discuss some macrofaunal data published by Korejwo (1993). Our integrated biostratigraphic database permitted to correlate the lithostratigraphic units and to date their boundaries.

The studies have been carried out in the Institute of Geological Sciences of the Polish Academy of Sciences, and in the Department of Regional and Petroleum Geology of the Polish Geological Institute.

LITHOSTRATIGRAPHY

The lithostratigraphic division used in the present paper is that by Lipiec (in Lipiec and Matyja, 1998). Inferred spatial relationships between the lithostratigraphic units are shown in Fig. 2. These relationships reflect a general regressive tendency from an open shelf during the Famennian–middle Tournaisian (Sąpolno Calcareous Shale Formation), through very shallow marine in the late Tournaisian (Kurowo Oolite Formation and Grzybowo Shale Member) to terrestrial environment during the latest Tournaisian (Drzewiany Sandstone Formation). The Gozd Arkose Formation reflects the Tournaisian volcanic activity episodes.

Sąpolno Calcareous Shale Formation

The uppermost Devonian–lowermost Carboniferous Sąpolno Calcareous Shale Formation overlies the Devonian Krojanty and Kłanino formations throughout the investigated area (see fig. 8 in Matyja, 1993). It is a succession of open marine carbonate and clayey deposits. The lower, Famennian part of the formation consists of two lithofacies: (1) fossiliferous marly limestones in the shallower part of the basin (northern part of the area), and (2) fossiliferous marls with thin intercalations of organodetrital limestones in the deeper part of the basin (southern part of the area) (see Matyja, 1993; Matyja & Stempień-Sałek, 1994).

The younger, Tournaisian part of the formation consists mainly of black, fine-laminated clayey deposits in which faunal remains are rare.

The thickness of the formation (excluding the Trzebiechowo marl Member) varies from more than 300 m in the Wierzchowo–Kurowo area to only about 30 m in the Karlino region in the northern part of the area.

Trzebiechowo Marl Member

This unit is an upper part of the Sąpolno Calcareous Shale Formation. It includes marls, limestones (including oolite limestones), dolostones, calcareous claystones, fine-grained quartz arenites and arkosic arenites. Fauna is represented mainly by brachiopods, echinoderms, bryozoans, lamellibranchs and gastropods. Ostracods and conodonts have also been encountered. In vicinity of Brda, the Trzebiechowo Marl Member is up to 600 m in thickness.

Gozd Arkose Formation

It contains arkosic sandstones (volcanoclastic, cf. Muszyński *et al.*, 1996), locally calcareous or dolomitic. Tuffites, claystones, marls and oolite limestones occur subordinately. The thickness of the formation may exceed 400 m.

Kurowo Oolite Formation

The formation includes oolite, and oolite-skeletal limestones and, subordinately, other types of limestones, often dolomitized. Marls and arkosic sandstones may be present locally. The oolite-skeletal limestones contain echinoderms, brachiopods, lamellibranchs, ostracods, corals, bryozoans and calcareous algae. The formation is up to 200 m thick.

Grzybowo Calcareous Shale Member

This member is distinguished within both the Gozd and the Kurowo formations. It contains black shales, calcareous claystones, marls, limestones, and nodules of anhydrite. Fauna is dominated by thin-shelled lamellibranchs, ostracods, gastropods and, locally, brachiopods. The maximum thickness is up to 300 m.

Drzewiany Sandstone Formation

In the northeastern part of western Pomerania, this is the uppermost unit of the Lower Carboniferous. It contains white and red, fine quartz sandstones, variegated mudstones and claystones, locally calcareous, with anhydrite and paleosol. Rare fauna is limited to few beds, and is represented by thin-shelled lamellibranchs, ostracods, brachiopods and crinoids. Goniatites were reported from the upper part of the formation in the Sarbinowo 1 section (Korejwo, 1993). The thickness of the Drzewiany Sandstone Formation may exceed 400 metres.

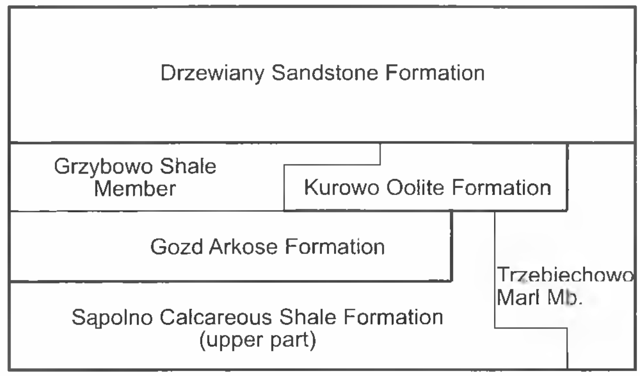

Fig. 2. Generalized lithostratigraphic chart of Lower Carboniferous deposits of Kołobrzeg–Chojnice area of western Pomerania (after Lipiec in Lipiec & Matyja, 1998, modified)

BIOSTRATIGRAPHY

In the study area, the main biostratigraphic tool for dating and correlating of the shale-rich, open marine lithofacies comprising lower and middle parts of the Tournaisian are conodonts supported by miospores and ostracods. The upper Tournaisian deposits represent generally very shallow-marine environments, where miospores and ostracods prevail, whereas conodonts are remarkably scarce. The uppermost Tournaisian and Viséan are dominated by terrestrial, mainly siliciclastic deposits, where miospores are the main stratigraphic tool.

Zonal schemes

In this section, we have omitted the names of the species creators. The list of complete specific names is given in the Appendix 1.

Conodonts

The preliminary "standard" Lower Carboniferous *Siphonodella*-based zonation of Sandberg *et al.* (1978) is based on the first occurrence of *Siphonodella* species that in most cases are the index species of the zones. The base of the Carboniferous in offshore marine sequences is defined at the base of the *sulcata* Zone. The upper limit of the *isosticha*–Upper *crenulata* Zone is defined by the last occurrence of the genus *Siphonodella*. Fortuitously, this extinction occurred almost simultaneously with the appearance of the new gnathodid species *Gnathodus typicus*, from *Gn. delicatus*. Lane *et al.* (1980) proposed a preliminary "standard" conodont zonation for the upper Tournaisian–lower Viséan interval to follow the "standard" *Siphonodella* zonation. As in the case of the *Palmatolepis*-based standard Upper Devonian conodont zonation, both these "standard" Lower Carboniferous schemes are applicable mainly to open marine, offshore settings. On the other hand, extensive shallow-water environments characterise most of the shelf areas in Belgium and in the British Isles where both "standard" zonations are difficult to apply. Therefore, several local schemes have been proposed in these areas (Groessens, 1974; Conil *et al.*, 1990; Varker & Sevastopulo, 1985; Webster & Groessens, 1990).

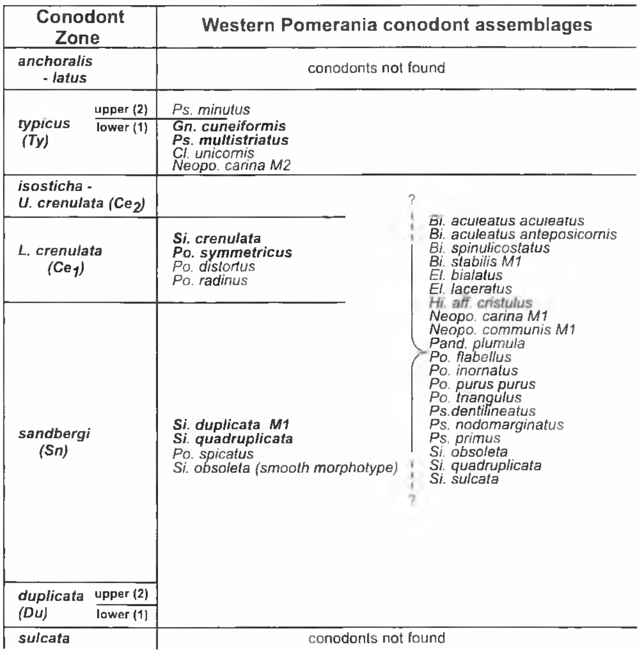

Fig. 3. Characteristic species of Tournaisian conodont zones in Western Pomerania. Important species in bold characters

Depositional environment within the Pomeranian sedimentary basin underwent evolution from an open shelf during the early and middle Tournaisian to a very shallow-water marine, and, subsequently, a terrestrial environment in the late Tournaisian. Therefore, the *Siphonodella*-based zonation of Sandberg *et al.* (1978) and part of the post-*Siphonodella* zonation of Lane *et al.* (1980) are applicable in western Pomerania up to the Tournaisian *typicus* conodont Zone (see Fig. 3). Conodonts younger than the *typicus* Zone have not been found so far as the uppermost Tournaisian and Visean represent mainly terrestrial deposits with only some marine influences.

The oldest documented Tournaisian conodont fauna in the Pomerania area is that of the *sandbergi* Zone. The presence of advanced siphonodellids such as *Siphonodella quadruplicata,* and its co-occurrence with *Siphonodella duplicata* morphotype 1 (Fig. 4/9) suggest that the lowermost part of the Tournaisian succession in the Rzeczenica 1 section is to be correlated with the upper part of the *sandbergi* Zone (Sandberg *et al.*, 1978; Clausen *et al.*, 1989). Accompanying forms include representatives of *Polygnathus spicatus* (Fig. 4/6) and *Siphonodella obsoleta* (smooth morphotype – Fig. 4/12). Other conodont faunas consisting almost entirely of long-ranging taxa (comp. Fig. 3) such as *Bispa- thodus spinulicostatus, Neopolygnathus communis* morphotype 1, *Polygnathus purus purus, Pandorinellina plumula, Elictognathus bialatus* (Fig. 4/13–14) and *Elictognathus laceratus* (Fig. 4/15), *Bispathodus stabilis* morphotype 1, and *Polygnathus inornatus.*

The succeeding Lower *crenulata* Zone has been recognized also in the Rzeczenica 1 section (Appendix 2) by the presence of *Siphonodella crenulata* and its co-occurrence with *Polygnathus symmetricus* (Sandberg *et al.*, 1978; Bełka, 1985), accompanied (see Fig. 3) by *Polygnathus radinus* (Fig. 5/1) and *Polygnathus distortus* (Fig. 5/6). Unfortunately, other accompanying fauna consists of long-ranging taxa including *Polygnathus triangulus* (Fig. 5/4) and *Polygnathus inornatus* (Fig. 5/2), representatives of *Siphonodella obsoleta* (Fig. 5/12) and *Siphonodella quadruplicata* (Fig. 5/3, 13), *Neopolygnathus communis* morphotype 1, *Pseudopolygnathus nodomarginatus* (Fig. 5/7–8), *Bispathodus spinulicostatus*, *Elictognathus bialatus* and *Elictognathus laceratus* (Fig. 5/11) and rare *Hindeodus* aff. *cristulus* (Fig. 5/10).

It should be mentioned that due to the extremely rare occurrence of *Siphonodella crenulata* and the lack of other diagnostic species in most of the investigated sections, it is not possible to separate the *sandbergi* Zone from the Lower *crenulata* Zone (comp. Fig. 3 and Appendix 2). The same problem arises with separation of the Lower *crenulata* Zone from the *isosticha*–Upper *crenulata* Zone because of the absence of *Gnathodus delicatus*. The unseparated interval between the *sandbergi* and the Lower *crenulata* zones is characterized by the presence of various polygnathids, pseudopolygnathids and bispathodids, *i.e. Pseudopolygnathus primus* (Fig. 4/1), *Polygnathus inornatus* (Fig. 4/3), *Polygnathus flabellus* (Fig. 4/7), *Neopolygnathus carina* morphotype 1 (Fig. 4/4), *Neopolygnathus communis* morphotype 1 (Fig. 4/5), *Bispathodus aculeatus anteposicornis* (Fig. 4/8) and *Siphonodella quadruplicata* (Fig. 4/11).

The presence of *Pseudopolygnathus multistriatus* morphotype 2 (Fig. 6/8) and *Gnathodus cuneiformis* (Fig. 6/11–12) well characterize the Lower *typicus* Zone (Lane *et al.*, 1980) and the equivalent zones (Bełka, 1985; Varker & Sevastopulo, 1985; Bełka & Groessens, 1986; Sevastopulo & Nudds, 1987; Carman, 1987; Riley, 1993). Other accom-

Fig. 4. Conodonts of the *sandbergi* (Sn) Zone (6, 9, 12-13, 15), unseparated *sandbergi* - Lower *crenulata* (Sn-Ce1) Zones (1, 3-5, 7-8, 10-11, 14), and unseparated *sandbergi* - *isosticha*–Upper *crenulata* (Sn-Ce2) Zones (2). All specimens are from Rzeczenica 1, except when indicated otherwise. All photographs are SEM upper views except 1, 9a (lower views) and 15 (side view). **1** – *Pseudopolygnathus primus* Branson & Mehl, 2907–2909 m, SEM-823, ×80; **2** – *Pseudopolygnathus dentilineatus* Branson, Biały Bór 1, 2680–2686 m, SEM-652, ×60; **3** – *Polygnathus inornatus* Branson, 2912–2916 m, SEM-817, ×80; 4 – *Neopolygnathus carina* (Hass), morphotype 1, 2912–2916 m, SEM-814, ×80; **5** – *Neopolygnathus communis* (Branson & Mehl), morphotype 1, 2909–2910 m, SEM-816, ×80; **6** – *Polygnathus spicatus* Branson, 2916–2920 m, SEM-668, ×50; **7** – *Polygnathus flabellus* (Branson & Mehl), 2907–2909 m, SEM-660, ×75; **8** – *Bispathodus aculeatus anteposicornis* (Scott, 1961), 2909–2910 m, SEM-666, ×120; **9–9a** – *Siphonodella duplicata* (Branson & Mehl), morphotype 1, 2916–2920 m, 9: SEM-818, ×50, 9a: SEM-822, ×45; **10** – *Siphonodella cooperi* Hass, morphotype 2, 2909–2910 m, SEM-661, ×60; **11** – *Siphonodella quadruplicata* (Branson & Mehl), 2912–2916 m, SEM-815, ×30; **12** – *Siphonodella obsoleta* Hass, smooth morphotype, 2920–2922 m, SEM-673, ×75; **13–14** – *Elictognathus bialatus* (Branson & Mehl), 13: 2920–2922 m, SEM-670, ×150, 14: 2909–2910 m, SEM-664, ×150; **15** – *Elictognathus laceratus* (Branson & Mehl), 2920–2922 m, SEM-669, ×100

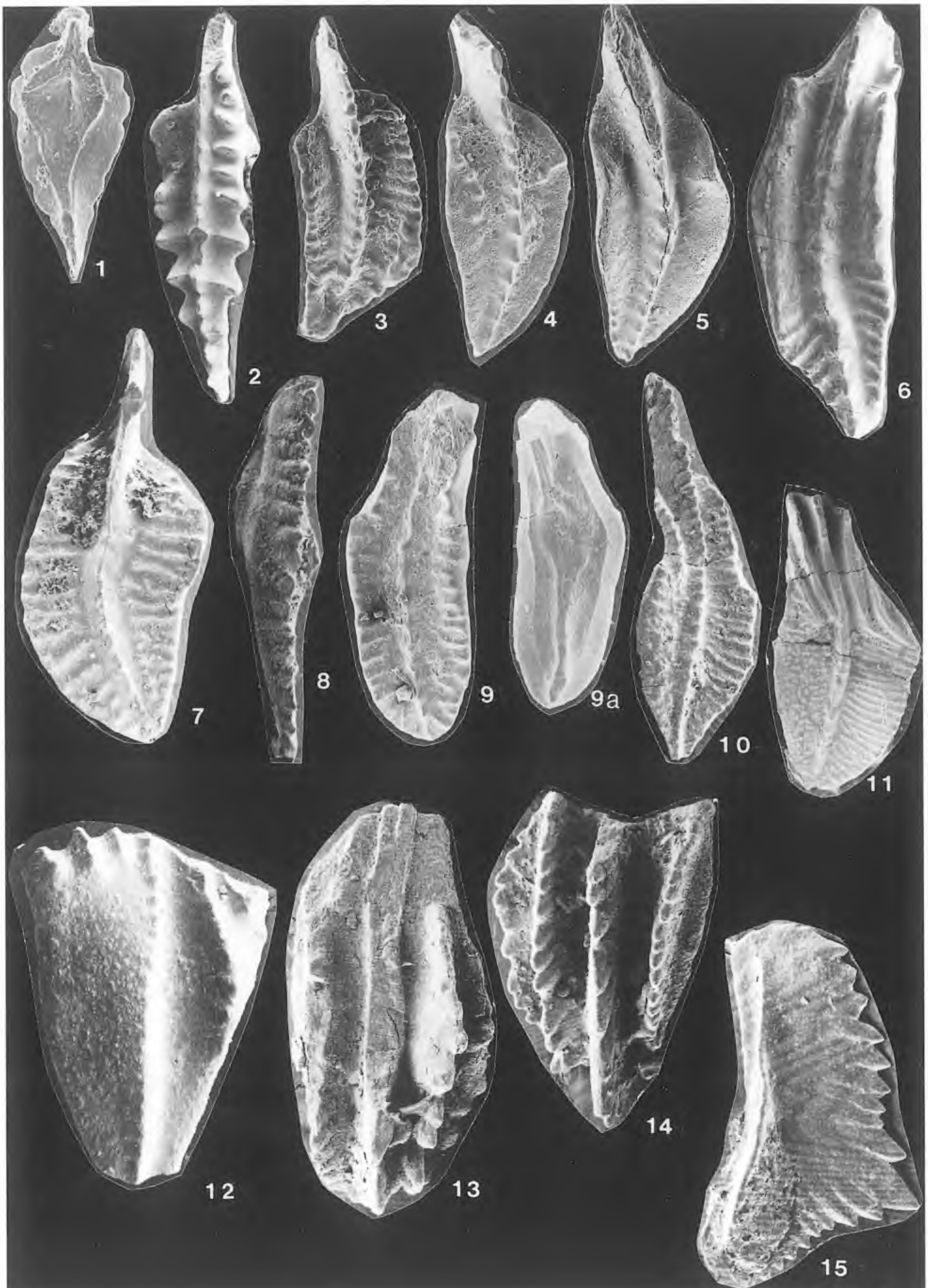
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Fig. 5. Conodonts of the Lower *crenulata* (Ce_1) Zone (1-4, 6-8, 10-12), unseparated Upper *duplicata* - *isosticha*–Upper *crenulata* (Du_2-Ce_2) Zones (5), and unseparated *sandbergi?* - Lower *crenulata?* (Sn?-Ce_1?) Zones (9). All specimens are from Rzeczenica 1, 2896–2899 m, except when indicated otherwise. All photographs are SEM upper views except 4, 5, 8 (lower views) and 9-11 (side views). **1** – *Polygnathus radinus* (Cooper), SEM-827, ×70; **2** – *Polygnathus inornatus* Branson, Rzeczenica 1, 2899–2901 m, SEM-657, ×70; **3, 13** – *Siphonodella quadruplicata* (Branson & Mehl): 3: SEM-829, ×30, 13: SEM-654, ×60; **4–5** – *Polygnathus triangulus* Voges; 4: SEM-824, ×60, 5: Bielica-1, 3516–3517 m, SEM-651, ×120; **6** – *Polygnathus distortus* Branson & Mehl, SEM-658, ×50; **7–8** – *Pseudopolygnathus nodomarginatus* (Branson), 7: SEM-659, ×100, 8: SEM-821, ×60; **9–10** – *Hindeodus* aff. *cristulus* (Youngquist & Miller), 9: Brda-1, 2469–2475 m, SEM-813, ×70, 10: SEM-656, ×80; **11** – *Elictognathus laceratus* (Branson & Mehl), SEM-655, ×80; **12** – *Siphonodella obsoleta* Hass, SEM-653, ×45

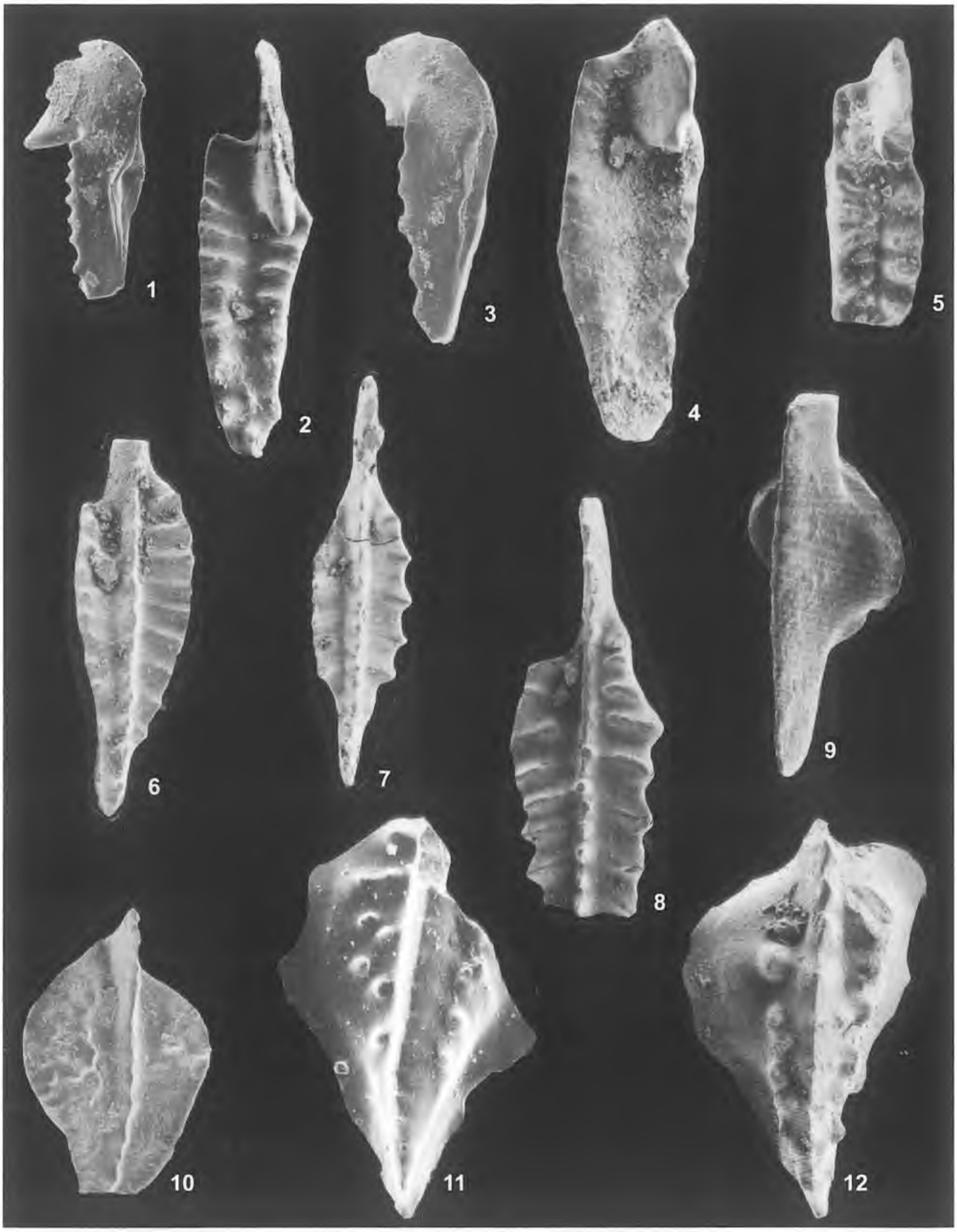
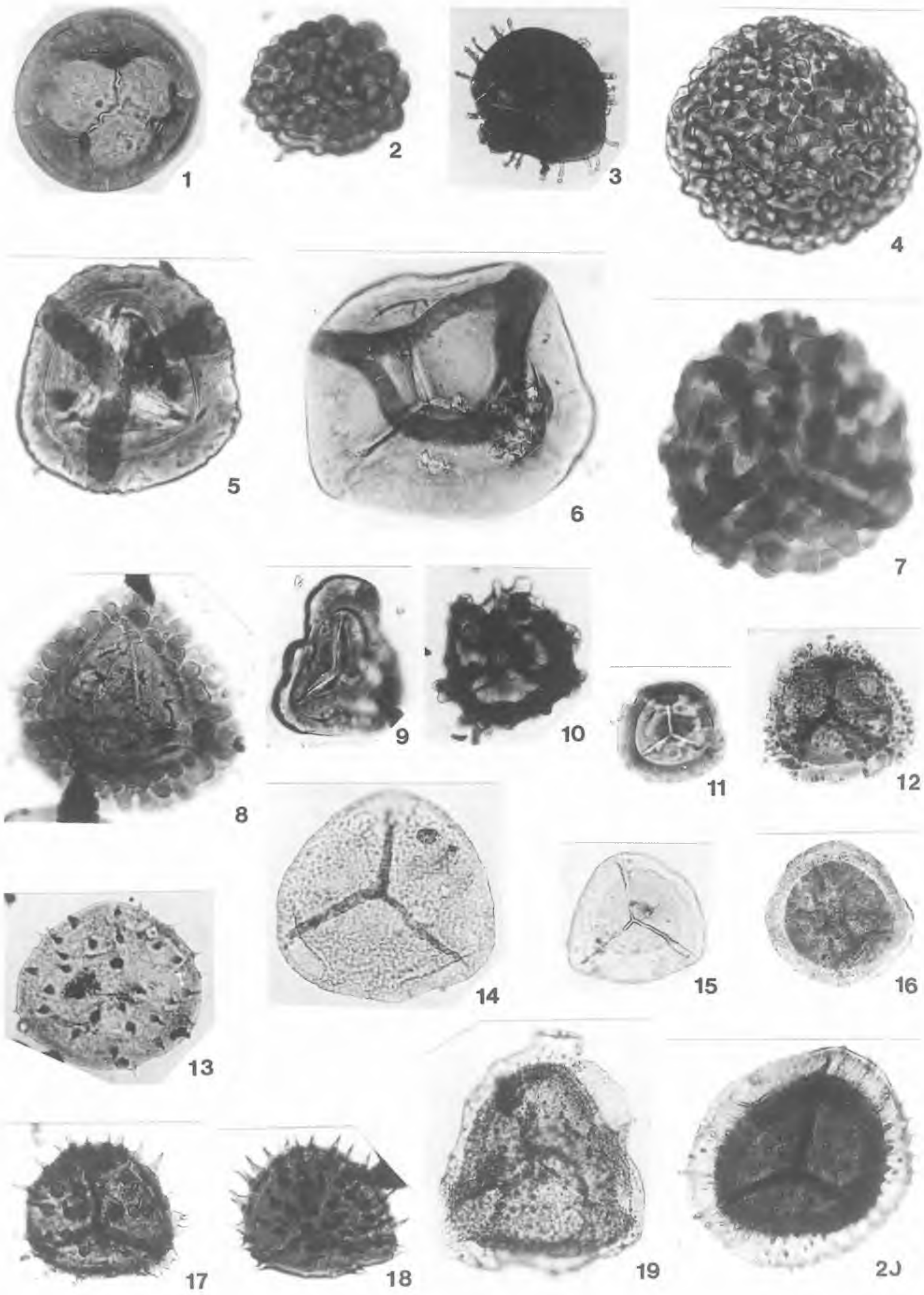


Fig. 6. Conodonts of the Lower *typicus* (Ty l) Zone. Specimens 1-4, 6, 7 are from Drzewiany 1, 2733–2736 m, other specimens as indicated below. All photographs are SEM upper views except 1 and 3 (side views). **1–5** – *Clydagnathus unicornis* Rhodes, Austin & Druce, 1: SEM-819, ×60, 2: SEM-644, ×100, 3: SEM-820, ×80, 4: SEM-643, ×140, 5: Brda 1, 2192–2198 m, SEM-111, ×95; **6–8** – *Pseudopolygnathus multistriatus* Mehl & Thomas, 6-7: morphotype 1, 6: SEM-641, ×100, 7: SEM-642, ×150, 8: morphotype 2, Drzewiany 1, 3003–3004 m, SEM-645, ×70; **9** – "*Hindeodus*" *crassidentatus* (Branson & Mehl), Chmielno 1, 3588–3599 m, SEM-648, ×50; **10** – *Neopolygnathus carina* (Hass), morphotype 2, Brda 1, 2325–2326 m, SEM-811, ×80; **11–12** – *Gnathodus cuneiformis* Mehl & Thomas, early phylogenetic forms, Chmielno-1, 3588–3599 m, 11: SEM-834, ×150; 12: SEM-647, ×150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Miospore Zone / Subzone		Species defining base of Zone/Subzone (*) other first appearances (** in the upper part of the Zone)	Characteristic assemblage
Dictyotriletes pactilis (Pa)		*D. plumosus* (*)	*Lophotriletes tribulosus* *L. pusilla* *Schulzospora* spp *Cingulizonates bialatus*
Schulzospora campyloptera (Ca)		*S. campyloptera* (*)	*Lycospora pusilla* *Knoxisporites* spp
Lycospora pusilia (Pu)		*L. pusilla* (*) *W. planiangulata* (**)	*P. claytonii* *A. baccatus* *C. multisetus* *A. trychera* *W. planiangulata*
Prolycospora claytonii (Cl)	upper (2)	*A. solisorta* *A. panda* *G. multiplicabilis* *S. claviger* (*)	*P. claytonii* *A. baccatus* *C.multisetus* *U. distinctus*
	lower (1)	*R.clavata* *C. multisetus* *A. baccatus* *P. claytonii* (*)	*R. corynoges* *V. nitidus* *P. uncatus* *D. glumaceus*
Convolutispora major (Ma)	upper (4)	*S. pretiosus* (*)	*R. corynoges* *V. nitidus* *A. macra* *Tumulispora spp* *Retusotriletes* spp *Knoxisporites* spp *Dictyotriletes* spp
	middle (3)	*S. balteatus* (*)	
	lower (2)	*C. trychera* *S. delicatus* *P. uncatus* *U. distinctus* (*)	
	lowermost (1)	*R. corynoges* *L. excisus* *K. hibernicus* (?)	

Fig. 8. Miospore zones and subzones for Lower Carboniferous in western Pomerania and their characteristic species

Series	British Isles: Stages	British Isles: miospore zonation	First appearances of index species	Western Pomerania miospore zonation
		NC Bellispores nitidus-Reticulatisporites carnosus		
VISEAN	BRIGANTIAN	VF Tripartites vetustus - Rotaspora fracta		
VISEAN	ASBIAN	NM Raistrickia nigra - Triquitrites marginatus	***R. fracta***	Pa Dictyotriletes pactilis
VISEAN	ASBIAN	TC Perotrilites tessellatus - Schulzospora campyloptera		Ca Schulzospora campyloptera
VISEAN	HOLKERIAN, ARUNDIAN	TS Knoxisporites triradiatus - Knoxisporites stephanephorus	***S. campyloptera***	Pu Lycospora pusilla
VISEAN	CHADIAN	Pu Lycospora pusilla	***W. planiangulata***	Pu Lycospora pusilla
TOURNAISIAN	CHADIAN, COURCEYAN	CM Schopfites claviger - Auroraspora macra	***L. pusilla*** ***S. claviger***	Cl Prolycospora claytonii 1, 2
TOURNAISIAN	COURCEYAN	PC Spelaeotriletes pretiosus - Raistrickia clavata		Ma Convolutispora major 4
TOURNAISIAN	COURCEYAN	BP Spelaeotriletes balteatus - Rugospora polyptycha	***S. pretiosus***	Ma Convolutispora major 3
TOURNAISIAN	COURCEYAN	HD Kraeuselisporites hibernicus - Umbonatisporites distinctus	***S. balteatus*** ***U. distinctus***	Ma Convolutispora major 2, 1
TOURNAISIAN	COURCEYAN	VI Vallatisporites verrucosus - Retusotriletes incohatus	***K. hibernicus ?***	

Fig. 9. Correlation of the zonal schemes for Lower Carboniferous of British Isles and westen Pomerania. Arrows indicate uncertain position of lower boundary of Ma Zone

panying forms (Fig. 3, Appendix 2) include many representatives of *Clydagnathus unicornis* (Fig. 6/1–5), *Pseudopolygnathus multistriatus* morphotype 1 (Fig. 6/6–7), rare *Neopolygnathus carina* morphotype 2 (Fig. 6/10), and *Hindeodus crassidentatus* (Fig. 6/9).

Miospores

Turnau (1978, 1979) erected a local miospore zonal scheme in this region encompassing uppermost Devonian to lower Westphalian strata. The Carboniferous part of the scheme comprises six zones and three subzones, two zones for the Tournaisian, three for the Viséan, and one for the Westphalian. The first two zones have been formally defined, and the succeeding ones are informal. The miospore species characteristic of the zones are shown in Figs 7, 10–11. In the following text, and in some figures, the names of the miospore zones are abbreviated to a two-letter notation. However, their full taxonomic titles are given in Figs 8–9.

The Tournaisian part of the zonation scheme was subsequently modified. Stempień-Sałek (in Matyja & Stempień-Sałek, 1994) erected four subzones of the *Convolutispora major* (Ma) Zone. They are designated here the lowermost (Ma_1), lower (Ma_2), middle (Ma_3) and upper (Ma_4). The characteristic of the revised and upgraded part of the zonal scheme is shown in Fig. 8.

The *Prolycospora claytonii* (Cl) Zone was initially divided into three subzones. The base of the upper subzone was based on the first appearance of *Rugospora minuta*. However, subsequently, it was established that in western Pomerania, the range of this species was much wider. Thus, Avchimovitch & Turnau (1994) revised the zonal scheme as to recognize only two subzones designated Lower Cl (Cl_1) Subzone and Upper Cl (Cl_2) Subzone. The new Upper Cl Subzone contains the original middle and upper Cl subzones up to the redefined lower boundary of the *Lycospora pusilla* (Pu) Zone.

It must be emphasized that the statement by Turnau (1978) concerning the first appearance level of *Lycospora pusilla* was erroneous. This species does not occur throughout the *P. claytonii* Zone, *i.e.* part of the Tournaisian (see discussion in Avkhimovitch & Turnau, 1994).

The local miospore zonation for western Pomerania can be correlated at several stratigraphic levels with the zonal scheme for the type regions of the Lower Carboniferous stages in the British Isles (Fig. 9). This scheme was erected by Neves *et al.* (1973) and later gradually refined on the basis of new studies (see Clayton, 1985; Higgs *et al.*, 1988a: Higgs *et al.*, 1992). The scheme is keyed to the British Isles Carboniferous stages (Higgs *et al.*, 1988b; Riley, 1993), and at some stratigraphic levels to the Irish and *Siphonodella* based conodont zonations which is discussed in more detail in the Subsection *Results*.

The correlation of the Pomeranian and western European schemes for the Tournaisian was discussed in Clayton & Turnau (1990) and Avkhimovitch & Turnau (1994). The present version differs in details from the previous ones due to the results of Stempień-Sałek (Matyja & Stempień-Sałek, 1994, Stempień-Sałek, 1997) who established, that *Spelaeotriletes balteatus* and *S. pretiosus* appeared earlier than *Prolycospora claytonii*.

The correlation shown in Fig. 9 is based on the first apperances of stratigraphically important species. A further comment is needed only for correlations at some levels.

The base of the Ma Zone cannot be confidently correlated with the base of the HD Zone of northwestern Europe. This is because the presence of *Kraeuselisporites hibernicus* in the lowermost assemblages of the zone (in the Rzeczenica 1 borehole, see Appendix 2) is not certain. Higgs *et al.* (1992) considered *Cymbosporites acutus* as an important species for defining the base of the HD Zone in Belgium. This species has been recorded from the Ma_1 assemblages; however, we consider it as an unreliable stratigraphic marker because in Ireland, it ranges downwards into the Famennian (Van der Zwan, 1980), and in the East European Platform, it appears in the *Tumulispora malevkensis* Zone (Byvsheva, 1985; Avkhimovitch, 1993) very near the Devonian/Carboniferous boundary.

The correlation of upper part of the (Pomerania) Pu Zone with a part of the TS Zone is based on the presence of *Waltzispora planiangulata* in higher assemblages of the Pu zone. In Rügen, this species first appears in the TS Zone (Carson & Clayton, 1997).

The base of the Pa zone was correlated by Turnau (1979) with the base of the NM Zone on the first appearance of *Dictyotriletes pactilis*. However, specimens assigned at that time to *D. pactilis* represent an older species *D. plumosus* (see the Section *Systematic comments (miospores)*. The Pa zone assemblages contain also *Potoniespores delicatus*. This species appears in the upper part of the TC Zone (Clayton *et al.*, 1977b). Thus, the base of the Pa zone is now considered not older than the upper part of the TC Zone.

Fig. 7. Miospores of the *Convolutispora major* (Ma) Zone. Specimens 1, 4-9, 15, 16 are from Biely Bór 1, 2792–2796 m, specimens 2, 10, 11, 13 are from Rzeczenica 1, 1920–1921 m, other specimens as indicated below. All magnifications ×500. **1** – *Retusotriletes circularis* Turnau, slide V/67; **2** – *Verrucosisporites nitidus* Playford, slide V/85; **3** – *Umbonatisporites distinctus* Clayton, Wierzchowo 10, 3545–3551 m, slide VII/19: **4** – *Convolutispora mellita* Hoffmeister, Staplin & Malloy, slide V/65; **5** – *Knoxisporites triradiatus* Hoffmeister, Staplin & Malloy, slide V/65; **6** – *Knoxisporites hederatus* (Ishchenko) Playford, slide V/67; **7** – *Convolutispora major* (Kedo) Turnau, slide V/64; **8** – *Tumulispora variverrucata* (Playford) Staplin & Jansonius, slide V/65; **9** – *Murospora sublobata* (Waltz) Playford, slide V/65; **10** – *Lophozonotriletes excisus* Naumova, slide V/85; **11** – *Tumulispora malevkensis* (Kedo) Turnau, slide V/86; **12** – *Endoculeospora gradzinskii* Turnau, Rzeczenica 1, depth 2912–2916 m, slide V/83; **13** – *Grandispora upensis* (Kedo) Byvsheva, slide V/83; **14–15** – *Discernisporites micromanifestus* (Haquebard) Sabry & Neves, slide V/66; **16** – *Auroraspora macra* Sullivan, slide V/65; **17–18** – *Cymbosporites acutus* (Kedo) Byvsheva, Niekłonice 2, depth 2877–2891 m, slide VII/36; **19** – *Kraeuselisporites hibernicus* Higgs, Wierzchowo 10, depth 3513–3517 m, slide VII/51; **20** – *Indotriradites explanatus* (Luber) Playford, Kłanino 1, depth 27812787 m, slide III/83

In the description of the assemblages of the Pa zone, Turnau (1979) stated that they lacked *Rotaspora*. However, further study of samples from Sarbinowo 1 borehole revealed the presence of a single specimen of *R. fracta* in the highest assemblage representing the Pa zone. Therefore, it is suggested that the base of the western European *Tripartites vetustus-Rotaspora fracta* (VF) Zone corresponds to a level within the Pa Zone.

Ostracods

In the following text, and in some figures, the names of the ostracod assemblages are abbreviated to a two-letter notation. However, their full taxonomic titles are given in Fig. 12.

Only the lowest Carboniferous deposits bear rare entomozoacean ostracods. Specimens occur as internal or external, typically poorly preserved moulds. Only the *latior* (La) entomozoid Zone has been distinguished based on the presence of single specimens of the index species *Richterina latior*. This zone corresponds to the lowest Tournaisian *sulcata* to *sandbergi* conodont zones (Gross-Uffenorde, 1984; Gross-Uffenorde & Schindler, 1990).

About 80 species of benthic ostracods have been found in the Tournaisian strata. Only some have been described (Błaszyk & Natusiewicz, 1973). The majority of ostracods belong to unknown and undescribed taxa, but the preliminary investigation of the fauna has shown that about one third of the species is known from other, sometimes distant areas.

A preliminary, informal Tournaisian local zonation that comprises 4 assemblages, based only on small part of the ostracod fauna, is proposed here by Żbikowska. This is the first attempt to show the stratigraphic value of the Tournaisian benthic ostracods from Pomerania. Establishing of a formal zonation would be possible only after a detailed analysis of the fauna, which is beyond the scope of this paper.

The characteristics of the assemblages are given in Fig. 12. Lowermost is the *Pseudoleperditia venulosa* (Vn) assemblage which is divisible into the lower (Vn_1) and the upper (Vn_2) ones.

The Vn_1 assemblage is characterized by the co-occurrence of *Pseudoleperditia venulosa* and the short ranging species *Namaya reticulata*. The accompanying known species are listed in Fig. 12 and Appendix 2, and illustrated in Fig. 13. They are characteristic of the lower Tournaisian deposits of Belgium, North America and Russian Platform (Green, 1963; Becker & Bless, 1974; Becker *et al.*, 1974; Tchigova, 1977; Bless *et al.*, 1986; Coen *et al.*, 1988).

The Vn_2 assemblage (Fig. 14) is characterized by the co-occurrence of *Pseudoleperditia venulosa* and the short ranging species *Chamishaella obscura*. It does not contain stratigraphically important species, and its age can be only approximately established on its relation to miospore samples, which is discussed below.

The succeeding assemblage *Cribroconcha postfoveata – Marginia tchigovae* (P–T) (Fig. 15) contains species known from the upper Tournaisian deposits of Germany and the Russian platform (Blumenstengel, 1975a; Gründel, 1975; Tschigova, 1977).

The youngest recognized assemblage, *Glyptopleura ruegensis–Carbonita fabulina* (R–F) (Fig. 16) contains species known from the uppermost Tournaisian and Viséan of Germany and Great Britain (Blumenstengel, 1975a, b; Robinson, 1978).

Results

Comparison of conodont, miospore, and benthic ostracod stratigraphic schemes

Conodonts and, to a lesser extent, entomozoids from the Tournaisian succession of the Koszalin–Wierzchowo area provide new biostratigraphic information and control on the age of the miospore zones and benthic ostracod assemblages (Fig. 17). In the following discussion, we will also use information on occurrence of ammonoids, which was provided by Korejwo (1979, 1993). There is little faunal control on the age of informal, local miospore zones for the Viséan.

Correlation of various biostratigraphic schemes has been the concern of Carboniferous biostratigraphers for a long time. In western Europe, miospore assemblages from the Tournaisian conodont dated sequences were studied in Ireland (Clayton *et al.*, 1977a, 1978, 1980; Sleeman *et al.*, 1978; Marchant *et al.*, 1984; Higgs *et al.*, 1988a, b), and Belgium (Higgs & Streel, 1984; Higgs *et al.*, 1992). The palynological boundaries within the Irish Dinantian are also dated by other microfauna (Higgs *et al.*, 1988b). Owing to these contributions, the miospore zonation scheme for the Tournaisian proposed by Higgs *et al.* (1988a) has been correlated with the Irish conodont zonation scheme and the siphonodellid based scheme, which is shown in Fig 17. This chart shows also the correlation of the British Isles and western Pomerania miospore zonation schemes for the Tournaisian, based on palynological criteria (see also Fig. 9). The validity of this correlation is controlled at a few stratigraphic levels by conodonts and entomozoids. Conodonts and miospores provide also control on the age of benthic ostracod assemblages. These data are discussed below, and the details of the occurrences are presented in Figs 18, 19, and in the Appendix 2.

In the Rzeczenica 1 section (Fig. 18), the Ma_1 assemblages occur just below conodont fauna indicative of the *sandbergi* Zone, and are bracketed by such fauna (see also Matyja & Stempień-Sałek, 1994). These assemblages were also found below the *latior* Zone entomozoids and *sandbergi - isosticha*–Upper *crenulata* Zone conodonts (Chmielno 1 borehole, Fig. 18) and in the same 6 m interval as goniatites *Pseudoarietites dorsoplanus dorsoplanus* H. Schmidt (Ga α) (Grzybowo 1, 3297–3303 m, and Wierzchowo 10, 3545–3552 m, Fig. 18). The results indicate that the base of the Ma Zone is located either within or slightly below the *sandbergi* Zone. Palynologically, the equation of the base of the Ma Zone with that of the western European HD Biozone (which is within the *sandbergi* Zone) is poorly substantiated because the assignment of specimens from the lowermost Ma_1 assemblage from the Rzeczenica 1 section to *Kraeuselisporites hibernicus* is uncertain.

The Ma_2 miospore assemblages occur with conodonts of the unseparated *sandbergi - isosticha*–Upper *crenulata* zones, and entomozoids of the *latior* Zone (Chmielno 1), and with the Lower *crenulata* conodont fauna (Rzeczenica 1). Thus, the base of the Ma_2 subzone is within the *sandbergi* Zone, and a higher part of the subzone corresponds to a part of the Lower *crenulata* Zone. This agrees well with the miospore and conodont data from Belgium (Higgs *et al.*, 1992) where *Umbonatisporites distinctus* first appears at a level within the *sandbergi* Zone.

In the Gorzysław 9 borehole, a miospore assemblage representing the Ma_3 subzone was found at depth 3141–3142 m by Stempień-Sałek (1997). This level is bracketed by conodont faunas of the *sandbergi* or Lower *crenulata* zones (Fig. 18). Thus, the base of the Ma_3 subzone is not younger than the Lower *crenulata* Zone. This is the same stratigraphic position as that of the lower boundary of the *balteatus–polyptycha* (BP) Zone in Belgium (Higgs *et al.*, 1992).

The Cl_1 miospore assemblages were found below, and/or in association with conodonts of the Lower *typicus* Zone (Chmielno 1, Drzewiany 1, and Kłanino 1 boreholes, see Figs 18, 19), and the Cl_2 miospore assemblages occur above the Lower *typicus* faunas (Brda 2 and Drzewiany 1 boreholes, see Fig. 19). In the Biały Bór 1 borehole, a conodont specimen determined as *Polygnathus* cf. *purus purus* has been found above the base of the Cl Zone (Matyja, 1976). *Polygnathus purus purus* ranges to the upper boundary of the Lower *crenulata* Zone (Bełka, 1985), but in Belgium *P.* cf. *purus purus* was found in the *cuneiformis* Zone (Bełka & Groessens, 1986, table I) which is equivalent of the Lower *typicus* Zone.

This, and the conodont data on the Ma Zone discussed above, suggest that the Ma/Cl boundary is within the span Lower *crenulata* - Lower *typicus* zones, and the lower boundary of the Cl_2 Subzone is within or above the Lower *typicus* Zone.

Faunal control on the Visean miospore zones is very scarce. The ammonoid index species of the Goα Zone - *Goniatites crenistria* Phill. – has been found in the Sarbinowo 1 borehole at depth 2656–2662 m (Korejwo, 1993), *i.e.* between the intervals included in the Ca and Pa miospore zones (Fig. 19). This agrees well with the ammonoid data on the equivalents of these zones (see Fig. 9) in the British Isles (Riley, 1993).

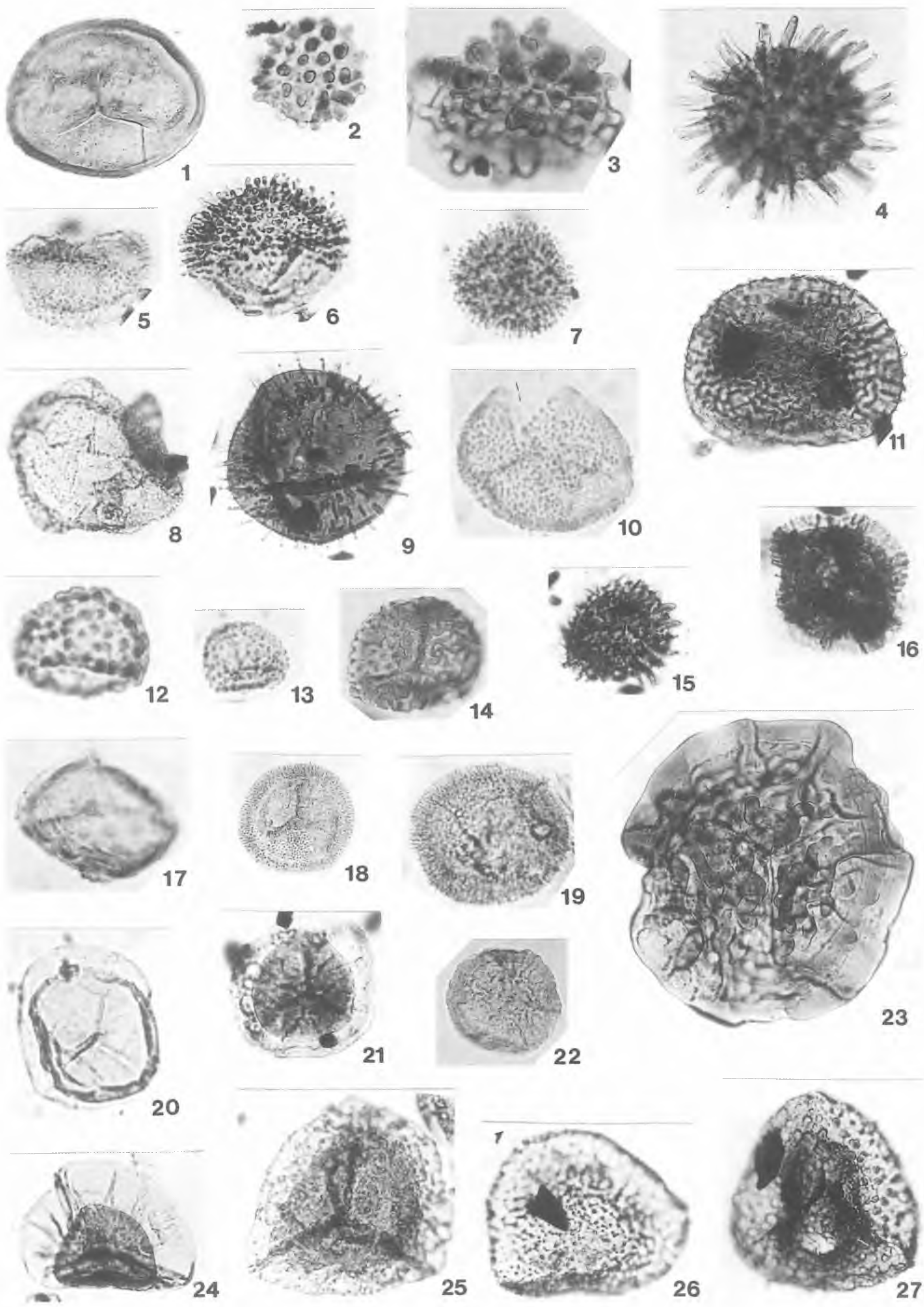
In some sections, benthic ostracods were found in association with conodont, entomozoid and miospore assemblages. The ostracod Vn_1 assemblage has been found in association with Ma_1 miospores (Brda 1 borehole), and with the *latior* entomozoids, *sandbergi* - *crenulata* conodonts, and Ma_2 miospores (Chmielno 1 borehole, see Fig. 18). The Vn_2 assemblage co-occurs with Ma miospores in the Brda 1 borehole. The P–T assemblage occurs below the Lower *typicus* conodonts (Brda 1 borehole, see Fig. 19) and in association with the Cl_1 miospores (Chmielno 1 borehole). The R–F assemblage is associated with the Upper *typicus*(?) conodonts (Biesiekierz 1 borehole) and with the Cl_2 miospores (in the Kłanino 1 borehole) (Fig. 19). These data allow to establish approximate correlation between the miospore and benthic ostracod zonations (Fig. 17).

Age of formations

The stratigraphic positions and biozonal assignments of the micropalaeontological samples in the boreholes studied are shown in Fig. 18 and Fig. 19, and a generalized chronostratigraphic chart of the Tournaisian deposits is in Fig. 18. Species range charts are in the Appendix 2.

The younger, Carboniferous part of the Sąpolno Calcareous Shale Formation is well dated by means of conodonts, miospores, ostracods, and macrofossils. The oldest conodonts indicate the upper part of the *sandbergi* Zone, the entomozoid ostracod *Richterina (R.) latior* indicates the *latior* Zone (Żbikowska, 1992), and miospore assemblages represent the Ma Zone, the Ma_1 or Ma_2 subzones. Goniatites found in Grzybowo 1 borehole (depth 3297–3303 m), and Wierzchowo 10 (depth 3545–3552 m) give well constrained dates for this part of the Sąpolno Calcareous Shale Formation owing to the occurrence of ammonoids *Pseudarietites dorsoplanus dorsoplanus* Schmidt and *Gattenpleura* sp., indicative of the Gaα (*Gattendorfia subinvoluta*) Zone of the lowermost Carboniferous (Korejwo, 1979, 1993). Benthic ostracods belonging to the Vn_1 subassemblage including species indicative of a lower Tournaisian (Tn1b) age, are also present.

Fig. 10. Miospores of the *Prolycospora claytonii* (Cl) Zone and basal part of *Lycospora pusilla* (Pu) zone. Specimens 1, 12, 13, 17, 22, 23 are from Karsina I, 2242–2249 m, specimens 3, 8, 20, 24 are from Karsina 1, 2535–2538 m, other specimens as indicated below. All magnifications ×500, except when indicated. **1** – *Punctatisporites aerarius* Butterworth & Williams, slide III/8; **2** – *Pustulatisporites uncatus* (Kedo) Byvsheva, Wierzchowo 10, 3332–3339 m, slide VII/25; **3** – *Raistrickia clavata* Haquebard emend. Playford, slide III/22; **4** – *Raistrickia corynoges* Sullivan, Gozd 2, depth 2807–2812 m, slide IV/87; **5** – *Schopfites delicatus* Higgs emend. Higgs, Clayton & Keegan, Biesiekierz 1, 2907–2913 m, slide IV/93; **6–7** – *Schopfites claviger* Sullivan, 6: Drzewiany 1, 2581–2585 m, slide X/35, 7: Wierzchowo 9, 3424–3430 m, slide VII/80; **8** – *Crassispora trychera* Neves & Ioannides, slide III/22; **9** – *Umbonatisporites distinctus* Clayton, Brda 1, 2260–2266 m, slide IV/45; **10** – *Anaplanisporites baccatus* Hoffmeister, Staplin & Malloy, Karsina 1, 2591–2594 m, ×1000; **11** – *Dictyotriletes membranireticulatus* Bertelsen, Drzewiany 1, 3053–3056 m, slide X/82; **12–13** – *Prolycospora claytonii* Turnau, slide III/8, 12: ×1000; **14**: *Bascaudaspora submarginata* (Playford) Higgs, Clayton & Keegan, Biesiekierz 1, 2907–2913 m, slide IV/87; **15** – *Acanthotriletes socraticus* Neves & Ioannodes, Drzewiany 1, 30533056 m, slide X/82; **16** – *Dictyotriletes glumaceus* (Byvsheva) Byvsheva, Wierzchowo 9, 3424–3430 m, slide VII/77; **17** – *Lycospora pusilla* (Ibrahim) Somers, slide III/9; **18–19** – *Colatisporites multisetus* (Luber) Avchimovitch & Turnau, 18: Gozd 2, depth 2807–2812 m, slide IV/87, 19: Wierzchowo 9, depth 3323–3330 m, slide VII/67, ×750; **20** – *Auroraspora panda* Turnau, slide III/22; **21** – *Auroraspora macra* Sullivan, Wierzchowo 10, 3332–3339 m, slide VII/12; **22** – *Rugospora minuta* Neves & Ioannides, slide III/7; **23** – *Gorgonispora multiplicabilis* (Kedo) Turnau, slide III/8; **24** – *Auroraspora* cf. *solisorta* Hoffmeister, Staplin & Malloy, slide III/22; **25** – *Kraeuselisporites hibernicus* Higgs, Brda 2, 2207–2213 m, slide VI/37; **26** – *Spelaeotriletes balteatus* (Playford) Higgs, Wierzchowo 10, 3301–3307 m, slide VII/8; **27** – *Spelaeotriletes pretiosus* (Playford) Neves & Belt, Gozd 3, 2810–2813 m, slide IV/82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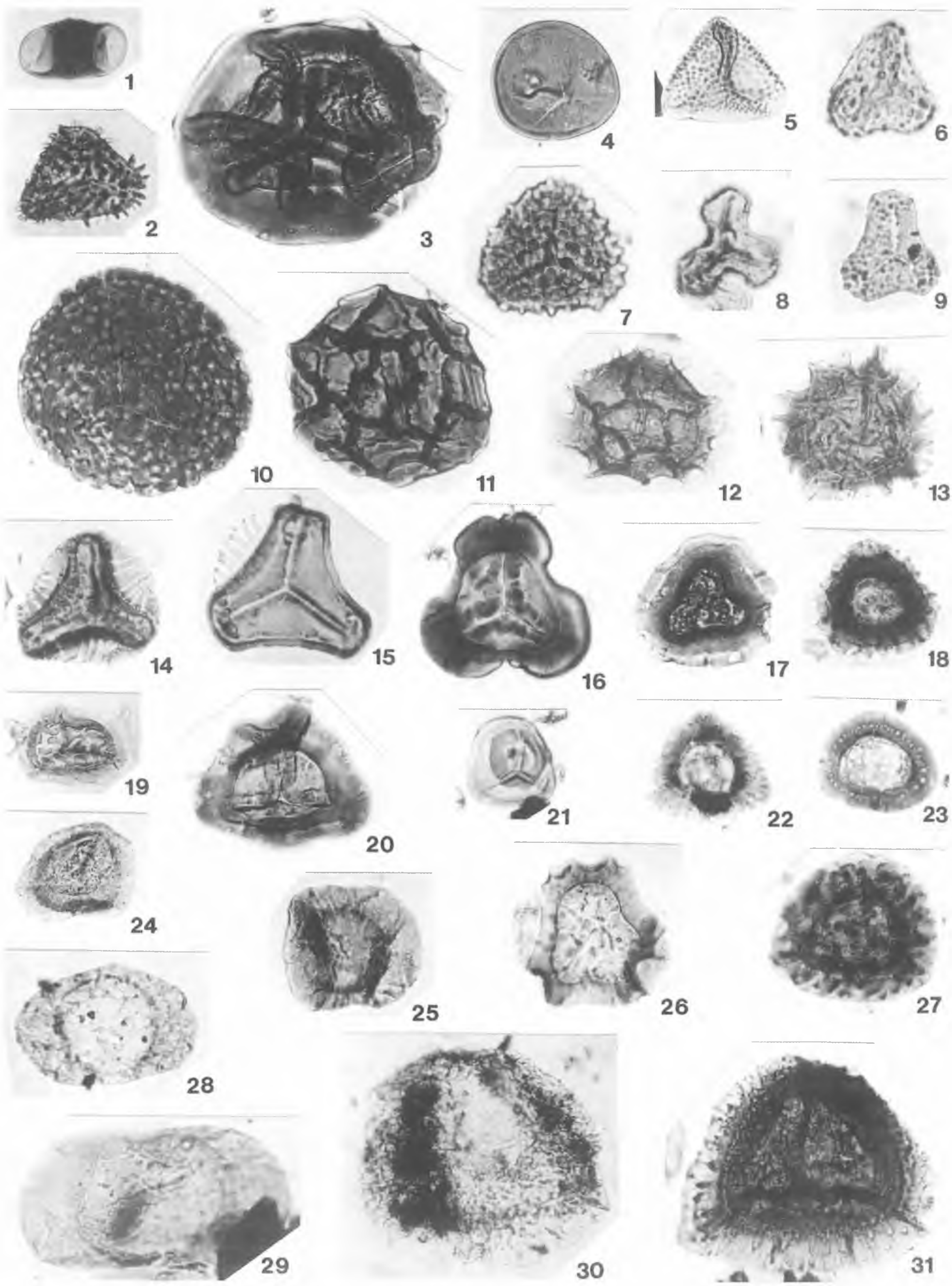

The top of the Sąpolno Calcareous Shale Formation is dated as the *latior* entomozoid Zone, and *sandbergi* or *crenulata* conodont Zone (Gorzysław 9, Karlino 1, and Chmielno 1 boreholes). The benthic ostracod P–T assemblage occurs in the top part of the formation in the Daszewo R3p borehole.

In the southeasternmost part of the study area, between Biały Bór and Brda, the upper boundary of the Sąpolno Calcareous Shale Formation (*i.e.*, the upper boundary of the Trzebiechowo Marl Member) is erosional, except for the Brda 2 borehole. The stratigraphic position of this boundary is dated as the Lower *crenulata* conodont Zone and Ma_2 miospore subzone (in the Rzeczenica 1 borehole), Cl_1 miospore subzone (in the Biały Bór 1 borehole) and Cl_2 miospore subzone (in the Biały Bór 3 borehole).

Over the entire Kołobrzeg–Chojnice area, except for its southeasternmost part, the limestones and shales of the Sąpolno Calcareous Shale Formation are overlain by coarse-grained sediments included in the Gozd Arkose Formation. In the northwestern part of the study area, west of the Kurowo 1 - Wierzchowo 10 line, the boundary between the two formations is within the *Convolutispora major* miospore Zone, Ma_2 to Ma_3 subzones (Niekłonice 1, Chmielno 1, Gozd 4 boreholes, probably also Kłanino 1 borehole), but to the east (Kurowo 1, Wierzchowo 10, and Drzewiany 1), it is within a lower part of the *Prolycospora claytonii* (Cl) Zone. In the terms of the conodont zonation, this lithostratigraphic boundary is within the Lower *crenulata* Zone in the northwest and in the *isosticha*-Upper *crenulata* or lower part of the Lower *typicus* Zone in the east.

In upper Tournaisian, in the area along the Gozd–Biesiekierz–Grzybowo line, calcareous claystones replaced the coarse grained, arkosic sediments. The boundary between the lower part of the Gozd Arkose Formation and the Grzybowo Calcareous Shale Member is dated as Lower *typicus* Zone (Kłanino 1 borehole), and is within a higher part of the Cl_1 subzone (Niekłonice 1), or within undivided Cl Zone. Benthic ostracod data (Kłanino 1) are in agreement with this position. Conodonts representing probably the Upper *typicus* Zone have been found found in the Grzybowo Calcareous Shale Member in the Biesiekierz 1 borehole, and miospore assemblages representing the Cl_2 subzone have been recorded from the Rosnowo 1 borehole.

To the west and south from the Gozd–Biesiekierz–Grzybowo line, the Gozd Arkose Formation is overlain by the Kurowo Oolite Formation. The boundary between the two formations is within or above the Lower *typicus* Zone (Drzewiany 1, Chmielno 1 boreholes). Benthic ostracods (Daszewo R3p) indicate a position of the boundary not older than the R-F assemblage, *i.e.* in upper part of the Cl_1 Subzone (cf. Fig. 17). In the Brda 2 borehole, a higher part of the formation is dated as the Cl_2 subzone. Thus, the Kurowo Oolite Formation is roughly a time equivalent of the Grzybowo Calcareous Shale Member.

During the latest Tournaisian, deposition of quartz sandstones of the Drzewiany Sandstone Formation replaced that of clayey and carbonate sediments of the Grzybowo Calcareous Shale Member and Kurowo Oolite Formation. The lower boundary of the Drzewiany Sandstone Formation is within the Cl_2 Subzone (Rosnowo 1, Gozd 2, probably Wierzchowo 9 and Drzewiany 1 boreholes).

There are considerable differences between the above, miospore based age assignment and that based on macrofauna (Korejwo, 1993). Controversies concern mainly the lower parts of the Drzewiany Sandstone Formation (boreholes Drzewiany 1, Gozd 2, Wierzchowo 9) assigned here, basing on spores, to the Tournaisian. In the opinion of Korejwo (1993), the presence in these deposits of brachiopod species *Schizodus orbicularis* (Mc Coy) and bivalve species *Sanguinolites abdenensis* Ether. indicates the lower Viséan (V1). Although these species are known from the entire Dinantian, Korejwo (1993) argued that they had been recorded mainly from the Viséan.

The undisputed assignment of the higher parts of the Drzewiany Sandstone Formation in the Karsina 1 section to the Viséan has been confirmed by the occurrence of a miospore assemblage of the lower-middle Viséan *Lycospora pusilla* (Pu) Zone. The formation is relatively well dated in the Sarbinowo 1 section (Fig. 18). Miospores indicate the presence of the Viséan *Lycospora pusilla* (Pu), *Schulzospora campyloptera* (Ca) and *Dictyotriletes pactilis* (Pa) zones. The assemblages of the Pu zone in this section include younger elements not found below the *triradiatus-stephanephorus* (TS) Zone (see Fig. 11) suggesting a middle Viséan age, while miospore species present in the uppermost assemblage point to a late Viséan (Brigantian) age. In

Fig. 11. Miospores of the *Dictyotriletes pactilis* (Pa) zone. All specimens are from Sarbinowo 1 borehole, specimens 1, 4, 28 are from depth 2559–2562 m, slide IV/16, specimens 2, 3, 6, 7, 9, 10-12, 15 17-19, 21-27, 31 are from depth 2534–2537 m, slide IV/7, specimens 5, 8, 13, 14, 29 are from depth 2534–2537 m, slide IV/9, specimens 16, 20 are from depth 2534–2537 m, slide IV/14, specimen 30 is from depth 2559–2562 m, slide IV/21. All magnifications ×500. **1** – *Chetosphaerites pollenisimilis* (Horst) Butterworth & Williams; **2** – *Pilosisporites venustus* Sullivan & Marshall; **3** – *Orbisporis convolutus* Butterworth & Spinner; **4** – *Punctatisporites aerarius* Butterworth & Williams; **5** – *Anapiculatisporites concinnus* Playford; **6** – *Lophotriletes tribulosus* Sullivan; **7** – *Converrucosisporites horridus* (Ishchenko) Turnau var. *trigonalis* Jachowicz; **8** – *Waltzispora* sp.; **9** – *Waltzispora planiangulata* Sullivan; **10** – *Foveosporites insculptus* Playford; **11** – *Corbulispora cancellata* (Waltz) Bharadwaj & Venkatachala; **12–13** – *Dictyotriletes plumosus* (Butterworth & Spinner) Neville & Williams; **14** – *Diatomozonotriletes cervicornutus* (Staplin) Playford; **15** – *Diatomozonotriletes saetosus* (Haquebard & Barss) Hughes & Playford; **16, 20** – *Murospora aurita* (Waltz) Playford; **17** – *Potoniespores delicatus* Playford; **18** – *Cingulizonates bialatus* (Waltz) Smith & Butterworth; **19** – *Lycospora noctuina* Butterworth & Williams; **21** – *Knoxisporites* cf. *stephanephorus* Love; **22** – *Densosporites* sp.; **23** – *Densosporites variabilis* (Waltz) Potonié & Kremp; **24** – *Lycospora pusilla* (Ibrahim) Somers; **25** – *Schulzospora plicata* Butterworth & Williams; **26** – *Monilospora culta* (Byvscheva) Byvscheva; **27** – *Densosporites* sp.; **28** – *Schulzospora ocellata* (Horst) Potonié & Kremp; **29** – *Schulzospora campyloptera* (Waltz) Hoffmeister, Staplin & Malloy; **30** – *Perotrilites tessellatus* (Staplin) Neville; **31** – *Kraeuselisporites echinatus* Owens, Michell & Marshall

Benthic ostracod assemblage/subassemblage		Species restricted to assemblage / subassemblage		Other species present
Glyptopleura ruegensis* - *Carbonita fabulina **R - F**		*B. binodosus* *B. fortis* *G. annularis* *G. ruegensis* *A. quadrata* *C. fabulina*		*S. electa*
Cribroconcha postfoveata* - *Marginia tschigovae **P - T**		*E.* cf. *kiselensis* *M. tschigovae* *G. reticulocostatus* *C. quasicornigera* *C. postfoveata*		*S. electa*
Pseudoleperditia venulosa **Vn**	upper (2)	*P. venulosa* *C. triceratina*	*C. obscura*	*A. similaris* *S. alekseevae* *S. longa* *C. elata* *A. acutiangulata*
	lower (1)		*N. reticulata* *S. tersiensis* *A. rara*	*B. lecta*

Fig. 12. Benthic ostracod assemblages/subassemblages for Tournaisian in western Pomerania and their characteristic species

middle part of this section, the goniatites *Goniatites crenistria* Phill. and *Prolecanites* cf. *serpentinus* (Phill.) have been recorded by Korejwo (1993). They indicate the presence of the late Viséan Goα ammonoid Zone. The deposits of a higher part of the Drzewiany Sandstone Formation in the Gozd 2 section (depth 2508–2504 m) yielded a macrofaunal assemblage similar to that found in Sarbinowo 1 borehole in the middle Viséan (V2) deposits.

It is concluded that the Drzewiany Sandstone Formation spans the uppermost Tournaisian and much of the Viséan.

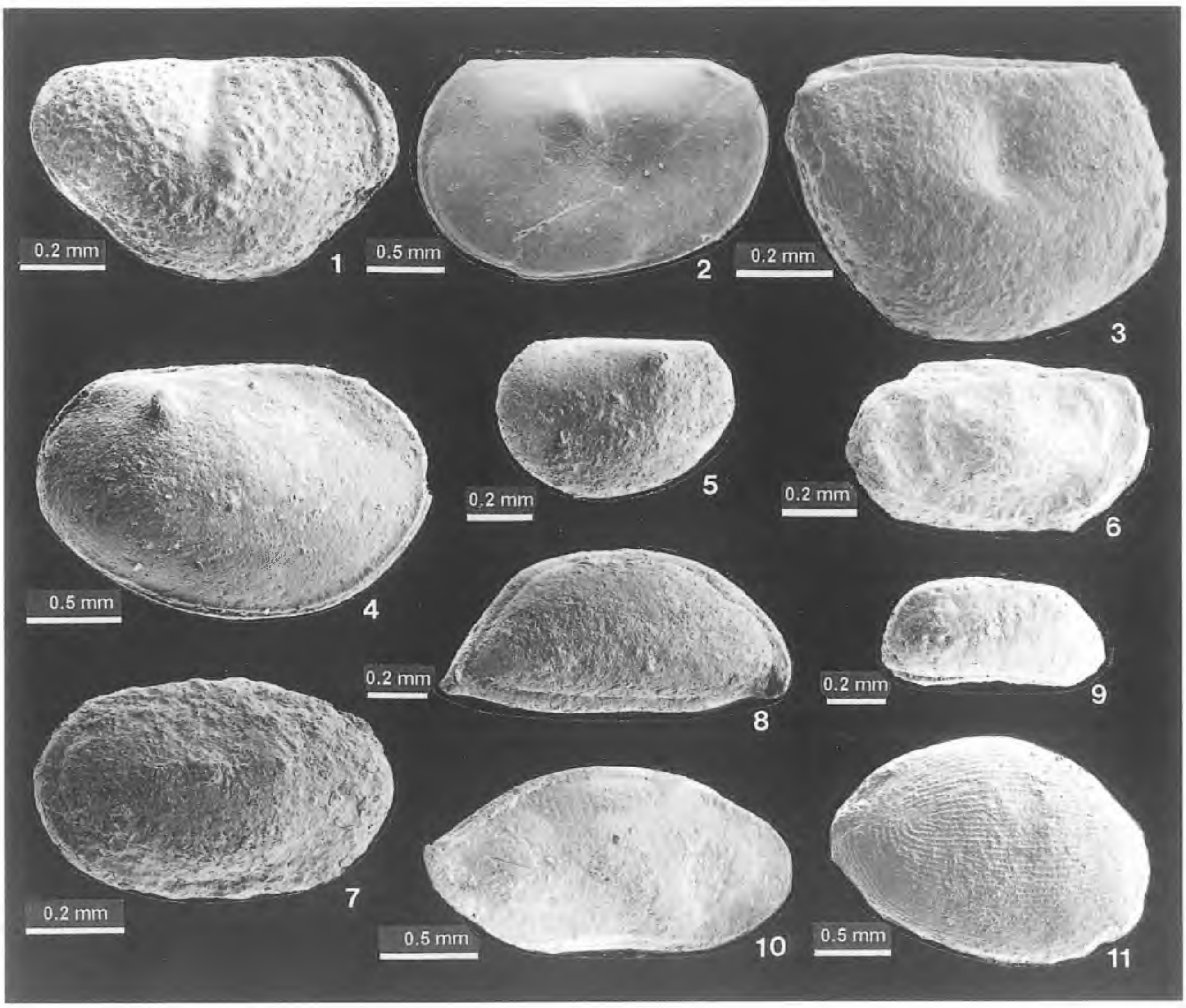

Fig. 13. Ostracod assemblage lower *Pseudoleperditia venulosa* (Vn_1). Specimen 1 is from Brda 1, 2676–2682m, specimens 2-11 are from Chmielno 1, 3952–3962 m. **1** – *Namaya reticulata* Green; **2** – *Pseudoleperditia venulosa* (Kummerow); **3** – *Coryellina triceratina* (Posner); **4** – *Shishaella alekseevae* Tschigova; **5** – *Shivaella longa* (Tschigova); **6** – *Amphissites similaris* Morey; **7** – *Sulcocavellina tersiensis* Bushmina; **8** – *Acutiangulata acutiangulata* (Posner); **9** – *A. rara* Bushmina; **10** – *Bairdia lecta* Bushmina; **11** – *Richterina (Richterina) latior* Rabien

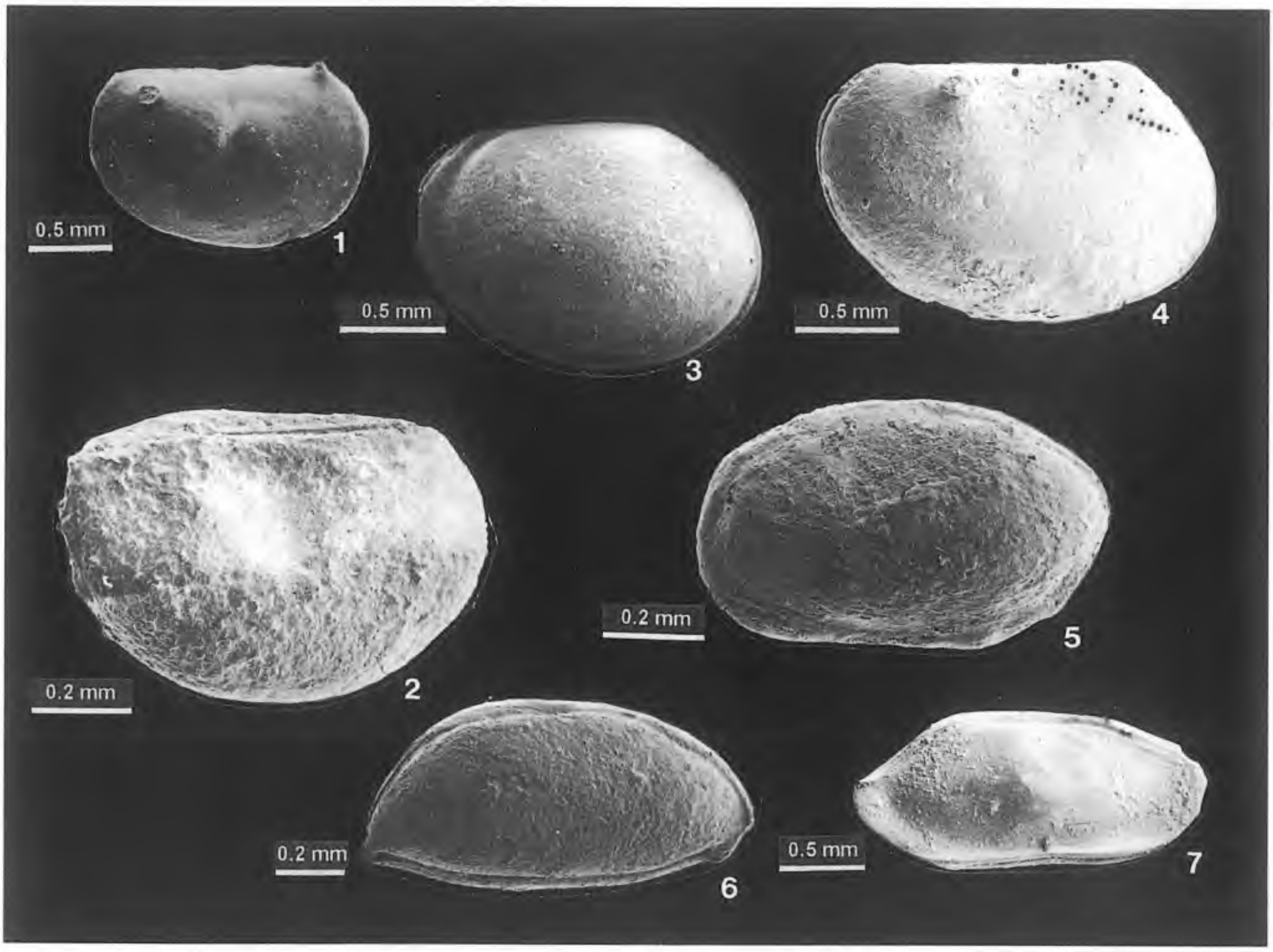

Fig. 14. Ostracod assemblage upper *Pseudoleperditia venulosa* (Vn_2). All specimens are from Brda 1. **1** – *Pseudoleperditia venulosa* (Kummerow), 2524.5–2528 m; **2** – *Coryellina triceratina* (Posner), 2611–2616 m; **3** – *Chamishaella obscura* Tschigova, 2560–2563 m; **4** – *Shishaella longa* (Tschigova), 2676–2682 m; **5** – *Sulcocavellina tersiensis* Bushmina, *ibidem*; **6** – *Acutiangulata acutiangulata* (Posner), 2611–2616 m; **7** – *Bairdia lecta* Bushmina, *ibidem*

Chronostratigraphic boundaries

Devonian/Carboniferous boundary

The Global Stratotype Section and Point for the Devonian–Carboniferous boundary has been defined at La Serre, southeast Montagne Noir France (see Paproth *et. al.*, 1991). The section fulfills the demands of the Group, especially the condition that specimens of *Siphonodella praesulcata* should be followed by *S. praesulcata-sulcata* transitional forms.

In western Pomerania, the top of the Upper Devonian sequence yielded abundant and diverse conodont fauna indicative of the Upper *expansa* and/or Lower *praesulcata* zones (Matyja, 1993). The base of the Lower Carboniferous sequence is characterised by rare though relatively diverse conodonts characteristic of the *sandbergi* Zone. In the Rzeczenica 1 section, there are only some metres of a shale devoid of fauna between the documented Devonian Upper *expansa* - Lower *praesulcata* zones and the Carboniferous *sandbergi* Zone. In other investigated sections, in which Devonian/Carboniferous boundary runs within cored intervals, the biostratigraphic gap seems to comprise a similar time interval. There is no conodont data suggesting the presence of conodont zones older than the *sandbergi* Zone.

A similar range of this stratigraphic gap is also indicated by miospore analysis. Two consecutive, local miospore zones - *Tumulispora rarituberculata* (Ra), and *Convolutispora major* (Ma) were distinguished in the Devonian/Carboniferous transition beds (Turnau, 1978). This author suggested (see Turnau, 1978, fig. 3) that a high rate of species disappearances and the first appearances at the Ra/Ma zonal boundary indicates the presence of a stratigraphic gap. Varying opinions on the extent of this gap were discussed in Turnau (1979), Clayton & Turnau (1990), Avkhimovitch *et al.* (1993), Matyja & Stempień-Sałek (1994). The up to-date information on stratigraphical ranges of several critical species in the nortwestern Europe (Higgs *et al.*, 1988a) and Belarus (Avkhimovitch, 1993) suggests that in western Pomerania, the counterparts of the northwestern European spore zones *lepidophyta–explanatus* (LE), *lepidophyta–nitidus* (LN) and most of, or the entire *verrucosus–incohatus* (VI) Zone are missing.

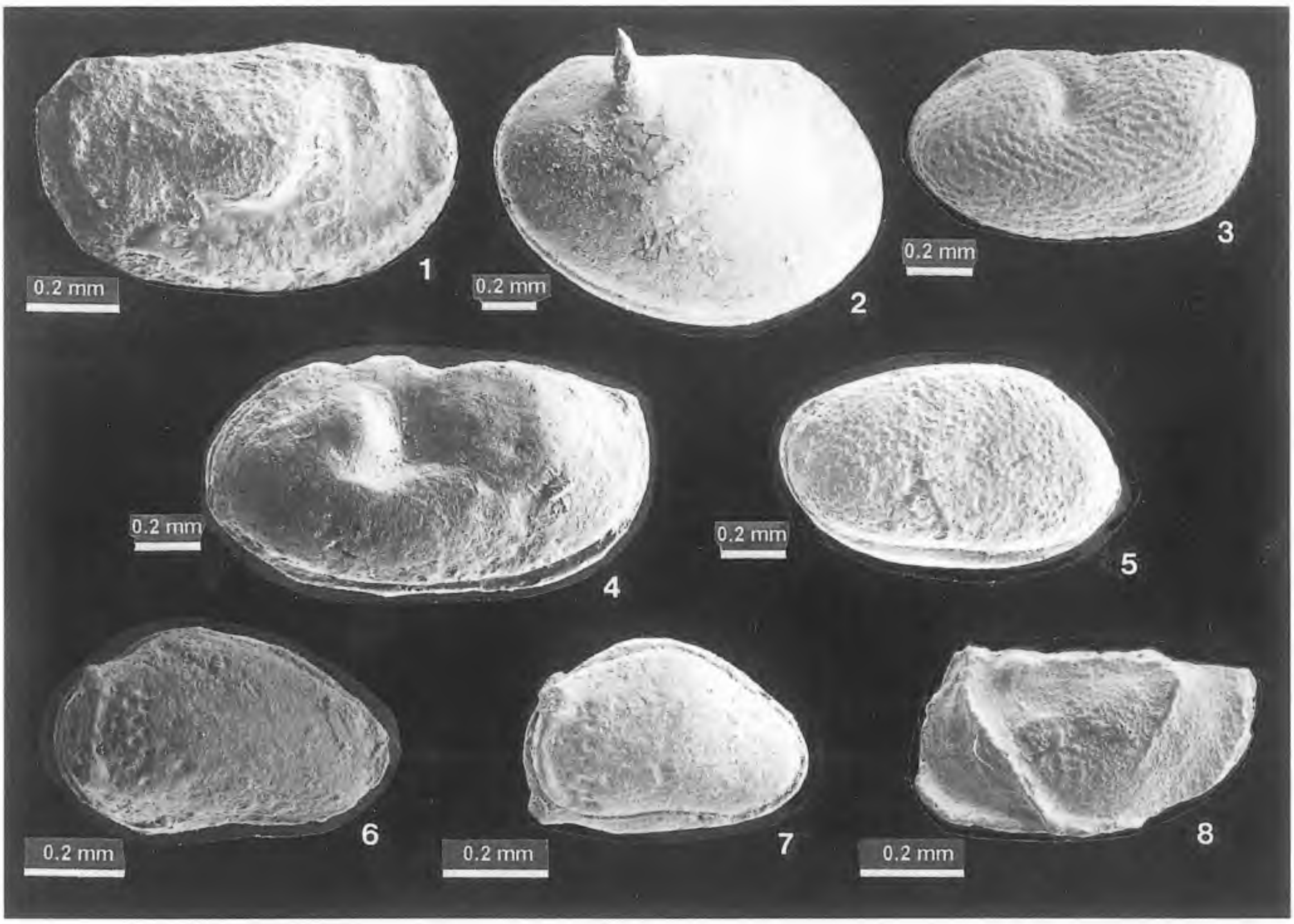

Fig. 15. Ostracod assemblage *Cribroconcha postfoveata-Marginia tschigovae* (P–T). Specimens 1, 2 are from Brda 1, 2319–2326 m, specimens 3, 4, 6, 8 are from Brda 1, 2260–2266 m, specimens 5, 7 are from Chmielno 1, 3794–3796 m. **1** – *Amphissites similaris* Morey; **2** – *Shivaella longa* (Tschigova); **3** – *Marginia tschigovae* (Palant); **4** – *Carboprimitia elata* Tschigova; **5** – *Graphiadactyllis reticulocostatus* Gründel; **6** – *Cribroconcha quasicornigera* Bushmina; **7** – *C. postfoveata* Gründel; **8** – *Editia* cf. *kiselensis* (Posner) s. Robinson

The presence in some sections of goniatites of the *Gattendorfia subinvoluta* (Go) Zone of the lowermost Tournaisian (see Korejwo, 1979, 1993) suggests, however, that the range of the stratigraphic gap could be smaller (in some sections?), and limited to the Devonian Middle-Upper *praesulcata* Zones and the Carboniferous *sulcata*-Lower *duplicata* Zones.

The nature and possible causes of the gap were discussed in details by Matyja (1993). Apart from the question of the range of the gap, it is clear, however, that the uppermost Famennian–lowermost Tournaisian deposits show extremely reduced thickness, not more than several metres (see Figs 18–19).

Tournaisian–Viséan boundary

The working group of the Subcomission of Carboniferous Stratigraphy of IUGS is currently trying to identify a boundary and to select the boundary stratotype and GSSP that would closely correspond to the base of Viséan as proposed during the 1967 Carboniferous Congress at Sheffield. A lineage within *Eoparastaffella* has been established in sections in southern China, and sections in Ireland are under investigation (Sevastopulo & Hence, 1999).

It is difficult to establish the position of the Tournaisian–Viséan boundary in the investigated sections of western Pomerania mainly because of the lack of key fauna. The boundary is placed tentatively at the first appearance of *Lycospora pusilla.* This first appearance, at least in Europe, has been traditionally equated with the discussed boundary (Clayton *et al.*, 1990; Turnau *et al.*, 1997) but, in precise terms, the CM/Pu boundary may be older (Riley, 1993, see also Carson & Clayton, 1997).

SUMMARY AND CONCLUSIONS

The detailed conodont, miospore and ostracod analyses permitted to distinguish:

(a) the Tournaisian *sandbergi*, Lower *crenulata, isosticha*–Upper *crenulata* and *typicus* conodont zones;

(b) nine local Tournaisian and Viséan miospore zones and subzones: *major* (Ma_1-Ma_4), *claytonii* (Cl_1-Cl_2), *pusilla, campyloptera* and *pactilis*;

(c) three Tournaisian, local benthic ostracod assem-

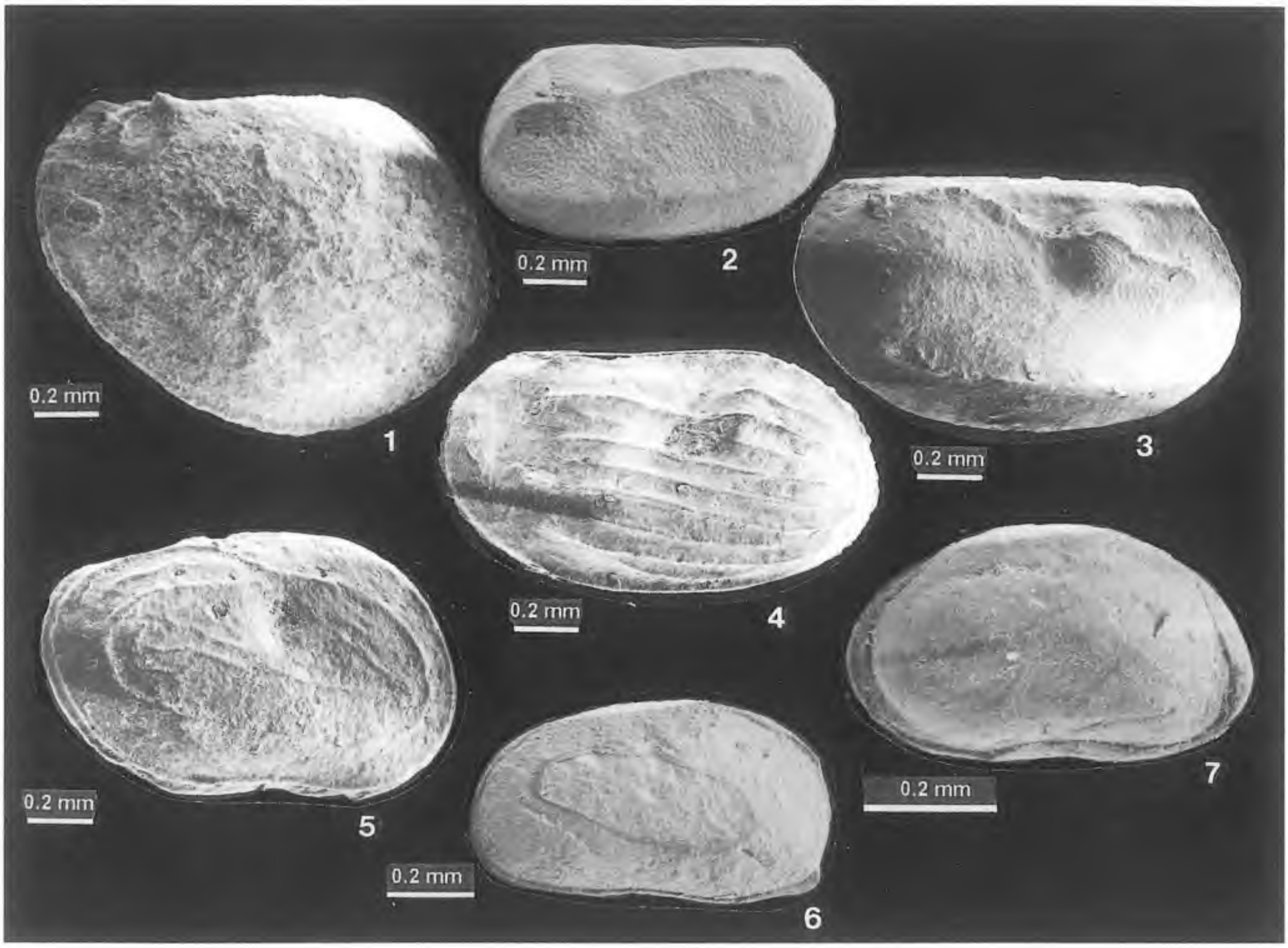

Fig. 16. Ostracod assemblage *Glyptopleura ruegensis-Carbonita fabulina* (R–F). Specimens 1, 3, 4 are from Kłanino 1 (depth indicated below), specimens 2, 5-7 are from Biesiekierz 1, 2890–2894 m. **1** – *Shishaella electa* Tschigova, 2392.3–2394 m; **2** – *Beyrichiopsis fortis* Jones & Kirkby; **3** – *Beyrichiopsis binodosus* Błaszyk & Natusiewicz, 2394–2397 m; **4** – *Glyptopleura ruegensis* Blumenstengel, 2463–2467 m; **5** – *Glyptolichwinella annularis* (Kummerow); **6** – *Acutiangulata quadrata* Robinson; **7** – *Carbonita fabulina* (Jones & Kirkby)

blages and two subassemblages: *Pseudoleperditia venulosa* (Vn_1-Vn_2), *Cribroconcha postfoveata–Marginia tchigovae* (P–T) and *Glyptopleura ruegensis–Carbonita fabulina* (R–F).

Integrated biostratigraphic analysis enabled correlation of local miospore and ostracod schemes with the "standard" conodont zonation. The base of Ma_1 subzone is within or below the *sandbergi* Zone, that of Ma_2 subzone is within *sandbergi* zone, the Ma_2/Ma_3 subzonal boundary is not younger than the Lower *crenulata* Zone, and base of Cl Zone is within or below the *typicus* Zone. The benthic ostracod assemblage Vn corresponds to Ma_1 - Ma_3 (part) subzones; P–T assemblage encompasses Ma_3 (part), Ma_4 and Cl_1 (part) subzones; R–F assemblage corresponds to Cl_1 (part) and Cl_2 subzones.

The oldest Carboniferous part of the Sąpolno Calcareous Shale Formation corresponds to the *sandbergi* or Upper *duplicata* zones. The top of the formation is diachronous, corresponding to the Lower *crenulata* Zone (in the northwest), *isosticha*-Upper *crenulata* or *typicus* (in the east), and Upper(?) *typicus* (Trzebiechowo Marl Member in the Brda area). The Kurowo Oolite Formation and Grzybowo Calcareous Shale Member are late Tournaisian in age, and are roughly time equivalents. The Drzewiany Sandstone Formation spans latest Tournaisian and Viséan.

The uppermost Famennian–lowermost Tournaisian unfossiliferous, black clayey deposits rich in pyrite and organic matter are reduced to several metres in thickness. The results of both conodont and miospore studies suggest presence of a stratigraphic gap that comprises the uppermost Famennian (part of the Middle and the Upper *praesulcata* Zones) and the lowermost Tournaisian (the *sulcata, duplicata*, and the lower part of the *sandbergi* Zone). A similar range of the gap is also indicated by the miospore data as the equivalents of the western European miospore zones *lepidophyta– explanatus, lepidophy–tanitidus*, and most of, or the entire *verrucosus–incohatus* Zone are missing. The results of earlier studies on macrofauna suggest that the gap could be smaller and limited to the Middle - Upper *praesulcata* Zones and to the Carboniferous *sulcata* and Lower *duplicata* zones.

The Tournaisian–Viséan boundary has been established

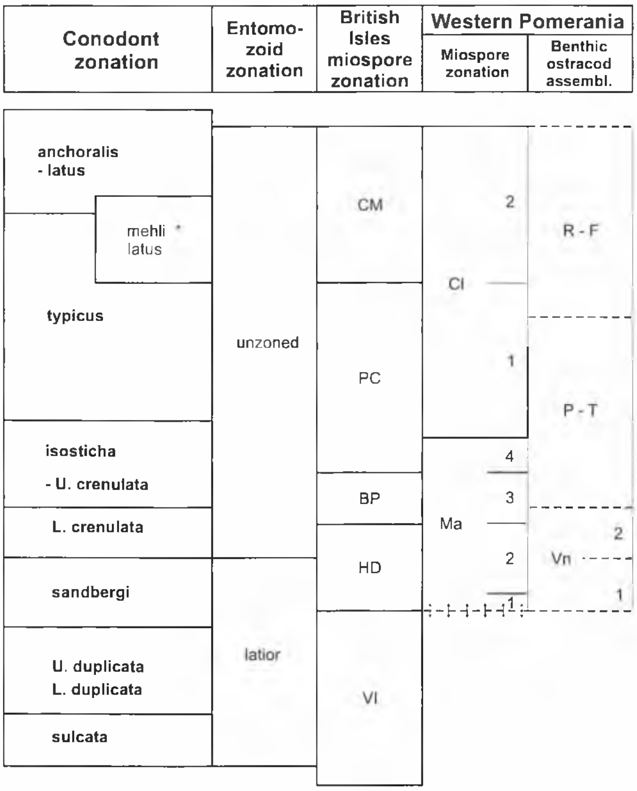

Fig. 17. Correlation of biostratigraphic zonations for Tournaisian; * conodont zone of Irish conodont zonation (shallow water facies) dating the PC/CM boundary (Higgs *et al.*, 1988b); relevant range charts are shown in the Appendix 2

approximately on the first appearance of the miospore species *Lycospora pusilla* Somers. The boundary runs within the lower part of the Drzewiany Sandstone Formation.

The maximum thickness of the most completely preserved Tournaisian deposits exceeds 800 metres (e.g., in the Kurowo 1 and Grzybowo 1 boreholes) and might have been even greater in the Wierzchowo–Brda area where the Tournaisian deposits, devoid of their upper parts (*i.e.*, rocks of Upper *typicus* and *anchoralis–latus* conodont Zones), are over 650 m thick.

The penetrated fragments of the lower Viséan are up to 200 m thick (Gozd 2 borehole) and those assigned to the middle and upper parts of the Viséan, are 260 m thick in the Sarbinowo 1 section.

SYSTEMATIC COMMENTS (MIOSPORES)

Most miospore species dealt with in this paper were determined and described more than 20 years ago. Subsequently, the second author worked on miospore taxonomy with such specialists in Carboniferous palynology as T.V. Byvsheva, V.I. Avkhimovitch, G. Clayton, and K. Higgs. These studies, and the general progress in taxonomy of Palaeozoic spores resulted in changes in some specific and generic assignments. This topic was discussed in Clayton & Turnau (1990), Avkhimovitch & Turnau (1994), and Turnau *et al.* (1994). The discussion concerned the following taxa: *Anaplanisporites baccatus, Colatisporites multisetus, Prolycospora claytonii, Schopfites delicatus, Schopfites claviger* and *Verrucosisporites nitidus*.

In the present paper, some other species are listed under generic or specific names differing from those used in the aerlier papers (Turnau, 1975, 1978, 1979). These are *Kraeuselisporites hibernicus* Higgs (formerly *Hymenozonotriletes explanatus* (Luber) Kedo morphological type 1; Turnau 1978, pp. 12–13, pl. 5, figs. 16, 19, 20), *Lophozonotriletes excisus* Naumova, 1953 (formerly *Tumulispora dentata* (Hughes et Playford) n. comb.; Turnau, 1975, p. 516, pl. 5, fig. 1), and *Dictyotriletes glumaceus* Byvsheva, 1972 (formerly *Dictyotriletes margodentatus* nov. sp.; Turnau, 1978, p. 8, pl.2, fig. 15). Some other taxonomic problems are discussed below.

Genus *Dictyotriletes* Naumova emend. Smith et Butterworth, 1967

Dictyotriletes plumosus (Butterworth et Spinner) emend Neville et Williams, 1963
Fig. 9 (12–13)

1979 *Dictyotriletes pactilis* Sullivan; Turnau, pl. 2, figs 6-8.

Description: Trilete spores c. 60 μm in diameter, trilete mark tectate, rays extending almost to spore body margin. Exine 3 μm thick. Distal surface bears a prominent reticulum. Lumina up to 24 μm across, muri narrow, up to 10 μm high, wider at base, tapering to u membranous ridge with a frilled crest. One murus may almost completely encircle the equator.

Remarks: The assignement to *D. pactilis* was incorrect, the latter species lacks trilete rays.

Genus *Pustulatisporites* Potonié et Kremp emend. Imgrund, 1964

Pustulatisporites uncatus (Kedo) Byvsheva, 1985
Fig. 8 (2)

1978 *Pustulatisporites gibberosus* (Haquebard) Playford; Turnau, p. 7, pl. 1, figs 26, 27.
1979 *Pustulatisporites gibberosus* (Haquebard) Playford; Turnau, pl. 1, fig. 20.
1980 *Pustulatisporites uncatus* (Kedo) nov. comb; Byvsheva, p. 58 (combination not valid).
1985 *Pustulatisporites uncatus* (Kedo) Byvsheva; Byvsheva, pp. 95-96, tab. 18, figs 11-13, *cum synonimis*.

Dimensions (after Turnau, 1978): 34.5(41.5)49.9 μm (26 specimens).

Remarks: Turnau (1978, p. 7) noted that Pomeranian specimens assigned to *P. gibberosus* were smaller than those from the type material (see Playford, 1964). It appears that our specimens answer more closely the description of *P. uncatus* (Byvsheva, 1985, p. 95-96).

Genus *Indotriradites* Tiwari, 1964

Indotriradites explanatus (Luber) Playford, 1991
Fig. 7 (20)

1941 *Zonotriletes explanatus* Luber; Luber & Waltz, p. 10, pl. 1, fig. 4.
1978 *Hymenozonotriletes explanatus* (Luber) Kedo morphologi-

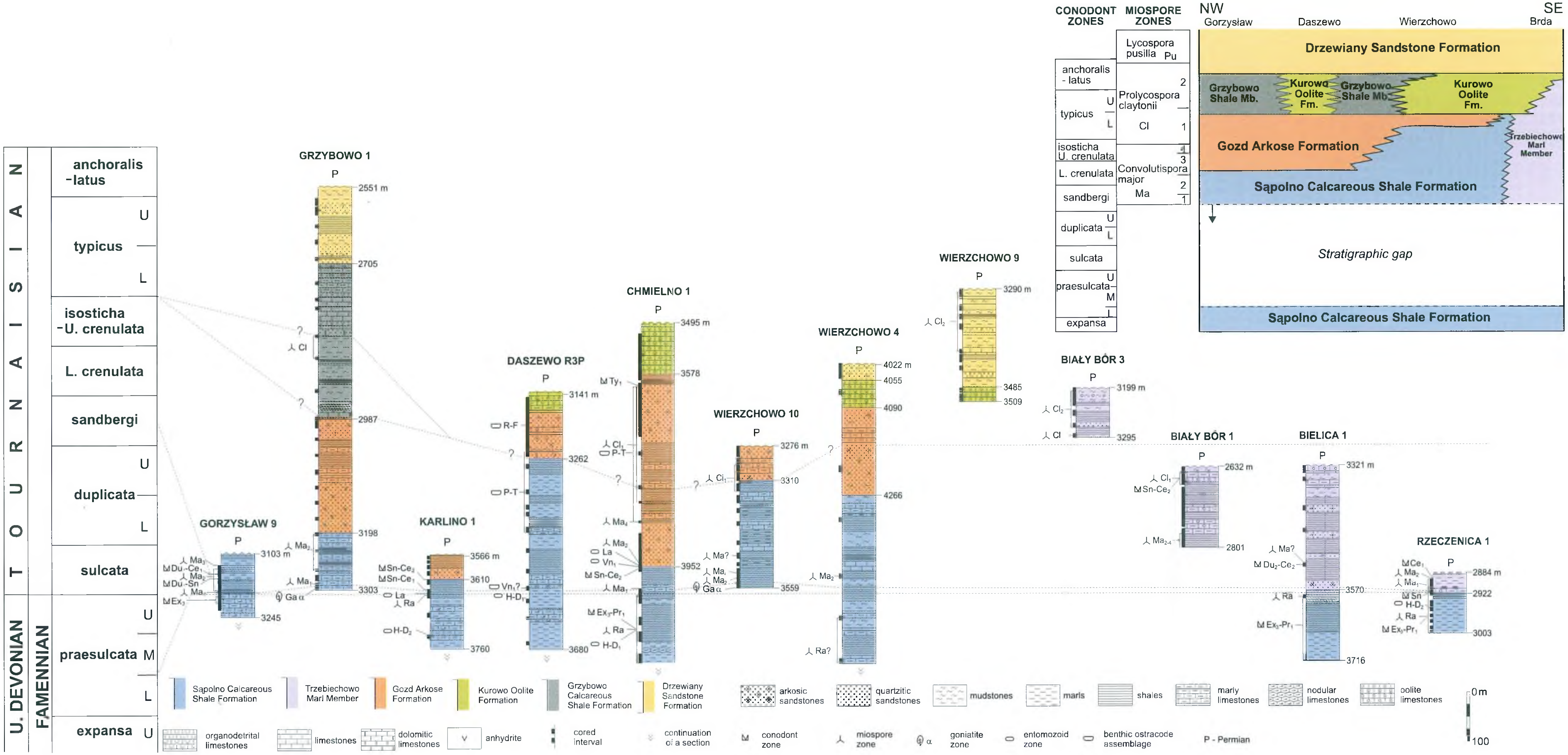

Fig. 18. Biostratigraphic correlation of borehole sections between Gorzysław and Rzeczenica; all microfossil and goniatite bearing intervals are marked. Carboniferous biostratigraphic zones/assemblages marked by two letter notations: full zonal names are in Figs 3, 10, 12, other notations: La – *latior* Entomozoid Zone, Gaα – *Gattendorfia subinvoluta* Zone, Goα – *Goniatites crenistria* Zone, Famennian zones: Ex_3 - Pr_1 – Upper *expansa* - Lower *praesulcata* conodont zones, Ra – *rarituberculata* Miospore Zone, H–D_1 and H–D_2 – Lower and Upper *hemisphaerica-dichotoma* Entomozoid Zone. Insert shows biostratigraphic correlation of Pomerania Carboniferous lithostratigraphic units. Range of Famennian–Tournaisian stratigraphic gap within the Sąpolno Calcareous Shale Formation is also shown, arrow indicates an alternative position of the gap upper range (lithostratigraphic units after Lipiec in Lipiec & Matyja, 1998)

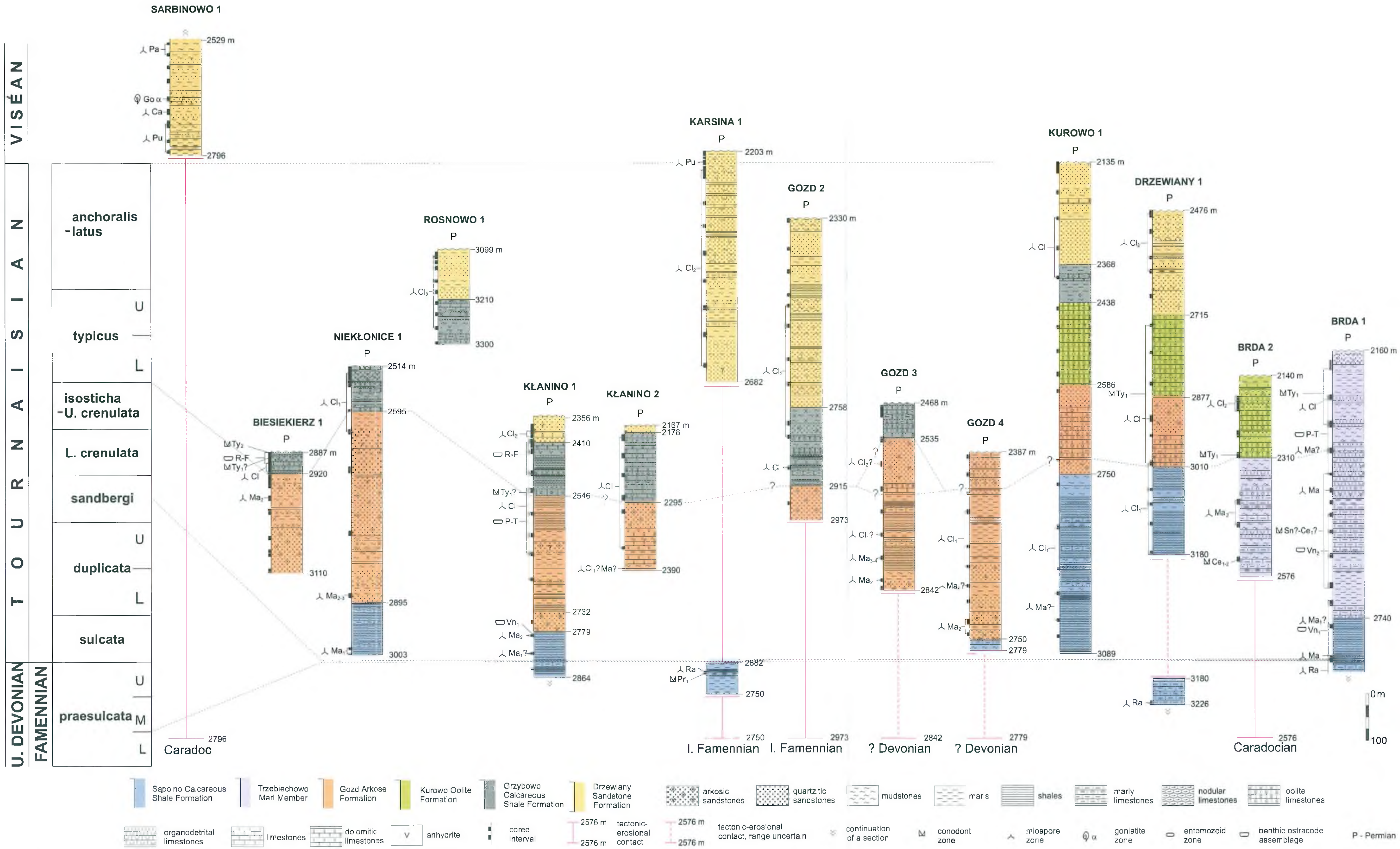

Fig. 19. Biostratigraphic correlation of borehole sections between Biesiekierz and Brda; all microfossil and goniatite bearing intervals are marked. See Fig. 18 for additional explanations

Appendix 2 Range charts of conodont, miospore and ostracod species

Conodont species range charts

Rzeczenica 1

Formation / Member	Sąpolno Calc. Sh. Fm.	Trzebiechowo Marl Member								
Depth (m)	2925 - 2924	2922 - 2920	2920 - 2916	2916 - 2912	2912 - 2911	2911 - 2910	2910 - 2909	2909 - 2907	2901 - 2899	2899 - 2896
Conodont Zone	Lower *praesul.* - Upper *expansa* (Ex_3-Pr_1)	*sandb.* (Sn)		Lower *crenulata* — *sandbergi* (Sn - Ce_1)					Lower *crenulata* (Ce_1)	
Polygnathus distortus										+
Polygnathus radinus										+
Siphonodella crenulata									+	+
Neopolygnathus carina (morphotype 1)				+		+				
Polygnathus flabellus								+		
Polygnathus symmetricus										+
Polygnathus triangulus				+						+
Hindeodus aff. *cristulus*				+						+
Pseudopolygnathus primus							+			
Pseudopolygnathus nodomarginatus							+			+
Siphonodella cooperi (morphotype 2)							+			
Siphonodella obsoleta							+		+	+
Bispathodus aculeatus anteposicornis							+			
Bispathodus spinulicostatus		+		+		+	+			+
Neopolygnathus communis (morphotype 1)		+	+	+		+	+		+	+
Polygnathus purus purus		+				+	+			
Polygnathus purus subplanus				+						
Polygnathus spicatus			+							
Pandorinellina plumula			+							
Siphonodella duplicata (morphotype1)		+	+							
Siphonodella obsoleta (smooth morphotype)		+								
Siphonodella quadruplicata		+		+	+		+			+
Elictognathus bialatus		+					+			+
Elictognathus laceratus		+								+
Bispathodus aculeatus aculeatus	+					+	+			
Bispathodus stabilis (morphotype 1)	+		+	+		+	+			
Bispathodus ultimus (morphotype 2)	+									
Branmehla inornata	+									
Branmehla suprema	+									
Polygnathus inornatus	+	+	+	+		+	+	+	+	+

Gorzysław 9

Formation	Sąpolno Calcareous Shale Fm.								
Depth (m)	3201 - 3200	3199 - 3198	3188 - 3187	3183 - 3182	3181 - 3180	3170 - 3169	3163 - 3162	3155 - 3154	3137 - 3136
Conodont Zone	Upper *expansa* (Ex_3)		?			*sandb.* — L. *dupl.* (Du_1- Sn)		L. *cren.* — L. *dupl.* (Du_1 - Ce_1)	?
Bispathodus spinulicostatus			+						
Polygnathus vogesi							+		
Siphonodella duplicata (morphotype 2)						+	+	+	
Bispathodus costatus (morphotype 1)		+							
Neopolygnathus communis (morphotype 1)	+		+	+					
Polygnathus inornatus	+				+				+
Polygnathus streeli		+							

Karlino 1

Formation	Sąpolno Calcareous Shale Fm.		
Depth (m)	3642 - 3641	3635 - 3632	3616 - 3614
Conodont Zone	L. *cren.* - *sandb.* (Sn - Ce_1)	?	isost. - U. *cren.* — *sandb.* (Sn - Ce_2)
Polygnathus inornatus		+	
Siphonodella sulcata	+		
Siphonodella quadruplicata	+		+
Neopolygnathus communis (morphotype 1)	+		

Kłanino 1

Formation	Grzybowo Shale Fm.
Depth (m)	2506 - 2505
Conodont Zone	Lower *typicus ?* (Ty_1?)
Pseudopolygnathus multistriatus (morphotype 1)	+

Chmielno 1

Formation	Sąpolno Calc. Sh. Fm.	Gozd Arkose Fm.	
Depth (m)	4010 - 4009	3953 - 3952	3599 - 3588
Conodont Zone	Lower *praesulcata* - Upper *expansa* (Ex_3 - Pr_1)	*isosticha* - U.*crenulata* — *sandbergi* (Sn - Ce_2)	Lower *typicus* (Ty_1)
„*Hindeodus*" *crassidentatus*			+
Gnathodus cuneiformis (early morphotype)			+
Pseudopolygnathus primus		+	
Siphonodella quadruplicata		+	
Bispathodus costatus (morphotype2)	+		

Bielica1

Formation / Member	Sąpolno Calc. Sh. Fm.	Trzebiechowo Marl Member
Depth (m)	3587 - 3586	3517 - 3516
Conodont Zone	Lower *praesulcata* - Upper *expansa* (Ex_3 - Pr_1)	*isosticha* - U. *crenulata* — U. *duplicata* (Du_2 - Ce_2)
Bispathodus aculeatus anteposicornis		+
Polygnathus inornatus		+
Polygnathus triangulus		+
Pseudopolygnathus dentilineatus		+
Pandorinellina plumula		+
Bispathodus costatus (morphotype 2)	+	

Biesiekierz 1

Formation	Grzybowo Shale Fm.	
Depth (m)	2907 - 290[illegible]	2887.3 - 288[illegible]
Conodont Zone	L. *typicus ?* (Ty_1?)	U. *typicus ?* (Ty_2?)
Pseudopolygnathus minutus		+
Clydagnathus unicornis	+	

Brda 2

Member / Formation	Trzebiechowo Marl Member	Kurowo Oolite Fm.
Depth (m)	2478 - 2473	2311 - 2305
Conodont Zone	*isosticha* - U. *crenulata* — L. *crenulata* (Ce_{1-2})	Lower *typicus* (Ty_1)
Pseudopolygnathus multistriatus (early morphotype)		+
Clydagnathus unicornis		+
Siphonodella isosticha	+	

Brda 1

Formation / Member	Trzebiechowo Marl Member			
Depth (m)	2682 - 2677	2475 - 2469	2326 - 2325	2196 - 2192
Conodont Zone	L. *crenulata* ? — *sandbergi* ? (Sn? - Ce_1 ?)		Lower *typicus* (Ty_1)	
Neopolygnathus carina (morphotype 2)			+	
Pseudopolygnathus multistriatus (morphotype 1)				+
Clydagnathus unicornis				+
Bispathodus aculeatus aculeatus	+			
Neopolygnathus communis (morphotype 1)	+			
Polygnathus inornatus		+		
Hindeodus aff. *cristulus*	+	+		
Siphonodella sulcata		+		

Drzewiany 1

Formation	Sąpolno Calc. Sh. Fm.		Gozd Arkose Fm.	Kurowo Oolite Fm.
Depth (m)	3172 - 3167	3125 - 3122	3004 - 3003	2736 - 2733
Conodont Zone	?		Lower *typicus* (Ty_1)	
Pseudopolygnathus multistriatus (morphotype 1)				+
Pseudopolygnathus multistriatus (morphotype 2)			+	
Clydagnathus unicornis				+
Neopolygnathus communis (morphotype 1)	+	+		

Appendix 2

Miospore species range charts (selected boreholes)

Rzeczenica 1

Formation / Member	Sąpolno Calc. Sh. Fm.		Trzebiechowo Marl Member						
Depth (m)	3003 - 2999	2937 - 2933	2923 - 2922	2921 - 2920	2920 - 2916	2915 - 2913	2911 - 2910	2901 - 2899	2899 - 2896
Miospore Zone/ Subzone	Ra		Ma$_1$					Ma$_2$	
Miospores :									
Grandispora cornuta	+	+	+			+	+	+	+
Auroraspora macra	+						+		
Converrucosisporites curvatus	+						+		
*Retispora lepidophyta**	+	+		+	+	+			
*Diducites versabilis**	+	+		+	+	+	+		
Grandispora conspicua	+						+	+	+
Grandispora lupata	+	+		+	+	+	+	+	
Raistrickia variabilis	+						+		
*Retispora cassicula**	+					+			
Tumulispora rarituberculata	+	+	+	+	+	+	+	+	+
Knoxisporites literatus	+		+	+	+	+	+	+	+
Endoculeospora gradzinskii	+		+		+			+	+
Umbonatisporites abstrusus	+			+					
Tumulispora malevkensis		+	+		+				
Grandispora uncata			+		+	+	+		
Retusotriletes incohatus			+		+			+	
Knoxisporites pristinus			+				+		
Tumulispora variverrucata			+						
Kraeuselisporites hibernicus?			+						
Grandispora upensis			+						
Reticulatisporites planus			+						
Convolutispora major			+				+		
Lophozonotriletes excisus			+		+	+	+	+	+
Asperispora acuta			+						
Raistrickia corynoges			+	+					
Tumulispora ordinaria				+	+				
Umbonatisporites distinctus								+	
Cyrtospora cristifera							+		
*Vallatisporites pusillites**				+					
*Rugospora radiata**				+					
Grandispora echinata				+					
Verrucosisporites nitidus					+	+	+		
Indotriradites explanatus								+	
Umbonatisporites distinctus								+	

Wierzchowo 10

Formation	Gozd Arkose Fm.					
Depth (m)	2547 - 2545	2517 - 2513	3474 - 3467	3363 - 3356	3339 - 3332	3304 - 3301
Miospore Subzone	Ma	Ma		Cl		
Miospores:						
Auroraspora macra	+	+	+	+	+	+
Auroraspora asperella	+					
Baculatisporites fusticulus	+	+	+			
Bascaudaspora submarginata	+	+			+	+
Convolutispora major	+					
Convolutispora mellita	+	+		+		
Crassispora trychera	+		+	+	+	+
Discernisporites micromanifestus	+			+		
Diaphanospora angusta	+	+				
Endoculeospora gradzinskii	+					
Foveospores insculptus	+					
Indotriradites explanatus	+					
Knoxisporites hederatus	+			+		
Lophozonotriletes excisus	+	+				
Pustulatisporites uncatus	+	+	+		+	+
Spelaeotriletes obtusus	+					
Tumulispora rarituberculata	+	+			+	+
Umbonatisporites distinctus	+	+			+	+
Verrucosisporites nitidus	+	+	+		+	+
Spelaeotriletes balteatus		+				+
Spelaeotriletes pretiosus		+		+	+	+
Raistrickia variabilis		+				
Schopfites delicatus		+				
Prolycospora claytonii				+	+	+
Anaplanisporites baccatus				+	+	+
Colatisporites multisetus				+	+	+
Dictyotriletes glumaceus					+	+
Acanthotriletes socraticus					+	+
Kraeuselisporites hibernicus						+
Knoxisporites literatus						+
Raistrickia corynoges						+

Drzewiany 1

Formation	Kurowo Oolite Fm.					Drzewiany Sandstone Fm.		
Depth (m)	3172 - 3167	3086 - 3085	3056 - 3053	3004 - 3003	2916 - 2910	2585 - 2581	2527 - 2522	2489 - 2483
Miospore Subzone	Cl					Cl		
Miospores:								
Acanthotriletes socraticus	+		+					
Auroraspora macra	+	+	+	+	+	+	+	
Colatisporites multisetus	+		+	+	+	+	+	+
Convolutispora mellita	+		+				+	
Crassispora trychera	+	+	+		+	+		
Corbulispora cancellata	+	+	+					
Dictyotriletes glumaceus	+		+					
Discernisporites micromanifestus	+		+					
Knoxisporites literatus	+		+	+				
Lophozonotriletes excisus	+							
Prolycospora claytonii	+	+	+	+	+	+	+	+
Punctatosporites scabratus	+				+			
Pustulatisporites uncatus	+	+	+	+	+			
Retusotriletes occultus	+		+		+	+		
Schopfites delicatus	+	+	+		+	+	+	+
Spelaeotriletes pretiosus	+	+	+	+	+			
Umbonatisporites distinctus	+		+	+				
Tumulispora rarituberculata	+	+	+	+				
Verrucosisporites nitidus	+		+	+	+			
Leiotriletes sphaerotriangularis		+	+					
Anaplanisporites baccatus			+		+	+	+	+
Convolutispora major			+	+	+			
Reticulatisporites planus			+					
Baculatisporites fusticulus			+			+		
Grandispora uncata			+	+				
Murospora sublobata			+					
Dictyotriletes membranireticulatus			+					
Bascaudaspora submarginata			+	+				
Punctatisporites pseudobesus			+				+	+
Perotrilites ordinarius			+	+			+	
Raistrickia corynoges				+		+	+	
Raistrickia condylosa					+			
Schopfites claviger						+	+	
Auroraspora panda						+	+	
Tripartites incisotrilobus							+	
Rugospora minuta							+	
Gorgonispora multiplicabilis							+	+
Raistrickia clavata								+

Sarbinowo 1

Formation	Drzewiany Sandstone Fm.					
Depth (m)	2788 - 2784	2761 - 2760	2725 - 2719	2694 - 2688	2562 - 2559	2536 - 2534
Miospore Zone	Pu			Ca	Pa	
Miospores:						
Anaplanisporites baccatus	+	+	+	+		
Crassispora trychera	+			+		
Lycospora pusilla	+	+	+	+	+	+
Rugospora minuta	+	+		+		+
Waltzispora planiangulata	+	+	+	+	+	+
Colatisporites multisetus		+	+			
Punctatisporites aerarius		+	+	+	+	
Corbulispora cancellata			+	+	+	+
Lophotriletes tribulosus				+	+	+
Convolutispora mellita				+		
Schulzospora campyloptera				+	+	+
Knoxisporites stephanephorus				+		+
Dictyotriletes castanaeformis				+	+	+
Knoxisporites cf. *ruhlandi*				+		
Dictyotriletes plumosus					+	+
Murospora aurita					+	
Microreticulatisporites densus					+	
Lycospora noctuina					+	+
Cingulizonates bialatus					+	+
Kraeuselisporites cf. *echinatus*					+	+
Chaetosphaerites pollenisimilis					+	+
Perotrilites tesselatus					+	+
Densosporites variabilis						+
Potoniespores delicatus						+
Schulzospora ocellata						+
Schulzospora plicata						+
Diatomozonotriletes cervicornutus						+
Densosporites dentatus						+
Pilosisporites venustus						+
Foveospores insculptus						+
Rotaspora fracta						+

Niekłonice 1

Formation	Sąpolno Calc. Sh. Fm.		Gozd Arkose Fm.		
Depth (m)	3003 - 3000	2991 - 2987	2991 - 2877	2681 - 2679	2530 - 2527
Miospore Subzone	Ma		Ma	Cl	
Miospores:					
Auroraspora macra	+	+	+	+	+
Knoxisporites triradiatus	+		+		
Lophozonotriletes excisus	+	+	+		
Endoculeospora gradzińskii	+		+		
Raistrickia corynoges	+	+	+	+	+
Grandispora cf. *lupata*	+				
Punctatisporites glaber	+	+	+		
Verrucosisporites nitidus				+	+
Retusotriletes incohatus	+	+	+		
Pustulatisporites uncatus		+			
Convolutispora major		+	+		
Indotriradites explanatus		+			
Knoxisporites literatus		+	+	+	+
Cyrtospora cristifera			+		
Convolutispora mellita			+	+	+
Discernisporites micromanifestus			+		
Knoxisporites pristinus			+		
Knoxisporites hederatus			+		
Corbulispora cancellata			+		+
Foveosporites insculptus			+		
Umbonatisporites distinctus			+		+
Dictyotriletes papillatus			+		
Rupospora polyptycha			+		
Anaplanosporites baccatus				+	+
Crassispora trychera				+	+
Colatisporites multisetus				+	+
Kraeuselisporites hibernicus				+	+
Prolycospora claytonii				+	+
Retusotriletes occultus				+	
Reticulatisporites planus				+	
Schopfites delicatus					+
Raistrickia clavata					+
Tripartites incisotrilobus					+

* probably redeposited

Biały Bór 1

Member	Trzebiechowo Marl Member		
Depth (m)	2797 - 2796	2674 - 2673	2666 - 2664
Miospore Subzone	Ma$_{2-4}$	Cl$_1$	
Miospores:			
Auroraspora macra	+	+	+
Convolutispora major	+		+
Convolutispora mellita	+	+	+
Corbulispora cancellata	+	+	+
Discernisporites micromanifestus	+	+	
Endoculeospora setacea	+		
Foveosporites appositus	+		
Knoxisporites literatus	+	+	
Knoxisporites hederatus	+		
Knoxisporites pristinus	+		
Knoxisporites triradiatus	+		
Knoxisporites margarethae	+	+	
Leiotriletes sphaerotriangularis	+	+	
Murospora sublobata	+		
Punctatosporites scabrosus	+	+	
Pustulatisporites uncatus	+	+	
Schopfites delicatus	+	+	
Tripartites incisotrilobus	+		
Tumulispora rarituberculata	+	+	
Tumulispora variverrucata	+		
Verrucosisporites nitidus	+	+	
Anaplanisporites delicatus		+	
Acanthotriletes socraticus		+	
Baculatisporites fusticulus		+	
Bascaudaspora submarginata		+	+
Colatisporites multisetus		+	+
Crassispora trychera		+	
Dictyotriletes glumaceus		+	
Dictyotriletes membranireticulatus		+	
Prolycospora claytonii		+	+
Raistrickia clavata		+	
Spelaeotriletes pretiosus		+	
Umbonatisporites distinctus		+	
Dictyotriletes planus			+

Karsina 1

Formation	Drzewiany Sandstone Fm.					
Depth (m)	2649 - 2646	2594 - 2591	2538 - 2535	2484 - 2481	2249 - 2242	2240 - 2239
Miospore Subzone / Zone	Cl				Pu	
Miospores:						
Anaplanisporites baccatus	+	+	+	+	+	+
Auroraspora macra	+	+	+	+	+	+
Auroraspora panda	+	+			+	
Colatisporites multisetus	+	+	+	+	+	+
Convolutispora mellita	+	+	+	+	+	
Gorgonispora multiplicabilis	+	+	+		+	+
Leiotriletes sphaerotriangularis	+	+	+	+	+	
Prolycospora claytonii	+	+	+	+	+	+
Punctatisporites aerarius	+	+	+	+	+	
Raistrickia corynoges	+	+	+			
Raistrickia clavata	+	+	+		+	
Retusotriletes occultus	+					
Schopfites claviger	+		+	+	+	+
Schopfites delicatus	+	+	+	+	+	+
Auroraspora solisortus		+				
Retusotriletes circularis		+				
Crassispora trychera		+			+	+
Knoxisporites hederatus		+	+			
Retusotriletes incohatus			+			+
Baculatisporites fusticulus			+			
Discernisporites micromanifestus					+	
Lycospora pusilla					+	
Rugospora minuta					+	+

Ostracod species range charts

Brda 1

Formation/Member	Sąpolno Calc. Sh. Fm.	Trzebiechowo Marl Member		
Depth (m)	2855-2771.5	2723-2718	2682-2496	2433-2257
Benthic ostracod assemblages	Vn		Vn	P-T
Ostracodes:				
Pseudoleperditia venulosa	+	+	+	
Shishaella alekseevae	+	+	+	+
Coryellina triceratina	+	+	+	
Amphissites similaris	+		+	+
cutiangulata acutiangulata	+	+	+	+
Acutiangulata rara	+	+	+	
Chamishaella obscura			+	
Shivaella longa			+	+
Sulcocavellina tersiensis			+	
Bairdia lecta			+	
Cribroconcha quasicornigera				+
Marginia tschigovae				+
Carboprimitia elata				+
Editia cf. *kiselensis*				+

Biesiekierz 1

Formation	Grzybowo Shale Fm.
Depth (m)	2917.6-2890.7
Benthic ostracod assemblages	R-F
Ostracodes:	
Shishaella electa	+
Beyrichiopsis fortis	+
Glyptolichwinella annularis	+
Acutiangulata quadrata	+
Carbonita fabulina	+

Chmielno 1

Formation	Gozd Arcose Fm.		
Depth (m)	3962-3952	3826-3734	3599-3588
Benthic ostracod assemblages	Vn	P-T	
Ostracodes:			
Namaya reticulata	+		
Pseudoleperditia venulosa	+		
Coryellina triceratina	+		
Shishaella alekseevae	+	+	
Shivaella longa	+		+
Amphissites similaris	+		
Sulcocavellina tersiensis	+		
Bairdia lecta	+		
Acutiangulata rara	+		
Richterina (R.) latior	+		
Acutiangulata acutiangulata	+	+	
Marginia tschigovae		+	
Cribroconcha postfoveata		+	
Graphiadactyllis reticulocostatus		+	+

Kłanino1

Formation	Sąpolno Calc. Sh. Fm.	Grzybowo Shale Fm.		Drzewiany Sandstone Fm.
Depth (m)	2782-2781	2672-2547.3	2467.1-2463.5	2416.4-2379
Benthic ostracod assemblages	Vn	P-T	R-F	
Ostracodes:				
Carboprimitia elata	+			
Amphissites similaris	+			
Marginia tschigovae		+		
Cribroconcha postfoveata		+		
Graphiadactyllis reticulocostatus		+		
Shishaella electa		+	+	+
Beyrichiopsis binodosus			+	+
B. fortis				+
Glyptolichwinella annularis			+	
Glyptopleura ruegensis			+	+
Acutiangulata quadrata			+	+

Daszewo R3P

Formation	Sąpolno Calc. Sh. Fm.		Gozd Arcose Fm.	
Depth (m)	3545-3544	3429-3290	3255.5-3243.5	3202-3199
Benthic ostracod assemblages	Vn	P-T		R-F
Ostracodes:				
Carboprimitia elata	+			
Coryellina triceratina		+	+	
Graphiadactyllis reticulocostatus		+	+	
Cribroconcha quasicornigera		+		
Autiangulata acutiangulata		+	+	
Beyrichiopsis binodosus				+
Acutiangulata quadrata				+

cal type II; Turnau, p. 13, pl. 5, fig. 18.
1985 *Hymenozonotriletes explanatus* (Luber) Kedo; Byvsheva, pp. 139-140, pl. 27, fig. 13.
1991 *Indotriradites explanatus* (Luber) Playford, pp. 103-104, pl. 3, figs 17, 18.

Remarks. Turnau (1978, pp. 12-13) noted, that in various papers, the concept of *H. explanatus* varied, probably because the species was originally too generally described, and not sufficiently illustrated. This author described two differing morphological types (type I and type II) that represented *H. explanatus* in the broad sense. At the present state of recognition of the world Carboniferous miospore floras, the concept of the discussed species is quite clear (see Byvsheva, 1985; Playford, 1990).

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APPENDIX 1 – LIST OF CONODONT, MIOSPORE AND OSTRACOD SPECIES

CONODONTS

Bispathodus aculeatus aculeatus (Branson & Mehl, 1934)
Bispathodus aculeatus anteposicornis (Scott, 1961)
Bispathodus spinulicostatus (Branson, 1934)
Bispathodus stabilis (Branson & Mehl, 1934)
Clydagnathus unicornis Rhodes, Austin & Druce, 1969
Elictognathus bialatus (Branson & Mehl, 1934)
Elictognathus laceratus (Branson & Mehl, 1934)
Gnathodus cuneiformis Mehl & Thomas, 1947
Hindeodus aff. *cristulus* (Youngquist & Miller, 1949)
"*Hindeodus*" *crassidentatus* (Branson & Mehl, 1934)
Neopolygnathus carina (Hass, 1959)
Neopolygnathus communis (Branson & Mehl, 1934)
Pandorinellina plumula (Rhodes, Austin & Druce, 1969)
Polygnathus distortus Branson & Mehl, 1934
Polygnathus flabellus (Branson & Mehl, 1934)
Polygnathus inornatus Branson, 1934
Polygnathus purus purus Voges, 1959
Polygnathus purus subplanus Voges, 1959
Polygnathus radinus (Cooper, 1939)
Polygnathus spicatus Branson, 1934
Polygnathus symmetricus Branson, 1934
Polygnathus triangulus Voges, 1959
Polygnathus vogesi Ziegler, 1962
Pseudopolygnathus dentilineatus Branson, 1934
Pseudopolygnathus multistriatus Mehl & Thomas, 1947
Pseudopolygnathus nodomarginatus (Branson, 1934)
Pseudopolygnathus primus Branson & Mehl, 1934
Siphonodella cooperi Hass, 1959
Siphonodella crenulata (Cooper, 1939)
Siphonodella duplicata (Branson & Mehl, 1934)
Siphonodella isosticha (Cooper, 1939)
Siphonodella obsoleta Hass, 1959
Siphonodella quadruplicata (Branson & Mehl, 1934)
Siphonodella sulcata (Huddle, 1934)

MIOSPORES

Acanthotriletes socraticus Neves & Ioannides, 1974
Anapiculatisporites concinnus Playford, 1962
Anaplanisporites baccatus Hoffmeister, Staplin & Malloy, 1955
Auroraspora asperella (Kedo) Van der Zwan, 1980
Auroraspora macra Sullivan, 1968
Auroraspora panda Turnau, 1978
Auroraspora solisorta Hoffmeister, Staplin & Malloy, 1955
Baculatisporites fusticulus Sullivan, 1968
Bascaudaspora submarginata (Playford) Higgs, Clayton & Keegan, 1988
Cingulizonates bialatus (Waltz) Smith & Butterworth, 1967
Chaetosphaerites pollenisimilis (Horst) Butterworth & Williams, 1958
Colatisporites multisetus (Luber) Avkhimovitch & Turnau, 1994
Converrucosisporites curvatus (Naumova) Turnau, 1975
Converrucosisporites horridus (Ishchenko) Turnau, 1979 var. *trigonalis* Jachowicz, 1967
Convolutispora major (Kedo) Turnau, 1978
Convolutispora mellita Hoffmeister, Staplin & Malloy, 1955
Corbulispora cancellata (Waltz) Bharadwaj & Venkatachala, 1971
Crassispora trychera Neves & Ioannides, 1974
Cymbosporites acutus (Kedo) Byvsheva, 1985
Cyrtospora cristifera (Luber) van der Zwan
Densosporites dentatus (Waltz) Potonié & Kremp, 1956
Densosporites variabilis (Waltz) Potonié & Kremp, 1956
Diaphanospora angusta (Haquebard) Playford & McGregor, 1993
Diatomozonotriletes cervicornutus (Staplin) Playford, 1963
Diatomozonotriletes saetosus (Haquebard & Barss) Hughes & Playford, 1961
Dictyotriletes castanaeformis (Horst) Sullivan, 1964
Dictyotriletes glumaceus (Byvsheva) Byvsheva, 1980
Dictyotriletes membranireticulatus Bertelsen, 1972
Dictyotriletes plumosus (Butterworth & Spinner) Neville & Williams, 1963
Dictyotriletes papillatus (Naumova) Byvsheva, 1963
Diducites versabilis (Kedo) Van Veen, 1981
Discernisporites micromanifestus (Haquebard) Sabry & Neves, 1971
Endoculeospora gradzinskii Turnau, 1975
Foveosporites appositus Playford, 1971
Foveosporites insculptus Playford, 1962
Gorgonispora multiplicabilis (Kedo) Turnau, 1978
Grandispora conspicua (Playford) Playford, 1964
Grandispora cornuta Higgs, 1975
Grandispora echinata Haquebard, 1957
Grandispora lupata Turnau, 1975
Grandispora upensis (Kedo) Byvsheva, 1980
Grandispora uncata (Haquebard) Playford, 1971
Indotriradites explanatus (Luber) Playford, 1991
Knoxisporites hederatus (Ishchenko) Playford, 1963
Knoxisporites literatus (Waltz) Playford, 1976
Knoxisporites margarethae Hughes & Playford, 1961
Knoxisporites pristinus Sullivan, 1968
Knoxisporites ruhlandi Doubinger & Raucher, 1966
Knoxisporites stephanephorus Love, 1960
Knoxisporites triradiatus Hoffmeister, Staplin & Malloy, 1955
Kraeuselisporites echinatus Owens, Mishell & Marshall, 1976
Kraeuselisporites hibernicus Higgs, 1975
Leiotriletes sphaerotriangularis (Loose) Potonié & Kremp, 1954
Lophotriletes tribulosus Sullivan, 1968
Lophozonotriletes excisus Naumova, 1953
Lycospora noctuina Butterworth & Williams, 1958
Lycospora pusilla (Ibrahim) Somers, 1972

Microreticulatisporites densus (Love) Sullivan, 1964
Monilospora culta (Byvsheva) Byvsheva, 1980
Murospora aurita (Waltz) Playford, 1962
Murospora sublobata (Waltz) Playford, 1962
Orbisporis convolutus Butterworth & Spinner, 1967
Perotrilites ordinarius Turnau, 1979
Perotrilites tessellatus (Staplin) Neville, 1973
Pilosisporites venustus Sullivan & Marshall, 1966
Potoniespores delicatus Playford, 1962
Prolycospora claytonii Turnau, 1978
Punctatisporites aerarius Butterworth & Williams, 1958
Punctatisporites glaber (Naumova) Playford, 1962
Punctatisporites pseudobesus Playford, 1962
Punctatosporites scabrosus (Kedo) Turnau
Pustulatisporites uncatus (Kedo) Byvsheva, 1985
Raistrickia clavata (Haquebard) Playford, 1964
Raistrickia condylosa Higgs, 1975
Raistrickia corynoges Sullivan, 1968
Raistrickia variabilis Dolby & Neves, 1970
Reticulatisporites planus Hughes & Playford
Retispora macroreticulata (Kedo) Byvsheva, 1985
Retispora lepidophyta (Kedo) Playford, 1976
Retusotriletes circularis Turnau, 1978
Retusotriletes incohatus Sullivan, 1964
Retusotriletes occultus Turnau, 1978
Rotaspora fracta Schemel, 1950
Rugospora minuta Neves & Ioannides, 1974
Rugospora polyptycha Neves & Ioannides, 1974
Rugospora radiata (Jushko) Byvsheva, 1985
Schopfites claviger Sullivan, 1968
Schopfites delicatus Higgs emend. Higgs, Clayton & Keegan, 1988
Schulzospora campyloptera (Waltz) Hoffmeister, Staplin & Malloy, 1955
Schulzospora ocellata (Horst) Potonié & Kremp, 1956
Schulzospora plicata Butterworth & Williams, 1958
Spelaeotriletes balteatus (Playford) Higgs, 1996
Spelaeotriletes obtusus Higgs, 1975
Spelaeotriletes pretiosus (Playford) Neves & Belt, 1970
Tripartites inciso-trilobus (Naumova) Karczewska & Turnau, 1974
Tumulispora malevkensis (Kedo) Turnau, 1978
Tumulispora ordinaria Staplin & Jansoniu, 1964
Tumulispora rarituberculata (Luber) Potonie, 1966
Tumulispora variverrucata (Playford) Staplin & Jansonius, 1964
Umbonatisporites abstrusus (Playford) Clayton, 1970
Umbonatisporites distinctus Clayton, 1970
Vallatisporites pusillites (Kedo) Dolby & Neves, 1970
Verrucosisporites nitidus Playford, 1964
Waltzispora planiangulata Sullivan, 1964

OSTRACODS

Acutiangulata acutiangulata (Posner, 1960)
Acutiangulata quadrata Robinson, 1978
Acutiangulata rara Bushmina, 1978
Amphissites similaris Morey, 1936
Bairdia lecta Bushmina, 1970
Beyrichiopsis fortis Jones & Kirkby, 1886
Beyrichiopsis binodosus Błaszyk & Natusiewicz, 1973
Carbonita fabulina (Jones & Kirkby, 1879)
Carboprimitia elata Tschigova, 1977
Chamishaella obscura Tschigova, 1977
Coryellina triceratina (Posner, 1955)
Cribroconcha quasicornigera Bushmina, 1968
Cribroconcha postfoveata Gründel, 1975
Editia cf. *kiselensis* (Posner in Tschigova, 1960) s. Robinson, 1978
Glyptopleura ruegensis Blumenstengel, 1977
Glyptolichwinella annularis (Kummerow, 1939)
Graphiadactyllis reticulocostatus Gründel, 1975
Marginia tschigovae (Palant, 1960)
Namaya reticulata Green, 1963
Pseudoleperditia venulosa (Kummerow 1939)
Richterina (Richterina) latior Rabien, 1960
Shishaella alekseevae Tschigova, 1977
Shishaella electa Tschigova, 1977
Shivaella longa (Tschigova, 1960)
Sulcocavellina tersiensis Bushmina, 1968

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Streszczenie

STRATYGRAFIA DOLNEGO KARBONU (MISSISIPPIANU) POMORZA ZACHODNIEGO: PORÓWNANIE ZON KONODONTOWYCH, MIOSPOROWYCH I MAŁŻORACZKOWYCH

Hanna Matyja, Elżbieta Turnau & Barbara Żbikowska

Przedstawiona w pracy biostratygrafia utworów dolnego karbonu strefy Koszalin–Wierzchowo Pomorza Zachodniego (Fig. 1) oparta jest na zintegrowanych badaniach konodontów, miospor i małżoraczków. Konodonty i małżoraczki pozyskano jedynie z utworów turneju. Zbadane materiały pochodziły z 25 otworów wiertniczych. Posłużono się podziałem litostratygraficznym Lipca (Lipiec & Matyja, 1998) przedstawionym schematycznie na Fig. 2. Dla przeprowadzonych wydzieleń biostratygraficznych wykorzystano stratygraficzne schematy zonalne: (1) "standardowy" schemat konodontowy oparty na linii ewolucyjnej rodzaju *Si-*

phonodella i "po-siphonodellowy" schemat Lane *et al.* (1980), (2) lokalny schemat miosporowy zaproponowany przez Turnau (1978, 1979) i zmieniony/uzupełniony przez Avkhimovitch & Turnau (1994) i Matyję & Stempień-Sałek (1994), (3) wprowadzony w niniejszej pracy podział oparty na małżoraczkach bentonicznych. Wyróżniono także jedną zonę standardowego podziału opartego na entomozoidach.

Nie we wszystkich zespołach konodontów napotkano gatunki przewodnie, toteż w licznych przypadkach można było określić jedynie przedziały obejmujące dwie lub trzy zony (por. Fig. 3). Typowe zespoły gatunków konodontów zilustrowano na Fig. 4–6.

Zespoły gatunków miospor typowych dla zon lokalnego schematu turneju i wizenu zilustrowano na Fig. 7, 10–11, a charakterystykę zmodyfikowanego schematu dla turneju i wizenu pokazano na Fig. 8. Schemat ten można na podstawie pierwszych pojawień gatunków zonalnych korelować ze schematem miosporowym dla rejonów typowych pięter dolnego karbonu Wysp Brytyjskich (Fig. 9).

Wprowadzony w niniejszej pracy podział biostratygraficzny dla turneju, oparty na małżoraczkach bentonicznych, obejmuje trzy zespoły, z których najniższy podzielono na dwa podzespoły. Charakterystykę schematu przedstawiono na Fig. 12, a gatunki typowe dla poszczególnych zespołów i podzespołów zilustrowano na Fig. 13–16.

Konodonty, miospory i małżoraczki pozyskano niejednokrotnie z tych samych profili, z wzajemnie przekładających się poziomów opróbowania. Pełną dokumentację dotyczącą głębokości pobrania prób i występowania gatunków zamieszczono w dodatku (Appendix 2). Dzięki zintegrowaniu badań można było ustalić wzajemne relacje pomiędzy poszczególnymi podziałami, co przedstawiono na Fig. 17.

Przeprowadzone badania pozwoliły na określenie wieku formacji karbońskich i ich granic (Fig. 18, 19) oraz ustalenie położenia granic chronostratygraficznych – granicy dewon/karbon i turnej/wizen. W terminologii zon konodontowych, karbońska część formacji iłowców wapnistych z Sąpolna zawiera się w przedziale *sandbergi* - dolna *crenulata*, tylko na południowym wschodzie (ogniwo margli z Trzebiechowa) utwory te sięgają aż do zony *typicus*. Granica formacji iłowców wapnistych z Sąpolna z nadległą formacją piaskowców arkozowych z Gozdu jest diachroniczna; na zachód od linii Kurowo 1 - Wierzchowo 10 przebiega ona w zonie dolna *crenulata*, a na wschód od tej linii w zonie *isosticha*–górna *crenulata*, lub w dolnej części poziomu *typicus*. Formacja iłowców wapnistych z Grzybowa i formacja wapieni oolitowych z Kurowa są w przybliżeniu równowiekowe mieszcząc się w zakresie zony *typicus*. Formacja piaskowców kwarcowych z Drzewian obejmuje najwyższy turnej po górny wizen (brygant).

Potwierdzono obecność luki stratygraficznej obejmującej pogranicze systemów dewońskiego i karbońskiego. Brakujące zony konodontowe to środkowa *praesulcata, sulcata, duplicata*, (lub, na podstawie goniatytów, za Korejwo (1979, 1993), tylko dolna *duplicata*) i ich odpowiedniki w zonacji miosporowej. Luka ta nie manifestuje się żadnymi widocznymi oznakami przerwy w sedymentacji lub niezgodnością. Ustalenie położenia granicy turnej/wizen jest trudne z powodu braku diagnostycznej fauny. Postawiono ją w przybliżeniu w poziomie pierwszego pojawienia się gatunku miospor *Lycospora pusilla* Somers.