

# MIOspore TAXONOMY AND STRATIGRAPHY OF UPPER DEVONIAN AND LOWERMOST CARBONIFEROUS IN WESTERN POMERANIA (NW POLAND)

Marzena STEMPIEŃ-SALEK

*Polish Academy of Sciences, Institute of Geological Sciences, ul. Twarda 51/55, 00-818 Warszawa, Poland,  
e-mail: mstempie@twarda.pan.pl*

Stempień-Sałek, M., 2002. Miospore taxonomy and stratigraphy of Upper Devonian and lowermost Carboniferous in western Pomerania (NW Poland). *Annales Societatis Geologorum Poloniae*, 72: 163–190.

**Abstract:** Five local miospore zones, six subzones and two assemblages are distinguished for the Frasnian to lower Tournaisian deposits in the Kołobrzeg region (western Pomerania): assemblage I, *Membrabaculisporis radiatus-Tholisporites densus* (RD), *Membrabaculisporis radiatus-Cymbosporites boafeticus* (RB), *Lagenoisporites immensus-Diducites poljessicus* (IP) Zone, assemblage II, *Tumulispora rarituberculata* (Ra) and *Convolutispora major* (Ma) Zone. The first three biozones and the two assemblages are new in this region. The local miospore zones distinguished in western Pomerania are correlated with the European standard miospore and conodont zonations. Two new miospore species and one new variety are described, two species is emended.

**Key words:** Frasnian, Famennian, lowermost Carboniferous, NW Poland, miospores, stratigraphy.

*Manuscript received 6 November 2001, accepted 13 June 2002*

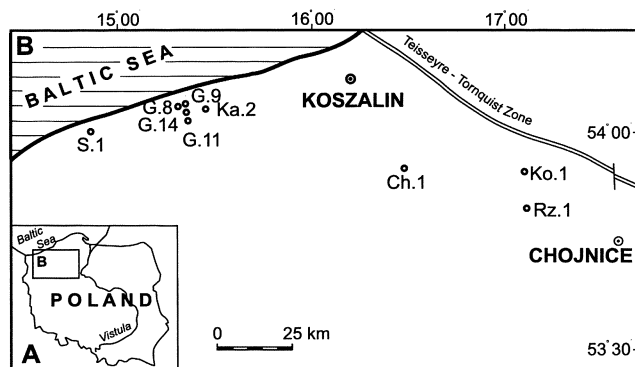
## INTRODUCTION

The main purpose of this study was to determine, using palynological methods, the stratigraphical position of the Człuchów, Kłanino, Sapolno Calcareous Shale, and Gozd Arkose formations of western Pomerania. The zones of the miospore zonal scheme for Famennian and Lower Carboniferous of that area established by Turnau (1978, 1979) are rather wide. The present studies have allowed to establish a provisional zonation for the Frasnian and lower part of the Famennian, and to subdivide some of the previously erected zones. The studied borehole sections are dated on conodonts, which permits to define the boundaries of the miospore zones in terms of the “standard” conodont zonation. The preliminary results of my studies, concerning the upper Famennian and lowermost Carboniferous have been published in the paper by Matyja & Stempień-Sałek (1994), and those on the Frasnian and lowermost Famennian are summarised in Stempień-Sałek (2000).

The palynological material on which this work is based is derived from the Strzeżewo 1, Gorzysław 8, Gorzysław 9, Gorzysław 11, Gorzysław 14 and Karcino 2 boreholes drilled in the area near Kołobrzeg, and from Chmielno 1 and Rzeczenica 1 boreholes from the area to south-east from Kołobrzeg (Fig. 1).

## PREVIOUS PALYNOLOGICAL STUDIES OF UPPER DEVONIAN AND LOWER CARBONIFEROUS OF WESTERN POMERANIA

The earliest results of palynological studies concerning the Devonian–Carboniferous succession of western Pomerania were published in the seventies of the twenty century. The evolution of palynostratigraphical divisions of the Upper Devonian–lowermost Carboniferous is shown in figure 2. The first account of the Carboniferous miospore assemblages from the study area was that by Krawczyńska-Grocholska (1975), who included the deposits from the Sarbinowo 1 borehole in the Namurian and Westphalian. Subsequently, the strata included by this author in the Namurian were assigned by Turnau (1979) to the Viséan. Turnau (1975, 1978, 1979) studied miospore assemblages from more than thirty borehole sections and proposed a miospore zonal scheme including eleven zones, five for the Famennian, two for the Tournaisian, three for the Viséan and one for the Westphalian. The youngest Tournaisian zone of this scheme, i.e. the *Prolycospora claytonii* (Cl) Zone was divided into three subzones. Avkhimovitch & Turnau (1994) revised that division, distinguishing only two subzones, and presented a new proposal of palynological correlation of the



**Fig. 1** Position of western Pomerania (A) and location of studied boreholes (B): S.1 – Strzeżewo 1, G.8 – Gorzysław 8, G.9 – Gorzysław 9, G.11 – Gorzysław 11, G.14 – Gorzysław 14, Ka. 2 – Karcino 2, Ch.1 – Chojnice 1, Ko.1 – Koczała 1, Rz.1 – Rzecznica 1

lower zonal boundary (Fig. 2). The present author (in Matyja & Stempień-Sałek, 1994) upgraded the scheme proposed by Turnau (1978, 1979) introducing two subzones of the *Tumulispora rarituberculata* (Ra) Zone, and four of the *Convolutispora major* (Ma) Zone (Fig. 2). This subdivision allows a more precise correlation of the local scheme with that for northwestern Europe (Higgs *et al.*, 1988).

Other contributions to the miospore stratigraphy of the upper Famennian and Carboniferous of the study area are those by Górecka & Parka (1980), and Kmieciak (1991, 1995). The former authors included in the Westphalian the deposits from the Koszalin IG 1 borehole assigned by Turnau (1979) to the Viséan. The latter author studied some upper Famennian to Stephanian deposits, and distinguished 8 miospore zones of the northwestern European scheme. This results are not shown in figure 2 as they were published in a brief conference abstract, without photographic documentation and species range charts.

In sum the miospore stratigraphic scheme in western Pomerania for the Devonian and Carboniferous, includes more than ten zones distinguished for the Famennian to Stephanian (Turnau, 1978, 1979; Kmieciak, 1986). Some of the zones, however, are very wide, especially those for the Famennian. The Frasnian in Pomerania has not been, till now, studied by palynologists.

The problem of the presence and extent of the stratigraphic gap at the Devonian–Carboniferous boundary has been the concern of biostratigraphers for a long time. Varying opinions on this matter are illustrated in figure 2. The presence of a gap was first suggested by Turnau (1978), and it was discussed, in the terms of miospore zonation, in Clayton & Turnau (1990) and Avkhimovitch *et al.* (1993a). The extent of the gap was first defined in terms of the conodont zonation in Matyja & Turnau (1989), it was also discussed in Matyja & Stempień-Sałek (1994) and Matyja *et al.* (2000). In Matyja & Stempień-Sałek paper, the present author suggested that the upper extent of the gap coincides with the lower boundary of the *Krauselisporites hibernicus-Umbonatisporites distinctus* (HD) Zone of the division of Higgs *et al.* (1988). Previously, it was considered that the gap ends slightly below (Clayton & Turnau, 1990), or slightly above (Avkhimovitch *et al.*, 1993a) this level.

## MATERIAL AND METHODS

The palynological samples were black, dark grey and grey shales, claystones and mudstones some of which were intercalations within carbonates. Standard laboratory methods were employed. Samples were crushed and immersed in hydrochloric acid to remove carbonates. Subsequently, the mineral matter was dissolved in hydrofluoric acid, and the organic residues were oxidated using fuming nitric acid. This was followed by heavy liquid flotation using solution of cadmium-jodate + potassium-jodate of specific weight  $2.2 \text{ g/cm}^3$ . Slides were prepared using elvacite or glycerine jelly. The number of the samples processed was 125, and 83 of these contained determinable spores. Two hundred sixty five slides were prepared.

## GEOLOGICAL BACKGROUND

### GEOLOGICAL SITUATION

Western Pomerania is dissected by the Teisseyre tectonic zone called within its Polish part the Teisseyre–Tornquist zone (Dadlez, 1990, 1993; see also Fig. 1). The zone forms also the south-eastern limit of the East European Platform. The Teisseyre–Tornquist zone is characterized by high mobility expressed by high rate of sedimentation, erosion and tectonics. In the younger Palaeozoic, these processes increased gradually and rhythmically from the Late Devonian up to the Late Carboniferous (Dadlez, 1978).

In western Pomerania, the Devonian–Carboniferous succession rests unconformably on the Ordovician and Silurian graptolite shales strongly folded due to the Caledonian orogeny. In the region of Kołobrzeg the Devonian rests on steeply deeping Caradocian shales (Dadlez, 1993). The Caledonian deformation in that area may be due to the oblique collision of small crustal blocks, related to the Baltica or Gondwana, with the East European craton (Dadlez, 1993). None of the boreholes studied reaches this older Palaeozoic substratum.

Sedimentation of the Devonian–Carboniferous cycle started probably in Early Devonian (Dadlez, 1978, 1990, 1993), and not later than the Eifelian (Łobanowski, 1968; Pajchłowa, 1968; Turnau, 1995), covering different units of the Silurian (Teller, 1974), and Ordovician (Bednarczyk, 1974). The Devonian deposits are developed in various facies. Generally, those older than the Upper Devonian are mostly siliciclastic rocks (Dadlez, 1978). In Late Devonian, or at the close of the Givetian, the discussed area was invaded by marine transgression leaving elastic and carbonate sediments. The next widening of the marine basin took place in the early Famennian, and regressive tendencies reigned during the late Famennian (Dadlez, 1993). The Carboniferous deposits, resting concordantly on the Devonian vary both vertically and laterally in facies development. They are represented by three main types of sediments. Starting from the oldest, they are clayey shales, arkosic sandstones and various limestones (marly, oolitic, dolomitic and other). Vertical displacements (the diastrophic movements toward the close of the Early Carboniferous) caused

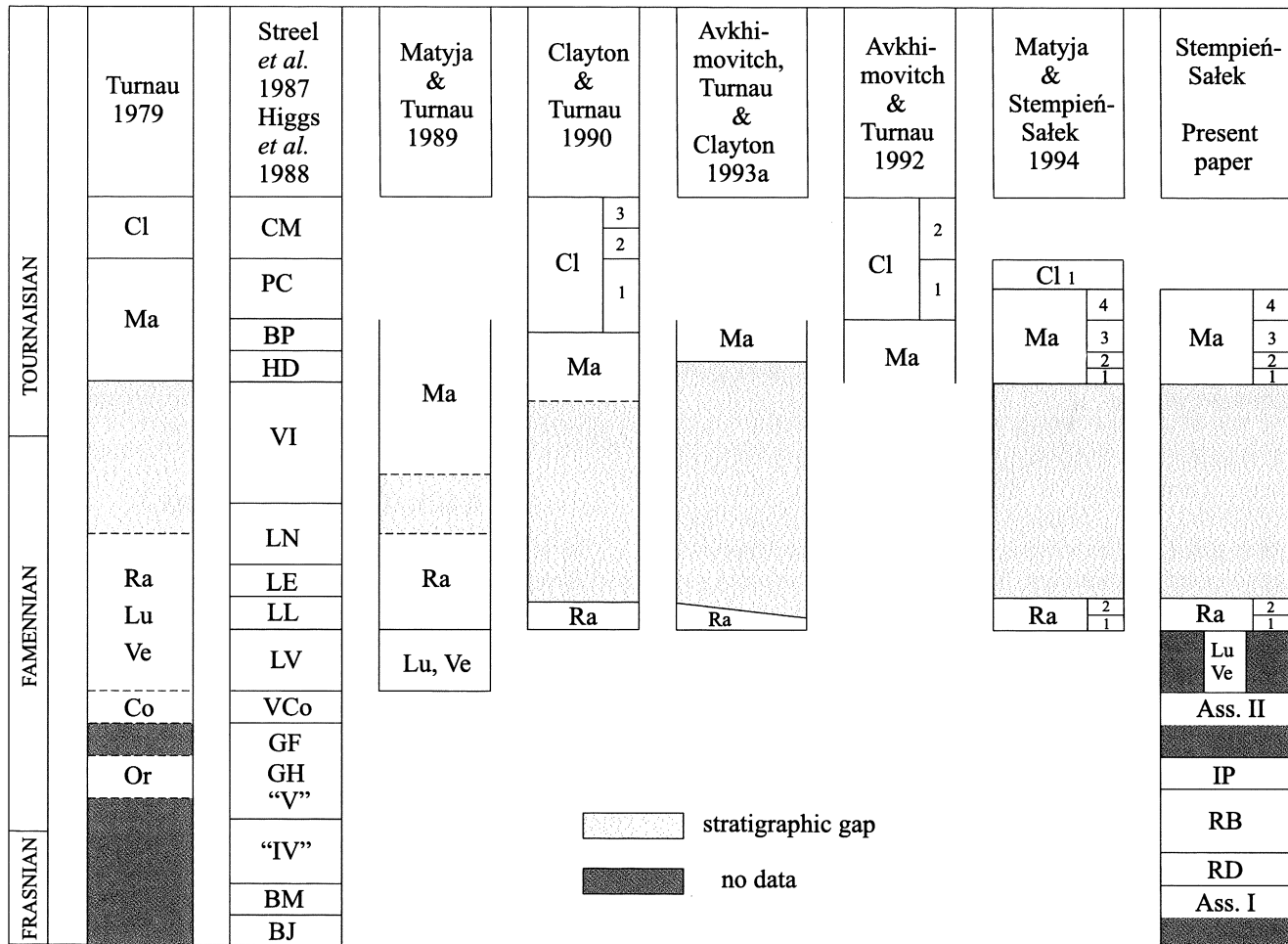


Fig. 2. Evolution of palynostratigraphical divisions of the Upper Devonian–lowermost Carboniferous in western Pomerania

the regional absence of the Namurian and Westphalian and the variable truncation of the Lower Carboniferous sediments. The Upper Carboniferous grey limnic sediments of coal-bearing association pass upwards into clastic sediments of red-bed association. The thickness of the Lower Carboniferous is at least 1500 m (Dadlez, 1993) or about 1300 m (Żelichowski, 1983, 1987).

Starting from the Late Devonian, there was a gradual and rhythmical intensification of erosional processes and tectonic movements. The main phases of these processes took place (1) at the beginning of the Carboniferous, and (2) at the end of the Early and the beginning of the Late Carboniferous. The main structural reorganisation and strongest erosion of the Devonian–Carboniferous succession took place at the Carboniferous–Permian transition, after the block movements in the area. Due to these movements, the discussed region is divided into tectonic blocks of various sizes, one of which is the Kołobrzeg block (Dadlez, 1990, 1993). The erosion removed, first of all, the Upper Carboniferous deposits, subsequently, to a lesser extent, the Lower Carboniferous ones. The Devonian deposits are still less affected, but erosion has reached in places the Middle Devonian (Dadlez, 1978). The Devonian–Carboniferous succession of complicated structure is overlain discordantly by red, clastic deposits of the Lower Permian, Zechstein

clastic-carbonate-evaporitic rocks, and the Mesozoic successions.

LITHOSTRATIGRAPHY

The first, informal lithostratigraphic division of the Devonian–Carboniferous succession of western Pomerania was proposed by Dadlez (1978) who distinguished several lithostratigraphic units called complexes and sub-complexes. The division by Dadlez was subsequently modified and complemented by Miłaczewski (1979, 1980, 1986, 1987), Żelichowski (1983, 1987), and Matyja (1993) who distinguished in the Upper Devonian sequence five (informal) formations and four members. Most of these formations correspond to the “complexes” of Dadlez (1978), and have the same names, but the members are new units. Recently, Lipiec (Lipiec & Matyja, 1998) introduced a lithostratigraphic scheme for the Lower Carboniferous. It includes seven formations and two members.

The lithostratigraphic division adopted in this paper (Figs 3 and 4) is that by Matyja (1993, 1998) and Lipiec & Matyja (1998).

In Człuchów Formation (boreholes: Strzeżewo 1, Gorzysław 8, Gorzysław 11 and Gorzysław 14) Matyja (1993) distinguished five members, namely the Unisław, Strze-

żewo, Gorzysław, Bielica, and Gościno members. The Uniśław and Gościno members are not represented in the boreholes studied (Fig. 3). The thickness of the Człuchów Formation in this region varies from 400 m to 700 m.

The Strzeżewo Member, lowest of the investigated units, has been pierced in the Strzeżewo 1, and Gorzysław 8, 11, 14 boreholes. The unit includes monotonous, thin bedded, almost black bituminous shales and marly shales and subordinate micritic, more or less marly, limestones. The shales include pyrite aggregates and rare fossils characteristic mainly of pelagic environment, such as entomozocean ostracods and tentaculitids. Plant detritus and land plant spores are present.

The Gorzysław Member (boreholes Gorzysław 8 and 14, Karcino 2) includes mainly grey marls and nodular limestones. Contribution of shales in this unit is distinctly smaller than in the underlying member. The nodular limestones often contain crinoid debris, articulate brachiopods, agglutinated foraminifers, benthic and entomozocean ostracods as well as cephalopods, tentaculitids and conodonts. In some sections, crinoid-bryozoan wackestone with rare coral debris and chaetetid fragments are present. Thin shale partings are rich in miospores and acritarchs.

The Bielica Member (borehole Gorzysław 8) includes light micritic limestones with accumulations of bryozoan debris, brachiopods, ostracods, and crinoids, as well as massive micritic limestones with dispersed crinoid detritus, bryozoans, coral colonies, less commonly with stromatoporoids, algae, conodonts and miospores.

In the region of Kołobrzeg, the Kłanino Formation (boreholes Gorzysław 8 and 9) is typified by predominance of carbonates, mainly laminated, sandy grainstones with algae, foraminifers, gastropods, ostracods, crinoidal detritus, conodonts and miospores, and dasycladacean grainstones with intraclasts and almost devoid of organic remains. The thickness of the Kłanino Formation in the region of Kołobrzeg is 150 m.

The Sapolno Calcareous Shale Formation (boreholes: Gorzysław 8 and 9, Karcino 2, Rzeczynica 1 and Chmielno 1) includes the uppermost Devonian and lowermost Carboniferous deposits. Grey, marly limestones and marls prevail within the lower, Devonian part of the formation. They contain abundant fossils of which the most important are foraminifers, ostracods, stromatoporoids, crinoids, brachiopods, conodonts and miospores (Matyja & Stempień-Sałek, 1994), also acritarchs (Stempień-Sałek, 1996). Such deposits are characteristic for shallow environment of marly-carbonate ramp developed below the wave base level but within the photic zone (Matyja, 1998). The younger, Carboniferous part of the formation includes mainly dark grey and black, finely laminated claystones, calcareous claystones, marls and limestones (Lipiec & Matyja, 1998; Matyja *et al.*, 2000) containing abundant spores and infrequent acritarchs. Fauna is rare. The thickness of the Carboniferous part of the Sapolno Calcareous Shale Formation may exceed 300 m.

The Devonian–Carboniferous system boundary lies within this formation. This is a hidden stratigraphic gap. Its extent defined in the terms of the conodont zonation is from middle *praesulcata* to part of *sandbergi* zones (Fig. 4). The

boundary runs within a bed of black claystone and is not marked by any characteristic sedimentary features (Matyja 1993, 1998; Matyja & Stempień-Sałek, 1994).

The Lower Carboniferous Gozd Arkose Formation, the deposits of which have been pierced in the Chmielno 1 borehole, includes mainly clastic rocks. As a rule, the base of the formation is placed at the base of the first bed of arkosic sandstone. Various sandstones of grey colour, arkosic sandstones including pyroclastic material, dark grey mudstones and black claystones are common. Thin beds of shale, claystone and oolitic limestone occur subordinately. They contain rare foraminifers, crinoids, brachiopods, conodonts, miospores and acritarchs. The present paper concerns only the basal part of the formation.

### FAUNAL STRATIGRAPHY

In western Pomerania, the rocks of the Devonian–Carboniferous succession contain diverse fossils that make dating of these sediments possible. Ammonoids are rare and accordingly the ammonoid stages have not been distinguished. Biostratigraphy is based on conodonts, brachiopods, entomozooids, and miospores. In the following text, the author gives the borehole names only if they are concerned in the present paper (Fig. 1). Unless otherwise stated, all conodont data given below are after Matyja (1993) and Matyja *et al.* (2000).

The Człuchów Formation is dated on conodonts (Figs 3, 4), entomozocean ostracods and brachiopods. The oldest part of the Strzeżewo Member is dated as the conodont *punctata* Zone, and the top part as the Middle *triangularis* Subzone. In the region of Kołobrzeg, conodonts indicative of the Upper *hassi*, *jameiae*, or Lower *rhenana* zones/subzones have been found within this member (Figs 3, 4; boreholes Strzeżewo 1 and Gorzysław 8, 11). The overlying Gorzysław Member is dated in the Kołobrzeg region as the Upper *triangularis* and *crepida* zones (Figs 3, 4; boreholes Gorzysław 8, 14 and Karcino 2). In other regions of Pomerania, the lower part of the Gorzysław Member is dated as Middle *triangularis* Subzone, and its top part as the Upper *rhomboidea* Subzone. In the higher part of the Bielica Member, in the region of Kołobrzeg, there occur conodonts of the *marginifera* Zone (Figs 3, 4; borehole Gorzysław 8). In other parts of Pomerania, the Lower and the Upper *marginifera* subzones have been distinguished within this member. Entomozocean ostracods have been recorded from the Człuchów Formation by Żbikowska (1992). In the Strzeżewo Member, this author distinguished the *cicatricosa* Zone (the boreholes Gorzysław 8 and 11), the *sartenaeri* Zone (the borehole Gorzysław 8) and the *serratostriatanehdensis* Zone (the boreholes Gorzysław 8, 11 and Koczała 1). In the Gorzysław Member, the zones *sartenaeri* and *sigmoidale* have been distinguished. Brachiopods from the Człuchów Formation have also been determined. Matyja (1972) recorded several Devonian and Famennian species from the Bielica Member.

The Kłanino Formation is, in the region of Kołobrzeg, dated by means of conodonts as upper Famennian *expansa* Zone (Figs 3, 4). No other fauna has been recorded here. In other regions of Pomerania, the dating is more precise. The



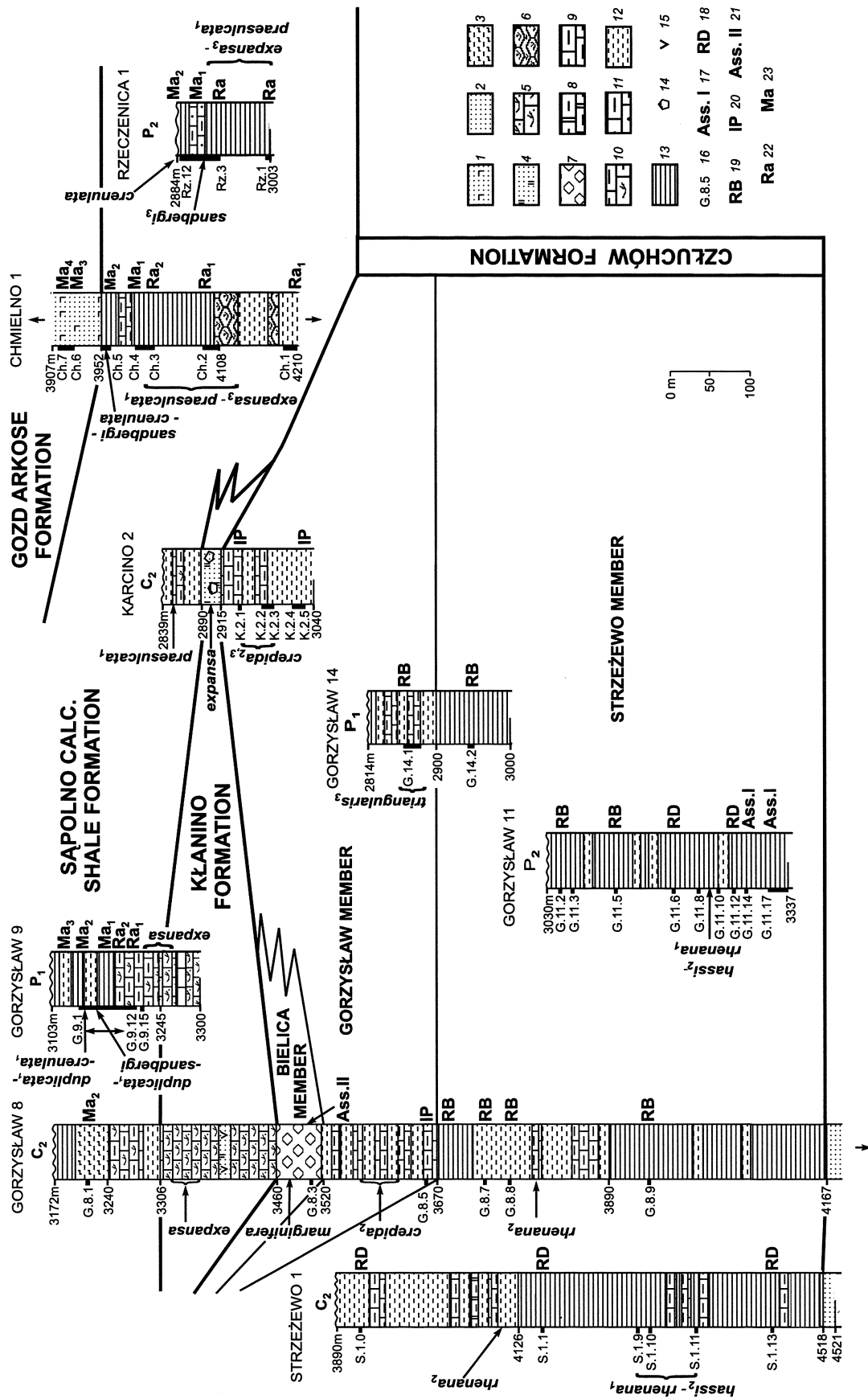


Fig. 3. Lithology, lithostratigraphy and stratigraphic biozonation (conodont and palynological zones) of studied boreholes. 1 – arcose sandstone, 2 – fine-grained quartz sandstone, 3 – mudstone, 4 – dolomitic sandstone, 5 – algal-foraminiferal-peloidal grainstone, 6 – nodular algal-foraminiferal-oolitic, packstone/grainstone, 7 – massive micritic limestone, 8 – marly dolomite, 9 – marly limestone, 10 – marly limestone to packstone, 11 – marly brachiopod-oolitic wackestone, 12 – marl, 13 – marly shale, 14 – conglomerate, 15 – anhedralite nodules, 16 – palynological sample, 17 – Assemblage I, 18 – RD – *Membraculispinis radiatus*, 19 – RB – *Membraculispinis radiatus* - *Cymbosporites boafeticus* Zone, 20 – IP – *Lagenosporites immensus* - *Didicites poljessicus* Zone, 21 – Assemblage II, 22 – Ra – *Tumulispora rarituberculata* zone, 23 – Ma – *Convolutispora major* zone

	FORMATIONS	Members	SPORE DIVISION		CONODONT DIVISION		
			BOREHOLES this paper			OTHER BOREHOLES in Pomerania	
			CI	Ma	Ra		
TOURNAISIAN	GOZD ARKOSE Fm		1	1	<i>typicus</i>		
			4	4	<i>isosticha</i> – up. <i>crenulata</i>		
	3		3	<i>l. crenulata</i>	X	X	
	2		2		X		
	1		1	<i>sandbergi</i>	X	X	
FAMENNIAN	SĄPOLNO CALCAREOUS SHALE Fm	BIELICA M GORZYŚLAW M.  STRZEŻEWO Member			<i>duplicata</i>		
					<i>sulcata</i>		
					<i>praesulcata</i>		
				<i>expansa</i>	X	X	
				<i>postera</i>			
				<i>trachytera</i>			
				<i>marginifera</i>		X	
				<i>Rhomboidea</i>		X	
				<i>Crepida</i>	X	X	
				<i>Triangularis</i>	X	X	
FRASNIAN	CZŁUCHÓW Fm			RB	<i>Linguiformis</i>		
					<i>rhenana</i>	X	X
					<i>jamiae</i>		
					<i>hassi</i>		
					<i>puncatata</i>		X
					<i>transitans</i>		
		<i>falsiovalis</i>					

stratigraphic gap   
 no data

Fig. 4. Generalized lithostratigraphy and biostratigraphy of Upper Devonian–lowermost Carboniferous in Western Pomerania

lower part of the formation corresponds to the Lower *expansa* Zone, though the basal part may belong to the *marginifera* Zone (Matyja, 1993). The top part of the formation is not younger than the Middle *expansa* Zone.

The stratigraphic position of the Sapolno Calcareous Shale Formation that belongs to the Famennian and Hasterian has been established on goniatites, brachiopods, conodonts, ostracods and trilobites. Goniatites are rare. Only Tournaisian *Pseudoarrietites dorsoplanus dorsoplanus* Schmidt, *P. ex gr. dorsoplanus dorsoplanus* Schmidt, and *Gattenpleura* sp. have been recorded in Wierzchowo 10 borehole, near the Chmielno 1 borehole (Korejwo, 1979, 1993). Brachiopods from the Famennian and Carboniferous part of the Sapolno Calcareous Shale Formation are described by Matyja (1976) and Korejwo (1993). In the region of Kołobrzeg, the basal part of the Sapolno Formation is dated on conodonts as *expansa-praesulcata* zones, and the top part as *sandbergi* or Lower *crenulata* Zone (Matyja *et al.*, 2000). In other regions of Pomerania, the dating is more precise – the lower part of the formation corresponds to the Upper *expansa* or Lower *praesulcata* subzones, and the upper to the Lower *crenulata* Subzone. Entomozoids date the

Devonian part of the formation as the *hemispherica-dichotoma* Zone (Żbikowska, 1992). Among trilobites, single specimens of *Moschoglossis* sp. indicate the lower and middle Tournaisian (Korejwo, 1976).

The present paper concerns only the basal part of the Gozd Arkose Formation. In this part no conodont faunas have been found. Brachiopods fauna is described by Korejwo (1993). Entomozoids indicate *latior* Entomozoid Zone (Żbikowska, 1992).

## PALYNOSTRATIGRAPHY

The miospore assemblages studied contain numerous stratigraphically important species known from the Devonian and the Lower Carboniferous of western and eastern Europe. However, it would have been difficult to adopt one of the zonal schemes for western (Streel *et al.*, 1987; Higgs *et al.*, 1988) or eastern Europe (Avkchimovitch, 1993; Avkchimovitch *et al.*, 1993a) because of quantitative and qualitative differences between the assemblages studied and those from the regions mentioned.



rect conodont data indicate that the SD Zone corresponds to the *punctata-hassi* zones. Thus, the base of the assemblage I is not older than the *punctata* Zone (Fig. 4). In the region of Kołobrzeg, the basal part of the Człuchów Formation is not dated on conodonts. In other regions of Pomerania, this part (included in the Unisław Member) corresponds to the *falsiovalis-punctata* zones and the basal part of the overlying Strzeżewo Member is thought to belong to the *punctata* Zone (Matyja, 1998).

#### ***Membrabaculisporis radiatus-Tholisporites densus* (RD) assemblage Zone**

The zone has been distinguished in the Strzeżewo 1 and Gorzysław 11 boreholes (Figs 1, 3). The lower zonal boundary is marked by the first appearance of *Membrabaculisporis radiatus*. Other species appearing close to and above this boundary are *Archaeoperisaccus concinnus*, *Convolutispora subtilis*, *Tholisporites densus*, *Laevigatosporites ovalis* and *Aneurospora greggsii*. Species *A. concinnus*, *C. subtilis*, *T. densus*, *S. triangulatus* and *S. acanthyrugosus* disappear at the upper zonal boundary. The characteristic assemblage includes the species mentioned above, and *Samarisporites triangulatus*, *Cristatisporites deliquescens* and *Cymbosporites acanthaceus*, also some forms of *Ancyrospora*, *Geminospora* and *Hystricosporites* (Fig. 5).

In eastern Europe, *M. radiatus* first appears in the *Archaeoperisaccus ovalis-Verrucosporites grumosus* (OG) Zone, and, more precisely, in its middle subzone *Cymbosporites vetlasjanicus* (CVe). It may be concluded that the RD zone for Pomerania corresponds to a higher part of the eastern European OG Zone. The miospore assemblages of the CVe Subzone occur in association with conodonts of the Lower *rhenana* Zone. It may be thus inferred that the base of the Pomeranian RD zone is not older than the *rhenana* Zone. This conclusion is in agreement with the results published by Matyja (1993) as in the boreholes studied the RD zonal assemblages are associated with conodont faunas indicative of Upper *hassi* or Lower *rhenana* zones (Fig. 3). Considering the conodont data, one can suppose that the RD zone may be the equivalent of a part of the "IV" zone of Streele *et al.* (1987) that corresponds to upper *hassi*-lower *triangularis* conodont zones.

#### ***Membrabaculisporis radiatus-Cymbosporites boafeticus* (RB) Zone**

The zone has been distinguished in the Gorzysław 8, G. 11 and G. 14 boreholes (Figs. 1, 3). The lower boundary of the zone is marked by the first appearance of *Cymbosporites boafeticus* and *C. vetlasjanicus*. *Membrabaculisporites radiatus* and do not range above the upper boundary of the zone and *Cristatisporites deliquescens* disappears in the lower part of the zone. The characteristic assemblage includes the index species and *Cristatisporites deliquescens*, *Laevigatosporites ovalis*, *Aneurospora greggsii*, *Apiculiretusispora nitida*, *Diducites radiatus*, *Perotrilites magnus*, *Retusotrilites planus*, *R. incohatus*, *R. pychovi* and also forms belonging to *Ancyrospora*, *Geminospora* and *Hystricosporites* (Fig. 5).

In Belorussia, *Cymbosporites boafeticus* first appears in an upper part of the *Archaeoperisaccus ovalis-Verruco-*

*sisporites grumosus* (OG) Zone (Obukhovskaya, 1986) which corresponds to the conodont *rhenana* Zone. The stratigraphic distribution of *Cristatisporites deliquescens* is wide. On the Russian Platform, the species disappears at the top of the *Cristatisporites deliquescens-Verrucosporites evlanensis* (DE) Zone that ranges to the uppermost *gigas* Zone (Avkhimovitch *et al.* 1993b). In Canada, the range of *C. deliquescens* extends into the lowermost part of the *torquata-gracilis* Zone, i.e. also to the conodont Lower *triangularis* Zone (Richardson & McGregor, 1986). It may be thus conjectured that the lower boundary of the RB zone is not older than the conodont *rhenana* Zone and the upper one is not younger than the *triangularis* Zone.

This is consistent with the direct conodont data (see Fig. 3) which indicate that the RB zone corresponds to the Upper *rhenana* and *triangularis* zones, and to Entomozocean *cicatricosa-sartenaeri* zones (Matyja, 1993).

The RB miospore assemblages do not contain species which would allow palynological correlation with the Ardenne-Rhine regions, but on conodont data one may suppose that the zone is the equivalent of a higher part of the zone "IV" and with zone "V" of the division by Streele *et al.* (1987).

#### ***Lagenosporites immensus-Diducites poljessicus* (IP) Zone**

The zone has been distinguished in the Gorzysław 8, and Karcino 2 boreholes (Figs 1, 3). The lower boundary of the IP zone is marked by the first appearance of *Lagenosporites immensus* and *Diducites poljessicus*. Other species appearing above and close to the boundary are *Corbulispora vimineus* and *Lophozonotrilites curvatus*. The last occurrence of *Laevigatosporites ovalis*, *Cymbosporites boafeticus* and *Corbulispora vimineus* has been recorded from the upper part of the zone. The characteristic assemblage includes, beside the species listed above, *Aneurospora greggsii* and *Hystricosporites* spp (Fig. 5).

On the Russian Platform *Lagenosporites immensus* first appears in the *Convolutispora zadonica* (Za) Subzone of the *Cyrtospora cristifer-Diaphanospora zadonica* (CZ) Zone, and the acme of its occurrence is in the *Lagenosporites immensus* (Im) Zone. *Diducites poljessicus* appears also in the Im Zone. It seems plausible that the IP zone is the equivalent of the eastern European Za Subzone and the Im Zone. These are approximately correlated with the conodont *crepida* and *rhomboidea* zones (Avkhimovitch *et al.*, 1993b). In western Pomerania, the miospore assemblages of the IP Zone occur below and in association with conodonts of the Middle and Middle-Upper *crepida* Subzones (Fig. 3).

In the Ardenne-Rhine regions, *L. immensus* is absent, and *D. poljessicus* appears in the "IV" zone, which is obviously earlier than in eastern Europe as the zone "IV" corresponds to the *jamae* Zone (Streele *et al.*, 1987). The presented conodont data suggests that the IP zone is a part equivalent of the *Grandispora gracilis-Acanthotrilites hirtus* (GH) Zone that is considered to correspond to Upper *crepida* - lowermost *marginifera* Subzones (Streele *et al.*, 1987).

TOURNAISIAN	Richardson & McGregor 1986 Old Red Sandstone Continent and adjacent regions	Streel <i>et al.</i> , 1987 Ardenne-Rhine regions	Higgs <i>et al.</i> , 1988 Ireland British Isles Belgium	This paper Pomerania	Avkhimovitch 1993	Avkhimovitch <i>et al.</i> , 1993b
			PC	Ma	U	
			BP			
			HD	3	M	
			VI	1, 2	PM	
					PLE	
FAMENNIAN	NV	LN	LN		LE	
	PL	LE	LE	Ra	LMB	
		LL	LL		LL	
		LV			LV	
	FC	Vco		Ass. II	LF	VF
	TG	GF		IP		Cva
GH					Im	
„V”			RB		CZ	
OB	„IV”		RD	VV	DE	
	BM		Ass. I		OG	
	BJ				SD	
OT part	Tco				OK	

Fig. 6. Correlation of the zonal schemes for Upper Devonian and lowermost Carboniferous of western Europe, eastern Europe and western Pomerania

**Assemblage II**

The miospore associations of the assemblage II were recovered only from the Gorzysław 8 borehole (Figs 1, 3). The assemblages were reasonably rich in specimens and taxa, but they have been recovered from few samples only and thus establishing a zone would not be justified. The lower boundary of the assemblage is marked by the first appearance of *Diducites versabilis*, *Grandispora villosa* and *Spelaeotriletes resolutus*. They are accompanied by *Aneurospora greggsii*, *Auroraspora macra*, *D. commutatus*, *D. poljessicus*, *Lagenosporites immensus*, *Lophozonotriletes curvatus* and *Hystricosporites* spp (Fig. 5).

In eastern Europe, *Diducites versabilis* first appears at the base of the *Discernisporites golubinicus* (DG) Subzone of the *Diducites versabilis-Grandispora famenensis* (VF) Zone. This subzone is correlated on indirect data with the Uppermost *marginifera* to Middle *expansa* conodont zones (Avkhimovitch *et al.*, 1993b). The miospore associations of the assemblage II were found 35 m below conodont fauna indicative of the *marginifera* Zone, and thus it is not younger than this conodont zone and is equivalent of the miospore VF Zone.

Avkhimovitch *et al.* (1993b) supposed that VF Zone is the equivalent of the Ardenne–Rhine *Rugospora versabilis-Grandispora cornuta* (Co) Zone that is dated as *trachyteraxpansa* conodont zones (Streel *et al.*, 1987). In the Ar-

denne–Rhine regions, *Diducites versabilis* appears earlier than in eastern Europe i.e. it appears in the zone “V”.

***Diducites versabilis* (Ve) and *Grandispora lupata* (Lu) Zones**

Turnau (1978) established *Diducites versabilis* (Ve) Zone. The base of this zone was defined on the first appearance of *D. versabilis* (synonym *Rugospora versabilis*) and *Retispora lepidophyta*. In the region of Kołobrzeg, *D. versabilis* has been found in associations lacking *R. lepidophyta*. Thus, the assemblage II is considered older than the zone Ve of Turnau. The latter zone is succeeded by the *lupata* (Lu) Zone characterized by the presence of *Grandispora lupata* and *R. lepidophyta*, and by the absence of *Tumulispora rarituberculata*. Such associations have not been encountered by the author. The reasons why, in the region of Kołobrzeg, the zones Ve and Lu have not been distinguished may be the incomplete coring of the boreholes and unfavourable lithology of the Kłanino Formation.

***Tumulispora rarituberculata* Zone**

Turnau (1978) has established the *Tumulispora rarituberculata* Zone. The present author distinguished this zone in the Gorzysław 9, Chmielno 1 and Rzeczenica 1 boreholes. The assemblages include: *Knoxisporites literatus*, *Raistrickia minor*, *Tumulispora rarituberculata*, *T. malevk-*

*ensis*, *T. obscura*, *Umbonatisporites abstrusus* and *Verrucosporites nitidus*. The two last mentioned species first appear in the higher part of the zone. The assemblages include also species which appear earlier, such as: *Diducites commutatus*, *D. versabilis*, *Auroraspora macra*, *Grandispora lupata* and *Retispora lepidophyta* (Fig. 5).

The author subdivided the Ra Zone into two subzones named Ra<sub>1</sub> and Ra<sub>2</sub>. The base of the Ra<sub>2</sub> subzone is marked by the first appearance of *U. abstrusus* and *V. nitidus*.

The Ra Zone was first correlated by Turnau (1978) with part of the *Vallatisporites pussillites-Spelaotriletes lepidophytus* (PL) Zone established for the British Isles and subsequently (Turnau, 1979) with the upper part of *Vallatisporites pussillites-Spelaotriletes lepidophytus* (PL) and lower part of *Verrucosporites nitidus-Vallatisporites vallatus* (NV) zones. At present, the Ra zone is considered to be older than the *R. lepidophyta-I. explanatus* (LE) Zone, because the Ra associations lack several species present in the LE Zone (Clayton & Turnau, 1990; Avkhimovitch *et al.*, 1993a). The species not found in the Ra Zone are *Indotriradites explanatus*, *Vallatisporites vallatus*, *V. verrucosus*, *V. pussillites* and *Rugospora flexuosa*.

It has been noted, that in Pomerania, *Verrucosporites nitidus* appears earlier than in other regions of Europe, in the level Lower or Middle *praesulcata* Zone (Matyja & Turnau, 1989). In Ireland, the first appearance of the species is believed to be Upper *praesulcata* Zone (Higgs *et al.*, 1988), and in Sauerland – Middle *praesulcata* or Upper *praesulcata* (Streel *et al.*, 1987).

To sum up – the Ra Zone is of late Famennian age, it corresponds to the conodont Upper *expansa* and Lower to Middle *praesulcata* zones.

### ***Convolutispora major* (Ma) Zone**

The Ma Zone established by Turnau (1978) has been distinguished by the author in deposits from the Gorzysław 8 and 9, Chmielno 1 and Rzeczenica 1 boreholes. The miospore associations of the zone include several species which have not been recorded from the preceding Ra Zone. These are: *Convolutispora major*, *Auroraspora asperella*, *Cymbosporites acutus*, *Lophozonotriletes excisus*, *Murospora dubitata*, *Pustulatisporites gibberosus*, *Rastrickia corynoges* and *Spelaotriletes obtusus*. The characteristic assemblage includes also some older species: *Tumulispora malevkensis*, *T. rarituberculata*, *T. obscura*, *Verrucosporites nitidus* and *Umbonatisporites abstrusus* (Fig. 5).

The succession of some first appearances within the Ma Zone has permitted to distinguish four interval subzones (Matyja & Stempień-Sałek, 1994). They have been designated Ma<sub>1</sub>, Ma<sub>2</sub>, Ma<sub>3</sub>, and Ma<sub>4</sub>.

The lowermost *Convolutispora major* (Ma<sub>1</sub>) Subzone has been distinguished in deposits from Gorzysław 9, Chmielno 1 and Rzeczenica 1 (Figs 1, 3, 5). The characteristic of the subzone is as that given for the entire zone. Notably, *Umbonatisporites distinctus* is absent. In the boreholes Rzeczenica 1 the assemblages of the Ma<sub>1</sub> subzone are accompanied and in the borehole Gorzysław 9 – by conodonts of the *duplicata*<sub>1</sub> - *sandbergi* Conodont Zone

The Lower *Convolutispora major* (Ma<sub>2</sub>) Subzone has been distinguished in Gorzysław 8 and 9, Chmielno 1 and

Rzeczenica 1 boreholes. The lower boundary of the zone is marked by the first appearance of *Umbonatisporites distinctus*. *Crassispora trychera* and *Schopfites delicatus* appear close to this boundary. In the Rzeczenica 1 borehole, the miospore assemblages of the Ma<sub>2</sub> subzone are accompanied by conodont faunas of the Lower *crenulata* Zone and in the Chmielno 1 boreholes – by unseparated *sandbergi-isosticha* Upper *crenulata* zones (Matyja *et al.*, 2000).

In the Ardenne–Rhine regions, the lower boundary of the *Krauselisporites hibernicus-Umbonatisporites distinctus* (HD) Zone is marked by the first appearance of *Krauselisporites hibernicus* and *Cymbosporites acutus*. *Umbosporites distinctus* appears some distance above the first appearance level of *Krauselisporites hibernicus* (Higgs *et al.*, 1992). In Pomerania, *U. distinctus* also appears above the base of the Ma Zone, such as *Cymbosporites acutus*, *Convolutispora major*, *Auroraspora asperella*, *Lophozonotriletes excisus*, *Murospora dubitata*, *Pustulatisporites gibberosus*, *Rastrickia corynoges* and *Spelaotriletes obtusus*. In the Ardenne–Rhine regions, the lower boundary of the HD zone has no faunal control, but the first appearance of *U. distinctus* is dated as the *sandbergi* conodont Zone (Higgs *et al.*, 1992). Thus, it appears, that the Ma<sub>1</sub> and Ma<sub>2</sub> subzones are equivalents of the western European HD Zone, and they may be correlated with the *sandbergi-crenulata* Zones.

The Middle *Convolutispora major* (Ma<sub>3</sub>) Subzone has been distinguished in the Gorzysław 9 and Chmielno 1 boreholes. Its lower boundary is marked by the first appearance of *Spelaotriletes balteatus*. The characteristic assemblage is the same as for the entire Ma Zone enriched with *Spelaotriletes balteatus*. In western Europe, *S. balteatus* appears in the *Spelaotriletes balteatus-Rugospora polypytcha* (BP) Zone (Higgs *et al.*, 1988, 1992). It is suggested that the lower boundaries of the Ma<sub>3</sub> Subzone and the BP Zone are time equivalents. The base of the BP Zone is within the Lower *crenulata* conodont Zone (Higgs *et al.*, 1992). In the Gorzysław 9 borehole, the assemblages of the Ma<sub>3</sub> subzone are accompanied by conodont faunas of *sulcata* or Lower *crenulata* zones.

The Upper *Convolutispora major* (Ma<sub>4</sub>) Subzone has been distinguished in the Chmielno 1 borehole. Its lower boundary is marked by the first appearance of *Spelaotriletes pretiosus*. The characteristic assemblage includes *S. pretiosus* and the species characteristic of the entire Ma Zone, except for *S. obtusus*.

In western Europe, *S. pretiosus* marks the base of the *Spelaotriletes pretiosus-Rastrickia clavata* (PC) Zone (Neves *et al.*, 1973, Higgs *et al.*, 1988). The lower boundary of the zone is dated as Lower *crenulata* conodont Zone. This level is close below the base of the *isosticha* Lower *crenulata* conodont Zone, at the base of Tn2b (Higgs *et al.*, 1992). On the Russian Platform *S. pretiosus* first appears at the base of the *Colatisporites multisetus-Spelaotriletes pretiosus* (MP) Zone which is also dated as the *isosticha*-Upper *crenulata* Zone (Avkhimovitch & Turnau, 1994). Thus it may be supposed that the base of the Ma<sub>4</sub> Subzone may also correspond to a level within the conodont zone mentioned above. So far, no conodont faunas have been found in association with the Ma<sub>4</sub> miospore assemblages.



## SYSTEMATIC DESCRIPTIONS

The suprageneric classification adopted in this section is that introduced by Potonié & Kremp (1954), with the subsequent modifications by Dybova & Jachowicz (1957), Butterworth & Williams (1958), Dettman (1963), Neves & Owens (1966), Smith & Butterworth (1967) and Potonié (1970).

Described are species defining the zonal boundaries, and some other, reasonably represented forms (at least 4 specimens found) which have not been described from the study area before. The type and figured specimens are housed in the Institute of Geological Sciences, Polish Academy of Sciences, Warszawa.

Anteturma SPORITES Potonié, 1893

Turma TRILETES Reinsch, 1881, emend. Potonié et Kremp 1954

Suprasubturma ACAVATITRILETES Dettman 1963

Subturma AZONOTRILETES (Luber) Dettman 1963

Infraturma APICULATI (Bennie et Kidston) Potonié 1956

Subinfraturma NODATI Dybova et Jachowicz 1957,  
*sensu* Potonié 1960

Genus *Corystisporites* Richardson 1965

Type species *Corystisporites pomeranius* Stempień-Sałek,  
new species  
Fig. 7 (A–C)

**Holotype:** ING PAN, slide G.8.5.1, Fig. 7A.

**Etymology:** (Latin) *pomeranius* – derived from Pomerania.

**Material:** 22 specimens.

**Dimension:** 80 µm.

**Diagnosis:** Azonate miospores with sculpture consisting of spinose processes with pointed apices. Triradiate mark with elevated lips.

**Description:** Miospores 75–90 µm in diameter, of circular, oval or subtriangular amb. Trilete rays 3/4 of spore radius in length, accompanied by elevated, sinuous labra 7 µm high at the proximal pole, diminishing in height toward equator, often poorly visible due to density of ornamentation. Exine of the distal hemisphere ornamented with densely set, translucent conical elements terminated with darker, massive spinose tips. Elements of ornamentation are 6 µm in length, 4–6 µm wide at base, and their massive terminal spines are up to 2 µm in length. The bases of these elements are often interconnected with irregular, triangular wrinkles to form a reticulate pattern. At equator, the overlapping basal parts of ornamentation elements appear as a deeply incised zona.

**Remarks:** The described species differs from *Corystisporites multispinosus* Richardson (1965) in having shorter ornamentation elements terminated with solid spines.

**Type-locality:** Gorzysław 8 borehole, western Pomerania.

**Type-level:** Człuchów Formation; IP Zone, sample G.8.5, depth 3667 – 3669 m.

**Stratigraphic distribution:** Gorzysław 8 and 11 boreholes, assemblage I, zones RD-IP, Frasnian, lower Famennian (this paper).

**Deposition of types:** slide G.8.5.1.

Genus *Hystricosporites* McGregor 1960

*Hystricosporites furcatus* Owens 1971

Fig. 7J

1971. *Hystricosporites furcatus* Owens: p. 28, tab. 6, figs. 7-9.

**Material:** 15 specimens.

**Description:** Miospores 71–87 µm in diameter, of circular amb. Trilete rays not always visible due to prominent ornamentation, 1/2–3/4 of spore radius in length, accompanied by elevated, slightly sinuous labra about 15 µm high at the proximal pole, terminating at curvatural ridges. Contact faces covered with radial, flat ridges 6–8 µm in width. Exine outside contact faces ornamented with regularly distributed cylindrical, bifurcate processes 18–25 µm in length, 5–8 µm wide at base. Tips of the bifurcation “extended” (*sensu* Owens, 1971). About 20 processes cross the equator.

**Remarks:** The specimens from Pomerania are smaller than those described by Owens (1971), which are 82.5–174.9 µm in diameter.

**Distribution:** Poland – western Pomerania, Gorzysław 8 and 11, Karcino 2 boreholes, zones RB, IP, assemblage II, Uppermost Frasnian, lower Famennian (this paper); Arctic Canada – Queen Elizabeth Islands, lower Frasnian (Owens, 1971).

*Hystricosporites multifurcatus* (Winslow) Mortimer et

Chaloner 1967

Fig. 7 (E, F)

1967. *Hystricosporites multifurcatus* (Winslow) Mortimer et Chaloner: p. 195-196, tab. 26, figs 5-9.

**Material:** 5 specimens.

**Description:** Miospores 68–86 µm in diameter. Amb circular or triangular with convex sides. Triradiate rays 2/3 of spore radius in length, accompanied by elevated, sinuous labra up to 15 µm high at the proximal pole, not always visible due to dense ornamentation. Contact faces smooth, exine outside contact faces ornamented with regularly distributed appendages 20–22 µm in length, up to 8 µm wide at base, with reflexed, multifurcate terminations. Width of appendages at the base of multifurcation about 6 µm. About 15 appendages cross the equator.

**Distribution:** Poland – western Pomerania, Gorzysław 8 and 11 boreholes, assemblage I, zones DT, RD, assemblage II, Frasnian, lower Famennian (this paper); France, middle and Upper Frasnian (Taugourdeau-Lantz, 1971), Frasnian and lower Famennian (Loboziak & Streel, 1988), Frasnian (Streel *et al.*, 1987); USA – Ohio, Middle Devonian, basal part of Mississippian (Winslow, 1962).

*Hystricosporites porrectus* (Balme et Hassel) Allen 1965

Fig. 7 (D, L)

1962. *Archaeotriletes porrectus* Balme et Hassel: p. 10, tab. 5, figs 1-4.

1965. *Hystricosporites porrectus* (Balme et Hassel), Allen: p. 698, tab. 95, figs 1-3.

**Material:** 31 specimens.

**Description:** Miospores 80–105 µm in diameter. Amb circular or triangular with convex sides. Triradiate rays 2/3 of spore radius in length, accompanied with elevated, sinuous labra up to 20 µm high at the proximal pole, not always visible due to dense ornamentation. Contact faces smooth. Exine outside contact faces ornamented with regularly distributed cylindrical, densely set appendages 20–35 µm in length, 5–6 µm wide at base, with bifurcate termination. Tips of the bifurcation “reflexed” are curved toward the spore body. About 28 appendages cross the equator.

**Distribution:** Poland – western Pomerania, Gorzysław 8 and 11, Strzeżewo 1 and Karcino 2 boreholes, zones RD, RB and IP, Upper Frasnian, lower Famennian (this paper); Spitsbergen, Givetian (Allen, 1965); France – Boulonnais, middle Frasnian (Taugourdeau-Lantz, 1971); western Australia, Upper Devonian (Playford, 1982).

*Hystricosporites suborlovicus* (Kedo) comb. nov.  
Fig. 7K

**Basionym:** 1974. *Archeozonotriletes suborlovicus* Kedo: p. 58, tab. 13, fig. 19.

**Material:** 8 specimens.

**Description:** Miospores 70–78 µm in diameter. Amb circular or subtriangular with convex sides. Triradiate rays not always visible due to dense ornamentation, about 1/2 of spore radius in length, accompanied by labra up to 4 µm wide. Contact faces smooth, exine outside contact faces ornamented with regularly distributed, cylindrical, densely set, bifurcate processes 10–12 µm in length, 2–3 µm wide at base, narrowing to 1.5 µm below the bifurcation at which point they are often broken off. Tips “reflexed or extended”. Up to 30 appendages project at the equator.

**Remarks:** According to the original description of *Archeozonotriletes suborlovicus* these spores possess a central body. This feature has not been observed in our material, probably because our specimens are much darker (more mature). Otherwise, the described specimens are closely comparable with those from the Pripyat Depression.

**Distribution:** Poland – western Pomerania, Gorzysław 8 and Karcino 2 boreholes, zone IP, assemblage II, lower Famennian (this paper); Belarus – Pripyat Depression, lower and middle Famennian (Kedo, 1974).

Genus *Umbonatisporites* (Hibbert et Lacey) Clayton 1971

*Umbonatisporites abstrusus* (Playford) Clayton 1971  
Fig. 8 (B, C)

1971. *Umbonatisporites abstrusus* (Playford) Clayton: p. 591.

**Material:** 8 specimens.

**Description:** Miospores 60–68 µm in diameter. Amb circular. Trilete rays straight, 1/3 to 1/2 of spore radius in length. Contact faces smooth, exine outside contact faces ornamented with small appendages up to 2 µm in diameter, about 1.5 µm wide at base, and about 2 µm apart. Terminations of the appendages are dome-shaped or flattened, their width equals the appendage length. Some terminations bear a small spine.

**Distribution:** Poland – western Pomerania, Gorzysław 8 and 9, Rzeczenica 1 boreholes, Subzones Ra<sub>2</sub> and Ma<sub>2</sub>, Uppermost Famennian, lowermost Tournaisian (this paper), Holy Cross Moun-

tains, Zone LN, Uppermost Famennian (Turnau, 1990), Pomerania and Holy Cross Mountains, zones LN-CI, Uppermost Famennian, Tournaisian (Clayton & Turnau, 1990); Brazil, zones LN-BP, Uppermost Famennian, lower Tournaisian (Loboziak *et al.*, 1988). The species is common in western and eastern Europe in Uppermost Famennian and lower Tournaisian.

*Umbonatisporites distinctus* Clayton 1971  
Fig. 8A

1971. *Umbonatisporites distinctus* Clayton: tab. 5, figs 16–17.

**Material:** 18 specimens.

**Description:** Miospores 55–75 µm in diameter. Amb circular. Trilete rays straight, 1/3 to 1/2 of spore radius in length. Contact faces smooth, the remaining exine surface ornamented with discrete, cylindrical appendages 8–15 µm in length, 2–3 µm in width, terminated by a wide, dome-shaped tip up to 4 µm in width surmounted by a spine up to 4 µm in length.

**Distribution:** Poland – western Pomerania, Gorzysław 9, Chmielno 1, and Rzeczenica 1 boreholes, Subzones Ma<sub>2</sub>, Ma<sub>3</sub> and Ma<sub>4</sub>, lower Tournaisian (this paper), zones Ma-CI, Tournaisian (Turnau, 1978, 1979); Belarus – Pripyat Depression, zone U, Tournaisian (Avkhimovitch, 1993), common in western Europe, from Zone HD.

Type species *Umbonatisporites distinctus* var. *crinitus* var. nov.

Fig. 7 (G–I)

**Holotype:** ING PAN, slide G.9.5.1., Fig. 7H.

**Etymology:** (Latin) *crinitus* – with long hair.

**Material:** 10 specimens.

**Dimension:** 65 µm in diameter.

**Diagnosis:** Azonate miospores with fine hair-like processes.

**Description:** Miospores 55–85 µm in diameter. Amb circular. Trilete rays straight, 3/4 of spore radius in length. Contact faces smooth, the remaining exine surface covered by densely set, cylindrical appendages 6–13 µm in length, 0.5–1 µm wide at base, 2–3 µm apart. Appendages have a 2.5 µm wide thickening situated at half of their length and a dome shaped tip up to 4 µm in width, surmounted by a spine about 4 µm in length.

**Remarks:** *Umbonatisporites distinctus* var. *crinitus* differs from *U. distinctus* Clayton (1971) in having more closely spaced, thinner and longer in relation to spore radius appendages.

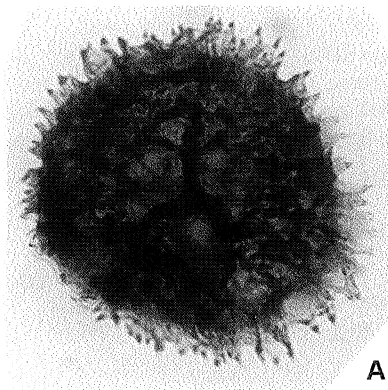
**Type-locality:** Gorzysław 9 borehole, western Pomerania.

**Type-level:** Sapolno Formation, Subzone Ma<sub>2</sub>, sample G.9.5, depth 3149–3150 m.

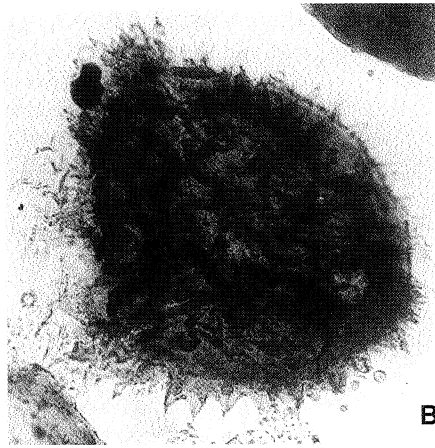
**Stratigraphic distribution:** Gorzysław 8 and 9, Chmielno 1 boreholes, Subzone Ma<sub>2</sub>, Tournaisian (this paper).

**Deposition of types:** slide G.9.5.1.

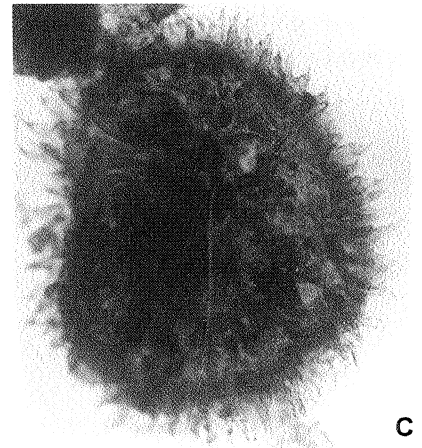
**Fig. 7.** Miospores from Upper Frasnian, Famennian and lower Carboniferous in western Pomerania. Specimens C, E, F are from Gorzysław 11.14, 3284–3285 m DT Zone, other specimens as indicated below. All magnifications × 500 except when indicated. A – *Corystisporites pomeranius* n. sp., holotype, Gorzysław 8.5, 3667–3669 m, IP Zone; B – *Corystisporites pomeranius* n. sp., Gorzysław 11.10, 3246–3247 m, RD Zone; C – *Corystisporites pomeranius* n. sp.; D – *Hystricosporites porrectus* (Balme et Hassel) Allen, Gorzysław 11.10, 3246–3247 m, RD Zone, magnification × 300. E, F – *Hystricosporites multifurcatus* (Winslow) Mortimer et Chalomer, magnification × 300 and × 1400; G – *Umbonatisporites distinctus* var. *crinitus* var. nov., holotype, Gorzysław 9.5, 3149–3150 m, Ma<sub>2</sub> Zone; H – *Umbonatisporites distinctus* var. *crinitus* var. nov., *ibidem*; I – *Umbonatisporites distinctus* var. *crinitus* var. nov., Gorzysław 9.4, 3148–3149 m, Ma<sub>2</sub> Zone, magnification × 400; J – *Hystricosporites furcatus* Owens, Gorzysław 8.3, 3514–3516 m, magnification × 400, assemblage II; K – *Hystricosporites suborlovicus* (Kedo) comb. nov., *ibidem*; L – *Hystricosporites porrectus* (Balme et Hassel) Allen, Gorzysław 8.5, 3667–3669 m, IP Zone



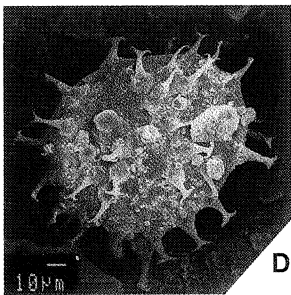
A



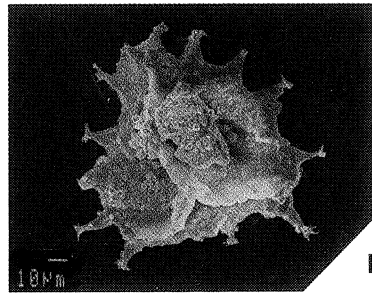
B



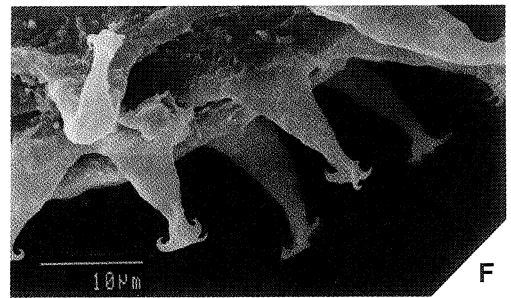
C



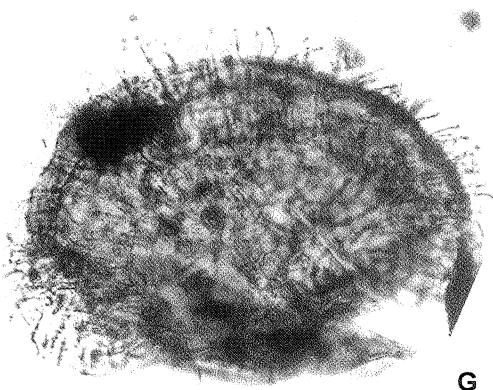
D



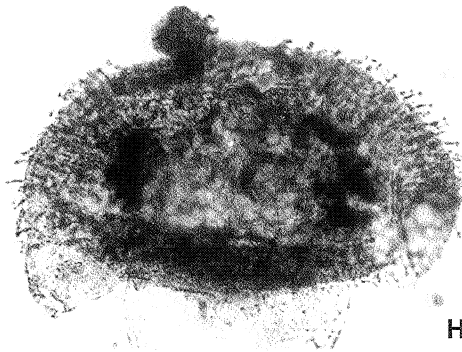
E



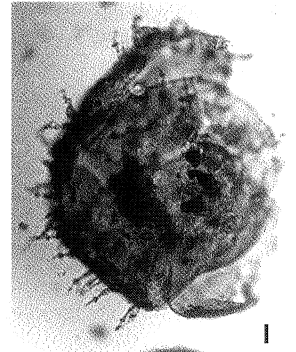
F



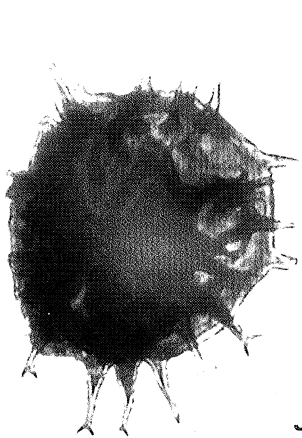
G



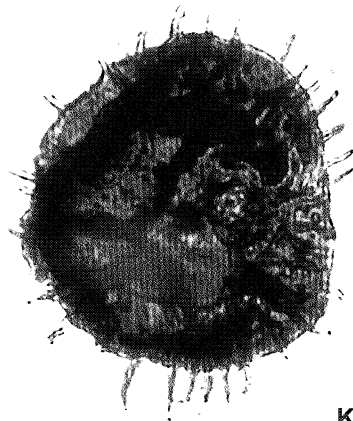
H



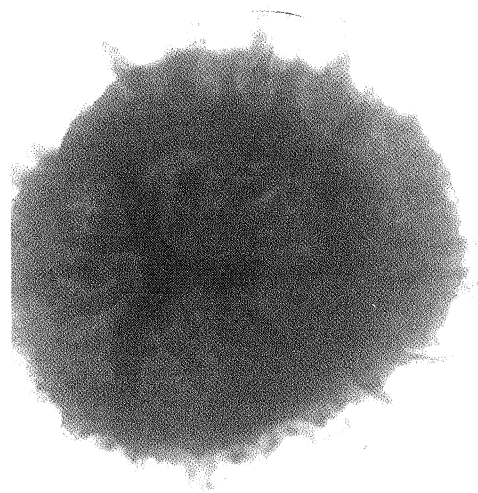
I



J



K



L

Subinfraturma BACULATI Dybova et Jachowicz 1957  
Genus *Raistrickia* (Schopf, Wilson et Bentall) Potonié et  
Kremp 1954

*Raistrickia ramiformis* (Kedo) Avkhimovitch et Higgs  
1988  
Fig. 8D

1978. *Raistrickia variabilis* Dolby et Neves: Somers et Stree, p.  
149, tab.1, fig. 2.

1988. *Raistrickia ramiformis* (Kedo) Avkhimovitch et Higgs:  
Avkhimovitch, Byvsheva, Higgs, Stree & Umnova, tab.1,  
fig. 16.

1988. *Raistrickia minor* (Kedo) Neves et Dolby: Higgs, Clayton &  
Keegan, p. 59, tab. 4: 14, 17.

**Material:** 7 specimens.

**Description:** Miospores 33–58 µm in diameter. Amb circular.  
Trilete rays not visible due to dense ornament covering the entire  
exine surface. The ornamentation elements are cylindrical, 1/2 to  
3/4 of spore radius in length, 2–6 µm wide at base, 10–15 µm  
apart, with flattened and laterally extended, ramified terminations  
which in some specimens are as wide as the appendages are long.  
The terminations of neighbouring appendages are often in contact.  
Exine about 2 µm thick at equator.

**Remarks:** *Raistrickia variabilis* Dolby et Neves *sensu* Somers et  
Stree (1978, tab. 1, fig. 2) and *R. minor sensu* Higgs *et al.* (1988,  
tab. 4, figs 14, 17) have been considered here as synonymous with  
the described species as they have identical appendages with later-  
ally extended terminations.

**Distribution:** Poland – western Pomerania, Gorzysław 8 and 9  
boreholes, Subzones Ra<sub>1</sub>, Ra<sub>2</sub>, Ma<sub>2</sub>, Upper Famennian, Tour-  
naisian (this paper); Belarus – Pripyat Depression, Zone PLE, Fa-  
mennian (Kedo & Golubtsov, 1971); Germany, Famennian  
(Somers & Stree, 1978).

Infraturma MURONATI Potonié et Kremp 1954  
Genus *Convolutispora* Hoffmeister, Staplin et Malloy 1955

*Convolutispora subtilis* Owens 1971  
Fig. 8L

1971. *Convolutispora subtilis* Owens: p. 35, tab. 9, figs 3-6.

**Material:** 5 specimens.

**Description:** Miospores 48–58 µm in diameter. Amb circular or  
subtriangular. Trilete rays straight, 3/4 of spore radius in length.  
Exine ornamented with fine, sinuous, densely set ridges 2–3 µm in  
length and width. The profiles of ridges rounded. On contact faces  
ridges are lower and more spaced. Exine about 2 µm thick at equa-  
tor.

**Distribution:** Poland – western Pomerania, Gorzysław 11,  
Strzeżewo 1 boreholes, zone RD, Upper part of Frasnian (this pa-  
per), Zone Ex, Givetian (Turnau, 1995); Belarus – Pripyat Depres-  
sion, Frasnian (Obukhovskaya, 1986), Zone OG, Frasnian  
(Avkhimovitch *et al.*, 1993 b); Canada – Queen Elizabeth Islands,  
Frasnian (Owens, 1971).

Genus *Corbulispora* Bharadwaj et Venkatachala 1961

*Corbulispora cf. cancellata* (Waltz) Bharadwaj et  
Venkatachala 1961  
Fig. 8N

**Material:** 9 specimens.

**Description:** Miospores 70–94 µm in diameter. Amb oval, trilete  
rays straight, 3/4 of spore radius long, accompanied by lips. Exine  
ornamented with ridges and rare warts; ridges slightly sinuous  
forming an irregular, imperfect reticulum. Width of ridges and  
warts 5–7 µm, width of lumina 8–10 µm. Exine about 2 µm wide at  
equator.

**Remarks:** The described form differs from *Corbulispora cancel-  
lata* (Waltz) Bharadwaj et Venkatachala (1961) in having less dis-  
tinct lips, more complete reticulum, more straight ridges and lower  
number of warts.

**Distribution:** Poland – western Pomerania, Gorzysław 8 borehole,  
Zone Ra and Ma (Ma<sub>2</sub> i Ma<sub>3</sub>), Upper part of Famennian, Tour-  
naisian (this paper).

Subturma ZONOTRILETES Waltz 1935  
Infraturma PATINATI Butterworth et Williams 1958  
Genus *Cymbosporites* Allen 1965

*Cymbosporites acutus* (Kedo) Byvsheva 1985  
Fig. 8 (E–H)

1985. *Cymbosporites acutus* (Kedo) Byvsheva: p. 127, tab. 24,  
fig. 13

non 1980. *Asperispora acuta* Van der Zwan: p. 227 tab. 13, figs  
1-5.

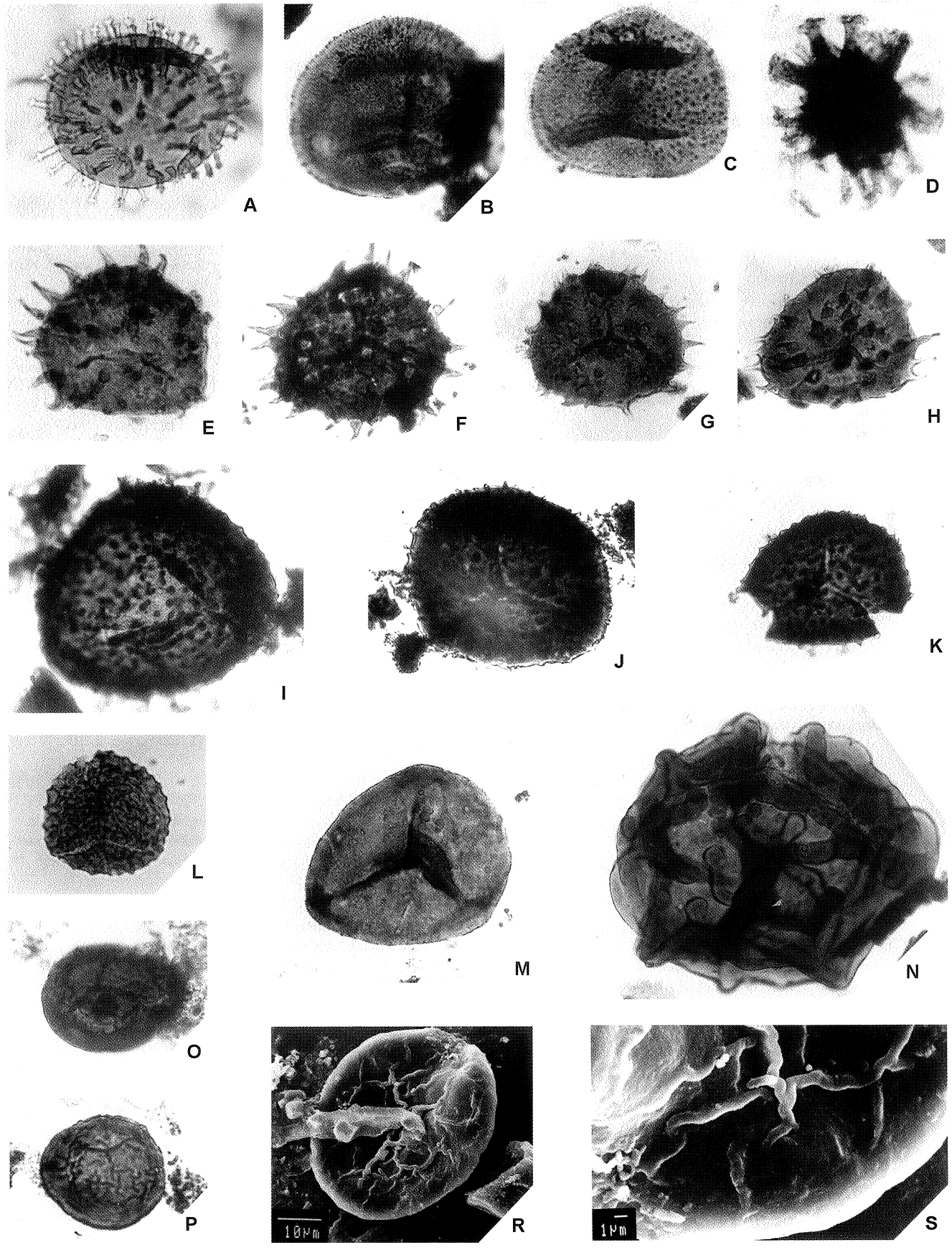
non 2000. *Grandispora acuta* Higgs, Avkhimovitch, Loboziak,  
Maziane-Serraj, Stempień-Sałek & Stree: pl. 1, figs 1-6.

**Material:** 48 specimens.

**Description:** Miospores 48–67 µm in diameter. Amb subtriangu-  
lar, sides convex, apices broadly rounded. Trilete rays straight or  
slightly sinuous, about 3/4 of spore radius in length. Proximal sur-  
face smooth, distal surface thicker than the proximal one, covered  
by discrete, closely set spines 5–13 µm in length, which have bul-  
bous bases 5–8 µm in diameter, and acute terminations. Exine  
about 3 µm thick at equator.

**Fig. 8.** Miospores from Upper Frasnian, Famennian and Lower Carboniferous in Western Pomerania. All magnifications × 500 except when indicated. **A** – *Umbonatisporites distinctus* Clayton, Chmielno 1.6, 3907–3925 m, Ma<sub>3-4</sub> Zone; **B** – *Umbonatisporites abstrusus* (Playford) Clayton, Gorzysław 9.3, 3146–3147 m, Ma<sub>2</sub> Zone; **C** – *Umbonatisporites abstrusus* (Playford) Clayton, Gorzysław 8.1, 3216–3218 m, Ma<sub>2</sub> Zone; **D** – *Raistrickia ramiformis* (Kedo) Avkhimovitch et Higgs, Gorzysław 9.13, 3207–3208 m, Ra<sub>1</sub> Zone; **E** – *Cymbosporites acutus* (Kedo) Byvsheva, Gorzysław 9.6, 3154–3155 m, Ma<sub>2</sub> Zone; **F, G, H** – *Cymbosporites acutus* (Kedo) Byvsheva, Gorzysław 9.4, 3148–3149 m, Ma<sub>2</sub> Zone; **I** – *Cymbosporites vetlasjanicus* (Medianik et Obukhovskaya): Avkhimovitch *et al.*, Gorzysław 14.2, 2943–2950 m, RB Zone, magnification × 700; **J, K** – *Cymbosporites boafeticus* (Tchibrikova) Obukhovskaya, *ibidem*; **L** – *Convolutispora subtilis* Owens, Gorzysław 11.6, 3193–3194 m, RD Zone; **M** – *Aneurospora greggsii* (McGregor) Stree: Becker *et al.*, Gorzysław 8.5, 3667–3669 m, IP Zone; **N** – *Corbulispora cf. cancellata* Bharadwaj et Venkatachala, Gorzysław 9.3, 3146–3147 m, Ma<sub>2</sub> Zone; **O, P** – *Tholisporites densus* McGregor, Gorzysław 11.10, 3246–3267 m, RD Zone; **R, S** – *Tholisporites densus* McGregor, 11.12, 3270–3271 m, RD Zone, magnification × 800 and × 2500





**Remarks:** Specimens included by Van der Zwan (1980, p. 227, tab. 13, figs 1-5) in *Asperispora acuta* and by Higgs *et al.* (2000, p. 213, pl. 1, figs 1-6) in *Grandispora acuta* are only superficially similar to *Cymbosporites acutus* as they are camerate while *Cymbosporites acutus* from Pomerania and *C. acutus* described from eastern Europe by Kedo (1963) and Byvsheva (1985) are acamerate. In comparison with specimens described in Kedo (1963) and Byvsheva (1985) those from Pomerania have larger spines, which have a wider size range (5–13 µm to 2.5–8 µm given by the above authors).

**Distribution:** Poland – western Pomerania, Gorzysław 8 and 9, Chmielno 1, Rzeczenica 1 boreholes, Zone Ma, Tournaisian (this paper); Belarus – Pripyat Depression, Upper Famennian–Tournaisian (Kedo, 1963); Russia – Tournaisian (Byvsheva, 1985).

*Cymbosporites boafeticus* (Tchibrikova) Obukhovskaya  
1986

Fig. 8 (J, K)

1972. *Archaeozonotriletes boafeticus* Tchibrikova: p. 128, tab. V, figs 1-2

1993. *Cymbosporites boafeticus* (Tchibrikova) Obukhovskaya: Avkhimovitch, Tchibrikova, Obukhovskaya, Nazarenko, Umnova, Raskatova, Loboziak & Streel, pl. 17, fig. 12, pl. 18, fig. 13, pl. 19, fig. 12.

**Material:** 9 specimens.

**Description:** Miospores 50–65 µm in diameter. Amb circular or subtriangular with convex sides and broadly rounded apices. Trilete rays slightly sinuous, accompanied with labra about 1 µm in height, extending almost to equator. Ray terminations forked which is often invisible due to dense ornamentation. Proximal surface smooth. Exine of the distal hemisphere distinctly thicker in relation to that of the proximal one, ornamented with discrete, conical elements up to 2 µm in length, up to 4 µm wide at base. Exine about 3 µm thick at equator.

**Distribution:** Poland – western Pomerania, Gorzysław 11 and 14, Karcino 2 boreholes, zones RB-IP, Upper Frasnian and lower Famennian (this paper); Russia – south Ural and Russian Platform, Frasnian (Tchibrikova, 1972); Belarus – Pripyat Depression, Frasnian (Obukhovskaya, 1986), Pripyat Depression, Frasnian, Famennian, zones DE-CZ (Avkhimovitch *et al.*, 1993b).

*Cymbosporites vetlasjanicus* Medianik et Obukhovskaya:  
Avkhimovitch *et al.* 1993

Fig. 8I

1993. *Cymbosporites vetlasjanicus* Medianik et Obukhovskaya: Avkhimovitch, Tchibrikova, Obukhovskaya, Nazarenko, Umnova, Raskatova, Loboziak & Streel: tab. 14, figs 6, 9.

**Material:** 2 specimens.

**Description:** Miospores 45–55 µm in diameter. Amb circular or subtriangular, with convex sides and rounded apices. Trilete rays straight, accompanied by labra up to 1 µm in height, extending almost to equator. Proximal surface smooth, exine of distal hemisphere distinctly thicker in relation to the proximal one ornamented with discrete conical elements up to 2 µm wide and high. Exine about 3 µm thick at equator.

**Distribution:** Poland – western Pomerania, Gorzysław 11 borehole zone RB, Frasnian/Famennian transition beds (this paper); Belarus – Pripyat Depression, Frasnian, zones OG and DE (Medianik & Obukhovskaya: Avkhimovitch *et al.*, 1993b).

Genus *Tholisporites* Butterworth et Williams 1958

*Tholisporites densus* McGregor 1960

Fig. 8 (O–S)

1960. *Tholisporites densus* McGregor: p. 37, tab. 13, figs 6, 7.

1987. *Archaeozonotriletes densus* Arkhangelskaya: p. 87, 88, tab. 6, fig. 5.

**Material:** 6 specimens.

**Description:** Miospores 45–52 µm in diameter. Amb circular or oval. Trilete rays slightly sinuous, accompanied by lips about 1 µm in height, extending 3/4 of spore radius. Exine much thicker distally than proximally. A thin, translucent, irregularly folded membrane extends over the proximal surface; the folds are about 1 µm in width, some of them touch or are fused; they peter out in equatorial region. Spores without ornamentation.

**Distribution:** Poland – western Pomerania, Gorzysław 11 borehole, zone RD, Upper Frasnian (this paper), Jamno IG 1 borehole, *punctata* conodont Zone (personal information, Turnau, 1995); northern Canada, probably Frasnian (McGregor, 1960), Upper Givetian–middle Frasnian, Zone OB and OT (McGregor & Playford, 1992); Russian Platform, Frasnian (Arkhangelskaya, 1987).

Suprasubturma LAMINATITRILETES Smith et  
Butterworth 1967

Subturma ZONOLAMINATITRILETES Smith et  
Butterworth 1967

Infraturma CRASSITI (Bharadwaj et Venkatachala)  
emend. Utting 1987

Genus *Aneurospora* Streel 1964

*Aneurospora greggsii* (McGregor) Streel 1974  
Fig. 8M

1972. *Archaeozonotriletes vasjamicus* Tchibrikova: p. 125, Tab. 4, fig. 11-13

1974. *Aneurospora greggsii* (McGregor) Streel: Becker, Bless, Streel & Thorez, p. 24, tab. 16, figs 6-15 *cum synonymis*.

1993. *Geminospora vasjamica* (Tchibrikova) Obukhovskaya et Nekryata: Avkhimovitch, Tchibrikova, Obukhovskaya, Nazarenko, Umnova, Raskatova, Loboziak & Streel, tab. 18, figs 4-5, tab. 19, fig. 5.

**Material:** 22 specimens.

**Description:** Miospores 50–65 µm in diameter. Amb subtriangular, sides convex, apices broadly rounded. Trilete rays straight, extending almost to equator, terminating at curvaturae imperfectae. Exine ornamented with densely set cones up to 1 µm in height. On contact faces, cones are more spaced or absent. Exine about 2 µm thick at equator.

**Distribution:** Poland – western Pomerania, Gorzysław 8 and 14, Karcino 2 boreholes, zones RB, IP, assemblage II, Uppermost Frasnian–lower Famennian (this paper), southeastern Poland, Pionki 4 borehole, Givetian/Frasnian (Turnau, 1985, 1986), Holy Cross Mountains, Zone LN, Upper Famennian (Turnau, 1990); southern Ural, lower Famennian (Tchibrikova, 1972); Belarus – Pripyat Depression, Frasnian–Famennian (Obukhovskaya and Nekryata in Avkhimovitch *et al.*, 1993b); Canada – Alberta, Ghost River Formation, Givetian–Frasnian (McGregor, 1964). Common in Europe from Frasnian to Famennian.



Subturma CINGULICAVATI Smith et Butterworth 1967  
Genus *Cristatisporites* (Potonié et Kremp) Butterworth  
1967

*Cristatisporites deliquescens* (Naumova) Arkhangelskaya  
1987  
Fig. 90

1953. *Hymenozonotriletes deliquescens* Naumova: p. 67, tab. 9, fig. 8.

1987. *Cristatisporites deliquescens* (Naumova) Arkhangelskaya: p. 89, tab. 6, fig. 4.

**Material:** 4 specimens.

**Description:** Miospores 86–96 µm in diameter. Amb subtriangular, sides convex, apices broadly rounded. Trilete rays slightly sinuous, accompanied by lips 2–3 µm in width, extending 2/3 of spore radius. Amb of the intexine oval or slightly subtriangular. Exoexine extended laterally at equator to form a differentially thickened zona; inner thicker portion 3–4 µm in width, thinner, outer portion 10–15 µm in width. Exine surface finely granulate, distal surface ornamented with spaced mamillate spines 4–6 µm long, 3–4 µm wide at base. Spines often corroded.

**Remarks:** In our specimens, the trilete rays extend to the inner part of the cingulizone while in those from the Russian Platform, they are longer, extending beyond this part of zona. The zona in specimens from Pomerania is narrower than in those from the Russian Platform. The spines of the specimens from Pomerania are corroded.

**Distribution:** Poland – western Pomerania, Gorzysław 11 and 14 boreholes, assemblage I, zones RD and RB, Frasnian and lowermost Famennian (this paper); Russian Platform – Voronezh area, Frasnian (Naumova, 1953), eastern part of Russian Platform, Upper Frasnian (Tchibrikova, 1977), Frasnian, equivalents of Zones OG-DE (Arkhangelskaya, 1987); Belarus – Pripyat Depression, Zones OG-DE (Avkhimovitch *et al.*, 1993b).

*Samarisporites triangulatus* Allen 1965  
Fig. 9 (A–D)

1965. *Samarisporites triangulatus* Allen: p. 716, tab. 99, figs 1–6.

**Material:** 23 specimens.

**Description:** Miospores 40–58 µm in diameter. Amb subtriangular, sides convex, apices slightly rounded, elongated, reminding of ears. Trilete rays straight, accompanied by slightly sinuous labra about 2 µm in height, extending onto the zona. Intexine circular or subtriangular in outline, closely appressed to exoexine. Contact faces smooth, exine outside contact faces finely granulate, and ornamented with spaced cones and spines up to 5 µm wide at base, 2–5 µm in length. Some cones are surmounted by a spine (the bifurcated elements are up to 6 µm in length). In equatorial view, at intexine margin, bases of spines and cones are fused to form a reticulum.

**Distribution:** Poland – western Pomerania, Strzeżewo 1, Gorzysław 11 boreholes, assemblage I, zone RD, Frasnian, (this paper), Givetian Subzone Ex<sub>3</sub>, (Turnau, 1985, 1986), central Poland, Holy Cross Mountains, Givetian, Subzone Ex<sub>3</sub> (Malec & Turnau, 1997; Turnau et Racki, 1999); France, middle Frasnian (Taugourdeau-Lantz, 1971), Givetian/Frasnian (Loboziak & Stree, 1981, 1988); Belgium, Frasnian (Stree & Loboziak, 1987); Ireland, Givetian/Frasnian (Clayton & Graham, 1974); Spitsbergen, Upper Givetian (Allen, 1965); Tunisia, Libya, Givetian/Frasnian (Loboziak & Stree, 1989); North America, Givetian/Frasnian (McGregor, 1979); Brazil – Parana Basin, Givetian–Frasnian<sub>1</sub> (Loboziak *et al.*, 1988).

*Samarisporites cf. triangulatus* Allen 1965  
Fig. 9E

**Material:** 5 specimens.

**Description:** Miospores 55–68 µm in diameter. Amb subtriangular, sides straight or slightly convex, apices triangular. Trilete rays accompanied with slightly sinuous labra up to 3 µm in height, extending to equator. Contact faces smooth, exine outside contact faces finely granulate and covered by spaced cones and spines up to 5 µm wide at base, 2–5 µm in length. Some cones are surmounted by spines (the total length of bifurcated elements up to 6 µm). In equatorial view, at intexine margin, the bases of spines and cones are joined to form a reticulum.

**Remarks:** *Samarisporites cf. triangulatus* from Pomerania differs from *Samarisporites triangulatus* Allen (1965) in being slightly larger, having less convex sides and less elongated, more acute apices.

**Distribution:** Poland – western Pomerania, Strzeżewo 1, Gorzysław 11 boreholes, assemblage I, zone RD, Frasnian (this paper).

Suprasubturma CAMERATITRILETES Neves et Owens  
1966

Subturma SOLUTITRILETES Neves et Owens 1966  
Infraturma DECORATI Neves et Owens 1966  
Genus *Grandispora* Hoffmeister, Staplin et Malloy emend.  
Neves et Owens 1966

*Grandispora villosa* (Avkhimovitch) comb. nov.  
Fig. 9 (G, K, L)

**Basionym:** 1974. *Hymenozonotriletes villosus* Avkhimovitch: p. 98, tab. 28, fig. 4.

**Material:** 5 specimens.

**Dimension:** 30–40 µm in diameter.

**Diagnosis:** Trilete camerate miospores, exoexine detached from intexine, sculpture consisting of discrete, spinose processes.

**Description:** Amb subtriangular, sides convex, apices broadly rounded. Trilete rays straight, extending almost to equator. Spores cavate, intexine well delimited, radius 1/2 to 3/4 of spore radius. Exoexine detached from intexine, forming a pseudosaccus appearing as an equatorial zone. Contact faces smooth, the remaining part of exine ornamented with discrete, regularly distributed cones 1–2 µm high and wide at base, 1–2 µm apart.

**Remarks:** Specimens are listed by Avkhimovitch (1974), non described.

**Distribution:** Poland – western Pomerania, Gorzysław 8 borehole, assemblage II, Famennian (this paper); Belarus – Pripyat Depression, Famennian (Avkhimovitch, 1974).

Genus *Rugospora* Neves et Owens 1966

*Rugospora granulatipunctata* (Hoffmeister, Staplin et  
Malloy) Higgs *et al.* 1988  
Fig. 9F

1988. *Rugospora granulatipunctata* (Hoffmeister, Staplin et Malloy) Higgs, Clayton & Keegan: p. 72, tab. 12, figs 4–5, *cum synonymis*.

**Material:** 10 specimens.

**Description:** Miospores 33–44 µm in diameter. Amb circular or subtriangular, sides convex, apices broadly rounded. Trilete rays straight, extending almost to equator, accompanied by slightly sinuous, wide lips up to 3 µm in height. Exine detached from intexine. Intexine distinct, outline conformable with amb, usually forming 5/6 of the total spore diameter, laevigate or finely granulate.

Exoexine densely ornamented by small wrinkles and rugulae. Wrinkles 1–2 µm in width, closely spaced, radially, sinuous arranged radially.

**Distribution:** Poland – western Pomerania, Gorzysław 8 and 9 boreholes, Zone Ma (Ma<sub>1</sub>, Ma<sub>2</sub>, Ma<sub>3</sub>), (this paper), Zone Ma, (Turnau, 1975); Belarus – Pripyat Depression, Tournaisian (Kedo, 1963); Russian Platform, Lower Carboniferous (Byvsheva, 1976); Ireland, Upper Famennian–Tournaisian (Van der Zwan, 1980), Zones LL-PC, Upper Famennian, Tournaisian (Higgs *et al.*, 1988); USA – Illinois, Kentucky, Mississippian (Hoffmeister *et al.*, 1955).

#### Genus *Retispora* Staplin 1960

##### *Retispora macroreticulata* (Kedo) Byvsheva 1985

Fig. 9N

1985. *Retispora macroreticulata* (Kedo) Byvsheva: p. 141, tab. 28, fig. 11, *cum synonymis*.

**Material:** 6 specimens.

**Description:** Spores 95–160 µm in diameter. Amb circular, oval or subtriangular. Trilete rays straight, extending to equator, often obscured by ornamentation. Exine cavate. Intexine oval in outline, radius 1/2–3/4 of spore radius. Exoexine reticulate, muri 2 µm high and wide, lumina polygonal, up to 15 µm in diameter.

**Distribution:** Poland – western Pomerania, Gorzysław 9 and Rzeczenica 1 boreholes, Zone Ra, Upper Famennian (Turnau, 1978; this paper) Holy Cross Mountains, Zone LL, upper part of Famennian (Turnau, 1990); Belarus – Pripyat Depression, Upper Famennian (Kedo & Golubtsov, 1971; Kedo, 1974); Russian Platform, Upper Famennian (Byvsheva, 1985); Ireland, Upper Famennian (Higgs, 1975), Zones LL-LE, Upper Famennian (Higgs & Russel, 1981; Higgs *et al.*, 1988); Germany – Rheinisches Schiefergebirge, zone LL, Upper Famennian (Higgs & Streeel, 1984).

#### Genus *Spelaeotriletes* Neves et Owens, 1966

##### *Spelaeotriletes obtusus* Higgs 1975

Fig. 9H

1975. *Spelaeotriletes obtusus* Higgs: p. 400, tab. 6, figs 1–3.

**Material:** 26 specimens.

**Description:** Miospores 56–72 µm in diameter. Amb circular, oval or subtriangular. Trilete rays straight, accompanied by sinuous lips ending at curvaturae imperfectae. Exine cavate. Intexine not always visible due to dense ornamentation, radius 1/2 to 3/4 of spore radius. Outside contact faces exine ornamented with densely set, discrete pila and bacula 2–4 µm long, 1–3 µm wide at base.

**Distribution:** Poland – western Pomerania, Gorzysław 8 and 9, Rzeczenica 1, Chmielno 1 boreholes, Zone Ma (Ma<sub>1</sub>, Ma<sub>2</sub>, Ma<sub>3</sub>),

Tournaisian (this paper); Ireland, Zones VI-BP, Tournaisian (Higgs *et al.*, 1988).

##### *Spelaeotriletes resolutus* Higgs

Fig. 9 (I, J)

1975. *Spelaeotriletes resolutus* Higgs: p. 400, tab. 6, figs 4–6, non figs 7–9.

1993. *Spelaeotriletes papulosus* (Sennova) Avkhimovitch: Avkhimovitch, Tchibrikova, Obukhovskaya, Nazarenko, Umnova, Raskatova, Loboziak & Streeel, tab. 21, fig. 4, tabl. 22, figs 7, 8, tabl. 24, fig. 4.

**Material:** 33 specimens.

**Description:** Miospores 40–57 µm in diameter. Amb subtriangular, sides convex, apices broadly rounded. Trilete rays accompanied by slightly sinuous lips up to 3 µm in height, extending almost to equator where they merge with short arcuate ridges. Exine cavate. Radius of intexine 3/4 of spore radius. Contact faces smooth, the remaining part of exine surface covered with elements varying in form in the same specimen. These are grana, cones and bacula with bulbous bases. Some cones are surmounted by a spine. The ornamentation elements are up to 4 µm in height, 1.5–2.5 µm wide at base; some bases of elements are in contact. Exoexine about 2 µm thick.

**Distribution:** Poland – western Pomerania, Gorzysław 8 and 9, Rzeczenica 1 boreholes, assemblage II, subzones Ra<sub>1</sub>, Ra<sub>2</sub>, Ma<sub>1</sub>, Ma<sub>2</sub>, Upper part of Famennian, Tournaisian (this paper); Ireland, Upper Famennian (Higgs, 1975), Zones VI-PC, Tournaisian (Higgs *et al.*, 1988); Russian Platform, Upper Famennian–Tournaisian, Zones Im-VF, Famennian (Avkhimovitch *et al.*, 1993b).

#### Infraturma PLANATI Neves et Owens 1966

##### Genus *Auroraspora* (Hacquebard, Staplin et Malloy)

Richardson 1960

##### *Auroraspora hyalina* (Naumova) Streeel 1974

Fig. 9R

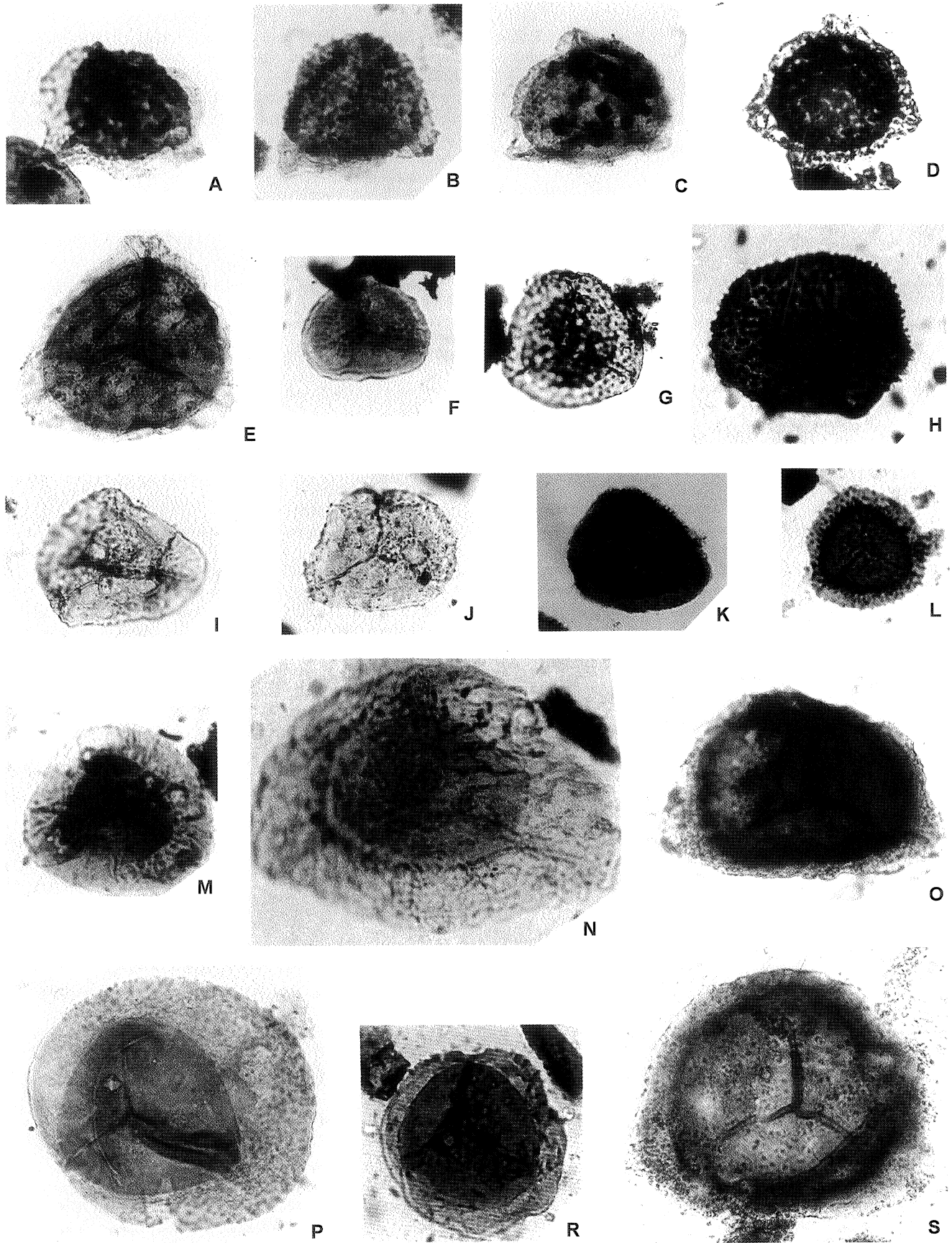
1974. *Auroraspora hyalina* (Naumova) Streeel: Becker *et al.*, p. 26, *cum synonymis*.

**Material:** 16 specimens.

**Description:** Miospores 30–50 µm in diameter. Amb circular or subtriangular. Trilete rays straight, 1/2 of spore radius in length, accompanied by labra about 3 µm in height. Exine cavate. Intexine small, radius 1/2 of spore radius, exoexine smooth or finely granulate, about 2 µm thick.

**Distribution:** Poland – western Pomerania, Gorzysław 8 and 9 boreholes, Subzones Ra<sub>1</sub>, Ra<sub>2</sub>, Ma<sub>1</sub>, Ma<sub>2</sub>, Upper Famennian–Tournaisian (this paper); Russian Platform, Famennian (Naumova, 1953), Famennian–Tournaisian (Byvsheva, 1985); France – Bou-

**Fig. 9.** Miospores from Upper Frasnian, Famennian and Lower Carboniferous in western Pomerania. Specimens **A, C, D, O** are from Gorzysław 11.17, 3319–3337 m, DT Zone, other specimens as indicated below. All magnifications × 500. **A, C, D** – *Samarisporites triangulatus* Allen; **B** – *Samarisporites triangulatus* Allen, Gorzysław 11.12, 3270–3271 m, RD Zone; **E** – *Samarisporites cf. triangulatus* Allen, Gorzysław 11.8, 3226–3227 m, RD Zone; **F** – *Rugospora granulatipunctata* (Hacquebard, Staplin et Malloy) Higgs *et al.*, Gorzysław 9.9, 3187–3188 m, Ma<sub>1</sub> Zone; **G, K, L** – *Grandispora villosa* (Avkhimovitch) comb. nov., Gorzysław 8.3, 3514–3516 m, assemblage II; **H** – *Spelaeotriletes obtusus* Higgs, Chmielno 1.5, 3952–3962 m, Ma<sub>2</sub> Subzone; **I, J** – *Spelaeotriletes resolutus* Higgs, Gorzysław 9.11, 3198–3199 m, Ra<sub>1</sub> Subzone; **M** – *Diducites versabilis* (Kedo) Van Veen, Gorzysław 9.13, 3207–3208 m, Ra<sub>1</sub> Subzone; **N** – *Retispora macroreticulata* (Kedo) Byvsheva, Gorzysław 9.11, 3198–3199 m, Ra<sub>1</sub> Subzone; **O** – *Cristatisporites deliquescens* (Naumova) Arkhangelskaya; **P** – *Diducites poljessicus* (Kedo) Van Veen, Karcino 2.1, 2939–2940 m, IP Zone; **R** – *Auroraspora hyalina* (Naumova) Streeel: Becker *et al.*, Gorzysław 9.4, 3148–3149 m, Ma<sub>2</sub> Subzone; **S** – *Cristatisporites cf. deliquescens* (Naumova) Arkhangelskaya, Gorzysław 11.14, 3284–3285 m, DT Zone



lonnais, Frasnian/Famennian transition (Loboziak & Streel, 1988); Belgium, Upper Frasnian–Famennian (Becker *et al.*, 1974); Brazil, palynozone IV, Frasnian (Loboziak *et al.*, 1988); Libya, palynozone 11, Upper Famennian (Massa & Moreau-Benoit, 1976; Moreau-Benoit, 1980, 1989).

*Diducites poljessicus* (Kedo) Van Veen 1981

Fig. 9P

1957. *Hymenozonotriletes poljessicus* (Kedo): p. 25, tab. 3, figs 6-8.

1974. *Auroraspora poljessica* (Kedo) Streel: Becker *et al.*, p. 26, tab. 20, figs 8-14.

1981. *Diducites poljessicus* (Kedo) Van Veen: p. 271, tab. 4, figs 1-4, 6.

**Material:** 4 specimens.

**Description:** Miospores 67–75 µm in diameter. Amb circular or oval. Trilete rays straight, extending to the intexine margin. Exine cavate. Intexine attached to exoexine proximally, often situated out of centre, outline subtriangular, sides convex, apices rounded, surface bearings few irregular folds. Radius of intexine 2/3–3/4 of spore radius. Exoexine bilayered, smooth or finely granulate. Outer exoexine thinner than the inner one, visible at equatorial margin.

**Distribution:** Poland – western Pomerania, Gorzysław 8, Karcino 2, zone IP, assemblage II, Famennian (this paper); Ireland, zones LL, LE, LN, Famennian (Van Veen, 1981; Van Veen et Van der Zwan, 1978), Zone PL (Higgs, 1975); Ardennes, Famennian (Streel in Becker *et al.*, 1974); Germany, LL, LE, LN zones (Higgs & Streel, 1984); France – Boulonnais, Frasnian and Famennian, from zone “IV” (Streel *et al.*, 1987; Loboziak & Streel, 1988); Belarus – Pripyat Depression, Famennian (Kedo, 1957); Famennian from Zone Im (Avkhimovitch *et al.*, 1993b).

*Diducites versabilis* (Kedo) Van Veen 1981

Fig. 9M

1981. *Diducites versabilis* (Kedo) Van Veen: p. 268, tab. 2, figs 5-6, tab. 3, figs 1-6, 9, *cum synonymis*.

**Material:** 17 specimens.

**Description:** Miospores 45–60 µm in diameter. Amb oval or subtriangular, sides convex, apices broadly rounded. Trilete rays extend almost to intexine margin, accompanied by labra up to 5 µm in height. Exine cavate. Intexine outline conformable with amb, radius 1/2–2/3 of spore radius. Exoexine smooth, bilayered, outer layer visible at equatorial margin, thinner than the inner one, translucent, radially folded, folds 2–6 µm in height.

**Distribution:** Poland – western Pomerania, Gorzysław 8 and 9, Chmielno 1 boreholes, assemblage II, Zone Ra, Famennian (this

paper), Zones Ve, Lu, Ra, Upper Famennian (Turnau, 1979), Holy Cross Mountains, Famennian (Turnau, 1990); Belarus – Pripyat Depression, Devonian/Carboniferous transition (Kedo, 1974; Avkhimovitch *et al.*, 1988b); Ireland, Zones LL-VI, Upper Famennian, Tournaisian (Van Veen, 1981), Zones LL-LN, Upper Famennian (Van der Zwan, 1980); France – Boulonnais, Upper Famennian (Streel *et al.*, 1987; Loboziak & Streel, 1988); Belgium – Ardennes, Famennian (Streel in Becker *et al.*, 1974); Germany – Rheinisches Schiefergebirge, Zones LL-LN, Upper Famennian (Higgs & Streel, 1984).

Subturma MEMBRANATITRILETES Neves et Owens  
1966

Infraturma CONTINUATI Neves et Owens 1966  
Genus *Geminospora* Balme 1962

Type species *Geminospora condensata* Stempień-Sałek, new species

Fig. 10 (A, D, E)

**Holotype:** ING PAN, slide G.9.11.2, 26/37, Fig. 10A.

**Etymology:** (Latin) *condensa* – dense (from densely set elements of ornamentation).

**Material:** 28 specimens.

**Dimension:** 52 µm in diameter.

**Diagnosis:** Miospores cavates, sculpture consisting of dense spinose processes.

**Description:** Miospores 50–65 µm in diameter. Amb subtriangular, sides convex, apices broadly rounded. Trilete rays straight or slightly sinuous, extending almost to equator, often obscured by dense ornament. Exine cavate, cava visible only in thinner and less densely ornamented specimens. Intexine thick, radius 4/5 of spore radius. Exoexine ornamented distally and proximo-equatorially with densely set, mamillate spines 2 do 3 µm wide at base, up to 3 µm in length. Some spines are fused at base with the neighbouring elements, or are about 1 µm apart.

**Remarks:** *Geminospora condensata* has similar amb, and size as *Grandispora lupata* Turnau (1975), but has thicker exine, more closely spaced and wider spines, and narrower camera.

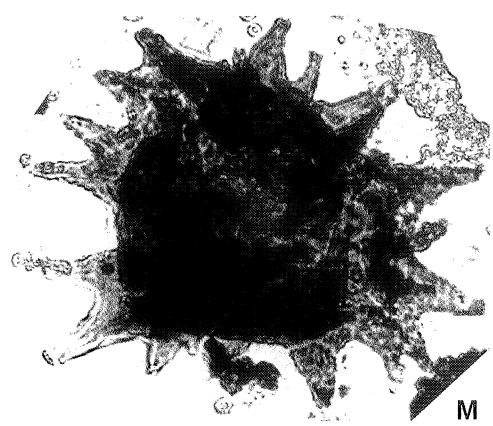
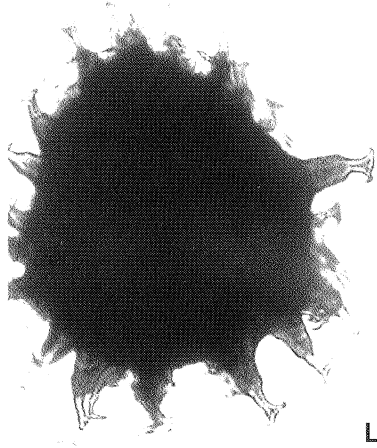
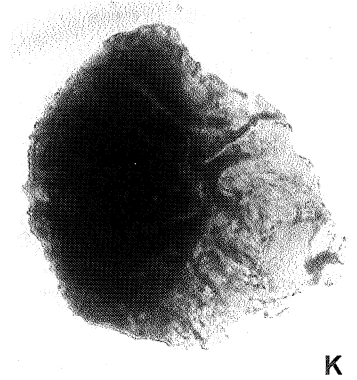
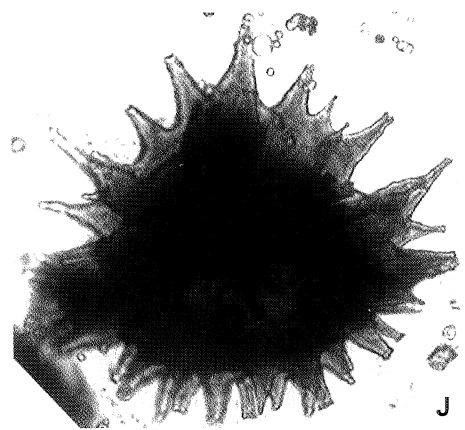
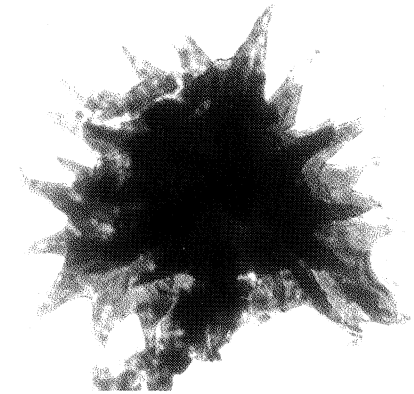
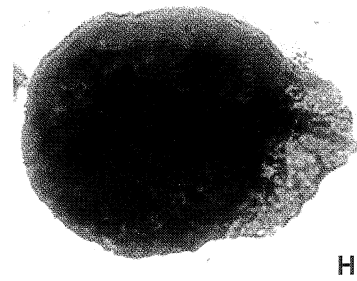
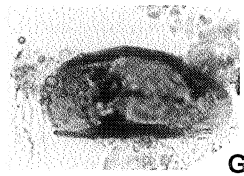
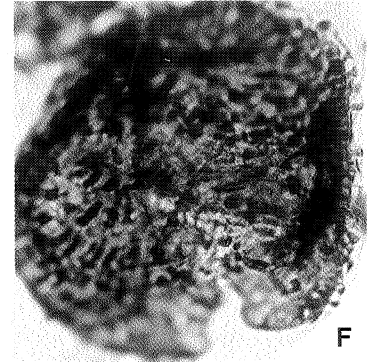
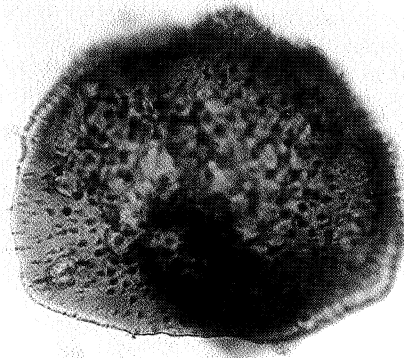
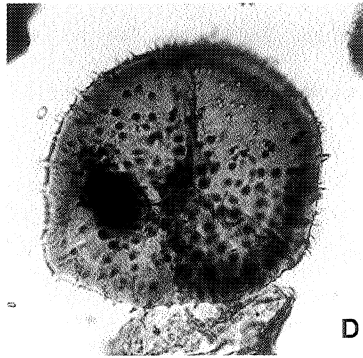
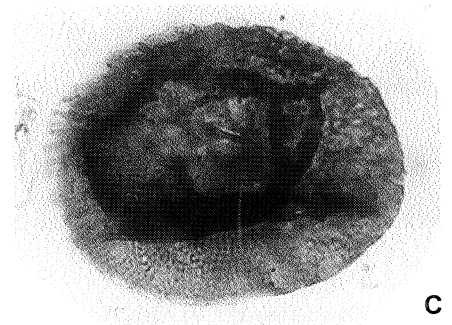
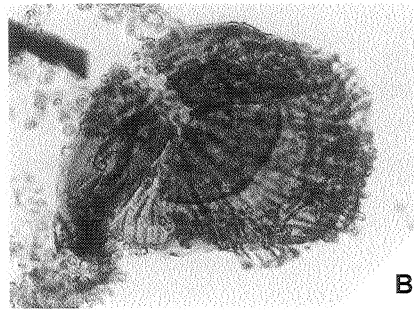
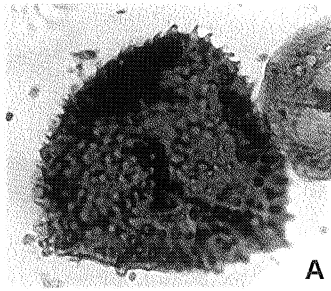
**Type-locality:** Gorzysław 9 borehole, western Pomerania.

**Type-level:** Sapolno Calcareous Shale Formation, Subzones Ra<sub>1</sub>, Famennian, sample G.9.11., depth 3198 m.

**Deposition of types:** slide G.9.11.2, 26/37.

**Fig. 10.** Miospores from Upper Frasnian, Famennian and Lower Carboniferous in eastern Pomerania. Specimens 9, 12, 13, are from Gorzysław 11.10, 3246–3247 m, RD Zone, other specimens as indicated below. All magnifications × 500, except when indicated. **A** – *Geminospora condensata* n. sp., holotype, Gorzysław 9.11, 3198–3199 m, Ra<sub>1</sub> Zone; **B** – *Membrabaculisporis radiatus* (Naumova) Arkhangelskaya, Gorzysław 11.12, 3270–3271 m, RD Zone; **C**, **F** – *Membrabaculisporis radiatus* (Naumova) Arkhangelskaya, Gorzysław 14. 2, 2943–2950 m, RB Zone; **D** – *Geminospora condensata* n. sp., *ibidem*; **E** – *Geminospora condensata* n. sp., Gorzysław 9.13, 3207–3208 m, Ra<sub>1</sub> Zone; **G** – *Archaeoperisaccus concinnus* Naumova, Gorzysław 11.12, 3270–3271 m, RD Zone; **H** – *Ancyrospora langii* (Taugourdeau-Lantz) Allen, Gorzysław 11.17, 3319–3337 m, DT Zone, magnification × 400; **I**, **M** – *Ancyrospora fidus* (Naumova) Obukhovskaya: Avkhimovitch *et al.*, magnification × 400; **J**, **K** – *Lagenosporites immensus* (Nazarenko et Nekryata) Avkhimovitch et Turnau: Avkhimovitch *et al.*, Karcino 2.1, 2939–2940 m, IP Zone; **L** – *Ancyrospora furcula* Owens, magnification × 400





Genus *Membrabaculisporis* Arkhangelskaya 1985*Membrabaculisporis radiatus* (Naumova) Arkhangelskaya 1985

Fig. 10 (B, C, F)

1953. *Hymenozonotriletes radiatus* Naumova: p. 62, tab. 8, fig. 13.  
1985. *Membrabaculisporis radiatus* (Naumova) Arkhangelskaya: p. 74.

**Material:** 10 specimens.

**Description:** Miospores 78–98 µm in diameter. Amb circular to oval. Trilete rays straight, extending to intexine margin, often obscured by ornamentation. Exine camerate, three layered. Intexine thin, occasionally folded, radius 1/3 of spore radius, attached to exoexine in proximal region. Exoexine of contact faces smooth. The remaining surface ornamented with densely set, narrow bacula with thickened, rounded terminations, up to 5 µm in length, about 2 µm wide at tip, 1–4 µm apart. In compressed spores the bacula have mostly radial orientation. Tips of bacula are covered by a membrane.

**Remarks:** In Remarks with specimens from the type area, those from Pomerania do not have punctation on the outer exoexine, which is reduced (or damaged).

**Distribution:** Poland – western Pomerania, Gorzysław 11 and 14, Strzeżewo 1 boreholes, zones RD, RB, Upper Frasnian–lower Famennian (this paper); Russian Platform, Upper Frasnian (Naumova, 1953), Zones OG, DE, Frasnian (Avkhimovitch *et al.*, 1993b).

## INCERTAE SEDIS

Genus *Ancyrospora* (Richardson) Richardson 1962*Ancyrospora fidus* (Naumova) Obukhovskaya: Avkhimovitch *et al.* 1993

Fig. 10 (I, M)

1953. *Archaeotriletes fidus* Naumova: p. 52, pl. VI, figs 5-6.  
1993. *Ancyrospora fidus* (Naumova) Obukhovskaya: Avkhimovitch, Tchibrikova, Obukhovskaya, Nazarenko, Umnova, Raskatova, Loboziak & Streel, tab. 9, fig. 16, tab. 12, fig. 10.

**Material:** 27 specimens.

**Description:** Miospores 66–90 µm in diameter. Amb subtriangular, sides straight or slightly convex. Trilete rays straight, extending to equator, accompanied by slightly sinuous labra up to 20 µm high at the pole. Exine extended laterally at equator to form a narrow zona. Contact faces smooth, the remaining surface covered by densely set appendages 10–30 µm in length, 8–10 µm wide at base. The appendages have slightly laterally extended or truncated terminations. Some 20–25 appendages cross the equator.

**Distribution:** Poland – western Pomerania, Gorzysław 8, 11 and 14, Strzeżewo 1 boreholes, assemblage I, zone RB, Frasnian, lower Famennian (this paper); Russian Platform, Upper Devonian (Naumova, 1953), zones EX-SD, Belarus – Pripyat Depression, Upper Givetian–Frasnian (Avkhimovitch *et al.*, 1993b).

*Ancyrospora furcula* Owens 1971

Fig. 10L

1971. *Ancyrospora furcula* Owens: p. 71, pl. 23, figs 1-4.**Material:** 7 specimens.

**Description:** Miospores 75–98 µm in diameter. Amb subtriangular, sides convex. Trilete rays extending almost to equator, accompanied by slightly sinuous labra up to 20 µm high at the proximal pole (visible only in specimens with thin exine). Contact faces smooth, the remaining surface ornamented with densely set ap-

pendages with bulbous bases and tapering stems which have flattened, bifurcate or multifurcate termination. Appendages 10–20 µm in length, 6–10 µm in basal width, about 5 µm wide at half of their length. About 20 appendages with bases in contact are visible around the equator.

**Distribution:** Poland – western Pomerania, Gorzysław 11 borehole, assemblage I, zone RD, Frasnian (this paper); north Canada, Frasnian (Owens, 1971).

*Ancyrospora langii* (Taugourdeau-Lantz) Allen 1965

Fig. 10H

1960. *Archaeotriletes langii* Taugourdeau-Lantz: p. 145, pl. 3, figs 33, 34, 39.1965. *Ancyrospora langii* (Taugourdeau-Lantz) Allen: p. 743, tab. 106, figs 5-7.**Material:** 14 specimens.

**Description:** Miospores 60–110 µm in diameter. Amb subtriangular, sides slightly convex. Trilete rays accompanied by slightly sinuous labra up to 10 µm in height at the proximal pole, extending almost to equator, visible only in specimens with thin exine. Contact faces smooth, the remaining part of exine ornamented with densely set appendages 12–40 µm in length, 10–12 µm wide at base, with tapering stems which are about 1 µm in width at 3/4 of their length and have bifurcate terminations. The appendages are often broken within the thinnest part. Bases of appendages are occasionally fused with the neighbouring ones.

**Distribution:** Poland – western Pomerania, Gorzysław 11, Strzeżewo 1 boreholes, assemblage I, zones RD-RB, Frasnian–lower Famennian (this paper); France – Boulonnais, Frasnian (Taugourdeau-Lantz, 1971), Givetian, Frasnian (Loboziak & Streel, 1981, 1988); Germany, Eifel, Upper Eifelian–Givetian (Loboziak *et al.*, 1990); Spitsbergen, Givetian (Allen, 1965); Tunisia, Libya, Frasnian (Loboziak & Streel, 1989); Algeria – Givetian–Frasnian (Boumendjel *et al.*, 1988).

Genus *Lagenosporites* Potonié et Kremp emend. Dybova-Jachowicz *et al.* 1979*Lagenosporites immensus* (Nazarenko et Nekryata)

Avkhimovitch et Turnau 1993

Fig. 10 (J, K)

1971. *Hymenozonotriletes immensus* Nazarenko et Nekryata: Kedo, Nazarenko, Nekryata, Raskatova, Sennova & Tchibrikova, p. 188, tab. 16: 1-4.1993. *Lagenosporites immensus* (Nazarenko et Nekryata) Avkhimovitch et Turnau: Avkhimovitch V. I., Turnau, E. & Clayton, pl. 21, fig. 1, pl. 22, fig. 12.**Material:** 7 specimens.

**Description:** Miospores 75–100 µm in diameter, usually preserved in lateral compression. Outline irregular. Trilete mark in the form of a gula. Exine cavate, exoexine forms a distal pseudosaccus which in an oblique compression forms an asymmetric zona 1/2 to 1/1 of spore radius in width. Exine finely punctate.

**Remarks:** *Lagenosporites* is a megaspore genus (Dybova-Jachowiczowa *et al.*, 1979). *L. immensus* is of miospore size and it should be transferred to some other genus. However, the material from Pomerania is poor in specimens giving insufficient base for a taxonomic evaluation.

**Distribution:** Poland – western Pomerania, Gorzysław 8, Karcino 2 boreholes, zone IP, assemblage II, Famennian (this paper); Belarus – Pripyat Depression, zone CZ (subzone Za-VF, Famennian (Avkhimovitch *et al.*, 1993b); USA, Zone *torquata-gracilis-fructicosa*, Famennian (Richardson & Ahmed, 1989).



## SUMMARY

The presented miospore data and their Remarks with those on conodont faunas from western Pomerania indicate that the first appearances of several stratigraphically important miospore species are isochronous over large areas, and thus, palynology is a good tool for local correlation of Upper Devonian and Tournaisian strata.

The Pomeranian miospore zonal scheme can be correlated, at several stratigraphical levels, with the schemes for the Devonian and Lower Carboniferous of eastern Europe. These levels are marked by the following events: first appearance of *Membrabaculisporis radiatus* (lower boundary of the RD zone), first appearance of *Lagenosporites immensus* (lower boundary of the IP zone), first appearance level of *Diducites versabilis* (lower boundary of the Assemblage II) and first appearance of *Knoxisporites literatus* (lower boundary of the Ra Zone).

The proposed miospore zonal scheme is also correlatable, at several stratigraphical levels, with the miospore zonal schemes for the type regions for Devonian and Lower Carboniferous in western Europe. These levels are marked by the following events: first appearance of *Knoxisporites literatus* (lower boundary of the zone Ra), first appearance of *Umbonatisporites distinctus* (lower boundary of the Ma2 Subzone), first appearance of *Spelaeotriletes balteatus* (lower boundary of the Ma3 Subzone), first appearance of *Spelaeotriletes pretiosus* (lower boundary of the Ma4 Subzone).

The results of the miospore study indicate that (a) the Czluchów Formation represents the Frasnian and most of the Famennian (except its Uppermost part), (b) the Sapolno Calcareous Shale Formation spans the Uppermost Famennian and lowermost Tournaisian, and (c) the Gozd Arkose Formation is of Tournaisian age.

The miospore zones distinguished may be considered equivalents of the conodont zones: Assemblage I = (probably) the *punctata* Zone, RD zone = *hassi-rhenana* zones, RB zone = *rhenana-triangularis* zones, IP zone = *crepida* zone, Assemblage II = (probably) *marginifera* Zone, Ra zone = Upper *expansa*-Lower *praesulcata* zones, Ma<sub>1</sub> and Ma<sub>2</sub> Subzones = middle and Upper part of *sandbergi* Zone, Ma<sub>3</sub> = Lower *crenulata* zone, Ma<sub>4</sub> = probably *isosticha*-Upper *crenulata* zone.

The composition of the Pomeranian miospore assemblages from the Frasnian and Lower Famennian is similar to that of the contemporaneous assemblages described from eastern Europe. On the other hand, the Upper Famennian and Tournaisian assemblages are closely comparable with those described from western Europe.

The stratigraphic gap within the Sapolno Calcareous Shale Formation includes an Upper part of the Famennian and the lowermost Tournaisian.

## Acknowledgements

The author wishes to express their sincere gratitude to Professor Elżbieta Turnau who translated and critically discussed the text and to Elżbieta Kowalczyk for rendering the drawings.

## APPENDIX 1

## List of all miospore species determined

- Ancyrospora fidus* (Naumova) Obukhovskaya: Avkhimovitch *et al.* 1993b  
*Ancyrospora langii* (Taugourdeau-Lantz) Allen 1965  
*Ancyrospora furcula* Owens 1971  
*Aneurospora greggsii* (McGregor) Strel in Becker *et al.* 1974  
*Apiculiretusispora nitida* Owens 1971  
*Archaeoperisaccus concinnus* Naumova 1953  
*Archaeozonotriletes variabilis* Naumova 1953  
*Auroraspora asperella* (Kedo) Van der Zwan 1980  
*Auroraspora hyalina* (Naumova) Strel: Becker *et al.* 1974  
*Auroraspora macra* Sullivan 1968  
*Colatisporites multisetus* (Luber) Avkhimovitch *et al.* 1994  
*Convolutispora crassitunicata* (Obukhovskaya) Obukhovskaya: Avkhimovitch *et al.* 1993b  
*Convolutispora major* (Kedo) Turnau 1978  
*Convolutispora mellita* Hoffmeister, Staplin *et al.* 1955  
*Convolutispora subtilis* Owens 1971  
*Corbulispora cf. cancellata* (Waltz) Bharadway *et al.* Venkatachala 1961  
*Corbulispora vimineus* (Nekryata) Obukhovskaya *et al.* Nekryata 1983  
*Corystisporites pomeranius* n.sp.  
*Crassispora trychera* Neves *et al.* Ioannides, 1974  
*Cristatisporites deliquescens* (Naumova) Arkhangelskaya 1987  
*Cymbosporites acanthaceus* (Kedo) Obukhovskaya: Avkhimovitch *et al.* 1993b  
*Cymbosporites acutus* (Kedo) Byvsheva 1985  
*Cymbosporites boafeticus* (Tchibrikova) Obukhovskaya: Avkhimovitch *et al.* 1993b  
*Cymbosporites eximius* (Obukhovskaya) Obukhovskaya: Avkhimovitch *et al.* 1993b  
*Cymbosporites vetlasjanicus* Medianik *et al.* Obukhovskaya: Avkhimovitch *et al.* 1993b  
*Cyrtospora cristifera* (Luber) Van der Zwan 1979  
*Cyrtospora cf. cristifera* (Luber) Van der Zwan 1979  
*Diaphanospora platyrugosa* (Naumova) Obukhovskaya: Avkhimovitch *et al.* 1993b  
*Diducites commutatus* (Naumova) Avkhimovitch 1988b  
*Diducites compactus* (Nekriata) Nekriata 1979  
*Diducites mucronatus* (Kedo) Van Veen 1981  
*Diducites poljessicus* (Kedo) Van Veen 1981  
*Diducites radiatus* (Kedo) Obukhovskaya: Avkhimovitch *et al.* 1993b  
*Diducites versabilis* (Kedo) Van Veen 1981  
*Diducites vishenensis* Obukhovskaya *et al.* Avkhimovitch: Avkhimovitch *et al.* 1993b  
*Discernisporites micromanifestus* (Hacquebard) Sabry *et al.* Neves 1971  
*Endoculeospora gradziński* Turnau 1975  
*Geminospora condensa* n. sp.  
*Geminospora micromanifesta* (Naumova) Arkhangelskaya 1985  
*Geminospora nalevkini* (Naumova) Obukhovskaya 1986  
*Geminospora notata* (Naumova) Obukhovskaya: Avkhimovitch *et al.* 1993b  
*Geminospora notata* var. *microspinosa* Tchibrikova 1972  
*Geminospora rugosa* (Naumova) Obukhovskaya: Avkhimovitch *et al.* 1993b  
*Gorgonispora crassa* (Winslow) Higgs *et al.* 1988  
*Grandispora aspersa* (Avkhimovitch) Avkhimovitch 1976  
*Grandispora cornuta* Higgs 1975  
*Grandispora echinata* Hacquebard 1957  
*Grandispora famenensis* (Naumova) Strel var. *minutus* Nekryata 1974

*Grandispora lupata* Turnau 1975  
*Grandispora uncata* (Hacquebard) Playford 1971  
*Grandispora villosa* (Avkhimovitch) comb. nov.  
*Hymenozonotriletes argutus* Naumova 1953  
*Hystricosporites corystus* Richardson 1962  
*Hystricosporites furcatus* Owens 1971  
*Hystricosporites multifurcatus* (Winslow) Mortimer et Chaloner 1967  
*Hystricosporites porrectus* (Balme et Hassel) Allen 1965  
*Hystricosporites reflexus* Owens 1971  
*Hystricosporites suborlovicus* (Kedo) comb. nov.  
*Indotrivadites explanatus* (Luber) Playford 1991  
*Knoxisporites literatus* (Waltz) Playford 1963  
*Laevigatosporites ovalis* Kosanke 1950  
*Lagenoisporites immensus* (Nazarenko et Nekryata) Avkhimovitch et Turnau: Avkhimovitch *et al.* 1993b  
*Lophozonotriletes excisus* Naumova 1953  
*Lophozonotriletes fursenkoi* Nekryata 1979  
*Lophozonotriletes multiformis* Tchibrikova 1972  
*Membrabaculisporis radiatus* (Naumova) Arkhangelskaya 1985  
*Murospora dubitata* Higgs 1975  
*Plicatispora scoleophora* (Neves et Ioannides) Higgs *et al.* 1988  
*Pustulatisporites gibberosus* (Hacquebard) Playford 1964  
*Raistrickia corynoges* Sullivan 1968  
*Raistrickia minor* (Kedo) Neves et Dolby 1967  
*Raistrickia ramiformis* (Kedo) Avkhimovitch et Higgs: Avkhimovitch *et al.* 1988b  
*Raistrickia spathulata* (Winslow) Higgs 1975  
*Raistrickia variabilis* Dolby et Neves 1970  
*Retispora lepidophyta* (Kedo) Playford 1976  
*Retispora macroreticulata* (Kedo) Byvsheva 1985  
*Retusotriletes cohatus* Sullivan 1964  
*Retusotriletes planus* Dolby et Neves 1970  
*Retusotriletes pychovi* Naumova 1953  
*Rugospora radiata*, Avkhimovitch *et al.* 1988a  
*Rugospora granulatipunctata* (Hoffmeister, Staplin et Malloy) Higgs *et al.* 1988  
*Samarisporites triangulatus* Allen 1965  
*Schopfites* cf. *delicatus* (Higgs) Higgs *et al.* 1988  
*Spelaeotriletes balteatus* (Playford) Higgs 1975  
*Spelaeotriletes obtusus* Higgs 1975  
*Spelaeotriletes pretiosus* (Playford) Neves et Belt 1971  
*Spelaeotriletes resolutus* Higgs 1975  
*Tholisporites densus* McGregor 1960  
*Tumulispora malevkensis* (Kedo) Turnau 1978  
*Tumulispora obscura* Staplin et Jansonius 1964  
*Tumulispora rarituberculata* (Luber) Playford 1991  
*Umbonatisporites abstrusus* (Playford) Clayton 1971  
*Umbonatisporites distinctus* Clayton 1971  
*Umbonatisporites distinctus* var. *crinitus*, n. var.  
*Vallatisporites* cf. *pussilites* (Kedo) Dolby et Neves 1970  
*Velamisporites* cf. *caperatus* (Higgs) Higgs *et al.* 1988  
*Velamisporites magnus* (Huphes et Hayford) Playford 1971  
*Verrucosisporites evlanensis* (Naumova) Obukhovskaya: Avkhimovitch *et al.* 1993b  
*Verrucosisporites* cf. *evlanensis* (Naumova) Obukhovskaya: Avkhimovitch *et al.* 1993b  
*Verrucosisporites grumosus* (Naumova) Sullivan 1964  
*Verrucosisporites nitidus* Playford 1964  
*Verrucosisporites oppressus* (Higgs) Higgs *et al.* 1988  
*Verrucosisporites scurrus* (Naumova) McGregor et Camfield 1982

## REFERENCES

- Allen, K. C., 1965. Lower and Middle Devonian spores of North and Central Vestspitsbergen. *Palaeontology*, 8: 687–748.
- Arkhangelskaya, A. D., 1985. Spory iz otlozhenij turnejskogo i vizenskogo jarusov Russkoj plity. (In Russian). In: Menner, V. V. & Byvsheva, T. V. (eds). *Atlas spor i pylcy neftegazonosnykh tolshch fanerozoja Russkoj i Turanskoj plit. Trudy VNIGRI Nedra*: 1–79.
- Arkhangelskaya, A. D., 1987. Novyj rod i nekatoryje widy spor franskovo jarusa wołgogradskoj oblasti. (In Russian). *Paleontologičeskij Žurnal*, (3), *Akademia Nauk USSR*: 84–92.
- Avkhimovitch, V. I., 1974. Palynological characteristics of the Upper Famennian saliferous formation in the Pripyat Depression. (In Russian). *Paleozoic spores of Belorussia, Minsk, BelNIGRI*: 95–107.
- Avkhimovitch, V. I., 1976. Famennian spore assemblages in the salt-bearing and suprasalt measures of the Pripyat Depression and their stratigraphic significance. (In Russian). *Thesis synopsis, Vilnius State University*: pp. 30.
- Avkhimovitch, V. I., 1986. Zonal differentiation and correlation of the Devonian/Carboniferous boundary deposits in Belorussia (Pripyat Depression) with the standard sections of the Franco-Belgian Basin by the spores. *Palaeontology and its role in the knowledge study of the Geological Structure of Belorussia*. (In Russian). *Nauka i Technika*: 145–165.
- Avkhimovitch, V. I., 1993. Zonation and spore complexes of the Devonian and Carboniferous boundary deposits of the Pripyat Depression (Belorussia). *Annales de la Société Géologique de Belgique*, 115: 425–452.
- Avkhimovitch, V. I. & Turnau, E., 1994. The Lower Carboniferous *Prolycospora claytoni* Zone of Western Pomerania and its equivalents in Belorussia and North-western Europe. *Annales Societatis Geologorum Poloniae*, 63: 249–263.
- Avkhimovitch, V. I., Nekryata, N. S. & Obukhovskaya, T. G., 1988a. Devonian palynostratigraphy of the Pripyat Depression, Byelorussia. In: *Devonian of the World. Proceedings of the II International Symposium. Devonian System, Calgary, Canada*, 3: 559–567.
- Avkhimovitch V. I., Turnau, E. & Clayton, G., 1993a. Correlation of uppermost Devonian and Lower Carboniferous miospore zonation in Belorussia, Poland and Western Europe. *Annales de la Société Géologique de Belgique*, 115: 453–458.
- Avkhimovitch, V. I., Byvsheva, T. V., Higgs, K., Streel, M. & Umnova, V. T., 1988b. Miospore systematics and stratigraphic correlation of Devonian–Carboniferous boundary deposits in the eastern part of the USSR and Western Europe. *Courier Forschungsinstitut Senckenberg*, 100: 169–191.
- Avkhimovitch, V. I., Tchibrikova, E. V., Obukhovskaya, T. G., Nazarenko, A. M., Umnova, V. T., Raskatova, L. G., Manturova, V. N., Loboziak, S. & Streel, M., 1993b. Middle and Upper Devonian miospore zonation of Eastern Europe. *Bulletin des Centres de Recherche Exploration-Production Elf Aquitaine*, 17: 79–147.
- Balme, B. E., 1962. Upper Devonian (Frasnian) spores from the Carnarvon basin, Western Australia. *The Palaeobotanist*, 9: 1–10.
- Becker, G., Bless, M. J. M., Streel, M. & Thorez, J., 1974. Palynology and ostracod distribution in the Upper Devonian and basal Dinantian of Belgium and their dependence on sedimentary facies. *Mededelingen Rijks Geologische Diensten, Nieuwe Serie*, 25: 9–99.
- Bednarczyk, W., 1974. The Ordovician in the Koszalin–Chojnice region (Western Pomerania). *Acta Geologica Polonica*, 24: 581–600.





- Bharadway, D. C. & Venkatachala, B. S., 1961. Spore assemblage out of a Lower Carboniferous shale from Spitsbergen. *The Palaeobotanist*, 10: 18–47.
- Boumendjel, K., Loboziak, S., Paris, F., Steemans, P. & Strel, M., 1988. Biostratigraphie des miospores et des chitinozoaires du Silurien supérieur et du Dévonien dans le bassin d' Illizi (S.E. du Sahara Algérien). *Géobios*, 21: 381–391.
- Butterworth, M. A. & Williams, R. W., 1958. The small spore floras of coals in the Limestone Coal Group and Upper Limestone Group of the Lower Carboniferous of Scotland. *Royal Society Edinburgh Transactions*, 63: 353–92.
- Byvsheva, T. V., 1976. Zonation of spore complexes from Devonian–Carboniferous boundary deposits from the eastern part of the Russian platform. (In Russian). In: Byvsheva, T. V. (ed.). *Results of palynological researches of the Precambrium, Paleozoic and Mesozoic of the USSR. Trudy VNIGRI*, 192: 67–93.
- Byvsheva, T. V., 1985. Spory iz otlozhenij turnejskogo i vizenkogo jarusov Russkoj plity. (In Russian). In: Menner, V. V. & Byvsheva, T. V. (eds). *Atlas spor i pylcy neftegazonosnykh tolshch fanerozoja Russkoj i Turanskoj plit. Trudy VNIGNI Nedra*: 80–158.
- Clayton, G., 1971. A Lower Carboniferous miospore assemblage from the Calciferous Sandstone Measures of the Cockburnspath region of eastern Scotland. *Pollen et Spores*, 12: 577–600.
- Clayton, G. & Graham, J. R., 1974. Miospore assemblages from the Devonian Sherkin Formation of south-west County Cork, Republic of Ireland. *Pollen et Spores*, 16: 565–588.
- Clayton, G. & Turnau, E., 1990. Correlation of the Tournaisian miospore zonation of Poland and the British Isles. *Annales Societatis Geologorum Poloniae*, 60: 45–58.
- Dadlez, R., 1978. Sub-Permian rock complexes in the Koszalin–Chojnice zone. (In Polish, English summary). *Kwartalnik Geologiczny*, 22: 269–294.
- Dadlez, R., 1990. Tektonika południowego Bałtyku. (In Polish, English summary). *Kwartalnik Geologiczny*, 34: 1–20.
- Dadlez, R., 1993. Pre-Cainozoic tectonic of the southern Baltic Sea. *Kwartalnik Geologiczny*, 37: 431–450.
- Dettman, M. E., 1963. Upper Mesozoic microfloras from South-eastern Australia. *Proceedings of the Royal Society of Victoria*, 77: pp. 148.
- Dolby, G. & Neves, R., 1970. Palynological evidence concerning the Devonian–Carboniferous boundary in the Mendips, England. *C. R. 6<sup>ème</sup> Congrès International Stratigraphie Géologie Carbonifère, Sheffield*, II: 631–646.
- Dybova, S. & Jachowicz, A., 1957. Mikrospory Górno-Śląskiego karbonu produktywnego. *Prace Instytutu Geologicznego*, 23: 1–329.
- Dybova-Jachowiczowa, S., Jachowicz, A., Karczewska, J., Lachkar G., Loboziak, S., Pierart, P., Turnau, E. & Żoldani, E., 1979. Note préliminaire sur la révision des megaspores à gula du Carbonifère. Les principes de la classification. *Acta Palaeontologica Polonica*, 24: 411–422.
- Górecka, T. & Parka, Z., 1980. Stratygrafia utworów karbonu z otworu Koszalin IG-1 na podstawie danych palinologicznych. *Prace Naukowe Instytutu Górniczego Politechniki Wrocławskiej*, 35, *Studia Materialowe*, 16: 35–44.
- Higgs, K., 1975. Upper Devonian and Lower Carboniferous miospore assemblages from Hook Head, County Wexford, Ireland. *Micropaleontology*, 21: 393–419.
- Higgs, K. & Russel, K. J., 1981. Upper Devonian Microfloras from Southeast Iveragh, County Kerry, Ireland. *Geological Survey Ireland, Bulletin*, 3: 17–50.
- Higgs, K. & Strel, M., 1984. Spore stratigraphy at the Devonian–Carboniferous boundary in the northern "Rheinisches-Schiefergebirge", Germany. *Courier Forschungsinstitut Senckenberg*, 67: 157–179.
- Higgs, K., Clayton, G. & Keegan, J. B., 1988. Stratigraphic and Systematic Palynology of the Tournaisian Rocks of Ireland. *The Geological Survey of Ireland. Special Paper No 1*: pp. 93.
- Higgs, K., Dreesen, R., Dusar, M. & Strel, M., 1992. Palynostratigraphy of the Tournaisian (Hastarian) rocks in the Namur Synclinorium, West Flanders, Belgium. *Review of Palaeobotany and Palynology*, 72: 149–158.
- Higgs, K., Avkhimovitch, V. I., Loboziak, S., Maziane-Serraj, N., Stempień-Sałek, M. & Strel, M., 2000. Systematic study and stratigraphic correlation of the *Grandispora* complex in the Famennian of northwest and eastern Europe. *Review of Palaeobotany and Palynology*, 112: 207–228.
- Hoffmeister, W. S., Staplin, F. L. & Malloy, R. E., 1955. Mississippian plant spores from the Hardinsburg Formation of Illinois and Kentucky. *Journal of Paleontology*, 29: 372–399.
- Kedo, G. I., 1957. Stratigraphy and spore-pollen complexes of the lower horizons of the Carboniferous of the Byelorussian SSR. (In Russian). *Doklady Akademi Nauk USSR*, 115: 1165–1168.
- Kedo, G. I., 1963. Spory turnejskogo jarusa pripiatskogo progiba i ikh stratigraficheskie znachenije. (In Russian). *Paleontologia i stratigrafija BSSR*, 4: 3–121.
- Kedo, G. I., 1974. Novyje vidy spor iz verkhnego devona pripiatskoj vpadiny. (In Russian). In: Golubtsov, V. K. & Manykin, S. S. (eds), *Spory paleozoja Belorussii. Izd. BelNIGRI, Mińsk*: 3–72.
- Kedo, G. I. & Golubcov, V. K., 1971. Palinologičeskij kriterij dla opredelenia granicy dewona i karbona w Pripiatskoj vpadinie. (In Russian). *Palinologia i Stratigrafia paleozoja. BelNIGRI Mińsk*: 5–34.
- Kedo, G. I., Nazarenko, A. M., Nekryata, N. C., Raskatova, L. G., Sennova, W. F. & Tchibrikova, E. V., 1971. New spore species from Famennian deposits of the Pripyat Depression, central regions of Russian Platform, Volga-Urals oil and gas bearing region and Timan. (In Russian). In: Golubtsov, V. K. (ed.), *Palinologičeskie Issledovania v Belorussii i drugikh raionakh SSSR. Nauka i Tekhnika, Minsk*: 172–205.
- Kmieciak, H., 1986. Palynostratigraphy of the Carboniferous at the margin of the Polish part of the east-European platform. *Review of Palaeobotany and Palynology*, 48: 327–345.
- Kmieciak, H., 1991. Wyniki badań sporowo-stratygraficznych karbonu północno-zachodniej Polski. (In Polish) *XIV Sympozjum Geologia Formacji Węglowych Polski. Formacja Karbońska*: 27–30.
- Kmieciak, H., 1995. Palynostratigraphy of the Carboniferous in Poland and some cosmopolitan palynological events. *XIII International Congress on Carboniferous–Permian, Kraków, Poland*: 75–76.
- Korejwo, K., 1976. Biostratygrafia of the Carboniferous sediments from the Wierzchowo area (Western Pomerania). *Acta Geologica Polonica*, 29: 457–473.
- Korejwo, K., 1979. The Carboniferous of the Chojnice area (Western Pomerania). *Acta Geologica Polonica*, 26: 541–555.
- Korejwo, K., 1993. Biostratygrafia utworów dinantu w strefie Koszalin–Chojnice (Pomorze Zachodnie). *Studia Geologica Polonica*, 103: 1–47.
- Krawczyńska-Grocholska, H., 1975. Z badań palinologicznych karbonu północno-zachodniej Polski. *Przegląd Geologiczny*, 23: 34–35.
- Lipiec, M. & Matyja, H., 1998. Architektura depozycyjna basenu dolno-karbońskiego na obszarze pomorskim. *Prace Państwowego Instytutu Geologicznego*, 165: 101–112.
- Loboziak, S. & Strel M., 1981. Miospores in Middle-Upper



- Frasnian to Famennian sediments partly dated by conodonts (Boulonnais), France. *Review of Palaeobotany and Palynology*, 34: 49–66.
- Loboziak, S. & Streel, M., 1988. Synthèse palynostratigraphique de l'intervalle Givétien–Famennien du Boulonnais (France). Le Dévonien de Ferques/ Bas-Boulonnais (N. France), in Brice D., (ed), *Biostratigraphie du Paléozoïque - Université de Bretagne Occidentale*, 7: 71–77.
- Loboziak, S. & Streel, M., 1989. Middle-Upper Devonian Miospores from the Ghadamis Basin (Tunisia–Libya): Systematics and Stratigraphy. *Review of Palaeobotany and Palynology*, 58:173–196.
- Loboziak, S., Streel, M. & Burjack, M. I. A., 1988. Miospores du Dévonien moyen et supérieur du bassin du Parana, Brésil: Systématique et stratigraphie. *Sciences géologiques*, 41: 351–377.
- Loboziak, S., Streel, M. & Weddige, K., 1990. Miospores the *lemurata* and *triangulates* Levels and their faunal indices near the Eifelian/Givetian boundary in the Eifel (F. R. G.). *Annales de la Société Géologique de Belgique*, 113: 1–15.
- Łobanowski, H., 1968. Wstępne dane o dewonie w strefie strukturalnej Chojnic (phn.-zach. Polska). (In Polish, English summary). *Acta Geologica Polonica*, 18: 765–786.
- Malec, G. & Turnau, E., 1997. Middle Devonian conodont, ostracod and miospore stratigraphy of the Grzegorzowice-Skały section, Holy Cross Mountains, Poland. *Bulletin Polish Academy of Sciences*, 45: 67–86.
- Massa, D. & Moreau-Benoit, A., 1976. Essai de synthèse stratigraphique et palynologique du système Dévonien en Libye occidentale. *Revue de L'Institut Français du Pétrole*, 31: 287–333.
- Matyja, H., 1976. Biostratigraphy of the Devonian–Carboniferous passage beds from some selected profiles of NW Poland. *Acta Geologica Polonica*, 26: 489–539.
- Matyja, H., 1993. Upper Devonian of Western Pomerania. *Acta Geologica Polonica*, 43: 27–94.
- Matyja, H., 1998. Architektura depozycyjna basenu dewońskiego na obszarze pomorsko-kujawskim. *Prace Państwowego Instytutu Geologicznego*, 165: 73–88.
- Matyja, H. & Turnau, E., 1989. Conodonts and spores from Devonian/Carboniferous boundary beds in Poland. *Proceedings of the XI Congrès International de Stratigraphie et de Géologie du Carbonifère, Beijing*, 1987.
- Matyja, H. & Stempień-Sałek, M., 1994. Devonian/Carboniferous boundary and the associated phenomena in Western Pomerania (NW Poland). *Annales de la Société Géologique de Belgique*, 116: 249–263.
- Matyja, H., Turnau, E. & Żbikowska B., 2000. Lower Carboniferous (Mississippian) stratigraphy of northwestern Poland: conodont, miospore and ostracode zones compared. *Annales Societatis Geologorum Poloniae*, 70: 193–217.
- McGregor, D. C., 1960. Devonian spores from Melville Island, Canadian Arctic Archipelago. *Palaeontology*, 3: 26–44.
- McGregor, D. C., 1964. Devonian miospores from the Ghost River Formation, Alberta. *Geological Survey of Canada*, 109: pp. 31.
- McGregor, D. C., 1979a. Devonian miospores of North America. *Palynology*, 3: 31–52.
- McGregor, D. C., 1979b. Devonian spores from the Barrandian region of Czechoslovakia and their significance for interfacies correlation. In: *Current Research, Part B, Geological Survey of Canada*, 79: 189–197.
- McGregor, D. C. & Camfield, M., 1976. Upper Silurian ? to Middle Devonian spores of the Moose River Basin, Ontario. *Geological Survey of Canada. Bulletin*, 263: pp. 63.
- McGregor, D. C. & Camfield, M., 1982. Middle Devonian miospores from the Cape de Bray, Weatherall, and Hecla Bay Formations of Northeastern Melville Island, Canadian Arctic. *Geological Survey of Canada. Bulletin*, 348: pp. 105.
- McGregor, D. C. & Playford G., 1992. Canadian and Australian Devonian spores: zonation and correlation. *Geological Survey of Canada. Bulletin*, 438: 1–125.
- Miłaczewski, L., 1979. Litologia i stratygrafia dewonu na Pomorzu. (In Polish). *Konferencja Naukowo-Techniczna w Tucznie. Poszukiwania Nafty i Gazu*. Piła: 176–189.
- Miłaczewski, L., 1980. Zarys badań dewonu w Polsce. Dewon na Pomorzu Zachodnim. *Kwartalnik Geologiczny*, 24: 944–945.
- Miłaczewski, L., 1986. Dewon na Pomorzu. (In Polish). *Konferencja Naukowo-Techniczna w Tucznie. Poszukiwania Nafty i Gazu*. Piła: 77–88.
- Miłaczewski, L., 1987. Stratygrafia i charakterystyka litologiczna. Rozwój i ukształtowanie basenu. In Raczyńska, A. (ed.). *Budowa geologiczna Wału Pomorskiego i jego podłoża*. (In Polish). *Prace Instytutu Geologicznego*, 119: 16–21.
- Moreau-Benoit, A., 1980. Les spores du Dévonien de Libye (deuxième partie). *Cahiers de Micropaléontologie, Centre National de la Recherche Scientifique*, 1: pp. 53.
- Moreau-Benoit, A., 1989. Les spores du Dévonien moyen et supérieur de Libye occidentale, In: Compléments-Systématique-Répartition stratigraphique. *Cahiers de Micropaléontologie, Centre National de la Recherche Scientifique*, 4: 5–32.
- Mortimer, M. G. & Chaloner, W. G., 1967. Devonian megaspores from the Wyboston borehole, Bedfordshire, England. *Palaeontology*, 10: 189–213.
- Naumova, S. N., 1953. Spore-pollen assemblages of the Russian platform and their stratigraphic significance. (In Russian). *Trudy Instituta Geologicheskikh Nauk, Akademia Nauk USSR* 143, (*Geologicheskaya seriya* 60): 1–204.
- Nekryata, N. S., 1979. Zonal spore assemblages in the Pripyat Depression intersalt deposits. (In Russian). *Doklady Akademi Nauk BSSR*, 23: 547–549.
- Neves, R. & Belt, E. S., 1971. Some observations of Namurian and Viséan spores from Nova Scotia, Britain and northern Spain. *Compte Rendu 6e Congrès International de Stratigraphie et de Géologie du Carbonifère Sheffield 1967*: 1233–1249.
- Neves, R. & Dolby, G., 1967. An assemblage of miospores from the Portishedd Beds (Upper Old Red Sandstone) of Mendip Hills, England. *Pollen et Spores*, 9: 607–614.
- Neves, R. & Ioannides, N., 1974. Palynology of the Lower Carboniferous (Dinantian) of the Spilmersford borehole, East Lothian, Scotland. *Bulletin of the Geological Survey of Great Britain*, 45: 73–79.
- Neves, R. & Owens, B., 1966. Some Namurian camerate miospores from the English Pennines. *Pollen et Spores*, 8: 337–360.
- Neves, R., Gueinn, K. J., Clayton, G., Ioanides, N., Neville, R. S. W. & Kruszevska K., 1973. Palynological correlation within the Lower Carboniferous of Scotland and northern England. *Transactions of the Royal Society of Edinburgh*, 69: 23–70.
- Obukhovskaya, N. S., 1986. Range and boundaries of the Frasnian deposits in the Pripyat Depression by palynological data. In: *Palaeontology and its role in the study of Geological Structure of Belorussia*. (In Russian). Mińsk, *Nauka i Technika*: 134–144.
- Obukhovskaya, N. S. & Nekryata, N. S., 1983. Palynological characteristics of the Frasnian/Famennian boundary deposits in the Pripyat Depression. In: Questions of regional geological structure of the BSSR. (In Russian). *BelNIGRI*: 108–122.
- Owens, B., 1971. Miospores from the Middle and early Upper De-



- vonian rocks of the western Queen Elizabeth Islands, Arctic Archipelago. *Geological Survey of Canada, Paper*, 70–98: pp. 157.
- Pajchlowa, M., 1968. Wstępne dane o dewonie Zachodniego Pomorza. *Kwartalnik Geologiczny*, 12: 1039–1040.
- Playford, G., 1964. Miospores from the Mississippian Horton Group, eastern Canada. *Geological Survey of Canada Bulletin*, 7: 1–47.
- Playford, G., 1971. Lower Carboniferous spores from the Bonaparte Gulf Basin, Western Australia and Northern Territory. *Bulletin Bureau of Mineral Resources, Geology and Geophysics*, 115: pp. 104.
- Playford, G., 1982. A latest Devonian palynoflora from the buttons beds, Bonaparte Gulf Basin, Western Australia. *BMR Journal of Australian Geology et Geophysics*, 7: 149–157.
- Playford, G., 1991. Australian Lower Carboniferous miospores relevant to extra-Gondwanic correlations: an evaluation. *Courier Forschungsinstitut Senckenberg*, 130: 85–125.
- Playford, G. & McGregor, D.C., 1993. Miospores and organic-walled microphytoplankton of Devonian–Carboniferous boundary beds (Bakken Formation), Southern Saskatchewan: a systematic and stratigraphic appraisal. *Geological Survey of Canada Bulletin*, 445: pp. 107.
- Potonié, R., 1970. Synopsis der Gattungen der Sporae dispersae. V. Teil: Die Nachträge zur allen Gruppen (Turmae). *Beihefte Geologischen Jahrbuch*, 87: pp. 222.
- Potonié, R. & Kremp, G., 1954. Die Gattungen der paläozoischen Sporae dispersae und ihre Stratigraphie. *Geologisches Jahrbuch*, 69: 111–194.
- Richardson, J. B., 1960. Spores from the Middle Old Red Sandstone of Cromarty, Scotland. *Palaeontology*, 3: 45–63.
- Richardson, J. B., 1962. Spores with bifurcate processes from the Middle Old Red Sandstone of Scotland. *Palaeontology*, 5: 171–194.
- Richardson, J. B., 1965. Middle Old-Red Sandstone spore assemblages from the Orcadian basin, north-east Scotland. *Palaeontology*, 7: 559–605.
- Richardson, J. B. & Ahmed, S., 1989. Miospores, zonation and correlation of Upper Devonian sequences from western New York State and Pennsylvania. In: McMillan, N. J., Embry A. F. & Glass D.J. (eds). *Devonian of the World, Vol. III, Paleontology, Paleoecology and Biostratigraphy, Canadian Society of Petroleum Geologists, Calgary Memoir*, 14: 541–588.
- Richardson, J. B. & McGregor, D. C., 1986. Silurian and Devonian spore zones of the Old Red Sandstone continent and adjacent regions. *Geological Survey of Canada Bulletin*, 364: 1–79.
- Sennova, V. F., 1972. Upper Devonian spore and pollen assemblages in the Timan–Pechora Province. In: *Geology and petroleum potential in the north-east of the European USSR*. (In Russian). *Syktvykar*, 2: 99–108.
- Smith, A. H. V. & Butterworth, M. A., 1967. Miospores in the coal seams of the Carboniferous of Great Britain. *Special Papers in Palaeontology*, pp. 324.
- Somers, Y. & Strel, M., 1978. Spores du sommet du Dévonien à Langenaubach. Relation entre la conservation des spores, le pouvoir réflecteur de la vitrinite et des intrusions diabasique. *Annales des Mines de Belgique*, 7-8: 147–154.
- Staplin F. L., 1960 Upper Mississippian plant spores from the Gollata Formation, Alberta, Canada, *Palaeontographica B*, 107: 1–40.
- Staplin F.L & Jansonius, J., 1964. Elucidation of some Paleozoic densospores. *Palaeontographica B*, 114: 95–117.
- Stempień-Sałek, M., 1993. Szczegółowszy od dotychczasowego podział zonalny utworów famenu i hastaru Pomorza Zachodniego. (In Polish). *XVI Sympozjum Geologia formacji węglonośnych Polski, materiały, Kraków*: 104–107.
- Stempień-Sałek, M., 1996. Some acritarchs of the Upper Palaeozoic from western Pomerania (NW Poland). *Acta Universitatis Carolinae*, 40: 667–675.
- Stempień-Sałek, M., 2000. Upper Devonian Miospore Stratigraphy in Western Pomerania (NW Poland). *Proceedings of the Fifth European Palaeobotanical and Palynological Conference, Acta Palaeobotanica, Supp.*, 2: 59–65.
- Strel, M., 1964. Etude palynologique du Dévonien du sondage de Booischoot (Belgique) Note préliminaire. *Bulletin Société belge Géologie, Paléontologie, Hydrologie*, 73: 172–185.
- Strel, M., 1967. Association de spores du Dévonien inférieur belge et leur signification stratigraphique. *Annales de la Société Géologique Belgique*, 90: 11–54.
- Strel, M., 1972. Dispersed spores associated with *Leclercqia complexa* Banks, Bonamo and Grierson from the late Middle Devonian of Eastern New York State (USA). *Review of Palaeobotany and Palynology*, 14: 205–215.
- Strel, M., 1974. Similitudes des assemblages de spores d'Europe, d'Afrique du Nord et d'Amérique du Nord au Dévonien terminal. *Sciences Géologique Bulletin*, 27: 25–38.
- Strel, M. & Loboziak S., 1987. Nouvelle datation par miospore du Givétien–Frasnien des sédiments non marins du sondage de Booischoot (Basin de Campine, Belgique). *Bulletin Société belge Géologie*, 96: 99–106.
- Strel, M., Higgs, K., Loboziak, S., Riegel, W. & Steemans, P., 1987. Spore stratigraphy and correlation with faunas and floras in the type marine Devonian of the Ardenne-Rhenish regions. *Review of Palaeobotany and Palynology*, 50: 211–229.
- Sullivan, H., 1964. Miospores from the Lower Limestone shales (Tournaisian) of the Forest of Dean Basin, Gloucestershire. *Compte Rendu 6e Congrès International de Stratigraphie et de Géologie du Carbonifère, Paris* (1963): 1249–1259.
- Sullivan, H., 1986. A Tournaisian spore flora from the Cementstone Group of Ayrshire, Scotland. *Palaeontology*, 11: 116–131.
- Taugourdeau-Lantz, J., 1960. Sur la microflore du Frasnien inférieur de Beaulieu (Boulonnais). *Revue de Micropaléontologie*, 3: 144–154.
- Taugourdeau-Lantz, J., 1971. Les spores du Frasnien d'une région privilégiée, le Boulonnais. *Mémoires de la Société Géologique de France (N. S.)*, 114: 1–86.
- Tchirikova, E. V., 1972. Plant microfossils from the South Urals and Cisuralia (In Russian). *Moskow, Nauka*: pp. 222.
- Tchirikova, E. V., 1977. Stratigraphy of the Devonian and more ancient Paleozoic deposits in the South Urals and adjacent areas. (In Russian). *Moskow, Nauka*: pp. 191.
- Teller, L., 1974. The Silurian of the margin of the East European platform in the region of Miastko-Chojnica (NW) Poland. *Acta Geologica Polonica*, 24: 563–580.
- Turnau E., 1975. Microflora of the Famennian and Tournaisian deposits from boreholes of northern Poland. *Acta Geologica Polonica*, 25: 505–528.
- Turnau, E., 1978. Spore zonation of Uppermost Devonian and Lower Carboniferous deposits of Western Pomerania (N Poland). *Mededelingen Rijks Geologische Diensten*, 30: 1–35.
- Turnau, E., 1979. Correlation of Upper Devonian and Carboniferous deposits of Western Pomerania, based on spore study. (In Polish, English summary). *Annales Societatis Geologorum Poloniae*, 49: 231–269.
- Turnau, E., 1985. Devonian–Carboniferous boundary in the borehole Kowala 1 (southern Holy Cross Mts, Poland): Spores. *Bulletin of the Polish Academy of Sciences*, 33(1-2): 1–5.
- Turnau, E., 1986. Lower to Middle Devonian spores from the vicinity of Pionki (Central Poland). *Review of Palaeobotany*

and *Palynology*, 46: 311–254.

- Turnau, E., 1990. Poziomy sporowe famenu i turneju z otworu wiertniczego Kowala 1. *Kwartalnik Geologiczny*, 34: 291–304.
- Turnau, E., 1995. Stratygrafia i korelacja utworów środkowego dewonu Pomorza środkowego na podstawie analizy palinologicznej. (In Polish, English summary). *Przegląd Geologiczny*, 43: 211–214.
- Turnau, E. & Racki G., 1999. Givetian palynostratigraphy and palynofacies: new data from the Bodzentyn Syncline (Holy Cross Mountains, central Poland). *Review of Palaeobotany and Palynology*, 106: 237–271.
- Umnova, V. T., 1971. On the Devonian/Carboniferous boundary in the Central regions of the Russian Platform by palynological data. (In Russian). *Izvestia Akademi Nauk USSR*, 4: 109–122.
- Utting, J., 1987. Palynology of the Lower Carboniferous Windsor Group and Windsor-Canso boundary beds of Nova Scotia, and their equivalents in Quebec, New Brunswick and Newfoundland. *Geological Survey of Canada, Bulletin*, 374: 1–93.
- Van der Zwan, C. J., 1979. Aspects of Late and Early Carboniferous palynology of southern Ireland; I. *The Cyrtospora cristifer* morphon. *Review of Palaeobotany and Palynology*, 28: 1–20.
- Van der Zwan, C. J., 1980. Aspects of Late Devonian and Early Carboniferous palynology of southern Ireland; III, Palynology of Devonian–Carboniferous transition sequences with special reference to the Bantry Bay area, Co. Cork. *Review of Palaeobotany and Palynology*, 30: 165–286.
- Van Veen, P. M., 1981. Aspects of late Devonian and early Carboniferous palynology of southern Ireland; IV, Morphological variation within *Diducites* a new form genus to accommodate camerate spores. *Review of Palaeobotany and Palynology*, 31: 261–287.
- Van Veen, P. M. & Van der Zwan, C. J., 1978. The Devonian–Carboniferous Transition sequence in southern Ireland: Integration of Paleogeography and Palynology. *Palinologia*, 1: 469–479.
- Winslow, M. R., 1962. Plant spores and other microfossils from Upper Devonian and Lower Mississippian rocks of Ohio. *U. S. Geology Survey*, 364: 93.
- Żbikowska, B., 1992. Entomozoaceans (Ostracoda) from the Upper Devonian and Lower Carboniferous of Western Pomerania (In Polish). *Przegląd Geologiczny*, 40: 612.
- Żelichowski, A. M., 1983. Carboniferous of Western Pomerania (In Polish, English summary). *Przegląd Geologiczny*, 31(6): 356–354.
- Żelichowski, A. M., 1987. Sedimentation and framework of the basin (In Polish, English summary). In: A. Raczyńska (ed.), Geological structure of the Pomeranian Swell and its basement. *Prace Instytutu Geologicznego*, 119, 48–51.

## Streszczenie

### TAKSONOMIA I STRATYGRAFIA MIOSPOROWA GÓRNEGO DEWONU I NAJNIŻSZEGO KARBONU POMORZA ZACHODNIEGO

Marzena Stempień-Sałek

W pracy określono metodą palinologiczną wiek formacji człuchowskiej, kłanińskiej, iłowców wapienistych z Sapolna i dolnej części piaskowców arkozowych z Gozdu wydzielanych dla górnego dewonu i najniższego karbonu Pomorza Zachodniego (Fig. 1), oraz zaprezentowano lokalny, stratygraficzny schemat miosporowy dla najwyższego dewonu i najniższego karbonu Pomorza Zachodniego (Fig. 2). Posłużono się podziałem litostratygraficznym Matyji (1993, 1998) i Lipca (Lipiec & Matyja, 1998) przedstawionym na figurach 3 i 4. Biostratygrafia powyższych utworów, oparta jest przede wszystkim na badaniach konodontów, a także małżoraczek, brachiopodów oraz miospor.

Stosowany dotychczas schemat miosporowy dla Pomorza Zachodniego (Turnau, 1978, 1979) jest, przynajmniej dla pewnych interwałów, mało szczegółowy, dlatego też wprowadzono podziały dla istniejących już zon, a także wydzielono nowe zespoły i zony miosporowe w osadach franu i dolnego famenu (por. Fig. 2). Zbadane materiały pochodziły z 9 otworów wiertniczych (por. Fig. 1). Z wyjątkiem otworów wiertniczych Rzeczenica 1 i Chmielno 1 (Turnau, 1978, 1979, Matyja *et al.*, 2000) utwory z badanych wierceń nie były do tej pory opracowywane pod kątem palinologicznym. Utwory starsze, które należą do dewońskiej formacji człuchowskiej, stały się obiektem zainteresowań palinologicznych po raz pierwszy.

Zespoły gatunków miospor wskaźnikowych dla zon lokalnego schematu miosporowego dla najwyższego dewonu i najniższego karbonu Pomorza Zachodniego zilustrowano na figurze 5. Na podstawie pierwszych pojawień gatunków wskaźnikowych, schemat ten można w części korelować ze schematem miosporowym przyjętym dla Europy Zachodniej (Streel *et al.*, 1987; Higgs *et al.*, 1988) i Wschodniej (Avkhimovitch, 1993; Avkhimovitch *et al.*, 1993b) co przedstawiono na figurze 6.

Zbadane utwory są dość szczegółowo datowane na podstawie konodontów (poziomy *punctata* - dolna *crenulata*). Miospory i konodonty pochodzą z tych samych profili i tych samych lub podobnych przedziałów głębokości (por. Figura 3). Fakt ten umożliwia datowanie granic wyróżnionych zon miosporowych. Próba korelacji stratygraficznego lokalnego schematu miosporowego i zonacji konodontowej zilustrowana została na figurze 4.

Potwierdzono obecność luki stratygraficznej na granicy dewon/karbon (Fig. 6), obejmującej brakujące zony miosporowe: LN i VI.

W części systematycznej opisano 31 gatunków miospor wyznaczających granice zon miosporowych oraz dotychczas nie opisanych z Pomorza Zachodniego. Gatunki te zilustrowane są na figurach 7–10. Listę wszystkich oznaczonych miospor zamieszczono w dodatku (Appendix 1). Dokumentacja ilościowa i jakościowa, oraz dotycząca głębokości pobrania pozytywnych prób na miospory przedstawiona jest w dodatku (Appendix 2).