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SPORE STRATIGRAPHY OF LOWER DEVONIAN AND EIFELIAN (?), ALLUVIAL AND MARGINAL MARINE DEPOSITS OF THE RADOM-LUBLIN AREA (CENTRAL POLAND)

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Abstract: The Czarnolas and Zwoleń Formations of the Terebin IG 5 borehole, and the Terrigenous suite of the Giełczew PIG 5 borehole were analyzed for their spores. Palynological slides from a previous study of the Czarnolas Formation from the Pionki 4 borehole were re-examined and re-interpreted based on new observations and recent spore zonation publications. Two new cryptospores (*Cymbohilates pusillus* n. sp., *Cymbohilates baculatus* n. sp.) and two new trilete spores (*Retusotriletes niger* n. sp., *Retusotriletes tuberiferus* n. sp.) are described and illustrated.

The Lower Devonian and probable Eifelian spore assemblages are assigned to Streelispora newportensis-Emphanisporites micrornatus (NM), Verrucosisporites polygonalis-Dibolisporites wetteldorfensis (PoW), Emphanisporites foveolatus-Verruciretusispora dubia (FD), and Acinosporites apiculatus-Calyptosporites proteus (AP) Oppel zones. These zones have been recognized in the Ardenne-Rhine regions. These data can also be compared to worldwide eustatic signatures. The spore data indicate that in the Radom-Lublin area marine sedimentation ended in either late early or early late Lochkovian, and the successive flooding commenced in late Emsian, probably the serotinus chron.

Key words: spore stratigraphy, Oppel zones, Lower Devonian, Eifelian, Radom-Lublin area, Poland.

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INTRODUCTION

The Devonian in the Radom-Lublin area of Poland subcrops Mesozoic or Carboniferous strata (Fig. 1), and has been encountered in more than one hundred boreholes. Some of these penetrations have taken long cores through the Devonian section. The biostratigraphic subdivision of the Devonian succession in this area is still not satisfactory, especially in relation to the marginal marine and terrestrial deposits that usually lack stratigraphically important marine fauna. Spore studies have proven to be useful for dividing and correlating these sediments, but are reported in only a few papers. Turnau (1985, 1986) described spore assemblages of Lower and Middle Devonian deposits from the Pionki 1 and Pionki 4 boreholes situated in the northwestern part of the Radom-Lublin area. Turnau and Jakubowska (1989) supplemented these earlier studies by describing the Lower Devonian assemblages from the nearby borehole Ciepielów IG 1 (Fig. 1).

The principal aim of this paper is to outline the main changes in palynological associations through the Lower Devonian, and probable Eifelian, marginal marine and alluvial deposits found in cores from the Giełczew PIG 5 and Terebin IG 5. These wells are located in the central and eastern parts of the Radom-Lublin area, respectively (Fig. 1). Both are considered the key borehole sections of the region. The palynological information from previous studies, re-evaluated in light of the present analysis, was compared to the Devonian transgressive-regressive (T-R) cycles outlined by Narkiewicz *et al.* (1998). Palynological analyses from the younger Devonian strata in the Giełczew PIG 5 has been the subject of other studies (Wood *et al.*, 1996; Wood & Turnau, 2001; Wood *et al.*, 2004) and will be the focus of future analyses.

GEOLOGICAL SETTING

The Devonian deposits of the Radom-Lublin area occur within the marginal, faulted part of the East European Craton. Distinct elevated and depressed, fault delimited elements are discernible here. These include the elevated part of the East European Platform (EPEEP), Mazowsze-Lublin Trough (MLT), and Radom-Kraśnik Uplift (RKU) (Fig. 1). In the neighbouring territory of Ukraine, the continuation of the EPEEP is called the North Volhynian Uplift (NVU) and South Volhynian Depression (SVD). The extension of the MLT is the L'viv Trough (LT) (Fig. 1).

The Devonian deposits of the Radom-Lublin area comprise all the three series of the system resting in continuity on Upper Silurian strata. The region represents a part of the Devonian epicontinental basin that stretched from western Europe to the Ukraine, along the periphery of the Old Red Sandstone Continent (Narkiewicz, 1988). The Lower and lower Middle Devonian deposits have been reached in many boreholes; some of them are indicated in Fig. 1.

Stratigraphical investigations of these deposits started in the 1960s (see the review of literature in Narkiewicz *et al.*, 1998), and resulted in the establishment of a formal lithostratigraphical division of the Devonian for the south-eastern part of the area (Miłaczewski, 1981). Miłaczewski *et al.* (1983) applied this lithostratigraphic scheme to the Devonian in the north-western part of the Radom-Lublin area. At present, only the Middle, and partly the Upper Devonian deposits in the vicinity of Radom and in the central part of the Lublin region are not divided into formal lithostratigraphic units.

The stratigraphic sequence of the lithostratigraphic units concerned in this paper consists of (1) Czarnolas Formation (that overlies Sycyna Formation), (2) Zwoleń Formation, and (3) Terrigenous suite ("seria terygeniczna" in the literature in Polish). These formations were defined by Miłaczewski (1981). The Terrigenous suite is an informal unit whose characteristics are given by Miłaczewski in Narkiewicz *et al.* (1998).

Czarnolas Formation and Terrigenous suite. These units contain siliciclastic rocks, mainly dark to light grey in colour, and varying grain size ranging from silty claystones to quartz sandstones. Intercalations of carbonates and sulfates are present, but subordinate. A basal conglomerate containing quartz pebbles occurs at the base of theTerrigenous suite in the Giełczew PIG 5 borehole. The thickness of the Czarnolas Formation is 30–180 m, whereas that of the-Terrigenous suite does not exceed 36 m. Trace fossils are abundant in these deposits but organic remains are very rare. They include lamellibranch molluscs, lingulid brachiopods, and ostracods. Tentaculitids occur within the basal part of the Czarnolas Formation in the northwest. These sediments accumulated in a marginal marine setting (Miłaczewski, 1981; Miłaczewski *et al.*, 1983; Narkiewicz *et al.*, 1998).

There is very little faunal biostratigraphic data concerning these units. Hajłasz (1974) distinguished two successive tentaculitid assemblages, which she named Assemblage I and Assemblage II. In the opinion of Hajłasz (1974) the presence of the genus *Alternatus* in the Assemblage II indicates that the deposits may be the lateral equivalent of the

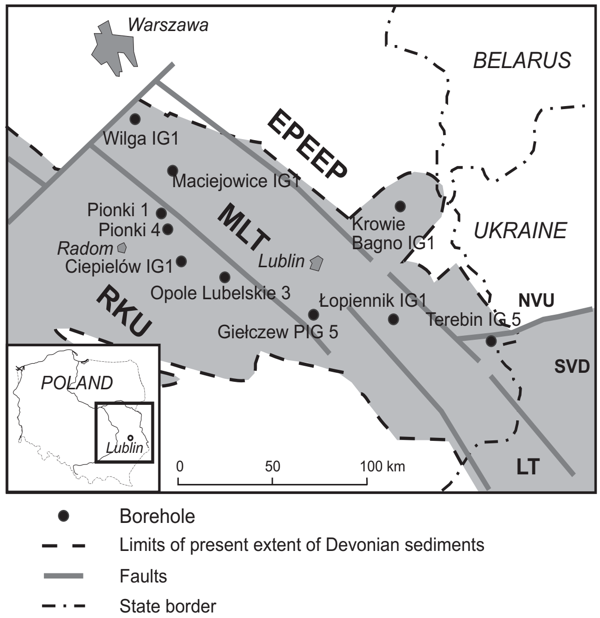

Fig. 1. Map of Radom-Lublin area schowing location of boreholes, present extent of Devonian deposits and tectonic units. EPEEP – elevated part of the East European Platform; MLT – Mazowsze-Lublin Trough; RKU – Radom-Kraśnik Elevation; NVU – North Volhynian Uplift; SVD – South Volhynian Depression; LT – L'viv Trough

Lochkovian Ivanye Horizon of Podolia. This assemblage occurs in an upper part of the Sycyna Formation and in the basal strata of the Czarnolas Formation. In the latter case the assemblage occurs only in the Maciejowice IG 1 and Ciepielów IG 1 boreholes (Hajłasz, 1974; Miłaczewski *et al.*, 1983). Łobanowski (unpubl., cited in Miłaczewski *et al.*, 1983) recorded the lamellibranch *Pterinea (Tolmaia) lineata erecta* (Dahmer) from the Czarnolas Formation of the Pionki 4 borehole. H. Łobanowski stated that this lamellibranch is known from Siegenian and Emsian of the Rhine region.

The Terrigenous suite has not been dated on fauna. The probable lateral correlative of this unit is the Przewodów Member distinguished in the Terebin IG 5 borehole and the neighbouring wells (Miłaczewski, 1981). The Przewodów member overlies the Zwoleń Formation, and in some boreholes, it starts with a basal conglomerate containing fish bones. Like the Terrigenous suite, this member is not biostratigraphically dated. Another lateral correlative of the Terrigenous suite is the informally termed Carbonate-Terrigenous suite ("seria węglanowo-terygeniczna" in the literature in Polish) found in the northwestern part of the area (Miłaczewski *et al.*, 1983). There is a ~36 m interval (depth 1759.3–1796 m) in the lower part of the Carbonate-Terrigenous suite present in the Pionki 4 borehole, where the brachiopods *Uncinulus coronatus* (Kayser), *Euryspirifer supraspeciosus* (Lotze), and *Eoreticularia aviceps* (Kayser) have been reported by Łobanowski and Przybyłowicz (1979). These authors suggested attribution of these strata to upper Eifelian or Givetian, based on stratigraphical ranges of these taxa in the Rheinisches Schiefergebirge (Germany), and the Góry Świętokrzyskie Mts (Holy Cross Mts.) in Poland.

Zwoleń Formation. This formation consists of alternating, red, green and variegated mudstones, light grey, fine-grained quartz sandstones or, less commonly, grey mudstones with layers of pedogenic dolomite concretions. The sandstones are often cross-bedded. Dark grey claystones, although not very common, often contain plant remains. Lithic wackes, silty claystones, and, subordinately, thin beds of conglomerates consisting of quartz pebbles are also present. This formation thickens from the northeast to the southwest. The most complete sections of the Zwoleń Formation can be found in the in the Pionki 4 and Opole Lubelskie 3 boreholes, where it reaches a thickness of 880 m and 1260 m respectively. Organic remains are represented by lingulid brachiopods, giganthostracans, and scales and carapace fragments of agnathid fishes. These deposits were formed in an alluvial plain depositional environment (Miłaczewski, 1981; Miłaczewski *et al.*, 1983; Narkiewicz *et al.*, 1998).

No marine fauna has been reported from the Zwoleń Formation. Fin spines assigned to *Machaeracanthus* sp. and *Porolepis* sp. were found in the upper part of the formation in the Ciepielów IG 1 borehole by Krassowska and Kulczycki (1963). These authors state that these remains are are identical to those found in the Emsian deposits of Daleszyce in the Góry Świętokrzyskie Mts.

MATERIAL AND METHODS

Palynological samples were taken from cores from the Giełczew PIG 5 (Latitude 50° 52’ 05" North; Longitude 22° 39’ 44" East) and Terebin IG 5 (Latitude 50° 49’ 07" North; Longitude 23° 50’ 33" East). Both wells were completely cored. The Giełczew PIG 5 section ranges from the Emsian into the Famennian (Miłaczewski, 1995), and the Terebin IG 5 section spans the Lochkovian to Frasnian (Miłaczewski, 1981).

Palynomorphs were isolated from the core samples using an HCL-HF-HCL acidation sequence followed by heavy liquid separation. Residues are embedded in Clearcol or Cellosise and cemented to a microscope slide with Elvacite for permanent palynological mounts. Type specimens are stored at the Institute of Geological Sciences, Polish Academy of Sciences in Kraków.

PALYNOSTRATIGRAPHY

Spore material was examined from the Czarnolas and Zwoleń Formations of the Terebin IG 5 borehole and theTerrigenous suite of the Giełczew PIG 5 borehole (Fig. 2). Palynological slide mounts representing the Czarnolas Formation from the Pionki 4 borehole were re-examined and reinterpreted. The latter material was studied more than twenty years ago (Turnau, 1985, 1986), using a light microscope with inferior optics. The goal of the re-examination, using a modern optical system, was to achieve a better biostratigraphic resolution in the section being studied.

The spore taxa identified in this study, and their distribution in the wells, are shown in Tables 1 and 2, and full taxonomic titles of the species are given in the Appendix. The characteristic and stratigraphically important species are illustrated in Figs 3 to 6. Diverse and abundant spores occur in the Czarnolas and Zwoleń formations from the Terebin IG 5 borehole. Less diverse assemblages have been recovered from theTerrigenous suite of the Giełczew PIG 5 borehole. The assemblages contain several Devonian species that are stratigraphically significant in other regions of the Northern Hemisphere. This permits comparison of the assemblages to the Lower Devonian spore zonal schemes for the Old Red Sandstone Continent and adjacent areas (Richardson & McGregor, 1986) and Ardenne-Rhine region (Streel *et al.*, 1987). The Old Red sandstone scheme comprises four assemblage zones for the Lower Devonian, and a fifth that spans the Emsian/Eifelian boundary. The equivalent part of the scheme for the Ardenne-Rhine region includes six Oppel zones that are divisible into several interval and lineage zones. Both schemes are correlatable, with varying degrees of precision based on direct or indirect data, to the international conodont scheme for the Devonian, and/or with other faunal zonations (Richardson & McGregor, 1986; Streel *et al.*, 1987, 2000; Ashraf *et al.*, 1991). The Ardenne-Rhine region scheme of six Oppel zones allows a finer biostratigraphical resolution and has been employed in this paper. However, not all the interval/lineage zones can be discerned in the study area because of preservational issues (e.g., the majority of the lithologies present in the cores are not conducive to palynomorph preservation). For brevity, the names of the Oppel zones are abbreviated as two-letter notations in the following text. Their full taxonomic titles are cited in Fig. 2. The interval/lineage zones have originally been named solely by abbreviations of specific names (these abbreviations are used throughout the text). The succession of spore assemblages recorded, described below, follows the framework of the zonation scheme for the Ardenne-Rhine region.

Seven assemblages assignable to the **Streelispora newportensis-Emphanisporites micrornatus (NM) Oppel Zone/M Lineage Zone** have been recognized in the upper part of the Czarnolas Formation of the Terebin IG 5 borehole (Fig. 2, Table 1). They are not particularly well preserved and of moderate-to-good diversity. The most commonly occurring taxa are *Ambitisporites dilutus*, *Laevolancis divellomedia*, and *Archaeozonotriletes chulus*. Cryptospores are not diverse, but quite abundant (43% of the spore assemblage from the sample at 2012.75 m; based on the count of 100 specimens). The commonest cryptospores are *Laevolancis divellomedia* and *Qualisaspora spinifera*. The index species of the NM Oppel Zone (i.e., *Streelispora newportensis*) is present in almost all samples, and *Emphanisporites micrornatus* var. *micrornatus*, first appearing in the M Interval Zone, was found in almost all samples. This indicates the presence of the M Interval Zone. This zone was indirectly correlated, by way of Brittany, with chitinozoan zones recognized in the Bohemian Lower Devonian (Steemans, 1989). The zone has been attributed to either upper part of lower Lochkovian or to lower part of upper Lochkovian.

Assemblages assignable to the **Streelispora newportensis-Emphanisporites micrornatus (NM) Oppel**

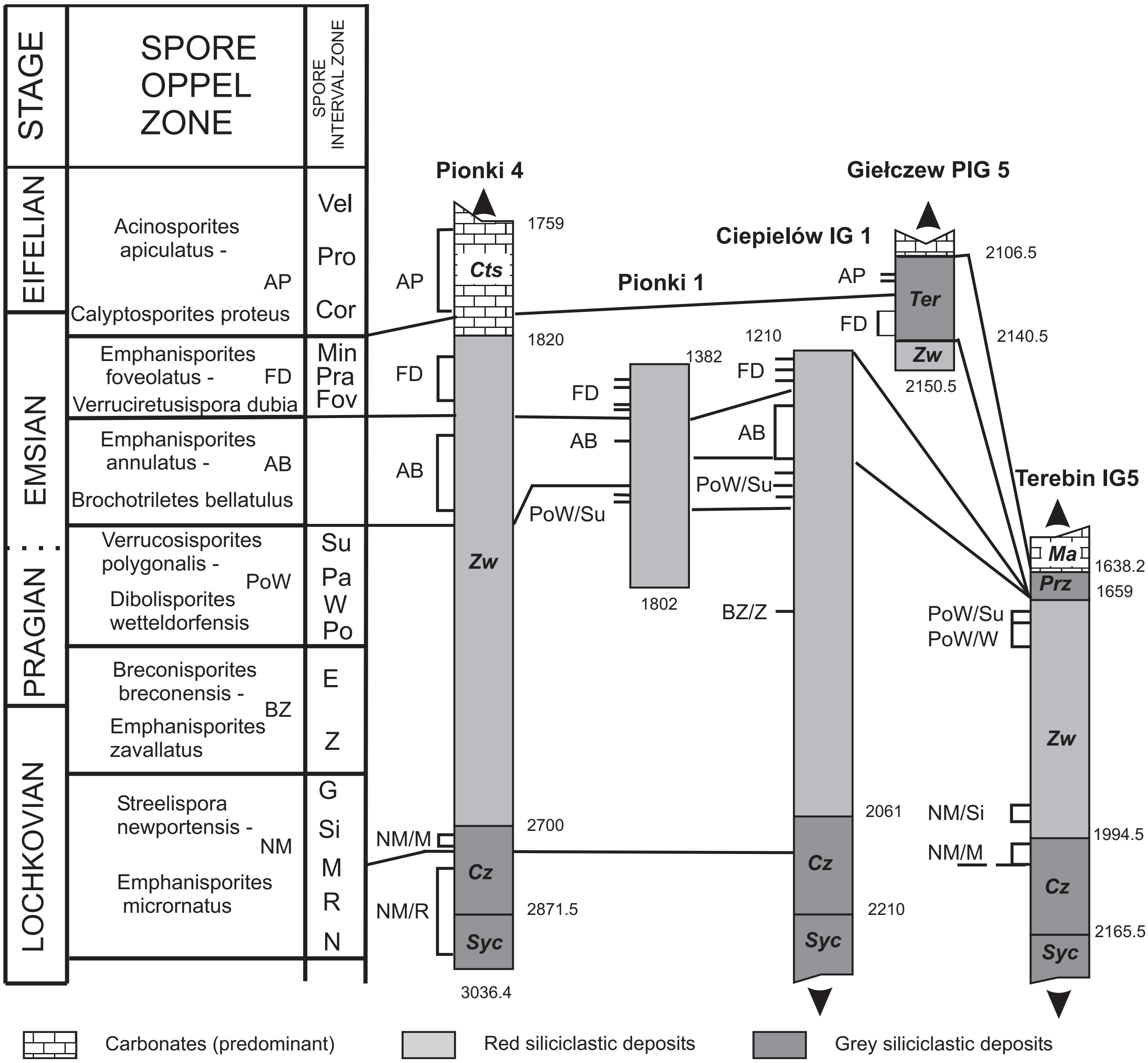

Fig. 2. Lower and lower Middle Devonian spore zonation of Streel *et al.*, 1987, and stratigraphical extent of spore zones in boreholes discussed. Symbols of lithostratigraphic units: Cts – Carbonate-Terrigenous suite; Zw – Zwoleń Formation; Cz – Czarnolas Formation; Syc – Sycyna Formation; Ter – Terrigenous suite; Prz – Przewodów Member; Ma – Machnów Member

Zone/Si Lineage Zone were recovered from two samples (see Table 1) from the lower part of the Zwoleń Formation in the Terebin IG 5 borehole. They are similar in composition to those described above. Cryptospores are only slightly less abundant (34% of the total sporomorph population at the depth 1989.15 m; based on the count of 100 specimens). *Emphanisporites micrornatus* var. *micrornatus* occurs with *Emphanisporites micrornatus* var. *sinuosus*. Species defining the base of the succeeding breconensis-zavallatus Oppel Zone were not encountered. This indicates the presence of the Si Lineage Zone that has been attributed by Steemans (1989) to upper (not uppermost) Lochkovian.

Assemblages assignable to the **Verrucosisporites polygonalis-Dibolisporites wetteldorfensis (PoW) Oppel Zone/W Interval Zone** were recovered from the upper part of the Zwoleń Formation in the Terebin IG 5 borehole. They differ, in many respects, from those characterized in the M and Si Lineage zones (discussed above). The first (=basal) appearance of *Breconisporites breconensis* and *Dibolisporites eifeliensis* is in a sample from the depth 1705.02 m. *Breconisporites breconensis* marks the base of the BZ Oppel Zone spanning the Lochkovian/Pragian boundary, and *Dibolisporites eifeliensis* appears in the W Interval Zone (Steemans, 1989). *Dibolisporites wetteldorfensis*, which marks the base of the W Interval Zone, was noted in the higher sample (1697.25 m, Table 1). The presence of the two species of *D. eifeliensis* and *D. wetteldorfensis*, and the absence of *Dictyotriletes subgranifer*, indicate that the assemblages are assignable to the W or Pa interval zones that were attributed to the lower and middle Pragian respectively.

Table 1

Distribution of spore taxa in samples from the Terebin IG 5 borehole

Lithostratigraphy	Czarnolas Formation							Zwoleń Formation				
Depth (m)	2052.50	2045.70	2017.10	2012.75	2003.10	2000.72	1996.14	1989.15	1967.27	1705.02	1697.25	1671.70
Spore Oppel Zone	NM							NM		PoW		
Spore Interval/Lineage Zone	M							Si		W		Su
Ambitisporites dilutus	+	+	+	+		+	+	+	+		+	
Apiculiretusispora plicata	+		+	+	+	+	+	+	+	?		+
Archaeozonotriletes chulus var. *chulus*	+	+	+		+	+	+		+	+	+	+
Breconisporites sp. A	+		+	+								
Chelinospora retorrida	+	+	+	+	+	+	+	+	+	?	+	
Chelinospora cassicula	+			+								
Chelinohilates glabrimarginatus	+			+				+		+	+	
Cymbosporites dittonensis	+			+								
Cymbosporites sp. A	+		+									
Cymbohilates pusillus	+			+				+				
Dibolisporites confertus	+		+									
Emphanisporites epicautuus	+				+			+				
Emphanisporites micrornatus var. *micrornatus*	+	+	+	+	+		+	+				
Laevolancis divellomedia	+	+			+	+	+	+	+	+	+	+
Laevolancis plicata	+	+			+	+	+	+	+	+	+	+
Qualisaspora spinifera	+	+	+	+			+	+		?	+	
Retusosporites maculatus	+											
Retusotriletes pychovii	+			+	+			+				
Retusotriletes scabratus	+			+		+	+	+	+			
Retusotriletes tuberiferus	+			+								
Streelispora newportensis	+	+	+	+	+	+		+	?			
cf. *Scyllaspora vetusta*	+											
Aneurospora crinita			+		+							
Artemopyra sp.			+									
Emphanisporites rotatus			+									
Leonispora agroveiae			+				+	+				
Chelinospora subfavosa			+			+					?	
Camptozonotriletes cf. *caperatus*			+	+								
Verrucosisporites sp. A			+									
Aneurospora geriennei				+								
Quadrisporis variabilis					+							
Retusotriletes warringtoni					+							
Archaeozonotriletes salantaicus					+							
Emphanisporites micrornatus var. *sinuosus*								+				
Emphanisporites neglectus								+				
Emphanisporites spinnaeformis										+	+	+
Emphanisporites zavallatus var. *gediniensis*										+		
Breconisporites breconensis										+	+	+
Apiculiretusispora limata										+		+
Apiculiretusispora brandtii										+		+
Stenozonotriletes niger										+	+	+
Dibolisporites eifeliensis										+	+	+
Apiculiretusispora arenorugosa											+	

Table 1 continued

Distribution of spore taxa in samples from the Terebin IG 5 borehole

Lithostratigraphy	Czarnolas Formation							Zwoleń Formation				
Depth (m)	2052.50	2045.70	2017.10	2012.75	2003.10	2000.72	1996.14	1989.15	1967.27	1705.02	1697.25	1671.70
Spore Oppel Zone	NM							NM		PoW		
Spore Interval/Lineage Zone	M							Si		W		Su
Brochotriletes foveolatus											+	
Dibolisporites wetteldorfensis											+	+
Oculatisporites mirandus											+	
Amicosporites jonkeri												+
Apiculiretusispora brandtii												+
Cymbohilates baculatus												+
Diaphanospora subita												+
Dictyotriletes subgranifer												+
Kraeuselisporites gaspesiensis												+
Limbosporites crassus												+
Verrucosisporites polygonalis												+

Neither *Streelispora newportensis* nor *Emphanisporites micrornatus* were present in the assemblages discussed. In the Ardenne-Rhine region, however, these species persist to the Su Interval Zone (Steemans, 1989).

An assemblage assignable to the **Verrucosisporites polygonalis-Dibolisporites wetteldorfensis (PoW) Oppel Zone/Su Interval Zone** was recovered from the sample taken at a level near the top of the Zwoleń Formation (1671.7 m, Terebin IG 5). The sample yielded a diverse assemblage of spores and cryptospores. Cryptospores account for 22% of the total sporomorph population recovered in this sample (based on the count of 100 specimens). The species *Dictyotriletes subgranifer*, which marks the base of the Su Interval Zone, is present in this sample. Other stratigraphically important taxa include *Diaphanospora subita* and *Limbosporites crassus*. *Diaphanospora subita* was described from the Pragian strata associated with the Šešuvis Formation and the Kemeri Suite of Lithuania (Arkhangelskaya, 1978, 1980). In the Radom-Lublin area, this species is restricted to the Pragian and basal Emsian (Turnau, 1985, 1986; Turnau & Jakubowska, 1989). In the Ardenne-Rhine region *Diaphanospora subita* is restricted to the Su Interval Zone of upper Pragian or basal Emsian (Steemans, 1989). In Ireland, *Diaphanospora subita* is recorded from assemblages representing the lower Emsian E. annulatus-B. bellatulus (AB) Oppel Zone (Higgs, 1999). *Limbosporites crassus* was described from the Kemeri Suite of Lithuania, where it occurs in assemblages representing the Pragian and basal Emsian (Arkhangelskaya, 1980). *L. crassus* is also known from the Radom-Lublin area where it has the same stratigraphical distribution (Turnau, 1985, 1986). The presence of *Diaphanospora subita* and *Limbosporites crassus*, and the absence of *Emphanisporites annulatus* (the eponymous species of the succeeding AB Zone), allows assignment of this assemblage to the Su Interval Zone. Indirect correlation, by way of Spain, between Belgian sections and the Global Stratotype Section in Uzbekistan suggest that the base of the Su Interval Zone is close to the Lochkovian/Pragian boundary, but it is not known on which side (Streel *et al.*, 2000).

Eight samples taken from a level near the base of the Terrigenous suite (see Table 2) from the Giełczew PIG 5 borehole yielded assemblages assignable to the **Emphanisporites foveolatus-Verruciretusispora dubia (FD) Oppel Zone.** These assemblages consist almost exclusively of trilete spores, with only single specimens of cryptospores. The assemblages are of low diversity and dominated by *Apiculiretusispora plicata*. Other forms present include *Archaeozonotriletes chulus* var. *chulus*, *Emphanisporites annulatus*, *E. erraticus*, *Verruciretusispora dubia*, *Dibolisporites eifeliensis*, *Dibolisporites wetteldorfensis*, *Brochotriletes hudsonii*, *Amicosporites jonkeri* and *Oculatisporites mirandus* (?). This is a typical Emsian assemblage, although most species range into the succeeding (younger) zone, or higher (Riegel, 1973, 1982; Richardson & McGregor, 1986; Ashraf *et al.*, 1991). *Emphanisporites annulatus* marks the base of the AB Oppel Zone, and *Verruciretusispora dubia* marks the base of the succeeding FD Oppel Zone. *Amicosporites jonkeri* is known from the Eifel only from the Nohn Beds, from the AP Oppel Zone (Riegel, 1973), but in the region of Pionki it is found in the lower-to-mid Emsian (Turnau, 1985, 1986). *Brochotriletes hudsonii* is known from the Pragian *caperatus–emsiensis* zone of Canada (McGregor & Camfield, 1976), but in the region of Pionki it occurs in the Emsian (Turnau, 1985, 1986). This, and the lack of taxa characteristic of the succeeding zone, suggests that the assemblages from the basal part of the Terrigenous suite represent the FD Zone. An upper part of considerable thickness of the Zwoleń Formation (Pionki 1, 4, Ciepielów IG 1) was also included in the FD Zone (see Fig. 2). This suggests that in the Terrigenous suite in Giełczew 5 we deal with an upper part of the zone.

Table 2

Distribution of spore taxa in samples from the Giełczew PIG 5 borehole

Lithostratigraphy	Terrigenous Suite									
Depth (m)	2137.37	2136.46	2133.50	2132.40	2126.97	2124.25	2124.00	2123.94	2120.16	2113.50
Spore Oppel Zone	FD?	FD							AP	
Apiculiretusispora brandtii	+	+	+	+	+	+	+	+	+	
Apiculiretusispora plicata	+	+	+	+	+	+	+	+	+	+
Archaeozonotriletes chulus var. *chulus*	+			+	+					
Dibolisporites eifeliensis	+	+		+	+		+		+	
Emphanisporites annulatus	+	+		+	+	+	+			
Emphanisporites rotatus	+	+	+	+	+	+	+	+		+
Laevolancis divellomedium	+	+	+	+	+	+		+		
Retusotriletes pychovii	+	+	+							
Apiculiretusispora arenorugosa		+							+	
Camarozonotriletes sextantii		+								
Cymbohilates sp. A		+				+				
Dibolisporites cf. *gibberosus*		+							+	
Dibolisporites wetteldorfensis		+								
Emphanisporites erraticus		+			+					
Emphanisporites spinnaeformis		+								
Verruciretusispora dubia		+							+	
Camptozonotriletes caperatus			+							
Amicosporites jonkeri				+			+			
Brochotriletes hudsonii				+			+			
Oculatisporites mirandus?				+						
Qualisaspora spinifera				+			+			
Retusotriletes clandestinus					+	+	+	+		
Acinosporites obnubilus							+			
Acinosporites lindlarensis var. *minor*							+			
Ambitisporites dilutus							+			
Leiotriletes pagius								+		
Ancyrospora nettersheimensis									+	+
Ancyrospora eurypterota									+	
Dibolisporites antiquus									+	+
Dibolisporites echinaceus									+	+
Grandispora diamphida									+	+
Hystricosporites spp.									+	+
Acinosporites lindlarensis var. *lindlarensis*									+	
Ancyrospora kedoae										+
Cymbosporites fuscus										+

The FD Zone has been defined in the Eifel. The base of the zone coincides with the base of the Klerf Formation (Riegel, 1982; Ashraf *et al.*, 1991), in the nothoperbonus Conodont Zone (Ashraf *et al.*, 1991). In the Barrandian region, the first appearance of *V. dubia* is also within the nothoperbonus Zone (direct correlation by tentaculitids, McGregor, 1979). The upper limit of the zone is close to the serotinus/patulus zonal boundary (see below)

Two samples (see Table 2) from a level near the top of the Terrigenous suite yielded assemblages assignable to the **Acinosporites apiculatus-Calyptosporites proteus (AP) Oppel Zone**. They contain only trilete spores, among them species assignable to *Ancyrospora*, *Hystricosporites*, and *Grandispor*a. The first appearance of several species belonging to these genera characterises the AP Oppel Zone. The assemblages lack *Calyptosporites velatus* and *Rhabdo-*

sporites langii, which are known to appear in an upper part of this zone (Riegel, 1982; Streel *et al.*, 1987). The assemblages from the upper part of the Terrigenous suite are assignable to the AP Oppel Zone that spans the Emsian–Eifelian boundary.

The AP Zone has been defined in the Eifel region. Its base is in the upper part of the Wetteldorf Formation (Ashraf *et al.*, 1991). The position of the base of the zone in relation to the conodont succession is uncertain within the range *serotinus-patulus* (Streel *et al.*, 2000).

STRATIGRAPHIC POSITION OF FORMATIONS, CORRELATION AND DISCUSSION

Biostratigraphical correlation is possible only at few levels because most of the lithologies present in the sections studied are not conducive to palynological preservation. The Giełczew PIG 5 and Terebin IG 5 borehole sections are correlated with those studied by Turnau (1985, 1986) and Turnau and Jakubowska (1989) (Fig. 2). Samples from the Czarnolas Formation from the Pionki 4 borehole (Turnau, 1985; 1986) were assigned to the micrornatus–newportensis Zone of the scheme by Richardson and McGregor (1986). Turnau and Jakubowska (1989) suggested that they represented the R Interval Zone of Streel *et al.* (1987). The original palynological mounts from this borehole were reexamined using a microscope equipped with modern optics. In this reassessment, *Emphanisporites micrornatus* var. *micrornatus* was identified in a sample from the depth 2736.8 m in the Pionki 4 . This indicates that the M Lineage Zone that has been attributed to upper part of lower Lochkovian or lower part of upper Lochkovian (Steemans, 1989) is represented in at least the upper part of the Czarnolas Formation. The upper part of the Czarnolas Formation in the Terebin IG 5 borehole also belongs to this zone, indicating that the strata from these boreholes can be considered time equivalent (see Fig. 2). This justifies the suggestion that in the study area, the end of marine sedimentation within the early stage of regression of the T-R cycle I (see Narkiewicz *et al.*, 1998) was synchronous at least between Pionki and Terebin, it may have been synchronous over the whole area of the Mazowsze-Lublin Trough and its SE extension – the L'viv Trough. But to the east of the Terebin IG 5 borehole and in the South Volhynian Depression, this event was heterochronous, in the eastern part of the depression the marine sedimentation ended at the beginning of the Lochkovian, while in its western part it ended in late Lochkovian (Pomyanov'ska, 1974).

The lower part of the Zwoleń Formation (Terebin IG 5) can be assigned to the upper (not uppermost) Lochkovian, and its upper part represents Pragian, possibly also basal Emsian. In the northwest part of the Radom-Lublin area (Pionki 1, Pionki 4, Ciepielów IG 1), the top part of the Zwoleń Formation represents mid-or-upper Emsian (Turnau, 1985, 1986, Turnau & Jakubowska, 1989). This shows that in the area of Terebin, a substantial part of representative Emsian sediments were not deposited or have been removed by erosion. To the east of Terebin, in the North Volhynian Uplift and the South Volhynian Depression (Fig. 1), the deposits of The Old Red Sandstone type, such as those of the Zwoleń Formation of the Radom-Lublin area or the Dnister Suite from the L'viv Trough, are not present. In the North Volhynian Uplift and the South Volhynian Depression, erosion and nondeposition prevailed during the late Lochkovian to late Emsian (Pomyanovs'ka, 1974).

The spore assemblages from the Terrigenous suite in the Giełczew PIG 5 borehole are assignable to the FD (an upper part) and AP spore zones, which indicates that the unit may be attributed to upper Emsian, and probably basal Eifelian (see the previous section). The younger AP Zone, or its equivalent (i.e., the douglastownense-eurypterota Zone) in the zonal scheme by Richardson and McGregor (1986) has been also distinguished in the Carbonate-Terrigenous suite in the Pionki 4 borehole (Turnau 1985, 1986). Its position within the section is at depth between 24 to 61 m above the base of the unit (depth interval 1759– 1796 m). The long-ranging brachiopod *Euryspirifer supraspeciosus* (Lotze), which first appears in the Couvinian (Eifelian) (Vandercammen, 1963, fide Łobanowski & Przybyłowicz, 1979), was recorded from the same borehole by Łobanowski and Przybyłowicz (1979), from strata 24 m above the base of the Carbonate-Terrigenous suite (depth interval 1795.6–1796.0). The lowermost part of this unit in the Pionki 4 borehole remains undated. The problem which requires further investigation is the character of the new marine transgression in the Radom-Lublin area. The transgression may have occurred in several stages. During the first phase, siliciclastic sedimentation started in the depressed areas of the flooded region. In such cases, the Zwoleń Formation is overlain by deposits of the type represented by the Terrigenous suite or Przewodów Member. In the second phase, carbonates and/or sulphates were deposited over the leveled surface. This may explain the difference in sedimentary sequences of the Pionki 4 (where the Zwoleń Formation is directly overlain by carbonates) Giełczew PIG 5 and Terebin IG 5 boreholes (Fig. 2).

Till now, the lower boundary of the marginal marine sediments resting on the alluvial strata of the Zwoleń Formation was identified, on lithological criteria, with the Lower/Middle Devonian boundary (e.g., Narkiewicz *et al.*, 1998; Miłaczewski, table 1b in Pajchlowa & Miłaczewski, 2003). The results of this palynological analysis of the Terrigenous suite from the Giełczew PIG 5 borehole show that this lithostratigraphical boundary occurs within Emsian, as it lies within the FD Oppel Zone (an upper part of it). In the terms of conodont succession, the FD zone ranges from nothoperbonus to serotinus or patulus zones (see previous section). In the Terrigenous suite, we deal with an upper part of the FD Zone (see correlations in Fig. 2), most probably the part corresponding to the serotinus Conodont Zone. Thus, the lower boundary of the suite may coincide with the lower boundary of the Grzegorzowice Formation and its correlatives in the Góry Świętokrzyskie Mts. The lower part of this formation axposed at the village of Grzegorzowice was included in the patulus Conodont Zone basing on correlation with the borehole section Wierzbontowice 1 where *Icriodus corniger rectirostratus* Bultynck was recorded from a level 45 m above the formation base (Malec, 1986).

Malec (1990b) correlated, on ostracod evidenc, the Bukowa Góra shales from the same region with the basal part of the Grzegorzowice formation. In the southern region of the Góry Świętokrzyskie Mts, there occur black shales and shales with syderite containing abundant marine fauna. They were correlated with the basal part of the Grzegorzowice Formation on ostracod evidence (Malec, 1992). In his earlier papers, Malec (1986, 1990a, b) supposed that the base of the Grzegorzowice Formation and its correlatives corresponded to the patulus Conodont Zone, but later (Malec et al., 1996, fig. 2) this authors placed this boundary in the serotinus Conodont Zone. In the opinion of Malec (1990a) the onset of sedimentation of these beds is the signature of the Cycle Ic of Johnson *et al.*(1985).

It seems probable that the beginning of the new sedimentary cycle (Cycle II) was synchronous over the Radom-Lublin area, North Volhynian Uplift (NVU), South Volhynian Depression (SVD), and L'viv Trough. In the last two areas, the deposits of the new cycle overlie unconformably and overstepping various units of the Lower Devonian (Pomyanovs'ka, 1974). But precise biostratigraphical data which could support this supposition are lacking.

SELECTED SPORE SYSTEMATICS

The holotypes and figured specimens are in the collection of the Institute of Geological Sciences, Polish Academy of Sciences, Research Centre in Kraków.

The Lower Devonian and basal Eifelian spores from the Radom-Lublin area have been described by Turnau (1985, 1986) and Turnau and Jakubowska (1989). In this brief section, the descriptions of new species are presented including discussions of selected taxa.

Anteturma CRYPTOSPORITES (Richardson, Ford et Parker, 1984) Richardson 1988

Genus *Chelinohilates* Richardson 1996
Chelinohilates glabrimarginatus (Turnau et Jakubowska) Turnau 2003
Figs 3 (D, H)

1989. *Chelinospora glabrimarginata* Turnau et Jakubowska: p. 400, 401, pl. 2, figs 9, 10.
2003. *Chelinohilates glabrimarginatus* (Turnau et Jakubowska) Turnau: Turnau, Fijałkowska-Mader, Filipiak & Stempień-Sałek, p. 632, pl. 365, fig. 2.

Description: Amb rounded. Proximal hilum laevigate, diameter 2/3 of cryptospore diameter. Distal surface reticulate, lumina rounded or elongate, ca 2 μm wide, muri 1–2 μm wide. Proximo-equatorial surface smooth, thickened.
Diameter: 28 (29) 30 μm (4 specimens).
Remarks: these palinomorphs have no visible haptotypic features, and thus they have been transferred (Turnau *et al.*, 2003) to *Chelinohilates*.

Genus *Cymbohilates* Richardson 1996
Cymbohilates pusillus Turnau, new species
Figs 3 (B, C)

Holotype and type locality: Fig. 3 C, slide T5I/41, co-ord. H55.4, Terebin IG 5 borehole, depth 2012.75 m, Czarnolas Formation, Lochkovian.
Diagnosis: A *Cymbohilates* sculptured outside the central area with evenly distributed microconi that have truncated tips. Proximal hilum laevigate.
Description: Amb rounded. Proximal hilum laevigate, occasionally cracked, diameter 2/3 to 4/5 of cryptospore diameter. Distal and proximo-equatorial surface sculptured with evenly distributed microconi. Microconi have truncated apices, are up to 1 μm high and less than 1 μm apart.
Diameter: 20 (26.5) 30 μm (10 specimens).
Comparisons: *Cymbohilates allenii* var. *magnus* Richardson (1996), and *Cymbohilates* sp. B. (Lavender & Wellman, 2002, pl. 1, figs 7, 10) are larger, and ornamentation elements in *Cymbohilates variabilis* Richardson (1996) are variable in shape. *Cymbohilates microgranulatus* Wellman et Richardson (1996) is larger and ornamented with grana.

Cymbohilates baculatus Turnau, new species
Figs 5 (B, C)

Holotype and type locality: Fig. 5B, slide T5I/87, co-ord K59.1, Terebin IG 5 borehole, depth 1671.70 m, Zwoleń Formation, Pragian.
Diagnosis: A *Cymbohilates* sculptured outside the central area with spaced microbacula. Proximal hilum laevigate.
Description: Amb rounded. Proximal hilum laevigate, often cracked, diameter 3/4 of cryptospore diameter. Distal and proximo-equatorial surface sculptured with spaced microbacula 1–2.5 μm in height, 1 μm wide, and spaced 2–6 μm apart.
Diameter: 27 (29.5) 36 μm (13 specimens).
Comparison: All varieties of *Cymbohilates allenii* Richardson (1996), and *C. cymosus* Richardson (1996) differ in having double wall the layers of which are separated; *Cymbohilates variabilis* Richardson var. *variabilis* Richardson (1996), and *C. variabilis* Richardson var. *parvidecus* Richardson (1996) have radial muri on the hilum and ornamentation elements of variable shape.

Cymbohilates sp. A
Fig. 6A

Description: Amb rounded. Proximal hilum laevigate, diameter 2/3 of cryptospore diameter. Distal and proximo-equatorial surface sculptured with irregularly distributed grana 1 μm in diameter, 0.5–4 μm apart.
Diameter: 45, and 50 μm (3 specimens).

Laevolancis divellomedia (Tchibrikova) Burgess et Richardson 1991
Figs 3F, 5A

non 1993. *Gneudnaspora divellomedium* (Tchibrikova) Balme: Avkhimovitch, Tchibrikova, Obukhovskaya, Nazarenko, Umnova, Raskatova, Mantsurova et Streel, pl. 2, fig. 3.

Remarks: *L. divellomedia* from the investigated sections occurs in two forms: 1) the hilum in the typical form is laevigate and without any openings, and 2) the hilum is cracked (Fig. 5A) giving the appearance of a germinal aperture (e.g., a monolete, trilete). In *Cymbohilates pusillus* from our material, the hilum is also whole or cracked (Fig. 3B, C). The cracking of the hilum is considered a taphonomic alteration and not of taxonomic value. For this reason all unornamented, hilate cryptospores with a rigid, unfolded wall are included in *L. divellomedia*. *Gneudnaspora divellomedium* in Avkhimovitch *et al.* (1993, pl. 2, fig. 3) has an obvious trilete mark and therefore does not represent the discussed cryptospore.

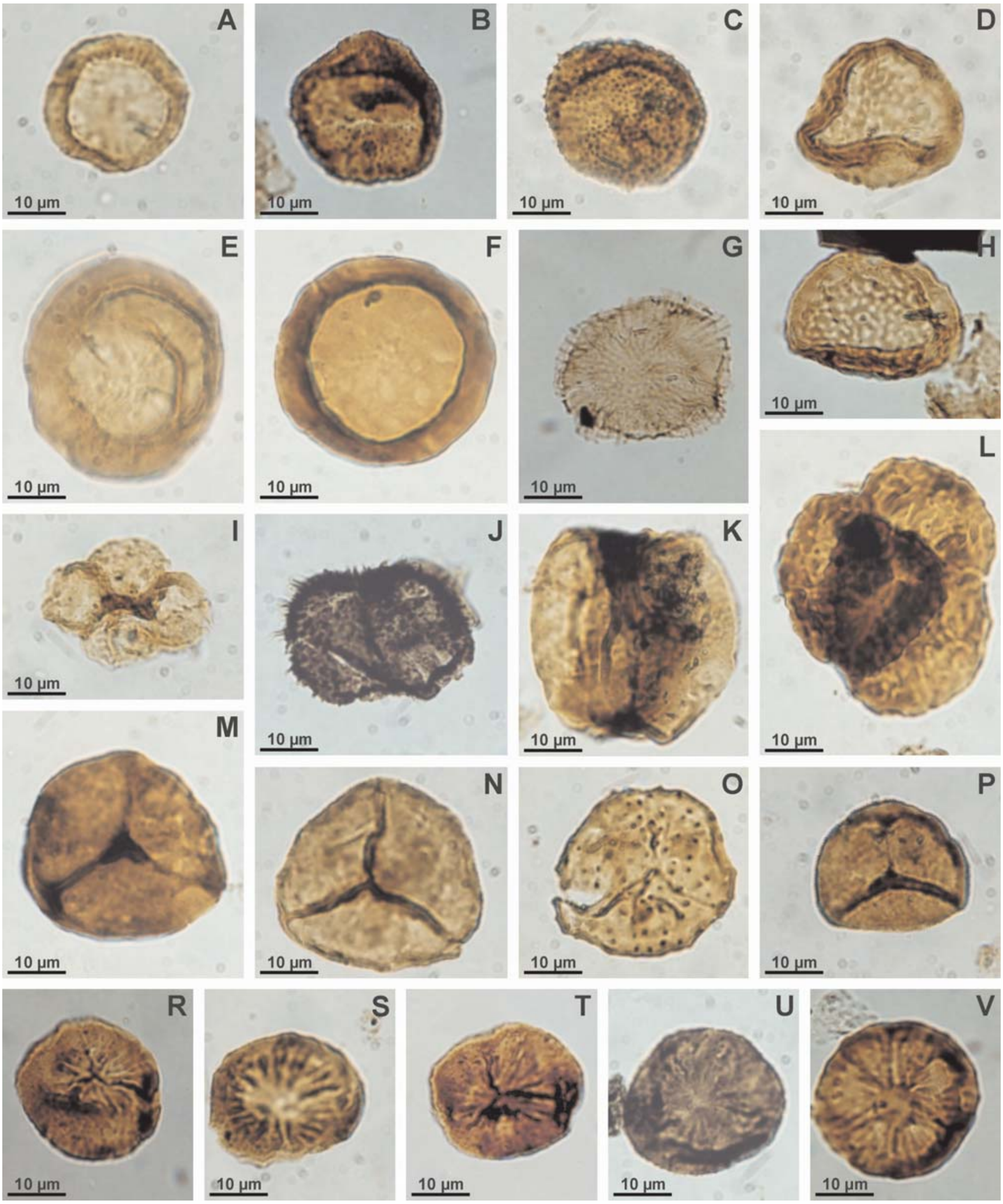

Fig. 3. Lochkovian cryptospores and spores from the Terebin IG 5 borehole. Specimens are identified by sample depth, slide number and England finder coordinates. Photographs A, G, L, S are from depth 2017.10 m, slide T5/I/33, and E, F, K, M, N are from depth 2052.5 m, slide T5/I/13, others as indicated below. All photographs × 1000. **A** – *Artemopyra* sp., J52.2; **B, C** – *Cymbohilates pusillus*, B – 1989.15 m, T5/I/64, G24; C – holotype, 2012.75 m, T5/I/41, H55.4; **D, H** – *Chelinohilates glabrimarginatus*, D – 2012.75 m, T5/I/41, H53.5; H – 1989.5 m, T5/I/64, G26; **E** – *Laevolancis plicata*, P30.02; **F** – *L. divellomedia*, N32.1; **G** – *Qualisaspora spinifera*, J63.1; **I** – *Quadrisporites variabilis*, 2003.10 m, T5/I/45, R65.4; **J** – spinose diad, 1989.15 m, T5/I/63, O52.4; **K** – laevigate diad, O40; **L** – murornate tetrad, F32.2; **M** – *Retusotriletes tuberiferus*, J32.2; **N** – *Retusotriletes maculatus*, J34.2; **O** – *Aneurospora geriennei*, 2012.75 m, T5/I/41, Q38.1; **P** – *Retusotriletes warringtoni*, 2003.10 m, T5/I/45, S65.1; **R, S** – *Emphanisporites micrornatus* var. *micrornatus*, R – 2003.10 m, T5/I/47, K57.3, S – R66.2; **T, U** – *E. micrornatus* var *sinuosus*, T – 1989.5 m, T5/I/64, K27.2, U – ibidem, T5/I/63, S52.4; **V** – *E. epicautuus*, 2003.10 m, T5/I/47 m, M57.1/3

Genus *Qualisaspora* Richardson, Ford et Parker 1984
Qualisaspora spiniferea (Turnau et Jakubowska) Turnau 2003

1989. *Micaspora spinifera* Turnau et Jakubowska: p. 402, pl. 3, Figs 7-9.
2003. *Qualisaspora spinifera* (Turnau et Jakubowska) Turnau: Turnau, Fijałkowska-Mader, Filipiak & Stempień-Sałek, p. 632, 633, pl. 365, fig. 3.

Description: Cryptospores of two-layered wall, amb almost circular, in lateral compression the cryptospore outline is vase-shaped (subcircular with straight "top"). Outer wall layer thinner than the inner one; layers separated over the whole cryptospore, except one pole. At the equator, the outer layer appears as a zona up to 1/3 the radius. Wall sculptured by radial muri which converge at two foci on opposite surfaces. Muri straight or sinuous, tapering from base to top, 1–1.5 µm high, about 1 µm wide at base and about 1 µm apart, bearing fine spines.
Diameter: 28 (33) 37 µm (13 specimens).
Remarks: Turnau and Jakubowska (1989) proposed a new genus *Micaspora* which differed from the cryptospore genus *Qualisaspora* in having a zona and lacking two-layered wall showing separation of the layers. However, the original material was very poorly preserved, and subsequent studies on morphology of *Micaspora* have shown that it does not differ from *Qualisaspora,* and should be considered the younger synonym of the latter genus.

Anteturma SPORITES Potonié 1893

Genus *Breconisporites* Richardson, Streel, Hassan et Steemans 1982
Breconisporites? sp.A
Fig. 4N

Description: Bizonate spores with subcircular amb. The triradiate mark is distinct and accompanied by narrow lips or folds, approximately 1 µm wide. Laesurae are sinuous, extending to the equatorial margin. Equatorial zona, differentially thickened, is ca 1/3 the spore radius wide. The inner (thick) and the outer (thin and diaphanous) portions of the zona are of similar width. Rare radial thickenings extend from the inner part of the zona to the spore margin. Exine of the distal and proximal spore surfaces is entirely smooth.
Diameter: 48 and 43 µm (only two specimens recorded).
Remarks: These specimens are only tentatively assigned to *Breconisporites* because they do not show the cristate, plicate ridges on the contact faces. Bizonate spores are not frequently recorded from below the breconensis-zavallatus Biozone. So far, Turnau (1986) described *Breconisporites* sp. of the Radom-Lublin area, Wellman (1993) described *Breconisporites simplex* from Scotland, and *Breconisporites* sp. A, B, C have been described from the Cantabrian Mountains by Richardson *et al.* (2001). In all the three cases, the specimens of *Breconisporites* have been recorded from the micrornatus-newportensis Biozone.

Genus *Camptozonotriletes* Staplin 1960
Camptozonotriletes cf. *caperatus* McGregor 1973
Fig. 4L

Description: Zonate spores with rounded triangular amb. The triradiate mark accompanied by narrow lips or folds approximately 1 µm wide. Laesurae sinuous, extending almost to the equatorial margin. Equatorial zona is ca 1/3 the width of the spore radius, its outer margin may be rolled into a 2 µm wide, limbus-like structure. The zona is indistinctly sculptured with poorly preserved grana or cones. Exine over the outer part of the proximal face is wrinkled. Distal surface of the central body ornamented by radially arranged rugulae.
Diameter: 45 µm (only one specimen was found).
Comparison: *Camptozonotriletes caperatus* McGregor (1973) is larger.

Genus *Emphanisporites* McGregor 1961
Emphanisporites micrornatus Richardson et Lister var. *micrornatus* Steemans et Gerienne 1984
Figs 3 (R, S)

Description: Amb subcircular. The triradiate rays are 3/4 of the spore radius long, and accompanied by narrow lips which end abruptly near the proximal pole. The contact areas bear more or less straight, radial muri, 6–7 in number in each sector. Distal and proximo-equatorial surfaces ornamented by conical processes usually 0.5 µm in height, and always less than 1 µm.
Diameter: 22.5 (27.5) 32,5 µm (14 specimens)

Emphanisporites micrornatus Richardson et Lister var. *sinuosus* Steemans et Gerienne 1984
Figs 3 (T, U)

Description: Amb subcircular. The triradiate rays are 3/4 of the spore radius long, and are accompanied by narrow lips which end abruptly near the proximal pole. The contact areas bear radial muri that are sinuous and widening towards the equator; 7 muri occur in each sector. Distal and proximo-equatorial surfaces ornamented by conical processes 1 µm in height, and 1–2 µm apart.
Diameter: 19 (27) 31 µm (13 specimens)

Genus *Cymbosporites* Allen 1975
Cymbosporites sp. A
Figs 4 (B, C)

Description: Patinate spores with subcircular amb. The triradiate rays are 3/4 of spore radius long, and are accompanied by sinuous lips which are c. 1 µm wide in the apical area and increase in width towards equator. Contact area smooth, thin. Distal and proximo-equatorial surfaces ornamented by spines that are 3–4.5 µm in length, have 2–2.5 µm wide, bulbous bases and rounded tips. The spines are 1.5–2 µm apart.
Diameter: 40 and 45 µm.
Comparison: *C. multispinosus* Steemans (1989, p. 122-123, pl. 32, figs 7-12) has acute and more closely spaced spines.

Genus *Retusotriletes* Naumova emend. Richardson 1965
Retusotriletes niger Turnau, new species
Figs 5 (D, G)

Holotype and type locality: Fig. 5D, slide TerI/88, co-ord. K57, Terebin IG 5 borehole, depth 1671.70 m, Zwoleń Formation, Pragian.
Diagnosis: A *Retusotriletes* with the curvatural ridges that coincide with equator giving the appearance of a crassitude that is slightly wider interradially than at the apices.
Description: Amb triangular, sides convex. The triradiate rays extend almost to the equatorial spore margin, and are accompanied by lips that diminish distinctly in height and width towards equator. The curvatural ridges coinciding with equator are 3–5 µm wide interradially, narrower (1–3 µm) at the apices.
Diameter: 27.5 (31.5) 35 µm (16 specimens).
Comparisons: *Retusotriletes dubius* (Eisenack) Richardson (in Richardson & Lister, 1969, p. 215-216, pl. 38, figs 1-2) and *R.* cf. *dubius* (in Richardson & Ioannides, 1973, p. 272, pl. 1, figs 12-13) are larger, have a darkened apical polar area, and the curvatural ridges are of uniform width.

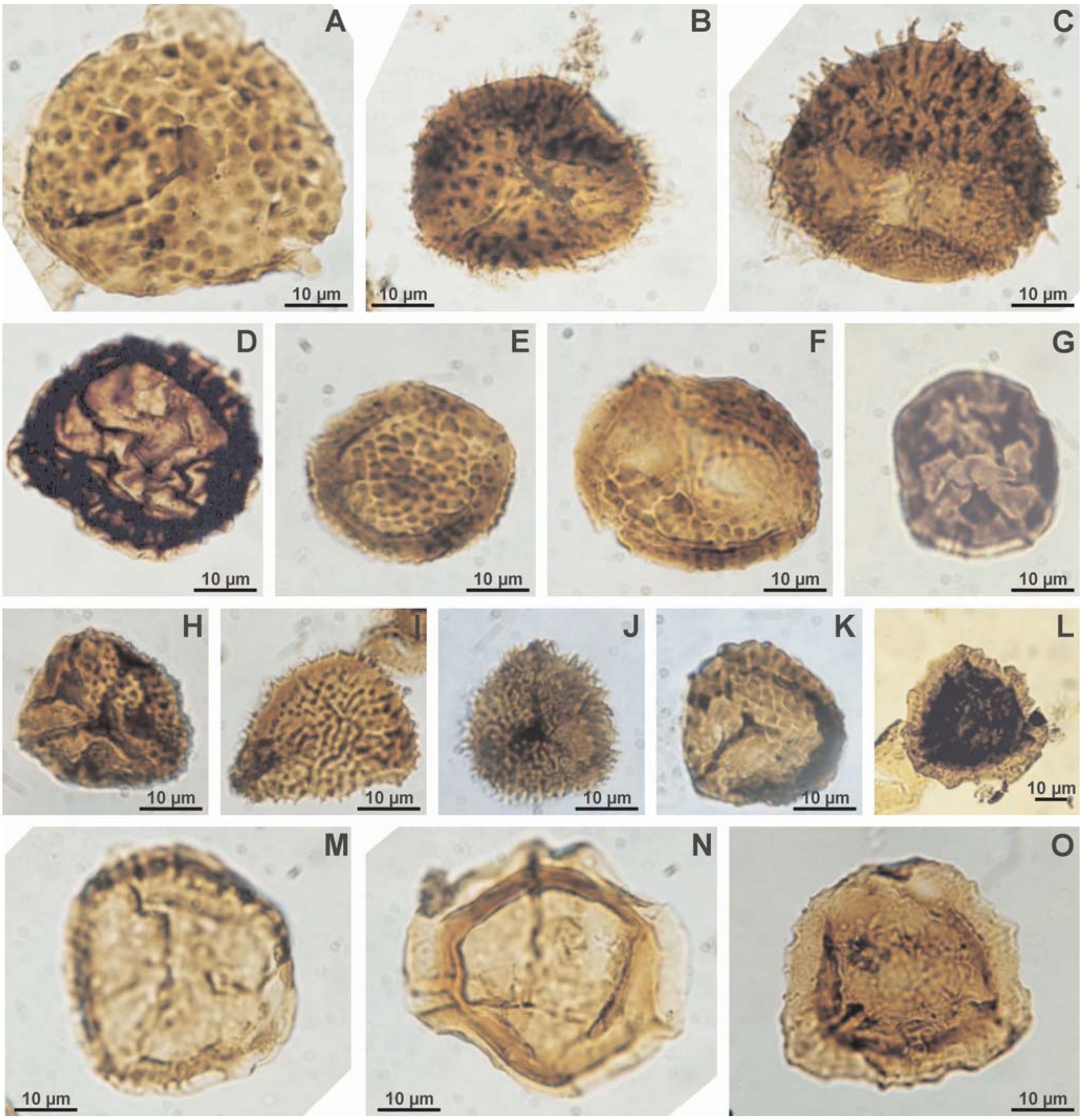

Fig. 4. Lochkovian spores from the Terebin IG 5 borehole. Specimens are identified by sample depth, slide number and England finder coordinates. Photographs A, B, C, I, L are from depth 2017.10 m, slide T5/I/33, others as indicated below. All photographs × 1000 except specimen L × 500. **A** – *Verrucosisporites* sp. A, H37; **B, C** – *Cymbosporites* sp. A, F38, M41; **D** – *Chelinospora cassicula*, 1989.15 m, T5/I/63, J49.3; **E, F** – *Cymbosporites dittonensis*, 2052.5 m, T5/I/13, G41.4, L36.3; **G** – *Leonispora agroveie*, 1989.5 m, T5/I/63, T57.4; **H** – *Streelispora newportensis*, 2003.0 m, T5/I/45, T59.2; **I, J** – *Aneurospora crinita*, I – K67.2; J – 2003.10 m, T5/I/45, O69.3; **K** – *Chelinospora retorrida*, 2003.10 m, T5/I/45, T69; **L** – *Camptozonotriletes* cf. *caperatus*, R33.4; **M** – cf. *Scylaspora vetusta*, 2052.5 m, T5/I/13, F36.4; **N** – *Breconisporites* sp. A, 5052.5 m, T5/I/13, G.46.4; **O** – Zonate spore, 1989.5 m, T5/I/63

Retusostriletes tuberiferus Turnau, new species

Fig. 3M

Holotype and type locality: Fig. 3M, slide Ter5I/13, co-ord. J34.2, Terebin IG 5 borehole, depth 2052.50 m, Czarnolas Formation, Lochkovian.

Diagnosis: A *Retusotriletes* with lips thickened apically.

Description: Spores with subtriangular amb. The triradiate mark accompanied by narrow lips or folds approximately 1 µm wide. Laesurae sinuous, extending almost to the equatorial margin, ending at imperfect curvaturae. The apical part of the lips is thickened forming a 5 µm wide boss of convexly triangular outline. Exine punctate.

Diameter: 25 (30.5) 37 µm (5 specimens).

Comparisons: The described species differs from other *Retusotriletes* by having the apical thickening of the lips.

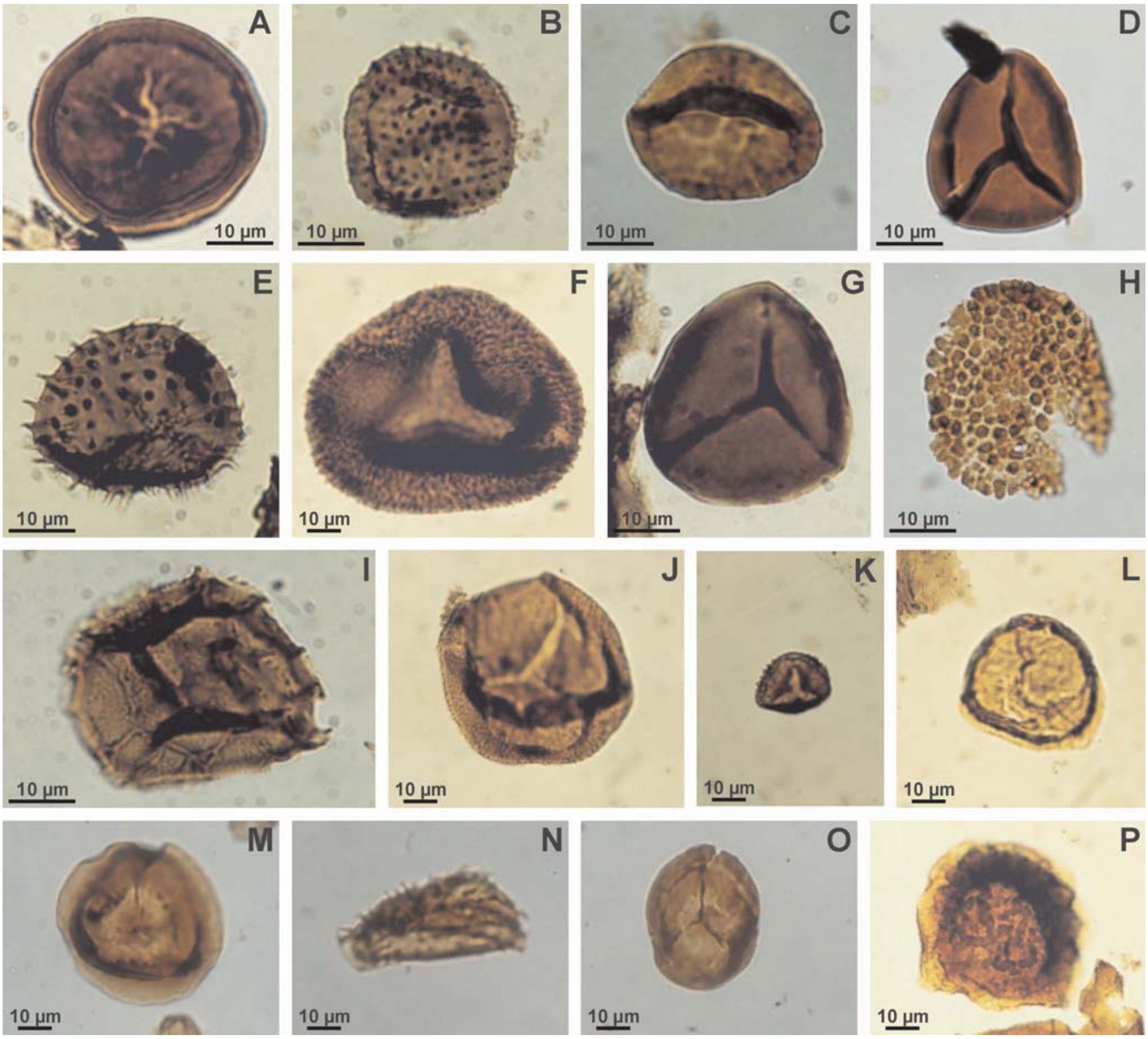

Fig. 5. Pragian cryptospores and spores from the Terebin IG 5 borehole. Specimens are identified by sample depth, slide number and England finder coordinates. Photographs B, C, I, J, L are from depth 1671.7 m, slide T5/I/87, and D, F, H, K, M, N, O, P are also from this depth, slide T5/I/88, others as indicated below. Specimens A–I × 1000; specimens J–P × 500. **A** – *Laevolancis divellomedia*, specimen showing cracked hilum, 1705.02 m, T5/I/75, W63.3; **B, C** – *Cymbohilates baculatus*, B – holotype, K59.1, C – specimen showing cracked hilum, K58.3; **D, G** – *Retusotriletes niger*, D – holotype, K57, G –1697.25 m, T5/I/81, U68; **E** – *Dibolisporites eifeliensis*, 1705.02 m, T5/I/75, R55.4; **F** – *Apiculiretusispora brandtii*, W35.3; **H** – *Verrucosisporites polygonalis*, T56; **I** – *Dictyotriletes subgranifer*, R40; **J** – *Apiculiretusispora plicata*, T40; **K** – *Dibolisporites wetteldorfensis*, J63.4; **L** – *Diaphanospora subita*, O32.1; **M** – *Breconisoporites breconensis*, F57.4; **N** – *Kraeuselisporites gaspesiensis*, V54; **O** – *Amicosporites jonkeri*, T52.2; **P** – *Limbosporites crassus*, P37.3

Genus *Verrucosisporites* Ibrahim emend. Smith et Butterworth 1967

Verrucosisporites sp. A

Fig. 4A

Description: Amb rounded subtriangular. The triradiate rays extend almost to the equatorial spore margin, and are accompanied by narrow lips. The proximal surface smooth, distal surface ornamented by closely set, isodiametric verrucae which are polygonal or irregular in outline, somewhat conical in profile, 2–4 μm in width, less than 1 μm in height, less than 1 μm apart.

Diameter: 47.5–50 μm (three specimens).

Comparison: The described form is similar to *V. polygonalis* Lanninger but the verrucae appear very low and slightly conical in profile, while those in *V. polygonalis* (Lanninger, 1968, pl. 22, fig. 19) they are rounded or flattened. McGregor (1973), McGregor and Camfield (1979), and Steemans (1989) observed that the verrucae were rounded or flat-topped, and surmounted by a spine.

Verrucosisporites polygonalis Lanninger 1968

Fig. 5H

Description: Amb subtriangular. The triradiate rays 3/4 of the spore radius in length, indistinct. The proximal surface smooth, distal surface ornamented by closely set verrucae which are polygonal in outline, rounded or flattened in profile, some verrucae

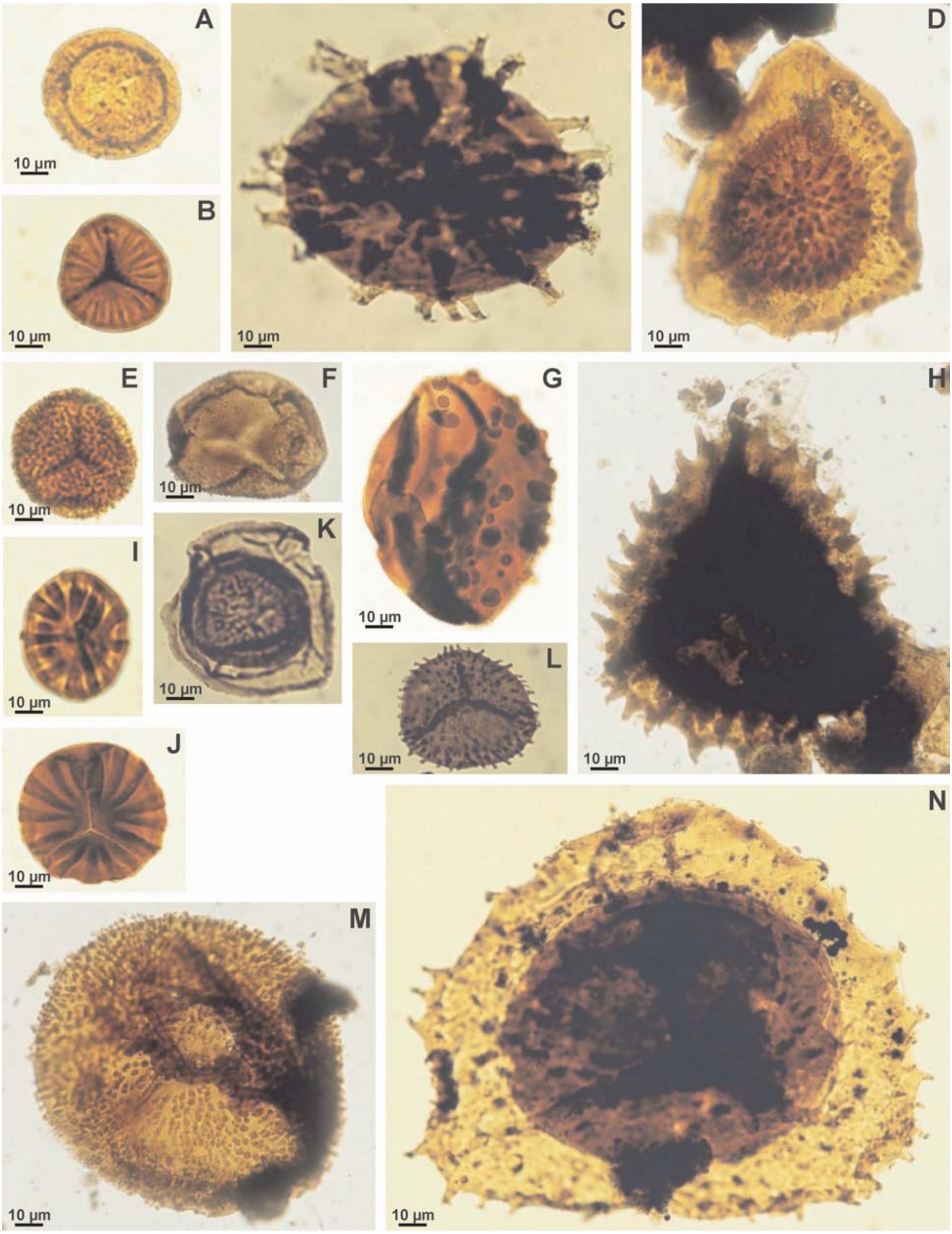

Fig. 6. Emsian and Eifelian (?) cryptospores and spores from the Giełczew PIG 5 borehole. Specimens are identified by sample depth, slide number and England finder coordinates. Photographs A, B, E, I, J, L are from depth 2136.46 m, slide G5/I/62, others as indicated below. **A** – *Cymbohilates* sp. A, H67; **B** – *Emphanisporites rotatus*, L39; **C** – *Hystricosporites* sp., 2120,16 m, G5/I/15, K59.2; **D** – *Ancyrospora eurypterota*, 2113.5 m, G5/I/85, W39.2; **E** – *Camarozonotriletes sextantii*, C59; **F** – *Apiculiretusispora plicata*, 2124.0 m, G5/I/83, R50; **G** – *Verruciretusispora dubia*, 2136.46 m, G5/I/63, N57.2; **H** – *Grandispora diamphida*, 2113.5 m, G5/I/84, V46.2; **I** – *Emphanisporites annulatus*, S57.3; **J** – *Emphanisporites erraticus*, N37.2; **K** – *Camptozonotriletes caperatus*, 2133.50 m, G5/I/55, X65; **L** – *Dibolisporites eifeliensis*, N37.2 ; **M** – *Dibolisporites echinaceus*, 2113.5 m, G5/I/84, N44.1; **N** – *Ancyrospora nettersheimensis*, 2120.16 m, G5I/15, Y54.1.

are surmounted by a minute spine. The verrucae are 1.5–3 μm in width, 1.5 μm in height, less than 1 μm apart.
Diameter: 33 μm (one specimen only).

CONCLUSIONS

1. The upper part of the Czarnolas Formation in the Pionki 4 and Terebin IG 5 boreholes belongs to the M Lineage Zone (upper part of lower Lochkovian or lowermost part of upper Lochkovian). This suggests that in the study area, the cessation of earliest Devonian marine sedimentation was synchronous, at least between Pionki and Terebin.

2. The lower part of the Zwoleń Formation (Terebin IG 5), representing the Si Lineage Zone, is attributable to lower part of the upper Lochkovian. The upper part of the formation, assigned to the W–Su interval zones, represents Pragian and possibly basal Emsian. In this borehole a substantial part of Emsian is not represented by sediments or they have been removed by erosion.

3. The Terrigenous suite (Giełczew PIG 5 borehole) belongs to the FD (an upper part) and AP Oppel zones (uppermost Emsian, and probably basal Eifelian). The lower boundary of this unit lies probably within the Emsian serotinus Conodont Zone. This suggests that this lithostratigraphical boundary coincides with the lower boundary of the Grzegorzowice Formation and its correlatives in the Góry Świętokrzyskie Mts. The II T-R cycle of Narkiewicz *et al.* (1998), indicating the onset of marine sedimentation, is probably the eustatic signature (sea level rise) represented by the IC cycle of Johnson *et al.* (1985).

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APPENDIX

List of spore species recorded

Acinosporites lindlarensis var. *lindlarensis* McGregor et Camfield 1976
Acinosporites lindlarensis var. *minor* McGregor et Camfield 1976
Ambitisporites dilutus (Hoffmeister) Richardson et Lister 1969
Amicosporites jonkeri (Riegel) Steemans 1989
Ancyrospora kedoae (Riegel) Turnau 1974
Ancyrospora eurypterota Riegel 1973
Ancyrospora nettersheimensis Riegel 1973
Aneurospora crinita Turnau et Jakubowska 1989
Aneurospora geriennei Steemans 1989
Apiculiretusispora arenorugosa McGregor 1973
Apiculiretusispora brandtii Streel 1964
Apiculiretusispora limata Turnau et Jakubowska 1989
Apiculiretusispora plicata Allen 1965
Archaeozonotriletes chulus Cramer var. *chulus* Richardson et Lister 1969
Breconisporites breconensis Richardson, Streel, Hasaan et Steemans 1982
Brochotriletes foveolatus Naumova 1953
Brochotriletes hudsonii McGregor 1973
Camarozonotriletes sextantii McGregor et Camfield 1976
Camptozonotriletes caperatus McGregor 1973
Chelinohilates glabrimarginatus (Turnau et Jakubowska) Turnau 2003
Chelinospora cassicula Richardson et Lister 1969
Chelinospora subfavosa Turnau 1986
Chelinospora retorrida Turnau 1986
Cymbohilates pusillus n. sp.
Cymbohilates baculatus n. sp.
Cymbosporites fuscus Turnau 1986
Cymbosporites dittonensis Richardson et Lister 1969
Diaphanospora subita (Arkhangelskaya) Higgs 1999
Dibolisporites antiquus Kedo 1955
Dibolisporites confertus Turnau 1986
Dibolisporites echinaceus (Eisenack) Richardson 1965
Dibolisporites eifeliensis Lanninger 1968
Dibolisporites cf. gibberosus (Naumova) Richardson 1965
Dibolisporites wetteldorfensis Lanninger 1968
Dictyotriletes subgranifer McGregor 1973
Emphanisporites annulatus McGregor 1961
Emphanisporites epicautuus Richardson et Lister 1979
Emphanisporites erraticus McGregor 1961
Emphanisporites micrornatus var *micrornatus* Steemans et Gerienne 1984
Emphanisporites micrornatus var *sinuosus* Steemans et Gerienne 1984
Emphanisporites neglectus Vigran 1964
Emphanisporites rotatus McGregor 1961
Emphanisporites spinnaeformis Lanninger 1968
Emphanisporites zavallatus var *zavallatus* Steemans et Gerienne 1984
Grandispora diamphida Allen 1965
Kraeuselisporites gaspesiensis McGregor 1973
Laevolancis divellomedia (Tchibrikova) Burgess et Richardson 1991
Laevolancis plicata Burgess et Richardson 1991
Leiotriletes pagius Allen 1965
Leonispora agroveiae Cramer et Diez 1975
Limbosporites crassus Arkhangelskaya 1980
Oculatisporites mirandus Arkhangelskaya 1978
Quadrisporites variabilis (Cramer) Jardiné, Combaz, Magloire, Peniguel et Vachey 1972
Qualisaspora spinifera (Turnau et Jakubowska) Turnau 2003
Retusotriletes maculatus McGregor 1973
Retusotriletes niger n. sp.
Retusotriletes pychovii Naumova 1953
Retusotriletes scabratus Turnau 1986
Retusotriletes tuberiferus n. sp.
Retusotriletes warringtoni Richardson et Lister 1989
Scylaspora cf. *vetusta* (Rodriguez) Richardson, Rodriguez et Southerland 2001
Streelispora newportensis (Chaloner et Streel) Richardson et Lister 1969
Verruciretusispora dubia (Eisenack) Richardson et Rasul 1978
Verrucosisporites polygonalis Lanninger 1968

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Streszczenie

STRATYGRAFIA SPOROWA ALUWIALNYCH I PRZYBRZEŻNOMORSKICH UTWORÓW DOLNEGO DEWONU I EIFLU (?) OBSZARU RADOMSKO-LUBELSKIEGO

Elżbieta Turnau, Lech Miłaczewski & Gordon D. Wood

Utwory dewońskie obszaru radomsko-lubelskiego występują w obrębie brzeżnej części platformy wschodnioeuropejskiej. Można tu wyróżnić wyraźne, ograniczone uskokami jednostki strukturalne, a to: wyniesiona część platformy (EPEEP), rów mazowiecko-lubelski (MLT) i wyniesienie radomsko-kraśnickie (RKU). Na ościennym terytorium Ukrainy przedłużenie wyniesionej części platformy zwane jest wyniesieniem północno-wołyńskim (NVU) i depresją południowo-wołyńską (SVD), a kontynucja rowu mazowiecko-lubelskiego nosi nazwę rowu lwowskiego (LT) (Fig. 1).

W omawianym rejonie obecne są wszystkie trzy oddziały systemu dewońskiego leżące zgodnie na górnym sylurze. Ich podział biostratygraficzny jest wciąż niepełny, szczególnie jeśli chodzi o przybrzeżnomorskie i aluwialne osady nie zawierające diagnostycznej fauny. Celem niniejszej pracy jest przynajmniej częściowe wypełnienie tej luki.

Przeprowadzone badanie palinologiczne dotyczyły formacji czarnoleskiej i zwoleńskiej z otworu Terebin IG 5 oraz serii terygenicznej z otworu Giełczew PIG 5 (Tabele 1, 2). Formacja czarnoleska i seria terygeniczna reprezentują osady przybrzeżnomorskie, zaś formacja zwoleńska osady aluwialne. Ponownie zbadano zespoły spor z formacji czarnoleskiej z otworu Pionki 4. Uzyskane przed 20 laty wyniki zostały w tej pracy reinterpretowane w oparciu o najnowsze obserwacje i nowsze publikacje dotyczące zonacji sporowej (Fig. 2).

Zbadane zespoły były na ogół urozmaicone. Zawierały one zarówno kryptospory, jak i spory ze znakiem zrostowym (por. Figury 3–6). W interpretowaniu uzyskanych wyników badań posłużono się zonacją sporową stworzoną dla dewonu obszaru ardeńsko-reńskiego. Wyróżniono szereg zon Oppla oraz zon filogenetycznych lub interwałowych (Fig. 2). Górną część formacji czarnoleskiej (Terebin IG 5 i Pionki 4) zaliczono do zony Oppla Streelispora newportensis-Emphanisporites micrornatus (NM), zony filogenetycznej M (górna część dolnego lochkowu lub dolna część górnego lochkowu). Dolną część formacji zwoleńskiej (Terebin IG 5) zaliczono również do zony Oppla NM, zony ewolucyjnej Si (dolna część górnego lochkowu). Górna część formacji zwoleńskiej (Terebin IG 5) należy do zony Oppla Verrucosisporites polygonalis-Dibolisporites wetteldorfensis (PoW), zon interwałowych W i Su (prag, być może także najniższy ems). Seria terygeniczna (Giełczew PIG 5) należy do zon Oppla Emphanisporites foveolatus-Verruciretusispora dubia (FD) górnego emsu i Acinosporites apiculatus-Calyptosporites proteus (AP), obejmującej pogranicze ems/eifel.

Uzyskane wyniki pozwalają na wysunięcie następujących stwierdzeń:

1. Górna część formacji czarnoleskiej (Pionki 4 i Terebin IG 5) reprezentuje ostatni etap sedymentacji morskiej, zakończonej w późnym wczesnym lochkowie (lub wczesnym późnym lochkowie).

2. Formacja zwoleńska (Terebin IG 5) zawiera utwory górnego lochkowu po prag lub najniższy ems. W tym rejonie brakuje znacznej części osadów emsu obecnych w rejonie Radomia (Pionki 1, 4, Ciepielów IG 1)

3. Seria terygeniczna (Giełczew PIG 5) należy do górnego emsu i (prawdopodobnie) dolnego eiflu. Początek sedymentacji morskiej w tym rejonie można datować pośrednio jako poziom konodontowy serotinus. Dolna granica tej serii odpowiada więc dolnej granicy formacji grzegorzowickiej i jej odpowiedników w Górach Świętokrzyskich. Zatem cykl transgresywno-regresywny II Narkiewicza *et al.* (1998) odpowiada cyklowi Ic Johnsona *et al.* (1985).