Biostratigraphy of the Emsian to Eifelian in the Holy Cross Mountains (Poland)

Anna FIJAŁKOWSKA-MADER and Jan MALEC

The paper gives a biostratigraphic interpretation of the Emsian to Eifelian in the Łysogóry and Kielce regions of the Holy Cross Mountains, based on different groups of microfossils: miospores, conodonts, ostracods and foraminifers. Four miospore zones were identified in the uppermost Pragian, Emsian and lowermost Eifelian: Verrucosisporites polygonalis–Dibolisporites wetteldorfensis (PW), Emphanisporites annulatus–Brochotriletes bellatulus (AB), Emphanisporites foveolatus–Verruciretusispora dubia (FD) and Acinosporites apiculatus–Grandispora protea (AP). In the Łysogóry region, the Emsian and lowermost Eifelian comprises four conodont zones: serotinus, patulus, partitus and costatus, three ostracod assemblages and several foraminifer assemblages. In the Kielce region, deposits from the Emsian/Eifelian boundary interval yield conodonts from the patulus and partitus zones, two ostracod assemblages and assemblages of agglutinated foraminifers. The joint biostratigraphic analysis allows a tentative correlation of the lithostratigraphic units from both areas. It also provides independent control/calibration on the different biostratigraphical systems. The Pragian/Emsian boundary is located in the lower part of the Barcza Formation and in the lower part of the Haliszka Formation, whereas the Emsian/Eifelian boundary lies in the upper part of the Grzegorzowice Formation and in the upper part of the Winna Formation.

Key words: Holy Cross Mountains, palynomorphs, conodonts, ostracods, foraminifers, biostratigraphic correlation.
across the Łysogóry region between the upper Emsian clastic deposits of the Zagórze Formation and the lower Eifelian dolomites of the Wojciechowice Formation (Czarnocki, 1950; Pajchłowa, 1959). These are: the Bukowa Góra Claystone Member, the Kapkazy Sandstone Member and the Zachelmie Mudstone and Sandstone Member in the western part of the Łysogóry region and the Warszówek Dolomite Member, the Godów Marl Member, the Wydryszów Limestone Member, the Rzepin Dolomite Member as well as the Dąbrowa Limestone Member in the eastern part of the Łysogóry region (Malec, 2005; Fig. 2).

In the Kielce region, the Lower Devonian succession composed mainly of clastic deposits and subordinate claystones and limestones, encompassing the lowermost Pragian and Emsian, lies unconformably with a stratigraphic gap on various lithological units of the lower Paleozoic (Czarnocki, 1936; Kowalczewski, 1971; Tarnowska, 1976; Głazek et al., 1981; Szulczewski, 1995; Turnau and Tarnowska, 1997). The terrigenous deposits were subdivided into informal lithostratigraphic units by Tarnowska (1976, 1981, 1987, 1988, 1995), i.e. the Haliszka and Winna formations, with three subordinate units at the rank of members: lower sandstone member, mudstone member and upper sandstone member. Above the Winna Formation occur: the pyrite-bearing and sideritic claystone member; the dolomite member; the Dąbrowa Lime- stone Member and the bioturbated dolomite member (Gürich, 1896; Czarnocki, 1951; Tarnowska, 1976; Narkiewicz and Ołkowicz-Paprocka, 1983; Malec, 1993; Fig. 2).

**PALYNOLOGY**

**MATERIAL AND METHODS**

A total of 190 samples for palynological analysis were collected by the author from the uppermost Pragian, Emsian and lowermost Eifelian from 11 core sections of the Borków 1, Bostów PIG 1, Du a Skala 5, Dyminy 2, Haliszka 1, Poreba 1, Poreba 2, Winna 1, Winna 2, Wszachów 4 and Zaręby 2 boreholes (Fig. 1). 132 samples contained palynomorphs. The samples were subject to the maceration techniques described by Orłowska-Zwolińska (1983) in the Stratigraphic Laboratory of the Holy Cross Branch of the Polish Geological Institute in Kielce. Samples were crumbled mechanically and then treated with following reagents: HCl, HF in the cold state and heavy liquid with a specific gravity of 2.1.

The studies were supplemented with results obtained by Jakubowska (1968, 1971, 1972, 1974) from the Emsian–lowermost Eifelian of the Zaręby 2, Haliszka 1, Dyminy 2, Cedro 1, Napęków 1 and Belno 1 boreholes, by Turnau (1994, 1995a, b) from the upper Pragian–lowermost Eifelian of the Modrzewie 2A, Modrzewie 4, Dąbrowa D4, Dąbrowa D5 and Dyminy 2 boreholes, by the author (Fijałkowska-Mader et al., 1997; Fijałkowska-Mader, 2011) from the upper Pragian–lowermost Eifelian of the Tarczek 1, Tarczek 1A and Tarczek 2 boreholes as well as by Filipiak (2011) from the Emsian–lower Eifelian of the Dyminy 2A, Chełmowa 3, Jeziorko 1, Kowalkowice 1, Modrzewie 2A, Tarczek 1 and Tarczek 1A boreholes, the Bukowa Góra Quarry and the Zbrza I trench.
Table 1

<table>
<thead>
<tr>
<th>Paper/unpublished report</th>
<th>Chronostratigraphic unit</th>
<th>Biostratigraphic method</th>
<th>Boreholes/outcrops (o)</th>
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<td>Jakubowska (1968)</td>
<td>Emsian</td>
<td>palynomorphs</td>
<td>Zaręby 2</td>
</tr>
<tr>
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<td>Emsian</td>
<td>palynomorphs</td>
<td>Belno 1, Cedro 1, Dyminy 2, Haliszka 1, Napęków 1</td>
</tr>
<tr>
<td>Jakubowska (1974)</td>
<td>Emsian–Eifelian</td>
<td>palynomorphs</td>
<td>Borków 1, Borków 2, Cedro 1</td>
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<tr>
<td>Turnau in: Malec et al. (1990)</td>
<td>Emsian</td>
<td>palynomorphs</td>
<td>Golieniawy IG 1</td>
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<td>Fijalkowska (1995a, this paper)</td>
<td>u. Pragian–Eifelian</td>
<td>palynomorphs</td>
<td>Borków 1, Du a Skła 5, Dyminy 2, Haliszka 1, Poręba 1, Poręba 2, Winna 1, Winna 2, Wszchów 4, Zaręby 2</td>
</tr>
<tr>
<td>Fijalkowska (1995b)</td>
<td>u. Pragian–Eifelian</td>
<td>palynomorphs</td>
<td>Tarczek 1, Tarczek 1A, Tarczek 2</td>
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<td>Filipiak (2009, 2011)</td>
<td>u. Emsian–Eifelian</td>
<td>palynomorphs</td>
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<tr>
<td>Malec (1984b)</td>
<td>l. Eifelian</td>
<td>conodonts</td>
<td>Zaręby 2</td>
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<tr>
<td>Malec (1990a)</td>
<td>u. Emsian</td>
<td>conodonts</td>
<td>Modrzewie 2A</td>
</tr>
<tr>
<td>Malec (1986b, 1992, 1993)</td>
<td>u. Emsian–Eifelian</td>
<td>conodonts</td>
<td>Dyminy 2, Kowalkowice 1, Porzecze IG 5A, Starą Góra IG 1, Zaręby 2, Grzegorzowice (o), Kielce (o), Zbrza (o)</td>
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<tr>
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<td>conodonts</td>
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<td>Adamczak (1968, 1976)</td>
<td>u. Emsian</td>
<td>ostracods</td>
<td>Grzegorzowice (o), Wydryszów (o)</td>
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<td>ostracods</td>
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<td>Malec (1986a)</td>
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<td>ostracods</td>
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<td>Wola Zamkowa 2</td>
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<td>ostracods</td>
<td>Kielce (o), Grzegorzowice (o), Zbrza (o)</td>
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<td>ostracods</td>
<td>Modrzewie 2A</td>
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<td>Malec (1990b)</td>
<td>u. Emsian</td>
<td>ostracods</td>
<td>Bukowa Góra (o)</td>
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<td>ostracods</td>
<td>Golieniawy IG 1, Lekomin IG 1</td>
</tr>
<tr>
<td>Malec (2002, 2003a, 2007, 2008)</td>
<td>u. Emsian–Eifelian</td>
<td>ostracods</td>
<td>Chelmowa 3, Jeziorko 1, Kowalkowice 1, Lekomin IG 1, Modrzewie 2A, Tarczek 1, Wierzbontowice 1, Bukowa Góra (o), Godów (o), Grzegorzowice (o), Rzepin (o), Wydryszów (o)</td>
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<td>Duszyńska (1959)</td>
<td>u. Emsian</td>
<td>foraminifers</td>
<td>Wydryszów (o)</td>
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<tr>
<td>Malec (1979, 1984a)</td>
<td>u. Emsian–Eifelian</td>
<td>foraminifers</td>
<td>Porzecze IG 5A</td>
</tr>
<tr>
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<td>l. Eifelian</td>
<td>foraminifers</td>
<td>Zaręby 2</td>
</tr>
<tr>
<td>Malec (1984c)</td>
<td>u. Emsian</td>
<td>foraminifers</td>
<td>Chelmowa 3, Jeziorko 1, Wierzbontowice 1, Grzegorzowice (o)</td>
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<tr>
<td>Malec (1986b)</td>
<td>l. Eifelian</td>
<td>foraminifers</td>
<td>Dąbrowa D5, Wola Zamkowa 2, Kielce (o), Miedziana Góra (o)</td>
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<tr>
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<td>u. Emsian</td>
<td>foraminifers</td>
<td>Kielce (o)</td>
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<tr>
<td>Malec (1992)</td>
<td>u. Emsian</td>
<td>foraminifers</td>
<td>Dąbrowa D5</td>
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<td>Malec (2002, 2003b)</td>
<td>u. Emsian–Eifelian</td>
<td>foraminifers</td>
<td>Chelmowa 3, Jeziorko 1, Kowalkowice 1, Modrzewie 2A, Tarczek 1, Tarczek 1A, Wierzbontowice 1, Bukowa Góra (o), Godów (o), Grzegorzowice (o), Wydryszów (o)</td>
</tr>
</tbody>
</table>
RESULTS

In total 184 spore species were recognized in the upper Pragian, Emsian and lowermost Eifelian of the HCM; the species belong to 49 genera, of which 20 are recorded in Poland for the first time (Tables 2 and 3; Appendix). Three new species, one new variety and one combination were created by the author.

DESCRIPTIONS OF NEW FORMS

*Hystricosporites brevispinosus* sp. nov. (Fig. 3G)

**Holotype.** – Museum of the Polish Geological Institute – National Research Institute, Holy Cross Mts. Branch 3073/94, Figure 3G.

**Type horizon.** – Lower Devonian, upper Emsian, Winna Formation.

**Type locality.** – Borków 1 borehole, depth 38.7 m, Kielec region of the HCM.

**Derivation of the name.** – *brevis* [lat.] short, *spina* [lat.] spine; forms with short spines.

**Diagnosis.** – Suturae accompanied by folds, contact areas laevigate, characteristic short spines ended with small hooks and anchors.

**Description.** – Amb circular; suturae straight, extending at 2/3 of radius, accompanied by 10 µm high and 4–6 µm broad folds. Contact areas laevigate, about 2/3 of radius in extent. Exine 4–10 µm thick, laevigate, distally and equatorially sculptured with irregular cone-shaped spines, dilated at the base and ended with small hooks or anchors, 3–12 µm high and 4–8 µm basal diameter.

**Size.** – Spore body diameter: 110–114 m, size with spines: 125–130 m (holotype 114 and 129 m respectively) (3 specimens measured).

**Comparison.** – The species differs from other species of *Hystricosporites* in shorter and more massive spines.

**Occurrence.** – Poland, HCM: upper Emsian.

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**Fig. 2. Correlation of lithological profiles of the upper Pragian to Eifelian in the Holy Cross Mts.**

bdm – bioturbated dolomite member, BGCM – Bukowa Góra Claystone Member, DLM – Dąbrowa Limestone Member, dm – dolomite member, GMM – Godów Marl Member, KSM – Kapkazy Sandstone Member, Ism – lower sandstone member, mm – mudstone member, pscm – pyrite-bearing and sideritic claystone member, RDM – Rzepin Dolomite Member, usm – upper sandstone member, WDM – Warszów Dolomite Member, Wf – Wojciechowice Formation, WLM – Wydryszów Limestone Member, ZMSM – Zachelmie Mudstone and Sandstone Member
Table 2

Stratigraphic ranges of selected miospores in the lower Pragian to Eifelian in the Kielce region of the Holy Cross Mts.

<table>
<thead>
<tr>
<th>LOWER DEVONIAN</th>
<th>MIDDLE DEVONIAN</th>
<th>CHRONOSTRATIGRAPHY</th>
</tr>
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<tr>
<td>PRAGIAN</td>
<td>EMSIAN</td>
<td>EIFELIAN</td>
</tr>
<tr>
<td>PW</td>
<td>AB</td>
<td>FD</td>
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<tr>
<td>Su</td>
<td>Fov</td>
<td>Pra</td>
</tr>
</tbody>
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### Table 3
Stratigraphic ranges of selected mioospores in the upper Pragian to Eifelian in the Lysogóry region of the Holy Cross Mts.

<table>
<thead>
<tr>
<th>LOWER DEVONIAN</th>
<th>MIDDLE DEVONIAN</th>
<th>CHRONOSTRATIGRAPHY</th>
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<tr>
<td>PRAGIAN</td>
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<td>EIFELIAN</td>
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<tr>
<td>PW</td>
<td>AB</td>
<td>FD</td>
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<tr>
<td>Su</td>
<td>Fov</td>
<td>Pra</td>
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<tr>
<td></td>
<td>Min</td>
<td>Cer</td>
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<td></td>
<td></td>
<td>Vel</td>
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<tr>
<td></td>
<td></td>
<td>Mac</td>
</tr>
<tr>
<td>BARCZA FORMATION</td>
<td>ZAGÓRZE FORMATION</td>
<td>GRZEGORZOWICE FORMATION</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LITHOSTRATIGRAPHY</td>
</tr>
</tbody>
</table>

- *Retusoirlettes opulus*
- *Emphanisporites obtusus*
- *Cliviniospora verrucata var. verrucata*
- *Ovalatosporites mirandus*
- *Krauseiisporites gasgensis*
- *Dictyotryites eminesis*
- *Chelinospora subfascia*
- *Tholiosporites chilas var. chilas*
- *Cliviniospora verrucata var. convoluta*
- *Preconosporites spinulosa*
- *Tholiosporites divellummedium*
- *Apiculoresinuspora arenaria*
- *Diboliosporites wetzelii*
- *Apiculoresinuspora minor*
- *Retusoirlettes dubius*
- *Acinosporites ombibus*
- *Apiculoresinuspora plicata*
- *Diboliosporites ephelensis*
- *Emphanisporites rotatus*
- *Dictyotryites subgranulifer*
- *Verrucosporites polygonalis*
- *Brochotrietes hudsonii*
- *Brochotrietes robustus*
- *Cymbiosporites proteus*
- *Emphanisporites erraticus*
- *Camptoconosorites caperatus*
- *Stenozonotrietes irregularis*
- *Brochotrietes feveolatus*
- *Emphanisporites annulatus*
- *Retusoirlettes pychovii*
- *Diboliosporites gibberosus*
- *Camptoconosorites alpinus*
- *Retusoirlettes triangulatus*
- *Emphanisporites schultzii*
- *Verrucosporites dubia*
- *Acinosporites lindersiensis*
- *Retusoirlettes rotundus*
- *Grandispora eximia*
- *Diboliosporites capitellatus*
- *Grandispora protea*
- *Apiculoresinuspora microconias*
- *Grandispora diaphila*
- *Hystricosporites mirtatua*
- *Diboliosporites radiatus*
- *Diboliosporites bullatus*
- *Grandispora velata*
- *Ancyrospera ancyrus var. ancyrus*
- *Ancyrospera apiculata*
- *Hystricosporites corystus*
- *Grandispora douglasiwenzii*
- *Grandispora c.f. endemica*
- *Hystricosporites microancyru*
- *Hystricosporites porrectus*
- *Grandispora arduiniae*
- *Calypsozoolesia bicornata*
- *Ancyrospera euphiera*
- *Ancyrospera kedae*
- *Grandispora nasonovii*

Combined after: Turnau in: Malec et al. (1990); Turnau (1994, 1995a, b); Fijałkowska (1995b); Fijałkowska-Mader et al. (1997); Kowalczeński and Turnau (1997); Filipiak (2009, 2011); Fijałkowska-Mader (2011); explanations as in Table 2
Verrucosisporites rarirerrucosus sp. nov.  
*(Fig. 3J)*

**Holotype.** – Museum of the Polish Geological Institute – National Research Institute, Holy Cross Mts. Branch 3383/94, *Figure 3J*.

**Type horizon.** – Lower Devonian, upper Pragian, Haliszka Formation.

**Type locality.** – Zaręby 2 borehole, depth 1192.1 m, Kielce region of the HCM.

**Derivation of the name.** – rarus [lat.] sparse; forms with sparse verrucae.

**Diagnosis.** – Suturae well developed, curvaturae perfecta, about 5/6 of radius, accompanied by 6 µm broad folds. Exine 2–4 µm thick, distally and equatorially sculptured with delicate 0.5–3 µm broad and 1–2 µm high muri, which form an irregularly polygonal or oval network with mesh diameter of 0.5–7 µm.

**Size.** – 50–96 µm (holotype 80 µm; 4 specimens measured).

**Comparison.** – The large size of the spores and sparse, irregularly spaced verrucae distinguish this species from *V. polygonalis* Lanninger and V. grumosus (Naumova) Taug.

**Occurrence.** – Poland, HCM: upper Pragian–lower Emsian.


Verruciretusispora dubia  
*(Eisenack, 1944) Richardson et Rasul, 1978, var. multituberculata var. nov.  
*(Fig. 3L)*

**Holotype.** – Museum of the Polish Geological Institute – National Research Institute, Holy Cross Mts. Branch 3271/95, *Figure 3L*.

**Type horizon.** – Lower Devonian, upper Pragian–lower Emsian, Haliszka Formation.

**Type locality.** – Dyminy 2 borehole, depth 138.0 m, Kielce region of the HCM.

**Derivation of the name.** – multituberculata [lat.] many; forms with numerous tubercula.

**Description.** – Amb subcircular; suturae straight, extending from the radius, poorly visible. Contact areas delimited by fine curvaturae. Exine 3–4 µm thick, covered with irregular verrucae, 2–4 µm in diameter.

**Size.** – 50–96 µm (holotype 80 µm; 4 specimens measured).

**Comparison.** – The larger number and density of the verrucae distinguish this species from *V. dubia* (Eisenack) Richardson et Rasul.

**Occurrence.** – Poland, HCM: upper Pragian–lower Emsian.


Dictyotriletes delicatus sp. nov. 
*(Fig. 4C)*

**Holotype.** – Museum of the Polish Geological Institute – National Research Institute, Holy Cross Mts. Branch 3308/95, *Figure 4C*.

**Type horizon.** – Lower Devonian, upper Pragian–lower Emsian, Haliszka Formation.

**Type locality.** – Wszachów 4 borehole, depth 55.5 m, Kielce region of the HCM.

**Derivation of the name.** – Forms with thin, delicate muri.

**Diagnosis.** – Suturae weekly visible, delicate muri forming polygonal or oval net.

**Description.** – Amb subcircular to subtriangular; suturae straight extending to 3/4 of radius, weekly visible, accompanied by 2 m broad folds. Exine 2–4 µm thick, distally and equatorially sculptured with delicate, 0.5–3 m broad and 1–2 µm high muri, which form an irregularly polygonal or oval network with mesh diameter of 0.5–7 m.

**Size.** – 54–58 µm (holotype 54 µm; 3 specimens measured).

**Comparison.** – Smaller and more irregular meshes of the network distinguish his species from *D. subgranifer* McGregor, whereas the thinner exine and more delicate muri distinguish it from *D. nigratus* Naumova.

**Occurrence.** – Poland, Kielce region of the HCM: upper Pragian–lower Emsian.

**PALYNOSTRATIGRAPHY**

In the section studied four Oppel zones of Streel *et al.* (1987) are identified: the *Verrucosisporites polygonalis–Dibolisporites wettdorfensis* (PW) Zone, the *Emphanisporites annulatus–Brochotriletes bellatulus* (AB) Zone, the *Emphanisporites foveolatus–Verrucitrinitespora dubia* (FD) Zone and the *Aclinosporites apiculatus–Grandispora protea* (AP) Zone. Moreover six interval zones of Streel *et al.* (1987), determined by the author as subzones, were recognized: the *Dictyotriletes subgranifer* (Su) Subzone in the uppermost part of the PW Zone, the *Emphanisporites foveolatus* (Fov), the *Rhabdosporites minutus* (Min) subzones in the FD Zone, the *Hystricosporites corystus* (Cor), the *Grandispora protea* (Pro) subzones and the *Grandispora velata* (Vel) subzones in the AP Zone (Tables 2 and 3).

The Su Subzone of the PW Zone was described in the Kielce region as assemblage I in the Haliszka Formation from the Cedro 1 (at the depth of 51.4–96.5 m) and Dymyń 2 (168.1–184.8 m) boreholes (Jakubowska, 1972). Fijałkowska-Mader (1995a, this paper) determined this subzone, in deposits belonging to the Haliszka Formation in the Haliszka 1 (145.7 m), Zaręby 2 (1186.9–1199.9 m; *Fig. 5*), Wszachów 4 (55.1–55.5 m), Borków 1 (139.1–118.4 m) and Dymyń 2 (184.6–168.5 m) boreholes, Tarnau (Tarnau and Tarnowska, 1997) distinguished it within the Haliszka Formation in the Dymyń 2 (168.5 m) borehole (Tarnau, 1995a, b), Filipiak (2011) described this subzone in the Dymyń 2
Fig. 3. Apiculate spores from the upper Pragian–lower Eifelian of the Holy Cross Mts.

A – *Apiculiretusispora arenorugosa* McGregor, Haliszka 1 borehole, depth 53.5 m; B – *A. brandtii* Strel, Tarczak 2 borehole, depth 393.0 m; C – *A. plicata* (Allen) Strel, Haliszka 1 borehole, depth 53.5 m; D – *Diboliosporites eifeliensis* (Lanninger) McGregor, Haliszka 1 borehole, depth 53.5 m; E – *D. verrucosus* (Kedo) comb. nov., Tarczak 2 borehole, depth 130.8 m; F – *D. wetteldorfensis* Lanninger, Haliszka 1 borehole, depth 80.2 m; G – *Hystricosporites brevispinosus* sp. nov., Borkow 1 borehole, depth 38.7 m; H – *H. corystus* Richardson, Purba 1 borehole, depth 69.8 m; I – *H. mitratus* Allen, Tarczak 1 borehole, depth 151.7 m; J – *Verrucisporites rariverrucosus* sp. nov., Zarzby 2 borehole, depth 1192.1 m; K – *Verruciretusispora dubia* (Eisenack) Richardson et Rasul, Dymyny 2 borehole, depth 138.0 m; L – *V. dubia* Richardson et Rasul var. *multituberculata* var. nov., Dymyny 2 borehole, depth 138.0 m; scale bar – 10 µm
Fig. 4. Murornate spores from the upper Pragian–lower Eifelian of the Holy Cross Mts.

A – Acinosporites lanceolatus Streel, Poręba 1 borehole, depth 69.8 m; B – A. lindlarensis Riegel var. lindlarensis McGregor et Camfield, Borków 1 borehole, depth 35.7 m; C – Dictyotriletes delicatus sp. nov., Wszachów 4 borehole, depth 55.5 m; D – D. emsiensis (Allen) McGregor, Zaręby 2 borehole, depth 1192.1 m; E – D. subgraniifer McGregor, Wszańów 4 borehole, depth 55.1 m; F – Brochosorites bellulatus Steemans, Zaręby 2 borehole, depth 2116.1 m; G – B. foveolatus Naumova, Borków 1 borehole, depth 86.5 m; H – B. hudsonii McGregor et Camfield, Tarczek 2 borehole, depth 327.9 m; I – Emphanisporites annulatus McGregor, Haliszka 1 borehole, depth 80.2 m; J – E. foveolatus Schultz, Winna 2 borehole, depth 16.9 m; K – E. radiatus (Schultz) Jakubowska, Dymny 2 borehole, depth 138.0 m; L – E. schultzii McGregor, Haliszka 1 borehole, depth 76.5 m; scale bar – 10 µm
Fig. 5. Occurrence of selected spores in the Poręba 1 and Zareby 2 boreholes (Kielce region)

CS – chronostratigraphy; SZ – spore zones and subzones after Streel et al. (1987), for explanations see Table 2;
LS – lithostratigraphy after Tarnowska (1995); L – lithology after Tarnowska (1995); explanations as in Figure 2
(169.0–157.2 m) borehole. It covers the lower part of the Haliszka Formation and in some boreholes (Wszachów 4, Dyminy 2) also its upper part. In the Lyszogóry region, the subzone was described in the lower and middle part of the Barca Formation in the Tarczêk 2 (327.9–399.9 m; Fig. 6) and Modrzewie 4 (59.0–30.4 m) boreholes (Fijalkowska-Mader et al., 1997) and in the Bostów PIG 1 (140.1–198.0 m) borehole. The pyroclastic horizon T1 described by Tarnowska (1983, 1988, 1995, 1999) lies within this subzone.

Beside the index taxa – *Verrucosisporites polygonalis*, *Dibolisporites wetteldorfensis* (Fig. 3F) and *Dictyotriletes subjungifer* (Fig. 4E) the characteristic taxa of this subzone are: *Breconisporites breconensis*, *Retusotriletes opuleus*, *Dibolisporites apsogus*, *Tholisporis chulus var. chulus* (Fig. 7A), *Brochotriletes hudsonii* (Fig. 4H) and *Amicosporites streeli* (Fig. 7F). The spore assemblage is dominated by spores of the genera *Apiculiresquispora*, *Leiotriletes* and *Emphanisporites*.

The assemblages of the AB Zone were described by Jakubowska (1971, 1972, 1974) in the Haliszka Formation from the Cédro 1 (43.5–51.3), Dyminy 2 (157.0–157.3 m), Borków 1 (93.7–139.5 m) and Haliszka 1 (125.0–138.8 m) boreholes, as well as by Turnau (1995a) from the Dąbrowa D4 (124.5 m) and Dąbrowa D5 (109.0–112.4 m) boreholes. Fijalkowska-Mader (1995a, this paper) identified this zone in the Kielce region in the upper part of the Barcza Formation from the Belno 1 (140.0–147.0 m), Napęków 1 (81.4–87.2 m), Borków 1 (72.2–86.5 m), Borków 2 (38.3–55.0 m) and Cedro 1 (26.1–26.6 m) boreholes in the Kielce region. Turnau (1995a) identified an assemblage of this subzone in the upper part of the Winna Formation in the Dyminy 2 (150.9 m) borehole. Fijalkowska-Mader (1995a, this paper) recognized this subzone in the lower sandstone member and in the base of the mudstone member of the Winna Formation in the Du a Skala 5 (57.0–65.2 m), Dyminy 2 (150.8 m), Haliszka 1 (76.8–92.0 m), Poręba 1 (126.7 m; Fig. 5), Winna 2 (16.9–43.6 m) and Ząbrczeń 2 (1119.5–1131.0 m; Fig. 5) boreholes. In the Lyszogóry region the subzone occurs in the upper part of the Zagórze Formation in the Tarczêk 2 (130.8 m; Fig. 6) and probably Modrzewie 3 (98.1–127.0 m) boreholes (Fijalkowska-Mader et al., 1997).

Besides the index taxa – *Emphanisporites foveolatus* (Fig. 4I) and *Verrucosporispora dubia* (Fig. 3K) characteristic species first appearing in the Pragian and having their last appearance in the HCM within this subzone, such as *Apiculiresquispora brandii* (Fig. 3B), *Dictyotriletes emsiensis*, *Calyptosporites biornatus*, *Calyptosporites porrectus*, *Grandispora cf. endemica* (Fig. 8E), and *Emphanisporites schultzi* (Fig. 4L). The dominant taxa are spores belonging to the genera *Retusotriletes*, *Apiculiresquispora* and *Emphanisporites*.

The assemblage from the upper part of the FD Zone, which can represent the Subzone Min, occurs in the lower part of the mudstone member of the Winna Formation in the Haliszka 1 (65.2–69.4 m), Poręba 1 (111.1 m; Fig. 5) and Du a Skala 5 (45.0 m) boreholes in the Kielce region (Fijalkowska-Mader, 1995a, this paper). Filipiak (2011) described this subzone in the Dyminy 2 (147.0–149.0 m) borehole. In the Lyszogóry region, Turnau (1995a, b) described the assemblage from the FD Zone in the lower part of the Zagórze Formation in the Modrzewie 2A (282.9–320.4 m) borehole.

The assemblage differs from that of the Fov Subzone in the slightly higher abundance of the monopseudosaccite forms representing the genera *Grandispora* and *Calyptosporites*. *Dibolisporites capitellatus* and *D. pseudoreticulatus* are characteristic taxa.

The Cor Subzone of the AP Zone was described by Jakubowska (1972, 1974) as assemblage II from the upper part of the Winna Formation in the Borków 1 (28.3–36.0 m), Borków 2 (24.4–24.7 m), Cédro 1 (24.0–24.8 m) and Dyminy 2 (137.2–142.1 m) boreholes. Turnau (1994, 1995a) described this subzone in the Dyminy 2 (145.0 m) borehole. Fijalkowska-Mader (this paper) recognized this subzone in the upper part of the mudstone member of the Winna Formation in the Haliszka 1 (53.1–55.0 m) and Borków 1 (28.4–35.7 m) boreholes. In the Haliszka 1 borehole the subzone was identified at the top of the pyroclastic horizon T3 (see Tarnowska, 1999) at a depth of 53.5 m and in the conglomerate bed, containing intraformationally reworked material of the pyroclastic horizon T4 (Turnau, 1995a; Tarnowska, 1999), in the Dyminy 2 borehole. In the Lyszogóry region the subzone was identified in the upper part of the Zagórze Formation and in the lower part of the Bukowa Góra Member of the Grzegorzowice Formation in the Tarczêk 1 (149.2–230.2 m; Fig. 6) and Modrzewie 2A (216.7–278.8 m) boreholes (Turnau, 1995a, b; Fijalkowska-Mader et al., 1997).

Beside the index taxa, *Ancyrospora apiculatus*, *Grandispora protea* (Fig. 8F) and *Hystricosporites coryustum* (Fig. 3H), characteristic taxa are *Grandispora douglastownense* (Fig. 8D), *G. eximia*, *Hystricosporites porrectus*, *Ancyrospora loganii* (Fig. 8I), *A. euryterota* and *Acinosporites lanceolatus* (Fig. 4A). The assemblage is dominated by spores of the genera *Grandispora*, *Hystricosporites* and *Emphanisporites*. 
Fig. 6. Occurrence of selected spores in the Tarczek 1, Tarczek 1A and Tarczek 2 boreholes (Lysogóry region)

LS – lithostratigraphy after Malec et al. (1995); L – lithology after Malec et al. (1995); spores after Fijalkowska (1995b); E. – Emsian;
G.F. – Grzegorzowice Formation; explanations as in Figures 2 and 5
Fig. 7. Patinante, cingulate and zonate spores from the upper Pragian–lower Eifelian of the Holy Cross Mts.

A – Tholisporites chulus (Cramer) McGregor var. chulus Richardson et Lister, Winna 2 borehole, depth 16.9 m; B – Chelinospora cf. favosa (McGregor et Camfield) Steemans, Haliszka 1 borehole, depth 80.2 m; C – Stenozonotriletes irregularis Schultz, Haliszka 1 borehole, depth 78.2 m; D – Coronaspora mariae Rodriguez, Haliszka 1 borehole, depth 145.7 m; E – Amicosporites jonkeri (Riegel) Steemans, Tarczek 1 borehole, depth 187.8 m; F – A. streeli Steemans, Tarczek 2 borehole, depth 327.9 m; G – Clivosispora sp., Zaręby 2 borehole, depth 1192.1 m; H – Kraeuselisporites gaspensis McGregor, Tarczek 2 borehole, depth 284.6 m; I – Membrabaculisporis cf. radiatus (Naumova) Arkhangelskaya, Haliszka 1, depth 53.5 m; J – Camptozonotriletes aliquantus Allen, Zaręby 2 borehole, depth 1159.8 m; K – C. caperatus McGregor, Tarczek 2 borehole, depth 285.2 m; L – Oculatisporites mirandus Arkhangelskaya, Haliszka 1 borehole, depth 20.2 m; scale bar – 10 µm
The Pro Subzone of the AP Zone was distinguished in the Kielce region in the upper sandstone member of the Winna Formation in the Poręba 1 (69.8–74.7 m; Fig. 5) and Winna 1 (67.3 m) boreholes (this paper). Filipiak (2011) described this subzone in the upper sandstone member of the Winna Formation, pyrite-bearing and sideritic claystone member and dolomite member from the Zbrza I trench. It was also noted in the upper part of the Bukowa Góra and Kapkazy members, and in the lower part of the Zachelimite Member of the Grzegorzowice Formation (previously referred to the Tarczek Claystone Member) in the Tarczek 1 (43.9–130.8 m), Tarczek 1A (45.0 m; Fig. 6) and Modrzewie 2A (126.4–215.3 m) boreholes (Fijałkowska, 1995b; Turnau, 1995a, b; Fijałkowska-Mader et al., 1997; Fijałkowska-Mader, 2011; Filipiak, 2011). Moreover Filipiak (2009, 2011) identified this subzone in the Bukowa Góra Member in the Bukowa Góra Quarry, in the Bukowa Góra and Wydryszów members in the Chelmowa 3 (81.0–136.0 m) and Jeziorko 1 (88.0–179.0 m) boreholes and in the Wydryszów Member in the Kowalkowice 1 (156.0–194.0 m) borehole in the Łysogóry region. The absence of Ancyrospora kedoeae and A. nettersheimensis in the some assemblages described by Filipiak as Pow Subzone may indicate the Subzone Cor.

In comparison to the Cor Subzone, the abundance of spores representing the genera Grandispora and Hystrocysporites is higher, whereas spores belonging to Emphanisporites and Dibolisporites disappear within the Pro Subzone.
The Vel Subzone of the AP Zone was recorded by Filipiak (2011) in the Dąbrowa Limestone Member in the Dyminy 2 (96.0–110.0 m) borehole, Dąbrowa Limestone Member and bioturbated dolomite member in the Zbrza I trench in the Kielce region as well as in the Zachełmie Mudstone and Sandstone Member in the Tarczek 1A borehole at a depth of 38.0–28.0 m by the author (Fiłajkowska, 1995b; Fig. 6) and at 17.0–23.0 m by Filipiak (2011) in the Łysogóry region.

CONODONTS

In the Łysogóry region, middle and upper Emsian as well as lower Eifelian conodonts have been documented within the Zagórze Formation and in the Grzegorzowice Formation. The oldest Lower Devonian conodonts Icriodus sp. are found in the middle part of the Zagórze Formation in the Modrzewie 2A borehole (Malec, 1986a, 1990a). Four conodont zones were distinguished in the succession from the Emsian/Eifelian boundary interval in the Grzegorzowice Formation of the Łysogóry region, i.e. serotinus, patulus, partitus and costatus (Malec, 2001, 2002; Nehring-Lefeld et al., 2003b; Figs. 9–11 and Table 4).

Conodonts characteristic of the serotinus Zone have been documented in the lower part of the Grzegorzowice Formation. Here, the Warszówek Dolomite Member yields the subspecies Icriodus corniger ancestralis Weddige and the species I. rectirostratus (Bultynck). The boundary interval between the Warszówek Dolomite Member and the Godów Marl Member contains Caudicriodus cf. culicellus culicellus (Bultynck). The lower part of the Warszówek Dolomite Member in the Wydrysów trench contains I. corniger ancestralis Weddige (Malec, 2001, 2002; Fig. 11). In the Devonian stratotype section I. corniger ancestralis occurs in the upper inversus and serotinus zones and does not cross the top of the latter zone (Weddige, 1977; Requadt and Weddige, 1978; Weddige and Requadt, 1985). The range of C. culicellus culicellus (Bultynck) spans the upper inversus and serotinus zones, whereas I. rectirostratus (Bultynck) spans the serotinus and patulus zones (e.g., Bultynck, 2003). The co-occurrence of I. corniger ancestralis and I. rectirostratus indicates the serotinus Zone.

Conodonts of the patulus Zone have been recognized in the lower and middle part of the Grzegorzowice Formation (Malec, 1986a, 2001). The species I. rectirostratus occurs within the Bukowa Góra Claystone Member in the Grzegorzowice outcrop (Fig. 10) and the Bukowa Góra Quarry as well as within the Bukowa Góra Claystone Member and the Wydrysów Limestone Member in the sections and in the Chelmowa 3, Zejziocko 1, Kowalkowice 1, Modrzewie 2A and Wierzbontowice 1 boreholes. Conodonts such as C. culicellus altus, I. corniger leptus Weddige, I. werneri Weddige, Polygonathus cooperi cooperi Klapper, P. costatus cf. patulus Klapper and P. linguaformis bułynci Klapper are recorded mainly in the Wydrysów Limestone Member and to a lesser extent in the Bukowa Góra Claystone Member and the Rzepin Dolomite Member. The assemblage is assigned to the patulus Zone based on the presence of C. culicellus altus (e.g., Bultynck, 2003) as well as the common occurrence of I. rectirostratus and I. werneri. The first taxon disappears in standard Devonian sections at the Emsian/Eifelian boundary in the lowermost part of the partitus Zone, whereas the second taxon is known from the lower part of the patulus Zone (Weddige, 1977, 1982; Bultynck, 1985; Feist et al., 1985; Belka et al., 1997).

Conodonts of the partitus Zone have been documented in the Grzegorzowice section and in the Kowalkowice 1 borehole, in the lower part of the Dąbrowa Limestone Member (Malec, 1986a, 1993, 2002). The limestones contain P. linguaformis bułynci, I. werneri and I. corniger leptus that are present also in the older members of the Grzegorzowice Formation. The assemblage comprises also taxa represented by Polygonathus costatus partitus Klapper, Ziegler et Mashkova, Icriodus retrodepressus (Bultynck) and I. corniger corniger Wittekindt. The occurrence of the latter three taxa is recorded in the lowermost Eifelian in the partitus Zone (Weddige, 1977, 1982). The subspecies P. costatus partitus, the index taxon of the partitus Zone was noted in the lower part of the Dąbrowa Limestone Member in the Grzegorzowice Formation (Fig. 10).

Conodonts of the costatus Zone are recorded in the upper part of the Dąbrowa Limestone Member in the Grzegorzowice Formation (Malec, 2001, 2002). The presence of I. amabilis in this assemblage places the upper part of the Dąbrowa Limestone Member into the costatus Zone (Fig. 10). In the lower Eifelian successions, the species appears for the first time in the lowermost part of the costatus Zone (Bultynck, 2003).

In the Kielce region, upper Emsian and lower Eifelian conodonts have been observed in several boreholes (Dyminy 2, Porzecze IG 5A, Zareby 2, Stara Góra IG 1) and in exposures in the Zbrza and Kielce (Fig. 9 and Table 5). The oldest Devonian conodonts are recorded in the lower part of the pyrite-bearing and siderititic claystone member in the Stara Góra IG 1 borehole (Malec, unpubl.), which yielded I. rectirostratus. Lower Eifelian conodonts I. retrodepressus are described from a dolomite bed from the mudstone member of the Winna Formation in the Zareby 2 borehole (Malec, 1984b). They occur also in the lower part of the Dąbrowa Limestone Member in the Zbrza and Kielce successions and in the Porzecze IG 5A borehole (Fig. 12), where they form an assemblage comprising I. retrodepressus, I. corniger corniger and I. werneri (Malec, 1992, 1993), characteristic of the partitus Zone (Weddige, 1977, 1982; Bultynck, 2003).

OSTRACODS

In the Lower Devonian of the Łysogóry region, ostracods were observed in the Zagórze Formation and the Grzegorzowice Formation (Adamczak, 1968, 1976; Malec, 1984c, 1990b, 2002; Nehring-Lefeld et al., 2003b). The uppermost part of the latter unit contains also lower Eifelian ostracods (Malec, 1989, 2002; Figs. 9–11 and Table 6). The oldest ostracod assemblage has been documented in the Modrzewie 2A borehole, in dark grey claystones of the middle part of the Zagórze Formation (Malec, 1990a). The taxonomic composition of this assemblage is most similar to ostracod as-
semblages described from the Tentakulitenchiefer (Horizon III) in the Devonian of Thuringia, pointing to the upper part of the Nowakia cancellata tentaculite Zone (Zagora, 1968; Zagora and Zagora, 1986), lying within the inversus Zone of the middle Emsian (see Oliver and Chlupac, 1991).

Numerous ostracod assemblages have been described from the upper Emsian of the Łysogóry region (Adamczak, 1968, 1976). Four local ostracod zones have been distinguished in the upper Emsian of the Grzegorzowice Formation (Adamczak, 1976): Kozlowskiella corbis (C), Bairdia cultijugati–Bairdiocypris lamellaris (CL), Arikloedenia magna (M) and Poniklacella abnormis (Ab.; Table 6). Three informal, younger ostracod zones have been distinguished in the upper members of the Grzegorzowice Formation (Malec, 2002, 2003a), i.e. Kozlowskiella spriestersbachi (S), Bythocyproidea polaris (P) and “Acratia” (Ac.). The first zone is marked by the FAD of Kozlowskiella spriestersbachi (Dahmer), documented in the uppermost Emsian at the top of the Rzepin Dolomite Member in the Grzegorzowice Formation (Fig. 10). The zone yields also large leperditicopids representing the genus Herrmannina. The lower boundary of the second zone is marked by the FAD of Bythocyproidea polaris (Gürich), along with the ostracod as-

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**Fig. 9. Biostratigraphy of the upper Pragian to Eifelian in the Holy Cross Mts.**

* – boundary suggested by Filipiak (2011); other explanations as in Figure 2 and Table 2
Biostratigraphy of the Emsian to Eifelian in the Holy Cross Mountains (Poland)

**Fig. 10.** Co-occurrence of selected microfossils in the Grzegorzowice outcrop (Łysogóry region)


<table>
<thead>
<tr>
<th>Emsian</th>
<th>Eifelian</th>
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<td>patulus</td>
<td>partitus</td>
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**Grzegorzowice Formation**

<table>
<thead>
<tr>
<th>BGCM</th>
<th>Wydryszów Limestone Member</th>
<th>Kapkazy Sandstone Member</th>
<th>Rzepin Dolomite Member</th>
<th>Dabrowa Limestone Member</th>
</tr>
</thead>
</table>

- Icriodus rectirostratus
- Panderodus sp.
- Ozarkodina sp.
- Icriodus corniger leptus
- Icriodus weimeri
- Polygnathus costatus partitus
- Icriodus retrodepressus
- Icriodus corniger comiger
- Pandoeodus recurvatus
- Icriodus amabilis
- Coelocerodontus sp.
- Tubulbardia clava
- Kozlowskella cortis
- Bairdia culrjugati
- Evlanella miltis
- Polyzigia knemelbkini
- Rhishona pentagonalis
- Jenningsina catenulata
- Poloniella tertia
- Arktodontia magna
- Kozlowskella spiniestersbechi
- Bythocyprioides polansis
- Cytherellina clara
- Evlanella renana
- Knoszka polonica
- Sulcataella pusilla
- Acrota sp.

- Webbinelloidea similis
- Stegammia sp.
- Tolypammina sp.
- Reophax sp.
- Amphipteroida pachlowana
- Lagenammina silica
- Saccammina scutellii
- Hyperammina sp.
semblage found in the lower part of the Dąbrowa Limestone Member, which is assigned to the partitus Zone. The lower boundary of the “Acratia” Zone is marked by the appearance of an abundant ostracod assemblage of the genus Acratia in the upper part of the Dąbrowa Limestone Member, assigned to the lower part of the costatus Zone (Malec, 2002).

At the base of the Bukowa Góra Claystone Member in the Wierzbontowice 1 borehole Zygoberrychia onusta (Kummerow) was found (Malec, 1986a, 2002), a species characteristic of the upper Emsian of the Eifel Hills and the Rhenish Schiefergebirge (Becker and Groos-Uffenorde, 1982; Groos-Uffenorde, 1982a). In the Eifel Hills, it occurs in the Wetteldorf and lowermost part of the Heisdorf formations (Groos-Uffenorde, 1982b), assigned to the serotinus and lowermost part of the patulus zones interval (Weddige and Ziegler, 1977; Weddige et al., 1979; Weddige, 1982, 1988).
In the Kielce region, ostracod assemblages have been recognized in the upper Emsian and lower Eifelian (Fig. 9 and Table 7). The upper Emsian taxa, occurring in the *patulus* conodont Zone are recorded in the Porzecze IG 5A borehole (Fig. 12) in the western part of the area (Malec, 1980, 1992). The species *Kozlowskiella spriestersbachi* (Dahmer), typical of the uppermost Emsian, is recorded in the Kielce region in the Zbrza section, in the lower part of the marly shales between the dolomite member and Dąbrowa Limestone Member (Malec, 1995). Abundant ostracod assemblages from the lowermost Eifelian, typical of the *Bythocyprideoides polaris* ostracod Zone, occur in the Dąbrowa Limestone Member in the Dąbrowa D5 borehole and in the Zbrza section and in the pyrite-bearing and sideritic member in the Woła Zamkowa 2 borehole (Malec, 1986b, 1989, 1995).

**FORAMINIFERS**

Abundant foraminifer assemblages occur in the upper Emsian of the Łysogóry region (Fig. 9 and Table 8; Duszyńska, 1959; Malec, 1984c, 2002, 2003b, 2007, 2008; Soboń-Podgórka and Tomasz, 2003). The foraminifers are represented mainly by agglutinated specimens of the genera *Ammodiscus*, *Amphitrema*, *Hemisphaeraminina*, *Hyperammina*, *Lagenamminina*, *Psammosphera*, *Reophax*, *Saccamminina*, *Saccharina*, *Sorospheera*, *Stegnamminina*, *Thuramminina*, *Tolypanminina* and *Webbinelloidea* (Duszyńska, 1959; Malec, 1984c, 2003b, 2007, 2008). Rare foraminifers with calcareous shells belong to the species *Pseudopalmula palmoloides* Cushman et Stainbrook, *P. polonica* Duszyńska,
Stratigraphic ranges of selected ostracods in the Emsian and Emsian/Eifelian boundary interval from the Lysogóry region of the Holy Cross Mts.

<table>
<thead>
<tr>
<th>LOWER DEVONIAN</th>
<th>MIDDLE DEVONIAN</th>
<th>CHRONOSTRATIGRAPHY</th>
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<tr>
<td></td>
<td>EMSIAN</td>
<td>EIFELIAN</td>
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<td></td>
<td>C</td>
<td>CL</td>
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<td>ZAGÓRZE FORMATION</td>
<td>GRZEGORZOWICE FORMATION</td>
<td>W. FM.</td>
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<tr>
<td></td>
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<td>Birdsallella sp.</td>
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<td>Ulrichia sp.</td>
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<td></td>
<td></td>
<td>Zygobyrixia onusta (Kummerow)</td>
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<tr>
<td></td>
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<td>Tubuliharida clava (Kegele)</td>
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<td>Poloniella devonica Gürich</td>
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<td>Sulciatella pusilla Malec</td>
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<td>Acratia sp.</td>
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</table>

P. aff. extremitata Bykova and Semitextularia thomasi Miller et Carmer. The most diverse foraminifer assemblages occur in the lowermost members of the Grzegorzowice Formation (Bukowa Góra, Warszówek, Godów and Wydryszów members) in the Grzegorzowice and Wydryszów outcrops (Figs. 10 and 11). The lower Eifelian part of the Grzegorzowice Formation (Dąbrowa Limestone Member) is dominated by Webbinelloidea similis Stewart et Lampe, whereas Hyperammina specimens occur rarely.

In the Kielce region, agglutinated foraminifers from the upper Emsian and lowermost Eifelian were recognized in Devonian sections from the western and central part of the area in the pyrite-bearing and sideritic claystone member (Fig. 9 and Table 9). They are dominated by numerous morphotypes of W. similis Stewart et Lampe distinguished by Conkin and Conkin (1970), with small amounts of specimens of Amphitremoida, Hyperammina, Lagenammina and Saccammina (Malec, 1986b, 1992; Malec and Studencki, 1988). An assemblage with a similar taxonomic composition was described from the dolomite member and the Dąbrowa Limestone Member in the Porzecze IG 5A borehole (Malec, 1979, 1980, 1986b, 1989, 1992); Tarnowska and Malec (1987); explanations as in Table 5.

### BIOSTRATIGRAPHIC CORRELATIONS

The correlation between standard palynological zones and standard conodont zones in the stratotype regions is often indirect and should be treated as tentative, particularly at the Pragian/Emsian boundary and in the Emsian (Turnau et al., 2003). The boundary between the PW and AB zones cannot be determined because the base of the AB Zone is correlated to the Emsian (Streel et al., 1987), but at this time it was not clear in which formation in the Eifel and Ardenne regions the Emsian boundary is placed. Therefore the base of the AB Zone could be correlated only roughly to the lower part of the dehicens Zone, which is correlated to the upper part of the kitaabicus Zone (Kaufmann, 2006) and the top of the AB Zone to the lower nothoperbonus Zone (Turnau et al., 2003; Fig. 9). Filipiak (2011) correlated the top of AB Zone to the uppermost gronbergii Zone. The age of the AB Zone is early Emsian. The intercalibration of younger spore zones with conodont zones was given by Streel et al. (1987) for the Eifel region. The Fov Subzone of the FD Zone is correlated with the upper part of the nothoperbonus Zone. The two remaining subzones Pra and Min correspond to the inversus and lower serotinus zones. The Cor Subzone of the AP Zone correlates with the upper serotinus and lower patulus zones and is late Emsian in age.

### Table 7

<table>
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<tr>
<th>Lower Devonian</th>
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<th>Chronostratigraphy</th>
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<td>Sulcella (Sulcella) kowadlenellides Adamczak</td>
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<td>Évaneilla renana (Kummerv)</td>
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<td>Jefina larga Malec</td>
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<td>Ochescapha ornainssima (Gürich)</td>
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<td>Orthocypsis magna Malec</td>
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<td>Polyzygia krommelenhini Lefevre et Weyant</td>
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<td>Rishona obliqua (Gürich)</td>
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<td>Sulcatella puillia Malec</td>
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Fig. 12. Co-occurrence of selected micro- and macrofossils in the Porzecze IG 5A borehole (Kielce region)

C – conodonts after Malec (2002); ostracods and foraminifers after Malec (1979, 1984c, 1992); B – brachiopods after Malec (1984c); strata occur in the reversed position in the Porzecze IG 5A borehole; other explanations as in Figure 10.
The Pro Subzone correlates with the upper *patulus* Zone and with the lowermost part of the *partitus* Zone. The Emsian/Eifelian boundary is placed within this subzone. The Vel Subzone is correlated with the upper part of the *partitus* Zone and the lower part of the *costatus* Zone.

A co-occurrence of conodonts of the *patulus* Zone with spores of the Pro Subzone was recorded in the Bukowa Góra Claystone Member of Bukowa Góra Quarry, in the Wydryszów Limestone Member of the Chełmowa 3 (81.0 and 93.0 m) and Kowalkowice 1 (156.0, 166.0, 178.0 and 194.0 m) boreholes as well as in the Bukowa Góra Claystone Member (164.0 and 179.0 m) and Wydryszów Limestone Member (88.0, 112.0 and 125.0 m) of the Jeziorko 1 borehole (e.g., Filipiak, 2011) and Wydryszów Limestone Member of the Modrzewie 2A (81.0, 89.0, 97.0 and 109.0 m) borehole in the Łysogóry region. Conodonts of the *partitus* Zone co-occur
with spores of the Vel Subzone in the Dąbrowa Limestone Member of the Dyminy 2A (96.0, 99.0, 102.0, 106.0 and 110.0 m) borehole and Zbbrza I trench (e.g., Filipiak, 2011) in the Kielce region.

Three main ostracod assemblages have been recorded in the Emsian and lower Eifelian of the Łysogóry region. The oldest is present in the middle part of the Zagórze Formation, the middle one occurs in the lower part of the Grzęgorzowice Formation, in the upper part of the *serotinus* Zone and in the *patulus* Zone from the upper Emsian, and the youngest in the upper part of the Grzęgorzowice Formation, within the *partitus* Zone and in the lower part of *costatus* Zone of the lower Eifelian. In the Kielce region, two main ostracod assemblages have been distinguished at the Emsian/Eifelian boundary: in the upper Emsian *patulus* Zone and in the lower Eifelian *partitus* Zone. In both regions, the upper Emsian and lower Eifelian ostracod assemblages have a similar taxonomic composition.

In the upper Emsian of the Łysogóry region, in the upper part of the *serotinus* Zone and in the *patulus* Zone there occurs a rich assemblage of mainly agglutinated foraminifers with minor calcareous foraminifers. In the Kielce region, agglutinated foraminifers have been documented in the upper Emsian *patulus* Zone within the pyrite-bearing and sideritic claystone member as well as in the lower Eifelian limestones of the Dąbrowa Limestone Member.

CONCLUSIONS

1. Four palynozones: PW, AB, FD and AP have been identified in the uppermost Pragian, Emsian and lower Eifelian in the HCM and correlated to lithostratigraphical units. In the Łysogóry region the middle and upper part of the Barca Formation is palynologically dated to the Su Subzone of PW Zone and the AB Zone (upper Pragian–lower Emsian), the lower part of the Zagórze Formation is dated to the AB Zone and the Fov Subzone of the FD Zone (lower Emsian), the upper part of the Zagórze Formation can be correlated to the Min Subzone of the FD Zone and the Cor Subzone of the AP Zone (upper Emsian). The Grzęgorzowice Formation is dated to the AP Zone and its subzones: the lower part of the Bukowa Góra Claystone Member to the Cor Subzone (upper Emsian), the upper part of the Bukowa Góra Claystone Member, the Wydryszów Limestone Member, the Kapkazy Sandstone Member and the lower part of the Zachelmie Mudstone and Sandstone Member to the Pro Subzone (uppermost Emsian–lowermost Eifelian) and the upper part of the Zachelmie Mudstone and Sandstone Member to the Vel Subzone (lower Eifelian). In the Kielce region the upper part of the Haliszka Formation is correlated to the Su Subzone and the upper part to the AB Zone. The lower sandstone member of the Winna Formation is dated to the Fov Subzone of the FD Zone, the mudstone member can be correlated to the Min and Cor subzones, the upper sandstone member of the Winna Formation as well as the pyrite-bearing and sideritic claystone member, the dolomite member and the lowermost part of the Dąbrowa Limestone Member are dated to the Pro Subzone. The upper part of the Dąbrowa Limestone Member and bioturbated dolomite member can be correlated to the Vel Subzone.

2. There are no differences in the taxonomic composition of miospore assemblages characterizing particular zones and subzones between the Łysogóry and Kielce regions. The older assemblages are strongly dominated by apiculate spores, representing the Rhyoniphoza, Trimerophyza and Pteridophyza. In the younger assemblages the number of pseudomonosaccate spores increases, which are the first representatives of the Progymnospermophyza.

3. Four conodont zones have been distinguished in the Emsian/Eifelian boundary interval of the Grzęgorzowice Formation in the Łysogóry region: two in the upper Emsian – the *serotinus* and *patulus* zones, and two in the lower Eifelian – the *partitus* and *costatus* zones. In the Kielce region the *patulus* Zone have been recognized in the upper Emsian and the *partitus* Zone in the lowermost Eifelian.

4. The co-occurrence of miospore subzones and conodont zones was documented in the following lithostratigraphic units: the upper part of the Bukowa Góra Claystone Member and the Wydryszów Limestone Member (Pro Subzone and *patulus* Zone) and the Dąbrowa Limestone Member (Vel Subzone and *partitus* Zone).

5. The Emsian and lower Eifelian succession of the Łysogóry region contains three main ostracod assemblages: the oldest within the middle Emsian, the second in the upper part of the *serotinus* Zone and in the *patulus* Zone and the youngest in the *partitus* Zone and in the lower part of the *costatus* Zone. In the Kielce region, two ostracod assemblages have been identified in the Emsian/Eifelian boundary interval, in the *patulus* and *partitus* zones. In both regions the upper Emsian and lower Eifelian ostracod assemblages are characterized by high taxonomic similarity.

6. Within the upper Emsian in the upper part of the *serotinus* Zone and in the *patulus* Zone of the Łysogóry region occurs a rich and diverse assemblage of agglutinated foraminifers with minor calcareous foraminifers. In the Kielce region, agglutinated foraminifers have been documented in the pyrite-bearing and sideritic claystone member of the upper Emsian in the *patulus* Zone and in the lower Eifelian Dąbrowa Limestone Member. In both regions, lower Eifelian carbonates are characterized by the presence of an abundant but low-diversity foraminifer assemblage comprising mainly multicellular, convex shells of *Webbinelloidea similis* Stewart et Lampe.

7. Joint analysis of palynological and microfossil data show that the Pragian/Emsian boundary lies within the lower part of the Barca Formation in the Łysogóry region and in the lower part of the Haliszka Formation in the Kielce region. The Emsian/Eifelian boundary in the Łysogóry region lies in the upper part of the Grzęgorzowice Formation, in the lower part of the Dąbrowa Limestone Member and Zachelmie Mudstone and Sandstone Member. In turn, in the Kielce region, this boundary is located in several different lithological units related to different contemporay facies realms in this region: in the upper part of the mudstone member and in the upper part of the upper sandstone member of the Winna Formation, just as in the pyrite-bearing and sideritic claystones member, in the dolomite member and in the lower part of the Dąbrowa Limestone Member.
8. Pyroclastic horizons T1–T4 described in the Lower Devonian of the Kielce region by Tarnowska (1999) are correlated with the following palynological zones and subzones: T1 with the Su Subzone, T2 with the AB Zone, T3 and T4 within the Cor and Pro subzones of the AP Zone.

Acknowledgements. A. Fijalkowska-Mader wishes to express her gratitude to Prof. E. Turnau for introducing to the polyvalency of the Lower Devonian, for assistance in sparse identification and positive opinions on papers, as well as to Dr. M. Tarnowska for help in core sampling and introduction to the lithostratigraphy of the Lower Devonian of the southern part of the Holy Cross Mountains. The authors would like to thank the reviewers of the manuscript: Dr. M. Oliwkiwicz-Miklasirska, Dr. H. Jäger and Prof. PIG-PIB H. Matyja for their very helpful remarks.

REFERENCES


APPENDIX

Listing of spores encountered in the upper Pragian–lower Eifelian deposits of the Holy Cross Mountains

Acanthotriletes polygamus Naumova
Acanthotriletes similars Kedo
Acanthotriletes teniaspinosus Naumova
Acanthotriletes sp.
Acinospores acanthomammilatus Richardson
Acinospores apiculatus (Strel) Steeves
Acinospores bellus (Arkhangelskaya) Steemans
Acinospores crassus Riegel
Acinospores lanceolatus Steeves (Fig. 4A)
Acinospores lindlarensis Riegel
Acinospores lindlarensis Riegel var. lindlarensis McGregor et Camfield (Fig. 4B)
Acinospores lindlarensis var. minor Riegel
Acinospores macrospinous Richardson
Acinospores m. ntereifensis (Frake) Steeves
Acinospores obnubilus Turnau
Acinospores sp.
Amicosporites cf. infraornatus Rodriguez
Amicosporites jonkeri (Riegel) Steemans (Fig. 7E)
Amicosporites lobatus (Rodriguez) Steemans
Amicosporites streilii Steemans (Fig. 7F)
Amicosporites sp.
Anapiculatisporites acerosus (Naumova) Lanning
Anapiculatisporites echinatus (Hoffmeister, Staplin et Malloy) Lanning
Anapiculatisporites petilus Richardson

Anapiculatisporites sp.
Anplanisporeites extremus McGregor et Camfield
Ancyrospora ancyrea var. ancyrea Richardson
Ancyrospora euryptera Riegel
Ancyrospora kedoe (Riegel) Turnau (Fig. 8H)
Ancyrospora loganii McGregor (Fig. 3A)
Ancyrospora nitidissima McGregor et Camfield
Ancyrospora sp.
Archeozonotriletes
Apiculiretusispora arenorugosa
Apiculiretusispora branditi Steel (Fig. 3B)
Apiculiretusispora densicornata Tiwari et Schaarschmidt
Apiculiretusispora leberidos McGregor et Camfield
Apiculiretusispora minor McGregor
Apiculiretusispora plicata (Allen) Steeves (Fig. 3C)
Apiculiretusispora sp.
Anachoniisporites sp.
Brechtisporites breconensis Richardson, Steeves, Hassan et Steemans
Brechtisporites sp.
Brochotriletes bellatus Steemans (Fig. 4F)
Brochotriletes foveolatus Naumova (Fig. 4G)
Brochotriletes hadsonii McGregor et Camfield (Fig. 4H)
Brochotriletes rarum Arkhangelskaya
Brochotriletes robustus (Scott et Rouse) McGregor
Brochotriletes sp.
Calamospora atava (Naumova) McGregor
Calamospora microrugosa (Ibrahim) Schopf, Wilson et Bentall
Calamospora microrugosa (Ibrahim) Schopf, Wilson et Bentall var. minor
Moreau-Benoit
Calamospora nigrata (Naumova) Allen
Calamospora pannacea Richardson
Calamospora sp.
Calycysporites borraniatus (Lanning) Richardson (Fig. 8A)
Calycysporites decorus Tiwari et Schaarschmidt
Calycysporites heisdorfensis Riegel (Fig. 8B)
Calycysporites radiatus Riegel (Fig. 8C)
Calycysporites sp.
Camarazonotriletes sextantii McGregor et Camfield
Camptozonotriletes aliqautanus Allen (Fig. 7J)
Camptozonotriletes caperatus McGregor (Fig. 7K)
Chelinospora concinna
Chelinospora cf. favosa (McGregor et Camfield) Steemans (Fig. 7B)
Chelinospora retorida
Dibolisporites gibberosus
Dibolisporites jakubowskae
Dibolisporites pseudoreticulatus
Dibolisporites nodosus
Dibolisporites quebecensis McGregor
Dibolisporites radiatus Tiwari et Schaarschmidt
Dibolisporites rarispinosus Fijakowska-Mader
Dibolisporites subgibberosus (Naumova) Turnau
Dibolisporites cf. triangulatus Tiwari et Schaarschmidt
Dibolisporites verrucosus (Kedo) comb. nov. (Fig. 3E)
Dibolisporites wetteldorfiensis Lanninger (Fig. 3F)
Dibolisporites sp.
Dictyotriletes delicatus sp. nov. (Fig. 4C)
Dictyotriletes emsenensis (Allen) McGregor (Fig. 4D)
Dictyotriletes favosus McGregor et Camfield
Dictyotriletes cf. grandis Lanninger
Dictyotriletes minor Naumova
Dictyotriletes nigratus Naumova
Dictyotriletes subgranifer McGregor (Fig. 4E)
Dictyotriletes sp.
Enphansisporites annulatus McGregor (Fig. 4I)
Enphansisporites decoratus Allen
Enphansisporites epicautus Richardson et Lister
Enphansisporites erraticus (Eisenack) McGregor
Enphansisporites foveolatus Schultz (Fig. 4J)
Enphansisporites mcgregori Cramer
Enphansisporites microrugosus Richardson et Lister
Enphansisporites microscrsatus Richardson et Lister f. micronsatus
Enphansisporites minuteus Allen
Enphansisporites neglectus Vigan
Enphansisporites novellus McGregor et Camfield
Enphansisporites obscurus McGregor
Enphansisporites orbicularis Turnau
Enphansisporites partitus Lanninger
Enphansisporites pataqiatus Allen
Enphansisporites pseudoeroticatus Schultz
Enphansisporites radiatus (Schultz) Jakubowska (Fig. 4K)
Enphansisporites rotatus (McGregor) McGregor
Enphansisporites schultzi McGregor (Fig. 4L)
Enphansisporites sp.
Enigmaticysporospora simplex Virgan
Enigmaticysporospora sp.
aff. Forveolatrilites sp.
Grandispora aculeata Fuglewicz et Prejibisz
Grandispora arduinnae (Riegel) Knight
Grandispora diaphida Allen
Grandispora douglasiwense McGregor (Fig. 8D)
Grandispora cf. endemica (Tchibrikova) Tchibrikova (Fig. 8E)
Grandispora eximia (Allen) McGregor et Camfield
Grandispora inculata Allen
Grandispora macrostibidula (Arkhangelskaya) McGregor
Grandispora meagformis (Richardson) McGregor
Grandispora micronsatus Tiwari et Schaarschmidt
Grandispora naumovii (Kedo) McGregor
Grandispora protea (Naumova) Moreau-Benoit (Fig. 8F)
Grandispora sanctaecriciensis Fijakowska-Mader
Grandispora velata (Eisenack) Playford (Fig. 8G)
Grandispora sp.
Graniulatisporos sp.
Hystricosporites brevispinosus sp. nov. (Fig. 3G)
Hystricosporites corysatus Richardson (Fig. 3H)
Hystricosporites gravis Owens
Hystricosporis micronocyclusus Riegel
Hystricosporites mitratus Allen (Fig. 3I)
Hystricosporites porrectus (Balme et Hassel) Allen
Hystricosporos sp.
Iberospora sp.
Kraeuselisporis gaspensis McGregor (Fig. 7H)
Kraeuselisporos sp.
Leiotriletes adnatoide Potonie et Kremp
Leiotriletes marginalis McGregor
Leiotriletes microcosmigus (Ibrahim) Naumova
Leiotriletes minutissimus Naumova
Leiotriletes ornatus Ischenko
Leiotriletes pagius Allen
Leiotriletes priddyl Potonie et Kremp
Leiotriletes rotundus Naumova
Leiotriletes sphaero-triangulus (Lossie) Potonie et Kremp
Leiotriletes tecta Moreau-Benoit
Leiotriletes sp.
Lycopodiaddiates oggygus McGregor
Membrebaculisporis cf. radiatus (Naumova) Arkhangelskaya (Fig. 7I)
Oculatisporospora mirando Arkhangelskaya (Fig. 7L)
Perotriletes sp.
Procoronaspora spinulosa Turnau et Jakubowska
Procoronaspora sp.
Punctatisporites confussus Richardson
Punctatisporites sp.
Retusotriletes actinomorphus Tschibrikova
Retusotriletes biarealis McGregor
Retusotriletes communis Naumova
Retusotriletes concinnus Kedo
Retusotriletes dilatus (Hoffmeister) Richardson et Lister
Retusotriletes distinctus Richardson
Retusotriletes dubiosus (Eisenack) Richardson emend. McGregor
Retusotriletes goensis Lele et Streel
Retusotriletes gregssi McGregor
Retusotriletes infrapunctatus Schultz
Retusotriletes maculatus McGregor et Camfield
Retusotriletes microgranulatus (Vigran) Streel
Retusotriletes ocellatus McGregor
Retusotriletes opaleus Turnau
Retusotriletes psychovii Naumova
Retusotriletes psychovii Naumova var. major Naumova
Retusotriletes rotundus (Streel) Streel
Retusotriletes rugulatus Riegel
Retusotriletes semicongalis McGregor
Retusotriletes simplex Naumova
Retusotriletes cf. tenerimedium Tschibrikova
Retusotriletes triangulatus (Streel) Streel
Retusotriletes warringtoni Richardson et Lister
Retusotriletes sp.

Rhabdosporites langii (Eisenack) Richardson
Rhabdosporites cf. parvulus Richardson
Rhabdosporites cf. scarnus Allen
Rhabdosporites sp.
Rugulatisporites sp.
Samarisporites rhenanus Riegel
Samarisporites sp.
Sinoxisporites sp.
Stenozonotriletes furivus Allen
Stenozonotriletes incessus Allen
Stenozonotriletes irregularis Schultz (Fig. 7C)
Stenozonotriletes minimus McGregor et Camfield
Stenozonotriletes simplex Naumova
Stenozonotriletes sp.
Tholisporites chulas (Cramer) McGregor var. chulas Richardson et Lister
(Fig. 7A)
Tholisporites divellomedium (Tschibrikova) Turnau
Tholisporites salantaicus (Arkhangelskaya ) Turnau
Tholisporites sp.
Verrucosisporites grumosus (Naumova) Taug
Verrucosisporites polygonalis Lanninger
Verrucosisporites rariverrucosus sp. nov. (Fig. 31)
Verrucosisporites sp.
Verruciretusispora dubia (Eisenack) Richardson et Rasul (Fig. 3K)
Verruciretusispora dubia (Eisenack) Richardson et Rasul var.
multibruculata var. nov.
Verruciretusispora sp.