AUTOREFERAT

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4. Indication of achievement under Article 16 Paragraph 2 of the Act of March 14, 2003, on Academic Degrees and Scientific Title and Degrees and Title in the Field of Arts (Journal of Laws No. 65, item 595, with amendments)

Monographic study

a) Title of scientific achievement

b) "Cambrian phytoplankton of the Brunovistulicum - taxonomy and biostratigraphy."

c) (Author, title of publication, year of issue, name of publisher)

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a) The scientific achievement

During the last several tens of years, assemblages of organic microfossils belonging to an informal *Acritarcha* group were successfully employed in stratigraphic subdivision of the Palaeozoic, and especially of the Lower Palaeozoic rocks. Their cell membranes are built of extraordinary chemically resistant organic substance. This indicates a dormant stage of the organisms. Massive occurrence of those fossils in marine sediments suggests their planktonic way of life. Therefore, rich and possible to determine acritarch assemblages could be recovered from small rocks samples, even of few grams of weight, only.

In the Lower Palaeozoic, acritarchs were very quickly changing, and new morphological types appeared. Their stratigraphic value is very high for Cambrian rocks,

especially for sediments devoid of macrofossils. The massive appearance of the acritarch assemblages in Cambrian sediments, and their distinct taxonomic differentiation, allowed for development of the reliable paleontological zonation, broadly used in paleontological recording. The oldest associations of the Cambrian acritarchs, which in many areas have been closely correlated with faunistic horizons (Martin & Dean, 1984, 1988; Volkova, 1990; Jankauskas & Lendzion, 1992; Parsons & Anderson, 1996, 2000), have cosmopolitan character in geographical sense. That allowed for a detail correlation of the areas sometimes very distant from each other.

On the base of different acritarchs associations, Cambrian sediments have been subdivided in detail within the East European Craton (Moczydłowska, 1991, 1999; Volkova, 1990; Jankauskas & Lendzion, 1992; Jankauskas, 2002), in Scandinavia (Hagenfeldt, 1989a, b; Welsch, 1986), Newfoundland (Martin & Dean, 1981, 1988), Belgium, and France (Vanguestaine & Van Looy, 1983). Within those areas, a dozen or so acritarchs horizons have been distinguished in Cambrian sediments, from *Platysolenites* horizon to begin with, up to the Cambrian and Ordovician border. The proposed subdivisions were correlated with Cambrian occurrences in other areas, for instance in Northern Africa (Albani *et al.,* 1991), Spain (Fombella, 1977, 1978, 1979; Mette, 1989; Palacios, 2008, 2010), and Bohemian Massif (Fatka, 1989). Well known assemblages of Cambrian acritarchs from the areas located nearest to the investigated region were the ones reported from Holy Cross Mountains (Szczepanik, 2009; Żylińska & Szczepanik, 2009), from the Upper Silesian Block (Buła & Jachowicz, 1996; Jachowicz-Zdanowska, 2010), and from the Lublin-Podlasie Slope of the Eastern European Platform (Moczydłowska, 1991, 1999).

In the Upper Silesian Block, assemblages of the Cambrian *Acritarcha* have been since 1970. recognised within individual boreholes (Konior, Turnau, 1974; Turnau, 1974). During the next years, age determinations of many microfossils assemblages, recovered from two boreholes: Goczałkowice IG 1 and Sosnowiec IG 1, stratotypical for Cambrian of that area, have been changed several times. Their age was ascribed to various Cambrian stages, and even to Ordovician (Kowalczewski *et al.*, 1984; Kowalczewski, 1990; Moczydłowska, 1998). Therefore, stratigraphical interpretations and correlations made on their base have caused many doubts and discussions (Buła, Jachowicz, 1996; Vanguestaine, 2000; Vanguestaine, Brück, 2005; Jachowicz, 2006). Geological models of the Upper Silesian Block, constructed on those determinations base, have also been very doubtful (Kowalczewski 1990; Buła, 2000; Buła, Żaba, 2005; Geyer *et al.*, 2008).

Systematic and detailed palynological studies of the Lower Palaeozoic deposits in Upper Silesian and Brno Blocks forming Brunovistulicum have been carried out for the last several years by the author. During the 1990, in the first stages of the studies, (Jachowicz, 1994; Jachowicz, Moryc, 1995; Buła, Jachowicz, 1996; Jachowicz, Přichystal, 1996, 1997), the main objective of the analyses was age determination of the clastic rocks existed in Brunovistulicum, between carbonate Devonian deposits and anchimetamorphic and crystalline Precambrian rocks. Stratigraphical age of those rocks, practically devoid of index fossils, used to be variably defined as Precambrian, up to Carboniferous (vide: Buła, Jachowicz, 1996; Buła, 2000).

As the result of the investigations carried out within Polish part of the Brunovistulicum (Upper Silesia), it has been proved that in the carbonate Devonian deposits basement, except for Lower Devonian clastics (Turnau, 1974), also Lower- and Middle Cambrian (Jachowicz, 1994; Buła, Jachowicz, 1996), as well as Ordovician (Gładysz *et. al.*, 1985; Jachowicz, 2005) clastic deposits appeared.

All the available microfloristic data, collected from boreholes that have penetrated Cambrian deposits in Brunovistulicum area, have been compiled in this study. That

information have been derived from 22 boreholes drilled in southern and north-eastern parts of Upper Silesia, and from three boreholes located in Moravia area (Brno Block).

Many of the analysed Cambrian profiles from Upper Silesian area have got no stratigraphical elaboration. The author has, as the first one, performed detailed investigation on the organic microfossils of the *Acritarcha* group content in over the dozen boreholes located in Upper Silesian Block. Results of those studies have already been partly published (Jachowicz, 1994; Jachowicz, Moryc, 1995; Buła, Jachowicz, 1996; Moryc, Jachowicz, 2000), or have been included into the unpublished archival reports (Jachowicz, 1995, 1999, 2000). That concerned also three profiles located within Brno region in Moravia (Jachowicz, Přichystal, 1996, 1997).

In order to obtain credible comparative material, palynological investigations have been carried out additionally on boreholes profiles where from the presence of the Cambrian microflora has been reported earlier by other scientists (Turnau, 1974; Brochwicz-Lewiński *et al.*, 1986; Harańczyk, 1982, 1983; Kowalczewski *et al.*, 1984, Moczydłowska, 1998). Finally, detailed palynological analyses have been performed on already examined Cambrian profiles of Goczałkowice IG 1, Sosnowiec IG 1, and Potrójna IG 1 boreholes, which stratigraphical position, established by Kowalczewski et al. (1984), Kowalczewski (1990), and Moczydłowska (1992, 1998), have aroused some doubts.

Very rich microfloristic data gathered during the palynological stratigraphical investigations of Cambrian deposits from Brunovistulicum allowed for carrying out the detailed taxonomic studies of their microfossil assemblages. As result of those observations, new genera and species of the *Acritarcha* microfossil group have been defined within Cambrian deposits. What was more, many earlier known taxa have been verified. Based on new palynological data, assemblages of the index microflora have been recognised and described in detail for each Cambrian stratigraphical unit defined in Upper Silesian profiles (Buła, Jachowicz, 1996; Buła, 2000). A full picture of their succession has also been prepared within the analysed Cambrian profiles of the Upper Silesian Block. Microflora assemblages, recognised within Cambrian deposits of Brno region, have been correlated with Cambrian associations of the Upper Silesian Block. The obtained results allowed for identification of the Cambrian index microflora assemblages in the whole Brunovistulicum area, from Brno in Moravia, to Kraków in southern Poland.

OUTLINE OF GEOLOGY

Under the „Brunovistulicum" term (sensu Dudek, 1980; Kotas, 1985; Buła, Żaba, 2005; Żelaźniewicz *et al.*, 2005), a tectonic unit is understood, composed of crystalline and anchimetamorphic Precambrian (Achaean and Proterozoic) rocks that occurred in Palaeozoic deposits basement of the Upper and Lower Silesia (Poland), and of Moravia area (Czech Republic). Brunovistulicum Terrane constitutes, according to Buła and Żaba, 2005, rigid fragment of the Earth crust, separated from the adjacent areas by distinct structural discontinuities, represented by multiphase developing large fault zones of over regional importance. Odra and Kraków-Lubliniec fault zones demarcate its north-eastern boundary, separating Brunovistulicum from Małopolska Block. The above mentioned zones are fragments of much larger, transcontinental, Hamburg-Kraków fault zone. The Moravia-Silesia tectonic zone constitutes the western boundary, separating Brunovistulicum from crystalline complex of Western Sudetes Mts., thrusted over it from the West. From the South, Brunovistulicum borders the Inner Carpathian Block along the Peri-Pieniny fault zone.

Within the Brunovistulicum area have been thoroughly studied Variscan deposits (Devonian - Carboniferous) of the structural cover complex, first of all of the Upper Carboniferous coal bearing deposits of the Upper Silesian Coal Basin.

Development of the Early Palaeozoic sedimentary cover within the Brunovistulicum area is still an open question. A significant progress in solving that question has been reached in the Polish part of Brunovistulicum (within Upper Silesia), where presence of the Lower- and Middle Cambrian, and Ordovician deposits have been recognised in the Devonian-Carboniferous or Mesozoic deposits basement (Jachowicz, 1994; Buła, Jachowicz, 1996; Buła, 2000). In Moravia (the Czech part of Brunovistulicum), the sub-Devonian clastic rocks have been until recently regarded entirely as the Lower Devonian ones (Dvořak, 1998), and called „the Lower Devonian Basal Clastics". However, the palynological studies of that rock complex, recognised in few boreholes, have established that they represented both the Lower Cambrian and the Lower Devonian ages (Jachowicz, Přichystal, 1996, 1997; Fatka, Vavrdová, 1998; Vavrdová, Bek, 2001; Purkňova *et al.*, 2004).

The Lower Palaeozoic deposits, occurring below the Devonian deposits or directly under the Mesozoic ones, have been recognised in 47 boreholes located in southern, south-eastern, and northern parts of the Upper Silesian Block (Buła, 2000; Pacześna, 2005). Within majority of those boreholes (42), only partial Lower Cambrian profiles have been acquired. The whole Lower Cambrian profiles have been fully penetrated within few boreholes, only, located entirely in the southern part of the Upper Silesian Block. In its northern part, a fragment of the Middle Cambrian profile has been received in one borehole (Sosnowiec IG1), and fragmentary Ordovician profiles have been recovered from 4 boreholes (Buła, Jachowicz, 1996; Buła, 2000; Jachowicz, 2005).

Lower Cambrian sediments in the Upper Silesian Block area overly unconformably the anchimetamorphic or crystalline Precambrian basement (Buła, Żaba, 2005).Those deposits constitute compact cover on the Upper Silesian Block, except for its southern part (Cieszyn-Bielsko Biała-Żywiec region), where Devonian rocks or Miocene deposits of the Fore-Carpathian Trough lie on the uplifted Precambrian rocks. The Lower Cambrian deposits thickness rises from that region into the northern direction, and especially into the north-eastern one, up to 2500-3000 m (Buła, Jachowicz, 1996; Buła 2000). Two lithostratigraphical units have been distinguished within the Lower Cambrian sediments profile of the Upper Silesian Block: Borzęta formation and Goczałkowice formation (Buła, Jachowicz, 1996). They have been defined by Buła (2000) as the lower range units – formations.

Borzęta Formation is represented by clastic sediments recognised, so far, in the eastern, marginal part of the Upper Silesian Block, only. The following successive members have been distinguished within that formation (Buła, 2000): Myślenice claystones, Osieczany mudstones, and Rajbrot sandstones. Myślenice claystones member is composed of black claystones interbedded with mudstones, and with sporadic intercalations of marly limestones. Infrequent trace fossils have been observed in those sediments. The trace fossils were represented by fodinichnia of the deposit feeders: *Planolites beverleyensis* (Billings). Their development is related to fairly deep sedimentation environment with oxygen deficiency (Pacześna, Poprawa, 2001). Osieczany mudstones member is composed mainly of mudstones interbedded by fine grained sandstones. Sparse trace fossils have been observed in its upper part, indicating for formation of their sediments distant upper offshore environment (Pacześna, Poprawa, 2001). Rajbrot sandstones member is represented mainly by middle- and fine grained sandstones with mudstones intercalations. The sequences of the sedimentary structures, observed within that member deposits, indicate an environmental zone spreading above the minimal waves base, and their development is related to the sea-shore depositional system (Pacześna, Poprawa, 2001).

Sediments of the Goczałkowice formation, occurring widely in the Upper Silesian Block area (Buła, 2000), are composed of clearly tripartite, transgressive, lithological-facial sequence (Kotas, 1982b). Its particular sections have been granted the members ranges (Buła, 2000; Buła, Żaba, 2005) as follows (listing from bottom upwards): Mogilany *Scolithos*

sandstones (og) member, Głogoczów bioturbational sandstones member, Pszczyna mudstones with trilobites (og) member, and Jarząbkowice claystones member.

The bottom part of the Mogilany *Scolithos* sandstones member is composed of fine pebbly conglomerates, aggregates, and variably of grained sandstones. Its upper part is represented by variably grained sandstones, with intercalations of conglomerates and sandy mudstones. The characteristic feature of that member is presence of sometime very numerous *Scolithos* burrows in sediments. Sediments building the lower part of the member developed, according to Pacześna (2005), in alluvial-deltaic environment, and the ones building its higher part - in marginal-marine environment.

The Głogoczów bioturbational sandstones member is represented by quartz or greywacke, fine- and middle grained, light- and green-grey sandstones, laminated by mudstones. Numerous, varied trace fossils assemblages, with *Bergaueria*, *Diploceraterion*, *Monoceraterion*, and *Planolites* ichnofossils, are the characteristic features of these sediments. Sedimentological and ichnological analyses have proved that these sediments were characteristic for shallow marine depositional systems, deposited in upper and middle offshore zones (Pacześna, 2005).

Pszczyna mudstones with trilobites member is composed of sandy, grey and green-grey mudstones, laminated by fine grained sandstones. Lithology of these sediments, their dark colour, presence of pyrite, and sporadic trace fossils indicate deep sedimentation environment with deficiency of oxygen (Pacześna, 2005). Within rocks of that member, Lower Cambrian trilobites and fragmentarily preserved inarticulate brachiopods have been encountered (Biernat, Baliński, 1973; Orłowski, 1975a).

During the recent years, within the Goczałkowice formation deposits another separate member: Jarząbkowice claystones has been distinguished. To that formation have been included massive claystones, encountered in the Jarząbkowice 1 borehole, only, (at the depth of 3980-4028 m; Buła, Żaba, 2005).

The Lower Cambrian sediments, recognised in Měnín 1, and Němčičky 3 and 6 boreholes, in the Brno Block (Jachowicz, Přichystal, 1996, 1997; Fatka, Vavrdová, 1998) are, according to Buła et al. (1997b), and Buła and Żaba (2005), stratigraphical and lithofacial equivalents of the Lower Cambrian deposits of the Goczałkowice formation, distinguished in the Upper Silesian Block (Buła, 2000). The following facts are confirming that: presence of the similar Lower Cambrian rock lithotypes within the two mentioned above Brunovistulicum regions, with similar petrographic character; clear gradual gradation of granulation within the Lower Cambrian profiles (from coarse grains at the bottom, to fine grains at the top); presence of the similar sedimentary structures; occurrence of the similar trace fossils genera, indicating approximate environmental conditions of sedimentation (Mikulaš *et al.*, 2008; Poprawa, Pacześna, 2001; Pacześna, 2005); presence of acritarchs assemblages with almost similar genera and species content (Buła *et al.*, 1997b).

The Middle Cambrian sediments have been encountered, so far, in the northern part of the Upper Silesian Block, in the Sosnowiec IG1 borehole, only. A partial Middle Cambrian profile was composed by alternating sandstones and mudstones beds, there. Variably grained sandstones occur in its lowest part, with tiny gravel admixture. The Middle Cambrian deposits, recognised in Sosnowiec IG1 borehole, have been established as the Sosnowiec formation (Buła, Jachowicz, 1996; Buła, 2000). In that formation profile, Radocha varied-grained sandstones member has been distinguished (Kowalczewski, 1990).

Fragmentary profiles of the Ordovician sediments, which have been recognised in four boreholes located in the northern part of the Upper Silesian Block, have been represented by claystones intercalated with quartz sandstones and silicified dolomites. Those deposits have been grouped in Bibiela formation (Buła, 2000). Their attachment to the Ordovician has been established on the base of conodonts (Siewniak-Madej, Jeziorowska, 1978) and organic

remnants of the *Acritarcha* group (Linczowska-Makowska 1978; Gładysz *et al.*, 1990; Jachowicz, 2005).

VI. MATERIAL STUDIED AND APPLIED TECHNIQUES

Cambrian deposits from Brunovistulicum have been rather difficult target for palynological studies. The natural constrains of the investigated deposits sampling have been caused by absence of the continuous Cambrian profiles, by limited coring of many boreholes, and by substantial destructions of the cores because of their improper storing. Within the analysed profiles of Brunovistulicum, clastic rocks complexes have been encountered beneath the carbonate deposits of the Middle Devonian, and of the Lower Devonian clastics. They were devoid of macrofossils, except for Goczałkowice IG 1 borehole profile. The age of those deposits have been defined based on the palynological analyses.

The palynological analyses have based on samples collected from 22 boreholes located in the Upper Silesian Block area, and on the ones collected from three boreholes drilled in Moravia (Brno Block). Ten of the analysed boreholes have been located in the eastern, marginal zone of the Upper Silesian Block, where the Borzęta formation deposits have been encountered. Those were the following boreholes: Borzęta IG 1, Chrząstowice, Rajbrot 1, Rajbrot 2, Trojanowice, WB 141, WB 137, Wiśniowa IG 1, Wiśniowa 3, and Wiśniowa 6. Within those boreholes, complexes of lithologically differentiated clastic rocks have been encountered below Jurassic, and Lower or Middle Devonian deposits. Age of those complexes has been problematic for many years.

The whole or partial Goczałkowice formation profiles have been obtained from boreholes located mainly in the southern part of the Upper Silesian Block. The following boreholes (except for stratotypical Goczałkowice IG 1 one) were, there: Andrychów 3, Głogoczów IG1, Jarząbkowice 1, Piotrowice 1, Kęty 8, Kęty 9, Klucze 1, Kozy Mt3, Potrójna IG1, and Sułoszowa. The detailed palynological analyses have also been carried out of Middle Cambrian deposits encountered in the Sosnowiec IG 1 borehole. The results of the palynological analyses performed on the Lower Cambrian deposits from Měnín 1, Němčičky 3, and Němčičky 6 boreholes, located in Czech part of the Brunovistulicum, in the Brno Block area, have also been used.

Above 6500 m of Cambrian profiles have been analysed, in total. Over 280 rocks samples have been collected for palynological analyses from the preserved cores or from archival rocks samples, derived from 25 boreholes. Density of the collecting samples depended on the cores condition. Therefore, the intervals between the analysed samples have oscillated between several centimetres, and up to several tens of meters.

The standard maceration techniques of clastic rocks have been adapted for all the analysed samples, with the use of concentrated hydrochloric and hydrofluoric acids (Wood *et al.*, 1996). The obtained residues have been sifted through the nylon sieve, with holes of 10 microns in diameter. The cleansed and condensed residues have been a base for preparation of standard, microscopic drop preparation that have been analysed planimetrically in the transmitted light, with the use of the Olympus BX 50 microscope. The organic substance from the chosen rocks samples has been analysed with the use of the electron microscope, too.

In the Polish part of Brunovistulicum, in the Upper Silesian Block area, the detail palynological analyses have been carried out on the Borzęta, Goczałkowice and Sosnowiec formations deposits. On the Czech part of that tectonic unit, the Brno region, has been analysed microfloristic material obtained from equivalents of lithostratigraphical units distinguished in the Lower Cambrian deposits of the Upper Silesian Block.

TACSONOMICAL STUDIES

As the results of the palynological analyses, appearance of rich, differentiated acritarchs taxonomic assemblages have been established within majority of the analysed rocks samples allowing for age dating of the studied deposits. Very rich microfloristic material has been assembled during the stratigraphical studies (Jachowicz, 1994; 1999; Jachowicz, Moryc, 1995; Buła, Jachowicz, 1996; Jachowicz, Přichystal, 1997; Jachowicz-Zdanowska, 2010). That allowed the author for carrying out the detailed taxonomic studies of the encountered acritarchs assemblages, as well as for revision of the chosen genera and species, and finally, for forming over a dozen new taxa (genera, species). The detailed descriptions, discussions, and extensions of the new and the revised taxa have been included into the palaeontological part of the present paper. Short characteristics of the index taxa, enclosed in the proposed new taxonomic frame, have been presented below. That should allow for easier orientation within genera and species content of the index acritarchs assemblages defined for particular Cambrian Series recognised in the studied area.

The new and revised taxa could be divided into two groups: the first one contains those that appear mainly in the Cambrian Series 2 deposits; the second one – contains acritarchs genera and species characteristic for the Cambrian Series 3.

Among the most important, newly created genera of the Series 2, the following one should be named: genus *Ichnosphaera* n.gen., with typical *Ichnosphaera flexuosa* (Eklund, 1990) n.comb. species, as well as with the remaining new and revised species: *Ichnosphaera robusta* n.sp, *I aranea* n.sp., *I.brachyspinosa* (Moczydłowska & Vidal, 1988) n.comb., and *I.stipatica* (Hagenfeldt, 1989) n.comb. That genus contains acritarchs described, in the first place, as *Skiagia ornata* type 1 (Moczydłowska, Vidal, 1986), and later as *Elektoriscos flexuosus* (Eklund, 1990). The morphologically differentiated genus *Ichnosphaera* n.gen. is characteristic, dominating component of the Głogoczów bioturbational sandstones (og) member, of the Goczałkowice Formation. Within sediments of that member, specimens of new, unknown so far, genus *Lechistania* n.gen., with typical *Lechistania magna* n.sp. species, have also been recognised.

The next characteristic acritarchs group, frequently represented within Cambrian Series 2 sediments, was composed of forms included into the new *Eklundia* n.gen. genus, with typical *Eklundia campanula* (Eklund, 1990) n.comb. species. This genus contains acritarchs with clearly visible, usually slightly darker central corpuscle, surrounded by transparent external one, with numerous morphologically differentiated appendices. That genus consisted earlier of acritarchs specimens regarded as various species of the following genera: *Baltisphaeridium*, *Multiplicisphaeridium*, *Goniosphaeridium*, or *Polygonium*. Deposits of the Series 2, except for typical species of the discussed genus, contain numerous specimens belonging to *E. pussilla* n.sp., *E. varia* n.comb., and *E. florentinata* n.sp. species. Within the Goczałkowice Formation deposits of the Upper Silesian Block area, the listed above species appear in a clear chronological succession. Therefore, the new species have been created for them.

In Cambrian Series 2 deposits of the studied area, forms variously classified earlier started to occur, for instance as: *Baltisphaeridium implicatum* (Fridrichsone, 1971), *Goniosphaeridium implicatum* (Fridrichsone) comb. nov. Downie 1982, *Polygonium implicatum* Sarjeant, Stancliffe, 1994 or *Solisphaeridium implicatum* (Fridrichsone) comb. nov. Moczydłowska 1998. For those specimens, with clearly visible thicker and darker central corpuscle, covered with shorter or longer needle-shaped appendices, the author suggest creation of new *Parmasphaeridium* n. gen. genus. Furthermore, two species should be distinguished within that genus - typical *P.implicatum* (Fridrichsone, 19971) n.comb. and *P. robustispinosum* n.sp. The latter appeared within Cambrian Series 2 deposits as the first representative of the discussed genus. Typical species appeared slightly later, within the higher members of the Series 2, and continued its occurrence in Cambrian Series 3 sediments.

Several other new acritarchs species have been distinguished in sediments of the Cambrian Series 2: *C.spinosum* n.sp., *Globosphaeridum arenulatum* n.sp., *Pterospermella inordinata* n.sp., *P.gigantea* n.sp., *Pterospermopsimorpha rugulosa* n.sp., and *Skiagia pilosiuscule* (Jankauskas, 1983) n.comb.

Within Sosnowiec Formation sediments, correlated with Cambrian Series 3, a new acritarchs assemblage has been recognized, with the index-form - genus *Turrisphaeridium* n.gen., and its *T. semireticulatum* n.sp. and *T. turgidum* n.sp. species. Another new species - *Retisphaeridum lechistanium* n.sp. occurs together with the listed above acritarchs associations of the same age. Beside the forms specified above, new combinations: *A. oligum* (Jankauskas, 1976) n.comb. and *Ammonidium notatum* (Volkova, 1969) n.comb. have been suggested for acritarchs known from the Cambrian Series 3 deposits. *Multiplicisphaeridum llynense* (Martin, 1994) n.comb. species occurring at the top of the Sosnowiec formation deposits has also been a new combination accompanying numerous specimens of the *Adara alea* (Martin, 1981) species.

BIOSTRATIGRAPHY

The taxonomic revision and systematic analysis of acritarch associations described from the Cambrian of Brunovistulicum allowed to establish the succession of microfloral assemblages. The best recognised and documented assemblages were obtained from the USB area, where the type sections of the Cambrian deposits are located (Buła, Jachowicz, 1996; Buła, 2000). Supplementary material, less abundant but stratigraphically very important, has been collected in the Brno Block region. This appeared particularly relevant in the case of the palaeontologicaly barren intervals of the USB profiles. Thus, important information was obtained from the Czech part of the Brunovistulicum from the strata corresponding to the Mogilany Member in the Měnín 1 section, and included also most probable uppermost Series 2 associations, recognised in partial Cambrian profiles of the Němčičky 3 and Němčičky 6 boreholes. Earlier, similarities in the facies development of the Cambrian in the Polish and Czech parts of Brunovistulicum allowed for accurate correlation of the USB sections with their stratigraphic equivalents in Moravia (Buła *et al.*, 1997a; Buła, Żaba, 2005; Pacześna, 2005).

Already the preliminary results of biostratigraphical analyses of the Cambrian from the USB indicated an enormous diversity and good preservation of organic microfossils (Jachowicz, 1994; Buła, Jachowicz, 1996). Majority of the forms encountered in the analysed deposits have been, for many years, classified as specimens of the informal *Acritarcha* group (Downie *et al.*, 1963). However, owing to an intensive research, more and more genera are now being systematically classified based on biological criteria (Talyzina, Moczydłowska, 2000; Talyzina *et al.*, 2000; Marshall *et al.*, 2005; Willman, Moczydłowska, 2007; Kaźmierczak, Kremer, 2009) .

As the aim of the present study is to apply microfossils for biostratigraphy and not to investigate their biological nature, the present author decided to use here the term „acritarchs" to describe and define index assemblages for all the documented organic microfossils. Consequently it was not attempted here to apply a distinction between arcritarchs and other groups of algae.

As a result of the present studies nine distinct regional acritarch assemblage zones have been recognised in the Cambrian deposits of Brunovistulicum. Two are the equivalents of the well-known acritarch assemblage zones: *Asteridium tornatum - Comasphaeridium velvetum* and *Volkovia dentifera – Liepaina plana* (Moczydłowska, 1991) whereas others have been established for the first time. These associations are similar in their generic and species composition to those of other Cambrian areas. However, they differ significantly in abundance of characteristic taxa which allows their easy identification. Present studies

documented occurrence of new genera and species of the *Acritarcha* group, and allowed taxonomic revision of same acritarch forms. Significant revision of the stratigraphic ranges of certain index acritarch taxa was also possible. The data obtained by the author justify the establishment of the new regional acritarch zonation for the Cambrian deposits of Brunovistulicum. They are characterized according to the Polish principles of stratigraphy (Racki, Narkiewicz, eds., 2006) and are presented in stratigraphical order below.

The term *BAMA* has been adopted for the described biostratigraphic units as an acronym of the expression ***Brunovistulicum Acritarch Microflora Assemblage***. The units are marked in ascending order by Roman numerals I to IX. For each assemblage, characteristic taxa have been indicated. These are, first of all, genera and species appearing for the first time in the given association, quantitatively dominant forms, and important taxa with relatively short durations, possibly limited to a single assemblage. An overwhelming majority of the characteristic taxa is here designated at a species level. A small number of characteristic genera refer mainly to the oldest *BAMA I* association of the Terreneuvian, this being related to a very weak morphological differentiation of the microflora of this age. The described acritarch assemblages were compared with similar associations recognised in other areas of Poland and worldwide. Especially important are correlations with acritarch zones that have been well dated in other regions basied on index fauna.

Most of recognized acritarch assemblage zones are documented as units superimposed in correlated stratotype sections of Cambrian Borzęta, Goczałkowice and Sosnowiec formations and in the Měnín 1 borehole. The exception is the *BAMA VI* Zone recognized in the partial profiles in the Jarząbkowice 1, Němčičky 3 and 6 boreholes. Four distinct, palynologically barren intervals are here distinguished. The first two were determined in the *Scolithos* sandstones of the Mogilany Member, whereas the other two just below and above the intrusion cross-cutting the Sosnowiec Formation in the Sosnowiec IG 1 borehole.

***BAMA I – Pulvinosphaeridium antiquum - Pseudotasmanites* Assemblage Zone**

Definition and boundaries – Diagnostic for the *BAMA I* assemblage is, first of all, the absence of taxa with a differentiated, more complicated morphology. The dominant components are representatives of genus *Leiosphaeridia* with various vesicle diameters (from several up to a few hundreds microns) and numerous filamentous forms representing *Cyanophyta*. Other important components are specimens of *Pulvinosphaeridium antiquum* and *Pseudotasmanites*. Their stratigraphic ranges in the study area are limited to the *BAMA I* Zone. The *BAMA I* Zone is bounded from the bottom and from the top by palynologically barren sediments of Potrójna Fm. (Wiśniowa 6, Wiśniowa 3 and Wiśniowa IG 1 boreholes) and *Scolithos* sandstones sediments of the Mogilany Member of Goczałkowice Formation (Borzęta IG 1 borehole).

Description – The diagnostic taxa are accompanied by tiny forms of *Pterospermopsimorpha* and *Granomarginata*. They are rather sparse, represented by a few specimens in a standard microscopic slide. Single, large (several hundred microns in diameter) specimens of the *Chuaria* and *Tawuia* genera are additional elements of this association. The other characteristic components are forms with a somewhat different morphology, representing the genera *Ceratophyton, Navifusa* and *Leiovalia*.

Regional occurrence – Poland, the USB area, Borzęta Formation, boreholes: Borzęta IG 1 Rajbrot 1, Rajbrot 2, Wiśniowa IG 1, Wiśniowa 3, Wiśniowa 6, Chrząstowice RCh 6, Trojanowice, WB 137 and WB 141

Bio- and chronostratigraphic aspects - Simple, spherical specimens of the genus *Leiosphaeridia* or successive genera *Pterospermopsimorpha* and *Granomarginata*, dominant in the described assemblage, have been widely recognised in oldest Cambrian deposits (Moczydłowska, 1991; Jankauskas, Lendzion, 1992). The characteristic species

Pulvinosphaeridium antiquum has been established in the Lithuanian Lower Cambrian deposits (Lontova Formation) being correlated with the *Platysolenites* Zone. They contain representatives of *Leiovalia* and *Navifusa* that were also noted in the *BAMA I* association. Here documented specimens of the *Chuaria circularis* „megaspheromorphs" and genus *Tawuia* are known from the Lower Cambrian and Proterozoic. Within the latter, they often attain large sizes that allowed even for macroscopic observation (Vidal *et. al.*, 1993). *Ceratophyton* appears at the Precambrian-Cambrian boundary and ranges into the Early Cambrian.

The *BAMA I* assemblage is similar in its taxonomic composition to the *Granomarginata prima* Zone (Jankauskas, Lendzion, 1992), established in the *Platysolenites* Zone deposits in the north-western part of the East European Craton (Jankauskas, Lendzion, 1992; Jankauskas, 2002). In the present stratigraphical division of the Cambrian, the described zone corresponds to the Terreneuvian Series, which in turn is correlated with the *Platysolenites* Zone.

BAMA I assemblages from the successive members of the Borzęta Formation, have a similar generic and species composition. Detailed observations demonstrated only quantitative differences in occurrence of some taxa within individual profiles. For instance, the dominant component of the assemblages from the Wiśniowa 6 borehole samples are fragments of the filamentous *Cyanophyta*, whereas in the Wiśniowa IG 1 borehole, numerous specimens of the *Granomarginata* and *Pterospermopsimorpha* genera were found. On the other hand, in samples from the Rajbrot 2 borehole profile, quite numerous (from a few up to over a dozen specimens in a standard slide) morphologically differentiated specimens of the genus *Ceratophyton* have been encountered. However, the observed differences are not neccessarily related to evolutionary changes observable along the formation profile. They can also be explained by changing conditions of sedimentation. At the present stage of the investigation, it is impossible to distinguish between the respective evolutionary versus environmental controls.

***BAMA II - Asteridium tornatum - Comasphaeridium velvetum* Assemblage Zone**

Definition and boundaries – *Asteridium tornatum*, *A. lanatum* and *Comasphaeridium velvetum* are regarded as the index taxa of the described Zone in the Brunovistulicum area (Vavrdová *et al.*, 2003). These tiny sculptured forms appear for the first time in the studied Cambrian deposits, similarly to the representatives of genus *Lophosphaeridium*, which gives a distinctly „Cambrian character" to the microflora (Moczydłowska, 1991). In the Měnín 1 borehole the *BAMA II Asteridium tornatum - Comasphaeridium velvetum* Zone is bounded from the bottom and from the top by palynologically barren sediments correlated with *Scolithos* sandstones deposits of the Mogilany Member of the Goczałkowice Formation.

Description – The *Asteridium tornatum - Comasphaeridium velvetum* Assemblage Zone was established by Moczydłowska (1991). The base of this zone was defined at the first appearances of *Comasphaeridium agglutinatum*, *C. formosum*, *C. velvetum* and *Pterospermella velata.* This zone is characterized by appearance of 15 new species, including the nominal species *A. tornatum* and *C. velvetum*.

Regional occurrence – Czech Republic, Brno Block; Měnín 1 borehole (sample from the depth interval 1565,0–1566,5 m) (Vavrdová *et al.*, 2003). In this profile in sediments occurring below the above sample (4 samples from the depth interval 1804,6-2100 m) and above it (3 samples from the depth interval 1059-1300,2 m) organic microfossil assemblages designated as Ediacaran in age have been described (Vavrdová *et al.*, 2003; Vavrdová, 2006). According to the author of this paper described associations do not include any taxa allowing for a proper identification of their age. Therefore, for the purposes of this study they can be regarded as the age equivalent of the discussed zone, Lack of index associations in the section correlated with the Mogilany Member can be explained by depositional facies conditions (Pacześna, 2005; Mikulaš *et al.*, 2008).

Bio- and chronostratigraphic aspects – The recognised association is similar to the acritarch assemblages of the *Asteridium tornatum* - *Comasphaeridium velvetum* Zone (Moczydłowska, 1991; Vavrdová *et al.*, 2003; Vavrdová, 2006). This zone corresponds to the *Platysolenites* Zone in the south-western margin of the East European Craton (Moczydłowska, 1991). The discussed assemblage clearly differs from associations described above from the Borzęta Formation. In the study area the *BAMA II* assemblage occurs above BAMA I assemblage that was not found in the East European Craton area, and therefore the range of the BAMA II Zone correlatable with the *Asteridium tornatum* - *Comasphaeridium velvetum* Zone (Vavrdová *et al.*, 2003; Vavrdová, 2006) should be restricted to an upper part of the Terreneuvian.

***BAMA III* - *Ichnosphaera flexuosa* – *Comasphaeridium molliculum* Assemblage Zone – Acme Zone**

Definition and boundaries - The acritarch assemblages of the *BAMA III* Zone are defined by the domination of a new genus *Ichnosphaera*, which is represented by a few species in the discussed zone. This genus is characterised in the analysed sections by a short stratigraphic range and, therefore, is here regarded as an index form. The lower boundary of the zone is marked by its first appearance. In the stratotype Goczałkowice IG 1 section the *BAMA III* Zone is bounded from the bottom by palynologically barren sediments of the Mogilany Member and its upper boundary conforms with the base of the *BAMA IV* Zone.

Description – Besides the *Ichnosphaera* n.gen., the described zone is characterized by the first appearance of the new genus *Lechistania* whose stratigraphic range in the study area is limited to the desribed zone. The acritarch assemblages of the *BAMA III* Zone frequently include representatives of the genus *Comasphaeridium* with *C. agglutinatum*, *C. velvetum* and *C. molliculum* species, as well as specimens of *Pterospermella* with *P. gigantea* n.sp. Representatives of the genera *Asteridium*, *Globosphaeridium* or *Tasmanites* appear more sporadically. Besides the above mentioned forms, only single specimens of the characteristic Early Cambrian genera *Skiagia* and *Archeodiscina* were found in the studied assemblages.

Regional occurrence – Poland, the USB area, Goczałkowice Formation, Głogoczów Member, boreholes: Goczałkowice IG, Głogoczów IG 1, Klucze 1, Sułoszowa, Kozy MT 3, Kęty 8, Kęty 9, Andrychów 3, Piotrowice 1; Czech Republic, Brno Block, Měnín 1, borehole.

Bio- and chronostratigraphic aspects - The index form *Ichnosphaera* n.gen. has been distinguished earlier in other areas of the Cambrian occurrence (Volkova *et al.*, 1983; Moczydłowska, Vidal, 1986; 1988; Hagenfeldt, 1989a; Eklund, 1990; Brück, Vanguestaine, 2004). This taxon together with the new species is described in the palaeontological part. Numerous specimens of the *Ichnosphaera* n.gen. have been usually documented from the deposits correlated with the lower part of the trilobite-bearing Early Cambrian successions (Moczydłowska, Vidal, 1986; Moczydłowska, 2011), especially with the *Schmidtiellus* Zone, and with the lower part of the *Holmia* Zone (Volkova *et al.*, 1983; Moczydłowska, Vidal, 1986; Hagenfeldt, 1989a; Eklund, 1990; Moczydłowska, 1991; Moczydłowska, 2011). The appearance of these forms is well documented in the Lower Cambrian of Scandinavia (Moczydłowska, Vidal, 1986). They frequently occur in „Mickwiztia Sandstone" of central and southern Sweden, from which, among others, the typical species *Ichnosphaera flexuosa* n.comb. has been described (= *Elektoriskos flexuosus*) (Eklund, 1990). They are also known from the „Green Shale" Formation from Bornholm (Moczydłowska, Vidal, 1986), from Buen in northern Greenland, and from Bastion in southern Greenland (Moczydłowska, Vidal, 1986). So far, outside Scandinavia, this characteristic genus is represented, first of all, by the species *Ichnosphaera delicata* n.sp = *Comasphaeridium brachyspinosum* (Kirjanov, 1974) Moczydłowska &Vidal, 1988. It has been found in many areas, among others in the Cambrian of the East European Craton (Volkova *et al.*, 1983; Moczydłowska, 1991; Jankauskas, Lendzion, 1992, 1994; Jankauskas, 2002; Moczydłowska, 2011), and in the Siberian Platform

(Rudavskaya, Vassileva, 1984). A good example of the acritarch associations with numerous specimens of this species are those encountered recently in the Lükati Formation of Estonia (Moczydłowska, 2011), correlated with the *Schmidtiellus mickwitzi* Zone. Of 20 taxa documented there, 16 were documented in the *BAMA III* Zone. Recently, species *Ichnosphaera robusta* n.sp. (= *Elektoriskos flexuosus*) was described from the Cambrian of southern Ireland (Brück, Vanguestaine, 2004) correlated with the trilobite *Olenellus* Zone (Young *et al.*, 1994).

The acritarch assemblages from the above mentioned areas, containing *Ichnosphaera* n.gen., included first of all, representatives of such Early Cambrian taxa as *Asteridium tornatum*, *A. lanatum*, *A. pallium*, *Archeodiscina umbonulata*, *Comasphaeridium molliculum*, *C. strigosum*, *Globosphaeridium cerinum*, *Granomarginata squamacea*, *Lophosphaeridium*, *Leiosphaeridia* spp. and *Tasmanites bobrowskae*. Genus *Skiagia*, diagnostic for upper Early Cambrian levels, is rare and is represented by single specimens only. Assemblages with similar taxonomic content occur also north-east and east of the USB, i.e. in the Łysogóry Region of the Holy Cross Mountains (Szczepanik, 2009, 2010), as well as in the eastern part of the Małopolska Block (Jachowicz-Zdanowska, 2011b), where they are correlated also with the *Schmidtiellus* Zone deposits.

The stratigraphical range of *Ichnosphaera* n.gen. in the discussed acritarch assemblages is clearly connected mainly with the strata, which according to the new Cambrian subdivision (Peng, Babcock, 2008), should be correlated with the Stage 3 or the bottom of the Stage 4 (equivalents of the *Schmidtiellus* Zone or lower part of the *Holmia* Zone).

The majority of the *Ichnosphaera* n.gen. species from the USB is documented in the Głogoczów Member only. Single specimens of *Ichnosphaera delicata* n.sp. were encountered in samples from the upper members, although it cannot be excluded that they are reworked from older strata.

***BAMA IV – Skiagia - Eklundia campanula* Assemblage Zone**

Definition and boundaries - A characteristic attribute of the *BAMA IV* Zone assemblages is the mass appearance of the genus *Skiagia* representatives with the vesicle diameter usually not exceeding 20 μm (without processes). This taxon is represented here by a majority of known species. However, some of them, such as *S. ciliosa,* or *S. scottica*, appear in the analysed profiles for the first time. The lower boundary of the *BAMA IV* Zone corresponds to the upper boundary of the *BAMA III* Zone in the stratotype of the Goczałkowice Formation.

Description - Besides the genus *Skiagia*, the described zone is characterized by the first appearances of the genus *Eklundia* with *E. pusilla* n.sp., *E. campanula* n.comb. and *E. varia* n.comb. species. *E. varia* n.comb. is represented by single specimens while other forms, especially *E. campanula* n.comb., occur fairly abundantly, often in numbers exceeding 100 specimens in a standard microscopic slide. Representatives of other newly appearing species, *Pterospermella inordinata* n.sp., *Parmasphaeridium robustispinosum* n.sp., or *Pterospermopsimorpha rugulosa* n.sp. are also abundant (over 200 specimens per slide). The first two forms have been identified only in the described zone. Other accessory taxa include *Archeodiscina umbonulata*, *Heliosphaeridium dissimilare*, *Multiplicisphaeridium xianum*, *M. primarium*, *Estiastra minima*, *Alliumella baltica*, *Globus gossipinus*, *Retisphaerdium pusillatum*, *R. brayense*, *Comasphaeridium strigosum*, *C. spinosum*, *Sagatum priscum*, *Solisphaeridium elegans* and *Leiovalia tenera*.

Regional occurrence – Poland, the USB area, Pszczyna Member of the Goczałkowice Formation, boreholes: Goczałkowice IG 1, Klucze 1, Sułoszowa, and Piotrowice 1.

Bio- and chronostratigraphic aspects - The flourishing of the *Skiagia* species has been noticed in many Cambrian settings. According to the new Cambrian subdivision (Babcock *et al.*, 2005), the *BAMA IV* deposits are to be correlated with the interval comprising the upper part of the Stage 3 and Stage 4 (Volkova, 1968, 1969b; Hagenfeldt, 1989a; Moczydłowska,

1991; Jankauskas, Lendzion, 1992; Jankauskas, 2002). On the other hand, *E. varia* (*Baltisphaeridium*, *Goniosphaeridium*), represented in this part of the Pszczyna Member by single specimens, has been commonly encountered mainly in the deposits of the *Holmia* and *Protolenus* zones (Volkova, 1969a, b, Volkova *et al.*, 1979, 1983; Moczydłowska, 1988, 1991; Downie, 1982; Moczydłowska, Vidal, 1986; Vidal, Peel, 1988; Hagenfeldt, 1989a). A few specimens are also documented from the *Acadoparadoxides oelandicus* and *Paradoxides paradoxissimus* Zones (Volkova *et al.*, 1979, 1983).

The type species *E. campanula* n.comb. has been described so far from the sediments of the "glauconitic sandstone", recognized only in the Bårstad 2 borehole in the Östergötland region of southern Sweden, and initially correlated with the *?Acadoparadoxides oelandicus* level (Eklund, 1990). This form, similar to the new *E. pusilla* n.sp., occurs only in the studied Brunovistulicum area, in the lower part of the Pszczyna Member, whereas *E. varia* n.comb. ranges higher in this member.

In terms of the taxonomic content the acritarch associations of the *BAMA IV* Zone are close to the assemblages described from the lower part of the *Heliosphaeridium dissimilare* - *Skiagia ciliosa* Zone (Moczydłowska, 1991) and the *Baltisphaeridium cerinum* Zone of the *Baltisphaeridium cerinum* - *Skiagia ciliosa* assemblage (Jankauskas, Lendzion, 1992; Jankauskas, 2002). Assemblages of both above-mentioned acritarch zones have been described as taxonomically diverse associations, although lacking any distinct index forms. Stratigraphic ranges of a majority of taxa extend to older and younger trilobite-bearing Lower Cambrian deposits (Moczydłowska, 1991; Jankauskas, Lendzion, 1992, 1994; Jankauskas, 2002). However, it should be mentioned that several most abundant forms from the lower part of the Pszczyna Member, display stratigraphical ranges limited to the discussed part of the Cambrian in the USB. These are: *Parmasphaeridium robustispinosum* n.sp., *Eklundia campanula* n.comb., *E. pusilla* n.sp. and *Pterospermella inordinata* n.sp. Together with the characteristic *Skiagia* specimens of smaller diameters, they compose acritarch assemblage distinctly differing from the associations documented in the higher part of the Pszczyna Member, distinguished as the *BAMA V* Zone.

***BAMA V – Skiagia - Eklundia varia* Assemblage Zone**

Definition and boundaries - A characteristic feature of the described zone is the appearance of *Skiagia* specimens with much larger diameters than those encountered in the *BAMA IV* Zone (twice as much in some cases). All known *Skiagia* species except for *S. pura* or *S. brachyspinosa* n.comb. occur in this acritarch zone. Distinct large forms ascribed to *S. pilosiuscula* n. comb. make their first appearances here. New successively appearing components of the analysed associations are *Parmasphaeridium implicatum* n. comb., *Polygonium volkovae*, and *Eklundia florentinata* n.sp. The lower boundary of the *BAMA V* Zone corresponds to the upper boundary of the *BAMA IV* Zone in the stratotype Goczałkowice IG 1 section.

Description – Besides the forms mentioned above, the assemblages in question comprise a majority of taxa known from the *BAMA IV* Zone. None of these taxa can be regarded as dominant, as most of them are represented by over a dozen or several scores of specimens per slide. Certain forms, such as *Leiovalia tenera*, *Sagatum priscum*, *Retisphaeridium pusillatum*, *Alliumella baltica* or *Globus gossipinus* are represented by single specimens only.

Regional occurrence – Poland, the USB area, Goczałkowice Formation, Pszczyna Member, boreholes: Goczałkowice IG 1 and Klucze 1; Czech Republic, Brno Block, Měnín 1.

Bio- and chronostratigraphic aspects - The *BAMA V* Zone has the best faunal documentation of all the biostratigraphic units distinguished here. It has been documented, among others, in the upper part of the Cambrian in the Goczałkowice IG 1 section. Trilobites characteristic for the *Holmia* Zone have been discovered in this section in the depth interval 2793-2850,45 m (Orłowski, 1975).

Microfossil associations with a similar taxonomic composition are characteristic for the *Heliosphaeridium dissimilare* - *Skiagia ciliosa* (Moczydłowska, 1991) and *Estiastra minima* - *Micrhystridium dissimilare* acritarch zones (Jankauskas, Lendzion, 1992; Jankauskas, 2002). The zones were established as correlatives of the *Holmia* Zone and recognised in many areas of the East European Craton (Moczydłowska, 1991; Jankauskas, 2002), Scandinavia (Hadenfeldt, 1989a; Eklund, 1990), Scotland, Greenland, and Canada (Downie, 1982; Vidal, 1984), China (Zang, 1992; Moczydłowska, Zang, 2006) as well as in southern Australia (Moczydłowska, Zang, 2006).

In SE Poland, acritarch assemblages of this age have been also documented in the Stalowa Wola-Lubaczów area, in the Małopolska Block (Jachowicz-Zdanowska, 2011b) and in the Lublin area (Moczydłowska, 1991). Acritarch associations characteristic for the *Holmia* Zone have been distinguished in Poland also in the western part of the Peribaltic Syneclise (Szczepanik, 2000), and in the Kielce Region of the Holy Cross Mountains (Szczepanik, 2009).

***BAMA VI – Volkovia dentifera - Liepaina plana* Assemblage Zone (Moczydłowska, 1991)**

Definition and boundaries - According to Moczydłowska (1991) the index taxa of this zone are newly appearing species *L. plana*, *Heliosphaeridum notatum, V. dentifera and H. longum.* In the Brunovistulicum area the *BAMA VI* assemblage is characterised by first appearances of single *L. plana* specimens, and representatives of the still very controversial *V. dentifera.* The boundaries of the *BAMA VI* Zone with both underlying and overlying zones have not been documented in any of the borehole sections investigated by the present author. Thus, although overall position of the zone in the zonation seems correct the exact boundaries need to be confirmed by future studies.

Description – In addition to the index taxa the *BAMA VI* assemblages comprise taxa known from the lower acritarch zones of the study area.

Regional occurrence – Poland, the USB area, Goczałkowice Formation, Jarząbkowice Member, Jarząbkowice 1 borehole; Czech Republic, Brno Block, boreholes: Němčičky 3, Němčičky 6.

Bio- and chronostratigraphic aspects - The index taxa of the *BAMA VI* Zone have been found so far only in the Czech part of Brunovistulicum (Vavrdová, Bek, 2001; Mikuláš *et al.*, 2008). On their basis, the age of the analysed sediments has been determined as the *Protolenus* Zone (Mikuláš *et al.*, 2008). In the Jarząbkowice 1 borehole located in the USB area only poorly preserved acritarch specimens have been documented, with strongly thermally altered vesicles and considerably damaged sculpture elements. The assemblages from the analysed interval contain small number of complete forms belonging to *Skiagia scottica*, *S. orbiculare*, *S. ciliosa*, *Heliosphaeridium dissimilare*, *Estiastra minima*, *Pterospermopsimorpha rugulosa* n.sp., *Pterospermella* and *Retisphaeridium*. Generally, the taxonomic composition appears to be very close to the earlier described *BAMA V* Zone association, characteristic of the upper part of the Pszczyna Member, well dated by trilobites of the *Holmia* Zone. It should be remembered, however, that majority of these acritarch taxa range into the younger *Protolenus* Zone, and usually index forms for the latter appear infrequently (Jankauskas, 2002). It is also well known that *Volkovia* - *Liepaina* (Moczydłowska, 1991) or *Volkovia dentifera* (Jankauskas, Lendzion, 1992; Jankauskas, 2002) acritarch zones are generally characterised by a gradual disappearance of the forms known from older deposits as well as the absence of any new distinct taxa. Therefore, it is here assumed that the acritarch assemblages recognised in the fragmentary Cambrian sections from the Brno Block (Němčičky 3, Němčičky 6) and the Jarząbkowice 1 borehole from the Polish Brunovistulicum area are the youngest microfloral associations of the Cambrian Series 2 recognised in the studied area. They should be correlated with the *Volkovia* - *Liepaina*

(Moczydłowska, 1991) or *Volkovia dentifera* (Jankauskas, Lendzion, 1992; Jankauskas, 2002) zones distinguished in the *Protolenus* Zone.

***BAMA VII – Ammonidium bellulum - Ammonidium notatum* Assemblage Zone**

Definition and boundaries – The zonal assemblage is dominated by characteristic small specimens determined as *Ammonidium bellulum*, *A. notatum* n.comb., and *A. oligum* n.comb. Other components are abundant forms of *Heliosphaeridium longum* and *Granomarginata parva* n.sp. The above mentioned species are here regarded as the index forms of the described zone whose appearance defines the lower boundary of the zone. In the stratotype section of the Sosnowiec Formation *BAMA VII* Zone is bounded from the top by palynologically barren sediments.

Description - In addition to index forms, the described zone is characterised by fairly abundant specimens of *Asteridium tornatum*, *A. spinosum*, *Lophosphaeridium dubium*, *Eliasum llanisum*, *Retisphaeridium howelii* and *R. dichamerum*. The following less abundant forms may occur as single specimens: *C. strigosum*, *C. longispinosum*, *Cristallinium cambriense*, *Cymatiosphaera cramerii*, *Parmasphaeridium implicatum* n.comb., *Retisphaeridium postae* and *R . capsulatum*.

It should be pointed out that acritarch taxa recognised in the lower part of the Sosnowiec IG 1 borehole section are distinctly different from the microflora occurring in the Lower Cambrian of the USB. Similar assemblages appear in other areas at the bottom of the *Acadoparadoxides oelandicus* Zone, replacing Early Cambrian acritarch associations characterised by very abundant specimens of the *Skiagia* genus (Moczydłowska, 1999; see below).

Regional occurrence – Poland, the USB area, Sosnowiec Formation, Sosnowiec IG 1 borehole

Bio- and chronostratigraphic aspects – In the studied area the *BAMA VII* assemblage has been recognised so far only in the Sosnowiec IG 1 borehole, below the magmatic intrusion. Specimens of *Ammonidium bellulum* dominate in two samples from the bottom part of the profile (3423,8 m; 3415,6 m), whereas more frequent, in places even abundant *A. notatum* n.comb. representatives have been recognised in the upper part, in samples from the depth 3412,5 and 3402 m. *Ammonidium oligum* n.comb. is represented in the analysed slides only by single specimens.

A. notatum n.comb. and *A. oligum* n.comb. have been earlier known from the *Protolenus* Zone and they are abundant in the sediments of the *Acadoparadoxides oelandicus* Zone (Volkova *et al.*, 1979, 1983; Vanguestaine, Van Looy, 1983; Hagenfeldt, 1989a b; Moczydłowska, 1991, 1998, 1999; Jankauskas, Lendzion, 1992; Vidal, Peel, 1993; Jankauskas, 2002). *A. notatum* (=*Heliosphaeridum notatum*) is one of the index taxa of the *Micrhystridium notatum - Lophosphaeridium variabile* Zone (Jankauskas, Lendzion, 1992), corresponding to lower parts of the *Acadoparadoxides oelandicus* Zone in the East European Craton (Jankauskas, Lendzion, 1992; Jankauskas, 2002). It was also recognised in the Cambrian of southern Spain as an index taxon of the acritarch *Heliosphaeridium notatum* Zone (Palacios *et al.*, 2006), the age equivalent of the Baltic *Protolenus* Zone (Palacios *et al.*, 2006). *A. bellulum* was first described from the Cambrian of the Sosnowiec IG 1 borehole as the *Heliosphaeridium bellulum* (Moczydłowska, 1998). These deposits, lacking the faunal dating, have been correlated with the *Acadoparadoxides oelandicus* Zone, based on their acritarch assemblages (Moczydłowska, 1998). Specimens of *A. bellulum* were recognised earlier in other contemporaneous deposits, for instance in Lithuania, where they were named *Micrhystridium notatum* (Jankauskas, 2002), or in Morocco, where they were determined as *Micrhystridium* aff. *coniferum* (Vanguestaine, Van Looy, 1983 – Plate 1:16, 17).

Some of the above-mentioned taxa already appear in older deposits of the Cambrian Series 2. However, stratigraphical ranges of forms such as *Eliasum llaniscum*, *Cristallinium cambriense* or *C. longispinosum* can be correlated only with the Cambrian Series 3. On the

basis of their first appearance, a new acritarch zone *Eliasum* - *Cristallinium* was proposed by Moczydłowska (1999), including the interval of the *Acadoparadoxides oelandicus* Zone.

***BAMA VIII – Turrisphaeridium semireticulatum* Assemblage Zone – Acme Zone**

Definition and boundaries - The appearance of a very abundant population (acme zone) of the characteristic new genus *Turrisphaeridium* is the basis for distinguishing the *BAMA VIII* Zone.

Description - The described zone is also characterised by the first appearance of fairly abundant forms of *Comasphaeridium soniae* n.sp., *C. francinae* n.sp. or *Retisphaeridium lechistanium* n.sp. occuring together with the index genus represented by two basic morphological forms: *Turrisphaeridium semireticulatum* n.comb. and *T. turgidum* n.sp. In addition to the above mentioned forms also typical "Middle Cambrian" acritarch species occur in the studied assemblages: *Comasphaeridium vozmedianum*, *Cristallinium cambriense*, *Eliasum llaniscum*, *Multiplicisphaeridium martae*, *M. ramosum*, *Solisphaeridium flexipilosum* and *S. multiflexipilosum*. Besides, species with longer stratigraphical ranges may occur, for instance: *Asteridium spinosum*, *A. tornatum*, *Granomarginata squamacea*, *Lophosphaeridium dubium*, *Parmasphaeridium implicatum* n.comb., *Retisphaeridium capsulatum*, *R. dichamerum*, *R. howelii*, *R. ovillense* and *Revinotesta* sp.

Regional occurrence – Poland, the USB area, Sosnowiec Formation, Sosnowiec IG 1 borehole.

Bio- and chronostratigraphic aspects - Most of the species from the *BAMA VIII* Zone are characteristic of acritarch assemblages described from other areas of the Cambrian Series 3 occurrence, where they are correlated with the *Paradxides paradoxissimus* Zone (Slaviková, 1968; Cramer, del Cramer, 1972; Fombella, 1977, 1978, 1979, 1986; Erkmen, Bozdoğan, 1981; Martin, Dean, 1983, 1984; 1988; Jankauskas, Lendzion, 1992, 1994; Hagenfeldt, 1989b; Volkova, 1990; Palacios *et al.*, 2006; Palacios, 2008, 2010).

***BAMA IX – Adara alea - Multiplicisphaeridium llynense* Assemblage Zone – Acme Zone**

Definition and boundaries – The analyzed acritarch assemblage zone has been established on the basis of a massive appearance (acme zone) of genus *Adara* represented by *A. alea* and *A. undulata* species. *Multiplicisphaeridium llynense* n. comb. is here regarded as the additional index taxon in the zonal assemblage. In the stratotype section of the Sosnowiec Formation the *BAMA IX* Zone is limited from the top by the erosional boundary of the Cambrian overlain by Lower Devonian clastics.

Description - Accompanying taxa in the described assemblage are *Cristallinium compactum* n.sp and the *Eliasum asturicum*. Species appearing here for the first time are fairly abundant in the analysed material, usually over a dozen specimens per slide.

Regional occurrence – Poland, the USB area, the uppermost part of the Sosnowiec Formation in the Sosnowiec IG 1 borehole.

Bio- and chronostratigraphic aspects - The index form of the *Adara alea* acritarch zone (Martin, Dean, 1988) = *A1* (Martin, Dean, 1981, 1984) was established in the Cambrian deposits of Newfoundland characterized by very good faunal records (Martin, Dean, 1981, 1983, 1988). A type species of *Adara* genus *Adara matutina* (= *Buendisphaeridum matutinum*), as well as that of *A. undulata* (= *Celtiberium ondulatum*), was first recognized in the Middle Cambrian of the Oville Formation in northern Spain (Fombella, 1977, 1978). Known *Adara* species have fairly short stratigraphical ranges limited to the trilobite *Paradoxides paradoxissimus* Zone (Martin, Dean, 1981, 1983, 1988; Palacios, 2010).

Multiplicisphaeridium llynense was found in northern Wales in the lower part of the Nat-y-big Formation (Young *et al.*, 1994). It occurs in large numbers in deposits of the *Tomagnostus fissus* Zone well dated by trilobite fauna (Rushton, 1974; Young *et al.*, 1994). It co-occurs there with *A. alea* and with other species characteristic of the Cambrian Series 3: *Comasphaeridium longispinosum*, *Cristallinium cambriense*, *Eliasum llaniscum*, and

Comasphaeridum silesiense (= *Comasphaeridium* sp. sensu Young *et al.*, 1994). However, in that area, the earliest appearance of the *Multiplicisphaeridium llynense* was noted in the lower part of the *Tomagnostus fissus* Zone (Young *et al.*, 1994) followed by the *AI Adara alea* acritarch assemblage (Young *et al.*, 1994).

In conclusion, it should be pointed out that the taxonomic composition of the discussed zonal assemblage is very close to the associations of the *A. alea* Zone, established on the basis of the index taxon appearance. The stratigraphical position of this association is well defined based on the findings of the trilobite fauna and is correlated with the *Hypagnostus pavifrons – Ptychagnostus punctuosus* zones, established in the stratotype area of Newfoundland in the strata of the upper *Paradoxides paradoxissimus* Zone. It should be also remembered that wider stratigraphical range of *A. alea*, suggested by some authors (for instance, Moczydłowska, 1998), is not supported by palaeontological evidence. Detailed palynological studies carried out by the present author on samples from the Sosnowiec Formation Cambrian profile do not confirm presence of such taxa as *Timofeevia phosphoritica*, *T. lancarae* or *Cristallinium randomense,* that were assumed as indicating the Furongian or even Ordovician age of the discussed deposits (Moczydłowska, 1998).

In view of the new acritarch data obtained from the Sosnowiec IG 1 borehole, it can be assumed that the association of the *BAMA IX* Zone is the youngest Cambrian assemblage documented so far in the Brunovistulicum area.

SUMMARY OF THE RESULTS

The aim of this study was to describe the acritarch assemblages from the Cambrian of the Brunovistulicum area and to assess their value for the stratigraphical and correlative purposes. Recent palynological analyses have confirmed the corresponding age of the Early Cambrian sediments in the Upper Silesian and the Brno blocks (Buła *et al.*, 1997a; Jachowicz, Přichystal, 1997). During the deposition of the Goczałkowice Formation sediments in the USB, similar facies were also developing in the Brno Block, and both areas contain similar microfossil assemblages. Rich and morphologically diverse acritarch associations recognised in the studied deposits indicate conditions favourable for the development of marine phytoplankton in shelf environments.

Acritarch assemblages characteristic for the *BAMA I Pulvinosphaeridium antiquum - Pseudotasmanites* Zone were documented only in the Borzęta Formation sediments.According to the present stratigraphical division of the Cambrian System, the acritarch association distinguished in the above strata, correspond to the oldest, i.e. Terreneuvian series, correlated with the *Platysolenites* Zone.

The acritarch association of the successive *BAMA II Asteridium tornatum - Comasphaeridium velvetum* Zone has been identified so far only in the Brno Block (Vavrdová *et al.*, 2003). According to the present knowledge of the Cambrian deposits this zone constrains the biostratigraphic position of the sandstones and conglomerates complex distinguished as the Mogilany Member of the Goczałkowice Formation in the USB area (Buła, 2000). These sediments have variable thicknesses, from several tens to over 1200 m (boreholes Měnín 1, Głogoczów IG 1, and Mogilany 1; Buła *et al.*, 1997a; Buła, Żaba, 2005). In the Brno Block, their base is unknown and they are interpreted as continental (alluvial) facies with some marine influence (Mikulaš, Nehyba, 2000; Mikulaš *et al.*, 2008). The Mogilany Member developed under similar conditions in the USB area where alluvial-deltaic deposits grade upwards into marginal marine facies (Pacześna, Poprawa, 2001; Pacześna, 2005). In the south-western part of the USB they rest upon the Precambrian basement whereas in the eastern part they are underlain by the palynologically documented Borzęta Formation, attributed here to the *BAMA I* Zone.

The three younger acritarch Assemblage Zones – *BAMA III Ichnosphaera flexuosa – Comasphaeridium molliculum, BAMA IV Skiagia - E.campanula and BAMA V Skiagia - E.varia,* comprise deposits of *Schmidtielus - Holmia* trilobite zones in the studied area. In the USB, they have been best documented in the Goczałkowice IG 1 borehole where they occur in the Goczałkowice Formation. This unit, as the only one within the whole Brunovistulicum area, has a very good faunal documentation (Orłowski, 1975).

The microflora assemblages of the *BAMA VI Volkovia - Liepaina* Zone (Moczydłowska, 1991), correlated with the *Protolenus* Zone, have been recognized only in the partial Cambrian sections from the Brno Block (Němčičky 3, Němčičky 6), and the USB area (Jarząbkowice 1). It is thus assumed that the massive claystones of the Jarząbkowice Member, represent the youngest transgressive sediments of the Goczałkowice Formation, recognised in the USB area. However, the top of the Cambrian in the Goczałkowice IG 1 borehole does not contain the youngest microflora of the Cambrian Series 2 (*Protolenus* Zone), as suggested in previous study by Moczydłowska (1998).

A continuous transition between the Cambrian Series 2 and 3 has not been documented so far in the Brunovistulicum area. The partial profile of the Series 3 was indentified in the Sosnowiec IG 1 borehole where, however, the base of the Sosnowiec Formation was not reached. The acritarch assemblages of the *BAMA VII* to *BAMA IX* zones recognized in this borehole are correlated with *Acadoparadoxides oeladicus* and *Paradoxides paradoxissimus* Zones. Results of the author's investigations do not confirm appearance of the younger Cambrian, or even Ordovician acritarch associations in the Sosnowiec IG 1 borehole, suggested by Moczydłowska (1998). This conclusion is of a considerable importance for the correct reconstruction of the Early Palaeozoic sedimentation development in the USB area.

Equally important is the explanation of microfossils found by Moczydłowska (in: Kowalczewski *et al.*, 1984; Moczydłowska, 1998) in sandstones with trace fossils, encountered in the Potrójna IG 1 borehole below Devonian and above anchimetamorphic Precambrian rocks. On the basis of the discovered acritarch assemblages, the age of the above strata was determined as the Upper Cambrian or even Ordovician (Moczydłowska, 1998). However, the detailed palynological analyses of these deposits carried out by present author did not confirm the presence of any recognizable microfossil assemblages (Buła, Jachowicz, 1996). The Cambrian deposits encountered in Potrójna IG 1 and in over a dozen other boreholes in the southern part of the USB (Ślączka, 1976, 1982b; Buła, Jachowicz, 1996, Buła, Żaba, 2005, Pacześna, 2005; Jachowicz-Zdanowska, 2010) are attributed to the Lower Cambrian Mogilany Member which is generally devoid of microflora.

The biostratigraphical data collected by the present author from the Cambrian in 25 boreholes drilled in various parts of the Brunovistulicum allow for drawing some limited conclusions regarding the Cambrian depositional development of the investigated area. The present study indicates that the oldest Cambrian (Terreneuvian) sediments containing *BAMA I* Zone assemblages were deposited only in the eastern part of the Upper Silesian Block. Younger sediments, from the Terreneuvian and Series 2 with *BAMA II-VI* Zones assemblages were developing over much larger areas of the Upper Silesian and Brno blocks. Sediments of the Series 3 with *BAMA VII-IX* assemblages are known only from the northern part of the USB. The Furongian sediments, not yet found in the study area, potentially may occur in the northern part of the Block, where the Ordovician strata were found (Jachowicz, 2005). Nevertheless, a reliable reconstruction of the Early Palaeozoic deposition within the Brunovistulicum still remains an open question, which can be solved only by new borehole data.

The present study is so far the most comprehensive palynological analysis of the Cambrian from Brunovistulicum, based on a largest numer of studied borehole sections situated both in the USB area of Poland and in the Brno Block of Moravia in Czech Republic. Investigated

samples cover almost all lithostratigraphic units, except for a few palynologically barren intervals. The samples yielded rich collection of usually well preserved organic microfossils that allowed many important taxonomic, biostratigraphic and regional geological conclusions.

1. The systematic study of the collected palynological material allowed to make taxonomic revisions of previously analyzed acritarch associations. Five new genera and 19 new species and 11 species new combinations are described. The new and revised taxa include mainly those that appear in the Cambrian Series 2 and the forms characteristic for the Cambrian Series 3.
2. The most important new taxa of Series 2 include in particular *Ichnosphaera* n.gen., with the typical *Ichnosphaera flexuosa* (Eklund, 1990) n.comb. species, and other new and revised species: *Ichnosphaera robusta* n.sp, *I. aranea* n.sp., *I. delicata* n.sp. and *I. stipatica* (Hagenfeldt, 1989a) n.comb. Included into the new genus are acritarchs described as *Skiagia ornata* type 1 (Moczydłowska, Vidal, 1986) and later as *Elektoriscos flexuosus* (Eklund, 1990). *Ichnosphaera* n.gen. is a characteristic dominant component of the acritarch associations from the Głogoczów Member of the Goczałkowice Formation in the USB area. It is accompanied by specimens of *Lechistania* n.gen., with the type species *Lechistania magna* n.sp.
3. Another characteristic acritarch group, common in the Cambrian Series 2, comprises forms attributed to *Eklundia* n.gen. with the type species *Eklundia campanula* (Eklund, 1990) n.comb. This genus includes acritarch specimens earlier ascribed to various species of the genera *Baltisphaeridium*, *Multiplicisphaeridium*, *Goniosphaeridium* or *Polygonium*. Newly erected *Eklundia* n.gen. species, *E. pussilla* n.sp., *E. varia* n.comb. and *E. florentinata* n.sp. appear in a clear chronological succession in the Goczałkowice Formation deposits which supports their definition as separate taxa.
4. Several forms have their first appearances in the Cambrian Series 2 deposits of the studied area, including *Baltisphaeridium implicatum* (Fridrichsone, 1971), *Goniosphaeridium implicatum* (Fridrichsone) comb. nov. Downie 1982, *Polygonium implicatum* Sarjeant, Stancliffe, 1994 or *Solisphaeridium implicatum* (Fridrichsone) comb. nov. Moczydłowska 1998. These forms are included by the present author into *Parmasphaeridium* n.gen. Two species are distinguished within this genus: the typical *P. implicatum* (Fridrichsone, 1971) n.comb. and *P. robustispinosum* n.sp. The latter appears in the Cambrian Series 2 as the earliest representative of the discussed genus.
5. A new acritarch assemblage has been recognized in the Series 3 of the Sosnowiec Formation with the index genus *Turrisphaeridium* n.gen., represented by *T. semireticulatum* n.sp. and *T. turgidum* n.sp. Other new taxa from these strata include *Retisphaeridum lechistanium* n.sp., *A. oligum* (Jankauskas, 1976) n.comb., *Ammonidium notatum* (Volkova, 1969) n.comb. and *Multiplicisphaeridum llynense* (Martin, 1994) n.comb. species.
6. Analysis of a vertical distribution of studied microfossils allowed to establish a succession of nine acritarch assemblage zones, *BAMA I* to *BAMA IX*, correlated with the Lower to Middle Cambrian series: Terreneuvian, Series 2, and Series 3. The zones are partly separated by palynologically barren intervals.
7. The palynological subdivision proposed in this paper is more detailed then previous one and the identified acritarch assemblages are easily recognizable. Three assemblage zones are characteristic acme zones based on the dominant index forms of genus *Ichnosphaera* n.gen. (*BAMA III*, Series 2), *Turrisphaeridium* n.gen. (*BAMA VII*, Series 3) and *Adara* (*BAMA IX*, Series 3), respectively.
8. *BAMA I* and *II* acritarch associations, distinguished in the oldest Cambrian deposits of the Brunovistulicum, differing distinctly in terms of the genus and species content of their microfossil assemblages, are to be correlated with the *Platysolenites* Zone, in the basal part of the Cambrian system. The obtained results require distinguishing at least two microfloristic

assemblages in the Cambrian deposits of this horizon in the Brunovistulicum. The older one occurs in the Borzęta Formation in the eastern margin of the USB (Buła, Jachowicz, 1996; Buła, 2000). The *BAMA II* Zone was encountered so far only in the Měnín 1 borehole in the Brno Block (Vavrdová *et al.*, 2003). The zone was originally established as the *Asteridium tornatum - Comasphaeridium velvetum* Zone by Moczydłowska (1991) and was redefined for the purposes of the present study.

9. The *BAMA III-VI* zones, correlated here with the Series 2 are recognized in the Goczałkowice Formation of both the Upper Silesian and Brno blocks. The *BAMA VI* Zone is known so far only from fragmentary Cambrian sections and its boundaries with under- and overlying zones are not known.

10. The *BAMA III* assemblages, characterised by a dominance of weakly sculptured taxa *Comasphaeridium*, *Asteridium* and *Ichnosphaera* n.gen. are here correlated with the *Schmidtiellus* Zone, and the lower part of the *Holmia* Zone. Similar assemblages are documented from comparable lithology and facies in the Moravian Měnín 1 borehole.

11. The *BAMA IV* and *BAMA V* Zones, correlated with the upper part of the *Holmia* Zone of the Series 2 assemblages, were distinguished in the Pszczyna Member of the Goczałkowice Formation and are traced in other sections of the USB and in the Měnín 1 borehole (Brno Block).

12. The *BAMA VI* Zone is the equivalent of the *Protolenus* Zone of the uppermost part of the Series 2 and is established in fragmentary Cambrian sections of the Brno Block (Mikulaš *et al.*, 2008). These are correlated with the Jarząbkowice 1 section (USB) comprising the uppermost member of the Goczałkowice Formation (Buła, Żaba, 2005).

13. The *BAMA VII* to *BAMA IX* zones are correlated with the Series 3 of the Middle Cambrian, and were established in the Sosnowiec Formation known only from the Sosnowiec IG 1 borehole in the USB area (Buła, Jachowicz, 1996; Buła, 2000). The *BAMA VII* Zone is here correlated with the trilobite *Acadoparadoxides oelandicus* Zone, while *BAMA VIII* and *BAMA IX* Zones are regarded as equivalents of the *Paradoxides paradoxissimus* Zone. The key to above interpretations is the occurrence of the index species *Adara alea*, whose well-documented stratigraphic range is limited to the upper part of the *P. paradoxissimus* level (Martin, Dean, 1988). Thus, the Furongian to Ordovician age of the uppermost Lower Palaeozoic strata in the Sosnowiec IG 1, suggested earlier by Moczydłowska (1998), is not confirmed by the present study.

14. Stratigraphic distribution of the acritarch assemblages from the Cambrian of the Brunovistulicum well reflects the evolution of this group. The investigated material clearly demonstrates gradual changes in a generic composition of the assemblages, which are dominated in the Early Cambrian by *Asteridium* (*Platysolenites* Zone), *Comasphaeridium* (*Schmidtiellus* Zone), and *Skiagia* (*Holmia* Zone), and subsequently, in Series 3, by *Ammonidium bellulum*, *A. notatum* n.comb., *Turrisphaeridium* n.gen. and *Adara*.

d) Other scientific and research achievements.

SELECTED ACADEMIC ACHIEVEMENTS

Below are selected research achievements summarized in peer-reviewed scientific publications and reports as well as made-to-order expert's reports.

My professional career began during my student times at the Faculty of Earth Sciences, University of Silesia, in the Department of Paleontology and Stratigraphy as an employee in a group of engineering-technical workers. At that time, I was responsible for the preparation, protection and replenishment of teaching materials for the courses of palaeobotany,

micropalaeobotany and micropalaeontology. After being granted the master's degree in geology, I led classes on micropalaeobotany, palaeobotany, coal petrography and palaeontological practicum.

In 1991, I was granted the doctor's degree in natural sciences in the field of geology, submitting the thesis on "The occurrence of acritarchs in Upper Permian deposits of Poland".

In 1992, I participated in the "Tempus" scholarship program and took research trainings at the British Geological Survey, Nottingham, and the Palynological Research Center at the University of Sheffield, where I was studying Old Palaeozoic microflora. At that time I became a member of the international team of palynologists that studied Palaeozoic deposits from selected wells of Saudi Arabia. The results of the research were published in the *Review of Palaeontology and Palynology*.

Since 1993, I have been employed at the Polish Geological Institute-National Research Institute. I have introduced modern methods of rock maceration into the institute's micropalaeontological laboratory, which I learnt in the UK. In many cases, it enabled to acquire determinable microflora from rocks that were considered palaeontologically barren.

From the beginning of my research work, I have primarily dealt with palynology and stratigraphy of the Lower Paleozoic. The subject of my research is mainly microfossils of the Acritarcha group, their taxonomic diversity, state of preservation and degree of thermal alterations. The research has resulted in the determinations of age of basement rocks in many boreholes with no reliable palaeontological evidence. The results of my research on Silurian, Ordovician, Cambrian and Precambrian microflora in Poland are summarized the literature presented below. I also presented them at national and international scientific conferences. I am a leading performer and participant in research projects on Palaeozoic and Precambrian deposits in the area of Silesia, Małopolska and Pomerania. I run joint research projects on Palaeozoic deposits with geologists from the Czech Republic, Slovakia, Romania, Ukraine and the USA.

SELECTED ACADEMIC ACHIEVEMENTS

Below are selected research achievements summarized in peer-reviewed scientific publications and reports as well as made-to-order expert's reports.

1. Acritarch assemblages from the Silurian Pomeranian Caledonides and their foreland. *Geological Quarterly*, 44: 317-331.

This paper shows the results of recent palynologic research on the Silurian lithologies of Pomerania which have been carried out in the frame of the studies on Pomerania Caledonides and their foreland. Complex palynologic investigations of Silurian sediments in this area have been carried out for the first time; the exception is A. Eisenack's (1972) work. The

project have included the investigations of 250 samples of clastic rocks which came from deep boreholes. Three of the boreholes studied (Lębork IG1, Gdańsk IG1 and Kościerzyna IG1) are located NE of the TTZ and contain horizontally occurring sediments of western, marginal part of Eastern-European Platform. Other samples came from the boreholes (Bydgoszcz IG1, Klosnowo IG1 and Stobno 1) which contain folded Lower Palaeozoic sediments. These occur SE of the TTZ.

The investigations included a complete profile of Silurian, from Llandovery to Přidoli, which is documented in detail by graptolites. Associations of flora microfossils (*Acritarcha, Prasinophyceae, Sporites*) and fauna microfossils (*Chitinozoa, Scolecedonta*) different in terms of quality and quantity were found. Considerable differences were observed in preservation and the intensity of thermal alteration of the obtained organic microfossils. This paper discusses the detailed results of the investigations on *Acritarcha* microfossils. Based on the number and range of more important genera and species, 7 typical acritarch assemblages have been distinguished in this area. They were then correlated with the distinguished here graptolite horizons.

In the Llandovery sediments, the assemblage with *Domasia, Ammonidium* and *Tylotopalla* genera were documented. In the Wenlock sediments, the presence of *Tylotopalla, Leptobrachion* and *Cymbosphaeridium* genera was determined. The Upper Ludlow sediments contain well preserved assemblages with *Visbysphaera, Veryhachium, Ondondagella* and *Leoniella.* They are accompanied by *Neoveryhachium carmine, Geron gracillis*, some *Deflandrastrum* and *Visbysphaera* species generally more characteristic of the Gondwanan areas. In the whole Silurian profile, individual specimens of typical Ordovician genera, such as *Acanthodiacrodium, Frankea, Striatotheca* and *Coryphidium*, occur. Acritarch assemblages recognised in the Silurian sediments of the area studied show mixed character with Baltica and Gondwana areas.

Palaeoecology

Acritarchs occur mostly in marine sediments. They have been determined in shales, siltstone, claystone and also in limestone. They are abundant in fine-grained rocks. Their wide geographical expansion together with their small dimensions suggests their planktonic life. Their morphology, chemical composition, and the occurence of distinctive opening in many taxa suggest that many forms belonging to this group represent cysts analogous to *Dinoflagellata* or other planktonic algae. With reference to modern ecosystem, they are considered to represent phytoplankton associated with photic zone of the basin which produces large amount of organic matter and oxygen (H. Tappan 1980). Acritarch morphology is commonly interpreted as their adaptation to living conditions of deep sea and the best exploitation of photic zone. The system of well developed outgrowths, which allowed the organisms to preserve in water column, was very helpful.

Expansion of phytoplankton depends on many factors, such as temperature, salinity, intensity of light penetration and water turbulence in the basin.

The results of the hitherto investigations show that quantitative and qualitative differentiation depends on the environment sedimentation and this organisms show significant relationship with certain facies. Acritarchs, similarly to dinocysts, are more differentiated in shelf deposits located far from the shore. This differentiation significantly decreases in a deep water (D. Wall et al., 1977). F.L. Staplin (1961) was the first to associate differentiated acritarch associations with depth changes. Basing on quantitative and qualitative analysis of the obtained associations, K.J. Dorning (1981) considered that it is possible to determine features of the sea basin (distance to the shore and directly also the depth). He distinguished three acritarch associations in the Silurian of southern Wales according to the increasing depth and distance to the shore. Offshore association shows small differentiation (50-15 species) in the samples and it is dominated by small spherical

forms with smooth surface and short thorns. The second acritarch association is associated with deeper, open shelf. This association shows large differentiation (10-90 species in a sample), without a predominated taxon. The third association of deep water is less differentiated (2-5 species in a sample). Representatives of *Sphaeromorphitae* subgroup predominate here. They have thick walls which, according to some authors, may suggest high energy of the basin (F. Martin 1993).

Detailed analysis of microfloral material obtained in the Silurian profiles studied has revealed distinctive differentiation of the nature of the documented associations. The associations of the Lowest Silurian (Rhuddanian and Aeronian) are poorly diversified with predominance of simple spherical *Leiosphaeridia* with thick walls. They are accompanied by scarce spinose acritarchs. Such composition of the obtained associations suggests deep-water nature of the sediments.

Rich and taxonomically differentiated associations determined in Telychian, Ludfordian and Přidoli sediments are typical for the area of offshore shelf.

Palaeogeography

The period from Proterozoic to Devonian is an optimum of acritarch occurrence. The largest number of genera is associated with Cambrian, Ordovician, Silurian and Devonian marine deposits. In geographical terms, acritarch associations show mainly cosmopolitan nature which makes it possible to correlate sediments of far removed areas. For some time, however, many authors have suggested limited range of occurrence of some taxons and they attempted to use them in Lower Palaeozoic palaeogeographic reconstructions. The models by M. Vardová (1974) and F.H. Cramer & M.del C.R. Díez (1972) are the basic.

M. Vavrdová was the first to observe in 1974 distinctive geographical differentiation of acritarch associations in Lower Ordovician sediments in Europe. She suggested, basing on generic differences of the associations, determination of two provinces called Mediterranean and Baltic.

In the beginning of the 70s, F.H. Cramer (1970) and F.H. Cramer & M.del C.R. Díez de Cramer (1972) revealed distinctive geographical differentiation of acritarch associations in Silurian sediments. They assumed that each organism had its own maximal, optimal and minimal "living temperature". Basing on the data of Silurian occurrence of acritarch associations, they classified subequatorial zones, assuming that the location of the proposed zones is determined mainly by the climate.

In the light of new data, geographical differentiation of Lower Palaeozoic *Acritarcha* associations is widely discussed (A.C. Nautiyal 1976, 1977; P.J. Hill, S.G.Molyneux, 1988; G.K.Colbath, 1990) and proposed models have been revired (Le Hérissé 1989, A. Le Hérissé & R. Gourvennec, 1992). The differences of composition of acritarch associations of the same age are more and more interpreted as facies preferences of the individual taxons.

The data obtained during investigations of Silurian sediments in Pomerania reveal new information concerning the distribution of some Silurian acritarch taxons. Most of the form determined here shows cosmopolitan nature. The genera and species determined in continuous profiles of Silurian are known not only from Baltic area but also from northern Africa and South America. These are accompanied by the taxons which so far have been considered to show limited occurrence. For example, such species as *Domasia amphora, Tylotopalla pyramidalis* and *Dilatisphaera willieреae* have been determined in the area studied; earlier, these were known only from the areas of low latitudes. Also numerous specimens of *Geron gracilis, Deflandrastrum millepiedii, Neoveryhachium carmine, Hemibaltisphaeridium*, some *Visbysphaera* species have been documented; earlier, these were known only from the areas of high latitudes. Surprisingly, any specimens of typical Baltic genera such as *Hoegklintia* or *Pulvinosphaeridium* have been determined in the

samples studied. This may be associated with gaps in sampling of such thick Silurian profiles.

It should be emphasised that the Silurian sediments studied contain also typical Ordovician taxons such as *Acanthodiacrodium, Frankea, Striatotheca, Baltisphaerosum* and *Coryphidium* on secondary deposit. These are known from Lower Ordovician and represent main element of associations in Mediterranean Province as proposed by M. Vavrdová (1974). Very good preservation of the specimens of Ordovician *Acritarcha* should be emphasised. This suggests their short transport.

Preservation and intensity of thermal alteration of microflora

The obtained acritarch assemblages differ from each other not only in terms of their generic and specific composition. Also clear differences in the preservation of microfossils and intensity of thermal alteration of their organic substance can be observed in the Silurian profiles studied. It is generally known that organic substance changes its colour due to thermal transformations from light yellow, to orange, brown and black. Basing on the colour of palinomorphs, thermal conditions which influenced the rock in geological past, may be determined.

Distinctive differences in the intensity of carbonification of the organic matter in individual sections of the profiles have been observed.

Microfossils associations determined in *crispus* horizon of Llandovery sediments show the most intensive thermal metamorphosis. Their dark brown, sometimes even black colour suggests the temperature of about 200°C. Similar thermal conditions show microfossils determined in other horizons of Llandovery, Wenlock and Lower Ludfordian. Their brown and dark brown colour suggests the temperature of about 150-180°C.

A distinctive change of microfossils preservation occurs in Upper Ludfordian sediments. It is observed for the first time in the associations of *balticus* horizon. The specimens from this zone are very well preserved and do not show considerable changes of the organic matter. Their light brown and orange colour suggests temperature of about 100-150°C. Such an intensity of thermal alteration continues to the roof of the Silurian profiles studied.

These changes of intensity of thermal alteration of the organic substance observed in Silurian sediments in Gdańsk IG1, Kościerzyna IG1 and Lębork IG1 are probably associated with changes of subsidence rate during their sedimentation or with their multi-stages heating.

Acritarch associations determined in the Silurian deposits of western Pomerania show a compound nature; the genera and species determined here are known both from Baltica and Gondwana areas. The nature of these associations is not sufficient to univocal determination of their palaeogeographical position. Microfloristic data obtained from the Silurian sediments recognised in the area of Eastern European Platform and TESZ zone, show the presence of cosmopolitan associations.

2. Ordovician acritarchs from the Upper Silesian Block. *Przegląd Geologiczny*, 53: 756-762.

Lower Palaeozoic sediments of the Upper Silesian Block are not evenly investigated. Lower Cambrian sediments found in the southern and eastern marginal parts are so far best recognized. Sediments younger than Lower Cambrian (Middle Cambrian and Ordovician) are documented only in some boreholes. This paper presents new data about the distribution of Ordovician acritarch assemblages in this area. Ordovician microfossils were documented in three boreholes: 45-WB, 43-WB and 24-WB. In case of the latter, they represent the first stratigraphic record. The oldest assemblages of Llanvirn age were recorded in the borehole 43-WB. The Llanvirn and Caradoc sediments may also occur in the borehole 24-WB.

Acritarchs known mainly from Middle Ordovician – Caradoc occur in the profile 45-WB. The microfossil assemblages recorded in Ordovician sediments of the Upper Silesian Block show mixed character. The presence of genera and species typical for both Baltic province and Mediterranean province were recognized here.

3. Cambrian organic microfossils at the border area of the East – and West – European platforms (SE Poland and Western Ukraine). *Annales Societatis Geologorum Poloniae*, 81: 241–267.

The main aim of this paper was to summaries the results of the palynological investigations of Cambrian from Stalowa Wola – Lubaczów area in Poland, and to compare them with similar information obtained from boreholes drilled in Ukraine. At the same time, the published Ukrainian stratigraphic data have been verified with the use of new palynological information (Drygant, 2000).

The analysed area, covering south-eastern Poland and western Ukraine, is located within the Trans-European Tectonic Suture Zone (TESZ), which extends along the south-western edge of the East European craton. It constitutes a boundary between the old Precambrian craton at the East, and the West European Palaeozoic platform, consolidated during the multiple diastrophic processes (Mizerski & Stupka, 2005).Within that area, the Precambrian and Palaeozoic (from Cambrian to Carboniferous) rocks are covered tightly by younger sediments, of the Carpathian flysh and the Carpathian Foredeep, between others. They have been recognised due to numerous boreholes.

Precambrian and Palaeozoic rocks recognised in that area have been included into the following tectonic units: the Małopolska and Łysogóry-Radomsko Blocks within the territory of Poland, and the Leżajsk massif, and Kochanów and Rava Ruska zones within Ukraine (Buła & Habryn, 2011). Those units are usually regarded as fragments of the Palaeozoic European platform (Mizerski & Stupka, 2005). The Małopolska Block is regarded as a passive part of the East European craton (Żelaźniewicz *et al.,* 2009). It is usually being connected, together with some other tectonic units, with terranes group of the Teisseyre-Tornquist Zone (the Teisseyre-Tornquist Terrane Assemblage TTA) (Nawrocki & Poprawa, 2006; Żelaźniewicz *et al.,* 2009).

As for the areas adjacent to the investigated region, the Cambrian clastic sediments were well recognised in the Holy Cross Mountains area, and in the Lublin-Podlasie Slope of the East European Platform. However, no sediments of that system have been found in the western part of the Małopolska Block.

For many years, there were disputes on the age of the sediments occurring in the south-eastern Poland, in the Outer Carpathian Mountains and the Carpathian Foredeep basement. There had been commonly agreed that basement is built mainly of the Precambrian phyllite schists, and of Cambrian sediments of a rather unclear stratigraphic position (Karnkowski & Głowacki, 1961).

For the purpose of the presented here studies, palynological material has been collected from the boreholes located in the Stalowa Wola–Lubaczów area, where below the Jurassic or Miocene sediments clastic rocks have been encountered, there, without any organic remnants that would allow for defining their age. The first palynological investigations of that rocks have been carried out by Jagielska (1962). Results of more detailed acritarchs investigations of the Miocene basement in the eastern part of the Carpathian foreland have been presented in Głowacki *et al.,* (1963) paper. There has been presented the first subdivision of those Palaeozoic sediments, based on the recovered microflora assemblages. Unfortunately, difficult to verify taxonomic determinations methods, used during the 1960-ties, as well as the incomplete photographic records of the investigated associations, have made impossible to use them nowadays for stratigraphic analyses. On the

other hand, in the Ryszkowa Wola 3a borehole, located in the discussed area, presence of the determinable assemblages of Cambrian acritarchs have been recognised (Pożaryski *et al.*, 1981). Lower Cambrian sediments documented in that borehole have been correlated with the *Holmia* beds from the Holy Cross Mountains. Based on the palynological investigations, carried out on the fragmentary cores from few boreholes located SW of the Lubaczów elevation, Dziadzio and Jachowicz (1996) proved that the basement of the Carpathian Foredeepcis built there by Lower Cambrian rocks, and not by Precambrian rocks, as it was believed formerly (Karnkowski & Głowacki, 1961).

The systematic palynological investigations, carried out by the author of this paper, have brought many new information on the occurrence and extension of the Precambrian and Lower Palaeozoic rocks in Poland. Those investigations have been commissioned by Polish Oil & Gas Company (PGNiG). The so far obtained results of the stratigraphic investigations have been partly published by the author as well as by Polish Oil & Gas Company (PGNiG). specialists (Jachowicz & Moryc, 1995; Dziadzio & Jachowicz, 1996; Moryc & Jachowicz, 2000, Dziadzio & Probulski, 1997; Kowalska *et al.*, 2000; Maksym *et al.*, 2003).

The obtained stratigraphic data, presented in the mentioned above papers and the unpublished report (Jachowicz *et al.*, 2002), have been taken into consideration in geological model construction of the Precambrian and Palaeozoic rocks from south-eastern Poland, in the Outer Carpathian Mountains and Carpathian Foredeep basement (Buła & Habryn, (eds.), 2008).

Results of the stratigraphic palynological investigations, carried out in over 40 boreholes drilled in an area covering south-eastern Poland and western Ukraine, are presented in this paper. In that area, in numerous boreholes drilled mainly by the oil industry enterprises of both countries, Precambrian and Palaeozoic rocks have been encountered in the basement of the north-eastern part of the Carpathian Foredeep, and of the Outer Carpathian margin. This paper contains palynological and stratigraphic characteristics of the chosen Cambrian profiles encountered in the investigated area. The verified stratigraphic position of the rocks recognized so far in several profiles, in western Ukraine, as Cambrian, is also presented. Based on various assemblages of the organic microfossils belonging to the *Acritarcha* group, parts of the Lower, Middle, and Upper Cambrian sections, encountered by boreholes in the Stalowa Wola – Lubaczów area, as well as fragments of the Lower and Upper Cambrian sections, encountered in various boreholes in western Ukraine area, have also been described and evidenced.

Within the Lower Cambrian rocks appear acritarch assemblages dominated by species of the characteristic Lower Cambrian *Skiagia* genus. Middle Cambrian has been documented on the base of the assemblages with numerous specimens of the *Adara alea*, *Cristallinium cambriense*, *Heliosphaeridium notatum*, *Eliasum llaniscum*, *Multiplicisphaeridium martae,* and *Comasphaeridium longispinosum*. Upper Cambrian (Furongian) sediments were evidenced by strongly taxonomically diversified micro-floristic assemblages with acritarchs appearing in large quantities, containing *Timofeevia*, *Vulcanisphaera*, *Ninadiacrodium*, *Pirea*, *Leiofusa*, *Lusatia*, or *Polygonium* genera, as well as taxa characterized by diacrodial symmetry. Those taxa were dominated by such genera as: *Dasydiacrodium* or *Acanthodiacrodium*, and also by specimens with large polar opening of the central body, belonging to acritarchs of the galeate group. Within the studied Cambrian sediments, nine acritarch assemblages with different genera and species have been distinguished as the result of the palynological investigations. Those assemblages have been correlated with faunistic horizons. Further on, the younger than Palaeozoic age of the studied profiles from Ukraine area has been defined on the base of rich and very well preserved spores and pollen assemblages.

4. Organic microfossil assemblages from the Ediacaran rocks of the Małopolska Block, southeastern Poland. Geological Quarterly, 55: 85-94.

The results of palynological investigations of the oldest siliciclastic sediments recognized on the Małopolska Block, situated in the south-eastern Poland, within the Trans-European Tectonic Suture Zone (TESZ), are summarized in this paper. Rock samples collected from 12 boreholes, were analysed for palynology. Detailed analyses of the siliciclastic rocks of flysch type have recognized microflora assemblages that proved to be Late Ediacaran in age.

The siliciclastic sediments, devoid of macrofossils, have been encountered in over 1000 boreholes within the Małopolska Block below Palaeozoic, Mesozoic, and Cenozoic sediments of various age (from Ordovician up to Miocene). The boreholes, where the collected rock samples contained recognizable assemblages of the Late Ediacaran microfossil forms, are located in various parts of the Małopolska Block, between Kraków vicinity to the West, up to Leżajsk-Przemyśl area to the East. In the analysed profiles variously preserved assemblages of the organic microfossils have been encountered. The recovered associations are dominated by small spherical forms, without any ornamentation, belonging first to *Leiosphaeridia* species, and by straight or coiled thread-like specimens representing fragments of fossil cyanobacteria algae. Similar microflora assemblages, with poorly differentiated species and genera, were characteristic for the Late Ediacaran sediments.

The detailed quantitative and qualitative analyses of the recovered assemblages allowed to determine the two characteristic microflora associations occurring in the Małopolska Block basement.

The first association occurs in four boreholes: Okulice 2 borehole, in the Kraków region, and Zalasowa 1, Stawiska 1, and Radlna 2 boreholes, to the South of Tarnów. The microflora recognised in the profiles of those boreholes is characterised by domination of the thread-like cyanophyta, with very rare *Leiosphaeridia* specimens. A single specimens of *Eoentophsalis* sp. occurred. The specimens were accompanied by numerous, sometime fairly large fragments of amorphous organic matter.

The second association occurs in the remaining eigth profiles. That assemblage is characterized by high content of the small *Leiosphaeridia* species specimens, which are accompanied by straight fragments of the cyanophyta and individual forms of Granomarginata prima, wherein the investigated rocks complex is characterized by low contribution of the organic matter.

Because the analyzed rocks complex has a very large thickness, the differentiated microflora assemblages, recognized within the Małopolska Block area, may represent various sections of its profile. However, at the present stage of the investigations, it is impossible to reconstruct their vertical succession because of the too small amount of the available data.

The results of the palynological investigations, carried out on the flysch siliciclastic rocks of the dozen or so boreholes from the Małopolska Block area, suggested the Late Ediacaran age of those rocks. That has been confirmed by the earlier mentioned age dating of the zircons from a tuffite intercalation of the pre-Ordovician rocks from the Książ Wielki IG 1 borehole, The dating carried out with the use of the U-Pb method has suggested the age as 549±3 MA, it means the Late Ediacaran time (Compston *et al.*, 1995).

5. Made-to-order studies of Palaeozoic deposits

A significant element of my research on the Palaeozoic deposits of Poland is expert's reports and scientific studies commissioned by exploration companies, carried out mainly on

the orders of the Polish Oil and Gas Company. The development of a huge body of research materials, conducted over many years, has provided the opportunity to learn the range and the succession of microflora in Lower Palaeozoic deposits of southern Poland, its facies-dependent variations and the degree of thermal alterations of sediments.

The research has provided plenty of new data on the occurrence and extent of Precambrian and Palaeozoic rocks in southern Poland. The results of stratigraphic studies have been partially published in co-authored papers with specialists of the Polish Oil and Gas Company (Jachowicz & Moryc, 1995, Grandpa & Jachowicz, 1996; Moryc & Jachowicz, 2000), and they are also presented in the publications of some specialists from that company (Grandpa & Probulski, 1997; Kowalska et al., 2000; Maksym et al., 2003). The stratigraphic data presented in these papers and in an archival study (Jachowicz et al., 2002) were used for the construction of a model of the geological structure of Precambrian and Palaeozoic deposits of the basement of the Outer Carpathians and the Carpathian Foredeep in south-eastern Poland (Buła & Habryn (eds.), 2008).

6. Resumé

In summary, my research and didactic achievements include:

- Peer-reviewed papers published in English in the following periodicals: *Bulletin - Geological Survey of Canada, Review of Palaeobotany and Palynology, Acta Universitatis Carolinae-Geology, Studia Geologica Polonica, Geological Magazine, Bulletin of Geosciences, Terra Nostra, Geological Quarterly* and *Annales Societatis Geologorum Poloniae;*

Two of my publications were awarded for the best publication in 2011 – the paper entitled.... was awarded by the Director of PGI-NRI for the best publication in the Geological Quarterly, and the publication entitled "Cambrian organic microfossils at the border area of the East - and West - European platforms (SE Poland and Western Ukraine)" won the Ludwik Zejszner award for the best publication of *Annales Societatis Geologorum Poloniae*.

- Peer-reviewed papers published in Polish in the following journals: *Kwartalnik Geologiczny, Prace Naukowe Uniwersytetu Śląskiego, Przegląd Geologiczny, Biuletyn Państwowego Instytutu Geologicznego, Prace Państwowego Instytutu Geologicznego*;
- Authorship of more than 140 studies and made-to-order reports prepared for entities performing concessions granted for hydrocarbon exploration in Poland and national entities performing geological operations abroad;
- Chapter authorship in a science textbook;

- Chapter authorship in the Atlas of Fossils and co-authorship of the Atlas and Stratigraphic Table;

- Co-authorship of the exhibition scenario The Cambrian – in the Museum of the Polish Geological Institute-National Research Institute in Warsaw;

- Membership of editorial boards of Biuletyn Państwowego Instytutu Geologicznego and Prace Państwowego Instytutu Geologicznego.

As the chief of the Palynological Laboratory at the Upper Silesian Branch of PGI-NRI, I have also reorganized the laboratory that is specialized in the preparation of rocks for the content of microflora.

I was a leader and a performer of research projects financed by the Ministry of Science and Higher Education, as well as an author of annual and final reports.

I was a tutor of master's degree trainings and a reviewer of master's theses of students at the University of Silesia and the Silesian University of Technology. I also reviewed some publications for journals, such as: *Geological Quarterly, Bulletin of Geosciences, Geology Carpathica, Annales Societatis Geologorum Poloniae, Przegląd Geologiczny* and *Biuletyn Państwowego Instytutu Geologicznego.*

The results of my research were presented mainly in the form of presentations, sometimes of posters, at the following national conferences: PGS Congress in 1994, The role of palynological research in petroleum geology – the future and the past. Scientific and Technical Conference, Wysowa, 1998, PGS Congress in 2005, XX Conference of Palaeontologists and Stratigraphers PGS - 2007; I Geological Congress, Kraków, 2008; Precambrian and Palaeozoic of the Krakow region – a model of the geological structure - its utilitarian aspect, Kraków 2010; and at international conferences, such as : EUROPROBE, Książ, 1996; Česke Tektonice Skupiny, Ostrava, 1997, CIMP - Prague 1994, Pisa 1998, Prague 2006, Lisbon 2007, Faro 2009, Warsaw, 2010; Join Meeting EUROPROBE TESZ, TIMPEBAR, URALIDES & SW-IBERIA Project, Ankara, 2001; European Union of Geosciences EUG 9, EUG 11 in Strasbourg; 5th European Paleobotanical and Palynological Conference, Kraków 1998; Geological Congress, Florence, 2004, and 9th International Geological Congress, Oslo, 2008; 9th Czech-Polish-Slovak Palaeontological Conference, Warsaw 2008, 42th AASP Meeting, Kingsport, Tennessee; 8th European Palaeobotany - Palynology Conference, Budapest, 2010; International Palaeontological Congress, London, 2010; Geological and hydrogeological studies on the Polish-Ukrainian border - Lviv, 2012; 2th Alpine-Petrol Conference, Kraków , 2012.

My presentation entitled *Precambrian and Lower Paleozoic palynology of the Carpathian foredeep basement - Malopolska block (southern Poland)* at the 42th AASP (The American Association of Stratigraphic Palynologists) Annual Meeting was awarded as the best presentation of the conference.

As a member of the Organizing Committee, secretary, tour leader and editor of the conference proceedings, I organized the following national and international conferences: PGS Congress 1994, PGS Congress 2005, X Conference Pleistocene stratigraphy of Poland - Rudy-2003, CIMP – 2010, Scientific Conference: Precambrian and Palaeozoic of the Kraków region – a model of the geological structure - its utilitarian aspect, Kraków, November 19, 2010. Presently, I am a member of the Organizing Committee of the next PGS Congress "The challenges of the geology of the Upper Silesian region in the 21st century", Ustroń, 2013.

SCOPUS citation index 250, Hirsch index according to Web of Science 7, according to SCOPUS database 9.

7. Future research

I am currently a member of the teams performing tasks of the State Geological Survey, e.g. a project entitled "A drilling program of the State Geological Survey of PGI-NRI - drilling exploration of unexplored Precambrian and Lower Palaeozoic sections in the north-eastern part of the Upper Silesian Block and their economic potential" that started in 2013. In this team, I am responsible for stratigraphic studies of Lower Palaeozoic deposits. I am also the leader of the project that aims at developing a detailed stratigraphic calibration for the Silurian of northern Poland based on the varied organic microfossil assemblages of the Acritarcha group and correlating the results with the graptolite zones well documented in this area. The resulting zonation will find wide application in Palaeozoic stratigraphic studies. The identified acritarch zones will be a reference for the results of palynological studies carried out within the framework of shale gas exploration in the Silurian formations of Pomerania.

I am continuing my palynological studies for domestic and foreign entities pursuing concessions granted to explore the hydrocarbon potential in Poland and abroad. In this summary of my professional accomplishments it is not possible to determine more precisely the area and scope of this research due to the confidentiality clause in contracts.