

CARBONIFEROUS AND PERMIAN PALYNOLOGY IN POLAND – A REVIEW

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Nearly sixty years have elapsed since the beginning of the regular palynological investigations on the latest Palaeozoic rocks in Poland. They were pioneered by J. Zerndt who started publishing on Carboniferous megaspores in the late nineteen-twenties.

The varying scope of palynological studies, the progress in the extraction techniques and the growing possibilities of obtaining palynological samples divide this time interval into three periods.

The first period, between 1928 and 1955, is characterised by intensive studies on Carboniferous megaspores derived mainly from the coal seams of the Upper Silesian Coal Basin. The dispersed megaspores were studied by J. Zerndt (1928–1940) while fructifications of some Carboniferous lepidophytes and their spores were investigated by T. Bocheński (1934–1955). The impact of those early works on the present day megaspore taxonomy and Carboniferous spore stratigraphy can not be denied.

In the second period, between 1956 and 1975, the palynological studies of the Carboniferous deposits of Poland were carried on a much larger scale than before. The megaspore study was being continued and expanded and the miospore palynology was extended beyond the coal into a greater diversity of rock types. Also the area of palynological investigations was broadened to include the subsurface Carboniferous deposits from various areas of Poland and especially from the Lublin Coal Basin. The most important results of taxonomic and stratigraphic studies on megaspores, published in this period, are contained in the papers by M. Brzozowska (1960–1969), S. Dybova (1958–1960), A. Jachowicz (1960–1972), J. Karczewska (1967), H. Kmieciak and S. Knafel (1973–1975), S. Knafel (1966), H. Krawczyńska-Grocholska (1966) and Z. Żoldani (1960–1966).

Significant miospora data based on new materials collected in various parts of Poland are presented in the works by S. Dybova and A. Jachowicz (1956–1975), A. Jachowicz (1960–1975), T. Górecka (1961–1975),

J. Karczewska (1967), J. Karczewska and E. Turnau (1974), H. Kmieciak (1975), H. Krawczyńska-Grocholska (1966), K. Kruszevska (1963–1969) and E. Turnau (1970).

Some important monographic studies on taxonomy and morphology of selected megaspore, miospore and pollen genera and species (*Setosisporites*, *Valvisporites*, *Zonalesporites*, *Tripartites*, *Rotaspora*, *Diatomozonotriletes* and *Schulzospora*) were also published in this period. Some of those works in which several taxons, the new ones including, were described and illustrated, and in which spore based stratigraphical schemes for the Carboniferous of the Lower and the Upper Silesian Coal Basins and the Lublin Basin were proposed furnished the present basis of palynostratigraphy of the Carboniferous in Poland. In the late nineteen-sixties and in early nineteen-seventies, the stratigraphic and taxonomic papers on Lower Carboniferous spores from non-coal rocks from the Holy Cross Mts. and other areas of Poland were published. The expansion of palynology to include studies on Permian palynofloras and Devonian spores and acritarchs also took place in this period.

The results of the palynological studies of the third period, between 1976 and 1986, influencing directly the present state of the Carboniferous and Permian palynology in Poland, are dealt with in detail hereafter. Generally speaking, these studies resulted in the establishing of the stratigraphic schemes for the complete profile of the Carboniferous and a part of the Permian. They also concern the important problems of the Devonian/Carboniferous, Carboniferous/Permian and Permian/Triassic boundaries and correlations of the spore zones used in Poland with those of other parts of Europe and with some stratotype profiles.

CARBONIFEROUS

The most recent spore investigations on the Carboniferous deposits in Poland are carried on by the use of

various methods and for different purposes. They concern the deposits of various parts of the country belonging to the Dinantian and the Silesian starting from the Famennian/Tournaisian boundary up to that between the Stephanian and the Autunian.

Megaspore studies. A marked progress has been made in the field of the morphology and taxonomy of selected taxonomic groups of megaspores. The beginning of these studies was marked by the papers by J. Karczewska (27, 28). This line was later being continued by the international working group of CIMP including the following palynologists: S. Dybova, A. Jachowicz, J. Karczewska, G. Lachkar, S. Loboziak, P. Pierart, E. Turnau and Z. Żoldani (6, 7, 8, 11, 12). As the result of the working group activities, major taxonomic revisions of zonate megaspores (*Radiatisporites*, *Zonalesporites*, *Rotatisporites*) and those with gula (*Lagenicula*, *Lagenosporites*, *Crassilagenicula*, *Auritolagenicula*) were made. Such morphological terms as the hologula, crassigula and anguligula were defined and more than forty species were revised and described. The maximum stratigraphic ranges of those, basing on the data from Europe, Africa and America (Poland, Czechoslovakia, USSR, France, Belgium, Holland, Germany, Spain, Great Britain, Tchad and USA) were established. Recently, the group is working on the megaspore based zonal scheme for the upper Dinantian and the Silesian of the Euramerican province, and especially of Europe.

Those taxonomic revisions of the Carboniferous megaspore taxa were based in a great part on the spore collections from Poland. These contained some original specimens collected by J. Zerndt and new materials from the Upper Silesian Coal Basin and the Lublin Coal Basin. These materials are also of great importance for the present studies on the megaspore based subdivision of the Carboniferous in Europe and other areas.

The most recent stratigraphic studies based on megaspores are represented by the work by S. Knafel and Z. Żoldani (40) on the succession of megaspore assemblages in the Namurian A of the north-eastern part of the Upper Silesian Coal Basin. These authors distinguished three megaspore zones in the Flora and the Grodziec beds. This confirms the usefulness of megaspores in stratigraphic correlation and in identification of the individual coal seams.

Miospore studies. The miospore studies of the last ten years concern a wide stratigraphic profile of the Carboniferous including also the Lower Carboniferous. The latter deposits have been made accessible owing to numerous deep boreholes drilled west and south-west of the margin of the East European Platform (Western Pomerania, the regions of Bydgoszcz, Płock and Warsaw, the Lublin Coal Basin).

An important contribution to the Lower Carboniferous palynology has been made by E. Turnau (44, 45, 46, 47). This author distinguished in the uppermost Devonian and Lower Carboniferous deposits of Western Pomerania a few miospore zones useful for regional and interregional correlation. The zones of the Tournaisian are: Lu – *Grandispora lupata* Zone, Ra – *Tumulispora rarituberculata* Zone, Ma – *Convolutispora major* Zone and Cl – *Prolycospora claytonii* Zone. The latter zone spans the Tournaisian/Visean boundary. The Visean zones are: Pu – *Lycospora pusilla* Zone, Ca – *Schulzospora campyloptera* Zone, and Pa – *Dictyotriletes pacillis* Zone. The papers mentioned contain also descriptions of several miospore species and of the new genus *Prolycospora*. The palynology of the Devonian/Carboniferous boundary in the southern

part of the Holy Cross Mts was also discussed by this author (47). The papers by E. Turnau furnished the basis for the stratigraphic subdivision of the Dinantian in Poland and its correlation with other areas of Europe.

The numerous publications by H. Kmiecik, and by H. Kmiecik et al. (30–39, 49), concern the palynology of the Carboniferous deposits at the margin of the East European Platform. In the paper synthesizing the earlier studies (35) this author defined one Dinantian spore zone, the Ds – *Diatomozonotriletes setosus* Zone of the uppermost Visean, and ten zones for the Silesian. These are: Tr – *Tripartites rugosus* and Chp – *Chaetosphaerites pollensimilis* Zones (Namurian A), Rc – *Reticulatisporites carnosus* Zone (Namurian B), Gv – *Grumosisporites varioreticulatus* Zone (Namurian C), Lspp – *Lycospora punctatopusilla* Zone (lowermost Westphalian A), Ra – *Radiizonates aligerens* Zone (upper Westphalian A), Eg – *Endosporites globiformis* Zone and Ts – *Triquirites sculptilis* Zone (Westphalian B), Vf – *Vestispora fenestrata* Zone (Westphalian C) and Pg – *Punctatosporites granifer* Zone (Westphalian D). All these zones are correlated with those of Western Europe.

In the discussed period, intensive palynological studies were carried on also in other regions of Poland, in the Lower Silesia and within the Foresudetic monocline. The results of these investigations which were concentrated on the uppermost Carboniferous and lowermost Permian deposits are contained in the papers by S. Dybova-Jachowicz (5), S. Dybova-Jachowicz and J. Jerzykiewicz (10), T. Górecka (13–17), J. Jerzykiewicz (26) and H. Krawczyńska-Grocholska (41, 42). These papers give the palynological characteristic of the particular units of the Stephanian and define the equivalents of the standard spore zones: *Potnieisporites novicus-bhardwajii* – *Cheiledonites major* and *Disaccites striatiti*, furnishing new information on the Carboniferous/Permian boundary in Poland. The miospore investigations in those areas often provide the only stratigraphic information on the deposits discovered in various deep boreholes.

It is worth noting, that most of the recent miospore investigations of various units of the Carboniferous in Poland are based on non-coal material which involves modification of laboratory techniques, and processing and analysing a great number of diverse rock samples.

Some results of palynological investigations of the Carboniferous in Poland were presented at various international conferences and congresses. Synthetic or comparative papers written with foreign co-authors were also published. Some of these are: G. Clayton et al. (1), S. Dybova-Jachowicz et al. (12), A. Jachowicz (21, 22), J. Jerzykiewicz (26), H. Kmiecik (34) and S. Loboziak et al. (43).

Other investigations. The use of palynological methods in conjunction with some other ones for purposes other than stratigraphy has found its expression in the papers by H. Kmiecik and S. Knafel (36) on the processes and conditions of coal development exemplified by the coal seams of the Anticlinal Beds from the Upper Silesian Coal Basin. These authors presented the vertical distribution of different miospore and megaspore taxa in the terms of succession of the parent plants. By the use of statistic and palyno-petrographical interpretation of the results, telematic, terrestrial and limnic biofacies have been distinguished. The relation of these to the natural succession of plant assemblages of the Carboniferous pit-bogs has been explained in connection with the general pattern of peat formation by S. Kulczyński. The paper discussed is a good

example of possibilities connected with broad interpretation of palynological and petrographical studies of coal.

Information on Carboniferous acritarchs. The palynological studies on Carboniferous deposits provided also data on uni-cellular algae found in paralic and marine deposits. E. Turnau (46) described some species of *Micrhystridium* and *Gorgonisphaeridium* from Tournaisian deposits of Western Pomerania, A. Jachowicz (22) reported on the occurrence in the Lower Carboniferous of the Holy Cross Mountains of acritarchs belonging to *Leiosphaeridia*, *Micrhystridium* and *Baltisphaeridium* and of those related probably to prasinophycean algae (*Tasmanites* and *Cavatisporites*).

PERMIAN

The palynological investigations of the Permian deposits in Poland, which started in the early nineteen-seventies, were concentrated on the following main problems: 1) the occurrence of microflora in continental deposits and palynostratigraphy of the Rotliegendes and the problem of the Carboniferous/Permian boundary; 2) palynostratigraphy of the Zechstein and the problem of the Permian/Triassic boundary; 3) the application of acritarchs in palynostratigraphy and palaeogeography of the Permian. Records on occurrence of spores and pollen grains from various types of rock derived from Lower Permian deposits of different parts of Poland (mainly from the Lower Silesia), and discussion on their stratigraphical application are contained in papers by S. Dybova-Jachowicz (2-5, 10), T. Górecka (14, 15) and J. Jerzykiewicz (26). More than one hundred and fifty species of spores and pollen grains have been recorded hitherto from the deposits at the Carboniferous/Permian boundary. This enabled to distinguish spore assemblages corresponding to the standard spore zones of France: ST (Stephanian B), NBM (Stephanian CD), VS (Lower Autunian) and DS (upper Autunian). These assemblages are also correlatable with those of the substages C_3^2 (upper Casimovian - Lower Gzhelian), C_3^3 (Gzhelian), P_1^{nik} and P_1^{st} (upper Asselian) of the Donetz Basin. This furnished the basis for their wider stratigraphic correlation with various parts of Europe.

Some more important results of palynological investigations of the Zechstein deposits are presented in works by S. Dybova-Jachowicz (2, 4). They indicate that it is possible to distinguish in the Upper Permian sequences of the Polish sedimentary basin the lineage subzones of the *Lueckisporites virkkiae* Zone. In this way it is possible to distinguish the subzones Aa and Ab (the cyclothemes PZ1 and PZ2), Ac (the cyclothemes PZ3 and PZ4) and Bc (cyclothemes PZ4b, PZ4c and the uppermost part of the supraevaporite series). The extinction of *Lueckisporites* and *Vittatina* is taken as palynological criterion of the upper boundary of Upper Permian.

Information on occurrence of rich and diversified assemblages of acritarchs is contained in papers by S. S. Dybova-Jachowicz (2, 3), S. Dybova-Jachowicz and L. Jagielska (9), and M. Jachowicz (24, 25). The best recognised assemblages of acritarchs are those from the Zechstein limestone (Ca1) of the Holy Cross Mountains and those from the copper shale (T1) from northern Poland. More than thirty species of acritarchs belonging to *Leiosphaeridia*, *Baltisphaeridium*, *Micrhystridium*, *Veryhachium* and *Wilsonastrum*, and some *Tasmanites* belonging to *Prasinophyceae* were described and illustrated from these deposits. These preliminary studies on Permian acritarchs suggest that these microfossils can be useful for distinguish-

ing the Lower and Upper Permian deposits. Some horizons of mass occurrence of acritarchs may facilitate local and regional correlations.

CONCLUDING REMARKS

This brief and general account of the Permian and Carboniferous palynology in Poland shows that the studies of the last ten years have brought the results which are important for palaeobotany, stratigraphy, palaeogeography and geology. First to be mentioned is the stratigraphic subdivision of the whole Carboniferous, from the Famennian/Tournaisian to the Stephanian/Autunian boundaries, and of a part of the Permian up to the Rotliegendes/Zechstein boundary.

The intensity of the palynological studies on the Carboniferous and Permian deposits in Poland is not represented in the whole extent by the papers published during the last decade as many detailed and extensive works have been completed in the form of manuscripts for archives only. These may be used as the basis for studies on taxonomy or morphology of selected spore or pollen grain taxons and for broad interpretation of palynological results in various aspects.

It has been shown here that the Carboniferous and Permian palynology in Poland is at present concerned with various plant microfossils such as megaspores, isospores, microspores, pollen grains, and also acritarchs and other unicellular algae. It is thus possible to study rock bodies of various origin, formed in marine or continental conditions, which may provide the basis for new palaeobotanical and geological interpretation.

Translated by Elżbieta Turnau

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STRESZCZENIE

W okresie ostatnich 10 lat badania palinologiczne utworów karbonu i permu w Polsce przyniosły wiele nowych rezultatów, znacznemu poszerzeniu uległ także ich zakres metodyczny, taksonomiczny i stratygraficzny.

W badaniach nad megasporami karbońskimi, dzięki długoletniej pracy międzynarodowej grupy roboczej CIMP dokonano postępu taksonomicznego w wyniku przeprowadzonej rewizji grup, rodzajów i gatunków megaspor z koroną i gulą, uściślono również ich maksymalne zasięgi stratygraficzne w Europie i na innych obszarach. Prowadzone były również prace nad precyzowaniem stref zmian megasporowych w dolnonamurskiej części profilu karbonu produktywnego w Górnośląskim Zagłębiu Węglowym.

Miosporowe badania utworów karbonu miały w głównej mierze charakter stratygraficzny i prowadzone były również poza obszarami karbońskich zagłębi węglowych. Po raz pierwszy uzyskano podstawowe informacje palinologiczne dla całego profilu karbońskiego, od granicy dewon—karbon, przez wszystkie ogniwa dinantu i sylezu, od granicy karbon—perm włącznie. Dzięki wydzieleniu i scharakteryzowaniu kilkunastu ton miosporowych uzyskano lepsze podstawy zarówno dla korelacji między poszczególnymi regionami, jak i nawiązania do zon standardowych w zachodniej Europie.

Badania megasporowe i miosporowe w połączeniu z badaniami petrograficzno-węglowymi znalazły nowe zastosowanie w próbie określenia genezy karbońskich pokładów węgla, następstwa węglotwórczych zespołów roślinnych oraz interpretacji ekologicznej.

Przy okazji prowadzenia badań miosporowych dla najstarszych bezwęglowych utworów dinantu na Pomorzu i w obszarze Gór Świętokrzyskich uzyskano także interesujące informacje o występowaniu akritarch i innych glonów jednokomórkowych.

Rozpoczęte na początku lat siedemdziesiątych systematyczne badania utworów permских objęły przede wszystkim studia nad występowaniem mikroflory terestrycznej i palinostratygrafią czerwonego spągowca, mikroflorystycznym podziałem stratygraficznym profilu cechsztynu oraz możliwością wykorzystania akritarch permских dla celów korelacyjnych i paleogeograficznych.

W efekcie tych badań wydzielono i scharakteryzowano po raz pierwszy polskie ekwiwalenty niektórych stefanских i autunских зон sporowo-pyłkowych standardowego profilu francuskiego, porównano je również z odpowiednimi zespołami najwyższego karbonu i najniższego permu z Zagłębia Donieckiego.

Szczegółowe badania palinologiczne profilu cechsztyńskiego doprowadziły do określenia w poszczególnych cyklotemach kilku podzon opartych na palinodemach *Lueckisporites virkkiae*, dobrze korelujących się w różnych regionach i porównywalnych z innymi obszarami Europy; uzyskano również nowe dane dla precyzyjniejszego wyznaczenia granicy permu i triasu.

W utworach cechsztyńskich, częściowo także w utworach wyższego czerwonego spągowca, stwierdzono także zjawis-

ko występowania charakterystycznych poziomów liczniejszego nagromadzenia akritarch należących do różnych podgrup i rodzajów; mogą one stanowić podstawę dla uzupełnień danych palinostratygraficznych, korelacji regionalnej oraz formułowania niektórych wniosków paleogeograficznych.

РЕЗЮМЕ

За последние десять лет палинологические исследования карбоновых и пермских отложений в Польше дали ряд новых результатов, значительно расширился также их методический, таксономический и стратиграфический объём.

В исследовании карбоновых megаспор, благодаря многолетним работам рабочей группы ЦИМП, был достигнут таксономический прогресс, в результате проведенной ревизии групп, родов и видов megаспор с короной и шишкой, уточнены также их максимальные стратиграфические дальности в Европе и на других территориях. Были также проведены работы по уточнению зон megаспоровых изменений в нижнеамурской части разреза продуктивного карбона в Верхне-Силезском угольном бассейне.

Миоспоровые исследования карбоновых отложений имели главным образом стратиграфический характер и проводились также вне карбоновых угольных бассейнов. Впервые были получены основные палинологические информации для всего карбонового разреза, от границы девон—карбон через все звенья динанта и силеза, до границы карбон—перм (включительно). Благодаря выделению и схарактеризованию более десяти миоспоровых зон были получены лучшие основы как для корреляции между отдельными регионами, так и для установления связи со стандартными зонами в западной Европе.

Мегаспоровые и миоспоровые исследования вместе с петрографическими угольными исследованиями были применены для попытки определения генезиса карбоновых угольных пластов, последовательности углеобразующих комплексов растений, а также для экологической интерпретации.

При ведении миоспоровых исследований для самых древних безугольных отложений динанта на Поморье и в Свентокшиских горах были получены интересные информации касающиеся распространения акритарх и других одноклеточных водорослей.

В начале семидесятых годов были начаты систематические исследования пермских отложений. Исследованиям подвергались: распространение терестрической микрофлоры, палиностратиграфия красного лежа, микрофлористическое стратиграфическое деление разреза цехштейна, а также возможности применения пермских акритарх для коррелятивных и палеогеографических целей.

В эффекте этих исследований были выделены и впервые схарактеризованы польские эквиваленты некоторых stefанских и autunских споровопыльцевых зон стандартного французского разреза, а также проведено их сравнение с соответствующими комплексами самого верхнего карбона и самого нижнего перма из Донецкого бассейна.

Детальные палинологические исследования цехштейнового разреза привели к определению в отдельных циклотеммах нескольких подзон основанных на