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THE STUDIES ON STRATIGRAPHY OF THE CARBONIFEROUS IN POLAND

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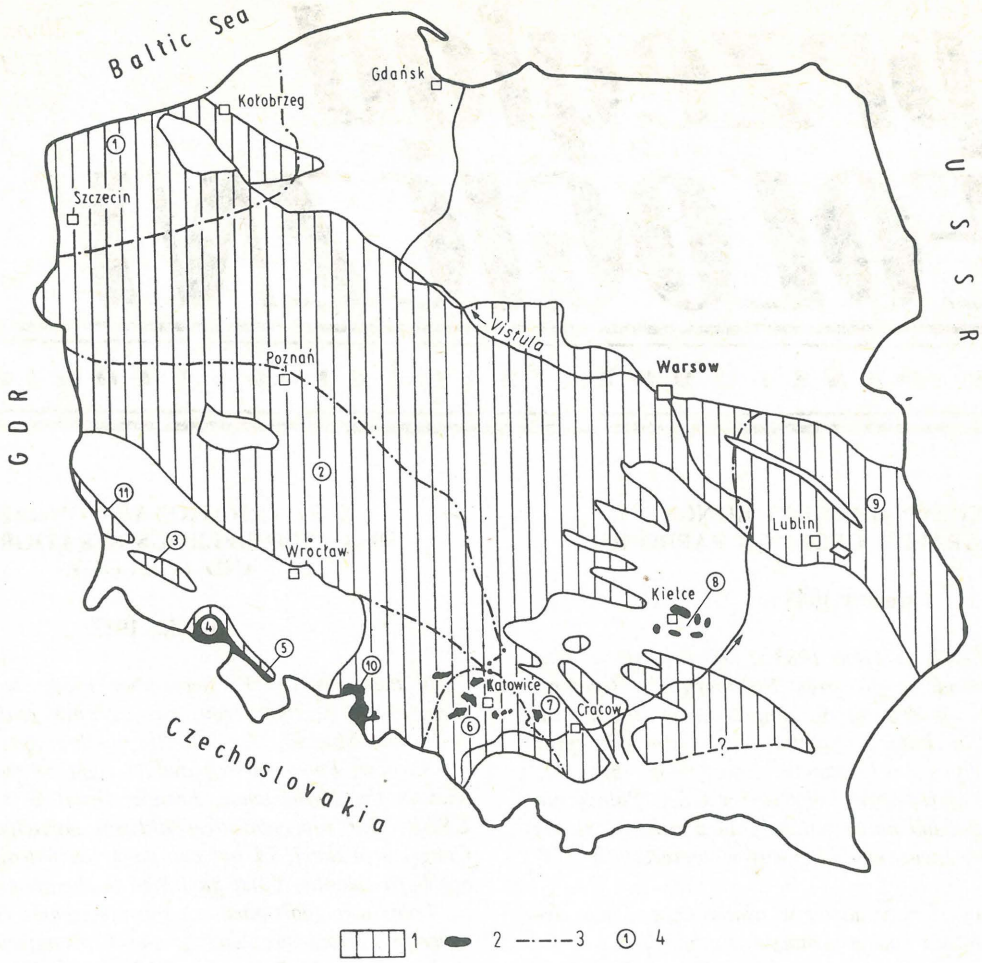
In Poland, Carboniferous strata are present in about 42% of area. They are overlain by a cover of younger ones, ranging from some meters to kilometers in thickness and their innumerous outcrops are known in the Holy Cross Mts, the Dębnik area near Cracow, Upper Silesian Coal Basin, eastern Sudety Mts, Middle Sudetic Depression and Bardo and Kaczawa structures in the Sudetes (Fig.).

Stratigraphic subdivision of the Carboniferous is based on bio- and lithostratigraphic data. Biostratigraphic subdivision has been established using the available macrofaunistic record and also microfloristic, macrofloristic and microfaunistic data. The order in which they are listed reflects importance of these groups for biostratigraphy of the Carboniferous but it should be noted that



Występowanie osadów karbonu w Polsce

1 – występowanie osadów karbonu pod pokrywą osadów młodszych, 2 – odsłonięcia karbonu, 3 – granice jednostek geograficznych lub tektonicznych, 4 – numeracja jednostek: 1 – Pomorze Zachodnie, 2 – monoklina przedsudecka, 3 – struktura kaczawska, 4 – depresja środkowosudecka, 5 – struktura bardzka, 6 – Górnośląskie Zagłębie Węglowe, 7 – okolice Dębnika, 8 – Góry Świętokrzyskie, 9 – Lubelskie Zagłębie Węglowe, 10 – Sudety Wschodnie, 11 – depresja północnosudecka.

Distribution of the Carboniferous in Poland.

1 – Carboniferous rocks beneath cover of younger ones, 2 – outcrops of Carboniferous rocks, 3 – boundaries of geographic or tectonic units, 4 – numbers of units: 1 – western Pomerania, 2 – Fore-Sudetic Monocline, 3 – Kaczawa structure, 4 – Middle-Sudetic Depression, 5 – Bardo structure, 6 – Upper Silesian Coal Basin, 7 – Dębnik area, 8 – Holy Cross Mts, 9 – Lublin Coal Basin, 10 – eastern Sudety Mts, 11 – North-Sudetic Depression.

the importance is locally varying, depending on preservation and frequency of occurrence of the material.

Microfloristic studies (megaspore and miospore analyses) mainly cover coal-bearing sequences but they are also widely used in dating core material of the Carboniferous. It should be noted here that miospore analyses appear more effective than the megaspore.

Lithostratigraphic subdivision of Carboniferous strata comprises both formal and informal units. The latter include traditional names, especially deep-rooted in coal mining, as well as those proposed at early stage of studies on lithostratigraphic succession (local subdivisions). The term beds as used here corresponds to member, and series – to formation.

Stratigraphic studies carried out in the last thirty years were mainly concentrated on coal-bearing Carboniferous strata but much attention has been also paid to the remaining ones. The studies have been carried out in the Geological Institute, Warsaw, and its regional branches and, on smaller scale, Institute of Earth Sciences of Polish Academy of Sciences, Jagiellonian University and Academy of Mining and Metallurgy in Cracow, A. Mickiewicz University in Poznań, B. Bierut University in Wrocław, Warsaw University and, in the last years also in the Wrocław Polytechnical Institute.

The studies made it possible to gather a vast amount of new data of basic importance for revision of the hitherto proposed stratigraphic subdivision, more accurate datings and proposals of new units.

DINANTIAN

The available data show that Dinantian rocks are wider distributed than the Silesian. The accuracy of stratigraphic subdivision of the Dinantian is, however, highly varying and the differentiated units are often informal.

The available biostratigraphic data are the most complete in the case of the Dinantian in the Holy Cross Mts. On the basis of corals, brachiopods, goniatites, trilobites, miospores and, partly, conodonts, it appeared possible to divided it into stages and zones. Moreover, bivalves appeared to be of stratigraphic value in the Tournaisian and foraminifers – in the Upper Visean (28, 29). The Devonian-Dinantian boundary has been drawn on the

basis of conodonts, bivalves and miospores as well as lithological premises whereas the data for drawing the Dinantian-Silesian boundary are still lacking. The Dinantian comprises here strata of the Tournaisian and Visean.

The studies on lithostratigraphy of the Dinantian in the Holy Cross Mts, carried out by H. Żakowa (28), resulted in establishing tripartite subdivisions of the Tournaisian and Visean. Moreover, relevant stratotypes were proposed. However, the developments in stratigraphic studies may make necessary revision of these lithostratigraphic units and their ranks.

In the Lublin Coal Basin, biostratigraphic subdivision of the Dinantian is primarily based on two groups of fossils: macrofauna and miospores as macroflora and microfauna are here of limited value (3, 13, 16, 19). Rich faunistic assemblages comprise brachiopods, bivalves, conodonts as well as occasional goniatitids, indicative of the Upper Visean age of the strata. Analyses of miospores made it possible to establish miospore zone I, corresponding to the Upper Visean.

Dinantian strata of the Lublin Coal Basin represent the Goniatites stage Go – Goniatites. However, lower boundary of that stage is still poorly defined. Moreover, it should be noted that the available biostratigraphic data do not show the presence of strata assignable to the Tournaisian and Lower and Middle Visean in this basin. Upper boundary of the Visean has been delineated there on the basis of the above mentioned groups of fossils and lithological premises.

Lithostratigraphic subdivision of the above strata comprises informal units proposed in the course of preliminary lithostratigraphic studies for local correlations (20).

The knowledge of the Dinantian in the Upper Silesian Coal Basin is varying because of scarcity of fossils in core material, especially guide fossils (1). The Tournaisian is here evidenced by marine micro- and macrofauna: foraminifers, conodonts and brachiopods whereas micro- and macroflora remain unknown. In some places, however, the paleontological record is very poor or even disputable.

The paleontological record for the Visean is also varying in quality. The Lower Visean was differentiated on the basis of marine micro- and macrofauna: foraminifers, corals, brachiopods, gastropods and cephalopods whereas micro- and macrofloristic premises are still missing.

An essential change takes place in the Upper Visean, the biostratigraphic position of which is much more accurately defined than in the case of the Lower Visean and Tournaisian. The strata were dated on the basis of macro- and microfauna and macro- and microflora. Faunal assemblages here comprise foraminifers, crinoids, corals, bryozoans, brachiopods, bivalves, gastropods, cephalopods and trilobites but guide taxa are not numerous. It is worth to note that cephalopods are here more common than in coeval strata in the Lublin Coal Basin.

The number of lithostratigraphic units differentiated in the Dinantian of the Upper Silesian Coal Basin is varying from one area to another. The units are informal, with features of local subdivision (1).

In the Middle-Sudetic Depression, Dinantian strata represent different type of sedimentary environment and several facies varieties may be recognized. The facies usually interfinge but at the same time they form some time succession which, however, is difficult to trace. Paleontological material was here recorded in the Visean, and fauna of higher stratigraphic value (bryozoans, brachiopods, bivalves, gastropods, cephalopods and trilobites) – in the Upper Visean only. Biostratigraphic units were here established on the basis of brachiopods, bivalves and cephalopods as well as megaflora (27) whereas Lower and Middle Visean strata were identified on the basis of megaflora and lithostratigraphic premises. The Visean – Namurian boundary was delineated using megafloral record and lower boundary of the Visean – arbitrarily, using lithostratigraphic premises.

The Visean was divided into a number of lithostratigraphic units for which stratotypes were proposed (27). Taking into account sedimentary sequences in the stratigraphic section, there was also differentiated a sedimentary series of the Tournaisian. The latest results of lithostratigraphic studies made possible revision of the above subdivision and to propose four formations within the Visean and one in the Tournaisian (10).

The results of studies carried out in the last decade made possible stratigraphic revision of the Dinantian in the Bardo and Kaczawa structures. In the former, the faunistic record is confined to two limestone horizons called as the Lower and Upper Coal Limestone. The Lower Coal Limestone is represented by breccias and limestone sandstones, and the Upper – a thin limestone horizon with corals occurring in situ. The former yielded brachiopods, foraminifers and conodonts indicative of the Lower Visean (zone 11 in foraminiferal subdivision), and the latter – brachiopods, corals and foraminifers indicative of the Upper Visean (Goniatites stage Goβ – 25).

Revision of the hitherto proposed lithostratigraphic subdivisions made it possible to establish three units corresponding to the biostratigraphic ones and to trace sedimentary gaps comprising Tournaisian and lower part of Lower Visean (25).

Biostratigraphic position of Dinantian strata of the Bardo structure was recently precised on the basis of conodonts found in limestones. The strata were previously dated at the Lower Carboniferous taking into account the presence of crinoids, bivalves, gastropods and foraminifers. Reanalysis of conodonts and a new material made it possible to precise the age and to state that at least a part of the strata originated in the Late Visean (4).

The Dinantian of the Fore-Sudetic Monocline is rather poorly known because of insufficient paleontological record, variability in lithology and tectonics of the strata and nonuniform distribution of drillings. The strata were usually dated on the basis of microspores which, at the present state of knowledge, are sufficient for discrimination of the Tournaisian and Visean but not any more subtle subdivision (6, 17). Moreover, cephalopods indicative of the Upper Visean have been found in a few drillings in eastern part of the monocline (7, 14). The available data are insufficient for proposal of formal lithostratigraphic units of any ranks so local subdivision are still being used.

In the western Pomerania, the knowledge of the Dinantian is also varying, mainly because of nonuniform distribution of boreholes which entered these strata, limited scale of coring, and tectonics. The biostratigraphic subdivision was established on the basis of faunistic, miospore and, sometimes, megafloristic data. The faunistic record is most complete in eastern part of that region where from there are known crinoids, corals, bryozoans, brachiopods, bivalves, gastropods, cephalopods, trilobites and conodonts. Of these, brachiopods and conodonts gave the basis for zonation of Tournaisian and identification of Visean (15). The presence of Tournaisian and Visean was also shown here by miospore analyses (23, 24).

In areas east and north-east of Cracow, the Dinantian is developed in coal facies, locally passing into dolomitic and upwards – shaly-sandstone. Biostratigraphic subdivision of these strata is based on macro- and microfauna and, sometimes, macroflora. Macrofauna is here represented by crinoids, corals, brachiopods and cephalopods and microfauna – by foraminifera and conodonts, making possible assignation the strata to the Tournaisian and Visean and even their zonation. Moreover, some stratigraphs were found. Not all the zonal boundaries are well established (12, 30). Lithostratigraphic units were still not formally proposed here.

In the vicinities of Dębnik, the Dinantian is represented by limestones passing upwards into shales. It is known from both exposures and earth works. Brachiopods and foraminiferes found in limestones and gastropods, trilobites and innumerous cephalopods from shales made possible assignation of these strata to some zones of the Tournaisian and Visean. The existing lithostratigraphic subdivision comprises a number of traditional low-rank units (22, 26).

SILESIAN

Stratigraphic subdivision of the Silesian are generally more precise than those of the Dinantian. This is due to a wide array of studies on coal-bearing strata, especially in the newly discovered Lublin Coal Basin and the old ones, in the Upper and Lower Silesia.

In the Lublin Coal Basin, biostratigraphic subdivision of the Silesian is based on marine and fresh-water macrofauna, micro- and megaflora and microfauna (3, 13, 16, 19). Goniatitids, bivalves and brachiopods enabled differentiation of the Namurian and its Goniatites stages E_1, E_2, H_1, R_1, R_2? and G_1 as well as Westphalian A and B. Moreover, fresh-water bivalve zones – Lemisalcata, Communis, Modiolaris and Lower Similis Pulchra zones – were differentiated in the Westphalian A and B.

In the Silesian section of that region, marine fauna has been found to occur up to the base of the Westphalian B, where it forms a boundary horizon. It follows that its extent is here greater than in other parts of the country.

Spore analyses made it possible to differentiate 6 zones: zone II – corresponding to Lower Namurian A, III – Upper Namurian A, IV – Namurian B–C, V – Westphalian A, VI – Westphalian B, and VII – Westphalian C (13).

Identifiable floral remains are here most common in upper parts of the Silesian section, becoming suddenly very scarce downwards. Analysis of floral assemblages makes possible identification of Namurian A, Namurian B–C, Westphalian A, Westphalian B and Westphalian C (16).

Microfaunistic (foraminiferal) studies are treated here as auxiliary in defining some biostratigraphic units.

The lithostratigraphy of the Silesian is still not precise for the whole area of the Lublin Basin. There are used units of various ranks, proposed within the frame of local subdivisions and having the stratotypes selected. There were defined four units, comprising marker limestone horizons with marine fauna. The horizons are marked with upper case Latin letters from A (the lowermost horizon at the base of Namurian A) to S (that from the top of Westphalian A – 20). The state of knowledge of lithostratigraphy is the result of steady supply of new data.

In the Upper Silesian Coal Basin, Silesian strata attain the maximum summative thickness in the country (over 7500 m). They display marked variability in facies laterally and in the vertical. The latter is especially the case in strata of the Namurian A than those of younger chronostratigraphic units. The Namurian A comprises marine strata in its lower part and paralic in the coal-bearing part. Limnic strata begin from the Namurian B.

Biostratigraphic subdivision of the above strata is based on faunistic and micro- and macrofloristic premises. Very rich faunistic assemblages, in which bivalves predominate, made possible zonation of the strata. Individual zones were not defined by single species but rather whole assemblages, taking into account the phenomenon of increased frequency of one or more species in different specific assemblages. The zones are marked with names of directly adjoining coal seams or Roman numerals. They are most important for dating and correlation of lithostratigraphic units. Goniatitids and some bivalve species and trilobites gave the basis for differentiation of the Goniatites stages E_1 and E_2 (except for upper part of the zone E_{2c}) in the Namurian A. The faunistic evidence for the presence of the Goniatites stages H_1 and H_2 is still missing (2, 3).

Spore studies gave data for differentiation of microspore zones N_1-N_7, correlable with lithostratigraphic units and chronostratigraphic subdivision (11).

Macrofloristic studies showed the possibility to identify assemblages and subassemblages typical of Namurian A. Macrofloristic boundary between Namurian A and B appears very sharp, indicating a stratigraphic gap corresponding to Goniatites stages H_1 and H_2 (16).

Lithostratigraphic subdivision comprises here 4–5 higher-order units and 2 lower-order ones. These are important traditional units, for decades used in the coal mining.

Limnic strata ranging in age from Namurian B to Westphalian D are productive. Their biostratigraphy is based on macro- and microflora. Macrofloristic analyses gave the basis for differentiation of assemblages typical for individual chronostratigraphic stages and substages up the Westphalian D, inclusively. For revision of the hitherto proposed phytostratigraphic subdivisions and ranges of some species see A. Kotasowa and T. Migier (16).

Spore studies made possible differentiation of microspore zones N_8-W_5, comprising the interval from Namurian B to Westphalian D, inclusively (11).

Lithostratigraphic subdivision comprises 6 units of lower rank (beds) and 3 higher-rank (series), traditionally used in this region.

The uppermost part of Silesian strata in the Upper Silesian Coal Basin belongs to the Stephanian. These nonproductive strata are represented by so-called Kwaczała Arcose, occurring in eastern part of the Basin. The strata, yielding fossilized trunks Dadoxylon only, are assumed to represent Stephanian B (21).

The Lower Silesian Coal Basin is situated in the Middle-Sudetic Depression. Silesian strata are cropping out in a zone along south-western, north-western and north-eastern margins of the depression. They display features of molasse and marked variability in lithology and thickness. Biostratigraphic subdivision of these strata is based on floral remains and miospores. Identifiable floral remains have been found in lower and middle parts of the Silesian section which determines definition of phytostratigraphic position of lithological units. The floristic and spore data made it possible to identify Namurian A, Namurian C and Westphalian A and B, and results of miospore analyses – Lower Namurian B and Westphalian D. The latter also show that Anthracosia Shales in the Nowa Ruda and Wałbrzych areas represent time equivalents of Upper

Carboniferous rocks dated at the Stephanian A – Stephanian C–D interval (6, 8, 9).

The biostratigraphic studies showed the presence of stratigraphic gap corresponding to Upper Namurian B and Lower Namurian C.

The current lithostratigraphic works are aimed at establishing formal units which would replace the traditional ones. In place of five traditional units, there were introduced four formal ones, corresponding to time interval Namurian C – Stephanian C (10).

Stratigraphic studies carried out in the last two decades contributed to revision of age of strata occurring in northern part of the North-Sudetic Depression. Miospore analyses showed that sedimentary complex comprising sandstones, siltstones and conglomerates about 300 m thick, are of the Westphalian D – Stephanian age (18).

Biostratigraphic studies on Silesian strata in the Fore-Sudetic Monocline are mainly based on results of spore analyses and innumerous megafloristic data. Zonation of the strata is impeded by small number of drillings which entered the strata and limited scale of coring. The strata were dated at Namurian A, Namurian B–C, Westphalian A and C as well as Westphalian B – Stephanian (6, 17). The available lithostratigraphic data appeared insufficient for proposing any lithostratigraphic subdivision.

In western Pomerania, Silesian strata were identified on the basis of miospore data as the results of megafloristic studies are here of auxiliary value only. The Westphalian has been identified in this region and presumable Namurian – in its eastern part (14, 24). The data are still insufficient for establishing formal lithostratigraphic units.

Stratigraphic studies on the Silesian in other parts of the country are in progress, especially those connected with datings on the basis of miospores.

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STRESZCZENIE

Przedstawiono wyniki badań stratygraficznych osadów dinantu i silezu w Polsce. Uwypuklono rolę poszczególnych grup skamieniałości, mających wpływ przy określaniu poszczególnych pięter i podpięter. W podziale biostratygraficznym uwzględnia się wyniki badań mikrofaunistycznych, a w następnej kolejności mikroflorystycznych, makroflorystycznych i mikrofaunistycznych. Wymieniona kolejność ulega lokalnym zmianom spowodowanym stanem zachowania i ilością występowania skamieniałości.

W podziale litostratygraficznym są stosowane jednostki formalne i nieformalne. Ostatnie wiążą się z nazewnictwem tradycyjnym lub są wynikiem wstępnego rozpoznania następstwa litostratygraficznego dla celów lokalnych.

РЕЗЮМЕ

В статье представлены результаты стратиграфических исследований динантского и силезского отделов в Польше. Подчеркнута роль отдельных групп окаменелостей оказывающих влияние при определении отдельных ярусов и подъярусов. В биостратиграфическом делении учётываются результаты макрофаунистических исследований, а в следующей очереди: микрофлористических, макрофлористических и микрофаунистических. Эта очередность может местно изменятся в зависимости от состояния сохранения и количества находящихся окаменелостей.

В литостратиграфическом делении применяются формальные и неформальные единицы. Эти последние связаны с традиционной номенклатурой или же являются результатом предварительной разведки литостратиграфической последовательности для местных целей.