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Regional and global chronostratigraphic correlation levels in the late Viséan to Westphalian succession of the Lublin Basin (SE Poland)

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Five informal complexes with isochronous boundaries have been distinguished in the Carboniferous succession of the Lublin Basin. A description of their internal architecture and discussion of stratigraphical aspects of their boundaries are presented. Isochroneity of boundaries has been proved biostratigraphically and it results from the eustatic control on deposition of marine bands in the paralic succession. On the basis of different biostratigraphical zonations the distinguished boundaries are related to the international chronostratigraphical correlation levels, and then, to the geochronological radiometric scales, mainly to the Ar/Ar scheme. In the analyzed interval of the Carboniferous (late Viséan–Westphalian C) it is comparable with other, mostly U/Pb radiometric scales. Durations of the defined complexes are nearly equal (4–5 m. y.).

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INTRODUCTION

Modern modelling of a basin development needs identification of isochronous time-levels, with possibly most precise determination of their geochronological positions. This purpose is usually realized in the way of biostratigraphical correlation of the sections in the investigated basin, and by establishing relations between the local biostratigraphical units, and radiometrically characterized horizons in other, sometimes very distant, successions. Although every step of this procedure may be a source of inaccuracies, the method is in common practice, and reduction of errors depends firstly on refinement of biostratigraphical conclusions, and secondly, on the improvement of geochronological time-scales. The former factor usually requires verification of the hitherto existing biostratigraphical schemes and decision which of them contain most probable isochronous and correlative levels. The latter one has been notably refined in the recent studies (J. C. Hess, H. J. Lippolt, 1986; N. J. Riley *et al.*, 1994; M. Menning, 1995; J. Roberts *et al.*, 1995; P. C. Lyons *et al.* 1997; M. Menning *et al.*, 1997), which significantly changed a time-scale for the Carboniferous.

The stratigraphy of the subsurface Carboniferous succession in the Lublin region (Fig. 1) is relatively well recognized on the basis of palaeontological data, supported by sedimentological investigations of cyclicity. However, in some cases the impress of primary lithostratigraphical subdivisions on the biostratigraphical conclusions is clearly visible. On the other hand some boundaries are based on benthic, only locally significant fauna, and their correlation with international schemes is doubtful. The aim of this paper is to review the traditional local correlation horizons in the Lublin Basin and to discuss a possibility of their comparison with geochronological time-scales. Owing to present investigations and review the author was able to distinguish five informal complexes, with more or less isochronous boundaries; some of them correspond to the international geochronological levels.

The Carboniferous succession in the Lublin region is generally composed of three units, differentiated with respect to the sedimentary environment. The oldest unit, comprising

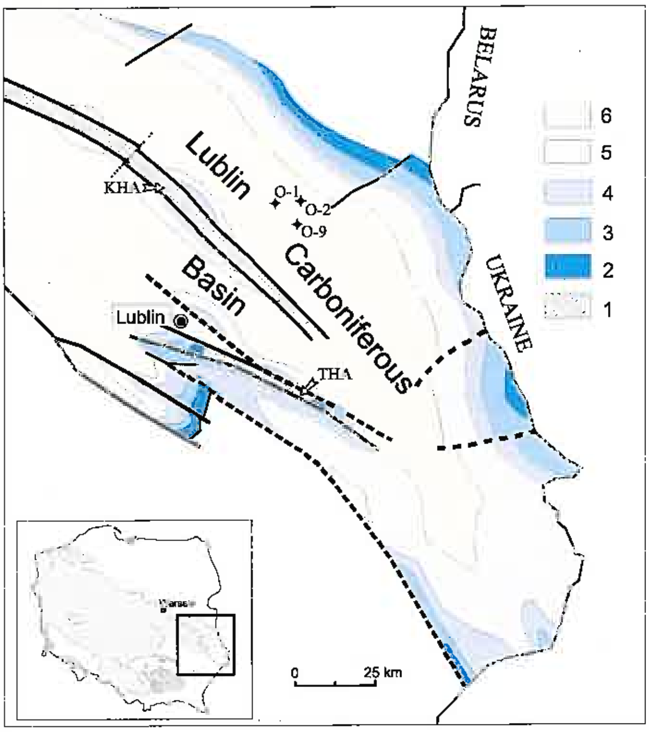

Fig. 1. Simplified geological map of the Carboniferous deposits in the Lublin region (without rocks younger than Carboniferous) after J. Porzycki (1988), with modifications of J. Porzycki and A. Zdanowski (1995); inset map of Poland shows the extent of Carboniferous

1 — Devonian rocks of the Kock Horst-Anticline (KHA) and Trawniki Horst-Anticline (THA); 2 — Huczwa Formation; 3 — Terebin Formation; 4 — Bug Member of the Dęblin Formation; 5 — Kumów Member of the Dęblin Formation; 6 — Lublin and Magnuszew Formations; boreholes: O-1 — Orzechów IG 1, O-2 — Orzechów IG 2, O-9 — Orzechów IG 9

Uproszczona mapa geologiczna osadów karbońskich Lubelszczyzny (mapa odkryta po karbon) według J. Porzyckiego (1988), ze zmianami J. Porzyckiego i A. Zdanowskiego (1995); na mapie Polski zaznaczono występowanie utworów karbonu

1 — utwory dewońskie antykliny zrębowej Kocka (KHA) i antykliny zrębowej Trawników (THA); 2 — formacja Huczwy; 3 — formacja Terebina; 4 — ogniwo bużańskie formacji Dęblina; 5 — ogniwo kumowskie formacji Dęblina; 6 — formacje Lublina i Magnuszewa; otwory wiertnicze: O-1 — Orzechów IG 1, O-2 — Orzechów IG 2, O-9 — Orzechów IG 9

the upper Viséan, is dominated by marine sedimentation; the second one (to the end of Westphalian A) is a typical paralic succession, dominated by terrigenous deposits, and third one (up to the Westphalian C–D?) is entirely terrigenous. Only first two units will be discussed here more strictly. They both are characterized by occurrence of limestones, which are developed as thick complexes in the lower unit, and thinner, individualized limestone bands in the upper one. The sedimentological investigations carried out by S. Skompski (1996) indicated that their development most probably was eustatically controlled. A review of different biozonations and detailed description of the Carboniferous lithology are extensively summarized in two volumes edited by Polish Geological Institute (Z. Dembowski, J. Porzycki, 1988; A. Zdanowski, H. Żakowa, 1995), which contain complete references; in the present paper only the most important and the latest literature is quoted. The lithostratigraphical subdivision of the Carboniferous succession, which has been changed several times in the last 25 years, is based here on the version presented by J. Porzycki and A. Zdanowski (1995).

In the present paper the author has in most cases used the geochronological radiometric scales compiled by M. Menning (1995), and slightly modified by M. Menning *et al.* (1997), who proposed two schemes: the first one based on Ar/Ar sanidine ages, and the second one based on methods other than Ar/Ar, mostly Pb/U zircon ages. It should be noticed that these two scales within the time-interval discussed in the paper (late Viséan–Westphalian C) are shifted one to another on about the value of 5–6 Ma for each boundary (Fig. 2). Although the reasons of this systematically appearing difference are not satisfactorily explained, its regularity causes that both scales are complementary. In biostratigraphical and chronostratigraphical tables and reviews the Ar/Ar scale is used more frequently (also in the official Stratigraphical Chart recommended by IUGS, see J. W. Cowie *et al.*, 1989), and therefore it is applied also in this paper.

LATE VISÉAN MARINE–PARALIC COMPLEX (I)

This complex, characterized by abundance of limestones and shales, with an increasing number of terrigenous intercalations towards the top, includes the Huczwa Formation (except of the Kłodnica Volcanic Member) and lowermost part of the Terebin Formation. Its lower boundary is related to the beginning of the Carboniferous sedimentation after the volcanic episode. Upper boundary is defined as a top of the Limestone Band C — relatively thick, easily identified limestone horizon, stable in the entire area of the basin.

Three stratigraphical aspects are crucial for definition of this unit:

— internal architecture of the complex,

— iso- or diachroneity of the lower boundary,

— identification of the upper boundary of the complex as the Viséan/Namurian boundary.

INTERNAL ARCHITECTURE

As it was mentioned above, the complex is composed mostly of carbonates and claystones, but numerous terrigenous interlayers indicate a cyclic pattern of its sedimentation. The cyclothems are irregular and their correlation is rather problematic. A thickness of the complex is smallest (several tens of metres) at the northeastern periphery and several times greater near southwestern tectonic border of the basin, with its maximum reaching in the southwestern Niedrzwica region about 450 m. Due to a cyclic pattern of sedimentation the changes in thickness can be explained by two models of internal architecture (Fig. 3). Their verification is impossible by means of traditional biostratigraphy. Although benthic macrofauna is abundant in this unit, it only generally indicates the late Viséan age. Sporadically appearing goniatites have constrained this conclusion to Goα, Goβ, Goγ goniatite "stages" (K. Bojkowski, 1979; Ł. Musiał, M. Tabor, 1988; Ł. Musiał *et al.*, 1995). This has been confirmed and somewhat narrowed by foraminiferal and conodont stratigraphy. J. Soboń-Podgórska (1988) distinguished the Zones 15 and 16, but in the lowermost part of the succession she found also the taxa characteristic of the Zone 14 (according to the zonal scheme of B. Mamet and B. Skipp, 1970), which corresponds to Peγ "stage". S. Skompski (1996) recognized the conodont *Lochriea nodosa* Zone in the same interval. Surprisingly more spectacular conclusions are based on the occurrences of calcareous algae. In the late Viséan this group of organisms remarkably flourished in the extensive, shallow marine areas along the European part of the Laurussian shelf. An extinction of the genus *Koninckopora*, sudden and luxuriant appearance of two species of the genus *Calcifolium*, local blooms of stacheiinids, palaeoberesellids and some specific dasycladacean algae has caused this group of fossils to be particularly useful in local and even interregional correlations (S. Skompski, 1981, 1996). In the described interval three zones have been recognized: *Koninckopora*, *Kulikia sphaerica* and *Calcifolium punctatum*. Their distribution indicates overlapping of the succeeding cyclothems and points to correctness of the model presented on the Figure 3A. This solution documented on the large scale of the entire basin (S. Skompski, 1996, fig. 10) is well discernible also on the local scale, in some areas in the northeastern part of the basin (Fig. 4), where the onlap of successive carbonate complexes on the volcanic massive is clearly visible.

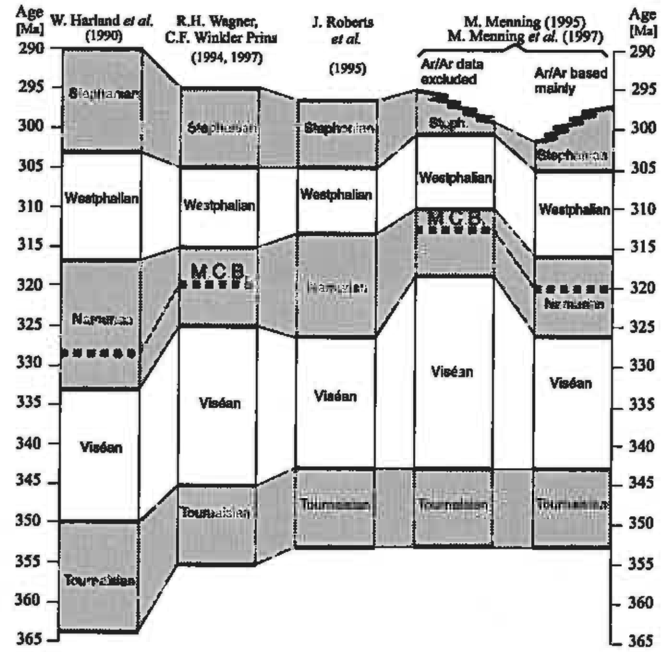

Fig. 2. Comparison of different Carboniferous time scales
M.C.B. — Mid-Carboniferous Boundary

Zestawienie różnych skal czasowych karbonu
M.C.B. — granica karbonu dolnego i górnego

AGE OF THE LOWER BOUNDARY

Although the late Viséan age of the complex is not questioned, the exact age of its lower boundary is still problematic.

The first question is connected with very informal definition and age of the "Variegated Rocks" complex, which underlays the Huczwa Formation. Generally speaking, these are terrigenous sediments, mainly coarse-grained and dominated by carbonate clasts, that were deposited in topographic depressions along major fault-zones (S. Cebulak, 1988). However, sometimes also weathered volcanics are included into this unit (a part of the "Bauxite Series" after S. Cebulak, 1988). In view of a complete lack of fossils the age of this unit was estimated as Famennian, Tournaisian or middle Viséan (summary on the fig. 19 in J. Porzycki, 1988). The equivalent of this complex in the Ukrainian part of the Carboniferous basin is ascribed to the Tournaisian, while J. Porzycki (1988) argued for its middle Viséan age. Unfortunately, none of these conclusions is sufficiently supported by biostratigraphical arguments. The range of uncertainty is narrowed by the Carboniferous age of clasts which have been found in conglomerates of "Variegated Rocks" complex (K. Korejwo, 1958 and unpublished data of J. Soboń-Podgórska *fide* J. Porzycki, 1988).

Similarly uncertain is an age of Kłodnica Volcanic Member, included by A. Grocholski and W. Ryka (1995) to the extensive (but nearly completely eroded) basaltoid plateau primarily ranging from the Lublin area as far as to the Western Ukraine. A time of volcanism is usually estimated as middle/late Viséan, but it is based on the sole argument of the late Viséan age of the overlying marine succession. The radiometric investigations, carried out by T. Depciuch (1974), indicated a very broad age interval (319 and 333 Ma), that can be related to the late Viséan or even to the earliest Namurian. The well preserved post-volcanic topography during early phases of transgression, as presented here on the Figure 4 and in: Ł. Musiał and M. Tabor (1979, fig. 2), is an important evidence pointing to relatively short timespan between volcanic activity and the late Viséan transgression.

In conclusion of the two above presented aspects, it may be assumed that the lower boundary of the complex is strongly diachronous. The transgression in southwestern part of the basin started approximately in the beginning of the late Viséan, more precisely in the Asbian stage, which corresponds to V_{3b} (older Belgian subdivisions of this epoch). In the northeastern part the first marine deposits were sedimented in the middle Brigantian.

UPPER BOUNDARY OF THE COMPLEX

The problem of a correlation of the Viséan/Namurian boundary with the Limestone Band C has been extensively discussed in two previous papers of the author (S. Skompski *et al.*, 1995; S. Skompski, 1996). It may be summarized that the most useful indicator of this boundary in the shallow-water areas of the Laurussian shelf is the conodont *Lochriea cruciformis* Zone. Fortunately, the indexes of this zone appeared in the Limestone Band C. On the other hand, the

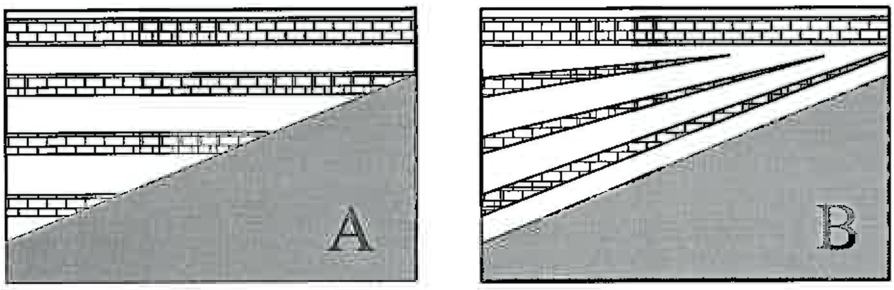

Fig. 3. Two schemes of internal architecture of the late Viséan marine-paralic complex (I)
The biostratigraphical analysis based mainly on calcareous algae indicates greater probability of the scheme A

Dwa schematy wewnętrznej architektury późnowizeńskiego kompleksu morsko-paralicznego (I)
Analiza biostratygraficzna oparta głównie na występowaniu glonów wapiennych wskazuje na większe prawdopodobieństwo schematu A

microfacies analysis of limestones around this boundary and significant increase of cyclic sedimentation regularity point to a notable change of the sedimentary regime, that is recorded in the succession above the discussed limestone band. An autocyclic factor, connected with deltaic regime of sedimentation, dominating in the Viséan, was replaced in the Namurian by an allocyclic component, interpreted as eustatic control of sedimentation. This feature is observed in numerous Carboniferous basins all over the world, also in those located on the East European Platform (A. S. Alekseev *et al.*, 1996; E. S. Dvorjanin *et al.*, 1996). Most probable explanation of this phenomenon links an appearance of the relatively rapid changes of sea-level with the beginning of the Gondwanian Glaciation. Consequently, glacieustatic origin of cyclothems implies chronostratigraphical significance of their typical elements, i.e. the marine bands in particular.

Both above mentioned arguments account for selecting the Limestone Band C as the boundary of the marine-paralic complex, although this horizon does not coincide with the boundary of lithostratigraphical units. The Limestone Band A, located slightly below the Limestone Band C, and considered traditionally as a limit of the Huczwa Formation, is difficult to identify anywhere in the Lublin Basin. Its stratigraphical position, indicated by extinction of gigantoproductids (Ł. Musiał, M. Tabor, 1980), has only a local significance (*cf.* V. I. Poletaev, S. S. Lazarev, 1995).

The age of the top of the complex (= Viséan/Namurian boundary) is assumed here as 326 Ma, as proposed by J. Roberts *et al.* (1995) and M. Menning *et al.* (1997). This conclusion is generally consistent with 325 Ma presented by J. C. Hess, H. J. Lippolt (1986) and R. H. Wagner, C. F. Winkler Prins (1994, 1997). This age is evidently better documented than 333 Ma, proposed by W. B. Harland *et al.* (1990) and still used in some recent papers (*cf.* A. S. Alekseev *et al.*, 1996). The beginning of the Carboniferous sedimentation in the Lublin Basin may be only estimated as about 330 Ma, basing on the assumption that all five stages of the Viséan epoch were equally long, and boundary between Tournaisian and Viséan is 343±3 Ma.

EARLY NAMURIAN PARALIC COMPLEX (II)

This complex includes the Terebin Formation above the Limestone Band C and lower part of the Bug Member of the Dęblin Formation (Fig. 6). Its upper boundary corresponds approximately to the Mid-Carboniferous Boundary (M.C.B. on the Fig. 2), which hitherto has not been recognized in the Lublin Carboniferous Basin. However, it seems that on the basis of appearance of bivalves and goniatites it is possible to indicate a position of this boundary with enough precision. The mass occurrences of bivalves in the lower part of the Bug Member allowed Ł. Musiał and M. Tabor (1980) to recognize two correlation Zones *Posidonia corrugata* I and *P. corrugata* II. The both are well established in the goniatite zonal scheme; Zone *P. corrugata* I is characterized by fauna typical for E_{2b}, while *P. corrugata* II by taxa of H_{1a} and H_{1b} "stages". According to the recently accepted definition of the Mid-Carboniferous Boundary ("the appearance of the conodont *Declinognathodus noduliferus s. l.*, at the transition between the *Eumorphoceras* and *Homoceras* goniatite Zones") it should be placed between the discussed correlation zones. Vertical distance between them is relatively small (20–40 m in the southern, 36–70 m in the western, several metres in the northern part of the basin). The sediments of both layers are included to different cyclothems, and they are usually separated by fluvial deposits, therefore a section with continuous transition is not observed. On the other hand, there are no traces of extensive erosion in this interval.

The early Namurian paralic complex coincides precisely with the Pendleian and Arnsbergian stages. This conclusion is confirmed by goniatites (*Eumorphoceras* Zone) as well as by conodonts. The conodont *cruciformis* Zone corresponds to E_1 Zone, while *bollandensis* Zone (commonly distinguished all over the world in E_2 position) appears above the Limestone Band F. Less clear is foraminiferal stratigraphy in this interval. According to the data presented by J. Soboń-Podgórska (1988) three foraminiferal zones are recognized in the discussed complex, but their boundaries are sometimes oblique to the limestone horizons (Fig. 5). This surprising conclusion is probably caused by incorrect identification of the limestone

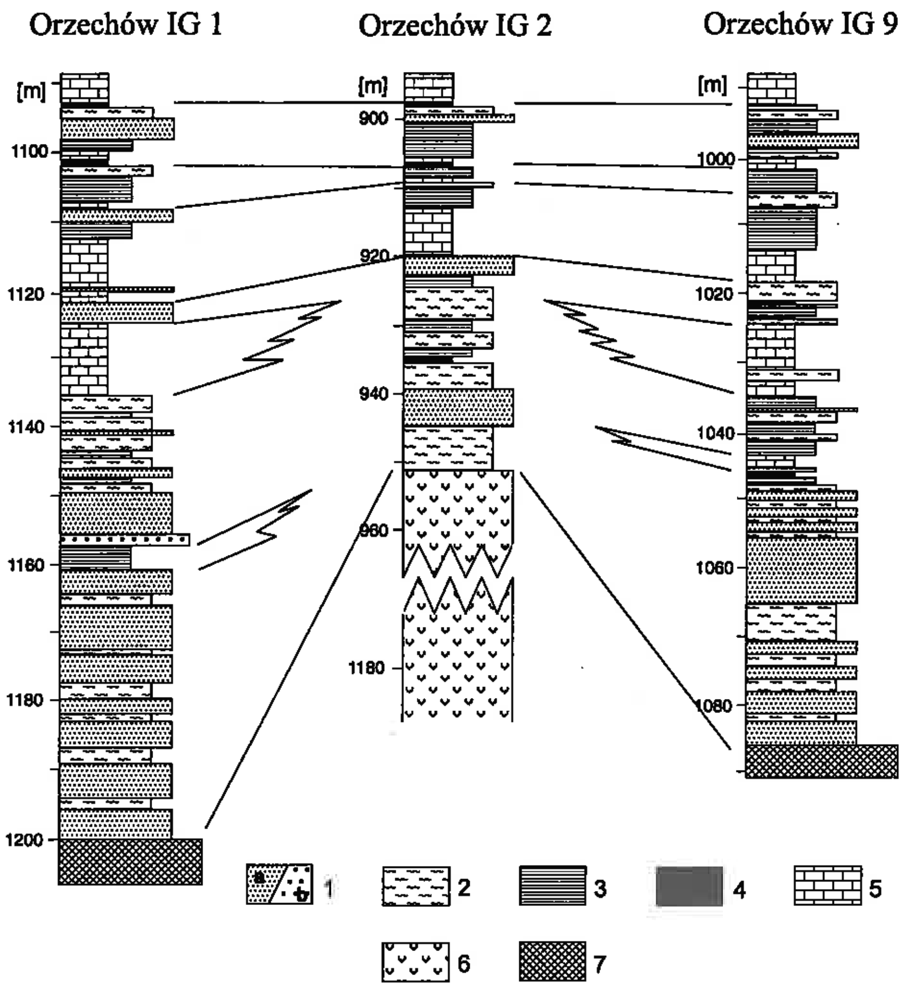

Fig. 4. Schematic correlation of selected marine members within the late Viséan marine–paralic complex (I) in the Orzechów area

The post-volcanic topography caused that during initial transgression episodes the area represented by the section Orzechów IG 2 had not been flooded; 1 — sandstones (a — fine-grained, b — coarse-grained), 2 — mudstones, 3 — claystones, 4 — coal or carbonaceous shales, 5 — limestones or marls, 6 — volcanics, 7 — pre-Carboniferous substrate

Schemat korelacyjny wybranych ogniw morskich późnowizeńskiego kompleksu morsko–paralicznego (I) w rejonie Orzechowa

Powulkaniczna topografia spowodowała, że obszar reprezentowany przez otwór Orzechów IG 2 nie został zalany w pierwszych fazach transgresji; 1 — piaskowce (a — drobnoziarniste, b — gruboziarniste), 2 — mułowce, 3 — iłowce, 4 — węgle lub łupki węglowe, 5 — wapienie lub margle, 6 — wulkanity, 7 — podłoże starsze niż karbon

bands in northern part of the basin, where sections are apparently shorter. Correlation of Zones 18 and 19 with upper part of the Namurian A and even with Namurian B and C, as it is presented by J. Soboń-Podgórska (1988, tab. 5, p. 115; *cf.* similar correlation by A. K. Armstrong *et al.*, 1976; A. S. Horowitz, H. L. Strimple, 1974) seems to be erroneous, and more accurate is the recognition of the Zones 17–19 as the uppermost part of the Mississippian (B. Mamet, B. Skipp, 1970; J. W. Baxter, P. L. Brenckle, 1982; J. R. Groves, 1988). The material from the Lublin Basin has confirmed this latter hypothesis.

The radiometric age of the Mid-Carboniferous Boundary is generally accepted to be 320 Ma (R. H. Wagner, C. F. Winkler Prins, 1994, 1997), and this conclusion is exactly confirmed by recent dating of zircons (Pb/U method) from the Stonehead Beck section (Great Britain), where an age of 314±4.6 Ma is indicated for deposits of $E_{2a\text{-}b}$ Zone, slightly below the discussed boundary (N. J. Riley *et al.*, 1994; *cf.* remarks above on the displacement of Pb/U and Ar/Ar radiometric scales).

MIDDLE NAMURIAN PARALIC COMPLEX (III)

POSITION OF BOUNDARIES

The proposed complex is limited by the Mid-Carboniferous Boundary in the bottom and by the Limestone Band M at the top. In practice, it contains the main portion of the Bug Member, except its lowermost (with the *P. corrugata* I Zone)

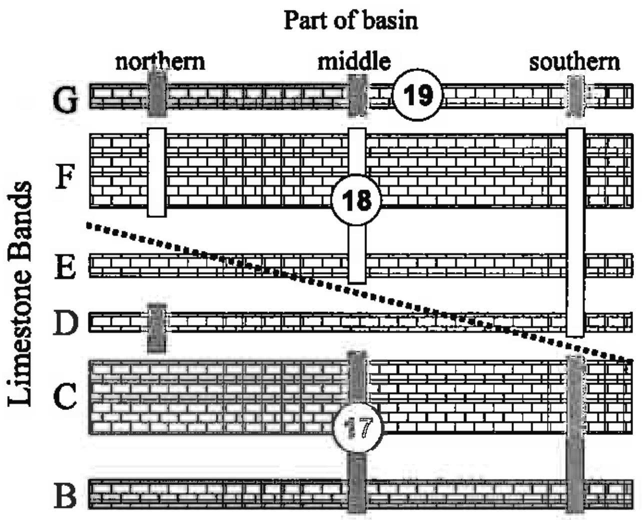

Fig. 5. Ranges of foraminiferal Zones 17–19 in different parts of the Lublin Basin (according to data presented by J. Soboń-Podgórska, 1988); dashed line indicates diachronism of the 17/18 boundary

Zasięgi poziomów otwornicowych 17–19 w różnych częściach basenu lubelskiego (według danych J. Soboń-Podgórskiej, 1988); linia przerywana wskazuje diachronizm granicy poziomów 17 i 18

and topmost (with the Limestone Band N) parts. Chronostratigraphically the complex corresponds to the late Namurian A and Namurian B. However, in the lower part of succession, related to the Namurian A, the world-wide hiatus is recorded, and therefore the attribute "Middle Namurian" seems to be acceptable in the name of the complex.

The Limestone Bands M and N constitute a specific couple of limestone horizons, both being very thin but extremely continuous in the entire basin. They are easily identified due to their characteristic microfacies, dominated in 80% by calcareous algae and microproblematics: *Anthracoporellopsis*, *Masloviporidium* and *Beresella*. This abundance of algal forms is exceptional even in comparison with Viséan algal limestones from the older part of the Lublin succession.

The biostratigraphical position of both above discussed limestone bands is not clear. The goniatite species *Agastrioceras carinatum*, typical of *Gastrioceras* "stage" (equivalent of Namurian C), appears just above the Limestone Band N, and according to these data the boundary of Namurian B/Namurian C is located at the top of Limestone Band N (Ł. Musiał, M. Tabor, 1988). More significant in this interval are conodonts, which are very frequent in both bands. An appearance of *Idiognathoides attenuatus, Id. sinuatus, Id. sulcatus, Idiognathodus sinuosus, I. delicatus, Declinognathodus noduliferus inaequalis, D. lateralis*, and *Neognathodus bothrops* indicates the latest Namurian and therefore the boundary Namurian B/Namurian C should be lowered below the Limestone Band M (S. Skompski, 1996). Similar conclusions were drawn by H. Kmiecik (1988) on the basis of miospores: the *Reticulatisporites carnosus* Zone typical of the N_B ranges not higher than the coal band in the bottom of Limestone Band M. According to the distribution of foraminifers (J. Soboń-Podgórska, 1988) the latest Namurian Zone 20 appeared even earlier, because a typical assemblage has been recognized in the Limestone Band L. However, the correlation of this zone with chronostratigraphical subdivisions of the Carboniferous is still controversial. This was demonstrated by J. R. Groves (1988) in relation to the stratotype of Bashkirian (Askyn river section, southern Ural), where the Zone 20 is considered to be an equivalent of the Namurian B (after D. E. Aizenverg *et al.*, 1979) or Namurian C (after S. V. Semikhatova *et al.*, 1979).

Generally, it may be concluded that here proposed upper boundary of the complex III is approximately coincident with the Namurian B/Namurian C boundary. Its geochronological position is not precisely determined. According to M. Menning (1995), M. Menning *et al.* (1977) and R. H. Wagner, C. F. Winkler Prins (1994, 1997) its age is only estimated to be about 317 Ma. However, this indirect appraisement is based on very doubtful assumption that thickness of the succession and number of biostratigraphical zones is proportional to the time (see M. Menning, 1995, p. 97–98).

THE STRATIGRAPHICAL GAPS WITHIN THE COMPLEX

The characterized unit includes the sediments deposited just after the Mid-Carboniferous eustatic event, (W. B. Saunders, W. H. C. Ramsbottom, 1986; Ch. A. Ross, J. R. P. Ross, 1988), which usually is connected with hiatuses in most of shelf sequences. In the Lublin region a lack of evident erosional surfaces within the lowermost part of the complex has promoted the idea of its continuous sedimentation (e.g. J. Porzycki, 1984). However, this conclusion is contradicted by both biostratigraphical and sedimentological analysis. A lack of indexes of H_2 (and probably R_2) goniatite stages is recognized in the marine fauna (review *fide* Ł. Musiał *et al.*, 1995, p. 28–29). Similar conclusion is based on the miospore distribution (hiatus in upper part of the *Lycospora subtriquetra* — *Kraeuselisporites ornatus* (SO) Zone — H. Kmiecik, 1995, p. 75). These data point to evident sedimentary break in the lower part of the Bug Member, recorded not only in the marine parts of the succession, but also in its terrigenous portion. M. Wiśniewska (1993) and M. I. Waksmundzka (in press) analyzed the cyclicity of sedimentation within this member in southern regions of the Lublin Basin and distinguished four sedimentary megacyclothems, comparable with the British eustatically controlled mesothems, recognized by W. H. C. Ramsbottom (1977) in the Craven Basin (northern England). The correlation of Polish and English sections indicates a lack of at least three mesothems in the Lublin area. Similar break in sedimentation is recorded in the Ukrainian part of the basin (P. L. Shulga, 1960; M. V. Vdovenko, V. I. Poletaev, 1981).

In the light of all presented arguments, it seems that hypothesis assuming the occurrence of gap within the complex III is evidently more probable than an idea of its continuity.

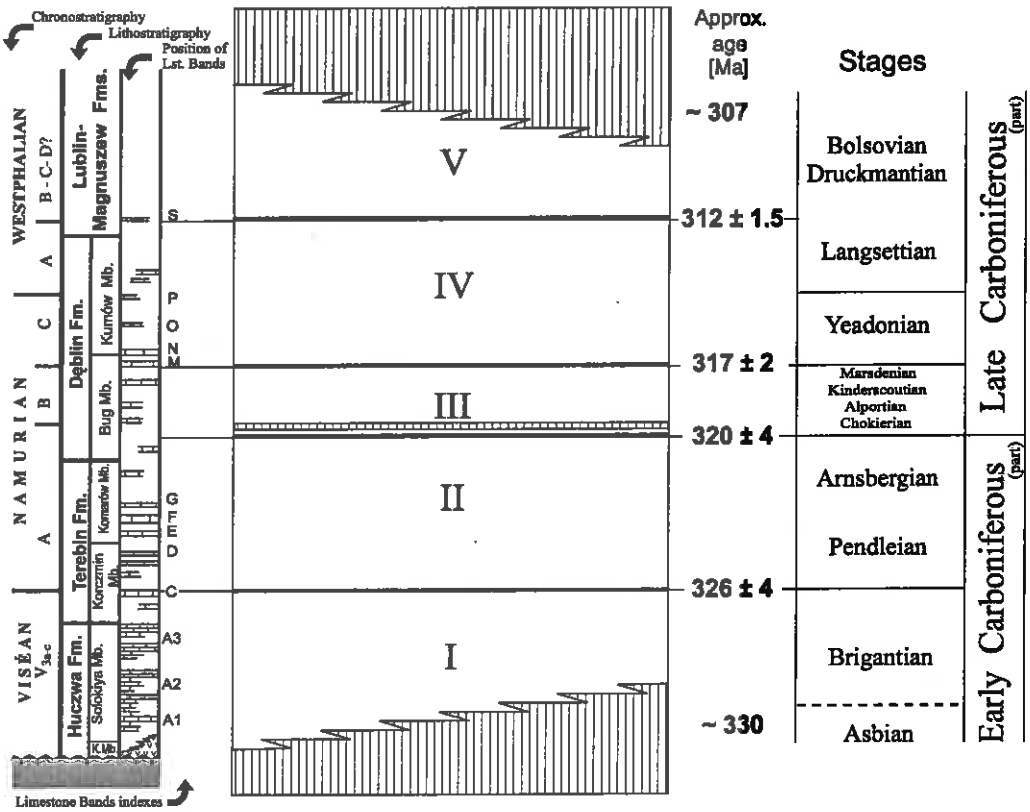

Fig. 6. Geochronologic and chronostratigraphical position of the complexes (I–V) distinguished in the Carboniferous succession of the Lublin Basin
Left column with lithostratigraphy and chronostratigraphy after J. Porzycki and A. M. Żelichowski (*fide* J. Porzycki, 1979), J. Porzycki, A. Zdanowski (1995), Ł. Musiał *et al.* (1995) and other parts of the 1995 volume "The Carboniferous system in Poland" (A. Zdanowski, H. Żakowa, 1995); A1, A2, A3 — indexes of marine complexes proposed by S. Skompski (1996); K. Mb. — Kłodnica Volcanic Member; vertical ruling — stratigraphic gaps

Pozycja geochronologiczna i chronostratygraficzna kompleksów (I–V) wyróżnionych w karbońskiej sukcesji basenu lubelskiego
Litostratygrafia i chronostratygrafia w lewej kolumnie według J. Porzyckiego i A. M. Żelichowskiego (*fide* J. Porzycki, 1979), J. Porzyckiego i A. Zdanowskiego (1995), Ł. Musiał i in. (1995) oraz innych części tomu "The Carboniferous system in Poland" (A. Zdanowski, H. Żakowa, 1995); A1, A2, A3 — indeksy kompleksów wapiennych proponowane przez S. Skompskiego (1996); K. Mb. — ogniwo wulkanitów Kłodnicy; linie pionowe — luki stratygraficzne

LATE NAMURIAN–EARLY WESTPHALIAN PARALIC COMPLEX (IV)

This complex comprises the highest portion of the paralic succession in the Lublin area and is limited from the top by the most constant correlation horizon in the entire Carboniferous succession, characterized by presence of marine fauna with typical species *Dunbarella papyracea*. In this very thin, but stable claystone layer with carbonate intercalations (= Limestone Band S), fauna occurs abundantly, leading to easy identification of this horizon in nearly all well-logs in the basin. It undoubtedly corresponds to the Katharina Horizon in the Ruhr Basin and the Clay Cross Horizon in Great Britain (Ł. Musiał, M. Tabor, 1988). The top of this bed is considered to be the boundary between Westphalian A and B. This conclusion is confirmed by goniatites (*Anthracoceras vanderbeckei*), as well as by conodonts (beginning of the *Idiognathoides tuberculatus* Zone after S. Skompski, 1996). The bed is also a boundary between two miospore *Schulzospora rara* and *Endosporites globiformis* Zones, which correspond respectively to the Westphalian A and B in West European sections (H. Kmiecik, 1988).

Quite recently the age of this boundary has been precisely determined by P. C. Lyons *et al.* (1997), on the basis of zircons from the Upper Bonner Tonstein (Virginia, U.S.A). The average U/Pb age of 5 samples is 308.3±0.5 Ma, and only a single sample with very low amount of uranium pointed for age 316±1 Ma. This last age corresponds to the beginning of Westphalian in the M. Menning's (1995) Ar/Ar scale, and in practice this single grain analysis should not be taken into account. After a correction of average U/Pb age given by P. C. Lyons *et al.* (1997) it can be considered as equivalent of 312 Ma in Ar/Ar scale and this value is accepted in the present paper (Fig. 6).

UPPER WESTPHALIAN TERRIGENOUS COMPLEX (V)

The complex is composed of deposits belonging to the Lublin and Magnuszew Formations and is devoid of any marine intercalations, what significantly limited the biostratigraphical considerations. While the lower boundary is unequivocally isochronous, the upper one is erosional and diachronous; moreover the scale of diachroneity is difficult to estimate. The miospore and floristic analysis indicate presence of the Westphalian B and C, while Westphalian D is recognized in only one borehole section (H. Kmiecik, 1995). On the Figure 6 the age of 307 Ma is proposed as terminal date in this scheme, according to the dating of boundary Westphalian C/D in M. Menning's scale.

CONCLUSIONS

1. Most of the boundaries of five complexes, distinguished in the Carboniferous succession of the Lublin Basin, and differing in some details from the hitherto used lithostratigraphical units, are isochronous and corresponding to the international correlation levels. The correlation is founded basically on goniatites as well as on conodonts and miospores; in specific intervals also calcareous algae are useful. In contrary to expectations, the foraminiferal distribution seems to be less effective as a correlation tool.

2. Isochroneity of boundaries has been proved biostratigraphically and it results from the eustatic control on development of marine bands in the paralic succession.

3. The distinguished boundaries have been related to the geochronological scales, mainly to the Ar/Ar scheme compiled by M. Menning (1995) and M. Menning *et al.* (1997). In the analyzed interval of the Carboniferous (late Viséan–Westphalian C) it is relatively precise and comparable with other, mostly U/Pb radiometric scales.

4. Durations of the defined complexes are nearly equal (4–5 m. y.).

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REFERENCES

AIZENVERG D. E., VASSILYUK M. P., REITLINGER E. A. (1979) — The Serpukhovian Stage of the Lower Carboniferous of the USSR. In: The Carboniferous of the USSR (eds. A. C. Higgins, S. V. Meyen). York. Geol. Soc. Occas. Publ., 4, p. 43–59.

ALEKSEEV A. S., KONONOVA L. I., NIKISHIN A. M. (1996) — The Devonian and Carboniferous of the Moscow Syneclise (Russian Platform): stratigraphy and sea-level changes. Tectonophysics, **268**, p. 149–168.

ARMSTRONG A. K., MAMET B. L., BROSGE W. P., REISER H. N. (1976) — Carboniferous section and unconformity at mount Doonerak, Brooks Range, Northern Alaska. Am. Ass. Petrol. Geol. Bull., **60**, p. 962–972, no. 6.

BAXTER J. W., BRENCKLE P. L. (1982) — Preliminary statement on Mississippian calcareous foraminiferal successions of the Midcontinent (USA) and their correlation to western Europe. Newsl. Strat., **11**, p. 136–153, no. 3.

BOJKOWSKI K. (1979) — Goniatites from the Carboniferous of the Upper Silesian and Lublin Coal Basins (in Polish with English summary). Biul. Inst. Geol., **311**, p. 5–68.

CEBULAK S. (1988) — Charakterystyka petrograficzna karbonu. In: Carboniferous of the Lublin Coal Basin (eds. Z. Dembowski, J. Porzycki) (in Polish with English summary). Pr. Inst. Geol., **122**, p. 77–87.

COWIE J. W., BASSETT M. G. (1989) — International Union of Geological Sciences 1989 Global Stratigraphical Chart with geochronometric and magnetostratigraphical callibration. Episodes, **12**, p. 2.

DEMBOWSKI Z., PORZYCKI J. (eds.) (1988) — Carboniferous of the Lublin Coal Basin (in Polish with English summary). Pr. Inst. Geol., **122**.

DEPCIUCH T. (1974) — Rocks of the Precambrian Platform in Poland. Part 2 — Sedimentary cover (ed. A. Łaszkiewicz) (in Polish with English summary). Pr. Inst. Geol., **74**, p. 81–83.

DVORJANIN E. S., SAMOLYLUK A. P., EGURNOVA M. G., ZAYKOVSKY N.Y A., PODLADCHIKOV Y.Y., VAN DEN BELT F. J. G., DE BOER P. L. (1996) — Sedimentary cycles and paleogeography of the Dnieper Donets Basin during the late Viséan–Serpukhovian based on multiscale analysis of well logs. Tectonophysics, **268**, p. 169–187.

GROCHOLSKI A., RYKA W. (1995) — Carboniferous magmatism of Poland. In: The Carboniferous system in Poland (eds. A. Zdanowski, H. Żakowa). Pr. Państw. Inst. Geol., **148**, p. 181–190.

GROVES J. R. (1988) — Calcareous foraminifers from the Bashkirian stratotype (Middle Carboniferous, south Urals) and their significance for intercontinental correlations and the evolution of the Fusulinidae. J. Paleont., **62**, p. 368–399, no. 3.

HARLAND W. B., ARMSTRONG R. L., COX A. V., CRAIG L. E., SMITH A. G., SMITH D. G. (1990) — A geologic time scale 1989. Cambridge University Press.

HESS J. C., LIPPOLT H. J. (1986) — $^{40}Ar/^{39}Ar$ ages of tonstein and tuff sanidines: new calibration points for improvement of the Upper Carboniferous time scale. Chem. Geol. (Isotope Geoscience Section), **59**, p. 143–154.

HOROWITZ A. S., STRIMPLE H. L. (1974) — Chesterian Echinoderm zonation in Eastern United States. C-R. Septieme Congr. Inter. Strat. Geol. Carbon., Krefeld, **3**, p. 207–220.

KMIECIK H. (1988) — Miospore stratigraphy of the Carboniferous deposits. In: Carboniferous of the Lublin Coal Basin (eds. Z. Dembowski, J. Porzycki) (in Polish with English summary). Pr. Inst. Geol., **122**, p. 131–147.

KMIECIK H. (1995) — Microflora. In: The Carboniferous system in Poland (eds. A. Zdanowski, H. Żakowa). Pr. Państw. Inst. Geol., **148**, p. 65–85.

KOREJWO K. (1958) — The Carboniferous at Strzyżów on the Bug river (Eastern Poland) (in Polish with English summary). Biul. Inst. Geol., **136**.

LYONS P. C., KROGH T. E., KWOK Y. Y., ZODROW E. L. (1997) — U-Pb of zircon crystals from the Upper Banner Tonstein (Middle Pennsylvanian), Virginia: absolute age of the Lower Pennsylvanian–Middle Pennsylvanian boundary and depositional rates for the Middle Pennsylvanian, Central Appalachian Basin. In: Proceedings of the XIII International Congress on the Carboniferous and Permian, 28th August–2nd September, 1995, Kraków, Poland. Part 1 (eds. M. Podemski *et al.*). Pr. Państw. Inst. Geol., **157**, p. 159–166.

MAMET B., SKIPP B. (1970) — Lower Carboniferous calcareous foraminifera: preliminary zonation and stratigraphical implications for the Mississippian of North America. C-R. 6e Congr. Inter. Strat. Geol. Carbon., **3**, p. 1129–1146.

MENNING M. (1995) — Carboniferous and Permian time scale for Central Europe and timing of the magmatic activity. Terra Nostra, **7**, p. 97–100.

MENNING M., WEYER D., DROZDZEWSKI G., VAN AMEROM H.W.J. (1997) — Carboniferous time scales revised 1997: time scale A (min. ages) and time scale B (max. ages) — use of geological indicators. Newsl. Carbon. Strat., **15**, p. 26–28.
MUSIAŁ Ł., TABOR M. (1979) — Stratigraphy of the Carboniferous of northeastern part of the Lublin Coal Basin (in Polish with English summary). Kwart. Geol., **23**, p. 141–152, no. 1.
MUSIAŁ Ł., TABOR M. (1980) — The Carboniferous zoostratigraphy of the Lublin Coal Basin and its correlation with lithostratigraphic members. Biul. Inst. Geol., **328**, p. 75–94.
MUSIAŁ Ł., TABOR M. (1988) — Macrofaunal stratigraphy of Carboniferous. In: Carboniferous of the Lublin Coal Basin (eds. Z. Dembowski, J. Porzycki) (in Polish with English summary). Pr. Inst. Geol., **122**, p. 88–111.
MUSIAŁ Ł., TABOR M., ŻAKOWA H. (1995) — Macrofauna. In: The Carboniferous system in Poland (eds. A. Zdanowski, H. Żakowa). Pr. Państ. Inst. Geol., **148**, p. 23–44.
POLETAEV V. I., LAZAREV S. S. (1995) — General stratigraphical scale and brachiopod evolution in the Late Devonian and Carboniferous subequatorial belt. Bull. Soc. Belge Géol., **103**, p. 99–107, no. 1–2.
PORZYCKI J. (1970) — Korelacja litostratygraficzna profilów karbonu z poszczególnych regionów Lubelskiego Zagłębia Węglowego. Kwart. Geol., **14**, p. 903–904, no. 4.
PORZYCKI J. (1979) — Litostratygrafia osadów karbonu Lubelskiego Zagłębia Węglowego. In: Stratygrafia węglonośnej formacji karbońskiej w Polsce, II Sym., Sosnowiec (ed. T. Migier), p. 19–28.
PORZYCKI J. (1984) — Zarys geologii Lubelskiego Zagłębia Węglowego. In: Przewodnik LVI Zjazdu Pol. Tow. Geol. (ed. M. Harasimiuk), p. 7–21.
PORZYCKI J. (1988) — Lithologic and sedimentologic characteristics of Carboniferous deposits. In: Carboniferous of the Lublin Coal Basin (eds. Z. Dembowski, J. Porzycki) (in Polish with English summary). Pr. Inst. Geol., **122**, p. 40–76.
PORZYCKI J., ZDANOWSKI A. (1995) — Lithostratigraphy and sedimentologic-paleogeographic development: southeastern Poland (Lublin Carboniferous Basin). In: The Carboniferous system in Poland (eds. A. Zdanowski, H. Żakowa). Pr. Państ. Inst. Geol., **148**, p. 102–109.
RAMSBOTTOM W. H. C. (1977) — Major cycles of transgression and regression (mesothems) in the Namurian. Proc. York. Geol. Soc., **41**, p. 261–291.
RILEY N. J., CLAOUÉ-LONG J. C., HIGGINS A. C., OWENS B., SPEARS A., TAYLOR L., VARKER J. W. (1994) — Geochronometry and geochemistry of the European Mid-Carboniferous boundary global stratotype proposal, Stonehead Beck, North Yorkshire, UK. Ann. Soc. Geol. Belgique, **116**, p. 275–289, no. 2.
ROBERTS J., CLAOUÉ-LONG J. C., JONES P. J. (1995) — Australian Early Carboniferous time. SEPM Spec. Publ., **54**, p. 25–40.
ROSS CH. A., ROSS J. R. P. (1988) — Late Paleozoic transgressive–regressive deposition. SEPM Spec. Publ., **42**, p. 227–247.
SAUNDERS W. B., RAMSBOTTOM W. H. C. (1986) — The mid-Carboniferous eustatic event. Geology, **14**, p. 208–212.
SEMIKHATOVA S. V., EINOR O. L., KIREEVA G. D., GUBAREVA V. S. (1979) — The Bashkirian stage in its type area of the Urals. In: The Carboniferous of the USSR (eds. A. C. Higgins, S. V. Meyen). York. Geol. Soc. Occas. Publ., **4**, p. 83–98.
SHULGA P. L. (1960) — O pereryve v otlozhenijakh na granice nizhnego i sredenego karbona vo Lvovsko-Volynskom Basseyne i jego istoriko-geologitcheskom znathenii. Geol. Zhurnal, **20**, p. 80–87, no. 5.
SKOMPSKI S. (1981) — Morphology and systematic position of the Carboniferous algal genus *Calcifolium*. N. Jb. Geol. Paläont. Mh., **1981**, p. 165–179, no. 3.
SKOMPSKI S. (1996) — Stratigraphic position and facies significance of the limestone bands in the subsurface Carboniferous succession of the Lublin Upland. Acta Geol. Pol., **46**, p. 171–268, no. 3–4.
SKOMPSKI S., ALEKSEEV A., MEISCHNER D., NEMIROVSKAYA T., PERRET M-F., VARKER W. J. (1995) — Conodont distribution across the Viséan and Namurian boundary. Cour.-Forsch. Inst. Senckenberg., **188**, p. 117–209.
SKOMPSKI S., CONIL R., LALOUX M., LYS M. (1989) — Etude micropaléontologique des calcaires du Viséen términal et du Namurien dans le Bassin Carbonifère de Lublin à l'est de la Pologne. Bull. Soc. Belge Géol., **98**, p. 453–473, no. 3–4.
SOBOŃ-PODGÓRSKA J. (1988) — Microfaunal stratigraphy of the Carboniferous deposits (foraminifers). In: Carboniferous of the Lublin Coal Basin (eds. Z. Dembowski, J. Porzycki) (in Polish with English summary). Pr. Inst. Geol., **122**, p. 112–119.
VDOVENKO M. V., POLETAEV V. I. (1981) — K voprosu o vozraste svit karbona Lvovsko–Volynskogo Ugolnogo Basseyna. Geol. Zhurnal, **41**, p. 133–138, no. 6.
WAGNER R. H., WINKLER PRINS C. F. (1994) — General overview of Carboniferous stratigraphy. Ann. Soc. Geol. Belgique, **116**, p. 163–174, no. 1.
WAGNER R. H., WINKLER PRINS C. F. (1997) — Carboniferous chronostratigraphy: *Quo vadis*?. In: Proceedings of the XIII International Congress on the Carboniferous and Permian, 28th August–2nd September, 1995, Kraków, Poland. Part 1 (eds. M. Podemski *et al.*). Pr. Państw. Inst. Geol., **157**, p. 187–196.
WAKSMUNDZKA M. I. (in press) — Architektura depozycyjna basenu karbońskiego Lubelszczyzny. Pr. Państw. Inst. Geol.
WIŚNIEWSKA M. (1993) — Wykształcenie facjalne i sedymentacja utworów wizenu i namuru południowej części Lubelskiego Zagłębia Węglowego. Arch. Inst. Geol. UW. Warszawa.
ZDANOWSKI A., ŻAKOWA H. (eds.) (1995) — The Carboniferous system in Poland. Pr. Państ. Inst. Geol., **148**.

REGIONALNE I ŚWIATOWE POZIOMY KORELACJI CHRONOSTRATYGRAFICZNEJ W KARBOŃSKIEJ SUKCESJI BASENU LUBELSKIEGO

Streszczenie

Dobry stan rozpoznania biostratygrafii karbońskiej sukcesji Lubelszczyzny (fig. 1), wzbogacony ostatnio o analizę występowania konodontów i glonów wapiennych, pozwala na dość wiarygodne określenie relacji lokalnych granic stratygraficznych do uniwersalnych, międzynarodowych poziomów chronokorelacji. Za najbardziej pewne uznano:

— granicę wizenu i namuru, utożsamianą z ławicą wapienia C (według terminologii J. Porzyckiego, 1979),

— granicę karbonu dolnego i górnego, przebiegającą w interwale pomiędzy horyzontem korelacyjnym *Posidonia corrugata* I i *P. corrugata* II,

— granicę namuru B i C, odpowiadającą spągowi ławicy wapienia M,

— granicę westfalu A i B, odpowiadającą horyzontowi korelacyjnemu *Dunbarella*.

Tak określone granice pozwoliły na wydzielenie pięciu kompleksów, których wiek i czas trwania depozycji określono na podstawie odniesienia granic chronostratygraficznych do ostatnio publikowanych skal geochronologicznych (fig. 2). Najbardziej wiarygodnym zestawieniem wydają się być skale przedstawione przez M. Menninga (1995) i M. Menninga i in. (1997), którzy rozdzielili wyniki otrzymywane za pomocą analizy Ar/Ar i te uzyskane innymi metodami, głównie U/Pb. W analizowanym zakresie (późny wizen– westfal C) przesunięcie tych skal jest niezwykle regularne (5–6 mln lat). Pomimo iż zależność ta jest na razie niewyjaśniona, umożliwia ona wzajemne przeliczenia obydwu skal. Interpretacje geochronologiczne oparte na takich właśnie szacunkach pozwoliły na określenie czasu sedymentacji karbonu Lubelszczyzny na 330 do 307 mln lat (fig. 6). Czas powstawania kolejnych kompleksów ograniczonych wyżej wymienionymi granicami był mniej więcej równy i wahał się od 4 do 5 mln lat.